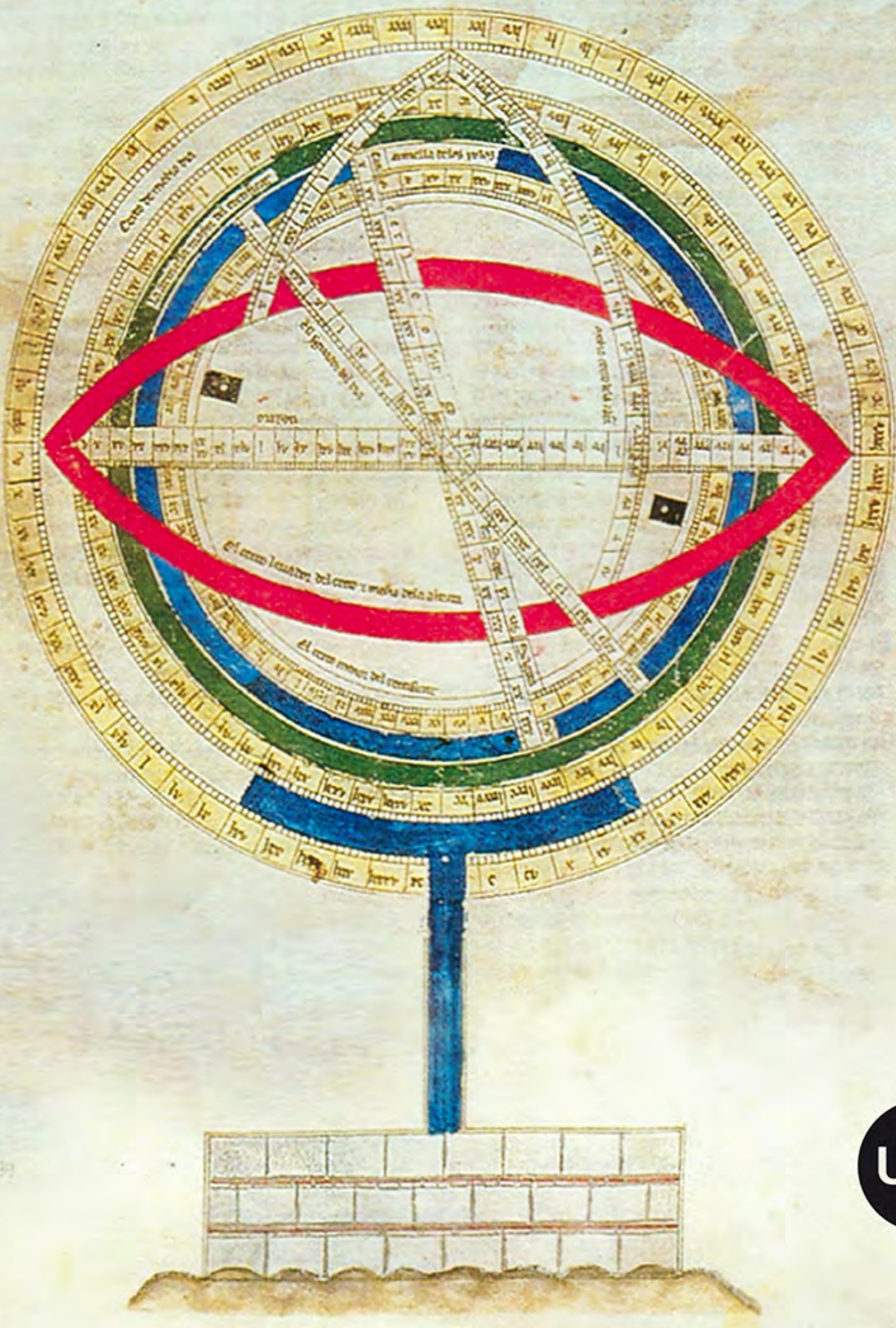
A SHARED LEGACY
Islamic Science East and West



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Homage to professor
J. M. Millàs Vallicrosa

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Publicacions i Edicions
UBe
UNIVERSITAT DE BARCELONA

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Il·lustració de la coberta: Biblioteca de la Universidad Complutense de Madrid.
Catàleg de Villa-Amil nº 156, fol.139r⁰

Disseny de la coberta: Cesca Simón

ISBN: 978-84-475-3985-7

Aquest llibre ha estat publicat amb el suport de dos projectes de recerca, *Ciencia y sociedad en el Mediterráneo occidental en la baja edad media* (HUM2004-02511/FILO) i *Cartografía náutica árabe en el contexto mediterráneo (c.1300-1600). Influencias entre oriente y occidente* (HUM2005-03375/FILO), dos ajuts complementaris del Ministerio de Educación y Ciencia (HUM2006-27959-E/HIST i HUM2006-27983-E/HIST) i un ajut de la Societat Catalana d'Història de la Ciència i de la Tècnica (Institut d'Estudis Catalans).

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Foreword

Julio Samsó

The 9th International Congress of History of Science took place in September 1959 in Barcelona and Madrid. At that time the organiser of the conference was my master Prof. Juan Vernet. The amount of work implied was so heavy that Vernet had a heart attack. This is why I decided that I would never become involved in the organisation of an international conference. This is also why my daughters in the spirit (Mercè Comes, Roser Puig, Emilia Calvo and Mònica Rius), with the very active help of the graduate students of our Department (Elia Romo, Glòria Sabaté and Marc Oliveras), were the ones responsible of *A Shared Legacy. Islamic Science East and West*, probably the most important international meeting on the history of medieval science held in Barcelona since 1959. The conference was also organised as an homage to Prof. J.M. Millàs Vallicrosa on the occasion of the 75th + 1 anniversary of the publication of his most important book: the *Assaig d'història de les idees físiques i matemàtiques a la Catalunya Medieval* (Barcelona, 1931).

Among the important absences in the congress I would like to mention those of E.S. Kennedy, Juan Vernet, David King, John North and Bernard Goldstein. David has, however, contributed to this volume with a brilliant state of the art of his life-time study of Islamic astronomical instruments. Other most important states of the art, presented by great masters, were those by Paul Kunitzsch (on translations and transmissions) and George Saliba, who succeeded in opening new ways to explain the process of the "obscure" transmission of the new planetary models, designed in and after Marāgha, to Copernicus and his contemporaries: to the possible Byzantine transmission suggested by Otto Neugebauer, we have to add now the importance of early European arabists like Guillaume Postel or the arrival to Italy in 1577 of the Jacobite patriarch Ighnāṭiyūs Niʿmatallāh. This has become an important new hypothesis which should be explored in the future.

This has also been the conference of a most ambitious new project: that of ISMI (Islamic Scientific Manuscripts Initiative), a brilliant idea developed by Jamil and Sally Ragep. I believe the time of encyclopedic works written by individual authors (Suter, Brockelmann, Sarton, Sezgin, Rosenfeld) has reached an end and international cooperation is necessary for such enterprises. The problem is how many generations of scholars will be needed to finish a project like ISMI?. Will future generations find people like Jamil and Sally willing to push such a heavy vehicle? On a more limited level, I would like to remind here an analogous collective Spanish enterprise: that of the *Enciclopedia de al-Andalus*, of which three big volumes have already appeared and which is going to be the great reference work on Andalusī culture, which obviously includes the history of science.

The papers presented at the conference deal with a mixture of subjects, use different methodologies and different languages are involved (Arabic, Persian, but also Greek and Latin, among others). We have, however, found similar problems and common interests which prove the unity of the discipline in spite of its variety. During the conference, we all paid attention to other people's problems and did our best to try to contribute to their solution. Topics raised in the conference went from textual studies trying to recover truncated texts important for the transmission of Euclid's *Elements* to theoretical analysis of the criticisms to Ptolemaic astronomy in a 12th century Andalusī author. Medicine was also present including such uncommon subjects as the medicine of the soul. More unusual were papers dealing with Aristotelian meteorology or cartography, a discipline which knew a very important development in the Western Mediterranean in an atmosphere in which it is really difficult to establish limits between knowledge born in the Iberian Peninsula, the Balearic Islands, Italy and the Maghrib. This is a scientific discipline which crosses easily the borders of different cultures, probably due to the fact that language difficulties had little importance. Cartography is possibly the best example we can give of a shared legacy.

On the whole, something has attracted everybody's attention: a growing interest in the social aspects of the history of our disciplines. David King explained to me, about twenty-five years ago, how he had discovered that the study of *mīqāt* was the bulk of what could really be called an Islamic contribution to Astronomy and how this concern promoted the design of new instruments mainly applied to timekeeping. We have all complained of the lack of information about the lives of our scientists due to the fact that the authors of biographical dictionaries did not consider them to have the same interest as those of of experts in *fiqh* or transmitters of *ḥadīth*. The exception we always had in mind was that of physicians and it was clear that a history of the medical profession was more feasible than that of the practitioners of other scientific disciplines. It was a surprise for me to discover the amount of information on *muwaqqit*s and *mu'adhdhin*s available in the work of Shams al-Dīn al-Sakhāwī, something that we cannot find in Andalusī biographical sources. This, in spite of the fact that there was, in al-Andalus, a clear interest in astronomical instruments which always had an application to timekeeping. Technology is another kind of scientific discipline having a great social importance and was dealt with in our conference from very different points of view: theoretical studies on Mechanics, analysis of sources dealing with recreational machinery (*ʻilm al-ḥiyal*), or the gathering of information extant in literary sources about hydraulic machines, the development of industry in the pre-industrial age and other aspects of science. On the whole we all agreed that there were a series of centuries and cultures completely forgotten by standard eurocentric historical research.

The conference ended with a session in honour of Prof. Millàs-Vallicrosa, precisely the scholar whose scientific contributions became the starting point of the Barcelona school of history of Arabic science. Its members, together with the Commission on the History of Science and Technology in Islamic Societies and the Societat Catalana d'Història de la Ciència i de la Tècnica of the Institut d'Estudis Catalans were the organisers of this international meeting, which was the first to be held by the Commission independently from the symposia usually organised in the frame of the International Congresses of History of Science. I hope that this example will be followed in the future.

The Islamic Scientific Manuscript Initiative

The Islamic Scientific Manuscript Initiative (ISMI)

Towards a Sociology of the Exact Sciences in Islam*

F. Jamil Ragep and Sally P. Ragep

Introduction

Virtually all serious researchers in the field of the history of science in Islamic societies have lamented, at one time or another, the lack of study, let alone editions, of the thousands of manuscripts dealing with scientific subjects that remain unexamined. Our knowledge of science in Islam is, for the most part, episodic, focusing mainly on texts that were translated or had some relevance to Europe, or on accidental discoveries. There have been few attempts to survey or categorize genres of writing, to understand the context in which texts were produced, or to study readership of those texts.[1]

There are several ways in which researchers have sought to remedy this situation. One is to edit and study the texts and, if possible, translate them into a European language. Starting in the nineteenth century, this has been done to a limited extent. There are, though, a number of limitations. While having an edited text is of inestimable value, it remains a single text. Editors have seldom attempted to address broader questions such as: Was the author working as an isolated individual or as part of a scientific

*Earlier versions of this paper were presented at the International Conference on Science in Islamic Societies, held in Rabat, Morocco in April 2004, and at the First International Conference on History of the Exact Sciences along the Silk Road, held in Xian, China in August 2005. We are appreciative to the organizers and participants of those two conferences who provided valuable feedback.

[1] This lack of historical data has, unfortunately, not deterred a number of modern commentators from providing us with "authoritative" accounts of those genres, those contexts, and those readers.

group? Was this a well-known text? Did it influence subsequent workers in the field? Was it studied in a school?

The reason for this lack of knowledge, or even the lack of an attempt to answer such questions, is not hard to uncover. Historians of Islam, like their medieval Latinist colleagues, are often overwhelmed by an embarrassment of riches.[2] The sheer quantity of manuscript material has made it difficult to manage or survey the material in a way that could allow one to address these issues. Another reason is the tedious and slow process involved in editing texts. Again numbers play a role. A limited corpus, such as the Greek scientific writings, were systematically edited in the nineteenth and early twentieth centuries and became the basis for careful analyses.[3] To do something similar for medieval Islamic scientific manuscripts would present a daunting task, and no such project has been proposed. Another reason is simply the lack of qualified and trained researchers. The interest in science in Islam has gone in cycles during modern times. In post-Enlightenment Europe, it was generally dismissed but recently it has been experiencing a revival. This has not, though, led to large numbers of competent researchers entering the field, whether in Europe, America, or in Islamic countries.[4]

Although the current available resources have been indispensable for research, they represent only a beginning. When dealing with such a mass

[2] For a comparable situation and how it has been dealt with in the field of medieval Latin studies, see Steven J. Livesey, "*Lombardus electronicus*: A Biographical Database of Mediaeval Commentators on Peter Lombard's *Sentences*," in *Medieval Commentaries on the* Sentences *of Peter Lombard. Current Research. vol. 1*, ed. Gillian R. Evans (Leiden: E. J. Brill, 2002), pp. 1-23. A resource for part of the corpus of medieval European scientific writings is Linda Ehrsam Voigts and Patricia Deery Kurtz (eds.), "Scientific and Medical Writings in Old and Middle English: An Electronic Reference" [on CD] (Ann Arbor: Univer-sity of Michigan Press, 2001).

[3] Here we are thinking foremost of the editions made by J. L. Heiberg for the Teubner series in Leipzig.

[4] On the other hand, there have been several noteworthy projects in recent years that have contributed to our knowledge of what we are calling the sociological aspects of science in Islam. These include the ones on timekeeping, astronomical tables, and instruments undertaken by David King and his group in Frankfurt, Germany; see now, David A. King, *In Synchrony with the Heavens: Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization* (Leiden: Brill, 2004). The recent publication of *Mathematicians, Astronomers and Other Scholars* by Boris Rosenfeld and Ekmeleddin İhsanoğlu has built upon the earlier work of Heinrich Suter as well as G.P. Matvievskaya and Rosenfeld (see note 8 for citations), and has provided us with an overview of the entire corpus of the exact sciences in Islam; an important feature of this work is that it incorporates the pioneering work on Ottoman science done by İhsanoğlu and his team in Istanbul. Another important research group is the "Barcelona School," centered at the University of Barcelona and led most recently by Julio Samsó, which has considerably increased our knowledge of science in al-Andalus and North Africa. We are also beginning to understand the relation of Islamic and East Asian Science, both along the Silk Road and further east, thanks to the work of Michio Yano and his colleagues in Japan and China, as well as the research of Benno van Dalen in Frankfurt.

of material, it is inevitable that there will be considerable ambiguity concerning many of the titles and authors we encounter. On the one hand, we have the problem of anonymous authors; on the other, we have the proliferation of authors with the same or similar name. In addition, libraries have on occasion changed the names of their collections and their numbering systems, often rendering older catalogues with important information difficult to collate with new listings. Indeed, some libraries have themselves ceased to exist and have been incorporated or centralized into other institutions. More importantly, we have few tools, aside from painstaking work, to connect the productions of our subjects with wider social, political, and intellectual contexts.

The Goals of the ISMI Project

As a contribution towards ameliorating the situation described above, the Islamic Scientific Manuscripts Initiative (ISMI) was developed to provide a means for rationalizing the cataloguing of both metadata (standard bio-bibliographical information) and content data for all manuscripts in the "mathematical" sciences (broadly conceived) that were produced in the Islamic world before 1900 CE. The basic tool is an electronic database that allows for the entry and extraction of data contained within Islamic scientific manuscripts. The ultimate goal is to catalogue all Islamic astronomical, mathematical, and related manuscripts[5] in a relational database; to record paleographic, codicological, content, and user information gleaned from these manuscripts; and to set up a convenient means to access this information. As such, it will not only provide a powerful research tool for scholars in the field, it will also furnish a means to answer some of the "sociological" questions discussed above.[6]

The ISMI database project is meant to be more than a simple catalogue. It will provide the user with information on some 1,700 authors, the content of texts (estimated at between 2,500 and 5,000) that were produced by these authors, and tens of thousands of manuscript witnesses to these texts, a fair percentage of which reveal details regarding readership and ownership, institutional locations where the manuscripts

[5] In the initial stage, the focus will be on astronomical manuscripts. But later, the database will include manuscripts in astrology, mathematical geography, optics, harmonics, and technology. Medicine and natural philosophy will generally be excluded, but a related database project at McGill (PIPDI: the Post-Classical Islamic Philosophy Database Initiative) will include works in natural philosophy. Our hope is that colleagues will use ISMI's open-source database for other fields.
[6] "Sociological" data would include information such as copyists, place of copying, readers, teachers, etc.

were copied, studied, and taught, and the relationship of original texts and their commentaries and supercommentaries –all of which will help draw a picture of the social and intellectual con-texts of these works. Of particular interest will be the capability of the data-base to allow for research into issues of the relationship of science and religion in Islam. For example, it will provide information on the teaching of the sciences and mathematics that occurred in the Islamic religious schools (*madrasa'*s) as well as the extent to which scientific material was used by religious scholars in their writings.

In addition, the database could also be used by scholars doing research into the history of Islamic and European scientific interactions. Since it contains a considerable amount of biographical and other general information, it will potentially be useful for persons outside the field of Islamic science who wish to find out about Islamic scientists, their works, and their social milieu.

Examples of "Sociological" Data Retrievable from the Database

It is often repeated that Islamic science declined precipitously after 1200 CE (usually attributed to the religious reactionaries such as al-Ghazālī [d. 1111 CE]), that the Ancient Sciences were not taught in the schools (*madrasa*'s), and that the influence of Islamic science on Europe ceased after the magical date of 1200. Each of these statements is contradicted, or at least seriously questioned, by information in the database.

1) An examination of the astronomical textbook *al-Mulakhkhaṣ fī ʿilm al-hay'a* by Maḥmūd ibn Muḥammad ibn ʿUmar al-Jaghmīnī (fl. 1220 CE) indicates that it and its commentaries and supercommentaries are extant in thousands of copies spread throughout the Islamic world. (There are more than 300 copies of Qāḍīzāde's commentary in Istanbul alone). This is during the time of the supposed decline of science in Islam. When combined with what we now know of the advanced astronomical work done from 1200-1800 CE in the Islamic world, we can see that there was an important network of learning and innovation that occurred during these centuries.

2) The case for the institutionalization of science is bolstered by examining Vatican arab. MS 319, which contains a copy of *al-Tadhkira fī ʿilm al-hay'a* by Naṣīr al-Dīn al-Ṭūsī (d. 1274 CE) that was copied in 1284 CE at the Niẓāmiyya College in Baghdad. A copy of the commentary on *al-Mulakhkhaṣ* by al-Sayyid al-Sharīf al-Jurjānī (d. 1413 CE) [Cairo, Dār al-kutub, Hay'a MS 96] has an indication that it was studied by a student at al-Azhar in Cairo.

3) Vatican arab. MS 319 contains a number of Latin glosses, probably dating from the fifteenth or sixteenth century, that indicate knowledge of Arabic at the time and interest in this important text.

Some Technical and Conceptual Issues

A prototype of the ISMI database is now running online. Thus far the first version of the database has been designed and successfully tested, and it currently contains entries for some 1 100 authors,[7] several hundred entries for titles and manuscripts, and supplementary material for a number of them.

As mentioned above, the database is currently being transformed from a fairly traditional Microsoft Access database into an object-oriented, open-source one. The advantages are manifold; in particular, the new structure will allow us to create relationships "on the fly," which will be especially useful as we discover new types of connections we wish to document. Thus it may be useful to distinguish student-teacher relationships from relationships between peers. And one can have more than one relationship between a text and an author. Thus "was written by" would only be one of several possibilities; another might be "has been mistakenly ascribed to."

There are any number of technical issues that need to be solved. Fortunately, with the wide acceptance of Unicode, the problem of diacritical markings and the use of multiple scripts in the same database, or even field, has been solved. Though still difficult, it has now become possible to search for text in both Latin and Arabic script, even when the text has diacritical marks. There still remains the problem of how to standardize entries for *hamza*, *ʿayn*, and dotless Arabic characters. And deciding on a transliteration (or transcription) system for Arabic-script languages presents both scholarly and political issues.

Another technical issue involves data flow and verification of data. Data will be submitted by both experts and non-experts, who may be encouraged to send information via forms on the internet. How will this

[7] The preliminary list of authors, which was compiled between 1996 and 1999, came from names listed in the works of G. P. Matvievskaya and B. A. Rosenfeld, *Matematiki i astronomi musulmanskogo srednevekovya i ikh trudi (VIII-XVII vv.)* [Mathematicians and Astronomers of the Muslim Middle Ages and Their Works (VIII-XVII centuries)], 3 vols. (Moscow: Nauka, 1983) and Heinrich Suter, "Die Mathematiker und Astronomen der Araber und ihre Werke," *Abhandlungen zur Geschichte der mathematischen Wissenschaften* 10 (1900). Additional names will be compiled from the ever expanding number of manuscript catalogues and from B. A. Rosenfeld and Ekmeleddin İhsanoğlu, *Mathematicians, Astronomers, and Other Scholars of Islamic Civilization and Their Works (7^{th} - 19^{th} c.)* (Istanbul: IRCICA, 2003).

information be tagged? Since it is unlikely that all sources will be treated equally, steps will be taken to verify data before it is certified for final entry into the database. This is a good example of a technical issue that is also conceptual. In a “WIKI” world, it is becoming more acceptable that information be considered provisional and open to continuous modification. But, somehow, traditional scholarly standards will also need to be maintained.

Another issue that needs to be addressed is accessibility of the sources themselves. From a scholarly perspective, having all the manuscripts online would be ideal. But ownership rights present a major hurdle. One possible compromise we are exploring with several libraries is the idea of putting manuscripts online with images acceptable for “scholarly use,” while libraries retain rights to publishable quality images.

Of course acknowledgment of sources is an issue when dealing with online publishing. We believe that the standard system of citation must continue to be used. But in addition, it is important that individual contributions that are made outside of normal publishing channels be acknowledged as well. And here we have made provisions for citing contributors who have sent us information on manuscripts.

Another issue of prime importance is the time-frame we envisage for the data base to be completed. Clearly the project will take generations even to reach a point of comprehensiveness, if by that we mean examination of all relevant manuscripts; in a sense the project will never reach completion because of the continual updating and reinterpretation of information. But here it is important to distinguish a useable database from a finished database. The latter may never be attainable, whereas the former could be available within a few short years. For example, bio-bibliographical data from existing catalogues could be entered in even a shorter time, but we hope to verify this data before disseminating it online –thus the need for the additional year or two. The important thing to keep in mind is that a structure would be in place for entering any data we obtain, whether from data editors working at McGill or from colleagues worldwide.

Finally, it is worth mentioning here that the resources provided by the Canada Foundation for Innovation and the Max Planck Institute for the History of Science will allow us to have some 5-10 editors, students, and technical experts working on the project at any one time for the next four years. Of course, we hope that our initial success will lead to renewed funding.

Funding and Partnerships

Because of a partnership agreement, ISMI has been able to obtain funding from the Max Planck Institute for the History of Science (MPIWG) in Berlin, Germany; technical expertise, including development of a new version of the database is also being provided by the MPIWG. Additional funding has been provided by the American Council of Learned Societies and the Institute of Islamic Studies at McGill University. Recently, long-term funding has been assured through a major grant from the Canada Foundation for Innovation.

ISMI has a distinguished Board of Advisors (made up of both individual and institutional members) that offers advice on the long-term goals and procedures the project should be taking. Consultants/data collectors are currently working in Turkey, Canada, Germany, and India, and we anticipate having data collectors in additional countries in the coming years. Promising talks are currently underway with several manuscript libraries, and our hope is that we will be able to digitize and put online manuscripts from those libraries for use by researchers. At present several libraries and institutions have ongoing projects to digitize and make accessible Islamic manuscripts; these include Leipzig University, the University of California in Los Angeles, the U.S. National Library of Medicine in Bethesda, Maryland (USA), the Turkish Ministry of Culture, and the Alexandrina Library in Egypt. It is also worth mentioning that the Iranian publishing organization, Miras Maktoob, has compiled a database of some 340,000 manuscripts held in Iranian libraries that it hopes to make available in the near future.

Ultimately, the success of ISMI will depend on the willingness of researchers in the field to share their expertise and information with their colleagues through the medium of the ISMI database. The project would then become ongoing, with information being continuously updated, corrected, and augmented. We are optimistic that this will indeed take place: first, because of the technologies that allow instant communication through means such as the listserve of the Commission on History of Science and Technology in Islamic Societies; and secondly, because of the spirit of cooperation and sharing that is everywhere evident in this generation of scholars that has grown up with the internet and the world wide web.

Technology

Hydraulic Imagery in Medieval Arabic Texts

Constantin Canavas

Abstract

The Arabic reports about irrigation, dams and water-powered machines form a cultural construction which could be called *hydraulic imagery*. The term *imagery* is related to the perception patterns concerning hydraulic constructions inasmuch these patterns are reproduced in documental *genres* in the specific geographical, historical and cultural context of the sources. Thus the references on water-power range from reports about milling output in terms of day-production of meal or flour up to impressive accounts about marvellous machines with the features of a *perpetuum mobile*. These references are embedded in various textual sources which belong to a quite heterogeneous spectre of literary *genres* including geographical and cosmographical works (like those of al-Dimashqī), technological treatises (like the compendia of ingenious devices presented by Banū Mūsā and al-Jazarī) as well as administration documents. Undoubtedly such reports are inspired by the historical reality of hydraulic constructions scattered from al-Andalus and the Maghreb in the Muslim West to Mesopotamia and Transoxania in the East. However, the specific reporting forms as well as several features attributed textually to the constructions under discussion reflect narrative conventions of the specific literary *genre* rather than realistic representation modes of technological artefacts.

The present study develops a typology of such patterns and proposes interpretation models for their emerging on the basis of the specific socio-economic context and the features of the dominant literary traditions in which the narrative patterns concerning the hydraulic imagery are encountered.

Hydraulic engineering in the medieval Arab world: the historical background

The use of water-power for operating machines has a long tradition in the several regions which came under the dominion of Islam in the medieval times. This heritage includes scientific traditions in the Greco-Roman world, as well as the numerous aspects and technological features of water-powered machines all over the Mediterranean, as well as the Near East and the Middle East.

The expansion of the Muslim state in the Mediterranean, the Mesopotamia and the Iranian territory during the 7th century AD enabled contacts and interactions of several scientific and engineering cultures under the Muslim rule. In the case of water-powered machines and hydraulic technology in general different geomorphological landscapes and climatic conditions acted as a polymorphic background for know-how transfer and further development. Novel techniques for crop irrigation were substantial for the transfer of species like cotton, sugar cane and oranges from East up to the Iberian Peninsula. On the other hand using water-power for milling cereals, oil seeds and sugar cane became increasingly important for the food supply of the rural and urban populations in the several Muslim states which resulted from the Arab expansion. Crucial importance obtained the several types of water-raising machines for both fresh-water supply and irrigation in the Arab-ruled regions which in many cases were characterised by shortage of surface water. Beside their role in every-day technological applications (mostly in rural context as well as in procedures of food processing) water-powered machines were engaged in many marvellous devices conceived and, to a certain extent, presumably realised in environments maintained and supported by princes, rulers and distinguished persons.

The importance of hydraulic science and engineering in the Muslim states and the Arab contribution to the transmission of previous know-how and to further development have been worked out and analysed by several authors. The purpose of the present study is to demonstrate characteristic patterns of presenting water-power plants in Arabic historical sources and to interpret these perception patterns in the specific political and cultural context.

Sources

Historical references and archaeological evidence concerning water-powered machines in the Greek, Roman and Islamic world are given in the works on history of technology by Forbes (1957), Schiøler (1973), Oleson (1984), Hill (1984/1996; 1986), Schnitter (1994), El Faïz (2005). In his monumental work on *Science and Civilisation in China* J. Needham (1965 & 1966) extended the comparative study by considering Chinese evidence.

If we focus our study upon *Arabic* primary sources, we encounter mentioning of such machines in travel reports as well as in works of cosmography (i.e. combination of geographical data with cosmological and philosophical doctrines) describing Islamic and non-Islamic countries. Further *genres* are treatises on agriculture, on the rural projects of the State, and finally special treatises concerned with the description of ingenious devices, a kind of marvellous machines conceived on the basis of mechanics and hydraulics.

In the following we shall present first some typical references in Arabic geographic texts of the 10th century AD. We shall then proceed by considering a treatise of the beginning of the 11th century on hydraulic projects of the Muslim state and several texts on agricultural engineering. We shall conclude by referring to several texts concerned with imagery and visions of hydraulic technology as well as with the typical Arabic tradition of hydraulic marvellous machines.

Utilitarian perspectives

Arab geographers often refer to agricultural production of the countries they describe. A special aspect in such descriptions is the dependency of agriculture on water management. Irrigation systems, dams, as well as water-mills belong to large-scale technology which becomes a positively connoted sign of the landscapes described.

Al-Muqaddasī (d. 1000 AD) describes several *dams* in Iran, among which a pre-Islamic dam which provided hydraulic power in Khuzistan, and a dam built in the 10th century AD on the river Kūr, in the Iranian province Fars, by the Buyid emir ʿAḍūd al-Dawla:

> "ʿAḍūd al-Dawla closed the river between Shiraz and Istakhr by a great wall, strengthened with lead. And the water behind it rose and formed a lake. Upon it the two sides were ten water-wheels like those mentioned in Khuzistan, and below each wheel was a mill, and it is today one of the wonders of Fars." (Al-Muqaddasī, Arabic text p. 344; Engl. translation quoted from Hill, 1984, p. 137)

The positive attitude of Arab and Persian writers towards water power and milling is expressed in the way they estimate water stream according its capacity in powering mills. Referring to Upper Mesopotamia, the granary of Baghdad, Ibn Ḥawqal (10th century AD) underlines the use of Tigris stream for powering *ship-mills*:

> "The ship-mills on the Tigris at Mosul have no equal anywhere, because they are in very fast current, moored to the bank by iron chains. Each [mill] has four stones and each pair of stones grinds in the day and night 50 donkey-loads. They are made of wood –sometimes of teak." (Ibn Ḥawqal, Arabic text p. 219; Engl. translation quoted from Hill, 1984, p. 137)

In 1184 AD Ibn Jubayr (1145-1217 AD) describes the ship mills across the river Khabur in Upper Mesopotamia with the exalting expression "forming, as it were, a dam" (Ibn Jubayr, Arabic text p. 243; Engl. translation quoted from Hill, 1984, p. 137).

Even *tidal mills* are mentioned, e.g. by al-Muqaddasī:

> "The ebb-tide is also useful for operating the mills, because they are at the mouths of the rivers, and when the water comes out it turns them." (Engl. translation quoted from Hill, 1984, p. 138)

What is characteristic in all above references is the narrative scheme of the Arab geographers according to which the utilitarian use of water-powered rural machines appears as an indicator for improving the prosperity of the regions described (Hill, 1991, p. 184). Only few technical details of functioning or construction are mentioned, which implies that the authors had poor knowledge of or no interest in such details. Their main goal was to present these human constructions as something exceptional, as "wonders" which contributed to the image and the prestige of the regions.

A different utilitarian perspective can be traced in treatises concerned with agriculture. Already in the *Nabatean Agriculture*, a treatise translated from the Syriac into Arabic in the 10th century AD (El Faïz, 2005, p. 30) we get a detailed description of water-raising machines, such as *sāqiya*, a perpendicular potgarland driven by an animal which rotates a horizontal beam fixed to the perpendicular axis with a gearing to the potgarland. The sources we will refer to come from al-Andalus. Most probably the *sāqiya* was introduced into the Iberian Peninsula by the Arabs. In the treatises of the Andalusī agronomists Ibn al-ʿAwwām and Abū l-Khayr several water-raising machines used in agriculture are not only described in their outlook and functioning but also with respect to their construction specifications and the possibilities of improving thief efficiency –perhaps a rational option of prestige writing (El Faïz, 2005, pp. 219-220; Glick, 1992, p. 981).

Patterns of prestige and political legitimacy

Prestige issues are conventionally associated to persons of the political stage (or, more generally, of the public sphere). It is, therefore, understandable that important works related to water –whether providing drinking water, establishing adequate irrigation of fields or constructing water-powered machines– have been honourably attributed to distinguished Muslims. A well-known example is the project to provide the pilgrimage route from Baghdad to Mecca with drinking water. The idea was inherent to the religious duties of the Muslim caliph. It is Zubayda (d. 831 AD), one of the wives of the Abbasid caliph Hārūn al-Rashīd (786-809 AD), who has associated her name with the project of a canal supposed to carry water from Baghdad all the way down to Mecca. The idea and some financial details of the project are mentioned in the biographical dictionary of Ibn Khallikān (1211-1282 AD) (Ibn Khallikān, vol. I, p. 337). However, no precise information concerning any realised parts is provided, except of the plant for supplying Mecca with water from a spring some 25 miles away. In his journey description Ibn Jubayr (1145-1217 AD) gives some aspects of the water supply along the route from Baghdad to Mecca (El Faïz, 2005, pp. 111-114). However, this hydraulic infrastructure is commonly attributed to the caliph al-Ma'mūn (813-833 AD) (El Faïz, 2005, p. 113). The imprecise and often contradictory information about the ambitious water-supply projects concerning the Islamic Holy Place (Hitti, 1970, p. 302; El Faïz, 2005, p. 111-114) underlines the symbolic value of the subject and renders the several versions of the narrative *a pattern of prestige and political legitimacy* rather than a puzzle of historical evidence.

Similar narratives of political prestige and power concern prestigious regional rulers or public persons, e.g. the "superintendent of irrigation" of Merv in the 10th century, who was said to have more power than the prefect of the city since he commanded some 10000 workers to build and maintain irrigation canals and dams, and a series of 10 *norias* and attached mills (Ibn Ḥawqal, pp. 635-636; Hill, 1984/1996, p. 25). With reference to the same dam of the river Kur in Fars mentioned by al-Muqaddasī (al-Muqaddasī, p. 344), Ibn al-Balkhī underlines 150 years later (12th cent. AD) the labour organised and the money spent by 'Aḍūd al-Dawla for constructing the dam (Lambton, p. 867).

A report combining description and admiration of administrating irrigation services is included in the *Kitāb al-Ḥāwī* dating to the 2nd quarter of the 11th century AD (Cahen, 1949-1951, pp. 117-143). Among fiscal regulations we find detailed data concerning the output of the various water-driven plants: mills, water-raising machines, etc. Written at the end of the Buyid era it is a typical demonstration of political legitimacy through a discourse based on the *hydraulic network*.

Hydraulic imagery and marvellous machines: cosmographies, *ḥiyal*

The Arabic reports about irrigation plants, dams and water-powered machines formed a cultural construction which could be called *hydraulic imagery*. Quite often patterns of this imagery were associated with individual biographies. The Egyptian historian Ibn al-Qifṭī (1172-1248 AD) reports about the audacious project of the Basrian scientist Ibn al-Haytham (965-1039 AD) who considered to erect a dam on the river Nile near the first cataract in the south of Aswan. The aim of this vision was the effective regulation of the annual overflow of the Nile (Ibn al-Qifṭī, pp. 114-116). After having been officially invited by the Fatimid caliph al-Ḥākim, Ibn al-Haytham surveyed the region, but apparently gave up his plan. It is reported that he then "simulated" madness in order to escape the wrath of the Fatimid caliph. It is not easy to exclude exaggerations and gigantomany with respect to the biographies of the Fatimid caliph or Ibn al-Haytham; this could be the contribution of the historiography to the formation of hydraulic imagery in the service of glorifying or colouring individuals. On the other hand the subject itself is the prototype of an incredible gigantesque project. The name of the Basrian scientist remained inherently associated with his hydraulic utopia and his "collateral madness" as embodied exaltation (El Faïz, 2005, pp. 129-137).

Exaltations in reports concerning agricultural technology, particularly hydraulic machines, as well as affinity to the Arabic literary form of the "wonders" (*ʿajā'ib*) (Dubler, pp. 203-204; Institut du Monde arabe, 1978) are typical characteristics of textual sources on travelling and geography of the 12th to the 14th centuries AD. These aspects are especially prominent in treatises which present both geographical evidence and cosmological models explaining the data on a philosophical and theological basis. In modern terms such treatises are usually called *cosmographies*. This is not to say that information on prestigious and highly estimated hydraulic constructions that is provided in such treatises is generally exaggerated. Many references of technological devices constitute today valuable information on medieval technology, i.e. the mention that we find in al-Qazwīnī's cosmography (1203-1283 AD) about the water-mill with horizontal wheel in Malaga. In the cosmography of al-Dimashqī (1256-1327 AD) such descriptions mostly refer to extraordinary ways of using natural resources (matter, wind or water).

In the description of the land of Azerbaijan al-Dimashqī presents the fortified town of Merend (Mehren, 1884, pp. 254-255, French translation; Mehren, 1866, p. 188, Arabic text). The information he gives about this place is concentrated on its remarkable water-mill:

> "In the place named Merend there is a mill which is put in rotation by a still water; and this belongs to the marvels of the world. It is built in the following way: The mill house comprises two stone mills with two water wheels. Each water wheel is put in rotation by its own water [stream]. The upper [mill] stone rotates and grinds the grain. The two water wheels are fixed at the lateral parts of a vault in which the water remains stored with a depth of a man's body and a breadth as well as a length of 6 cubits [e.g. ca. 4 m]. In the middle of this vault there is a pillar stretched like a bridge [horizontally] over the breadth of the vault and fixed on both side walls. This pillar bears two reinforced leaden water pipes which hold on each other tightly [unified] and hang over the pillar up to the surface of the water. Both water pipes are open. Inside there is a structure [device?] by means of which the water is sucked up towards a height of half a cubit [e.g. ca. 34 cm]. It is elevated in it [i.e. in the pipes] and kept on in stream until it flows down powerfully through the other pipe, which rises over the surface of the water in a certain distance. Thus the water flows out from this pipe and, as it falls on the water wheel, it revolves the wheel and moves the mill stone. After falling on the wheel scoops the flowing water reaches the same water [of the storing basin], then it is raised up in the other pipe turned to the other side and flows down from there. This pipe is of the same height and breadth [as the first one]. Thus each pipe sucks alternatively the water ejected by the other, so that the water mass neither decreases nor increases nor moves except at the openings of the two pipes where they suck up and pour out again the water."

It is not the purpose of the present study to smooth or modernise the text in order to make it understandable as far as the *functioning* of the twin water-pipes is concerned. The details provided by the text are not enough to reconstruct the outline of the plant; they do not even elucidate the several possible functions. Even the illustration embedded in the manuscript and referring to the water-mill does not just *illustrate* the text (Canavas, 2005, pp. 291-297). Moreover, it underlines the apparent goal of the presentation of the water-mill of Merend by al-Dimashqī: the marvel described here is a *perpetuum mobile*. Work (i.e. turning the mill stones) is done without any visible input of external power!

The textual treatment of hydraulic machines as *marvels* finds its most remarkable expression in the compendia of *ingenious* machines (Arabic: *ḥiyal*) composed by Banū Mūsā in Abbasid Baghdad (9th century AD) and by al-Jazarī in Diyarbakir (1206 AD). The *Book of Ingenious Devices* of the brothers Banū Mūsā contains descriptions and illustrations of 100 devices. Al-Jazarī's compedium yields descriptions and construction details for 50 elaborate devices which combine mechanics, pneumatics and hydraulics (Hill 1984/1996, p. 199 ff.). Both treatises refer to design and construction for palace environments –"utilitarian" purposes similar to those of the rural machines described above are not mentioned in the *ḥiyal* treatises.

Conclusions

In our study we analysed several Arabic textual sources concerning hydraulic machines. The various patterns traced are strongly related to the specific literary forms and the historical-cultural context of the texts. Whereas travellers and geographers of the 10th century AD underline utilitarian aspects and insert the hydraulic machines into the specific political and economic landscape, later historians and biographers introduce similar utility patterns as prestige criteria in assessing persons of the public sphere: dealing with hydraulic artefacts enables exalting and distinguishing (in case of failure: discrediting) individual persons. The hydraulic imagery finds a prominent position in the literary form of the "wonders" (*ʿajā'ib*), the Arabic *mirabilia*, and in the category of "tricky" devices in palaces and gardens.

The above patterns are expressed through specific *narrative* forms. As a consequence, these forms standardised the manners in which hydraulic know-how and technology are reported. Such reports were undoubtedly inspired by the practical reality; however, it would be an over-interpretation of poor reliability to assert that they depicted social and technological practice. Even if the textual sources in many cases allow the assumption of theoretical scientific insight in the period considered, this is not enough to conclude that "practical realisation of the theory" was just a question of logistics. Technology in the era considered here was not "applied science". The social conditions of technology development might have been quite different from those of literary production, and the motives for using certain narrative forms are not to be found in the literal content of these narratives. In order to trace the paths of know-how transmission from the Nabateans up to the Muslim Arabs additional historical sources and archaeological evidence are still required.

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Développement de la Technologie dans le Monde Arabe (du IX^e au XVI^e s. ap. J.C.)

Mona Sanjakdar Charani

1. Introduction

On définit la technologie comme suit: “étude systématique des procédés, des méthodes, des instruments ou des outils propres à un ou plusieurs domaine(s) technique(s), art(s) ou métier(s)” (*Dictionnaire Trésor*).

La présente étude vise le développement de la technologie dans le domaine de la mécanique appliquée tout en se limitant à trois sous-domaines bien précis:

- La mécanique amusante
- La mécanique des machines élévatrices d’eau
- La musique mécanique

Dans ces trois branches de la mécanique appliquée, les savants arabes ont innové et ont montré un talent très remarquable. Les plus célèbres sont: les Banū Mūsā (IX^e siècle), al-Jazarī (fin du XII^e siècle), Taqī al-Dīn (XVI^e siècle).

2. La biographie des savants arabes signalés plus haut

2.1 Les Banū Mūsā

Ils sont trois frères, Abū Jaʿfar Muḥammad (mort en 259 H / 873 ap. J.C.), Abū l-Qāsim Aḥmad et al-Ḥasan b. Mūsā b. Shākir. Sous les Abbassides, depuis al-Ma’mūn jusqu’à al-Mutawakkil, ils se sont fait un nom comme mathématiciens, astronomes, techniciens et musiciens.

Nous nous intéressons à deux de leurs œuvres:

- le livre *Kitāb al-ḥiyal* (Le livre des ingénieuses mécaniques)
- le manuscrit d'un instrument de musique intitulé *Al-ālāt allatī tuzammiru bi-nafsihā* (L'instrument siffleur qui donne un son de lui-même).

2.2 Al-Jazarī

Abū al-ʿIzz Ismāʿīl ibn al-Razzāz al-Jazarī, est un savant très célèbre en Orient. En fait c'est son volumineux traité *Al-jamīʿ bayna l-ʿilm wa-l-ʿamal al-nāfiʿ fī ṣināʿat al-ḥiyal* (Le livre qui réunit les deux sciences théorique et pratique utilisées pour la fabrication des mécanismes ingénieux), qui éveilla chez les orientalistes la curiosité d'une recherche sérieuse en histoire des techniques dans le monde arabe.

Le nom d'al-Jazarī est relatif à son pays natal "al-Jazīra", une île qui s'étend entre le Tigre et l'Euphrate. Une petite biographie de sa jeunesse est mentionnée dans le préambule de son traité. A ce sujet al-Jazarī précise qu'il a vécu à Diyār Bakr sous le règne de la famille "Artuq". Cette famille est arrivée au pouvoir en 750 de l'hégire avec Nūr al-Dīn (750 H / 1174 ap. J.C. – 581 H / 1185 ap. J.C.). Al-Jazarī est resté à son service pendant plus de quarante ans et c'est sous le règne de Nāṣir al-Dīn qu'il écrivit son traité.

2.3 Taqī al-Dīn b. Maʿrūf al-Dimashqī

C'est un savant arabe du XVI^{e} siècle connu comme ingénieur, physicien, mathématicien, technicien et astronome. Nous ne connaissons pas exactement la date de sa naissance, mais les quelques lignes réservées à sa vie personnelle dans le préambule de ses traités nous ont permis de tracer avec précision les détails de sa vie à Constantinople. Dans ces préambules il parle de sa jeunesse, des pays qu'il a visités, des postes qu'il a occupés et des personnes qu'il a fréquentées.

Né à Damas, Taqī al-Dīn a travaillé au service de ʿAlī Pasha, (gouverneur d'Egypte) en 965 de l'hégire, il s'est par la suite installé à Istanbul où il fit partie du comité des savants dirigé par Saʿd al-Dīn (professeur du sultan Suleyman). En l'an 979 de l'hégire Taqī al-Dīn devient le directeur général des astronomes. Il est décédé en 993 H / 1585 ap. J.C. en Turquie.

Dans cette étude nous nous intéressons à son traité *Al-ṭuruq al-saniyya fī l-ālāt al-rūḥāniyya* (Les méthodes sublimes des machines spirituelles).

3. Le développement de la technologie arabe dans le domaine de la mécanique appliquée

3.1 La mécanique amusante

3.1.1 La mécanique amusante des Banū Mūsā

Dans le monde arabe la mécanique amusante a vu le jour avec les Banū Mūsā b. Shākir. C'est dans leur traité *Kitāb al-ḥiyal* que nous trouvons la description d'un grand nombre de vases à astuces variées d'effets surprenantes, des fontaines, des lampes à huile, d'une chauffe-eau, etc.

Pour faire fonctionner ces mécanismes les Banū Mūsā ont utilisé des techniques très variées, à savoir: des siphons concentriques doubles et simples, des valves simples, d'autres coniques ou à double action, des poulies, des leviers des flotteurs, des manivelles, des roues d'engrenages et beaucoup d'autres techniques assez compliquées.

Nous citons quelques exemples de ces mécanismes:

I Une aiguière dans laquelle on verse par une même ouverture de l'eau chaude et de l'eau froide sans qu'elles se mélangent. Si une personne veut s'en servir pour l'ablution, elle peut avoir à sa guise de l'eau chaude, froide ou tiède (Fig. 1)

Mode de fonctionnement

Le petit tube (b) et le siphon double (j) permettent à l'eau chaude et à l'eau froide de s'accumuler séparément dans les deux compartiments de la jarre. La gargouille de la jarre permet l'écoulement simultané de l'eau chaude et de l'eau froide par l'intermédiaire des deux petits tuyaux (S) et (H), ce qui donne de l'eau tiède. Si on veut obtenir de l'eau froide ou chaude, il suffit de boucher avec le doigt l'orifice correspondant (F ou Q) perforé dans l'anse de la jarre.

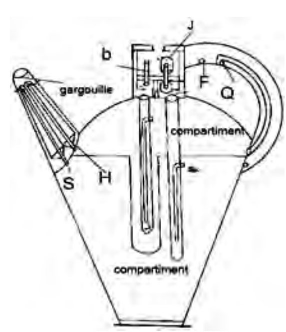


Fig. 1

II Fabrication d'un chauffe-eau à robinet unique qui donne une quantité d'eau chaude une fois qu'on y verse la même quantité d'eau froide (Fig. 2)

Mode de fonctionnement

Tant que la soupape (S) est fermée, l'eau chaude ne peut s'écouler du robinet (J). Par contre dès qu'on verse de l'eau froide dans l'entonnoir (K), elle s'écoule dans le bassinet (B) et soulève le flotteur (F) qui ouvre la soupape en question.

Il est à noter que lorsque le niveau de l'eau dans le bassinet (B) atteint le centre du siphon (P) celui-ci s'amorce et toute la quantité d'eau sort du tuyau (HJ) et la soupape (S) se referme.

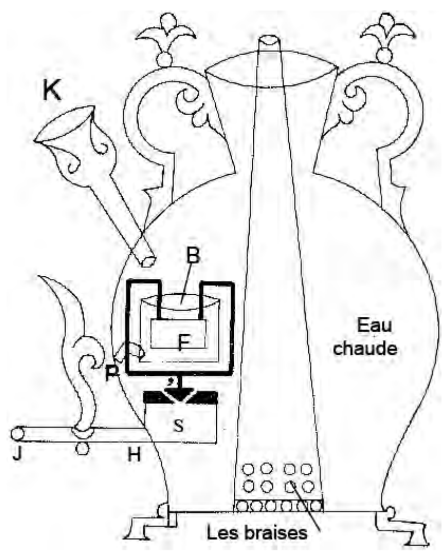


Fig. 2

III Une jarre qui peut recevoir plusieurs rafraîchissements sans les mé-langer. De son unique robinet on peut avoir une quantité bien déterminée de chacun (Fig. 3)

La figure 3 illustre la jarre avec son robinet à trois entrées et la fiole jaugée qui sert à mesurer la quantité de boisson nécessaire pour remplir chacun des réservoirs.

Pour avoir la boisson désirée il suffit de faire correspondre les canaux en tournant l'obturateur du robinet.

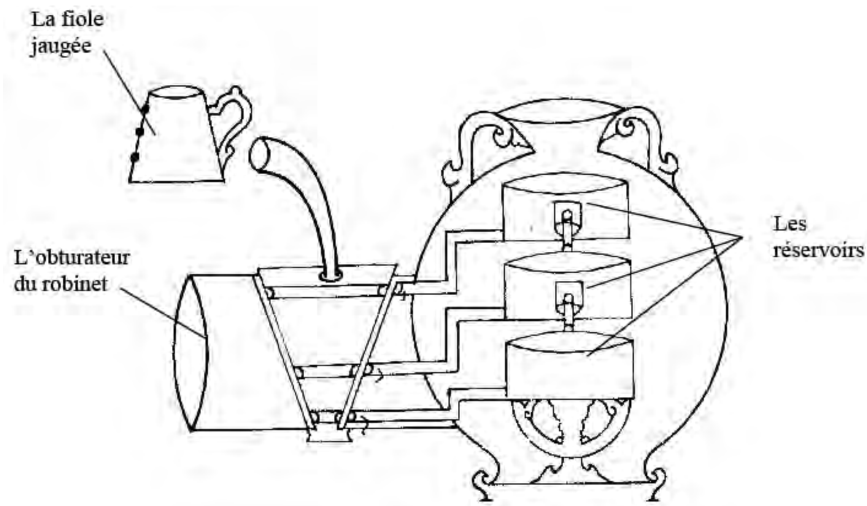


Fig.3

IV Une jarre à deux déversoirs dont l'un est réservé à l'eau et l'autre à la graisse (Fig. 4)

Mode de fonctionnement

L'équilibre du levier (FM) est établi lorsque le récipient (R) est plein de graisse. Dans ce cas la graisse s'écoule du petit tuyau (T) dans le compartiment de droite de la jarre et de là elle s'écoule du tuyau (z). Par contre, si le récipient est plein d'eau, l'équilibre du levier est rompu du côté du récipient et l'eau s'écoule du tuyau (J).

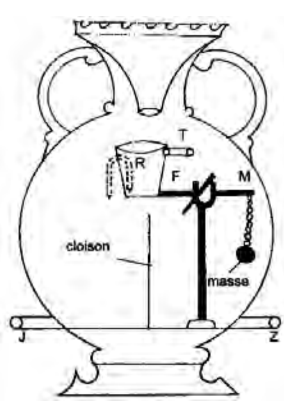


Fig. 4

V Une drague qui sert à récupérer les matières précieuses ou autres objets des profondeurs des puits et des mers (Fig. 5)

L'instrument est composé de deux demi-cylindres dont les extrémités sont dentées. Les deux demi-cylindres fixés par deux charnières portent chacun un anneau en son milieu et deux anneaux aux extrémités. Les anneaux du centre sont reliés par une longue corde (FM). Les quatre anneaux des extrémités sont rattachés par des cordes au même anneau (A).

Mode de fonctionnement

Si on tire sur la corde (FM), les deux demi-cylindres se rejoignent pour saisir les objets. Par contre si on tire sur la corde (C), ils s'écartent pour les libérer.

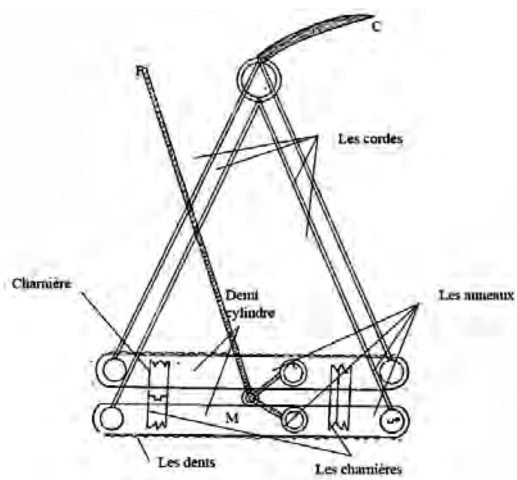


Fig. 5

3.1.2 La mécanique amusante d'al-Jazarī

Le traité d'al-Jazarī signalé plus haut est le seul traité arabe incluant les domaines essentiels de la mécanique appliquée. L'organisation des idées et la clarté des illustrations colorées ou non ajoute à son importance un caractère très spécial qui réside dans la profondeur des connaissances scientifiques et techniques de ce savant.

Al-Jazarī avait ses propres techniques dans la construction de ses machines en plus des siphons, des flotteurs, des roues hydrauliques, des poulies, des roues dentées et des systèmes d'engrenage, un récipient a bascule qui lui est spéciale se trouvait presque dans tous ses mécanismes. La partie (H) de la figure 7 montre la forme de ce récipient qui se dresse horizontalement tant qu'il est vide ou plein d'eau. Mais si on ajoute une goutte d'eau à son contenu, il se balance pour se vider et se redresser de nouveau.

Parmi les mécanismes d'al-Jazarī nous citons:

I La figurine d'un joyeux compère qui boit le fond du verre du roi (Fig. 6)

Le joyeux compère doit boire le fond de la coupe du roi. Et quand un courtisan le prend sur ses genoux et lui fait boire ce qui reste dans son verre, il déverse d'un seul coup tout ce qu'il a bu sur le courtisan mystifié.

Mode de fonctionnement

Quand nous versons la boisson dans la coupe (K), elle s'écoule par le bras dans le bassinet (B). Ce dernier alourdi entraîne la coupe vers le haut. Ce mouvement brusque fait osciller la tête de la figurine par l'intermédiaire du poids (M) qui lui est suspendu.

L'opération se répète jusqu'à ce que le bassinet (B) se rempli et se déverse d'un seul coup dans le bassin (L) à travers le siphon (s). Le flotteur (F) s'élève et la main gauche tourne autour de l'axe (H) sous l'effet du fil enroulé autour des poulies (q) et (v).

Ces mouvements se répètent chaque fois qu'on verse la boisson dans la coupe. Une fois le bassin (L) plein, le siphon s'amorce et le liquide se répand sur les habits du convive mystifié.

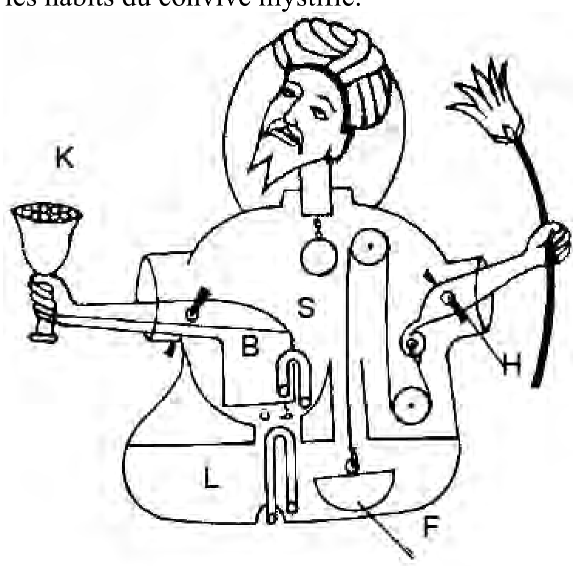


Fig. 6

II Une serveuse qui sort périodiquement d'une armoire avec un verre de boisson à la main (Fig. 7)

La figurine représente une serveuse qui tient dans sa main droite un verre et dans sa main gauche une serviette. Cette figurine se tient debout sur des roulettes derrière les deux battants de la porte d'une armoire.
Mode de fonctionnement:

L'eau versée dans le couvercle (K) coule dans le récipient à bascule (H). Ce dernier une fois rempli se déverse d'un seul coup par l'orifice (u) remplissant ainsi le verre (V). La main de la serveuse s'alourdit entraînant l'ouverture du crochet (C) qui la retient. Ainsi libérée la serveuse avance sur les roulettes (R) vers les battants de la porte et sort de l'armoire. Le roi prend le verre offert, en boit le contenu et, s'il veut, s'essuie la bouche.

Fig. 7

III Une cuvette permettant de quantifier le sang résultant d'une phlébotomie (Fig. 8)

Deux scribes (A) et (B) assis sur le toit d'un palais au dessus de douze portes. (A) porte un tableau et un crayon. (B) porte un bâton qu'il fait tourner sur un cercle gradué tracé devant lui.

La figurine d'un garçon se cache derrière les deux battants de chacune des douze portes.

Une brèche (P) laisse apparaître une main qui fait les mêmes signes que le garçon.

Au milieu de la figure ci-contre, apparaît une grande poulie (P) ayant à ses côtés deux autres poulies plus petites.

Une longue corde est enroulée sur les gorges de ces trois poulies.

Une des deux extrémités de cette corde porte un contre poids (M) tandis que l'autre est fixée au flotteur (F).

L'anneau (A) porteur de douze crochets tourne derrière les figurines des garçons.

L'anneau (B) porteur de douze poignées tourne derrière la brèche (P).

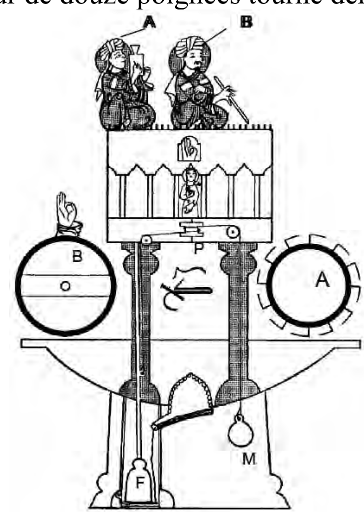


Fig. 8

Fonctionnement de l'appareil de phlébotomie

Al-Jazarī dit:

> "Le récipient humecté avec deux dirhams[1] d'eau est mis à la disposition de celui qui veut effectuer la phlébotomie. Il est clair que lorsqu'un dirham de sang s'écoule dans la cuvette, le bâton du scribe se déplace et se fixe devant la graduation d'un dirham. De même le tableau du second scribe s'élève et le bout de son crayon indique un dirham et ainsi de suite jusqu'à dix dirhams. Alors deux longs battants s'ouvrent sur une porte qui laisse voir d'une part la figurine d'un garçon faisant avec la main le signe du nombre dix et d'autre part une brèche qui découvre une main représentant le même signe. Ainsi, les deux scribes continuent à indiquer simultanément la quantité de sang écoulée dirham

[1] *Dirham*: unité de mesure de masse qui vaut 3,9 grs.

par dirham. Arrivé au vingtième dirham, deux autres battants s'ouvrent sur la seconde porte qui laisse voir de même la figurine d'un garçon et une main faisant le signe vingt. L'opération se répète jusqu'à ce que tous les battants soient ouverts faisant apparaître toutes les portes".

3.1.3 La mécanique amusante de Taqī al-Dīn

Dans ses mécanismes Taqī al-Dīn n'a pas ajouté des nouveaux techniques a ceux des Banū Mūsā et d'al-Jazarī bien que l'on trouve dans "le lit des amoureux" une nouvelle technique qui réside dans l'utilisation d'une lanière pour faire tourner simultanément les deux roues des automates.

I Le lit des amoureux (Fig. 9)

C'est une boîte surmontée de deux figurines (A) et (B). (A) a deux faces, une laide et une belle.

L'artifice fonctionne comme suit:

Si (A) tourne sa face laide vers (B), celle-ci lui tourne le dos

Si (A) montre sa belle face, (B) lui présente une pomme ou une fleur en tendant la main.

Mode de fonctionnement

La lanière (L) en cuir enroulée sur les deux poulies régularise le mouvement des figurines.

La tige (T) fixée à chaque axe empêche la poulie de faire un tour complet.

La petite poulie (p) et la corde (c) assurent le mouvement de la main de la figurine (A).

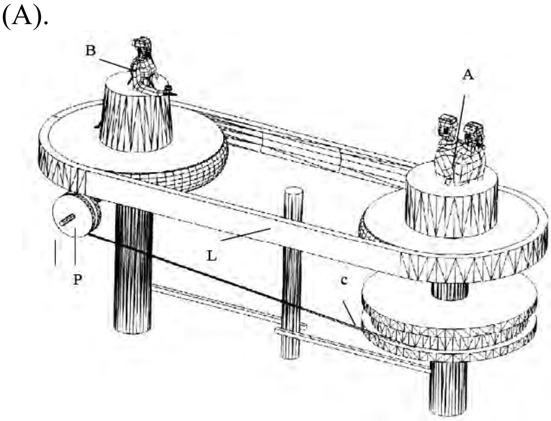


Fig. 9

II L'encensoir des lits (Fig. 10)

Taqī al-Dīn décrit cet encensoir comme suit:

Deux hémisphères creux, liés par deux charnières, sont solidement fermés par une serrure.

Par leur surface extérieure ajourée sort la fumée de l'encens. Dans l'un d'eux sont fixés trois anneaux mobiles autour de trois axes différents. Un godet lesté, mobile autour de son propre axe, occupe le centre de la sphère. C'est dans ce godet qu'on place la braise et l'encens.

L'encensoir bien fermé est glissé dans un lit pour le réchauffer et le parfumer.

Fig. 10

3.2 Les machines élévatrices d'eau

Les Banū Mūsā n'ont pas rédigé des traités relatifs aux machines élévatrices d'eau. Ils se sont contentés de la description des fontaines dans leur livre "Les moyens ingénieux", *Kitāb al-ḥiyal*. Par contre al-Jazarī a consacré, dans son traité, déjà signalé, tout un chapitre pour la description des fontaines, des machines élévatrices d'eau et d'une pompe à deux cylindres. Quant à Taqī al-Dīn il s'est concentré sur la construction de pompes très variées.

3.2.1 Les machines élévatrices d'eau d'al-Jazarī

I Une machine à puiser l'eau d'un puits (Fig. 11)

Mode de fonctionnement:

Le mouvement de cette machine est dû à la force d'une bête.

Quand la bête (H) fait un demi-tour le système d'engrenage droit, formé par les deux roues (p) et (q), entraîne la rotation de l'axe (Z) qui soulève l'écope (K) par l'intermédiaire du levier coudé (L). L'écope pleine plongée dans le puits étant soulevée, elle se vide par son extrémité (J) dans le canal approprié. Quand la bête fait son second demi-tour, l'écope libérée du levier retombe dans l'eau du puits et l'opération se répète tant que l'animal tourne.

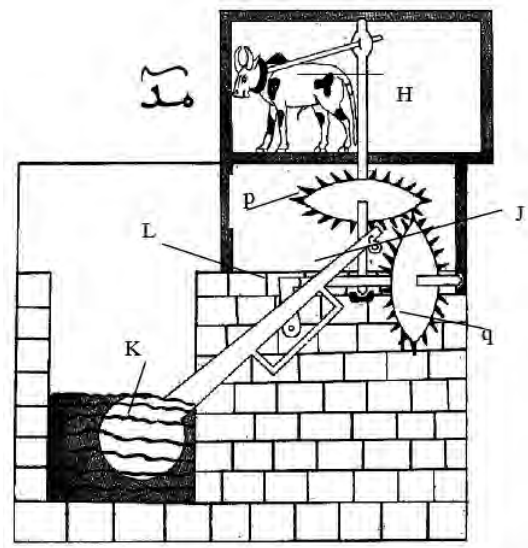


Fig. 11

II Un bassin au centre duquel se trouve une colonne creuse. Sur cette colonne est fixée une plate-forme surmontée de la statuette d'une vache qui fait tourner une roue. Cette dernière élève l'eau du bassin de dix empans (Fig. 12)

Mode de fonctionnement

Le bassin (s) est alimenté par l'eau des deux robinets (a) et (b). L'eau accumulée se déverse par l'ouverture (H) sur la roue à écopes (R), la fait tourner entraînant avec lui le système d'engrenage droit formé par les deux roues (P) et (Q). En conséquence l'axe (Z) tourne entraînant en rotation la plate-forme, la vache, le système d'engrenage droit formé par les deux roues (C) et (D) et la roue à lanternes porteuse de la chaîne à godets. Ces derniers plongent tour à tour dans l'eau du bassin, se remplissent et se vident dans le canal approprié.

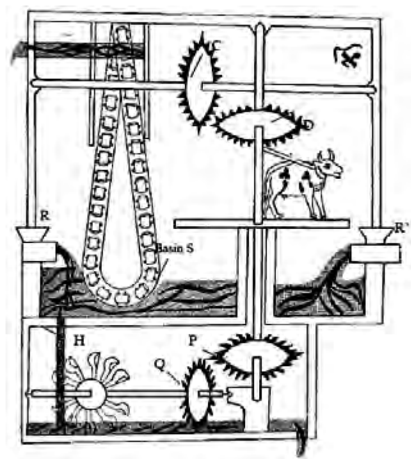


Fig. 12

III Une machine qui élève l'eau de vingt coudées environ (Fig. 13)

Cette machine se distingue des précédentes par le fait qu'elle est une véritable pompe hydraulique foulante et non seulement une machine élévatrice d'eau.

Description de la machine

Deux tuyaux de cuivre (B) et (B') plongés au trois quarts dans l'eau. À l'intérieur de chacun d'eux, sont fixées deux soupapes qui fonctionnent alternativement. Ces deux tubes communiquent avec deux autres tubes beaucoup plus longs (D et D') qui font pomper l'eau vers l'extérieur.

Un cylindre (C) muni d'un piston (P) est fixé horizontalement à chaque tuyau. Chaque piston est attaché à la tige à fente (X) par une autre petite tige rigide. La tige (X) glisse à la surface de la roue dentée (R) par l'intermédiaire d'un clou qui rentre dans fente.

Un autre axe horizontal (p q) porte une roue dentée (M) et une roue hydraulique à ailettes (K).

Mode de fonctionnement

Sous l'effet de la force de l'eau la roue hydraulique (K) tourne entraînant la rotation du système d'engrenage formé par les deux roues (R) et (M). Ainsi la tige à fente (X) tourne avec la roue (R) et son mouvement de rotation se transforme en un mouvement sinusoïdal par l'intermédiaire de deux tiges (T) et (T'). De ce fait, l'un des deux pistons se retire de son cylindre, ouvre la soupape inférieure (S') et aspire l'eau. Tandis que l'autre pénètre dans le sien, ouvre la soupape supérieure (S) et refoule l'eau dans le tuyau qui lui est accordé. Ainsi le cycle se répète et les deux pistons fonctionnent alternativement, permettant à l'eau d'être pompée continuellement vers le canal approprié.

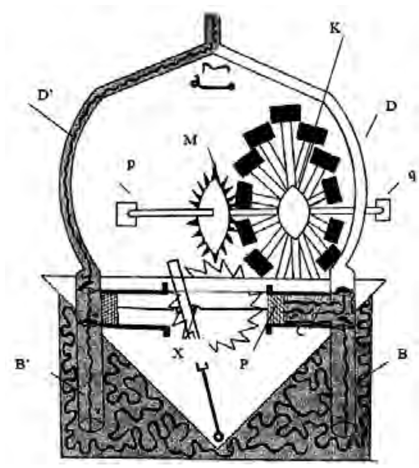


Fig. 13

3.2.2 Les pompes de Taqī al-Dīn

Dans son traité *Al-ṭuruq al-saniyya fī l-ālāt al-rūḥāniyya* Taqī al-Dīn décrit quatre pompes pour élever l'eau à différentes hauteurs.

I La première pompe

La description de la première pompe de Taqī al-Dīn nous ramène à la description faite par al-Jazarī pour sa pompe à deux pistons.

II La deuxième pompe. Machine à élever l'eau basée sur la vis d'Archimède (Fig. 14)

Les éléments de la machine

- Un tube (1) dans lequel est insérée une vis sans fin, possède à son extrémité une roue dentée (2). Son extrémité inférieure plonge dans l'eau.
- Un axe transversal porte une grande roue dentée (3) qui s'engrène avec (2) et une grande roue hydraulique à ailettes (4).

Mode de fonctionnement

La grande roue hydraulique tourne sous l'action du poids de l'eau sur ses ailettes. Elle entraîne la rotation du système d'engrenage donc du tube (1). Ainsi l'eau monte dans le tube et se déverse dans le canal approprié.

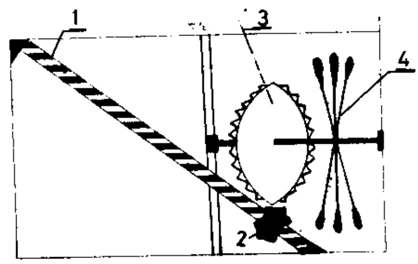


Fig.14

III La troisième pompe. La pompe à boules d'étoffe (Fig. 15)

Les éléments de la pompe

- Un tube vertical creux (1) plonge dans l'eau
- Un axe horizontal (4) mobile dans deux trous (3) pratiqués dans deux traverses verticales.
- Un système d'engrenage droit formé par les deux roues dentées (6) et (9).
- Deux roues à lanternes (5) et (11)
- Une tige (10) fixée à l'axe vertical de la roue (9).
- Une corde sans fin, portant des boules d'étoffes équidistantes, s'enroule sur les deux roues à lanternes. Ces boules glissent dans le tube (1).

Mode de fonctionnement

On fait tourner manuellement la tige (10), le système d'engrenage tourne ainsi que les roues à lanternes. Par la suite la corde se déplace entraînant les boules d'étoffes qui refoulent l'eau vers l'extérieur.

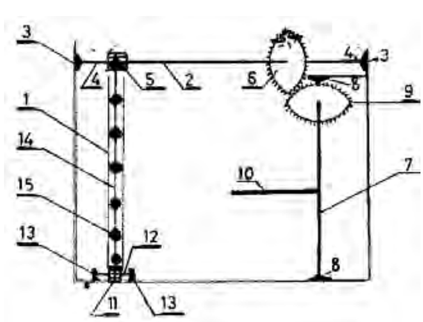


Fig. 15

IV La quatrième pompe. La pompe à six cylindres (Fig. 16)

Les éléments de la machine

- Une planche parallélépipédique de bois (A) est perforée de six trous verticaux équidistants. Sur chaque trou est fixée une soupape surmontée par un petit cylindre (C). Ce dernier renferme un piston muni d'une tige métallique qui se termine par une boule. Chaque tige est reliée à un levier dont le point d'appui appartient à un axe horizontal. L'autre extrémité de ce levier touche une cheville fixée sur l'une des faces d'un axe hexagonal (X). Sur cet axe est montée une grande roue hydraulique à ailettes (R).
- Six trous sont perforés dans une face latérale de la planche et donnent accès aux premiers trous. Ces derniers sont fermés par des valves anti-retour surmontées par des longs tuyaux qui se raccordent au tuyau d'échappement (T).

Mode de fonctionnement

La roue à ailettes tourne sous l'action du poids de l'eau entraînant la rotation de l'axe hexagonal. Les chevilles appuient respectivement sur les extrémités libres des leviers. Par la suite chaque piston s'élève à son tour dans son cylindre et le remplit d'eau. A chaque 1/6 de tour une cheville libère un levier, alors le piston correspondant redescend dans le cylindre sous l'action du poids de la boule. Par ce mouvement l'eau est refoulée dans le tuyau.

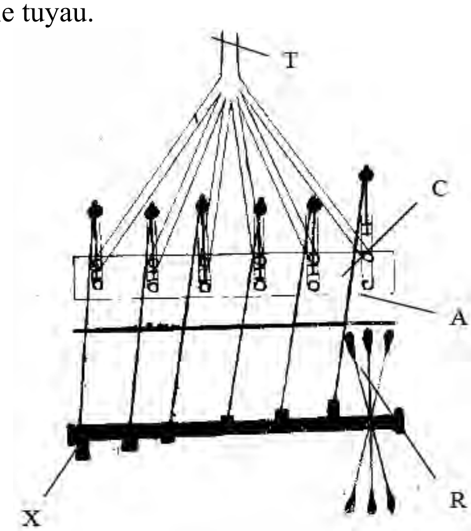


Fig. 16

3.3 La musique mécanique

La musique mécanique est produite par des instruments qui fonctionnent mécaniquement sans l'influence artistique de l'homme. Elle a vu le jour avec le son des carillons au début du quatorzième siècle. La première horloge de Strasbourg montée en 1352, et dont le constructeur est inconnu, groupait des automates et des carillons qui jouaient mécaniquement une mélodie composée de neuf airs différents.

L'élément essentiel d'un instrument de musique mécanique est le porteur du son ou cylindre pointe: c'est un cylindre en rotation uniforme autour de son axe, dont la surface est garnie de goupilles, ponts ou agrafes. Ces pointes font soit vibrer la lames d'un clavier ou d'une boite a musique, soit enlever un levier qui envoie par un système pneumatique l'air dans un tuyau d'orgue, soit soulever un marteau qui frappe sur des cordes (piano mécanique)

Dans le traité des Banū Mūsā *Al-ālāt allatī tuzammiru bi-nafsihā* (L'instrument qui siffle de lui-même) nous trouvons la description d'un instrument de musique mécanique. L'étude critique et analytique de ce manuscrit nous a permis d'identifier cet instrument. C'est un orgue hydraulique mécanique automatique.

Description de l'instrument, la figure 17 montre:

- A gauche, en haut, un système d'engrenage actionné par des roues hydrauliques
- Vers le milieu on trouve le ballon compresseur
- En bas se situe la pompe à deux compartiments
- A droite se présente le cylindre pointé avec son mécanisme de rotation

Mode de fonctionnement

Du grand robinet (A) qui communique directement avec le grand réservoir (R) l'eau se déverse abondamment sur la grande roue à aubes (R') et le fait tourner entrainant avec lui le pignon (P), le disque denté (T) et le demi-anneau (U). Celui-ci ouvre et ferme alternativement les deux soupapes opposées. Dès que l'une des deux soupapes s'ouvre, l'eau se précipite par le tuyau recourbe correspondant pour se déverser dans le petit récipient (r) fixé à l'extrémité inferieure de ce même tuyau, et déborde dans un autre récipient (r') fixé à l'extrémité d'un levier. Des que (r') est plein, le levier se balance de son côté pour détendre la chaine et fermer la soupape (S). L'eau s'amasse alors dans le compartiment (M), refoulant l'air par le tuyau (t) dans la boule (B). Cette opération s'effectue durant un demi-tour du demi-anneau. Au second demi tour l'eau s'amasse dans le second compartiment et l'air est toujours refoulé et comprimé dans la boule (B) et n’a d’autre issue que le tuyau qui communique directement avec la flûte. Les trous de cette dernière sont ouverts et fermés par des leviers actionnés par les chevilles du cylindre pointé.

Dans ce même manuscrit les Banū Mūsā décrivent une méthode pratique pour la distribution des chevilles sur le cylindre du son.

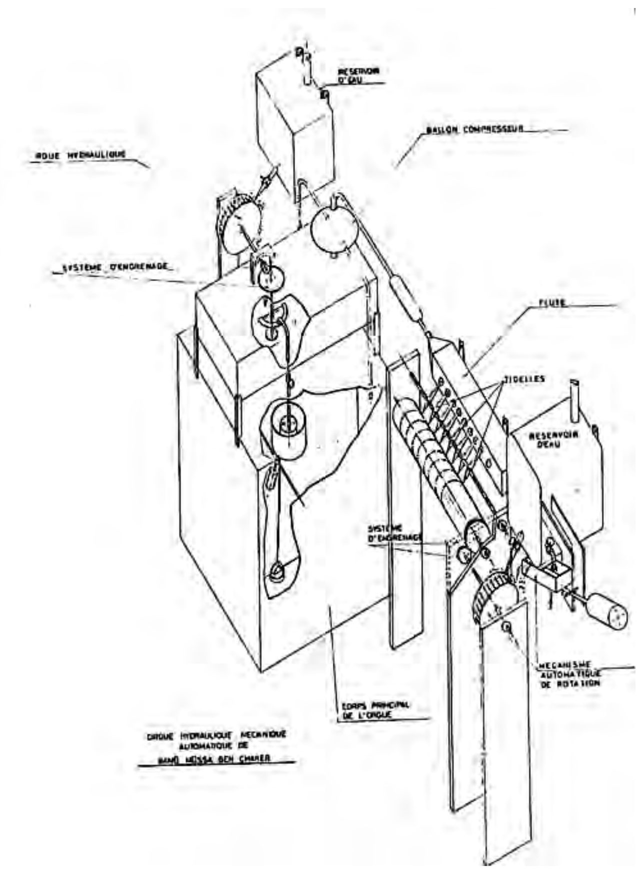


Fig. 17

D’après ce qui précède nous pouvons conclure que les Banū Mūsā ont innové dans le domaine de la musique mécanique et c’est à eux que nous devons l’invention du cylindre du son qui est l’élément de base de la musique mécanique.

4. Conclusion

Depuis le neuvième siècle, maintes techniques furent développées par les savants arabes, à savoir:

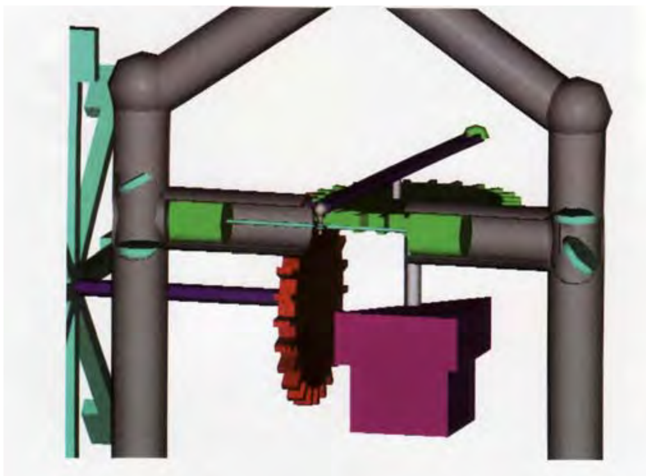
Les Banū Mūsā ont utilisé les soupapes coniques qui n'apparaissent en Europe que chez Léonard de Vinci. De même on les retrouve dans le livre de Ramielli (1558). De plus les Banū Mūsā ont utilisé des soupapes doubles sous différentes formes. Ils se sont appuyés sur la vitesse d'éjection de l'eau pour remplir plusieurs vases se trouvant sur un même plan horizontal et beaucoup d'autres techniques minutieuses.

Il est à noter que tous les appareils construits n'étaient pas fabriqués dans le but de l'amusement; il y en avait une majorité d'une utilité pratique.

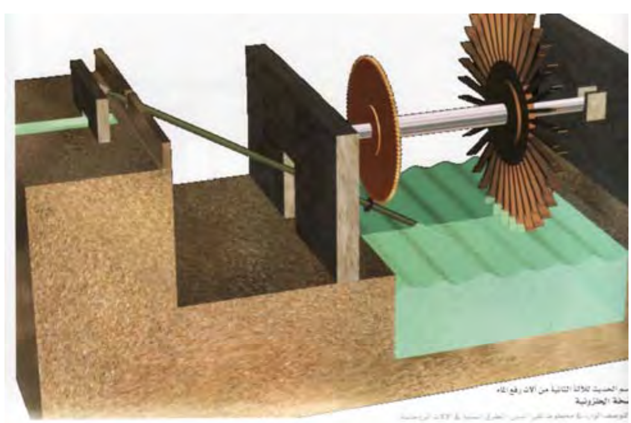
Pour les innovations d'al-Jazarī, il suffit de signaler que son traité est incomparable et que nous ne pouvons pas résumer en deux lignes toutes les techniques qu'il a utilisées pour construire ses horloges, ses pompes, ses aiguillières et beaucoup d'autres mécanismes. Mais nous pouvons faire remarquer les détails minutieux avec lesquels il a décrit chaque pièce de ses machines. Ainsi, il se présentait non seulement comme ingénieur mais un technicien et un bricoleur de grand talent.

Quant à Taqī al-Dīn, il continuait la chaine des innovations par ses horloges mécaniques et ses pompes hydrauliques.

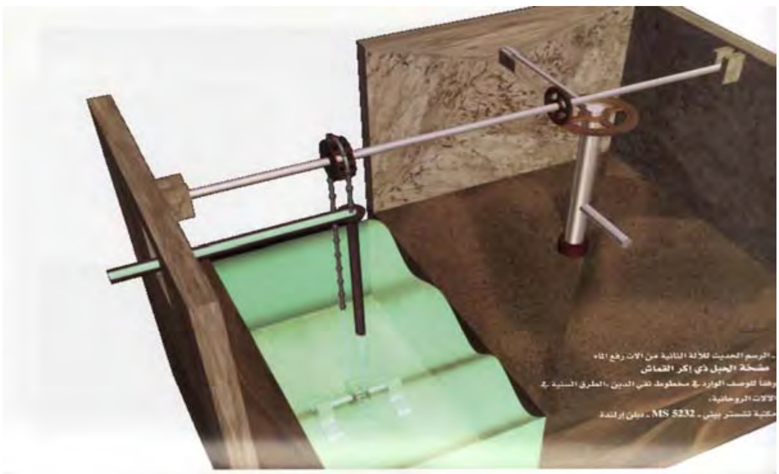
Nouvelles Illustrations en 3D



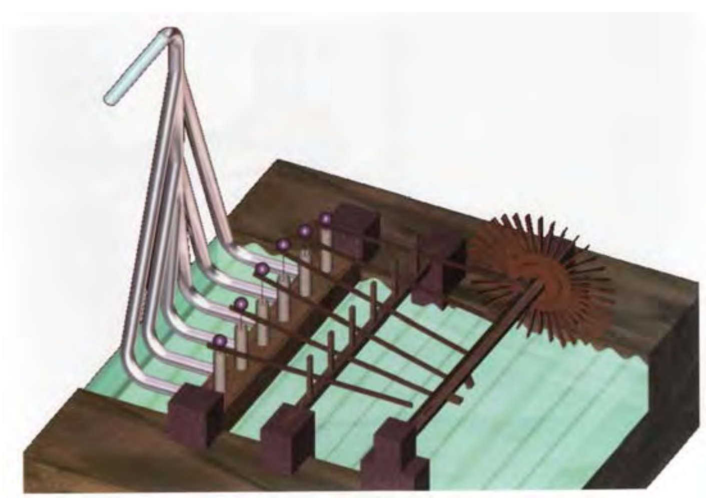
La pompe à deux pistons d'al-Jazarī



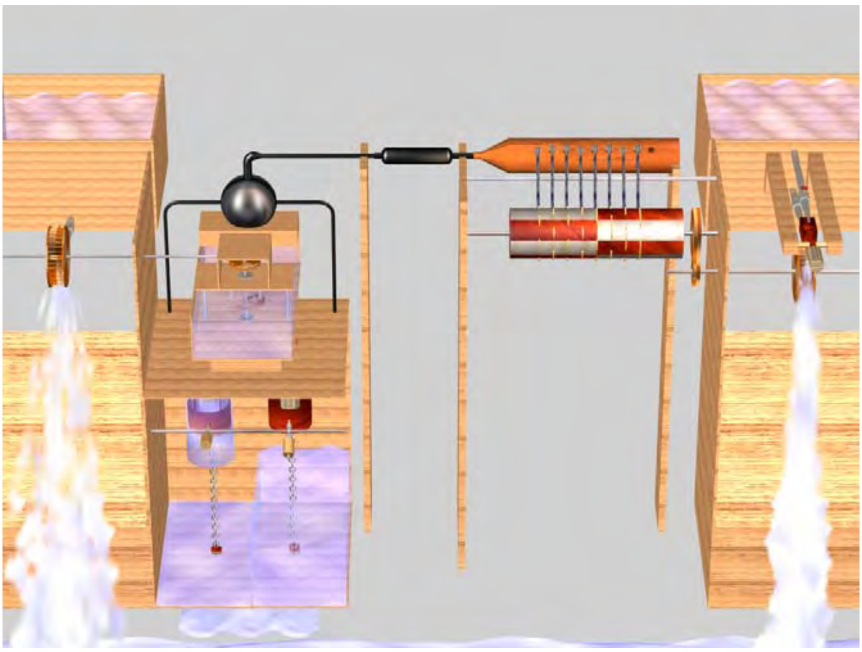
La deuxième pompe de Taqi al-Dīn



La troisième pompe de Taqī al-Dīn



La quatrième pompe de Taqī al-Dīn



Orgue hydraulique mécanique automatique des Banū Mūsā

1000 Years of Missing Industrial History

Salim T. S. al-Hassani

Abstract

Most educational systems, particularly those of Western countries, tell us that industry was born in Europe and that the Industrial Revolution was the mother that delivered industrial mass processes. This paper challenges this view and presents an overview of the industrial and engineering processes which preceded the Industrial Revolution. It briefly examines the vast industry which stretched from China to Spain during the Muslim Civilisation (circa 700-1700 CE); a period sometimes referred to as the "Dark" or "Medieval Ages".

A brief overview is given of some randomly selected aspects of Muslim industrial production which highlights not only the Islamic antecedents of many processes and products widespread in our modern industrial system, but also how erroneous is the opinion that industrial production was alien to Islamic society.

Windmills and water-wheels provided power for industrial production. Industrial processes ranged from composite steel to paper making, petroleum, pottery, glass making, textiles, agriculture, ship building, fishing, mineral extraction, metal working, and chemical products. An attempt is made to discuss the rise and fall of this vast industrial experience and reference is made to some lessons to be learnt from that vast human experience.

Introduction

A typical university graduate grows up with the notion that industrial production, or manufacturing, is a Western manifestation, dating from the mid to late 18^{th} century. This implies that there was no industry until the English Industrial Revolution of the mid 18^{th}-19^{th} century, followed by that of other countries, for example France, and later Germany, America and Japan, initiated the birth and development of manufacturing and mass production. This is what is taught to this day in most history and engineering departments in the UK, Europe and US. Also, according to such teaching, and the literature that went with it, the reason why the so-called Third World countries are backward is due to the absence of industrial tradition, and the difficulties they have in initiating what is somehow alien to their societies.

Thirty years after this author passed all his academic degrees secure in such knowledge and started teaching it in reputable Western universities, he came across new learning away from standard books and literature, which surprisingly taught him that[1]:

(i) Industrial production, manufacturing, and mass production for both vast urban populations and for export, relying on machinery powered by wind and water, had existed nearly ten centuries before the 18^{th} century English Industrial Revolution,

(ii) Metals were smelted in huge quantities, in the Muslim world, for local and foreign markets,

(iii) Textiles were produced, from China to Muslim Spain, in ways not so dissimilar from methods we have today,

(iv) Such products were not bartered but sold in exchange for cash, or paid for by cheques honoured and valued across Asia, Africa, and Southern Europe, and,

(v) Capital was invested and reinvested across vast domains according to lines and mechanisms corresponding to our modern methods.

For example, during the Abbasid Caliphate, manufactures of every kind were encouraged and fostered in Iraq and many other lands. Glass and soap were made in the factories of Basra. The paper industry particularly received much impetus. It attracted workers from all over the world, particularly from Egypt. Persia was noted for her gold and embroidery work, which was carried on in all the big cities. High class fabrics including satin, brocade, silk and carpets were manufactured in Islamic domains and were in great demand all over the world. Kufa was famous for its silk and silk handkerchiefs known as kuffiyeh. Khuzistan (ancient Susiana) produced superfine cloth.

[1] See literature as follows: M. Lombard, *The Golden Age of Islam*; translated by J. Spencer; Amsterdam: North-Holland publishers, 1975, p. 239; S.D. Goitein, *A Mediterranean Society*, 5 vols., Berkeley: University of California Press, 1967-1990; vol. 1, paperback edition, 2000; and various articles on mechanics, engineering, and industry at www.MuslimHeritage.com.

The chemical research in Jundishapur, possibly the oldest observatory and college of natural sciences, led to the knowledge of sugar refining which was successfully applied to sugar industry in Khuzistan and later on in Spain. In addition to being famous for its manufacture of Damascus steel swords, Syria was also known for its glass, where, as early as the 9th century, parti-coloured and enamelled glass was produced. The commodeties exported during the Abbasid Caliphate were agricultural produce, glass, hardware, silk, textiles, perfumes of all kinds, rose water, saffron, syrup, and oil. In short, every city in the Muslim world had its own particular manufacture in metal, glass, wool, silk or linen.

To sum up this trend of industrial production as accounted for in brief by recent historiographical works, let's quote the beginning of the only available synthesis on Islamic technology: "Technology is the tool of civilisation, and for Islamic civilisation to have been such a leading force for several centuries, clearly it must have been based on important technological achievements".[2]

Muslim Spain: Thriving Cities of Industry

Under Islam, Spain became very prosperous due to wide ranging industries and large-scale production with revenues from commercial duties exceeding the combined revenues of all the Christian states of Europe. The textile industry for instance in its capital Cordova, had 13,000 looms and Almeria had 4,800 looms[3]. The leather industry was thriving. The art of tanning and embossing leather had been developed to a high degree of perfection and from there it spread to Morocco and North Africa, England and France. High class woollen and silk fabrics were manufactured in Cordova, Malaga, Almeria and other towns. Almeria also produced glass-ware and brass work[4]. Sericulture (the production of raw silk by raising silkworms) was much developed in Spain. According to the Spanish historian Ibn al-Khaṭīb, Valencia was the home of pottery. The mining industry was fully developed. Jaen and Algrava were famous for their gold and silver mines, Cordova for its iron and lead and Malaga for its rubies. Toledo like Damascus was known throughout the medieval world for its swords. The art of inlaying steel and other metals with gold and silver and decorating them with flower patterns, which was

[2] A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*. Paris/Cambridge: UNESCO / Cambridge University Press, 1986, p. xiii.

[3] P. K. Hitti, *History of the Arabs*, MacMillan, London, 1970.

[4] Al-Maqqarī, *Nafḥ Al-Ṭīb*: translated by P. De Gayangos: *The History of the Mohammedan Dynasties in Spain* (extracted from *Nafḥ Al-Ṭīb* by al-Maqqarī), 2 vols., London: The Oriental Translation Fund, 1840-43.

introduced from Damascus, flourished in several European and Spanish centres and left a linguistic heritage in such words as *damascene*, *damaskeen*, French *damasquiner* and Latin *damschina*.

The Muslims had converted the barren lands of Spain into a garden and developed a vast agricultural industry. Seville alone had several hundreds factories. Besides the textiles and agricultural industries, paper, sugar, gunpowder, porcelain, earthenware, iron, steel and leather industries spread on an extensive scale. The tapestries of Cordova, the woollen stuffs of Murcia, the silk of Granada, Almeria and Seville, the steel and gold work of Toledo and the paper of Salibat were sought all over the world. The glazed tiles and the fine vases still found in the palaces of Alhambra bear testimony to the high quality of porcelain manufacture.[5]

Omission from History

There are many instances of distorted history, and many writers have given attention to this matter.[6] In this presentation the focus will be on the other means by which history is distorted, that is, the omission of centuries from the educational curriculum and associated history books, especially those aimed at the general public. The focus on this issue is to alert communities to the particular significance of the Muslim civilisation and its historical role in giving birth to much of modern science and technology.

John Glubb very clearly describes this distortion in his *History of the Arab People*. He tells us:

> "Modern oriental studies have proved the falsity of this historical propaganda (the idea of the 16th-17th century Renaissance, and that nothing happened between the 450s (the fall of the Roman Empire) and such Renaissance, although the latter is still widely believed by the general public. Unfortunately, a great part of the educational world still adheres to these ancient taboos and the period of some five or six centuries, which separates the decline of Rome from the Norman invasion of England, is omitted from school curricula and from public examination. As is always the case, this falsification of history for propaganda purposes has injured us more than anyone else, and has

[5] For an overview on the technology of al-Andalus, see D. R. Hill, "Andalusian Technology", in *Studies in Medieval Islamic Technology: From Philo to al-Jazarī − From Alexandria to Diyār Bakr*. Edited by David A. King. (Variorum Collected Studies Series). Aldershot, Eng. / Brookfield, Vt.: Ashgate, 1998, XVIII.

[6] For instance, D.H. Fischer, *Historians' Fallacies*, London: Routledge & Kegan Paul, 1971; J. Fontana, *The Distorted Past*, Blackwell, 1995; G. Fisher, *The Barbary Legend*, Oxford, 1957; P. Geyl: *Use and Abuse of History*, Yale University Press, 1955.

> largely been responsible for the many political errors, which our governments have committed in the Middle East in the last sixty years.
>
> The history of 'progress', the rise of man from a primitive state to his modern condition, is a fascinating story. The interest is lost, however, when the continuity is concealed by the omission of periods of several centuries and the presentation of bits and pieces of history, gathered from here and there, in accordance with our own emotional prejudices or our national vanity".[7]

Of course, Glubb only speaks of those centuries up to 1066 (the time of the Norman invasion of England), but the whole period 450-1492 is in fact passed over as Dark Ages, and is altogether ignored as far as science and civilisation are concerned, termed as '*a middle age*', an intermediary period, a uniform bloc, '*vulgar centuries"* and '*obscure times*', as Pernoud says.[8] One challenges any audience to pick ten history books, look into them to find that in at least nine, if not eleven of them (the numerical exaggeration is on purpose to highlight the case), the presentation of scientific achievements jumps from some Greek names of late Antiquity, whomsoever it is, whether Ptolemy, Archimedes, or Galen, straight to Galileo, consequently ignoring scientific and technological events of the period, between 1000 and 1500, as if it were a sterile period. And the same holds with respect to curricula at schools and colleges. Even more disastrously, as the curious audience can gather, from universities, too. How it is that higher learning institutions teach that nothing happened over a thousand years is not just beyond comprehension, but against academic rules of rigorous questioning. Students, who are trained to think critically, suddenly face a sudden darkness of ten centuries, and then are told things appeared, as if by a miracle, all at once in the Renaissance. It defies logic. Things, as any scientist knows, do not appear by chance. Continuity is basic in the birth and rise of sciences; it is equally so in almost every other field of study.[9]

Richness of industrial production during the "Dark Ages"

In this paper the situation pertaining to industry and production is considered. The subject is huge and unfortunately not much research has been done on it. It is hoped that this paper will trigger debate and interest on a wider scale. During 700-1700 CE, Muslim industrial production

[7] John Glubb, *A Short History of the Arab Peoples*; Hodder and Stoughton, 1969, pp. 289-90.
[8] Regine Pernoud: *Pour en finir avec le Moyen Age*, Paris: Editions du Seuil, 1977, p. 17.
[9] See also A. Y. al-Hassan's and D. R. Hill's enumeration of the factors behind the historians' reluctance to admit Islamic achievements in technology and industry in *Islamic Technology. An Illustrated History*, op. cit., pp. 279-281.

ranged from mineral extraction to the production of goods by means of complex processes (the manufacture of paper for instance).

A brief overview here of some randomly selected aspects of Muslim industrial production highlights not just the Islamic antecedents of many processes and products widespread in our modern industrial system, but also, and above all, how inane is the opinion that industrial production was alien to Islamic society.

Pacey, for instance, notes how mechanical techniques reached a high level of sophistication in the Islamic civilization as well as in China, notably with respect to the application of water wheels to generate power.[10]

Steel

Hammer Pugstall, on the other hand, has noted, how al-Kindī has left us a classification of sword steel, in which steel is divided into two main classes, namely iron works steel and non iron works steel.[11] Al-Kindī subdivides the iron works steel into two groups: carbon steel and wrought iron. He then states that from the two, a third steel is produced which is called composite steel (*murakkab*), "which owes its quality to a combination of both male and female properties, hardness and toughness.'' This is apparently laminated steel.[12] Wulf pursues this matter, explaining that the steel industry of Toledo (Spain) was founded by the Muslims, and that by living for centuries in Sicily side by side with the Muslims, the Normans acquired its knowledge, and rather than them transmitting it to the Indonesians, it was Muslim commerce with Java from the 10th to the 14th century which transmitted the pamor technique.[13]

The metalworkers of Islam made bronze, brass, or copper lamps, ewers, bowls, jugs, mugs, cups, basins, and braziers; cast them playfully into the forms of lions, dragons, sphinxes, peacocks, and doves; and sometimes incised them with exquisite patterns, as in a lacelike lamp which can be seen in the Art Institute of Chicago.[14]

The swords of Damascus were of highly tempered steel, adorned with reliefs or inlaid with arabesques, scripts, or other patterns in gold or silver threads.[15] Metallurgy was well developed throughout Spain; Murcia was famous for its iron and brass works, Toledo for its swords, Cordova for

[10] A. Pacey, *Technology in World Civilization*, Cambridge, Mass.: MIT Press, 1991, preface, p. 26.
[11] J. Hammer-Purgstall, "Sur les lames des Orientaux", *Journal Asiatique*, III - IV (1854), pp. 66 ff.
[12] H.E. Wulf, "Notes on Damascene Steel and Pamor", *Technology and Culture*; vol 6, pp. 627-629; p. 628.
[13] Ibid, p. 629.
[14] W. Durant, *The Age of Faith*, New York: Simon and Shuster, 1950, p. 274.
[15] Ibid, pp. 274-5.

shields.[16] "We may without hyperbole rank Islamic books of the ninth to the 18th century as the finest ever issued," tells Durant. "Which of us can be published in such splendour today?" he asks.[17]

Petroleum

Petroleum was an important product in Islamic economic life long before it attained its present global significance. Crude petroleum (*nafṭ*) was extracted and distilled extensively; it had both military and domestic uses.[18] Crude oil was usually called black *nafṭ* and the distillate white *nafṭ*, even though some of the crude oils were colourless in their natural state. We have a number of descriptions of the distillation process in Arabic writings, as in al-Rāzī's *Book of Secrets*. From this we learn that the crude oil was first mixed with white clay or salt ammoniac into "a dough like a thick soup" and then distilled. The light distillates, i.e. the white *nafṭ*, were used by him to "soften or loosen" some solid substances, such as certain gems and minerals. [19]

The oilfields at Baku were developed on a commercial scale by the Muslims at an early date; it is reported that in 885 the Caliph al-Muʿtamid granted the revenues of the *nafṭ* springs to the inhabitants of Draband. There are several accounts of Baku oil as by al-Masʿūdī, who, after visiting the wells in 915, wrote that "vessels carrying trade sail to Baku which is the oil-field for white *nafṭ* and other kinds." In the 13th century wells were dug at Baku to get down to the source of the *nafṭ*; it was at this time that Marco Polo reported that a hundred shiploads might be taken from it at one time. Other sources record crude oil production in Iraq where there were seepages on the eastern bank of the Tigris along the road to Mosul. Muslim travellers reported that it was produced on a large scale and was exported. Other reports give information on crude oil production at Sinai in Egypt and Khuzistan in Iran.[20]

Besides crude petroleum and its distillates, asphalts were also abundant. In Iraq, *qīr* (pitch) and *zift* (pitch or asphalt) were produced and exported. They became familiar in building construction, especially for baths, and in shipbuilding, while they were also adopted as ingredients in the recipes for many incendiary weapons.[21]

[16] Ibid, p. 298.
[17] Ibid, p. 275. For more details on the Islamic contribution to the industry of iron and steel, see A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*, op. cit., pp. 251-260.
[18] D. R. Hill, *Islamic Science and Engineering*, Edinburgh University Press, 1993, pp. 87-88.
[19] Ibidem.
[20] Ibidem.
[21] Ibidem. More details are in A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*, op. cit., pp. 145-146.

Mining, Metallurgy and Chemistry

Mineral deposits contributed to the prosperity of the various provinces. Emeralds were exploited in Upper Egypt, turquoises in Ferghana, rubies in Badakhshan, and various stones, varieties of cornelian and onyx in particular, in the Yemen and Spain. The mines of Spain provided gold, silver, tin, copper, iron, lead, alum, sulphur, and mercury. Rubies were also mined at Baja and Malaga in Spain. The cinnabar mines of Almaden in Spain had a workforce of somewhere near a thousand, some cutting the stone down in the pit, others transporting the wood for smelting, making the vessels for melting and refining the mercury, and manning the furnaces.[22]

Salt was mined at the Hadhramaut, Ispahan, Armenia and North Africa. "Throughout the greater part of Africa," writes Leo the African, "salt is entirely of the mined variety, taken from underground workings like those for marble or gypsum." The polishing of precious stones was done with emery, which was found in Nubia and Ceylon.[23] Egypt and the Sudan both had alum, and certain areas of western Egypt, notably the famous desert of Nitro, had natron, which was used for whitening copper, thread, and linen, and also for curing leather. It was also in demand with dyers, glass-makers and goldsmiths; bakers even mixed it in with their dough and meat-cooks used it as a tenderizer.[24]

The pearl industry thrived in the Arabian Sea, and along the Bahrain coast towards the island of Dahlak. Ibn Baṭṭūṭa offers some details of pearl-diving methods: "The diver attaches a cord to his waist and dives", he says. "On the bottom, he finds shells embedded in the sand among small stones. He dislodges them with his hand, or a knife brought down with him for the purpose, and collects them in a leather bag slung round his neck. When breath fails, he tugs at the cord, the sign for the man holding it in the boat to pull him up again. Taking off the leather bag, they open up the shells, and cut out with a knife pieces of flesh from inside. On

[22] G. Wiet *et al.*, *History of Mankind*, vol. 3: *The Great Medieval Civilisations*, translated from the French; UNESCO/George Allen and Unwin Ltd, 1975, p. 334; W. Durant, *The Age of Faith*, op. cit., p. 298.

[23] Ibidem.

[24] See A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*, op. cit., pp. 233-243, where the two authors quote a profusion of extracts from original manuscripts on the mining and metallurgy industries and techniques in Muslim lands; the joint article by al-Hassan and Hill, "Mining Technology", which constitutes section 2 of the entry on "Maʿādin", in *Encyclopaedia of Islam*, New Edtion, Leiden: E. J. Brill, 1986, vol. 5, pp. 967-973; and Michael G. Morony, "Mining: Sources of Gold and Silver According to al-Hamdānī", in Michael G. Morony, *Production and the Exploitation of Resources* (Series: The Formation of the Classical Islamic World). Aldershot, Hampshire: Ashgate Variorum, 2003.

contact with the air these harden and change into pearls, which are then collected, both large and small."[25] In Spain pearls were fished along the Catalonian coasts; whilst coral was gathered along diverse Andalusi shores.[26] There were coral reefs lying off the coasts, of and near Sicily, and al-Idrīsī gives an account of coral-gathering:

> "Coral is a plant which has grown like trees and subsequently petrifyed deep in the sea between two very high mountains. It is fished with a many-looped hemp tackle; this is moved from high up in the ship; the threads catch the coral branches as they meet them, and the fishermen then draw up the tackle and pick out from it the very considerable quantity of coral."[27]

When one deals with mining and metallurgy, it is necessary to allude to chemistry and chemical industry. In its beginnings, Artz explains, chemistry was mixed with superstition and magic, astrology and other branches of occultism and with fraudulent deception. The basic beliefs of the alchemists were the ideas of Aristotle that all matter consists of the four elements: earth, air, fire, and water, in various combinations, that gold is the "noblest" and "purest" of all metals, silver is next, that the transmutation of one metal into another is possible by an alteration in the admixture of the elements, and, finally, that base metals may be turned into noble ones by means of a precious substance often called the fifth element or quintessence. Much experimenting followed these theories, and the alchemists believed that they could discover an "elixir of life" that would prolong life.[28]

Muslim scientists, Ibn Sīnā and Ibn Khaldūn, for instance, attacked such beliefs and practices. Ibn Sīnā, for instance, in *The Book of Minerals*, denounces the artisans who dye metals in order to give them the outside resemblance of silver and gold. He asserts that fabrication of silver and gold from other metals is "practically impossible and unsustainable from a scientific and philosophical point of view."[29] Ibn Khaldūn, for his part,[30] denounces the counterfeiters who apply on top of silver jewellery a thin layer

[25] Ibidem.
[26] W. Durant: *The Age of Faith*, op. cit., p. 298.
[27] G.Wiet et al., *History*, op. cit., p. 334.
[28] F.B. Artz: *The Mind: The Mind of the Middle Ages*; Third edition revised. Chicago/London: The University of Chicago Press, 1980, p. 165.
[29] Georges Anawati: "Arabic Alchemy", in *Encyclopedia of the History of Arabic Science*, 3 vols. Edited by Roshdi Rashed *et al.*; Routledge, London and New York: 1996, pp. 853-885; p. 877. One has to be careful of Anawati's article, though. Whilst Ibn Sīnā and Ibn Khaldūn never attacked the science of chemistry, just the crooked versions of it, Anawati, like others, eagerly generalises and accuses them of attacking the science itself. In neither the work of Ibn Khaldūn or of Ibn Sīnā, who was himself a chemist, is there a single instance of an attack on the science itself.
[30] For greater detail on Ibn Khaldūn's view of alchemy, see: Hamed A. Ead: "Alchemy in Ibn Khaldun's *Muqaddimah*" at http://www.levity.com/alchemy/islam20.html.

of gold, and make other manipulations of metals. To Ibn Khaldūn, the Divine wisdom wanted gold and silver to be rare metals to guarantee profits and wealth. Their disproportionate growth would make transactions useless and would "run contrary to such wisdom."[31]

Together with al-Rāzī, they rid the science of its folkloric side to give it its modern outlook. Al-Rāzī, as noted above, in his chemical and medical works observes how he made use of oil lamps (*naffāṭa*) for gently heating chemicals; the fuel for these was either vegetable oils or petroleum.[32] Al-Rāzī also divided substances into animal, vegetable, and mineral. The mineral substances include mercury, gold, silver, pyrites, glass etc.; vegetable substances were mainly used by physicians. More importantly, al-Rāzī's *Book of Secrets*, according to D. R. Hill, foreshadows a laboratory manual, besides dealing with substances, equipment and processes.[33] In such a laboratory, distillation and sublimation was practiced and much of the chemical apparatus in use up to about 1650 was developed.[34] In fact, al-Rāzī's laboratory, includes many items still in use today, such as crucible, decensory, cucurbit or retort for distillation (*qār*) and the head of a still with a delivery tube (*ambīq*, Latin *alembic*), and various types of furnace or stove.[35]

Before al-Rāzī, Jābir Ibn Ḥayyān improved methods for evaporation, filtration, sublimation, distillation, and crystallization, described scientifically the two principal operations of chemistry: calcination and reduction, and knew how to prepare chemical substances like sulphide of mercury, arsenious oxide (arsenic trioxide) and lead carbonate.[36] His emphasis on the value of experimentation was passed on to later scientists. "The first essential," he wrote, "is that you should conduct experiments. For he who does not conduct experiments will never attain to the least degree of mastery. It must be taken as an absolutely rigorous principle that any proposition which is not supported by proofs is nothing more than an assertion which may be true or may be false."[37]

From the laboratory and experimentation spread the production of many industrial items, pharmaceutical, but also used in other industries such as tanning, dyeing, and paper making.

[31] G. Anawati, "Arabic Alchemy", op. cit., p. 881.
[32] D. R. Hill: *Islamic Science*, op. cit.; p. 87.
[33] D. R. Hill, *Islamic Science and Engineering*, op. cit., p. 83.
[34] F. B. Artz, *The Mind*, op. cit., pp. 165-66.
[35] C. J. Singer *et al.*, *History of Technology*, 5 vols; Oxford: Clarendon Press; see vol 2 (1956), particularly on pp. 753-777; D. R. Hill, *Islamic Science and Engineering*, op. cit., p. 83; C. Singer, *A Short History of Scientific Ideas to 1900*, Oxford University Press, 1959, p. 185.
[36] F. B. Artz, *The Mind*, op. cit., pp. 165-66.
[37] E. J. Holmyard, *The Great Chemists*, London, 1929.

Paper Industry

To show the ground breaking impact the Islamic industry of paper had in the universal history, historians of technology don't hesitate to write:

> "The introduction and spread of the paper-making industry in the Near East and Western Mediterranean was one of the main technological achievements of Islamic civilisation. It was a milestone in the history of mankind".[38]

Paper, originally, was brought by the Muslims from China. From an art, the Muslims developed it into a major industry. The Muslims employed linen as a substitute to the bark of the mulberry, which the Chinese used. Linen rags were disintegrated, saturated with water, and made to ferment. The boiled rags were then cleared of alkaline residue and much of the dirt, then beaten to a pulp by a trip hammer, an improved method of maceration invented by the Muslims.[39] By 950, water power was used in the fibre pounding process in Baghdad.[40]

In Baghdad many paper mills were built after 793, and from there, the industry spread to various parts of the world. Paper mills which first flourished in Iraq, Syria and Palestine, made their way West. Africa saw its first paper mill built in Egypt around 850. A paper mill was built in Morocco, and from there it reached Spain in 950.[41] The centre of manufacture was Xativa near Valencia. Paper was first made in Europe by Spanish Moors from the fine flax of Valencia and Murcia. During the Muslim rule, Xativa was the centre of the paper industry in Spain. The adoption of cotton as a material for the production of this article of commerce is said to be due to the practical genius of the artisans of Xativa. At a time when the scribes of Christian Europe were reduced to the necessity of erasing the works of Classical authors to obtain parchment for the preservation of pious homilies and monkish legends, the mills of Xativa were producing great quantities of paper, much of which in texture and finish will compare not unfavourably with that obtained by the most

[38] A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*, op. cit., p. 190.
[39] D. Hunter, *Papermaking: the History and Technique of an Ancient Craft*, London: Pleiades Books, 1943; 2nd edit. 1947, p. 139.
[40] F. and J. Gies, *Cathedral, Forge, and Waterwheel*: *Technology and Invention in the Middle Ages*. Harper Perennial, 1995, p. 97; J. Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress*, Oxford, 1990, p. 41.
[41] D. Hunter, *Papermaking*, op. cit., p. 470.

improved process as of modern manufacture.[42] From Spain and Sicily, paper making spread to the Christians of Spain and Italy.[43]

This product was indispensable among people of intellectual tastes like the Hispano-Arabs and demand for it was enormous.[44] By the year 1000, paper was in general use throughout the Islamic world, not only for books, but also as wrapping material and napkins.[45] The paper mills constructed in Damascus were the major sources of supply to Europe. As production increased, the product became cheaper, more available, and of better quality. Cotton paper, sold as *charta Damascena*, was previously made in Damascus.

Of course, paper seems so ordinary today, but its use is fundamental to modern civilisation. By making use of the new material, paper, manufacturing it on a large scale, and devising new methods for its production, the Muslims, in the words of Pedersen "accomplished a feat of crucial significance not only to the history of the Islamic book but also to the whole world of books."[46] The other decisive impact of Muslim manufacture of paper was, obviously, and directly to bring about the invention of printing.[47]

Pottery Industry

Extensive use was made of pottery, for cooking, lighting and washing. In the bazaar in Cairo, according to a Persian writer of the 11th century, grocers, druggists and ironmongers provided the glasses, the faience vessels and the paper to hold or wrap what they sold. "Daily", al-Maqrīzī (a 13th-century Muslim historian), tells, "there is thrown on to the refuse heaps and waste piles –waste to a value of some thousand dinars– the discarded remains of the red-baked clay in which milk-sellers put their milk, cheese-sellers their cheese, and the poor the rations they eat on the spot in the cook-shops."[48]

[42] S. P. Scott: *History of the Moorish Empire in Europe*, 3 vols., Philadelphia and London: J.B. Lippincott Company, 1904, vol. 2, p. 387.
[43] T. K. Derry and T. I. Williams, *A Short History of Technology*; Oxford Clarendon Press, 1960, p. 232; W. M.Watt, "L'Influence de l'Islam sur l'Europe médiévale", *Revue des Etudes Islamiques*, vol 40 (1974), p. 36.
[44] S. P. Scott, *History*, op. cit., vol 2, p. 387.
[45] F. and J. Gies, *Cathedral*, op. cit, p. 97; J. Mokyr, *The Lever of Riches*, op. cit.,p. 41.
[46] J. Pedersen, *The Arabic Book*, op. cit., p. 59.
[47] T. K. Derry and T. I. Williams, *A Short History of Technology*, op. cit., p. 231. For more accounts on the growth of the industry of paper in Islam, see: J. Pedersen, *The Arabic Book*, translated by Geoffrey French; Princeton, NJ: Princeton University Press, 1984; M. M. Sibai, *Mosque Libraries: An Historical Study*, London and New York: Mansell Publishing Limited, 1987, and Jonathan Bloom, *Paper Before Print. The History and Impact of Paper in the Islamic World*. New Haven: Yale University Press, 2001.
[48] Quoted in G. Wiet *et al.*, *History of Mankind*, vol. 3: *The Great Medieval Civilisations*, op. cit., p. 335.

Different uses were made of pottery in Muslim Spain. Because of the widespread diffusion of the water lifting machine, the *noria*, its pot, the *qādūs*, became the universal unglazed pot and it must have been the mainstay of the rural pottery industry until it was replaced by tin fairly recently. The most popular pot, with a middle waist and a knob on the bottom to facilitate the lashing of the pot to the *noria* rope, is related to Syrian pots. Also common were flat-bottomed vessels with a hole in the bottom, which historian of technology Glick explains had a variety of purposes: as a casserole, according to an Andalusi-Magribi cookbook of the 13th century; as a flower pot, according to the botanist Ibn Baṣṣāl; and, in irrigated areas where delivery of water was timed, as an outflow clepsydra (hanging water clock) through the vent of which water issued in a determinate time.[49]

In the East, pottery centres developed at Baghdad, Samarra and many other towns. In the 9th century the potters of Samarra and Baghdad distinguished themselves by making, perhaps inventing, lustre pottery. The decoration was painted in a metallic oxide upon the glazed coating of the clay, and the vessel was then submitted to a smoky and subdued second firing, which reduced the pigment to a thin layer of metal, and gave the glaze an iridescent glow.[50] Exquisite monochromes were produced in this manner, and still more exquisite polychromes in gold, green, brown, yellow, and red, in a hundred almost fluid tints.[51] The lustre technique was applied also to the ancient art of decorative tiles; the rich colours of these squares, and their harmonious combinations, gave unique splendour to the portals or *mihrabs* of hundreds of mosques, and to many palace walls.[52]

Ceramics Industry

Ceramics of finer quality were also produced, and firing workshops in general were very active throughout almost the entire Muslim world, the potteries of the Muslim east rivalling the faience workshops of Tunis and Cordova. The glazed faience tiles of Malaga, known as *azulejos*, are still famous. The diffusion of glazed wares into Spain from the East can be traced with great precision, owing to the chemical specificity of the glaze

[49] T. Glick, *Islamic and Christian Spain in the Early Middle Ages*. Princeton, NJ: Princeton University Press, 1979, p. 239.
[50] W. Durant, *The Age of Faith*, op. cit., p. 275.
[51] Ibid.
[52] See Venetia Porte, *Islamic Tiles*. New York: Interlink Books, revised edition, 2004. Earlier editions include British Museum Press, London, 1st edition 1995, 2nd 1999; Interlink Books, New York, 1995.

recipes.[53] Thus we know that the blue glaze of cobalt oxide was introduced from the East to Malaga during the Taifa period, from where it spread to Murcia and then to Christian Spain, to Valencia (at the beginning of the 14th century) and Barcelona (at the end of the century).[54]

This following description of a modern potter's wheel is probably applicable to all those of the Middle Ages:

> "The potter's wheel consists of a sloping tray over which is a wooden axis supporting a further piece of wood in the shape of a disc, the whole resting on a cross-bar. The lower wheel is turned by the craftsman with his foot, an action requiring no great expenditure of energy; in consequence of its inclination, the tray is carried round and over by its own weight."[55]

An 11th century Persian traveller conveys an idea of the quality of Egyptian faience at the time:

> "Egypt produces faience of every kind; so fine and transparent that a hand placed against the outside of a vase may be seen from inside. Bowls, cups, plates, and other utensils are made. They are decorated with colours that change with the position of the vessel."[56]

Historians today note with surprise the wide variety of eastern ceramics and the techniques employed in their manufacture. So rich was the Islamic industry in this field that it easily impacted on the West.[57]

The history of ceramic production in the medieval Muslim world, from the period of the Umayyads in the 7th century to the Ottomans and Safavids in the 17th century, attests to the superior creativity and experimentation of Muslim potters, demonstrated through their innovations in shape and design, clay recipes, glazes, and techniques of decoration.

As shown by the recent studies, glazed and painted ceramics were highly sought commodities in urban as well as courtly contexts. Potters of the Islamic lands experimented with specially made tin and alkaline glazes that fired to an opaque creamy-white finish. Around the 12th century, they also developed alternative clay recipes by adding large quantities of crushed quartz to produce a hard, white ceramic body, known as "frit-

[53] T. Glick, *Islamic and Christian Spain*, op. cit., p.239.
[54] Ibid.
[55] G. Wiet *et al.*, *History*, op. cit., p. 335.
[56] Ibidem.
[57] It is worth pointing out here that for anyone interested in how all these industries and crafts were passed onto the West, the briefest and most informative outline is provided by S. Feber, *Islam and the Medieval West*. A Loan Exhibition at the University Art Gallery, State University of New York at Binghamton, April 6-May 4, 1975. For ceramics, for instance, the article by R. Schnyder is very enlightening: R. Schnyder, "Islamic Ceramics: A Source of Inspiration for Medieval European Art", in S. Ferber ibidem.

ware" or "stone-paste". It was largely used in the Islamic world for different types of fine ceramics from the 12th century onward.[58]

Glass Industry

Throughout the Islamic world, glass was either cut from crystal or blown into moulds. Aleppo in Syria was mentioned as a glassmaking and decorating centre by the geographers Yaqūt al-Ḥamawī (d. 1229) and al-Qazwīnī (d. 1283). Damascus, too, was described as a glassmaking centre by Ibn Baṭṭūṭa (d. 1377) and Niccolo of Poggibonsi, who travelled in the Holy Land in 1345-46.[59] Excavations at Jabal, an Umayyad palace in the Syrian countryside, revealed a quantity of domestic glassware; excavations at Hama yielded a wide range of later material, mostly of the period between 1100 and 1400.[60] A large amount of glass has been recovered from excavations in Jerusalem where, according to the geographer al-Muqaddasī, lamps were made in the 10th century.[61] Syrian glasses were particularly prized the world over. Even such fragile objects as Syrian enamelled glass of the 13th century have been found in Sweden.[62] Islamic glass has also been found in a few medieval European sites, the discovery of such glass objects in Sweden, southern Russia, and even in China, indicating that distance did not always prevent them being transported.[63] Egypt was also famed for glassmaking, and continued to produce vessels of all qualities in the Islamic period.[64] Excavations at al-Fusṭāṭ (the forerunner of Cairo, founded in 969) have provided an immense quantity of glass, ranging in date from the 8th century to the later Middle Ages; the sheer abundance of such finds presumes that al-Fusṭāṭ was a centre of production. Among the earliest datable objects (the earliest datable glass weight was made in 708) are coin-like weights, stamped with the names of rulers or government officials.[65] They came in a variety of colours, among which are dark green, light green and turquoise, white

[58] Fahmida Suleman, "Ceramics", *Medieval Islamic Civilization, An Encyclopaedia*, ed. Josef W. Meri, New York-London: Routledge, 2006, vol. 1, pp. 143-144. See also the section on "ceramics" in A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*, op. cit., pp. 160-170 and James W. Allan, *Islamic Ceramics*. Oxford: Ashmolean Museum, 1991.
[59] D. Whitehouse, "Glass", in *Dictionary of the Middle Ages*, J. R. Strayer (editor in chief), New York: Charles Scribner's Sons, 1980 fwd., vol 5, pp. 545-58; p. 547.
[60] Ibid, p. 546.
[61] Ibidem.
[62] R. Ettinghausen, "Muslim Decorative Arts and Painting their nature and impact on the Medieval West", in S. Feber (ed.), *Islam and the Medieval West*, op. cit..
[63] Ibid.
[64] D. Whitehouse, *Glass*, op. cit., p. 546.
[65] Ibid, p. 546.

and purple. Some of the most sophisticated Egyptian glass vessels were decorated with lustre.[66] This shiny, sometimes metallic effect was achieved by painting copper or silver oxide on the surface of the object, which was then fired at a temperature of about 600º (1112º) in reducing conditions. The same technique, as al-ready noted, was used in the decoration of earthenware, not only in Egypt but also in Iraq and Iran. Until recently, controversy raged over the origin of lustre painting, but the problem appears to have been solved by the discovery at al-Fusṭāṭ, of a glass cup of local type, inscribed with the name of ʿAbd al-Ṣamad, governor of Egypt in 771-772; Egyptian glass painters were therefore using lustre some time before its appearance in Iraq.[67]

In al-Andalus, glass vessels were blown in Almeria, Malaga, and Murcia in imitation of eastern wares, such as the *irakes* –glass goblets– so favoured on the noble tables of 10th-century León. The technique of cutting crystal was said to have been introduced by ʿAbbās ibn Firnās (d. 887), scholar and inventor in the courts of ʿAbd al-Raḥmān II and Muḥammad I.[68] It is worth pointing here to the genius of Ibn Firnās, who was not only able to decipher the most complex writing, but also made attempts at flying by building artificial wings.[69] In relation to glass, he was familiar with the scientific properties of glass, and contributed to the early experiment with lenses and the idea of magnifying script by their use.[70] He also lent his skills to the glass making furnaces of Cordova, and made a representation of the sky in glass, which he was able at will to make clear or cloudy, with lightning and the noise of thunder at the press of a finger.[71]

Textile Industry

Textiles were exceptionally important in the art and economy of Islam from the earliest times. Their role, Whelan notes, has been compared to that of steel in the modern industrial economy, and it has been estimated that in the Middle Ages textile manufacture and trade may have occupied a majority of the working population.[72] Some sources claim that there were 3,000 weavers in Cordova alone.[73] Cordova made "Cordovan"

[66] On decoration techniques of glass, see A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*, op. cit., pp. 156-160.
[67] D. Whitehouse, *Glass*, op. cit., p. 546..
[68] T. Glick, *Islamic and Christian Spain*, op. cit., p. 241.
[69] A. Djebbar: *Une Histoire de la Science Arabe*, Paris: Le Seuil, 2001, p. 274; S. and N. Ronart, *Concise Encyclopaedia of Arabic Civilization. The Arab West*, Amsterdam, 1966, p. 142.
[70] A. Djebbar, *Une Histoire*, op. cit., 272-274.
[71] Levi Provençal, in G. Wiet *et al.*, *History*, op. cit., p. 336.
[72] E. Whelan, "Textiles", in *Dictionary of the Middle Ages*, vol. 11, p. 715.
[73] W. Durant, *The Age of Faith*, op. cit., p. 298.

leather for the "cordwainers" (*cordobanes*) of Europe, and also carpets, cushions, silk curtains, shawls, and divans, which found eager buyers everywhere.[74] In al-Andalus, the production of eastern-style cloth was concentrated in the towns of Malaga and Almeria, which, as ports, were the first to receive the new techniques or styles.[75] Almeria's role in this process was particularly important in the 12th century. In the industry of *ṭirāz* and of silk there were eight hundred workshops and one thousand for excellent tunics and brocade, and as many more for ciclaton.[76] This pre-eminence can be partly explained, Whelan notes, again, by the variety of uses to which textiles were put in the Near East and along the Mediterranean shores. Aside from clothing, they also constituted the bulk of house-hold furnishings; nomad women weaving tent bands, saddlebags, cradles, and other appurtenances of their mobile lives, but even in the urban centres and in the palaces furnishings consisted mainly of carpets, covers, curtains, and hangings of various kinds. Instead of chairs, people sat on cushions and leaned against bolsters, all covered with cloth whose quality and richness reflected their owners' means.[77] Textiles also played an important political role. As well as lavish diplomatic gifts, it was customary to reward high officials and other favourites, both at regular intervals and on special occasions, with "robes of honour" (*khilʿa*), turbans, and other garments woven in the rulers' own establishments. It was also the Caliphs' prerogative –and after 1250 that of the Mamluk Sultans– to provide each year the new *kiswa*, the richly ornamented cloth that veiled the Kaaba at Mecca.[78]

The full range of textile fibres was available in the Islamic world. Wool and linen were produced in quantity from Iran to Spain, and additional supplies of the latter were imported. Cotton, native to India was probably first produced on a large scale in the Mediterranean after the Muslim advance; especially in Syria and Palestine.[79] The Muslims eventually took both crop and industry to Western Europe.[80]

In addition to the various textile expressions derived from Arabic, some towns and cities were internationally recognised for their product. Shiraz was famous for its woollen cloths, Baghdad for its baldachin hangings and tabby silks; Khuzistan for fabrics of camel's or goat's hair; Khurasan for its sofa covers, Tyre for its carpets, Boukhara for its prayer rugs, Herat for

[74] Ibidem.
[75] T. Glick, *Islamic and Christian Spain*, op. cit., p. 243.
[76] Ibidem.
[77] E. Whelan, *Textiles*, op. cit., p.716.
[78] Ibidem.
[79] E. Whelan, *Textiles*, op. cit., p. 716.
[80] W. Heyd, *Histoire du Commerce du Levant au Moyen Age*, Amsterdam: A.M. Hakkert Editor, 1967.

its gold brocades.[81] However, no examples of these products from this period have survived the wear and tear of time.

In the embellishment of Islamic life all the arts mingled like the interlaces of a decorative theme. So the patterns of illumination and calligraphy were woven into textiles, burned into pottery, and mounted on portals and *mihrabs*. "If medieval civilization made little distinction between artist and artisan," Durant notes, again, "it was not to belittle the artist but to ennoble the artisan; the goal of every industry was to become an art. The weaver, like the potter, made undistinguished products for ephemeral use; but sometimes his skill and patience found expression, his dream found form, in robes or hangings, rugs or coverings, embroideries or brocades, woven for many lifetimes, designed with the finesse of a miniature, and dyed in the gorgeous colours so favoured of the East." [82]

Ship Building

The Muslim world was dotted with shipyards making ships and vessels of various sizes and types. In Muslim Spain, for example, the economy of the ninth and tenth centuries stimulated alongside the construction of war ships the development of a navy designed for sailing along the coasts of the kingdom, and to more distant places, whether to the Balearic islands, the North African coast or Egypt.[83] In addition to Almeria, there were many Andalusian ports which constituted more or less important bases for warships, and also were equipped with ship building yards, called either *Dār al-inshā'*, or *Dār ṣināʿat al-marākib* (or simply *Dār al-ṣināʿa*), from which the modern word *arsenal* originated. Amongst them, Alcacer do Sal, Silves, Seville, Algeciras, Malaga, Alicante, Denia. At Tortosa an inscription shows that a shipyard was established under the orders of ʿAbd al-Raḥmān III in 945, and it owed its renown to the quality of the wood of its surrounding forests.[84]

During the medieval period, shipbuilding was a major industry. It was directed towards the construction of merchant vessels and for building and fitting out warships. The main shipyards were the property of the state, but there existed private yards on the banks of the great rivers and the shores of the Gulf and the Red Sea, belonging to merchants and to private persons who use them for trade and travel. The shipbuilding industry was

[81] W. Durant, *The Age*, op. cit., p. 278.
[82] Ibidem.
[83] E. Levi Provencal: *Histoire de l'Espagne Musulmane*, vol 3, Paris, Maisonneuve, 1953, pp. 154, 321-22; M. Lombard, *The Golden Age of Islam*, transl. J. Spencer; North Holland publishers, 1975, p. 192.
[84] E. Levi Provençal, *Histoire de l'Espagne*, op. cit.; M. Lombard, *The Golden Age of Islam*.

engaged in building many varieties of ships, from small oared skiffs to huge vessels aimed at performing long travels, of over 1000 tonnes capacity and warships capable of carrying 1500 men.[85]

It is worth noting here that the world famous Chinese Admiral, Zheng He who built a fleet of gigantic junk ships (each the size of a football playground) chartering the great oceans of the world, was a Muslim who performed pilgrimage to Makka whilst quite young, some say must have influenced his vision of the world outside China.[86]

The impact of Muslim ship construction is not just perceptible through the large number of words of Arabic origin to be found in modern Western languages, the best known being Arsenal and Admiral (originally *Amīr al-baḥr*), but in the impact Muslim ship construction made on the West.[87]

Agriculture and Farming Industry

A short word here courtesy of Scott on how the Muslims impinged on their neighbours in southern Europe in some of the basic aspects of agro-industries and crafts:

> "The Moorish principality of Narbonne was subject to the Western Emirate only forty years; yet, during that short period, the impressions produced by Moorish occupancy were so deeply stamped upon the mental and physical characteristics of the population that no subsequent revolutions have ever been able to entirely efface them. The practical genius of the Arab, which considered utility as the first and most valuable of all the objects of civilization, was again exhibited in the improvements applied to all the arts and avocations of life, which sprang up in the track of his victorious armies. The Oriental principles of agriculture, with its painstaking tillage of the soil, its perfect irrigating

[85] On shipbuilding and navigation in the history of Islamic countries, see A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*, op. cit., pp. 123-131; and H. Homsi: "Navigation and Shipbuilding , in A. Y. al-Hassan, Y. Iskandar, A. Zaki, and A. Maqbul, (eds.), *The Different Aspects of Islamic Culture*. Paris: UNESCO, 2001; vol. IV: *Science and Technology in Islam*, Part 2, chap. 4-8.

[86] On Zeng He and his fleet, see Dreyer, Edward L. (2006). *Zheng He: China and the Oceans in the Early Ming, 1405–1433 (Library of World Biography Series)*. Harlow, Essex : Longman.

• Levathes, Louise (1997). *When China Ruled the Seas: The Treasure Fleet of the Dragon Throne, 1405–1433.* Oxford: Oxford University Press.

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• Menzies, Gavin (2003). *1421: The Year the Chinese Discovered the World.* New York: Morrow / Avon.

[87] This impact is competently outlined in W.M. Watt, *The Influence of Islam on Medieval Europe*, Edinburgh University Press, 1972, pp. 19-21.

> system, its introduction of foreign plants, were applied with wonderful success to the delightful region watered by the Rhone and the Garonne. The bark of the cork-tree, still one of the greatest sources of wealth to Catalonia and Provence, was then first made known to Europe. The boundless evergreen forests on the slopes of the Pyrenees were utilized for the manufacture of pitch and rosin. In every district, the breed of horses was improved by crosses with the best blood of Arabia. Innumerable articles of luxury pre-served in museums and private collections –beautiful objects of silver, ivory, and crystal, damascened armour, and silken robes– attest the variety and excellence of the Moorish manufactures." [88]

Science, Management and Industrial Growth

Ibn al-Haytham revolutionised optics and consultation of any of his works, *Kitāb al-Manāẓir* in particular, will surprise people how many industrial items (the camera, telescopes, glasses etc.) we owe to his pioneering work.[89] It was, indeed, Ibn al-Haytham, who completely dismissed the Greek theories of Euclid and Ptolemy, that the eye sends out visual rays to the object being viewed. Instead he demonstrated that the form of the perceived object passes into the eye and is transmuted by its lens. He found the relationship between the positions of a source of light and its image formed by a lens. He discussed the propagation of light and colours, optical illusions, and reflection of light, and gave methods for measuring the angles of incidence and refraction.[90] Ibn al-Haytham's experiments, recreated in modern history of science, are a precursor of all that has to do with optical technology and industry.[91] Muslim physics also included the determination of the specific gravity of certain metals and precious stones, and work on meteorology, on tides, and on such problems of applied mechanics as windmills and water-wheels (which the Muslims were the first to develop), balances, wells, water clocks, agricultural methods, irrigation, canal and road building, the preparation of iron and

[88] S. P. Scott, *History of the Moorish Empire in Europe*, op. cit., vol 3, p. 65. For a detailed account of the Islamic agricultural revolution, see D. R. Hill's studies of the irrigation techniques in *A History of Engineering in Classical and Medieval Times*, London & Sydney: Croom Helm, 1984, pp. 17 ff.; idem, *Islamic Science and Engineering*, op. cit, pp. 170-186; A. Y. al-Hassan and D. R. Hill, *Islamic Technology. An Illustrated History*, op. cit., "Agriculture and food technology", pp. 203-231, and Zohor Idrisi, *The Muslim Agricultural Revolution*, online at: http://muslimheritage.com/topics/default.cfm?ArticleID=515.

[89] See M. Schramm, *Ibn al-Haytham's Weg zur Physik*, Wiesbaden, 1963 and Hakim Mohammad Said (ed.), *Ibn al-Haytham*, Hamdard National Foundation, Pakistan 1-10. November 1969.

[90] R. Rashed, "Geometrical Optics", in *Encyclopedia of the History of Arabic Science*. Edited by Roshdi Rashed with the collaboration of Régis Morelon. London/New York: Routledge, 1996, vol. 2.

[91] Saleh Beshara Omar, *Ibn al-Haytham's Optics: A Study of the Origins of Experimental Science*. Minneapolis: Bibliotheca Islamica, 1977.

steel, methods of working metals, constructing scientific instruments, paper-making, leather work, and silk and cotton cloth manufacture.

For greater details on this matter, Pacey offers a good variety of examples, most particularly on how industrial techniques circulated between civilisations and down the ages.[92] Singer, though, in each of his works, especially the lesser known ones, highlights the role of the East, the Muslim world, and also China and India, who were centuries ahead of the rest in promoting industrial technologies.[93]

Muslim management and administrative skills can be seen in Norman Sicily as Scott explains. In the departments of government, finance, legislation, the regulation of commerce, in the protection and encouragement of agriculture, in the maintenance of order, Sicily offered the best example in Europe, with the exception of Muslim Spain.[94] Its coinage was one of the purest, the most convenient, the most beautifully executed that had ever been put in circulation by any government, and the regulations of the kingdom concerning the rural economy of its people were minute and specific, even paternal, in their character.[95] The supervision exercised by government officials over all occupations was most precise. Weights and measures, for instance, were prescribed by law, and any departure from honest dealing in this respect was visited with the severest penalties. Officers were appointed in every town for the detection of false weights and the sale of spurious merchandise. The laws of hygiene were understood and enforced with a degree of intelligence unknown to many European communities until recently in modern times, and unwholesome provisions could not be exposed for sale in the markets.[96]

All this reminds of the Muslim institution of *ḥisba*, operated by the *muḥtasib*.[97] The *muḥtasib*'s primary domain was the market, where he was charged with supervision of all trades and crafts. He ensured that all goods were properly made, that foodstuffs were well prepared and wholesome, and that services were performed correctly. Most particularly, he guarded

[92] A. Pacey, *Technology in World Civilization*, op. cit..

[93] C. Singer (ed.), *Studies in the History and Method of Science*, Oxford, 1921; C. Singer, *A Short History of Scientific Ideas to 1900*, Oxford: Oxford University Press, 1959; C. Singer: *Science: Medieval Contribution to Modern Civilisation*, London: Harrap, 1921.

[94] S. P. Scott, *History*, op. cit., vol. 3, pp. 41-42.

[95] Ibid.

[96] Ibidem.

[97] See the excellent entry by Laurence Conrad, "*Muḥtasib*", *Dictionary of the Middle Ages*, edited by Joseph Strayer, New York: Charles Scribner's Sons, 1989, vol. 9, p. 527. See also R. B. Buckley, "The *Muḥtasib*", *Arabica*, vol. 39, 1992, pp. 59-117; Mawil Izzi Dien, *The Theory and the Practice of Market law in Medieval Islam. A study of Kitāb Nisab al-Iḥtisāb of ʿUmar b. Muḥammad al-Sunāmī (fl. 7th-8th/13th-14th Century)*. Cambridge: E. J. W. Gibb Memorial Trust, 1997.

against misrepresentations, frauds, and deceptions of all kinds. Working conditions, sanitation, and public safety also came under his authority. He could not fix prices, but could take action against hoarding or price gouging. The *muḥtasib*'s responsibilities extended elsewhere. He supervised mosques, schools, baths, and workshops, made sure that the city walls were in good repair; and kept the streets clear of obstacles and encroachments. Realtors and builders were answerable to him for their transactions and constructions. He could prevent ship-owners from overloading their boats or setting out in bad weather and could order that overburdened beasts be relieved of part of their loads.[98]

To execute these tasks, the *muḥtasib* often employed assistants, who were knowledgeable in specific fields; at times he also had a body of troops at his command, which made him a force to be reckoned with in times of instability. His powers were considered to be subordinate to those of the *qāḍī* (judge); but while the latter could only pass judgment on matters formally presented to him, the *muḥtasib* intervened on his own initiative and made decisions on the spot. He could have offenders beaten, flogged, or hauled through the streets in disgrace; and it was within his powers to confiscate or destroy false weights and measures, defective merchandise, and forbidden items such as wine.[99]

This area of study may be expanded by looking at the whole system of trade, the diverse financial mechanisms, the role of the cheque and commenda, etc. However, this would mean opening a whole new subject, which is beyond the scope of this article. It would be important, however, to investigate where all such wealth and activity went. What made the Muslims, the initiators of industrial activity on the widest scale retreat into the state of impotence, which they suffer from today? Such questions remain to be answered.

Acknowledgements

The author would like to express his thanks to Professor Mohammed Abattouy, Dr. Zohor Shenan Idrisi and Margaret Morris for their editorial comments on the manuscript, Professor Steven Parker (Head of School of Linguistics, Languages and Cultures at University of Manchester) for providing research facilities and for Dr. Salim Ayduz for checking historical correctness.

[98] L. Conrad, "Muḫtassib", op. cit.
[99] L. Conrad, "Muḫtassib", op. cit., p. 527.

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The Arabic Science of Weights (*ʿIlm al-Athqāl*): Textual Tradition and Significance in the History of Mechanics*

Mohammed Abattouy

The following article will be devoted to two main concerns:

1. The description of the textual tradition of the Arabic corpus of the science of weights (*ʿilm al-athqāl*), a tradition of scientific and technical treatises reconstituted from manuscripts, most of which were never published before. The components of this corpus, amounting to more than thirty texts, cover the whole range of scientific activity in Islamic lands from the 9th through the 19th centuries. This group of text is unified by a common theme: the spectrum of theoretical and practical problems related to the description, the functioning and the use of various types of balances, and especially of the steelyard, the balance with calibrated beam, unequal arms and moving weights.

2. The interpretation of the Arabic corpus of the science of weights as a transformation in the history of mechanics. Such a transformation was represented by the creation of an independent theoretical branch that evolved from ancient contributions and nourished physical debates until the advent of modern science on the problems of equilibrium and the properties of weighing operations. As a result, *ʿilm al-athqāl* should no

* My work on Arabic mechanics began in the context of an interdisciplinary project on the history of mechanical thinking sponsorized between 1996 and 2003 by the Max Planck Institute for the History of Science in Berlin. An earlier version of the present article was published in Abattouy 2002b. This version was reworked and published as Abattouy 2007b. Different aspects of the research on the Arabic science of weights by the author are exposed in his other publications: see the references below in the bibliography section; a large array of resources on Arabic mechanics are available in Abattouy 2007d, section 5, pp. 131-149.

more be confused with *ʿilm al-ḥiyal*, understood as a general descriptive discourse on different types of machines.

Such an understanding of the historical significance of the Arabic science of weights brings about an important result, in the sense that this tradition was connected with the next important phase of the history of mechanics. Indeed, beyond cultural and linguistic boundaries, the Arabic science of weights afforded a foundation for the Latin *scientia de ponderibus* that emerged in medieval Europe from the 13th century.

1. The balance: instrument of the science of weights

The balance is an instrument of our current life, charged with history and science. In Islamic classical times, this familiar instrument was the object of an extensive scientific and technical debate of which dozens of treatises on different aspects of its theory, construction, and use are the precious remains. Different sorts of balances were the object of such an extensive enquiry, including the normal equal-armed balance (called in Arabic *mīzān*, *ṭayyār*, and *shāhīn*), the steelyard (called *qarasṭūn*, *qaffān*, and *qabbān*) and sophisticated balances for weighing absolute and specific weights of substances.

Several drawings of balances are preserved in Arabic manuscripts, such as those of al-Khāzinī, al-Ḥarīrī, and al-Qazwīnī. Further, some specimens of the ancient balances survived and are presently kept in museums. For instance, the National Museum in Kuwait (item LNS 65 M) held an Islamic steelyard built in Iran between the 10th and the 12th centuries (fig. 1). It is an instrument made of inlaid engraved steel, with marks on its beam. Its dimensions (height: 11.5 cm, length: 15.6 cm) show that it was used for weighing small quantities.[1] Two significant steelyards are owned by the Petrie Museum (University College, London). One of them (accession number Inv. 1935-457) is a huge balance (fig. 2). A scale of silver is inlaid along its 2.37m long, wrought-iron beam. It bears two suspending elements and corresponding calibrations: one ranging from 0 to 900 *raṭl*-s (1 *raṭl* is approximately 1 pound); the other ranging from 900 to 1820 *raṭl*-s.[2]

[1] This balance is described in al-Ṣabāḥ 1989, p. 32 and in Vaudour 1996, p. 88.
[2] It is described in Skinner 1967, p. 87 and in Knorr 1982, p. 118, plate 11.

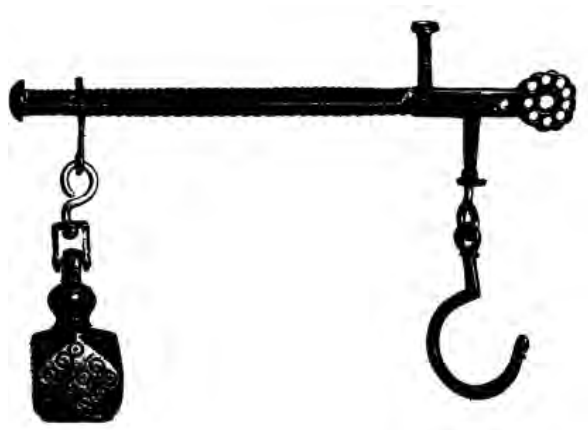

Fig. 1 Islamic steelyard from Iran
kept in the National Museum, Kuwait City.

Fig. 2 Islamic steelyard in Petrie Museum, London.

The interest in the balance in Islamic scientific learning was culturally nurtured by its role as a symbol of good morals and justice. The Qur'ān and the ḥadīth appealed extensively to a strict observance of fair and accurate weighing practices with the balance. Considered the tongue of justice and a direct gift of God, the balance was made a pillar of the right society and a tool of good governance. These principles were recorded explicitly in several treatises on the balance, such as the introduction to *Kitāb mīzān al-ḥikma* by al-Khāzinī, where the balance is qualified as "the tongue of justice and the article of mediation." Furthermore, it was counted as a fundamental factor of justice, on the same level with "the glorious Book of God," and "the guided leaders and established savants."[3]

The balance most widely used in the Islamic lands of medieval times was the equal-armed platform scale, made mostly in copper. There were tiny balances for gold and jewels, average ones for retail traders, and huge balances for the merchants of grains, wood, wool, etc. In general, the balances had beams and weights made of steel or iron. Steelyards, called *qarasṭūn* or *qabbān*, were also widely employed. As reported in a historical source,[4] a site called *Qarasṭūn* existed in the ancient medina in Fez until the early 20th century, probably because of a huge public balance set up there. Public balances are still located today in the *fanādiq* (bazaars) of the old medina. One can infer from in this context that a similar public weighing site must have been present in all the markets of Islamic cities.

The *qarasṭūn* or steelyard with a sliding weight was largely used since Antiquity. It is mentioned in Greek sources by its ancient name, the *charistion*, and was employed extensively in Roman times.[5] Composed of a lever or a beam (*ʿamūd*) suspended by a handle that divides it into two unequal arms, the center of gravity of the instrument is located under the fulcrum. In general the shorter arm bears a basin or a scale-pan in which the object to be weighed is set, or suspended from a hook. The cursor-weight, *rummāna* in Arabic, moves along the longer arm in order to achieve equilibrium. This arm, which has generally a quadrangular cross section, bears two different scales which are engraved along the two opposite sides. Due to the fact that the steelyard can be suspended by two hooks, there are two independent graduations. According to the choice made, there will be different relations between the lengths of the longer and smaller arms of the lever, corresponding to the different scales. On the beam or near the fulcrum, the number of units or fractions corresponding to the capacity of the balance was engraved as was the official stamp of the authorities. The advantage of the steelyard is that it provides an acceptable precision in weighing and allows heavy loads to be supported by small counterweights. In addition, it can be carried around easily.

[3] Al-Khāzinī 1940, pp. 3-4.
[4] Dozy 1927, vol. 2, p. 327.
[5] On the ancient history of the steelyard, see Ibel 1908 and Damerow *et al.* 2002.

Fig. 3 Maghribi balance

Another kind of balance is a combination of the ordinary balance and of the steelyard in the form of an equal-armed balance with mobile weight. A variety of it is the Maghribi balance presented in fig. 3.[6] Further, a typical example of such an instrument is the balance of Archimedes described by al-Khāzinī according to an account by Menelaus (fig. 4).[7] In addition to its two equal arms to which two fixed scale pans are suspended, this balance had on one of the arms a cursor weight which could be hang up on different points of a small scale graduated in two series of divisions. Presented as a hydrostatical balance for the determination of specific gravities, it could also serve for ordinary weighing. A variety of the Archimedes' balance consists in moving the scale pan on a part of the

[6] Described in Abattouy 2003a, pp. 105-.109
[7] Al-Khāzinī 1940, pp. 78-79.

arm. This is the main property of the *mīzān ṭabīʿī* (natural or physical balance) designed by Muḥammad ibn Zakariyyā al-Rāzī. In this model with equal arms and without counterpoise, one of the scale pans is movable and might behave as a counterweight.

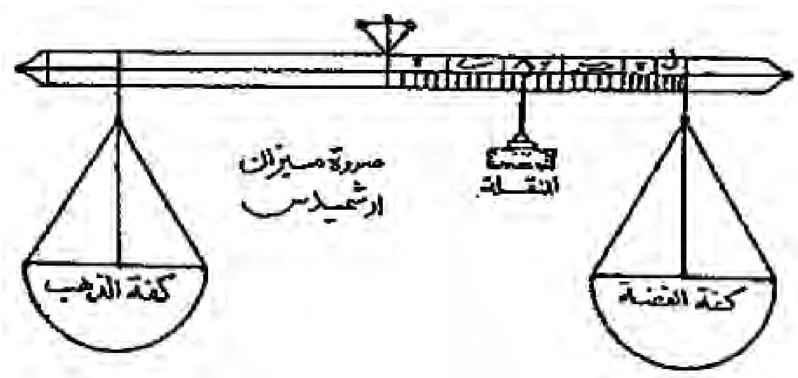

Fig. 4 The balance attributed to Archimedes

Nowadays, the steelyard balance is called in some Arab countries *al-mīzān al-qabbānī*; in Morocco it is designated as *mīzān al-qura*. Despite the introduction of modern balances more or less sophisticated, since long time ago (in the first half of the 19th century), the steelyards continue to be utilized in Arab and Islamic countries. They serve in popular markets and are widely used in some activities, such as in the slaughterhouses and in the shops of butchers. In Egypt, the industry of traditional steelyards is still active. Egyptian colleagues informed me that in the old city of Cairo, in an area called *ḥay taḥt al-rubʿ*, near the *Dār al-kutub*, not far from the Azhar Mosque, artisans build steelyards according to traditional methods. These balances are used massively throughout the country, for example in the weighing of cotton in the country side. In other Arab countries, the fabrication of these balance disappeared completely. For instance, in Morocco, it vanished since several decades, as a result of the introduction of modern balances and of the concurrence of the European industry of these same instruments. Therefore, the steelyards used in the country are imported from Southern Italy and Spain. But local artisans are able to repair the imported balances and to supply certain of their equipments, as I could see by direct observation during my visits to their shops in Fez in the recent period.

In his geographical book *Aḥsan al-taqāsīm fī maʿrifat al-aqālīm*, Muḥammad al-Muqaddasī, the Palestinian geographer of the 10th century, reports that the most accurate balances were those fabricated at Ḥarrān in northern Mesopotamia. Kūfa, in southern Iraq, was also famous for the accuracy of its balances. Other regions were celebrated for the honesty of the weighing practices of their merchants, such as Khurāsān. But others were better known for their fraudulent procedures. Various passages in the Qur'ān show that as early as the advent of Islam, false balances were in use in the markets. Later narratives report that some jewellers and goldsmiths, in order to fraudulently weigh their wares, blow gently on the scale-pan of their balance, stick a small piece of wax under it, or merely use false weights. Al-Jawbarī (fl. 1216-22) described two such arrangements. In the one the beam of the balance consisted of a hollow reed containing quicksilver, which was closed at both ends. By a slight inclination of the beam, the quicksilver could be made to flow as desired to the side with weights or with goods and thus make one or the other appear heavier. In the other case, the tongue of the balance was of iron and the merchant had a ring with a magnetic stone; by bringing the ring close to the balance, it moves down to the right or left.[8]

In order to reprimand these fraudulent tricks and deceitful behaviour, and to implement the instructions of Islam about the strict observance of the just weighing, the Islamic society invented a specific institutional setting, represented by the office of *ḥisba*. This office was occupied by the *muḥtasib*, an officer regularly appointed to take charge of the harmonization between the commands of Islam and the social practice, especially concerning the control of markets. As such, one of his main duties was to observe that correct scales and weights were used in commercial transactions.[9]

2. The corpus of science of weights

The emergence of Arabic mechanics is an early achievement in the scientific tradition of Islam. Actually, already in the mid-9th century, and in close connection with the translation of Greek texts into Arabic, treatises on different aspects of the mechanical arts were composed in Arabic, but with a marked focus on balances and weights. These writings, composed by scientists as well as by mechanicians and skilful artisans, gave birth to a scientific tradition with theoretical and practical aspects, debating mathematical and physical problems, and involving questions relevant to both the construction of instruments and the social context of

[8] Al-Jawbarī 1979-80, vol. 2, p. 162.

[9] A preliminary study of the interaction of the *ḥisba* institution with the science of weights may be found in Abattouy 2002b, pp. 124-126; 2004b; 2007b, pp. 72-75.

their use. Some of these Arabic treatises were translated into Latin in the 12th century and influenced the European science of weights.

The corpus of the Arabic science of weights covers the entire temporal extent of scientific activity in medieval Islam and beyond, until the 19th century. The reasons for such an abundance of literature on the problems of weighing can be explained only by contextual factors. In fact, the development of the science of weights as an autonomous branch of science was triggered by the eminent importance of balances for commercial purposes. In a vast empire with lively commerce between culturally and economically fairly autonomous regions, more and more sophisticated balances were, in the absence of standardization, key instruments governing the exchange of currencies and goods, such as precious metals and stones. It is therefore no surprise that Muslim scholars produced numerous treatises specifically dealing with balances and weights, explaining their theory, construction and use. This literature culminated in the compilation by ʿAbd ar-Raḥmān al-Khāzinī, around 1120, of *Kitāb mīzān al-ḥikma*, an encyclopaedia of mechanics dedicated to the description of an ideal balance conceived as a universal tool of a science at the service of commerce, the so-called ‘balance of wisdom.’ This was capable of measuring absolute and specific weights of solids and liquids, calculating exchange rates of currencies, and determining time (fig. 5).

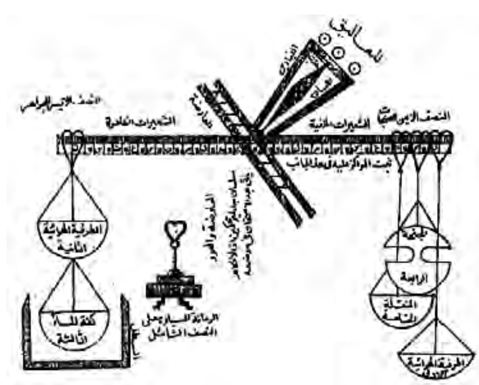

Fig. 5 Picture of the balance of wisdom (al-Khāzinī 1940, p. 103)

A complete reconstruction of the Arabic tradition of weights is currently being undertaken by the author. This project began in the context of a long-term cooperation with the Max Planck Institute for the History of Science in Berlin. The work on the establishment of the Arabic corpus of the science of weights started in Fall 1996 by the systematic reconstruction of the entire codicological tradition of the corpus of texts dealing –on theoretical and practical levels– with balances and weights. By now almost half of the corpus has been edited and translated into English; this part, including texts dating from the 9th through the 12th centuries, is being prepared for publication with the appropriate commentaries.

The preliminary analysis of the texts investigated so far established the importance of the Arabic tradition for the development of the body of mechanical knowledge. The Arabic treatises turned out to be much richer in content than those known from the ancient tradition. In particular, they contain foundations of deductive systems of mechanics different from those inferred from extant Greek texts, as well as new propositions and theorems. On the other hand, the Arabic treatises also represent knowledge about practical aspects of the construction and use of balances and other machines missing in ancient treatises.

The first phase of the research on the Arabic science of weights was focused on establishing the scope of its extant corpus. Surprisingly, this corpus turned out to be much larger than usually assumed in history of science. Up to now more than thirty treatises dating from the 9th through the 19th centuries have been identified which deal with balances and weights in the narrow sense. The majority of these treatises has never before been edited or studied, and only exists in one or more manuscript copies. Some important manuscripts have been discovered or rediscovered even in the course of the research activities conducted by the author.

The textual constituents of the Arabic works on the problems of weights can be classified chronologically into three successive units. First a set of Greek texts of mechanics extant in Arabic versions. Despite their Greek origin, these works can be regarded as an integral part of the Arabic mechanical tradition, at least because of the influence they exerted on the early works of Arabic mechanics. In the case of some of these texts, although they are attributed to Greek authors, their Greek originals are no more extant nor are they ascribed to their supposed Greek authors in antique sources. The second unit comprises founding texts composed originally in Arabic in the period from the 9th through the 12th centuries. This segment of writings laid the theoretical basis of the new science of weights, in close connection with the translations and editions of texts stemming from Greek origins. The third phase covers the 14th through the 19th centuries, and comprises mainly practical texts elaborating on the theoretical foundations laid in the earlier tradition. In the following, the texts belonging to these three phases will be described in brief, with a short characterization of some theoretical contents.

3. Arabic versions of Greek texts of mechanics

The corpus of Greek texts that were known to Muslim scholars through direct textual evidence and dealing with the problems of weighing and the theory of the balance are six in number:

1. First, *Nutaf min al-ḥiyyal*, an Arabic partial epitome of Pseudo-Aristotle's *Mechanical Problems*: The *Problemata Mechanica*, apparently the oldest preserved text on mechanics, is a Greek treatise ascribed to Aristotle, but composed very probably by one of his later disciples. It has long been claimed that this text was not transmitted to Arabic culture. It is possible now to affirm that the scholars of Islamic lands had access to it at least through a partial epitome entitled *Nutaf min al-ḥiyyal* (Elements / Extracts of Mechanics) included by al-Khāzinī in the fifth book of his *Kitāb mīzān al-ḥikma*.[10]

2-3. Two texts ascribed to Euclid on the balance (*Maqāla fī l-mīzān*) and on heaviness and lightness (*Kitāb fī l-thiql wa-l-khiffa*): Extant only in Arabic, the first one provides a geometrical treatment of the balance and presents a sophisticated demonstration of the law of the lever. It is not recorded if it was edited in Arabic, but there is enough evidence to conclude that this was probably the case. The second text survived in a version edited by Thābit ibn Qurra. It is an organized exposition –in 9 postulates and 6 theorems– of dynamical principles of the motion of bodies in filled media, developing a rough analysis of Aristotelian type of the concepts of place, size, kind and force and applying them to movements of bodies.[11]

4. A partial Arabic version of Archimedes' *On Floating Bodies*: Contrary to the highly creative impact Archimedes had on Arabic mathematics, it seems that his main mechanical treatises such as *Equilibrium of planes* and *Quadrature of the parabola* were not translated into Arabic. However, some elements of his theory of centers of gravity were disclosed in the mechanical texts of Heron and Pappus, whereas the main ideas of his hydrostatics were transmitted in a *Maqāla fī l-thiql wa-l-khiffa*, extant in Arabic in several manuscript copies. This short tract

[10] Al-Khāzinī 1940, pp. 99-100. The text of the *Nutaf* was edited and translated, with commentaries, in Abattouy 2001a.

[11] The contents of these two works are surveyed in Abattouy 2001b, p. 216 ff. On the textual tradition of *Maqāla fī l-mīzān*, see Abattouy 2004c and 2007a.

consists in a summarized digest of the treatise on the *Floating Bodies*, presenting mere statements of the postulates and propositions of Book I and the first proposition of Book II without proofs. [12]

5.6. Heron's and Pappus' *Mechanics*: Finally, the last two Greek texts to be connected with the Arabic tradition of the science of weights are the two huge treatises referred to as *Mechanics* of the Alexandrian scholars Heron (1st century) and Pappus (4th century). These texts are together major sources for the reconstruction of the history of ancient mechanical ideas. Given their composite character, only some of their chapters concern the foundations of theoretical mechanics as developed in the later Arabic tradition around the questions of weighing. Heron's *Mechanics* was translated into Arabic by Qusṭā ibn Lūqā under the title *Fī rafʿ al-ashyāʾ al-thaqīla* (On Lifting Heavy Loads).[13] After the loss of the Greek original text, it survived only in this Arabic version. On the contrary of Heron's *Mechanics*, Pappus mechanical treatise was preserved in Greek *and* in Arabic. Its Arabic version is titled *Madkhal ilā ʿilm al-ḥiyal* (Introduction to the Science of Mechanics), by a translator who has not yet been identified, but there is enough evidence to affirm that this version saw the light in 10th-century Baghdad.[14]

4. Founding texts of the Arabic science of weights

In close connection with the translation and study of the above mentioned Greek sources, the Muslim scientists composed in the period from the 9th up to the 12th century a set of original texts that laid the foundation to the new science of weights. To mention just the main treatises, these texts are seven in number:

7. First, the *Kitāb fī l-qarasṭūn* by Thābit ibn Qurra (d. 901): Without contest the most important text of the Arabic mechanical tradition, it was apparently one of the first Arabic texts to deal with the theory of the unequal-armed balance in Islam and to systematize its treatment. As such, it established the theoretical foundation for the whole Arabic tradition.

Kitāb fī l-qarasṭūn presents a deductive theory of the steelyard based on dynamic assumptions. It is extant in four known copies, of which three contain complete texts with variant readings. Two of these, preserved in

[12] A MS copy of this text was published in Zotenberg 1879 and translated into English in Clagett 1959, pp. 52-55.

[13] Heron's *Mechanics* was edited and translated twice respectively by Carra de Vaux in 1893, with French translation, and by Schmidt and Nix in 1900, with German translation. These editions were reprinted recently: respectively Herons 1976 and Héron 1988.

[14] The Arabic text of Pappus' *Mechanics* was transcribed and translated into English in Jackson 1970.

London (India Office MS 767-7) and Beirut (St. Joseph Library, MS 223-11), were studied and published recently.[15] The third copy, formerly conserved in Berlin (Staatsbibliothek MS 559/9, ff. 218b-224a), was reported lost at the end of World War II. Paul Weinig and I happened to rediscover it in the Biblioteka Jagiellonska in Krakow (Poland) in October 1996. Recently Sonja Brentjes kindly attracted my attention over a partial fourth copy that exists in the archives of the Laurentiana Library in Florence (MS Or. 118, ff. 71r-72r). Never mentioned before, this valuable three-page text includes the introductory two sections of Thābit's treatise. This part of the text exposes the dynamic foundation of the treatise and an important passage that was thought of up to now to occur only in Beirut MS copy (and thus known as Beirut scholium).[16]

8. *Kitāb fī ṣifat al-wazn* by the same Thābit ibn Qurra: This five-section text on the balance is about the conditions necessary to achieve equilibrium in weighing with balances, primarily the equal-armed sort.[17] An important connection between this text and *Kitāb fī l-qarasṭūn* is provided by the occurrence, in the last section of *Ṣifat al-wazn*, of the statement of a proposition identical with the postulate that opens *Kitāb fī l-qarasṭūn*.

9. *Ziyyāda fī l-qarasṭūn* or An Addition on the theory of the *qarasṭūn*: A short anonymous text extant in a unicum copy preserved in Beirut. In this codex, the *Ziyyāda* serves as an appendix to *Kitāb fī l-qarasṭūn.* The two texts are written in the same hand and display strong terminological affinities which include the basic vocabulary as well as the technical terms. Thābit ibn Qurra is mentioned twice in the *Ziyyāda*. This and several other elements induce us to consider it as an appendix intended to amplify the analysis developed in Thābit's original work. The text of the *Ziyyāda* is composed of five propositions. The first two are mere applications of the Proposition VI of *Kitāb fī l-qarasṭūn* while the last three establish a procedure for calculating the counterweight required to maintain equilibrium in a lever divided an evenly number of times.

10. A short text on the balance by Muḥammad ibn ʿAbd-Allāh b. Manṣūr al-Ahwāzī: al-Ahwāzī is a mathematician of the 10th century; his text is extant in a unique copy preserved in Khuda Baksh Library in Patna

[15] Respectively in Jaouiche 1976 and Knorr 1982.

[16] The mechanical theory of *Kitāb fī l-qarasṭūn* was studied in Jaouiche 1976, Abattouy 2000d, and Abattouy 2002a.

[17] This text was preserved thanks to its integration in *Kitāb mīzān al-ḥikma*: al-Khāzinī 1940, pp. 33-38. For translations, see the German version in Wiedemann 1970, vol. I, pp. 495-500 and a partial English version in Knorr 1982, pp. 206-208.

(Codex 2928, folio 31) without title, save for the one provided by the curators of the library: *Risāla fī l-mīzān*.[18]

11. The treatises on centers of gravity of al-Qūhī and Ibn al-Haytham: These important contributions by two most important Muslim mathematicians of the 10th-11th centuries survived only through their reproduction by al-Khāzinī in a joint abridged version that opens the first book of his *Kitāb mīzān al-ḥikma*.[19] The potential discovery of the complete versions of these texts will mean the recovery of fundamental sources.[20]

12. The statements on the law of the lever by the same al-Qūhī included in a discussion on the centers of gravity he had with Abū Isḥāq al-Ṣābī around 990-91.[21]

13. The treatise of Īlyā al-Maṭrān on measures and weights: Īlyā al-Maṭrān was the Archbishop of Nisibin (north Mesopotamia) in the first half of the 11th century. His *Maqāla fī l-makāyyīl wa-l-awzān* (Treatise of Measures and Weights) is essentially of practical interest, but it is based on the theory of the steelyard as elaborated in earlier Arabic works.[22]

14. *Irshād dhawī al-ʿirfān ilā ṣināʿat al-qaffān* (Guiding the Learned Men in the Art of the Steelyard) by al-Isfizārī: A fundamental and long-neglected treatise, written by Abū Ḥātim al-Muṣaffar b. Ismāʿīl al-Isfizārī, a mathematician and mechanician who flourished in Khurāsān (north-east Iran) around 1050-1110. In this original text on the theory and practice of the unequal-armed balance, different textual traditions from Greek and Arabic sources are compiled together for the elaboration of a unified mechanical theory. It is extant in a unique manuscript copy preserved in Damascus (al-Asad National Library, al-Ẓāhiriyya collection, MS 4460, folii 16a-24a). In addition, an abridged version reproduced by al-Khāzinī includes a section on the construction and use of the steelyard, which is omitted from the Damascus manuscript.[23]

15. *Kitāb mīzān al-ḥikma* by al-Khāzinī: A special mention should be made of *Kitāb fī mīzān al-ḥikma*, the encyclopedia of mechanics completed by al-Khāzinī in 1121-22, a real mine of information on all aspects of the theoretical and practical knowledge in the Islamic medieval

[18] On al-Ahwāzī, see Sezgin 1974, p. 312.
[19] Al-Khāzinī 1940, pp. 15-20.
[20] In his catalogue of Arabic manuscripts, Paul Sbath mentionned that there was a copy of Ibn al-Haytham's *Maqāla fī l-qarasṭūn* in a private collection in Aleppo in Syria. This *Maqāla* may be Ibn al-Haytham's treatise on centers of gravity: See Sbath 1938-1940, part 1, p. 86. For textual considerations on the treatise of al-Qūhī, see Bancel 2001.
[21] The correspondence was edited and translated into English in Berggren 1983.
[22] On Īlyā al-Maṭrān, see Abattouy 2005a.
[23] Al-Khāzinī 1940, pp. 39-45. Al-Isfizārī's biography and the contents of his *Irshād* are surveyed in Abattouy 2000b and Abattouy 2001b.

area about balances. The book covers a wide range of topics related to statics, hydrostatics, and practical mechanics, besides reproducing abridged editions of several mechanical texts by or ascribed to Greek and Arabic authors. This huge summa of mechanical thinking provides a comprehensive picture of the knowledge about weights and balances available in the Arabic scientific milieu up to the early 12th century. Therefore, it represents a major source for any investigation on ancient and medieval mechanics.[24]

The textual tradition of the Arabic science of weights between the 9th and the 12th centuries also contains additional sources that should be taken into account in any complete reconstruction of its corpus. These include the work of Muḥammad Ibn Zakariyyā al-Rāzī (865-923) on the natural balance,[25] extracts from texts on weights by Qusṭā ibn Lūqā and Isḥāq ibn Ḥunayn,[26] Ibn al-Haytham's largely expanded recension of Menelaus' (fl. Alexandria, 1st century) text on specific gravities,[27] and two writings on specific gravity and the hydrostatical balance by ʿUmar al-Khayyām.[28]

5. Texts of the later period

The third and last phase of the Arabic writings on weights and balances is represented by a group of texts dating from the 14th to the 19th century and originating principally from Egypt and Syria. These two countries were unified during this long period by the Ayyubid, Mameluk, and Ottoman dynasties, respectively, and they constituted for centuries a unified economic and cultural space. Whence the *raison d'être* of this large amount of writings on the theoretical and practical problems of the balance and weights, since it was a direct outcome of the integration of economic and cultural activities in this vast area. The authors of these texts are mathematicians, mechanicians, and artisans. In the following some names and works are mentioned for illustration.

16. *Masāʾil fī l-mawāzīn* (Problems on Balances) by Yaʿīsh b. Ibrāhīm al-Umawī: This short tract is by a mathematician of Andalusian origin who lived in Damascus (fl. 1373), and is known as author of several arithmetical works.[29] His *Masāʾil* consists in a small collection of

[24] On al-Khāzinī and his work, see Hall 1981, Abattouy 2000a, and Abattouy 2007c.
[25] Reproduced in an abridged version by al-Khāzinī 1940, pp. 83-86.
[26] These texts are preserved in Aya Sofya Library in Istanbul, Codex 3711.
[27] Obviously extant in a unique manuscript discovered in Lahore in 1979 by Anton Heinen: see Heinen 1983.
[28] Both edited in al-Khāzinī 1940, pp. 87-92, 151-153. On al-Khayyām's mechanics, see Aghayani Chavoshi and Bancel 2000, and Abattouy 2005b.
[29] On al-Umawī, see Saʿīdān 1981.

problems about weighing with hydrostatic and normal balances. The text is part of the codex DR 86 preserved in the Egyptian National Library in Cairo.

17. *Risāla fī ʿamal al-mīzān al-ṭabīʿī* by Taqī al-Dīn ibn Maʿrūf: The author is a well known mathematician, astronomer, and mechanician (born in Damascus in 1525, died in Istanbul in 1585). His short treatise on making the natural balance describes what was transmitted to Taqī al-Dīn of a previous writing on the balance that he ascribes to the mathematician Ghiyyāth al-Dīn al-Kāshī (died in Samarkand in 1429). It is part of the collections of the municipal library of Alexandria.

18. *ʿAmal mīzān li-ṣarf al-dhahab min ghayr ṣanj* (The Construction of a Balance to Convert Gold without Standard Weight) by Abū l-ʿAbbās Aḥmad b. Abī Bakr b. ʿAlī ibn al-Sarrāj. The author, who was alive around 714 H (1319-20) and 748 H (1347-8), was the most important specialist of astronomical instrumentation in the Mamluk period.[30] His short text is the sixth item of the codex MR 30 conserved in the Egyptian National Library in Cairo.

The Egyptian astronomer Muḥammad ibn Abī l-Fatḥ al-Ṣūfī (d. 1543) composed several treatises on the theory and the practice of the steelyard balance which enjoyed a wide diffusion. Al-Ṣūfī seems to be the last representative of the classical Arabic tradition of works on balances and weights. With him, this tradition arrives at an end, in the same time when pre-classical physics in Europe was operating a deep transformation that will finally integrate the science of weights in modern physics. Here are his main treatises, known in several extant copies preserved exclusively in Cairo and Damascus, attesting to their widespread use in Egypt and Syria over the centuries:

19. *Risāla fī ṣināʿat al-qabbān* (Treatise in the Art of the Steelyard): a systematic description of the steelyard and its use in different situations, showing a clear acquaintance with steelyards. The text is explicitly written for the practitioners;

20. *Irshād al-wazzān li-maʿrifat al-awzān bi-l-qabbān* (Guide to the Weigher in the Knowledge of the Weights of the Steelyard): similar to the previous text;

21. *Risāla fī qismat al-qabbān* (Treatise on the Division of the Steelyard): contains arithmetical and geometrical problems on the calculation of the parts of the steelyard;

[30] See on Ibn al-Sarrāj King 1987 and Charette 2003.

22. *Risāla fī iṣlāḥ fasād al-qabbān* (Treatise on Repairing the Defectuosity of the Steelyard): very detailed analysis of the different cases of deficiency of a steelyard and the solutions to repair these deficiencies.

Other later texts include:

23. *Nukhbat al-zamān fī ṣināʿat al-qabbān*: a short text on the steelyard by ʿUthmān b. ʿAlāʾ al-Dīn al-Dimashqī, known as Ibn al-Malik (fl. 1589);

24. *Risālat al-jawāhir fī ʿilm al-qabbān* (Treatise of Jewels in the Science of the Steelyard): a ten-chapter text written by Khiḍr al-Burlusī al-Qabbānī (d. in 1672).

25. Two writings on the "science" (*ʿilm*) and the "description" (*taʿrīf*) of the steelyard by ʿAbd al-Majīd al-Sāmūlī (18^{th} century);

26. *Al-ʿIqd al-thamīn fī mā yataʿallaq bi-l-mawāzīn* (The High Priced Necklace in What Concerns the Balances), a systematic treatise on the balance and weights, by Ḥasan al-Jabartī (1698-1774);

27. Several short texts dealing with the principles and the construction of the steelyard by Muḥammad al-Ghamrī (died before 1712);

28. *Risāla fī l-qabbān* by Muḥammad b. al-Ḥusayn al-ʿAṭṭār (d. 1819), a Syrian author, is among the very last works written in Arabic in the style of the earlier mechanical tradition.[31]

For some other texts, the authorship is not yet established firmly as they don't bear any name and they are catalogued until now as "anonymous texts". In this last category, we mention the following three tracts, which are very probably connected with the texts of the later period just mentioned above.

29. First, a huge summa titled *Al-qawānīn fī ṣifat al-qabbān wa-l-mawāzīn* (The Laws in the Description of the Steelyard and the Balances) existing in Codex TR 279, ff. 1-62 in the Cairote Dār al-kutub.

30. Then a short text, *Bāb fī maʿrifat ʿamal al-qabbān* (Chapter in the Knowledge of Making the Steelyard) (Cairo, Dār al-kutub, MS K3831/1, and MS RT 108/1).

[31] This treatise is a digest of earlier works composed of an introduction –devoted to the principle of the equilibrium of weights– and 2 chapters on the construction of the steelyard, and the conversion of weights between countries. Chapter 1 deals in a didactic way with the elementary properties of the balances and a certain emphasis is made on the law of the lever. The text exists in 3 copies: Damascus, al-Asad National Library, Ẓāhiriyya collection, MS 4297; Aleppo, al-Aḥmadiya Lib., al-Maktaba al-waqfiya, MS 1787; Rabat, National Library, MS D 1954.

31. An untitled tract which the beginning is: "*hādhihi risāla fī ʿilm al-qabbān*" (Cairo, Dār al-kutub, in the same MS K3831).

32. And finally two short tracts (*Risāla mukhtaṣara fī ʿilm al-qabbān* and *Risāla fī ʿilm ṣināʿat al-qabbān*) preserved in Damascus (National Library, al-Ẓāhiriyya Collection, MS 4).[32]

The texts mentioned so far afford a precious testimony to the fact that scientific and technical works –sometimes with a high level of originality– continued to be composed in Arabic in the field of mechanics until the 19th century. This corresponds to similar information derived from recent research in other fields of Arabic sciences, such as astronomy and mathematics. The ongoing research into this later phase will undoubtedly change our appreciation of the historical significance of Arabic science and of its place in the general history of science and culture.

6. The status of the science of weights (*ʿilm al-athqāl*)

The availability of the major part of the Arabic texts on the problems of weights and balances makes it possible, for the first time, to address the question of the historical significance of this large corpus of mechanical works. The investigation of this question has already led to a far-reaching conclusion. It turns out that this corpus represents no less than the transformation of the ancient mechanics into a systematic science of weights and balances. As disclosed in the treatises of Pseudo-Aristotle, Philon, Heron, and Pappus, the Greek classical doctrine of mechanics was shaped as a collection of descriptions and riddles about machines, instruments, and common observation. In contradistinction, the new Arabic science of weights is focused on a relatively small range of subjects –mainly the theory of the balance and equilibrium and the practical issues of weighing with different instruments. On the conceptual level, it is built on a dynamic foundation and seeks to account for mechanical phenomena in terms of motion and force. As such, it restores a strong link between mechanics and natural philosophy. This new science of weight lasted in Arabic culture until the 19th century and constituted since the 12th century a basis for the Latin *scientia de ponderibus* that developed in Western Europe.

[32] Among these anonymous texts, we should mention a "strange" text preserved in Paris (Bibliothḍque Nationale, Fonds Arabe, MS 4946, ff. 79-82) under the title *Nukat al-qarasṭūn* (The secrets or the properties of the steelyard) which is ascribed to Thābit ibn Qurra. Its contents are without any doubt related to the science of weights, and its main subject is very elementary and treats of some cases of weighing with the steelyard.

The emergence of the Arabic science of weights has been proclaimed by al-Fārābī (ca. 870-950) in his *Iḥṣā' al-ʿulūm*, where he produced an authoritative reflexion on the epistemological status of mechanics that set the stage for the question once and for all. In particular, he set up a demarcation line between the science of weights and the science of machines, and considered both as mathematical disciplines.

Al-Fārābī differentiated in his system between six principal sciences: those of language, logic, mathematics, nature, metaphysics and politics. The mathematics are subdivided into seven disciplines: arithmetics, geometry, perspective, astronomy, music, the science of weights (*ʿilm al-athqāl*) and the science of devices or machines (*ʿilm al-ḥiyyal*). The last two are characterized as follows:

> "As for the science of weights, it deals with the matters of weights from two standpoints: either by examining weights as much as they are measured or are of use to measure, and this is the investigation of the matters of the doctrine of balances (*umūr al-qawl fī l-mawāzīn*), or by examining weights as much as they move or are of use to move, and this is the investigation of the principles of instruments (*uṣūl al-ālāt*) by which heavy things are lifted and carried from one place to another.
>
> As for the science of devices, it is the knowledge of the procedures by which one applies to natural bodies all that was proven to exist in the mathematical sciences… in statements and proofs unto the natural bodies, and [the act of] locating [all that], and establishing it in actuality. The sciences of devices are therefore those that supply the knowledge of the methods and the procedures by which one can contrive to find this applicability and to demonstrate it in actuality in the natural bodies that are perceptible to the senses."[33]

Considering the two main branches of mechanics as genuine mathematical sciences, al-Fārābī located their objects respectively in the study of weights and machines. Hence, *ʿilm al-athqāl* is centered on the principles of the balances and of lifts, investigated with reference to measure and motion, whereas *ʿilm al-ḥiyyal* is conceived of as the application to natural bodies of mathematical properties (lines, surfaces, volumes, and numbers). As such, it includes various practical crafts: the overseeing of constructions, the measurement of bodies, the making of astronomical, musical, and optical instruments, as well as the fabrication of hydraulic mechanisms, mirrors, and tools like bows, arrows and different weapons.[34]

[33] Al-Fārābī 1949, pp. 88-89.

[34] *Ḥiyyal* (sing. *ḥīla*) translated the Greek word *mechanê* which means both mechanical instrument and trick and is at the origin of the words machine and mechanics. On the semantic affinities between *mechanê* and *ḥīla*, see Abattouy 2000c.

In this context, the main function of *ʿilm al-ḥiyyal* consists in bringing the geometrical properties from potentiality (*quwwa*) to actuality (*fiʿl*) and to apply them to real bodies by means of special engines (*bi-l-ṣanʿa*).[35] Developing an Aristotelian thesis,[36] al-Fārābī endows the science of machines with an eminent task, to actualize the mathematical properties in natural bodies. Such a function of actualization could not be extended to *ʿilm al-athqāl*. In fact, weight and motion, the two notions that delimit its field of investigation, can hardly be taken as geometric properties of natural bodies, limited by al-Fārābī to spatial and numerical aspects, in accordance with the canonical Euclidean paradigm that banishes all the material properties of magnitudes from the realm of geometry.

The distinction of the science of weights from the different crafts of practical mechanics is a crucial result of al-Fārābī's theory. The emphasis laid by the Second Master on *ʿilm al-athqāl* can not be stressed enough. It means no less than a solemn announcement of the emergence of an independent science of weights. With roots in the long tradition of the ancient mechanics, this new discipline came to light in the second half of the 9th century in the works of Thābit ibn Qurra and his colleagues in Arabic science.[37] It is this important scientific achievement that was recorded by al-Fārābī while building his system of knowledge.

Al-Fārābī's thesis had a long-lasting resonance in Arabic learning and was never challenged seriously. The fundamental singularity of the science of weights as an independent branch under the mathematical arts, distinct from the science of machines, became a feature of subsequent theories of science. For confirmation a great number of instances, in different kinds of works and in various literary contexts, can be called upon. Hereinafter, some of these instances are presented in chronological order.

In his *Risāla fī aqsām al-ʿulūm al-ʿaqliyya* (Epistle on the Parts of Rational Sciences), Ibn Sīnā (980-1037) enumerated the mechanical arts, considered as 'secondary constituents' of geometry, as *ʿilm al-ḥiyyal al-mutaḥarrika* (the science of movable machines, i.e., automata),[38] the pulling of weights (*jarr al-athqāl*), the science of weights and balances (*ʿilm al-awzān wa al-mawāzīn*), and the 'science of particular machines'

[35] In the Arabic partial version of Pseudo-Aristotle's *Mechanical Problems*, this very function of the *ḥiyyal* is said to be carried out with artificial devices (*ḥiyyal ṣināʿiyya*): see the edition of the *Nutaf min al-ḥiyyal* in Abattouy 2001a, pp. 110, 113 and Aristotle 1952, 847a 25-30. The function of *ʿilm al-ḥiyyal* as actualization of potentialities is surveyed in Saliba 1985.
[36] *Metaphysics* XIII.3, 1078 a 14-16.
[37] The thesis of the birth of the Arabic science of weights was first formulated in Abattouy, Renn and Weinig 2001.
[38] That *al-ālāt al-mutaḥarrika* refers to automata is established in Abattouy 2000c, pp. 139-140.

(*ʿilm al-ālāt al-juzʾiyya*).[39] Ibn Sīnā establishes a clear distinction between the science of weights and balances, the craft of pulling heavy loads, and the art of devices. In addition, the latter is subdivided into the arts of automata and of particular machines. Likewise, the pulling of weights, included in the science of weights by al-Fārābī, is assigned as a specific branch of geometry. The main point, however, in Ibn Sīnā's schema is the emphasis laid on the science of *awzān* and *mawāzīn* in which weights and balances are combined. The reference to the *wazn* instead of the *thiql* could be interpreted as a privilege given to the statical standpoint. Indeed, the *wazn* is a constant quantity measurable in a balance, whereas the *thiql* is that quantity –called gravity or heaviness– which varies during the weighing process and depends on the position of the weighed object relatively to a particular point, the center of the world or the fulcrum of the balance.[40]

In his discussion on the divisions of sciences in *Maqāṣid al-falāsifa* (The Intentions of philosophers), al-Ghazālī (1058-1111) subsumed the science of weights (*ʿilm al-athqāl*) as an independent branch under the mathematical arts and differentiates it from the study of ingenious devices (*ʿilm al-ḥiyyal*).[41] Ibn Rashīq, a Moroccan mathematician of the late 13th century, assumed a similar demarcation between weights and machines, and founded the latter on the former: the science of weights, of balances, and of catapults (*ʿilm al-athqāl wa-l-mawāzīn wa-l-majānīq*) deals with the downward motion of heavy bodies and constitutes the foundation of the science of machines (*wa-yatarattab ʿalā ʿilm al-athqāl ʿilm al-ḥiyyal*).[42] In his biography of al-Isfizārī, al-Bayhaqī did not confuse the two when he reported that al-Isfizārī "was mostly inclined to astronomy and to the science of weights and machines (*ʿilm al-athqāl wa-l-ḥiyyal*)."[43] This corresponds to what we know of his extant works in mechanics, the *Irshād* being clearly a book of *athqāl*, whereas al-Isfizārī's work on *ḥiyyal* is represented by a collection of compiled summaries (sometimes with comments) extracted from the mechanical works of Heron, Apollonius

[39] The other components of geometry are the sciences of measurement, of optics and mirors, and of hydraulics: see Anawati 1977, p. 330 and Ibn Sīnā 1989, p. 112.

[40] The difference is well illustrated by the definition opening Pseudo-Euclid's *Maqāla fī l-mīzān*: "weight (*wazn*) is the measure of heaviness (*thiql*) and lightness (*khiffa*) of one thing compared to another by means of a balance": Paris, Bibliothèque Nationale, MS 2457, f. 22b.

[41] Al-Ghazālī 1961, p. 139.

[42] Al-Ḥusayn b. Abī Bakr Ibn Rashīq (d. 1292), *Risālat fī taṣnīf al-ʿulūm al-riyāḍiyya*, Rabat, al-Maktaba al-ʿĀmma, MS Q 416, p. 422. On Ibn Rashīq, see Lamrabet 2002 and Abattouy 2003a, pp. 101-105.

[43] Al-Bayhaqī 1988, p. 125. Likewise, in the notice he devoted to the mathematician Abū Sahl al-Qūhī, al-Bayhaqī states that he was "well-versed in the science[s?] of machines and weights and moving spheres" (*baraza fī ʿilm al-ḥiyyal wa-l-athqāl wa-l-ukar al-mutaḥarrika*) (ibid., p. 88).

and Banū Mūsā.[44] Later on, Taqī al-Dīn ibn Maʿrūf, the 16th-century mechanician, followed the same pattern. Accounting for the books he read in his scientific curriculum, he mentioned, in addition to texts of mathematics, "books of accurate machines (*kutub al-ḥiyyal al-daqīqa*), treatises of the science of the steelyard and of the balance (*rasā'il ʿilm al-qarasṭūn wa-l-mīzān*), and of the pulling of weights (*wa-jarr al-athqāl*)."[45]

Sometimes *ʿilm al-athqāl* is referred to as *ʿilm marākiz al-athqāl*, one of its branches which enjoyed great reputation. A good instance of this is the following quotation extracted from the correspondence between al-Qūhī and al-Ṣābī. In a letter to al-Qūhī, al-Ṣābī says:

> "We did not obtain a complete book on this science, I mean centers of gravity (*marākiz al-athqāl*), nor was there done any satisfactory work by one of the ancients or one of the moderns. In my opinion it is in the rank of a singular science which merits to have a book of basic principles (*al-ṣināʿa al-mufrada allatī yuḥtāj an yuʿmal lahā kitāb uṣūl*)."[46]

A century later, al-Isfizārī qualified the centers of gravity as "the most elevated and honorable of the parts of the mathematical sciences" and defined it as:

> "the knowledge of the weights of loads of different quantities by the [determination of the] difference of their distances from their counterweights" (*Irshād*, f. 16b).

Al-Khāzinī specifies further the definition of his predecessor when he explains that the study of the steelyard is founded upon the science of the centers of gravity (*wa-ʿalayhi mabnā l-qaffān*).[47] Therefore, it is obvious that the expression *marākiz al-athqāl* is intended to account for the statical aspect of *ʿilm al-athqāl*, by the study of forces as they are related to weights, such as in the case of levers and scales. This same thesis is assumed by other Islamic scholars.[48]

In contrast, the tradition of *ḥiyyal* delimits the contours of a distinct discipline, centered on the investigation of the methods of applicability of

[44] In the incipit of this collection, al-Isfizārī writes: "We collected in this book what has reached us of the books on various devices (*anwā' al-ḥiyyal*) composed by the ancients and by those who came after them, like the book of Philon the constructor of machines (*sāḥib al-ḥiyyal*), the book of Heron the mechanician (*Īrun al-majānīqī*) on the machines (*ḥiyyal*) by which heavy loads are lifted by a small force... We start by presenting the drawings of the machines (*ṣuwwar al-ḥiyyal*) conceived by the brothers Muḥammad, Aḥmad and al-Ḥasan, Banū Mūsā ibn Shākir." Manchester, John Ryland Library, Codex 351, f. 94b; Hayderabad, Andra Pradesh Library, Asafiyya Collection, Codex QO 620, p. 1. I thank Sonja Brentjes who afforded me kindly a xerox copy of Haydarabad manuscript.

[45] In his *Kitāb at-ṭuruq al-saniyya fī l-ālāt al-rūḥāniyya* (The sublime methods in spiritual machines): al-Ḥasan 1976, p. 24.

[46] Berggren 1983, pp. 48, 120.

[47] Al-Khāzinī 1940, p. 5.

[48] For instance, Ibn al-Akfānī (fourteenth century) asserts that *ʿilm marākiz al-athqāl* shows "how to balance great weights by small ones, with the intermediary of the distance, such as in the steelyard (*qarasṭūn*)": Ibn al-Akfānī 1989, p. 409. The same idea is in al-Tahānawī 1980, vol. 1, p. 47.

mathematical knowledge to natural bodies. As represented in several Greek and Arabic mechanical texts, written by Heron, Pappus, Philon, Banū Mūsā and al-Jazarī, the tradition of *ḥiyyal* is focused on the description of machines and the explanation of their functions. Book I of Heron's treatise contains principles of theoretical mechanics, but the rest, more than three quarters of the whole, is predominantly about different kinds of devices. The same applies to the treatise of Pappus. As for Philon of Byzantium (fl. 230), his *Pneumatics* is just a catalogue of machines worked by air pressure. [49]

An important constituent of the Greek traditional doctrine of mechanics –as it is disclosed in the texts by Pseudo-Aristotle, Heron and Pappus– is represented by the theory of the simple machines (the windlass, the lever, the pulley, the wedge, and the screw). Those simple machines were dealt with in Arabic science by several scholars such as Ibn Sīnā,[50] al-Isfizārī,[51] and Sinān ibn Thābit[52] under the name of *ḥiyyal*. Besides this trend on the basic simple machines and their combinations, the science of *ḥiyyal* also included a description of other categories of machines necessary in daily life and useful for civil engineering. The most well known works describing this kind of engines are the texts of machines by Banū Mūsā and al-Jazarī. *Kitāb al-ḥiyyal* by the Banū Mūsā comprises a large variety of devices, the vast majority of which consist of trick vessels for dispending liquids. The book of al-Jazarī *al-Jāmiʿ fī ṣināʿat al-ḥiyyal* enlarges this same feature in an unprecedented way. The author incorporates in it the results of 25 years of research and practice on various mechanical devices (automata, musical machines, clocks, fountains, vessels, water-raising machines, etc.).[53]

The conception of *ḥiyyal* as the practical component of mechanics is additionally corroborated by the contents of a chapter of the *Mafātīḥ al-ʿulūm* by Muḥammad b. Yūsuf al-Khwārizmī (10th century). Chapter 8 of Book II of this lexicographic encyclopedia is dedicated to "*ṣināʿat al-ḥiyyal, tusammā bi-l-yūnāniyya manjanīqūn*" (The Art of Machines,

[49] Philon's *Pneumatics* was translated into Arabic under the title *Kitāb Fīlūn fī l-ḥiyyal al-rūḥāniyya wa-mājanīq al-mā'* (The Book of Philon on spiritual machines and the hydraulic machines). The Arabic text was edited and translated into French in Carra de Vaux: see Philon 1902.

[50] A Persian text called *Miʿyār al-ʿuqūl dur fan jar athqāl* is attributed to Ibn Sīnā. The treatise, in two sections, is devoted to the five simple machines. It presents the first successful and complete attempt to classify simple machines and their combinations: Rozhanskaya 1996, pp. 633-34.

[51] Al-Isfizārī is the author of a collection of summaries and commentaries extracted from the mechanical works of Heron, Apollonius, and Banū Mūsā. He dealt with simple machines in his commentary on Book II of Heron's *Mechanics*: see supra, n. 45, and Abattouy 2000b, pp. 147-48.

[52] Sinān (d. 942), the son of Thābit ibn Qurra, is presumably the author of a fragment on the five simple machines preserved in Berlin, Staatsbibliothek, MS Orient fol. 3306.

[53] For the two works of Banū Mūsā and al-Jazarī, see respectively Hill 1974 and Hill 1979 for English translations, and al-Ḥasan 1979 and al-Ḥasan 1981 for the Arabic texts.

Called in Greek *Manjanīqūn*). Besides a short mention of machines for the traction of weights, the *ḥiyyal* described are essentially of two types: automata (*ālāt al-ḥarakāt*) and hydraulic devices (*ḥiyyal ḥarakāt al-māʼ*).[54] The author devotes great attention to the first two kinds; this might be taken as evidence to the preeminence of these machines in the domain of *ḥiyyal* in his time. Significantly, al-Khwārizmī –like Ibn Sīnā– classifies the weight-pulling machines in the field of *ḥiyyal* in contrast to their arrangement among that of *athqāl* by al-Fārābī.

The analysis of the overall significance of the Arabic medieval science of weights showed that this tradition does not represent a mere continuation of the traditional doctrine of mechanics as inherited from the Greeks. Rather, it means the emergence of a new science of weights recognized very early on in Arabic learning as a specific branch of mechanics, and embodied in a large scientific and technical corpus. Comprehensive attempts at collecting and systematizing (as well as updating with original contributions) the mainly fragmentary and unorganized Greco-Roman mechanical literature that had been translated into Arabic were highly successful in producing a coherent and orderly mechanical system. In this light, a redefinition of Arabic mechanics becomes necessary, initially by questioning its status as a unified field of knowledge. Such a redefinition may be worked out briefly by setting a sharp distinction between *ʿilm al-athqāl* and *ʿilm al-ḥiyyal*. The latter corresponds to the traditional descriptive doctrine of machines, whereas the core structure of the *ʿilm al-athqāl* is determined by the balance-lever model and its theoretical and practical elaborations. Uniting the theoretical treatment of the balance with concrete practical information about its construction and use, and adopting an integrative treatment of physics and mechanics, overcoming their original separation in Antiquity, the new science of weights distinguishes itself by turning mechanics from being originally a marginal part of geometry into an independent science of weights.

On the methodological level, the new science of weights was marked by a close combination of experimentation with mathematization. The Aristotelian qualitative procedures were enriched with quantitative ones, and mathematics was massively introduced in the study of mechanical problems. As a result, mechanics became more quantitative and the results of measures and experiments took more and more weight in mechanical knowledge. Certainly, the fundamental concepts of Aristotelian physics continued to lie in the background, but the scholars were able to cross their

[54] Al-Khwārizmī 1968, pp. 246-247.

boundaries and to accomplish remarkable discoveries in physical ideas. For instance, the generalization of the theory of centers of gravity to three-dimensional objects, the introduction of a dynamic approach in the study of problems of statics and hydrostatics, the improvement of the procedures and methods for the determination of specific weights and of weighing instruments, the development of the theory of heaviness and the establishment of a theory of the ponderable lever. Further, the treatment of the law of equilibrium by Thābit ibn Qurra and al-Isfizārī opened the horizon of a unified theory of motion in which the dichotomies of natural-violent, upward-downward motions vanish, exactly as they disappear in the concomitant motions of the two arms of a balance lever. In this physical system, indeed, the weight of the body might be considered the cause of the downward as well as of the upward motion, overcoming the Aristotelian balking at making weight a cause of motion. For their parts, al-Qūhī and Ibn al-Haytham had the priority in formulating the hypothesis that the heaviness of bodies vary with their distance from a specific point, the center of the earth. Moreover, they contributed to unify the two notions of heaviness, with respect to the center of the universe and with respect to the axis of suspension of a lever. In his recension of the works of his predecessors, al-Khāzinī pushed forward this idea and drew from it a spectacular consequence regarding the variation of gravity with the distance from the centre of the world. All this work represented strong antecedents to the concept of positional weight (*gravitas secundum situm*) formulated by Jordanus in the 13th century.[55]

7. For an intercultural history of mechanics

The historians of mechanics, from Pierre Duhem until Marshal Clagett, assumed that the foundation of the science of weights must be credited to the school of Jordanus in Europe in the 13th century. Now it appears that this science emerged much earlier in Islamic science, in the 9th century. Moreover, the first steps of the Latin *scientia de ponderibus* should be considered as a direct result of the Arabic-Latin transmission, and especially as a consequence of the translation of two major Arabic texts in which the new science and its name are disclosed, *Kitāb fī l-qarasṭūn* by Thābit ibn Qurra and *Iḥṣā' al-ʿulūm* by al-Fārābī.

[55] It is evident that all these issues need to be treated and instantiated separetely and thoroughly, as they document the theoretical components of the new science of weight: see for a first analysis Abattouy 2001b and Abattouy 2002a. The interpretation of the Arabic sience of weights as a progress in science is developed in Abattouy 2004a.

Indeed, the very expression *scientia de ponderibus* was derived from the Latin translation of al-Fārābī's *Iḥṣā' al-ʿulūm*. Versions of this text were produced both by Gerard of Cremona and Dominicus Gundissalinus. The latter made an adapted version of the *Iḥṣā'* in his *De scientiis* and used it as a framework for his own *De divisione philosophiae*, which later became a guide to the relationships between the sciences for European universities in the 13th century. In the two texts, Gundissalinus reproduced –sometimes verbatim– al-Fārābī's characterization of the sciences of weights and devices, called respectively *scientia de ponderibus* and *sciencia de ingeniis*.[56] The reason for this close agreement is easy to find: he could not rely on any scientific activity in this field in his times in Latin.[57] Among all the sciences to which Gundissalinus dedicated a section, the sciences of weights, of devices, and of optics were obviously less known in the Latin west in the 12th century. Even the antique Latin tradition represented by Boece and Isidore of Sevilla could not furnish any useful data for a sustained reflection on their epistemological status. It must be added also that Gundissalinus seems to ignore all their developments in the Arabic science either, including Thābit ibn Qurra's book on the theory of the balance and Ibn al-Haytham's achievements in optics. Hence, the effort of theorization deployed by Gundissalinus, by showing the state of the sciences in the late 12th century in Western Europe, throws the light on a considerable underdevelopment in several sciences. This concerns particularly the different branches of mechanics.[58]

As said before, *Liber karastonis* is the Latin translation by Gerard of Cremona of *Kitāb fī l-qarasṭūn*. The general structure of both Arabic and Latin versions is the same, and the enunciations of the theorems are identical. Yet the proofs might show greater or lesser discrepancies. None of the Arabic extant copies of Thābit's *Kitāb* seem to be the direct model for Gerard's translation. The Latin version was repeatedly copied and distributed in the Latin West until the 17th century, as it is documented by several dozens of extant manuscript copies. This high number of copies instructs on the wide diffusion of the text. Further, the treatise was

[56] Gundissalinus 1903, *De Div. Phil.*, pp. 121-24 and Gundissalinus 1932, *De Scientiis*, pp. 108-112.
[57] It is to be noted that Hughes de Saint Victor who, in his *Didascalicon de studio legendi*, provided the most complete Latin classification of the sciences before the introduction of Arabic learning, just overlooked the two mechanical arts. On the *Didascalicon*, see Taylor 1991.
[58] This was noted by Hugonnard-Roche 1984, p. 48. Other Arabic works on the classification of the sciences translated into Latin might have been a source for the distinction of the science of weights and its qualification as the theoretical basis of mechanics. For instance, al-Ghazālī's *Maqāṣid al-falāsifa*, translated as *Summa theoricae philosophiae* by Gundissalinus and Johannes Hispanus in Toledo, and Ibn Sīnā's *Risāla fī aqsām al-ʿulūm*, translated by Andrea Alpago: *In Avicennê philosophi prêclarissimi ac medicorum principis, Compendium de anima, De mahad…, Aphorismi de anima, De diffinitionibus et quœsitis, De divisione scientiarum*, Venice, 1546, fols 139v-145v.

embedded into the corpus of the science of weights which was understood to be part of the mathematical arts or quadrivium, together with other works on the same topic, in particular the writings of Jordanus Nemorarius in the science of weights.[59] In addition, at least one version of Thābit's work was known in Latin learning as a writing of *scientia de ponderibus*. This version is the *Excerptum de libro Thebit de ponderibus*, a Latin text which appears frequently in the codexes. It is precisely a digest of the logical strucure of *Liber de karastonis*, in the shape of statements of all the theorems.[60]

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[59] The *Liber karastonis* is edited with English translation in Moody and Clagett 1952, pp. 88-117. For more details on its codicological tradition, see Buchner 1922 and Brown 1967.

[60] Brown, 1967, pp. 24-30 and Knorr, 1982, pp. 42-46, 173-80.

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Exact Sciences

Science between East and West: A Domain of Translation

Paul Kunitzsch

Let me begin with an anecdote shedding some light on the subject about which I am going to speak to you. After a talk that I gave in 1967 in the Institute for the History of Science in the University of Hamburg on the Arabic transmission of the *Almagest*, the first question asked in the discussion afterwards was: "What at all is science in all this?" The question came from a practising scientist. A kind of answer may be seen in what Walter Artelt, a German historian of medicine, wrote in his *Introduction to the History of Medicine* (Stuttgart, 1949) on the subject and methods in the history of medicine: "Ihr Gegenstand ist medizinisch, aber ihre Methoden sind die des Historikers und Philologen, sind geisteswissenschaftlich", i.e. "Its subject is medical, but its methods are those of the historian and the philologist, they belong to the humanities". In this sense it is also significant that, some years ago, the Institute for the History of Science in the University of Munich, which since its start had formed part of the Faculty of Mathematics, was transferred to the Department of History in the Philosophical Faculty. And when its director, Menso Folkerts, well known specialist in the history of mathematics, came to be elected member of the Academy of Sciences in Munich, it was in the philosophical-historical section that he was elected, not in the section of science.

This discrepancy of understanding between the practitioners of the sciences on the one hand and the historians of science on the other may be well-known to all of us who are active in the field of history of science. The fact is that most of what has been achieved in the sciences in Antiquity and in the Middle Ages, in the Orient as well as in Europe, has survived in written form, in texts, in the different languages involved, Greek, Latin and Arabic, apart from scarce artifacts from Antiquity and many from the Middle Ages, most of which however also carry inscriptions which need to be interpreted. It is therefore only natural that the study of the scientific achievements of those historical periods requires a philological skill on the side of the researcher in order to edit, translate and explain this scientific heritage.

Another observation is that, of course, in no civilization scientific endeavours started at zero. All the civilizations have been in one or the other contact with preceding or neighbouring civilizations and were influenced by them in one or the other way. So the Greeks were not independent of Babylonian and Egyptian influence, the Islamic world came under the influence of Persian, Indian and Greek knowledge, and Europe –both in the East, in Byzantium, and in its Western Latin part– had its scientific contacts with the Arabic-Islamic world. In this sense the bishop of Qinnasrin, in Syria, Severus Sebokht, wrote in AD 662, concerning the invention of the Indian system of writing numbers with only nine symbols, that not all great inventions in the sciences were made by the Greeks and the Babylonians, but that also the Indians contributed to the development of the sciences as, here, with the invention of the system of the nine symbols, which surpasses every word of praise. Strikingly, a notice in the same sense was inserted into a manuscript of Isidor of Sevilla's *Etymologiae* in Spain in AD 976, repeated in another manuscript of the same in AD 992.

The passage of knowledge from one civilization to another naturally implies the existence of individuals in command of the language of the other side, beside their own language. This may have led to oral contacts of various sorts, and it ended up in formal translations of written documents. That Ptolemy cites in the *Almagest* Babylonian astronomical observations and uses, for dating, the Babylonian era of Nabonassar (starting in 747 BC), implies that this material was accessible to him in Greek.

In our fields of research we are mostly concerned with two major translation movements, in the Orient the translations into Arabic, from Syriac, Middle-Persian (Pahlavi), Indian and Greek, and in Europe the translations from Arabic into Byzantine Greek, into Latin and, at some point, also into Old Spanish and Hebrew.

After centuries of living in an essentially oral culture in the Arabian Peninsula, more or less isolated from the neighbouring civilizations to their north and east, the Arabs entered history in and since the time of the prophet Muḥammad in the seventh century AD. United in the community of the newly founded religion of Islam they crossed the borders of the

Peninsula and soon conquered the territories of the Near and Middle East and North-Africa into the Iberian Peninsula until the Pyrenees. In their new realm, for severa1 centuries under the reign of the caliphs, they came into direct contact with the achievements of Greek-Byzantine and Persian background, part of which were also the sciences cultivated in these regions. Here then began what became known to us since the Middle Ages as ‘Arabic science’, the *doctrina Arabum*.

For the Arabic-Islamic world there exists a genre of bio-bibliographical literature presenting us with a wealth of names of authors and translators and book titles in the vast field of the sciences; we may here mention Ibn al-Nadīm, Ibn al-Qifṭī, Ibn Abī Uṣaybiʿa or Ḥājjī Khalīfa, and for al-Andalus specifically Ibn Juljul and Ṣāʿid al-Andalusī. –It may just be added that a similar kind of literature did not exist in Europe–. In our times the bibliographical information has been assembled in histories of Arabic literature of orientalists like Carl Brockelmann and Fuat Sezgin as well as, for certain branches of science, Max Krause or Manfred Ullmann. Text studies and editions since the last roughly two centuries have confirmed much of the information given in these sources, mostly for the periods when those sciences and their practitioners are sufficiently safely documented.

However the beginnings and the early stage of the Arabic contact with the sciences still remain in the dark. The Arabic reports here appear partly legendary, and texts ascribed to the earliest period often appear as forgeries of later times. Ascriptions of works to the times of Khālid ibn Yazīd (d. AD 704) or Jābir ibn Ḥayyān appear highly doubtful. On the other hand, a realistic view on the first two centuries of development in the Islamic area will leave no doubt that more things were going on than can now be firmly spotted. It is known that administration and especially the organization of the public finances were kept by the caliphs for roughly a hundred years going on in the Greek and Persian systems current in the respective areas, until they were Arabized. It can also be assumed that before the well-established translations began in the late eighth century, there had happened oral contacts between Arabic individuals and individuals in the conquered regions who were practising and teaching the sciences. In any way, the oldest known Arabic texts in astrology, still of the eighth century, already show a stable use of the subject’s terminology, in Arabic. Another hint: when caliph al-Manṣūr initiated the foundation of the new residence, Baghdad, in AD 762, he convoked a council of astrologers in order to determine the propitious moment for laying the foundation stone. Among these specialists there are mentioned in the sources ʿUmar ibn al-Farrukhān, Māshā’allāh and al-

Fazārī, astronomers and astrologers who are not legendary individuals and of whom written works have survived and are known. All this indicates that a period of contact and reception preceded these early manifestations of 'Arabic science' around the mid-eighth century.

To a neutral observer it may appear surprising how soon and eager the Arabs, those bedouins of the Arabian deserts, indulged in the acquisition and development of the sciences. In reality, they were not as unprepared as one might think. In the centuries of their life in the deserts and, partly, in some fertile oasises, they had been in permanent intimate contact with the natural phenomena. Over the centuries they had developed a rich knowledge of the land, its plants and animals, their cultivation and breeding, of the stars and the relationship between their risings and settings and the arrival of seasons, of periods of rain and drought, cold and heat etc. This knowledge, gathered through many centuries and transmitted orally from one generation to the next, has later been collected, in the ninth and tenth centuries and after, by philologists and lexicographers and put down in specialized monographs, as –for astronomy and meteorology– in the *kutub al-anwā'*, Books on weather prognostication. The nucleus for the many sciences that were later cultivated in the Arabic-Islamic world was thus present in the own cultural heritage of the Arabs, of course in a popular form based on the experience of generations. This rich tradition has certainly predisposed them to receive, cultivate and develop the sciences found in the conquered territories. Needless to say that in the further development of the sciences individuals from all the nations forming the Islamic world had their part.

Investigation of early scientific translations into Arabic points to a prominent role of Middle-Persian in the process of transmission, prior to the mass of translations from Greek. This way of transmission is sometimes formally expressed in a text itself, as, e.g., in the astrological *Kitāb al-mawālīd*, Book on nativities, ascribed to Zarādusht and circulating already in its ancient Greek version under the name of Zoroaster. Here it is clearly stated in the introduction that the Middle-Persian text was revised and put into 'Newer Persian' by one Māhānkard in AD 637 and afterwards translated into Arabic by Saʿīd ibn Khurāsānkhurra in the time of the Abbassid propagandist Abū Muslim, i.e. in the years between AD 747 and 754. Other elements in the text confirm the Persian derivation: some Persian star names retained in the Arabic version more or less correctly and the designation of the fixed stars as *biyābānīya*, with a Middle-Persian term literally rendering the Greek ἀπλανής. Similarly, a text of Greek origin, in the Oriental versions ascribed to Hermes, on the astrological virtues of the fixed stars uses that

Middle-Persian term for the fixed stars and Persian star names. Later, in its Latin translation, the term reappears as *(stelle) beibenie*, a term found also in many other astrological texts. Such Arabic versions of Middle-Persian translations from Greek can also appear as inserted sections in an Arabic work, as, e.g., the famous description of the decans of the zodiac in Abū Maʿshar's astrological *Introductorium maius*, where the decans called 'Persian' are basically also Greek (like those directly called 'Greek'), transmitted through Middle-Persian, with the effect that the majority of the mythological and other proper names appear in the Arabic heavily distorted, not to speak of what became of them in the two Latin versions by Johannes Hispalensis and Hermann of Carinthia, respectively. Also a number of astrological technical terms of Persian origin were retained in the Arabic astrological literature and appeared like that in their Latin translations, as, e.g., *hīlāj* or *haylāj*, *kadhkhudāh*, *namūdār*, *sālkhudāh*, or, accordingly, *ylech* and *hileg*, *hilegium*, *alcocoden*, *alnimodar, alcelcadeny*; they appear in the same way in the Byzantine translation of Abū Maʿshar's *De revolutionibus nativitatum*, near the end of the tenth century.

Also other fields of science are rich in Persian terminology, such as the *materia medica*, mineralogy, alchemy and magic.

The mass of translations of scientific works into Arabic was made from Greek, some of them through the medium of Syriac. Practically all the translators of this group of texts were Christians, with a background of Syriac and late hellenistic erudition. The outstanding figure among them may be called Ḥunayn ibn Isḥāq, a Nestorian from al-Ḥīra (d. 873 or 877). He translated more than a hundred works of Galen, Hippocrates and other physicians and established for himself rules for editing a text coming close to our modern standards: at first he endeavoured to collate as many manuscripts as possible and to establish a reliable Greek text, which then served as the basis for his translation.

We cannot here discuss all the aspects connected with the Arabic translations, a few observations must suffice. One observation in the field is that a number of Greek texts were translated more than once. The reason behind this phenomenon is not obvious, one could only speculate.

So the two great mathematical works, Euclid's *Elements* and Ptolemy's *Almagest*, were each translated into Arabic three or more times. The situation around the *Elements* is as yet not sufficiently clear. According to Arabic bibliographical reports there were two successive translations by al-Ḥajjāj and a translation by Isḥāq ibn Ḥunayn, which was revised by Thābit ibn Qurra. Intensive studies are still required in order perhaps to find out which of the surviving 19 Arabic manuscripts exactly represents which version. While the general impression now is that all of these manuscripts contain the version of Isḥāq, several of them contain extra pieces of text ascribed to al-Ḥajjāj (without however indicating whether his first or second translation). Also the possibility of contamination must always be taken into account.

On Ptolemy's *Almagest* I can speak from my own experience. In short: a so-called 'old' or 'ma'mūnian' translation, made probably around AD 800, that is before al-Ma'mūn became caliph in 813, is lost as a whole. Relics of it can be identified in the star catalogue included in al-Battānī's *al-Zīj al-Ṣābi'* and in a treatise by Ibn al-Ṣalāḥ (d. 1154) on the faults in the transmission of Ptolemy's star catalogue. Of the twelve known manuscripts of the Arabic *Almagest* two contain the translation of al-Ḥajjāj (one complete, the other only Books I-VI), ten the translation of Isḥāq ibn Ḥunayn as revised by Thābit ibn Qurra. Also here, in some places in the Isḥāq manuscripts portions of the Isḥāq text have been substituted by corresponding portions from al-Ḥajjāj. On the whole, for the *Almagest* the situation appears much clearer than for the *Elements*. Generally speaking, the Ḥajjāj version renders the Greek text in a simpler, rather straightforward, uncomplicated form, whereas Isḥāq aims at closer correspondence to the Greek and produces a highly complicate text.

At present I am working, together with Richard Lorch in Munich, on the edition of an Arabic translation of Theodosius' *Spherics* together with its Latin translation by Gerard of Cremona. The translator of this Arabic version is not known; one manuscript says in the colophon that the book is the *iṣlāḥ* –which can be either a revision or a translation– of Thābit ibn Qurra. But that could be a confusion with another Arabic translation of the *Spherics* which we do not edit and which is not the one translated by Gerard. Thanks goodness, the Greek text of the *Spherics* has survived and has been edited several times. Only with the help of the Greek text it was possible to establish many readings in the Arabic. A special problem is posed by the letters marking the important points in the accompanying diagrams. In the two manuscripts which are in Arabic script (the third one is in Hebrew script) these letters are written in the current text in connected form, as a block, like a word, and mostly without, or with wrong, dots. Without comparing the Greek, it would therefore almost be impossible to distinguish B, T and TH, or K and L, or R and Z, or Ḥ and KH, etc. One wonders what use the readers could ever have made of this mess, although at least one of the two Arabic manuscripts is full of corrections of these letters, but again in confused and incomplete form, perhaps by several, more recent, hands.

In view of the defects in the transmission of translated texts just mentioned we must not lose our confidence in them. We should always take into account that what has survived, what we now can see of such manuscripts, is but the tip of an iceberg. There will have existed many more copies of all these texts, more carefully written, nearer to the archetype. And we can assume that these texts did not have a lonely life. Already contemporaries will have discussed them with the translators and with colleagues, and also later they will continuously have been discussed and commented upon among scholars and with students. And also, those educated in the system of the time and specialized in the respective field of science, will certainly have understood the subjects of a manuscript easier and better than we Westerners in the twentieth or twenty-first century.

The second great movement of translation went in the opposite direction, from East to West. After the expansion of Islam along the eastern, southern and western coasts of the Mediterranean the Europeans in these areas came into immediate contact with the Arabs. From the beginnings Europe saw them as invaders and conquerors, but still worse as a serious concurrence and threat to the Christian faith which so far had been the single, undisputed guide of their lives. In contrast to the Orient, where the existence of Christian and Jewish groups and individuals was common, the population in the Christian lands was purely Christian, no followers of other faiths were living among them, apart of some Jews here and there who however were never fully accepted. So the sudden appearance of another, new, faith –Islam– was a mental shock for the Europeans. It is therefore a remarkable turn that at some point they surmounted their enmity towards the Saracens, recognized their superiority in many matters of life and eventually started endeavours to make available for themselves the achievements of Arabic science.

Translations from Arabic were made in great number. In the European east some astronomical and astrological texts were translated into Byzantine Greek between the late tenth and the fourteenth centuries. In Latin Europe we have several places of translation. Sicily and the crusaders' states are represented with only a few translated texts. Salerno became famous in the eleventh century through the translations of medical texts by Constantinus Africanus. Most of the Arabic-Latin translations were however made in Spain (it should be kept in mind that all these translations were made in the Christian parts of Spain, not in the Islamic part, al-Andalus).

A first period of contact with Arabic science developed in the late tenth century in Catalonia, in the area where we have the pleasure of being assembled. On the one hand, the astrolabe had somehow come to the knowledge of scholarly clerics in the monasteries of Ripoll and Vic. The result was a corpus of writings on this instrument which seems to have provoked curiosity and interest. In the second half of the tenth century the outstanding astronomer in al-Andalus was Maslama al-Majrīṭī who i.a. studied and re-edited Ptolemy's *Planisphaerium*, which had been translated into Arabic earlier in the Arabic east. No formal treatise on the astrolabe from his pen seems to exist, but at least he added to his edition of the *Planisphaerium* numerous comments and an extra chapter. Also a table of astrolabe stars established by him exists in Arabic and in a Latin version of unknown provenance; it is dated to AD 978. An echo of these endeavours seems to have reached the Catalonian clerics, together with some texts and an Andalusian astrolabe. Their corpus on the astrolabe consists of the description of the instrument –quite obviously written down with the instrument at hands and a person by the side who could explain all its parts and their names, in Arabic. The section on the use of the instrument is partly translated from al-Khwārizmī's treatise on the subject. These texts have been edited in 1931 by José Millàs whom we are going to honour during this conference. Among the often split up fragments of text scattered through several manuscripts of the eleventh century there are also two small fragments translated from the *Planisphaerium*.

On the other hand, also material on astronomy in general and astrology, including, or based on, Arabic and Hebrew materials, must have been available from which the Catalonian clerics compiled, about the same time, the *Liber Alchandrei* containing Arabic and Hebrew names of the planets, the zodiacal signs and (in Arabic) the lunar mansions. I hope I do not disclose a secret when I here add that this text complex has been edited by David Juste and will be available just about these days[*].

These early Arabic-based Latin texts exerted a remarkable influence on scholars beyond Spain, in France, Southern Germany and England. The fame of 'Arabic science' spread, and in the twelfth century the main period of translation developed in Spain. Now the greatest number of texts in various branches of the sciences were translated, in mathematics, astronomy and astrology, medicine, pharmacology, philosophy, alchemy, magic and divination and more. The so-called translators came, apart from Spain, from various parts of Europe. They were active in several places, among which also Barcelona. The greatest fame gained Toledo, because here –beside others– Gerard of Cremona was at work, the most prolific of all the translators, to whom more than eighty translations are ascribed,

[*] JUSTE, David, *Les* Alchandreana *primitifs. Études sur les plus anciens traités astrologiques latins d'origine arabe (Xème siècle)*, Brill Ed., Leiden-Boston, 2007 [editor's note]

among which such voluminous texts as Euclid's *Elements*, Ptolemy's *Almagest* or Avicenna's *Canon*. Toledo's fame even reached the German poet Wolfram of Eschenbach who, in the years 1200-1210, in his epic *Parzival* names *Dolet* as the place where the fictitious source of the grail story has been found. In addition, he also introduces, in *Parzival*, knowledge in astrology and medicine derived from the Arabic-Latin translations, and in a kind of horoscope he mentions the planets with their Arabic names.

As an orientalist with many years of experience in teaching Western students Arabic, one will of course ask oneself what might have been the so-called translators' knowledge of Arabic. One grown up in Spain like John of Seville may have known that language for more or less long time. But those translators coming from outside Spain, how will they have learnt Arabic, how much time may that have taken, which kind of Arabic would that have been –the current colloquial dialect or the correct classical language? Such doubts were already expressed by Roger Bacon (d. 1292) when he wrote: "Not one of these translators had any true knowledge of the languages or of the sciences". In support of such doubts it shall here be said that for several translations it is explicitly mentioned that the 'translator' was aided in his translation by a local helper named so-and-so, sometimes a Jew or a Mozarab (that is, a Christian living, or having lived, in the Arabic part of Spain). In this way, the Mozarab Galippus (= Ghālib) is mentioned by Daniel of Morley as having assisted to Gerard of Cremona's translation of the *Almagest*.

On the other hand, Francis J. Carmody, in his bibliography *Arabic Astronomical and Astrological Sciences in Arabic Translation* (1956), proposed to leave alone the Arabic sources and to use for historical research work the translated Latin texts alone.

On the whole, I must say from my own experience, it is astonishing how correctly most of the translations have rendered their Arabic sources. Naturally, there are differences of method and style among the numerous translators. Some convert the Arabic more or less freely as, e.g. Hermann of Carinthia, others render the Arabic almost verbatim as John of Seville or, especially, Gerard of Cremona. Such literal translations are often hard to understand. In my present work on Theodosius' *Spherics* I met with several places where the Latin can only be fully understood when having the Arabic by the side. On the other hand, it is amazing how Gerard managed to establish a system of rendering the diagram letters even when they exceeded the number of the letters in the Latin alphabet. Wrong reading of undotted words in the Arabic has sometimes led to ridiculous translations as when Gerard renders, in the star catalogue of the *Almagest*, the designation of the shepherd's staff in the hand of Bootes, with a crook on its upper end, as *hastile habens canes*, "a staff having dogs", or the pinion of the wing of Cygnus as *decima alae*, etc. More serious was his gross error (in the first edition his translation) to render the Arabic letter *sīn* (which in Eastern Arabic has the numerical value of 60) according to this letter's value in the Arabic West as 300, thus giving several northern stars in the catalogue latitude values of 300 and odd degrees. Later, in the revised edition of his translation, he has corrected this fault himself. Here, in the latter case I think the ideal of *fidus interpres* had outweighed his possible scruple vis-à-vis the astronomical facts; only in a laterstage, having more Arabic manuscripts –especially Maghrebi ones– at his disposal, he could correct the error on a firm text base. The erroneous or ridiculous translations of the first type may be due to the local helper who understood the spellings of those Arabic words in their most common meaning, unaware of other, rarer meanings.

In the light of my experience with this kind of texts I firmly think –in contrast to Carmody's opinion cited above– that the ideal and most successful way of editing scientific Latin texts translated from Arabic will always be to edit the Arabic and the Latin versions together, side by side. A number of texts has been luckily edited in that form in the last few decades, works of Abū Maʿshar, al-Qabīṣī and Ptolemy's star catalogue. It is to be hoped that this series will be followed by many other works in the same style.

In passing I here mention that also curious cases of cross-translation happened between Byzantium and the Latin West. So, for example, Abū Maʿshar's *De revolutionibus nativitatum* was translated at the end of the tenth century into Byzantine Greek, and afterwards, perhaps around 1264, from Greek further into Latin; in its printed edition of 1559 however, the Latin text was ascribed to Hermes. Vice versa, parts of the *Toledan Tables* and of the compiled treatise on the astrolabe falsely ascribed to Messahalla (Māshā'allāh) were translated into Greek in the fourteenth century.

The fundamental role of translation in the development of the sciences both in the Islamic world and in Europe is thus clear. The edition of the pertaining texts, as far as possible simultaneously in the two correspon-ding languages, Arabic and Latin, appears indispensable for a successful pursuit of the history of the sciences.

As a last remark I would add that in the seventeenth century a last translation movement started, now from the West back into the Orient. Works i.a. of Paracelsus and Lalande and geographical material including the new developments after the voyages of discovery together with maps were transferred into Arabic and Turkish. After Napoleon's campaign in Egypt, the viceroy of Egypt, Muḥammad ʿAlī, started a campaign of translation of Western scientific and technological books into Arabic which he thought might be useful for the development of his country.

Nowadays scientists of all countries on earth are linked by electronic devices and meet each other in endless congresses everywhere. As it seems they are no longer in need of translation in order to communicate, their common language now is that sort of international English which I also have used in this talk.

Shams al-Dīn al-Sakhāwī on *Muwaqqits*, *Mu'adhdhins*, and the Teachers of Various Astronomical Disciplines in Mamluk Cities in the Fifteenth Century

Sonja Brentjes

Dedicated to David A. King
on the occasion of his retirement in 2007

In appreciation of David's contribution to history of science in Islamic societies and of his intellectual generosity over many years I will take up in this paper some of his questions about the context of the sciences in certain Islamic societies and discuss them on the basis of sources other than those that he focused on. They complement the picture he has built, modify it and occasionally challenge it.

David has written about the new astronomical professional, the *muwaqqit*, who begins to be visible in the sources in the late thirteenth and early fourteenth century, and the work of these men, particularly in Mamluk and Ottoman Egypt and Syria.[1] Trying to contextualize the new profession David investigated the relationship between the *muwaqqits* and

[1] See, in particular, David A. King, "On the role of the muezzin and muwaqqit in medieval Islamic societies", in F. Jamil Ragep and Sally P. Ragep, with Steven J. Livesey (eds.), *Tradition, Transmission, Transformation: Proceedings of Two Conferences on Premodern Science Held at the University of Oklahoma*, Leiden, New York & Cologne: E.J. Brill, 1996, pp. 285-346; modified reprint: *In Synchro-ny with the Heavens. Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization. Volume One. The Call of the Muezzin*, Leiden, Boston: E.J. Brill, 2004, pp. 631-77. The page references in my paper are to the first version. See also the earlier paper David A. King, "The Astronomy of the Mamluks". Isis 74 (1983), 531-555 reprinted in David A. King, *Islamic Mathemati-cal Astronomy*. Aldershot: Variorum, 1986, item 3, which discusses the major Mamluk writers on as-tronomy and the types of astronomy they engaged with. It also notes their affiliation to mosques and madrasas as muwaqqits and, occasionally, as teachers.

the *mu'adhdhins* –asking which practices were used for determining the prayer times–, the rules of the *fuqahā'* or the procedures of the *muwaqqits*.[2] He sought to determine the profile and practice of a *muwaqqit* in addition to establishing what kind of tables and instruments they have left us.[3] He also asked where in the Islamic world and when did *muwaqqits* operate.[4]

While David focused primarily on texts written by *muwaqqits*, the tables they devised and used and the instruments they constructed, which he called the primary sources, supplementing them by legal and other texts, I want to discuss his three questions from the angle of a different kind of source –biographical dictionaries of the educated elite during Mamluk rule– .[5] I will limit myself here on information and views offered in one such dictionary, *al-Ḍaw' al-lāmiʿ fī ahl al-qarn al-tāsiʿ* (*The shining light on the people of the ninth century*) by Shams al-Dīn al-Sakhāwī (830-902 / 1427-1497), one of the most important *ḥadīth* transmitters and historians of the fifteenth century. The main reason for this focus is a point of methodology. I wish to show how our answers on questions that we ask are shaped by the genre of the sources we use, their specific character, the beliefs, methods and practices of their authors and our own beliefs, methods and practices. The persona of the *muwaqqit* in David's work is mainly presented as a well defined astronomer "in the service of Islam" who was attached to mosques, produced a huge, impressive body of astronomical tables as well as other written and instrumental work in the domain of *ʿilm al-mīqāt*, which the *muwaqqit* taught to students who later often also became *muwaqqits*. This new professional was, in David's opinion, however unable to influence the practice of prayer times of the *mu'adhdhin*, which remained guided by the views and positions of the *fuqahā'*. I wish to argue that when we look in a different kind of source, i.e. biographical dictionaries, this persona looses

[2] He claimed that the rules of the *fuqahā'* ("folk" or "ethno-" astronomy) generally prevailed over those of the *muwaqqits*. King, *On the role of the muezzin*, p. 288. An outline of the content of this 'folk'-astronomy and David's views on its relationship to mathematical astronomy see King, *Synchrony*, pp. 465-75.

[3] He briefly defined this profile as that of "the mosque official responsible for regulating the times at which the muezzin should perform." King, *On the role of the muezzin*, p. 286.

[4] He answered this third question by stating that astronomical timekeeping "involving complicated –and some times highly sophisticated– procedures […] seems to have been restricted mainly to Egypt (thirteenth century onwards), Syria, the Yemen, and also Tunis (fourteenth century onwards), and finally Istanbul (fifteenth century onwards). There is little evidence on the practice in the rest of the Islamic world, notably the Maghrib, Iraq, Iran, India, and Central Asia." King, *On the role of the muezzin*, p. 288. See also King, *On the role of the muezzin*, pp. 298-300. For the wealth of tables calculated for timekeeping and the determination of the direction of prayer direction and the mathematical methods developed in this context see King, *Synchrony*, pp.1-456.

[5] King, *On the role of the muezzin*, p. 288.

its clear contours, takes on different shades and appears much more to be a *mudarris* at a *madrasa* teaching a broad range of themes and treatises than being actively involved in regulating prayer times and creating or repairing instruments at mosques. This argument and its material underpinning does not mean, of course, that teaching *ʿilm al-mīqāt* was not an important component of the classroom work of this *muwaqqit-mudarris.* It rather means that from the perspective of the biographers it was not the most important element of this teaching. But not only is the ranking modified; the status of *ʿilm al-mīqāt* itself shifts. It is not primarily the training of a body of professionals that the teacher of this discipline achieves. *ʿIlm al-mīqāt* appears in al-Sakhāwī's dictionary rather as part of the general education given to members of the educational elite in the first place, but also to visitors in search of knowledge, well-off merchants and occasionally sons of the military elite.

Biographical dictionaries yield a similar effect of displacement with regard to the *mu'adhdhin* and the spread of *ʿilm al-mīqāt* towards the east. The *mu'adhdhin* moves away from his clear affiliation with or subordination under the *fuqahā'*, while *ʿilm al-mīqāt* moves east as part of pilgrimage, commerce and travel for knowledge. In addition, biographical dictionaries point to phenomena less visible in the manuscripts and on the instruments. According to al-Sakhāwī, an exchange of different types of mathematical, astronomical and astrological skills and practices takes place in which Iranian scholars played an important role. In addition, some scholars from Anatolia participated in this transfer. Biographical dictionaries also add new information about the social ranking of those we consider mainly as *muwaqqits* and teachers of arithmetic and algebra among the educational elite at large and about their interaction with the ruling military aristocracy.

1. *Muwaqqits*

The entries in Sakhāwī's *al-Ḍaw'* range from one line merely stating the name and the *nisbat al-mīqātī* to substantive descriptions of origin, family, education, reputation, social, professional and other activities. The briefest type are statements like ʿUmar b. ʿAbd al-Raḥmān al-Zawāwī al-Mīqātī; d. 885 h / 1480-81.[6] One of the longest entries for a person professionally involved with *ʿilm al-mīqāt* is that of Aḥmad b. Rajab b. Ṭaybughā, Shihāb al-Dīn, known as Ibn al-Majdī (767-850 / 1365-1447).[7] Ibn al-Majdī's biography and the information given about him in biographies of

[6] Shams al-Dīn al-Sakhāwī, *al-Ḍaw' al-lāmiʿ fī ahl al-qarn al-tāsiʿ*. Bayrut, s.d., vol. VI, p. 90.
[7] Al-Sakhāwī, *al-Ḍaw'*, vol. I, pp. 300-2.

his students neatly depict the shift in persona I referred to in the introduction to this paper. Al-Sakhāwī reports about him that he mostly taught *ʿilm al-farā'iḍ* and *ḥisab*, then algebra and only then *ʿilm al-mīqāt* writing profusely about these four disciplines. He is said to have taught occasionally *hay'a* and *handasa*, although he apparently did not write about these topics. But he wrote treatises on *ḥadīth* which he apparently never taught.[8] In addition, he also taught *fiqh*, *uṣūl al-fiqh*, Arabic and even *ḥikma*. The enumeration of *ḥikma* as one among other topics of teaching in fifteenth-century Cairo challenges the widespread assumption about the death of philosophy and related matters at least in the Arab-speaking parts of the Islamic world after al-Ghazālī's verdict on the four types of philosophical infidelity and subsequent declarations against non-religious fields of knowledge such as the infamous *fatwā* of Ibn al-Ṣalāḥ in Ayyubid Damascus against teaching anything but the religious sciences. The content of Ibn al-Majdī's teaching of *ḥikma* remains, however, opaque.[9] In *fiqh* or grammar, Ibn al-Majdī was famous for the quality of his reading of *al-Ḥāwī*, which he had learned by heart.

The elite of all *madhhabs* and classes studied with Ibn al-Majdī because of the benefits he brought to them. Among those who served (*lāzama*, third root) him were al-Sakhāwī's Shaykh Ibn Khidr and nine other scholars, only three of whom later also taught of *farā'iḍ*, arithmetic, algebra, *ʿilm al-mīqāt* and other disciplines. Al-Sakhāwī did not try to give a complete list of those who served Ibn al-Majdī. In other entries he names Ibn al-Majdī as served by scholars not mentioned in the biography dedicated to him.[10] This kind of incompleteness needs to be taken into consideration for any kind of information, i.e. silence in biographical dictionaries does not lend itself to infer, for instance, that a certain discipline or work was not taught.

Although the Mamluks did not sponsor astrology and astronomy officially at their courts, they did so individually and also included some of these disciplines in their patronage for madrasas, mosques and Sufi convents. David has pointed to a certain Ibrāhīm al-Ḥāsib al-Malikī al-Nāṣirī who is supposed to have compiled an astrological work in Cairo

[8] Al-Sakhāwī, *al-Ḍaw'*, vol. I, p. 301.
[9] This also applies to most of the entries in Sakhāwī's dictionary in which *ḥikma* is mentioned as part of the learning or teaching. In a few entries relating to Cairo works by Ibn ʿArabī, Suhrawardī and Mawlānāzāde are mentioned. In entries about Iranian and some Anatolian scholars, Ibn Sīnā, Naṣīr al-Dīn al-Ṭūsī, Athīr al-Dīn al-Abharī, Qutb al-Dīn Rāzī, Saʿd al-Dīn al-Taftāzānī, Ḥāfiz al-Dīn al-Taftāzānī, al-Sharīf al-Jurjānī and students of the last three named scholars appear. Al-Sakhāwī, *al-Ḍaw'*, vols. II, pp. 196, 197, 310; VI, pp. 184, 187, 190; VII, p. 261; VIII, pp. 127, 224 et al.
[10] Al-Sakhāwī, *al-Ḍaw'*, vols. I, pp. 310-1, 376-7; II, pp. 6-7; VI, p. 82; X, p. 226.

around 1358 and has worked for Sultan al-Nāṣir Aḥmad.[11] Sultan al-Nāṣir Muḥammad b. Qalā'ūn consulted astrologers and geomancers in addition to doctors when he fell ill.[12] Ibrāhīm b. Muḥammad al-Qurashī from Ghazza, known as Ibn Zuqqāʿa (1344-1407), a teacher of Ibn Ḥajar, did also some study of astrology, *ʿilm al-ḥarf* and the usefulness of plants and herbs which he searched for traveling across the country side. He became a Sufi with considerable powers whose fame spread widely. He was invited repeatedly to the festival of Mawlud. Several Mamluk sultans favoured him, among them Sultan al-Nāṣir Faraj who made him move to Cairo where he lived close to the Nile. "He became very close to al-Nāṣir until (the Sultan) did not leave for travels unless (Ibn Zuqqā'a) cast the horoscope for him and he did not (miss) the time (Ibn Zuqqā'a) specified for him."[13] Sultan al-Mu'ayyad, however, proved hostile against him due to his close connection with the previous sultan and dismissed him. Although al-Sakhāwī's formulation is somewhat ambiguous it could be that a part of al-Mu'ayyad's hostility against the Sufi was caused by his astrological counseling of Sultan al-Nāṣir Faraj.[14] Quoting from Ibn Ḥajar, al-Sakhāwī added that the sultan tried him for 'reprehensible' behaviour with many witnesses from among the eunuchs and others, but at the end decided to drop the case.[15] Some of the Mamluks had an undeniable interest in *ʿilm al-mīqāt* and other disciplines and entertained relationships with scholars of these fields. Sultan Ḥasan donated a professorship and six studentships for the study of timekeeping at his *madrasa*.[16] The Mamluk Qujmas hired ʿAlī b. ʿUmar al-Maqsī "who was passionately fond of *al-mīqāt*" as his client for his expertise in *ʿilm al-mīqāt*.[17] Ibn al-Majdī had the trust of Sultan al-Ashraf Barsbay who called on him for help in an affair that worried him and made him anxious and helpless. Ibn al-Majdī offered to pray for him and brought back as a good omen an inscription written at the side of the *miḥrāb* from the *madrasa* closest to the fortress. The sultan appointed Ibn al-Majdī as the head of the *Madrasa al-Jānībākiyya al-Dawādāriyya*. As a *mudarris*, Ibn al-Majdī turned the *madrasa* into a Sufi convent be-cause of the testament of its donor. As a

[11] King, *The Astronomy of the Mamluks*, pp. 535, 550.
[12] King, *The Astronomy of the Mamluks*, p. 535.
[13] Al-Sakhāwī, vol. I, p. 130.
[14] Al-Sakhāwī, vol. I, p. 130.
[15] Al-Sakhāwī, vol. I, p. 132.
[16] Jonathan Berkey, *The Transmission of Knowledge in Medieval Cairo. A Social History of Islamic Education*. Princeton: Princeton University Press, 1992, p. 69.
[17] Al-Sakhāwī, *al-Ḍaw'*, vol. V, p. 265.

widespread habit since the thirteenth century, Ibn al-Majdī made sure that his son in law inherited his position as the head of the convent.[18]

Al-Sakhāwī's other entries confirm by and large the picture set in Ibn al-Majdī's biography.

Muwaqqits were first and foremost teachers of *farā'iḍ* and *ḥisab*. The third place of their teaching activities is taken by algebra. Only then follows *ʿilm al-mīqāt*. The *muwaqqit-mudarris* all were teaching also other fields than mathematics and astronomy, in particular Arabic, grammar, *fiqh* and *ḥikma*. This contradicts in some sense the available evidence of treatises, which these teachers and *muwaqqits* left behind, because those treatises consist to a substantial degree of writings on *ʿilm al-mīqāt*. But al-Sakhāwī's record is fairly consistent throughout the volumes of his dictionaries for all of those he graced with the nisba *muwaqqit* or *mīqātī*. A possible interpretation of this contradiction is to assume that in fifteenth-century Cairo and other Mamluk cities teaching focused more on reading and debating than on writing texts.

Only rarely did al-Sakhāwī consider it worthwhile to mention the engagement of those he labeled *muwaqqit* or *mīqātī* with practical affairs such as setting the time in a mosque or a *madrasa* or constructing instruments or scales. Examples can be found in the biographies of Nūr al-Dīn b. al-Naqqāsh, ʿAbd al-Khāliq al-Ṣāliḥī and Ḥasan b. ʿAlī al-Takhawī al-Qāhirī.[19] While not everybody reported by al-Sakhāwī to have studied *mīqāt* became later a *muwaqqit* or *mīqātī*, he did not give this *nisba* even to some of those whom he mentioned as having set the time in a mosque or erected sundials[20]

Hence, in al-Sakhāwī's presentation, the *muwaqqit* does not appear to having been the result of a professional educational focus on *ʿilm al-mīqāt* and related disciplines. Rather, he describes the *muwaqqit* as only one facet of another persona, mostly that of a *mudarris*, but also that of an *imām*, a *khāṭib*, a *wāʿiẓ*, a *muḥtasib* or a *physician*.[21] The reason for this more complex persona, i.e. for the combination of several posts and professional obligations, is in all likelihood to be found in economic and social factors. As David has shown on the basis of *waqfiyyas*, the post of a *muwaqqit* was not well remunerated, although slightly better paid than that of a *mu'adhdhin*.[22] A *mudarris* in contrast often could reap a fair

[18] David A. King, *A Survey of the Scientific Manuscripts in the Egyptian National Library*. Winona Lake, Indiana 1986, C62.
[19] Al-Sakhāwī, *al-Ḍaw'*, vols. II, p. 25; III, p. 115; IV, p. 41.
[20] Al-Sakhāwī, *al-Ḍaw'*, vols. IV, p. 41; V, p. 108; VI, p. 285; VIII, pp. 75-6.
[21] Al-Sakhāwī, *al-Ḍaw'*, vols. II, p. 142; III, p. 150; IV, p. 192; V, p. 108; VI, p. 285; VII, p. 44; VIII, pp. 238-9; IX, p. 179; X, p. 95.
[22] King, *On the role of the muezzin*, pp. 301-3.

salary. This alone should have stimulated a healthy interest among those who worked as *muwaqqits* and taught *ʿilm al-mīqāt* to get an appointment as a *mudarris*. But even the salary of one professorship often did not satisfy the *ʿulamā'* in Cairo, Damascus and other cities of Egypt, Syria and Palestine. Simultaneous holding of several professorships was widespread. It brought higher prestige and more income. It also allowed for establishing a personal network of younger scholars (students, friends, family members) who deputized for the holder of the chairs in the smaller and less well paid *madrasas* for less than the stipulated salary. This network of patron-client relationships included marrying off one's daughter(s) or niece(s) to the most promising young scholars and choosing the successors for the held chairs, preferably the professor's son(s) or other younger male relative(s).[23] *Muwaqqits* were no exception of this widespread behavior. Ibn al-Majdī made his son in law successor of his post as head of the *Jānībākiyya Dawādāriyya*, ʿAlī b. ʿAbd al-Qādir al-Naqqāsh al-Mīqātī was "the leader (of the *muwaqqits*?) at *al-Maqsī Friday Mosque*, *al-Jamaliyya al-Ṣāḥibiyya madrasa* and others than the two, for instance the *Ashrafiyya tomb* of Sultan Inal, and taught the art (of *mīqāt*?) at several places" and Muḥammad b. Aḥmad al-Makhzūmī al-Qāhirī, known as Ibn al-Khashshāb, determined the prayer times at the *Ashrafiyya Barsbay madrasa*, the Friday mosque of *al-Ṣāliḥ* and at the *Manṣūriyya madrasa*.[24]

David raised two more issues, one referring to Taj al-Dīn al-Ṣubkī's (d. 771/1369) claim that the *muwaqqits* were engaged in astrology and occult sciences, not in science, and hence contributed to lower the religious moral of the Muslim population of Damascus.[25] The other issue relates to those who produced the yearly ephemerides.[26] In al-Sakhāwī's dictionary only two of the scholars named *muwaqqit* are explicitly mentioned for having studied astrology and possessed great knowledge in astrological procedures and judgments, although we know from David's survey of the scientific manuscripts of the Dār al-Kutub in Cairo that at least Ibn al-Majdī also wrote about astrological topics. Moreover, astronomical handbooks (*Zīj*) as a rule always included some astrological tables. Hence, the scholars who wrote ephemerides and studied Zījes encountered astrology at least as a reading matter. Ibrāhīm b. Aḥmad al-Shīrāzī, the *muwaqqit*, was in Alexandria where the *ḥadīth* transmitter al-Jamal b. Musa met him and subsequently described him to al-Sakhāwī as an excellent master and

[23] Berkey, *The Transmission*, pp. 105-27.
[24] Al-Sakhāwī, *al-Ḍaw'*, vol. V, p. 242.
[25] King, *On the role of the muezzin*, p. 307.
[26] King, *On the role of the muezzin*, p. 317.

muwaqqit who had written works on *ʿilm al-mīqāt* and was gifted in those branches that were connected with it from astrology and other (things). He gave *ijāzāt* to many people.[27] Aḥmad b. Ghulām Allāh al-Kawm al-Rishī al-Qāhirī al-Mīqātī (d. 832/1433) knew how to work with a *Zīj* and wrote ephemerides.[28] He was *muwaqqit* at the *madrasa* donated by Sultan al-Mu'ayyad Shaykh (d. 824/1421).[29] The compilation of ephemerides, which included astrological predictions, was not limited to *muwaqqits* alone, although other entries indicate that it was apparently one of the skills acquired and taught by *muwaqqits*. Ibrāhīm b. ʿAlī al-Shambārī al-Makkī, known as al-Zamzāmī, studied "with his brother al-Badr Ḥusayn *ʿilm al-farā'iḍ*, arithmetic, algebra, *hay'a*, *handasa*, *ʿilm al-mīqāt*, the derivation of an ephemeris from the (solar, lunar and planetary tables of a) *Zīj* and the (different) eras."[30] The *falakī* (astronomer) Aḥmad b. Ibrāhīm al-Sarmīnī al-Ḥalabī "was an excellent master of *ʿilm al-hay'a*, the work with the *Zīj* and the construction of the ephemeris. He was superior in it, unique in Aleppo in his time from where they used to take his ephemerides to the seat of the deputy (of the sultan) who asked for them."[31] This favor brought him only pain since the rest of the Mamluks ruling in Syrian cities bore down on him accusing him of "thinness of religion, disintegration of his creed, the avoidance of prayer and the drinking of wine."[32] As a result he had to leave Aleppo fearing some of the emirs and move to Safad where he died in the age of 80.[33] The *muwaqqit* Ibn Razin who had studied timekeeping with al-Nūr b. al-Naqqāsh in Cairo also "excelled in compiling the ephemeris in its perfection, being unique in his precision of the times and the desired exactitude. Hence many benefited from him."[34] The Alexandrian *ḥāsib* (calculator/astronomer) ʿAlī b. Aḥmad "spent efforts for (learning) *ʿilm al-mīqāt* and was excellent in the knowledge of how to work with a *Zīj* and in the writing of the ephemeris."[35] Then he turned to alchemy or chemistry, something al-Sakhāwī clearly disapproved of saying that he spent his life with works on "what is between evaporation and distillation etc. But he did not achieve a thing in this (respect)."[36] In one case only,

[27] Al-Sakhāwī, vol. I, pp. 5-6.
[28] Al-Sakhāwī, *al-Ḍaw'*, vol. II, p. 62.
[29] G. P. Matvievskaya, B. A. Rozenfel'd, *Matematiki i astronomy musul'manskogo srednevekov'ja i ich trudy (XIII-XVII vv)*. Moskva: Nauka, vol. 2, p. 479; King, Survey, C41.
[30] Al-Sakhāwī, *al-Ḍaw'*, vol. I, p. 86.
[31] Al-Sakhāwī, *al-Ḍaw'*, vol. I, p. 204.
[32] Al-Sakhāwī, *al-Ḍaw'*, vol. I, pp. 204-5.
[33] Al-Sakhāwī, *al-Ḍaw'*, vol. I, p. 205.
[34] Al-Sakhāwī, *al-Ḍaw'*, vol. IV, p. 189.
[35] Al-Sakhāwī, *al-Ḍaw'*, vol. V, p. 169.
[36] Al-Sakhāwī, *al-Ḍaw'*, vol. V, p. 169.

namely that of Khalīl b. Ibrāhīm Abū l-Jud al-Dimyāṭī al-Qāhirī, al-Sakhāwī provided a few more details when talking about the study of *ʿilm al-mīqāt* and the making of ephemerides saying that it included the study of tables, among them the tables (and diagrams) describing the new moon for each month.[37]

As rarely as a *muwaqqit* dealt according to al-Sakhāwī with astrology did practicing Sufis engage with *ʿilm al-mīqāt*. But ʿUmar b. ʿIsā al-Samnūdī al-Shafīʿī was knowledgeable in *farā'iḍ* and *mīqāt* and is remembered for his *karāmāt* (wonders).[38]

2. Studying *ʿilm al-mīqāt*

Al-Sakhāwī confirms what David has argued on the basis of manuscripts and instruments – later generations of *muwaqqits* acquired their expertise from earlier generations of *muwaqqits*, i.e. as a rule they did not study *ʿilm al-mīqāt* with teachers who were not themselves *muwaqqits*. Only a few cases occur where the teacher of *ʿilm al-mīqāt* is not called by al-Sakhāwī somewhere in his dictionary *muwaqqit*. In such cases, al-Sakhāwī explicitly mentioned the previous study of *ʿilm al-mīqāt* by the teacher.[39] It is in this sense that one can undoubtedly speak of a profession. The evolution of an analogous kind of professional kinship can be observed in al-Sakhāwī's dictionary for teachers of *fiqh*, *uṣūl al-Dīn*, *ḥadīth* and perhaps Arabic, although it is less prominent in the last case. The student body of *ʿilm al-mīqāt* was not limited though to these later *muwaqqits*. A good number of students who took such classes did not become *muwaqqits*, i.e. they were either not mentioned by al-Sakhāwī as such or do not seem to have written any treatise in the field. They studied treatises on timekeeping as part of their overall education.

> "Zakariyā b. Muḥammad al-Anṣārī al-Sanbakī al-Qāhirī al-Azharī al-Shafīʿī al-Qāḍī was born in 826 h in Sanbaka. He grew up in his hometown and received his education there. When he was 15 years old, he went to Cairo for further education. He lived for a while at al-Azhar, went home, and then came back for more education ... He studied *fiqh* with al-Qayatī and al-ʿIlm al-Bulqinī ... He took *ʿilm al-hay'a, handasa, mīqāt, farā'iḍ, ḥisab*, algebra and other things from Ibn al-Majdī. He read with him parts of his works. He also took *farā'iḍ* and *ḥisab* from al-Shams al-Ḥijāzī and al-Butijī and also on Abū l-Jud al-Yanabī. He read with him *al-Majmūʿ* and *al-Fuṣūl*. He took *ḥikma* with al-Shirwānī and Jaʿfar, mentioned previously, and medicine with al-Sharaf b. al-

[37] Al-Sakhāwī, *al-Ḍaw'*, vol. III, p. 187.
[38] Al-Sakhāwī, *al-Ḍaw'*, vol. VI, p. 112.
[39] See, for example, Al-Sakhāwī, *al-Ḍaw'*, vol. VIII, pp. 75-6.

> Khashshāb and *al-ʿurūḍ* with al-Warūrī and *ʿilm al-ḥarf* with Ibn Qurqmas al-Ḥanafī and *taṣawwuf* with Abū ʻAbdallāh al-Ghumārī et al ... And he also heard things from al-ʿIzz b. al-Furat and from Sarah b. Jamaʿa on *al-Muʿjam al-kabīr* by al-Tibranī in my reading ..."[40]
>
> "Muḥammad b. ʿAwad … al-Sikandarī …, known as Junaybat. He was born in Alexandria in 788 h. He read there the Qur'ān … he also studied with al-Muʿizz *ʿilm al-mīqāt* and the beginnings of Uqlidis …"[41]
>
> "Muḥammad b. Muḥammad al-Shams al-Ḥalabī al-Ḥanafī, ..., known as Ibn Amīr Ḥajj and Ibn al-Muwaqqit. ... He was seriously interested in *mīqāt* and led this at the Great Friday mosque of Aleppo. He lived as a student at the *Halwiyya*. Then he transferred to teach after his father at the *Jaradakiyya* and settled there. Then he led the office of the registrar with the judges in Aleppo. Then he became the tax collector of the markets."[42]

While the students of *ʿilm al-mīqāt* in the first two examples given above studied with one teacher only, several students took such classes with two, three or even more teachers. Judging by the names of the teachers given by al-Sakhāwī, there was evidently a desire to have had classes with a good number of the most prominent *muwaqqits* and *mīqāt* teachers of a given town and time. The content of the classes may not have mattered as much, since in some cases the same texts were read.[43]

Prominent scholars such as al-Sakhāwī himself, his teacher Ibn Ḥajar al-ʿĀsqalānī and his eminent colleague in the field of history Taqī al-Dīn al-Maqrizī also took classes in *ʿilm al-mīqāt*. [44] The latter studied it under Ibn Khaldūn together with instructions on the astrolabe and the occult sciences *raml* and *za'iraja*.[45] Sons of Mamluks apparently were not much drawn to *ʿilm al-mīqāt*. The only two examples given by al-Sakhāwī are ʿAlī b. Sudun al-ʿAlā' al-Yushbughāwī (c. 810-86/) and Qāsim b. Qutlubughā (802-879/1399-1474).[46] Two sons of Mamluks only are known who actually worked as a *muwaqqit* – ʿAlā' al-Dīn ʿAlī b. Ṭaybughā al-Dawādār al-Baklamishī at the end of the fourteenth and beginning of the fifteenth centuries and Ibrāhīm b. Qayt Bay in the early sixteenth century discovered by David.[47] A famous *muwaqqit*, i.e. Ibn al-

[40] Al-Sakhāwī, *al-Ḍaw'*, vol. III, p. 235.
[41] Al-Sakhāwī, *al-Ḍaw'*, vol. IX, pp. 272-3.
[42] Al-Sakhāwī, *al-Ḍaw'*, vol. IX, pp. 72-3.
[43] Al-Sakhāwī, *al-Ḍaw'*, vols. II, pp. 66, 172; III, p. 103; V, pp. 8, 108; VI, pp. 162, 285; VII, pp. 75, 82; IX, p. 254.
[44] Al-Sakhāwī, *al-Ḍaw'*, vols. II, p. 24; V, p. 19; VIII, p. 4;
[45] Al-Sakhāwī, *al-Ḍaw'*, vol. II, pp. 21-25, in particular p. 24.
[46] Al-Sakhāwī, *al-Ḍaw'*, vol. VI, pp. 184-90.
[47] King, *On the role of the muezzin*, p. 308; King, Survey, C54; David A. King, "Universal Solutions to problems of Spherical Astronomy from Mamluk Egypt and Syria". In F Kazemi, R.D. McChesney (eds.), *A Way Prepared: Essays on Islamic Culture in Honor of Richard Bayly Winder*. New York: New York University Press, 1988, pp. 153-84, in particular p. 163; reprinted in David A. King,

Majdī, was a grandson of a Mamluk. Other sons of Mamluks such as Yusuf b. Qurqmas al-Ḥamzāwī whose scientific treatises are extant or who are named by al-Sakhāwī as authors of such works focused exclusively on other astronomical disciplines such as *ʿilm al-falak* and *ʿilm al-hay'a* or on astrology and occult topics such as number magic.[48] Ibn Qurqmas' astrological history of events, which happened during the campaign in the region of Adana from 875 to 877, has been identified by David.[49] Mam-luks themselves as men of the military are not very likely candidates for studying, teaching or writing treatises on astronomical topics, whether *ʿilm al-mīqāt* or any of the other disciplines. But there was at least one Mamluk who did so. ʿAlā' al-Dīn Ṭaybughā al-Dawādār al-Baklamishī in the fourteenth century wrote on astronomical instruments and compiled a table for the direction of prayer for each degree of latitude and longitude.[50]

3. *Mu'adhdhins*

Based on sources from different regions and periods, David concluded that *mu'adhdhins* mostly used simple shadow-schemes for time-reckoning and thus had little knowledge of mathematical astronomy.[51] Several *mu'adhdhins*, however, were in the same time *muwaqqits*. It can even be speculated that the profession of a *muwaqqit* evolved from that of a *mu'adhdhin*. Several authors of astronomical works, timekeeping and other tables and makers of astronomical instruments of the fourteenth century held positions in both fields. Muḥammad b. Aḥmad al-Mizzī (690-750/1291-1349) studied in Cairo and worked in Damascus. He was a *mu'adhdhin*, but also appointed as *muwaqqit* in a small town near Damascus and later at the Umayyad Mosque in Damascus. He constructed astrolabes and quadrants, at least one of which is extant today in St Petersburg. He also wrote several, today extant treatises on such instruments.[52] The famous fourteenth-century *muwaqqits* Ibn al-Shātir and

Astronomy in the Service of Islam. Aldershot: Variorum, Ashgate, item VII and King, Synchrony, pp. 711-739.

[48] King, Survey, C91; Al-Sakhāwī, *al-Ḍaw'*, vols. III, pp. 115, 235; V, p. 217.

[49] King, Survey, C91; David A. King, "Mathematical geography in 15th-century Egypt – An episode in the decline of Islamic science". To appear in the Festschrift for Hans Daiber, edited by Anna Akasoy and Wim Raven, Leiden: E.J. Brill.

[50] Matvievskaya, Rozenfel'd, *Matematiki i astronomy*, vol. 2, p. 465; Charette, *Mathematical Instrumentation*, pp. 18-9; King, Survey, C53; King, Universal Solutions, pp. 169-70.

[51] King, *On the role of the muezzin*, pp. 291-8.

[52] Matvievskaya, Rozenfel'd, *Matematiki i astronomy*, vol. 2, pp. 453-4; King, Survey, C34; François Charette, *Mathematical Instrumentation in Fourteenth-Century Egypt and Syria. The Illustrated Treatise of Najm al-Dīn al-Miṣrī*. Leiden, Boston: Brill, 2003, p. 13.

Shams al-Dīn al-Khalīlī also were *mu'adhdhins*.[53] Entries in al-Sakhāwī's dictionary confirm too that in the fourteenth century some *muwaqqits* in Egypt and Syria worked as *mu'adhdhins* and some *mu'adhdhins* studied *mīqāt* texts. A certain Muḥammad b. ʿAlī al-Sikandarī al-Shafīʿī, who lived in Alexan-dria (731-807/1330-1404) is called by al-Sakhāwī *al-mu'adhdhin al-muwaqqit*.[54] Mūsā b. Muḥammad al-Sharaf al-Muwaqqit (d. 807/1404), a nephew of Shams al-Dīn al-Khalīlī, is described as "the most excellent of those who are left in al-Sham in *ʿilm al-hay'a*. ... In his hands was the leadership of the *mu'adhdhins* at the *Tunkuz* Friday Mosque and others."[55]

Students who later acted as *mu'adhdhins* for the Mamluks in Cairo also had taken classes in *ʿilm al-mīqāt*. ʿAbd al-Ḥayy b. Mubarakshāh al-Khwārazmī al-Qāhirī al-Ḥanafī, for instance, "was the head of the *mu'adhdhins* at the Friday mosque of the fortress and others. ... He benefited in *al-mīqāt* and other (fields) from al-ʿIzz ʿAbd al-ʿAzīz al-Wafā'ī and others."[56] ʿAbd al-Razzāq b. Aḥmad al-Qāhirī al-Ḥanafī was "one of the Sufis of the *Shaykhuniyya*. ... He read *al-mīqāt* with Ḥasan al-Qaymarī and al-ʿIzz al-Wafā'ī. ... The sultan made him one of his *mu'adhdhins* after Ibn Khālid and he was inclined towards him until he acted occasion-nally for him as *imām*."[57] Aḥmad b. Muḥammad al-Dahhān was "the head of the *mu'adhdhins* at the Umayyad mosque. He had a wailing voice, was knowledgeable in *mīqāt* and lived until he became the senior of the *mu'adhdhins* of the age."[58] The last part of this quote indicates that beco-ming the leader of any of the groups of scholarly offices was not primarily the result of merit, but of age.

The flow of expert knowledge in astronomical methods for timekeeping apparently did not always and perhaps not necessarily take place from one professional, the *muwaqqit*, to an other professional, the *mu'adhdhin*, although this is what the *waqfiyya* of the *Sultan Barqūq madrasa*, a Sufi convent, stipulated.[59] In one case, al-Sakhāwī tells us that Ibn Khashshāb, one of Jamal al-Dīn al-Māridānī's students of *ʿilm al-mīqāt*, came usually on Fridays to see Ibn Ḥajar al-ʿĀsqalānī for telling him the time to ride out for the *khuṭba*, the Friday sermon.[60] Much more often the flow of

[53] Matvievskaya, Rozenfel'd, *Matematiki i astronomy*, vol. 2, p. 465; King, Survey, C30 and C37; Benno van Dalen, *Preliminary New Zīj Survey*. Unpublished, D11.
[54] Al-Sakhāwī, *al-Ḍaw'*, vol. VIII, p. 196.
[55] Al-Sakhāwī, *al-Ḍaw'*, vol. X, p. 189.
[56] Al-Sakhāwī, *al-Ḍaw'*, vol. IV, p. 40.
[57] Al-Sakhāwī, *al-Ḍaw'*, vol. IV, p. 192.
[58] Al-Sakhāwī, *al-Ḍaw'*, vol. II, p. 219.
[59] King, *On the role of the muezzin*, p. 301.
[60] Al-Sakhāwī, *al-Ḍaw'*, vol. VI, p. 285.

knowledge on timekeeping occurred in al-Sakhāwī's book in the phase of educating people who later would work in the one or the other capacity. It is, however, impossible to find out how many *mu'adhdhins* went through such training in the Mamluk period, because biographical dictionaries are notoriously unsystematic. Their authors did not mean to create a census of education and professional qualifications, but pursued other, often more literary as well as personal goals. It is well known that many of the students of the *madrasa* system later took on a variety of different positions and worked in different fields of occupation.[61] This observation should warn us to assume too stable boundaries between the various *mansabs* and their responsibilities, including those of a *muwaqqit* and a *mu'adhdhin*. The occasional lack of care in the *waqf* documents David presented in regard to setting *mu'adhdhins* apart from *muwaqqits* supports such a reluctance to draw borderlines too rigidly.[62] Accumulating offices was a further important social trend since at latest the thirteenth century that contributed to increasing the permeability between the various fields of knowledge and their offices.[63] Education itself was not fixed on one or two major disciplines, but tended to be broad and inclusive.

4. *ʿIlm al-mīqāt* in Mecca

When discussing the territories of the Islamic world that either saw or did not see the rise of the *muwaqqit* (or people with similar duties, but other names), the only region of the Arabian Peninsula David discussed is the Yemen.[64] Al-Sakhāwī's dictionary allows extending the geographical scope of the *muwaqqit*. It records that *ʿilm al-mīqāt* was taught in Mecca and Medina at the latest in the late eighth/fourteenth century. The information provided by al-Sakhāwī leaves no doubt that the arrival of knowledge in this discipline and century was due to educational travels by inhabitants of the two Arabian towns to the Mamluk capital Cairo. The important role that Cairo played in this extension of *ʿilm al-mīqāt* towards the Ḥijāz is also pointed out by timekeeping tables for Mecca discovered by David. The extant copies of these tables are all of Egyptian origin.[65] One Meccan family was particularly influential in teaching this discipline in their hometown in the fourteenth and early fifteenth centuries – the Zamzāmīs, so called because of deputizing the Abbasid caliphs in the

[61] Carl Petry, *The Civilian Elite of Cairo in the Later Middle Ages*, Princeton: Princeton University Press, 1981, chapter IV, pp.202-272.
[62] King, *On the role of the muezzin*, p. 302.
[63] Berkey, *The Transmission*, pp. 112-9.
[64] King, *On the role of the muezzin*, pp. 288, 291, 300.
[65] King, *Synchrony*, pp. 311-13.

distribution of water from the Zamzām well to the pilgrims. Al-Sakhāwī mentions *ʿilm al-mīqāt* in relation to several members of this family, among them Burhān al-Dīn Ibrāhīm b. ʿAlī, Nūr al-Dīn ʿAlī b. Muḥammad, Badr al-Dīn Ḥusayn b. ʿAlī, Muḥammad b. ʿAbd al-ʿAzīz al-Jamal and Nabit b. Ismāʿīl. Knowledge of the field and other astronomical as well as mathematical disciplines was passed on in the family. Brothers studied with each other, sons with their fathers and nephews with their uncles or uncles of their fathers.[66] Burhān al-Dīn Ibrāhīm b. ʿAlī al-Shambarī al-Zamzāmī I mentioned previously. Nūr al-Dīn ʿAlī b. Muḥammad al-Baydawī al-Makkī al-Zamzāmī al-Shafīʿī "read with the uncle of his father, our shaykh al-Burhān al-Zamzāmī. He was (also) educated by his uncle Abū l-Fatḥ. He excelled in *mīqāt*, *farā'iḍ* and other (fields). And he had knowledge in *fiqh* and its *uṣūl* and Arabic. He became the one in which (people) trusted in regard to *mīqāt* and *rūḥānī* and other (things)... And there was nobody after him in his arts like him."[67] Muḥammad b. ʿAbd al-ʿAzīz studied *falak* with Nūr al-Dīn and *mīqāt*, *handasa*, arithmetic and *farā'iḍ* in Cairo.[68] Ḥusayn b. ʿAlī al-Baydawī al-Makkī al-Shafīʿī al-Farādī al-Ḥāsib studied a good number of mathematical and astronomical disciplines and topics. While al-Sakhāwī does not mention *ʿilm al-mīqāt* in this list, al-Maqrizī, as quoted by him, wrote that Ḥusayn was a capacity in this discipline as well as in arithmetic.[69] Ḥusayn b. ʿAlī "was seriously interested in *farā'iḍ* and *ḥisab*. He took it from al-Shihāb Ibn Zuhayra and al-Burhān al-Burullusī al-Farādī. ... He took *ʿilm al-falak* in Cairo from al-Jamal al-Māridānī and did not stop to add and pay attention until he became the imam, the knowledgeable, the excellent, the perfect whom the people knew in *farā'iḍ*, *hay'a*, arithmetic, *ʿilm al-khaṭa'ayn*, algebra, *handasa*, *falak* and calendars. The leadership in this knowledge came to him finally in the region of the Hijaz, Mecca, Medina and the Yemen."[70] In the biography of his brother Ibrāhīm mentioned previously, al-Sakhāwī listed *ʿilm al-mīqāt* as one of the disciplines Ḥusayn taught.[71] This neglect of *ʿilm al-mīqāt* in Ḥusayn's own biography reinforces my earlier statement that the information given in such entries is neither complete nor was it meant to be so. Hence, when it is said that Nabīt b. Ismāʿīl al-Zamzāmī studied with his uncle al-Burhān Ibrāhīm b. ʿAlī, al-Sakhāwī's shaykh, *farā'iḍ*, arithmetic and other (things), it is by no means excluded that he also took

[66] Al-Sakhāwī, *al-Ḍaw'*, vols., I, p. 86; VIII, p. 61, 278;
[67] Al-Sakhāwī, *al-Ḍaw'*, vol. V, p.291.
[68] Al-Sakhāwī, *al-Ḍaw'*, vol. VIII, p. 61.
[69] Al-Sakhāwī, *al-Ḍaw'*, vol. III, p. 152.
[70] Al-Sakhāwī, *al-Ḍaw'*, vol. III, p. 151.
[71] Al-Sakhāwī, *al-Ḍaw'*, vol. I, p. 86.

ʿilm al-mīqāt, since his uncle also gave classes in this discipline.[72] Nabit is the only Zamzāmī whom al-Sakhāwī credits with interest in astrology and an excellent hand in creating horoscopes.[73] Muḥammad b. Abī l-Fatḥ b. Ismāʿīl, a further member of the Zamzāmī family, studied with the uncle of his father Burhān al-Dīn and his cousin Nūr al-Dīn *ʿilm al-falak*. He was an avid religious traveler and led the prayer call in Mecca.[74] Another cousin of his, Ismāʿīl b. Nabit al-Zamzāmī, also led the *mu'adhdhins* and was the head of those who provided the pilgrims with water.[75] Unsurprisingly, the Zamzāmīs did not restrain their teaching of *ʿilm al-mīqāt* and other astronomical disciplines to family members only. Other Meccans and visitors of the city studied them with Burhān al-Dīn Ibrāhīm b. ʿAlī b. Muḥammad, Badr al-Dīn Ḥusayn b. ʿAlī b. Muḥammad and their great-nephew Nūr al-Dīn ʿAlī b. Muḥammad, among them possibly Ibn Ḥajar al-ʿĀsqalānī and al-Sakhāwī himself.[76]

5. *ʿIlm al-mīqāt* and other astronomical disciplines

In addition to the questions raised by David, al-Sakhāwī's entries contain information that supplement the knowledge that he has established about the *muwaqqits*. A surprisingly substantial number of *muwaqqits* and teachers of *mīqāt* also taught *ʿilm al-hay'a*, but did not write about it. Examples are Jamal al-Dīn al-Māridānī, Ibn al-Majdī, Ḥusayn al-Zamzāmī, Nūr al-Dīn al-Zamzamī, Nāṣir al-Dīn al-Barinbarī, al-Shihāb al-Sijinī, a former stdent of Ibn al-Majdī, and others.[77] Unfortunately al-Sakhāwī does not mention which texts exactly were taught. Jamal al-Dīn al-Māridānī, Ibn al-Majdī, al-Shihāb al-Khawāṣṣ, Ḥusayn al-Zamzāmī, Nūr al-Dīn al-Zamzāmī and al-Shams Muḥammad b. Ayyūb, the head of the ʿUmarī mosque, also taught *ʿilm al-falak*.[78] A few teachers of logic, *tafsīr*, *uṣūl al-Dīn* taught *hay'a* and *handasa*, but not *mīqāt* or *ʿilm al-falak*. This might have been a result of the discussion of *ʿilm al-hay'a* topics by *uṣūl al-Dīn* authors in Iran such as ʿAdud Ijī (d. 757/1355) whose *Mawāqif* was actively studied in fifteenth-century Cairo or al-Sayyid al-Sharif Jurjānī (741-816/1340-1413) who visited Cairo and

[72] Al-Sakhāwī, *al-Ḍaw'*, vol. X, pp. 194-5.
[73] Al-Sakhāwī, *al-Ḍaw'*, vol. X, p. 195.
[74] Al-Sakhāwī, *al-Ḍaw'*, vol. VIII, p. 278.
[75] Al-Sakhāwī, *al-Ḍaw'*, vol. II, p. 308.
[76] Al-Sakhāwī, *al-Ḍaw'*, vols. II, p. 134; III, pp. 120, 152; X, p. 239.
[77] Al-Sakhāwī, *al-Ḍaw'*, vols. I, pp. 300, 310, 317; II, p. 174; III, pp. 115, 235; King, Survey, C 47 (Jamal al-Dīn al-Māridānī).
[78] Al-Sakhāwī, *al-Ḍaw'*, vols. I, pp. 317-8; II, pp. 134, 142; III, p. 151; VIII, p. 278.

studied there for some time.[79] The prominent Anatolian scholar and al-Sakhāwī's teacher Muḥammad b. Sulaymān al-Kāfiyajī (before 790-c. 879/1388-1474), for instance, taught in Cairo several religious and philological disciplines, logic, *ḥikma*, medicine, *ʿilm al-hay'a* and several mathematical disciple-nes, namely *handasa*, spherics, optics and burning mirrors.[80] Al-Kāfiyajī studied, commented on and possibly taught at least five *hay'a* texts: Athīr al-Dīn al-Abharī's (d. 663 / 1263) *Mukhtaṣar fī ʿilm al-hay'a*, Jalāl al-Dīn Faḍl Allāh al-Abidī's *Mukhtaṣar fī maʿrifat maqādir al-abʿad wa-'ajram*, Maḥmūd Jaghmīnī's (fl. around 620 / 1223) *al-Mulakhkhaṣ fī l-hay'a*, a *Risāla fī maʿrifat ḥisab taʿdīl al-kawākib al-khamsa* ascribed to Ibn al-Shātir and an anonymous *Risāla fī ʿilm al-hay'a*[81]. He also studied at least one astrological text, Abū l-Ṣaqr al-Qabīsī's (d. c. 380/990) *al-Masā'il wa-ikhtiyārāt*, which may be the treatise called *Masā'il al-munajjimīn* in Qabīsī's *Risāla fī imtiḥān al-munajjimīn*[82]. In Mecca, a certain Salām Allāh al-Iṣbahānī taught al-Sayyid al-Sharīf Jurjānī's commentaries on Nāṣir al-Dīn Ṭūsī's *Tadhkira fī ʿilm al-hay'a* and Jaghmīnī's *al-Mulakh-khaṣ* as well as Niẓām al-Dīn al-Nisābūrī's *Shamsiyya fī l-ḥisab*.[83] Some sons of the Mamluks taught *hay'a*, *falak*, *nujūm* and *ḥurūf*.[84]

As indicated knowledge of *hay'a* texts came into Mecca through scholars from Iran being on pilgrimage and occasionally went further to Cairo or Jerusalem and other Northern cities, but *mīqāt* apparently was not taken further east than Mecca or Medina. This however may reflect more al-Sakhāwī's territorial focus than the question as to whether scholars interested in *mīqāt* not only traveled to Eastern cities, but also taught there their knowledge.

6. Conclusions

The most important conclusion from Sakhāwī's dictionary is that the fifteenth century saw a vivacious teaching of a good number of mathematical and astronomical sciences in Egypt, Syria, Palestine and the

[79] Al-Sakhāwī, *al-Ḍaw'*, vols. V, pp. 48, 328-30; VII, p. 7.
[80] Al-Sakhāwī, *al-Ḍaw'*, vol. VII, p. 261.
[81] Al-Sakhāwī, *al-Ḍaw'*, vol. VII, p. 260. For Jaghmīnī's date see Jamil F. Ragep, "On Dating Jaghmīnī and His *Mulakhkhaṣ fī l-Hay'a*". in *Essays in honour of Ekmeleddin İhsanoğlu*, Mustafa Kaçar and Zeynep Durukal (eds.), Istanbul: IRCICA, 2006, pp. 461-66. *Makhṭūṭāt al-falak wa-l-tanjīm fī maktabat al-mathaf al-ʿirāqī*. Usāma N. al-Naqshbandi, Dhamia M. Abbas (eds.), *Astronomical and Astrological manuscripts of the Iraq Museum Library*, Dār al-Ḥurriya li-l-Ṭabāʿa, Baghdad, 1982, pp. 100, 212, 215, 219.
[82] *Makhṭūṭāt al-falak wa-l-tanjīm*, p. 219, Matvievskaya, Rozenfel'd, *Matematiki*, p. 155.
[83] Al-Sakhāwī, *al-Ḍaw'*, vol. V, pp. 12, 78.
[84] Al-Sakhāwī, *al-Ḍaw'*, vol. V, p. 217.

Arabian Peninsula with close relationships between various groups of the elite. David has made the case for flourishing activities in astronomy on the basis of the body of texts, tables and instruments he has discovered, analyzed and interpreted. Al-Sakhāwī confirms that these scientific activities were part and parcel of the educational life in major Mamluk cities. A second important insight is that scholars teaching and writing on these sciences could acquire a solid reputation for their knowledge skills and could become well established among the educated and military elites. This included direct patronage by Mamluk sultans and high-ranking emirs. A third fascinating result is that our categories are too rigid: *muwaqqits* were –in the representation by al-Sakhāwī– not professionals in the sense of focusing exclusively or even primarily on this field of knowledge, but rather –like others– well educated across a broad range of disciplines, including *fiqh* and *ḥikma*. *Mu'adhdhins* went in principle through the same educational cycle as *muwaqqits*. The precise nature of this cycle, i.e. its details, depended on the individuals who taught and studied. Teachers of religious disciplines were the main sources for knowledge about logic and *ḥikma* and occasionally also of theoretical mathematical and astronomical texts. And finally, it is almost impossible to find out what either of these scholars did in scholarly practices other than teaching and occasionally constructing instruments. It is in this sense at least that biographical dictionaries compiled by members of the educated elite define the type of answers we can find to the questions we ask. These authors wrote about themselves and their circles and were not interested in issues that went too far beyond the boundaries set by the category of their work and their social and cultural profile. As repeatedly pointed out their ways of collecting and presenting information differ from our needs in regard to regularity and complete-ness. Taking their information at face value, both in terms of quantity and quality, will mislead us in our quest for understanding the contexts of the sciences and their practitioners in Islamic societies.

APPENDIX

Affiliations of muwaqqits, mīqātīs and teachers of *ʿilm al-mīqāt* according to al-Sakhāwī:

Name	Affiliation	Post	Further information
Aḥmad b. Asad al-Sikandarī al-Qāhirī, known as Ibn Asad (808-872)	-	teacher of children	Studied *mīqāt* with Ibn al-Majdī; transformed Ibn al-Majdī's *Risāla fī l- mīqāt* into *Urjūza Ghunyat al-ṭālib fī l-ʿamal bi-l-kawakib*
	al-Ḥakam Friday Mosque, al-Zayniyya Madrasa	notary and imam	
	Barqūqiyya Madrasa	teacher of *qirā'āt*	
	Fortress	*ḥadīth* classes	
Ibn al-Majdī	al-Jānībākiyya Dawādāriyya Madrasa	head of the teachers	Installed by al-Ashraf Barsbay; wrote book about *ḥadīth*; had beautiful handwriting in his fatwas
Aḥmad b. Ṣadaqa al-Makkī al-Qāhirī, known as Ibn Sīrāfī	Ṭaybarṣiyya Madrasa	Imam; teacher, *ḥadīth* classes, fatwas	Studied with Ibn al-Majdī algebra, arithmetic, *falak*, *muqanṭarāt*, geometry, *hay'a*, *ḥikma,* wrote *Muqaddima fī l-falak*
	Shaykhuniyya convent Barqūqiyya Madrasa	professor of *fiqh* repetitor; *tafsīr*	
Aḥmad b. ʿUbayd Allāh al-Shihāb al-Sijinī al-Qāhirī al-Azharī al-Farādī (810-85)	-	teacher of al-Sharaf al-Jayʿan's children	Was adlatus of Ibn al-Majdī in *ḥadīth*, *uṣūl al-fiqh*, Arabic, *farā'iḍ*, arithmetic, surveying, algebra, geometry, *mīqāt*; and of al-Šihāb al-Khawāṣṣ in *farā'iḍ* and *mīqāt.* Taught *mīqāt*, including its practical aspects, surveying, *farā'iḍ*, arithmetic
	al-Azhar Mosque	head of teachers of part called Riwaq Ibn Miʿmar	
	Turbat al-Ashraf Qaytbay	reader of *ḥadīth*	

Name	Affiliation	Post	Further information
Aḥmad b. ʿUthmān al-Rishī al-Qāhirī, known as al-Kawm Rishī (c. 778-852)	Friday Mosque in Kawm al-Rish; ʿAmru Friday Mosque and others in Cairo	khāṭib	Excellent chess player studied arithmetic with al-Jamal al-Māridānī
	-	taught children of al-Tāj b. al-Ẓarīf and Nāṣir al-Dīn b. al-Tansī in Cairo	
Aḥmad b. Muḥammad al-Dahhān	Umayyad Friday Mosque	head of *mu'adhdhins*	Well-versed in *mīqāt*
Al-Ḥasan b. ʿAbd al-Raḥmān al-Sharimsāhī al-Muwaqqit (c. 810-93)	Ṭuruqiyya Friday Mosque	head (of *muwaqqits*?)	Studied *mīqāt* with ʿAbd al-Raḥīm b. Razin, al-Majdī, al-Badr al-Māridānī
	-	taught children	
	-	notary	
	-	perhaps deputy *khāṭib*	
Ḥasan b. ʿAlī al-Badr al-Qaymarī (d 885, c. 70 years old)	Qanim bi-l-kabsh (?) Friday Mosque	head	Studied with Ibn al-Majdī and Abū l-Jud, including *mīqāt.* Abū l-Jud got him the job in al-Ramla taught *mīqāt*
	Friday mosque of the fortress	head	
	Ḥasaniyya Madrasa	*mu'adhdhin*	
	Jawhar al-Safawī Madrasa, al-Ramla	professor of *farā'iḍ*	
Al-Shams al-Tuntada'ī	Al-Ẓāhir Friday Mosque	*khāṭib*	Taught *mīqāt*
	Al-Baybarsiyya Ḫanqah	lived there	
Khalīl b. Ibrāhīm Abū l-Jud al-Dimyāṭī al-Qāhirī, known as Imām Manṣūr	-	was in retinue of Manṣūr b. Ṣafī + his imam; then in that of Jawhar al-Muʿīnī and others rose to be in entourage of caliph al-Mutawakkil ʿAlā Allāh al-ʿIz al-ʿAbd al-ʿAzīz	Studied *mīqāt* and other disciplines with several teachers; taught *mīqāt* and other disciplines

Name	Affiliation	Post	Further information
ʿAbd al-Ḥayy b. Mubarakshāh al-Khwārizmī al-Qāhirī (813-80)	Friday Mosque of the fortress	head of the *mu’adhdhins*	Studied *mīqāt* with al-ʿIzz ʿAbd al-ʿAzīz al- Wafā’ī and others
ʿAbd al-Khāliq b. Muḥammad al-Ṣāliḥī, known as Ibn al-ʿUqab (853-after 89)	al-Ḥakam Friday Mosque	head	Studied *mīqāt* and other things with al-Badr al-Māridānī; set up sundials and other things
	al-Jānībākiyya madrasa	head	
ʿAbd al-Raḥmān b. Muḥammad, known as al-Rashīdī (741-803)	several places	head of *mīqāt* and *farā’iḍ*	Studied *mīqāt*, arithmetic and *farā’iḍ*
	Amīr Ḥusayn Madrasa	*khāṭib*	
ʿAbd al-Raḥīm b. Muḥammad al-Hamāwī al- Qāhirī al-Muwaqqit (d. 885)	al-Ḥakam Friday Mosque	head deputy of two of his colleagues	Studied *mīqāt* with al-Nūr b. al-Naqqāsh
ʿAbd al-Razzāq b. Aḥmad al- Qāhirī	al-Shaykhuniyya	Ṣūfī	Studied *mīqāt* with Ḥasan al-Qaymarī and al-ʿIzz al-Wafā’ī
	-	sultan installed him as *mu’adhdhin*	
Al-Jamal al-Māridānī al-Qāhirī al-Ḥāsib (d. 809)	al-Khasikī	*shaykh*	Was leading scholar of *mīqāt* in his time; Ibn Ḥajar al-ʿĀsqalānī and Ibn al-Majdī studied with him; good knowledge in *hay’a* and arithmetic
ʿAbd al-Wahhāb b. Muḥammad al-Shawa al-Qāhirī (b. 766)	Shaykhuniyya Manṣūriyya Madrasa	living there determined the time	Studied *mīqāt* with al-Shams al-Ghazulī, al-Jamal al-Māridānī and Ibn al-Majdī; studied ophthal-mology; had knowledge on quadrant and astrolabe
	Al-Ḥakam Friday Mosque	determined the time	
	Hospital	treated eye diseases	
	-	transmitted *ḥadīth*	
ʿAlī b. ʿAbd al-Qadir al-Naqqāsh al-Mīqātī (d. 886)	*ḥanut* in al-Sagha	engraver	Studied *mīqāt* and geome-try with Ibn al-Majdī and engraving with his step-father; taught *mīqāt* to his son and al-ʿIzz al-Wafā’ī
	al-Maqsī Friday Mosque	head (muwaqqits ?)	
	al-Jamaliyya al-Ṣāḥibiyya Madrasa	head (muwaqqits ?)	
	Tomb of al-Ashraf Inal etc.	head (muwaqqits ?)	
	several places	taught mīqāt	

Name	Affiliation	Post	Further information
ʿAlī b. ʿUmar al-Qāhirī al-Maqsī (d. after 893)	Mu'ayyadiyya Madrasa	served Qujmas in *mīqāt* *mu'adhdhin* of the sultan Ṣūfī	
ʿAlī b. Muḥammad al-Haythamī al-Tibnawī al- Qāhirī (d. 888)	al-Ashrafiyya Barsbay Madrasa	Ṣūfī	Studied *mīqāt* with al-Shams Muḥammad b. Ḥusayn al-Sharinbabilī. Wrote two introductions on Sinus Quadrant and one on *muqanṭarāt*, but did not teach them
	-	in entourage of al-Amīr Jamīl	
ʿAlī b. Muḥammad al-Nūr al- Qāhirī (d. after 896)	Al-Zaynay al-Ustadar Friday Mosque	*muwaqqit*	
ʿUmar b. Aḥmad al-Siraj al-Hilālī al-Ḥamawī al-ʿAnbarī, known as Ibn al-Khadar (b. 816)	Great Friday Mosque Hama	head	Studied *mīqāt*
Muḥammad b. Aḥmad al-Makhzūmī al-Qāhirī, known as Ibn al-Khashshāb (793-873)	al-Ashrafiyya Barsbay Madrasa	determined time	Studied medicine; studied *ʿilm al-waqt* with al-Jamal al-Māridānī, al-Shihāb al-Sathī, al-Baridānī, Ibn al-Majdī
	al-Ṣāliḥ Friday Mosque	determined time	
	al-Manṣūriyya Madrasa	determined time	
	-	informed Ibn *Ḥajar* every Friday of time for sermon	
	al-Ẓāhiriyya Madrasa (the old one)	librarian and lived there	
Muḥammad b. ʿAbd al-Laṭīf al-Aqsaray, known as al-Mahallī (d. c. 860)	al-Sharabshiyya Madrasa near al-Aqmar Friday Mosque	lived there and led the teachers	Studied *mīqāt* with al-Shihāb al-Khawāṣṣ, Ibn al-Majdī, al-Nūr al-Naqqāsh. Taught *mīqāt* to al-Muẓaffar al-Amshatī, ʿAbd al-ʿAzīz al-Mīqātī (al-Wafā'ī ?) and Nāṣir al-Dīn al-Akhmīmī

Name	Affiliation	Post	Further information
Al-Badr (Sibt) al-Māridānī (826-	al-Ḥajibiyya Madrasa	teacher	Studied *mīqāt* with Ibn al-Majdī; al-Nūr al-Naqqāsh gave him his post at the Ibn Tulun Friday Mosque. Wrote more than 200 treatises, among them text on his work at Manṣūriyya Madrasa
	Ibn Tulun Friday Mosque + other places	head (*muwaqqits* / teachers ?)	
	al-Manṣūriyya Mosque	worked there (*muwaqqit* ?)	
Muḥammad b. Muḥammad al-Shams al-Ḥalabī, known as Amīr Ḥajj and Ibn al-Muwaqqit (791-868)	Great Friday Mosque in Ḥalab	led *mīqāt* led the signing of appointment certificates with the office of the judges	
Muḥammad b. Muḥammad al-Gharraqī (795-858)	Nabulsiyya Madrasa	lived there and taught there, among other things *mīqāt*, *fiqh*, *uṣūl al-fiqh*, Arabic, arithmetic, prosody and *rūḥānī* (automata?)	Studied *mīqāt* with Nāṣir al-Dīn al-Barinbarī, al-Shams al-Gharraqī and Ibn al-Majdī
Muḥammad b. Yusuf al-Faraskurī al-Ḥarīrī (d. c. 870)	al-ʿAṭiq Friday Mosque in Faraskur	Imam + *muwaqqit*	Knowledgable in *ʿilm al-waqt* and *farāʾiḍ*
Mūsā b. Muḥammad al-Sharaf al-Muwaqqit, nephew of al-Shams al-Khalīl (d. 807)	Tunkuz Friday Mosque and others	head of the *muʾadhdhins*	The most excellent in *hayʾa* in Syria

Mīqāt in Ibn Bāṣo's *al-Risāla fī l-Ṣafīḥa al-Mujayyaba Dhāt al-Awtār* (*Treatise on the Plate of Sines*)*

Emilia Calvo

1. Introduction

The aim of this paper is to present and analyze the way in which a trigonometric grid devised in al-Andalus at the end of the 13th century can be used to perform calculations related to the Islamic religious purposes and the procedures that are usually designated by the word *mīqāt.*

As it is well known, the *ʿilm al-mīqāt*[1] is the science of timekeeping by means of the sun and the stars and of the determination of the times of the five canonical prayers, usually called *mawāqīt*. The times during which these prayers can be performed are defined by the sun's apparent position with respect to the local horizon. This means that these times vary from one place to another and from one day to another, that is, depending on the latitude and the moment of the year.

There are different procedures to calculate these moments. One of these procedures is the one usually known as *tawqīt bi-l-ḥisāb*, time-keeping by arithmetical calculation, that we find in treatises used by *muwaqqits* in the Maghrib from the 14th century onwards[2]. These calculations can also be performed by means of tables or, as is the case in

* This paper was written with the support of the research project "Ciencia y Sociedad en el Mediterraneo Occidental en la Baja Edad Media" sponsored by the Spanish Ministerio de Educación y Ciencia (HUM2004-02511) and FEDER.

[1] On the characteristics of *mīqāt* see King, 1990b.

[2] See Jaṭṭābī, 1986, Calvo, 2004b.

Ibn Bāṣo's *Treatise on the Plate of Sines*, by means of an instrument. This approach to the topic could be called *tawqīt bi-l-ālāt.* In Ibn Bāṣo's treatise these procedures are performed by means of a trigonometric grid.

2. Trigonometric instruments

Trigonometric instruments are found in Islam since the beginning of the development of astronomy. Sine quadrants were constructed in the Islamic East as early as the ninth century. In the beginning, the quadrant was an independent instrument, but from the tenth century onwards it was found on the back of the standard astrolabe.

The first known description of an instrument of this kind was compiled by al-Khwārizmī, following his two treatises on the astrolabe[3].

Also in the ninth century Ḥabash al-Ḥāsib describes a trigonometric instrument which is a complete plate, not only a quadrant. This instrument is described as used only for timekeeping by the stars but, since the surviving text seems to be incomplete, it is possible that there are some missing parts of the description of the use of the plate[4].

As for al-Andalus, Ibn al-Zarqālluh was the first astronomer to introduce the sine quadrant on the back of an astronomical instrument, namely in the instrument called *al-ṣafīḥa al-zarqāliyya.* Ibn Bāṣo knew Ibn al-Zarqālluh's work, and it is possible that some elements in the treatise under study here come from Ibn al-Zarqālluh. But, as in the case of Ḥabash al-Ḥāsib's instrument, Ibn Bāṣo is describing a complete plate, not only a quadrant.

Ibn Bāṣo's plate is also related to the instrument called the *dastūr* circle. This instrument is described by several astronomers in the Islamic East. One of the earlier descriptions can be found in the 10th century astronomer Abū Jaʿfar al-Khāzin who described a trigonometric grid in his treatise on the *zīj al-ṣafā'iḥ* which was used to perform calculations related to spherical astronomy but also related to planetary motions.[5]

Al-Abharī, an astronomer from the 13th century[6], describes a trigonometric instrument[7] in his treatise entitled *Lawāmiʿ al-wasā'il fī maṭāliʿ al-rasā'il.*[8]

[3] See King, 1983, pp. 29-30.
[4] See Charette & Schmidl, 2001.
[5] See Calvo, 2004a.
[6] Abū Saʿid [b. ʿAbd al-Raḥmān b. Abī Ḥafsʿ Umar b. Muḥammad]. See Suter n. 369; Schmalzl, pp. 62-63.
[7] According to Schmalzl, he may have been the inventor of this instrument.

Abū ʿAlī al-Ḥasan al-Marrākushī, who worked in Egypt and lived also in the 13th century[9], describes a trigonometric instrument. This description is included in his treatise entitled *Jāmiʿ al-mabādiʾ wa-l-ghāyāt fi ʿilm al-mīqāt.* In fact, he describes the *dastūr* circle, the *dastūr* half circle and the *dastūr* quadrant[10].

One century later, Ibn al-Shāṭir[11], who was the head of the *muwaqqits* associated with the Umayyad Mosque in Damascus, was also concerned with spherical astronomy and timekeeping, although he worked mainly in planetary astronomy. He devised various instruments for solving problems in spherical astronomy for all latitudes, among them a circular plate, that he called *al-ṣafīḥa al-jāmiʿa* (universal plate), one side of which displayed two orthogonal grids superimposed at an angle equal to the obliquity of the ecliptic. Ibn al-Shāṭir wrote a treatise on the use of this plate entitled *Al-ashiʿʿa al-lāmiʿa fī l-ʿamal bi-l-jāmiʿa*[12]. An example of this instrument, made by Ibn al-Shāṭir himself, now missing the rete and alidade, is preserved in Cairo[13].

The *dastūr* is also described by Jamal al-Dīn al-Maridīnī (m. 1406), who was *muwaqqit* in al-Azhar, in his treatise entitled *Al-durr al-manthūr fī l-ʿamal bi-l-rubʿ al- dastūr*[14].

A trigonometric quadrant, known as *sexagenarium,* was introduced in the Iberian Peninsula at the end of the 15th century[15]. This instrument had two faces, one planetary and one trigonometric. This characteristic makes this instrument very close to the instrument described by al-Khāzin in his treatise on the *zīj al-ṣafāʾiḥ.* Of Arabic origin, the *sexagenarium* was used by the *muwaqqits* in Egypt. A *faqīh* brought it with him to Valencia in 1450 and, later, it was introduced in Europe. There are two translations of the treatise describing its use, one of them printed[16].

[8] It is preserved in MS. 965 of El Escorial. (See Renaud 1941, p. 109), and in Gotha, 1414. The third maqāla is divided into 40 chapters devoted to the *dastūr.*

[9] See Suter n. 363.

[10] See al-Marrākushī, pp. 387

[11] See King, 1975, pp. 357-364; Saliba, 1987, pp. 35-43.

[12] It is preserved in Aleppo. There are copies in Cairo and St. Petersburg. See King, 1986, p. 62, C30. Calvo, 2005

[13] See King, 1988, pp. 164-166.

[14] See Suter n. 421. It is preserved in several copies now in Berlin 5840, Madrid (Esc. 931), Oxford, Paris and Cairo. This treatise contains 60 chapters. Sedillot, p. 88 n. 2. Jamal al-Dīn al-Maridīnī was Sibt al-Maridīnī's grandfather. Sibt is also the author of a treatise on the use of the sine quadrant which is contained in the same Ms. 931 Escorial.

[15] On this instrument see Thorndike, pp. 130-133.

[16] On the characteristics of the *sexagenarium* see Poulle 1966, pp. 129-161; Poulle, 1980, I pp. 417-444 and Samsó 1992, pp. 216-217.

3. The treatise on the plate of sines and its author

The treatise on the use of *al-ṣafīḥa al-mujayyaba dhāt al-awtār* (the "plate of sines provided with chords") is preserved in manuscript 5550 in the National Library (Bibliothèque National) in Tunis (fols. 50r - 81v). The author of the treatise is mentioned on the first page of the manuscript (see fig. 1). His complete name is Abū ʿAlī al-Ḥusayn b. Abī Jaʿfar (there is a blank on the manuscript corresponding to Aḥmad) b. Yūsuf b. Bāṣo al-Aslamī and he is described as *imām al-mu'adhdhinīn* (chief of the muezzins), *qudwat al-muʿaddilīn* (an example for astronomers), and *amīn awqāt al-ṣalāwāt* (in charge of the times of prayer) in Granada[17]. On fol. 81v of the manuscript the name of the copyist is also given as Muḥammad b. Muḥammad, called al-Ṣaghīr, b. al-Ḥājj Abī ʿAbd Allāh Muḥammad b. al-Ḥājj Abī l-Faḍl Qāsim. The date of copy is 1305 H. (1887 AD).

There is no date of composition but this Ibn Bāṣo was also the author of a treatise on the use of a plate that he called *al-Ṣafīḥa al-jāmiʿa li-jamīʿ al-ʿurūḍ* (universal plate for all latitudes). This second treatise contains 160 chapters and, as it is stated in the introduction, it was completed in 673 H./1274 A.D. The author of this treatise is referred to in the first page and his complete name coincides in both cases. This second treatise, that I edited, translated and studied several years ago[18], shows that the author was aware of the *mīqāt* procedures in use among the *muwaqqits* of his time, especially in Egypt and Syria.

4. Description of Ibn Bāṣo's trigonometric plate

The treatise on the use of the plate of sines contains 59 chapters. The first chapter is devoted to the description of the lines traced on the plate. This description is rather vague. In most cases the author limits himself to give the name of the elements, without any indication of their appearance or characteristics. Besides, there are no figures accompanying the only existing copy of the treatise to clarify the nature of some of the lines described.

[17] On this author see Ibn al-Khatīb, p. 468; Sarton, vol. III p. 696; Suter, n 381 b, p. 157; Brockelmann, S 1, p. 869; Renaud 1932, no 381 b, p. 172; Renaud 1937, p. 112; Millás Vallicrosa, pp. 448-449; Samsó 1973, pp. 176-182; Calvo, 1991, pp. 65-79; Calvo, 1993, pp. 23-27 and Calvo, 1996, pp. 755-768.

[18] It is preserved in three extant manuscripts now in El Escorial (MS ar. 961), the National Library of Tunis (MS 9215) and the Royal Library of Rabat (MS 4288). See Calvo, 1993.

As for the back of the instrument, the author states that it is similar to the back of the astrolabe, without further explanation.

4.1 Face of the trigonometric plate

Ibn Bāṣo mentions the following elements on the face of the instrument (see fig. 2):[19]

I. *Dā'irat al-muḥīṭ*, external circumference: the outer circle, divided into 360 degrees. According to the author, this circumference can represent the circle of the equator, the circle of the horizon, the meridian circle, the altitude circle and the ecliptic. It depends on the calculation to be performed.

II. *Dā'irat ajzā'i-hā*, circle of its divisions: an inner circle, divided into four graduated quadrants. In each quadrant, as described by Ibn Bāṣo, every one of its 90 degrees is marked on the circle. The first quadrant goes from the beginning of Capricorn to the end of Pisces. The second goes from the beginning of Aries to the end of Gemini, and is also divided into 90 degrees. The third is not described in the text. It should go from the beginning of Cancer to the end of Virgo, and the fourth goes from the beginning of Libra to the end of Sagitarius, and is also divided into 90 degrees. Ibn Bāṣo states that the degree markings can be used for the ecliptic and the outer circle as well.

III. *Dā'irat tawassuṭ al-kawākib*, the stars' mediation circle. It is found inside the ecliptic.

IV. *Dā'irat abʿād al-kawākib ilā falak muʿaddil al-nahār,* the stars' declination circle, inside the mediation circle.

V. *Marākiz al-kawākib*, the stars centres. According to the text, the stars are represented between the mediation circle and the declination one. Their names are written there as well, while the names of the zodiacal signs are found between the mediation circle and the external one.

VI. *Quṭr al-sahām,* the diameter of the versed sines[20]: the horizontal diameter taken from the beginning of Capricorn to the beginning of Cancer.

VII. *Al-awtār*, the chords: the straight lines that intersect the diameter of the *sahām.*

[19] Fols. 51v-52v.

[20] The versed sine (*sahm*) of an angle equals the difference between the radius and the cosine of this angle

$$\text{vers } \alpha = R - \cos \alpha$$

VIII. *Al-watar al-aʿẓam*, the major chord: the diameter taken from the beginning of Aries to the beginning of Libra.

IX. *Al-juyyūb*, the sines: the straight lines that intersect the major chord.

X. *Al-khayṭ*, the thread: attached to the centre of the plate.

XI. *Al-murī,* the index: a bead moving along the thread. When the thread rotates, the bead describes circles on the plate, concentric with the outer circle.

XII. *Dā'irat al-mayl,* the declination circle.

XIII. *Dā'irat al-maṭāliʿ*, the ascension circle.

The text only says that, of the last two circles, the former is smaller, but gives no other clues to determine their situation on the plate. However, from the analysis of the instructions on the use of the plate given in the treatise, it is possible to determine the way in which these two circles are drawn.

From the indications given by the author it seems clear that the ascension circle has a radius

$$r_1 = R \cos \varepsilon$$

While the declination circle has a radius

$$r_2 = R \sin \varepsilon$$

4.2 Graduated Scales

The *sahām,* or versed sines, are graduated on the diameter of the *sahām*[21]. The graduation starts at the beginning of Capricorn and ends at the beginning of Cancer. The author adds that this is 120. This implies that the radius is divided into 60 parts.

The sines are graduated on the major chord. This graduation starts at the centre and ends at the beginning of Aries, going from 0 to 90 and at the beginning of Libra, also from 0 to 90.

The graduation of the zodiacal signs can be written between the mediation circle and the declination one.

The instructions on the graduation of the plate complete the description of the instrument (see fig. 3).

$$\text{vers } \alpha = R - \cos \alpha$$

[21] These divisions are determined by the chords.

5. Contents of the treatise

The use of this plate is described in chapters 2 to 59 of the treatise where Ibn Bāṣo describes the following topics:

2-3: Determination of sines, cosines and chords.
4-12: Determination of the solar degree, the latitude, the meridian altitude and the declination.
13-16: Determination of horizontal and vertical shadows.
17: Determination of the diurnal times of prayer: *al-zawāl, al-ẓuhr* and *al-ʿaṣr.*
18-20: Determination of the diurnal and nocturnal arcs and of the seasonal and equal hours.
21-28: Determinations related to the time elapsed since sunrise.
29-32: Calculations related to stars.
33: Determination of morning and evening twilight.
34-35: Determination of the altitude of a star from the hour and vice versa.
36-42: Determination of the azimuths.
43: Determination of longitudes.
44-53: Determinations related to stars.
54-58: Determination of right and oblique ascensions.
59: Determination of whether a planet is direct or retrograde.

Therefore, the topics dealt with in this treatise can be classified in three main sections according to the calculations performed:

I. Transformation of coordinates[22]
II. *Mīqāt* or timekeeping
III. Planets and fixed stars

6. *Mīqāt* in Ibn Bāṣo's plate of sines

Ibn Bāṣo deals with *mīqāt* maters in chapters 13 to 28 and in 33: he describes how to obtain the shadows (chapters 13-16), the determination of the diurnal times of prayer: *al-zawāl, al-ẓuhr* and *al-ʿaṣr* (chapter 17), the diurnal and nocturnal arcs, the seasonal and equal hours (chapters 18-20), the time elapsed since sunrise (chapters 21-28), and the morning and evening twilight (chapter 33).

[22] See Calvo, 2001.

Ibn Bāṣo gives geometrical explanations but there are underlying trigonometric procedures as can be seen in the following examples.

6.1 Determination of shadows and altitudes

Chapter 13 and 14 describe how to determine on the plate the equivalent of the shadow quadrant found in the back of an astrolabe, divided in 12 units or digits.

Chapter 13[23] determines shadows from altitude. The instructions are:

- To put the thread on the quadrant according to the solar altitude.
- Then, we have to make two markings: one over the chord the distance of which is 12 and the other on the sine line the distance of which to the diameter is 12: the distance between the sine and the major chord is the horizontal shadow (*al-ẓill al-mabsūṭ*) and the distance between the chord and the diameter is the vertical shadow (*al-ẓill al-mankūs*). This allows us to have the equivalent of the shadow quadrant of an astrolabe.

The author also gives the possibility of calculating the shadows in feet. In this case the parameter given is 6 2/3 instead of 12. This parameter is also given in Ibn Bāṣo's treatise on the universal plate and it can also be found in al-Bīrūnī's treatise on shadows where he ascribes it to Abū Maʿshar[24].

Chapter 14[25] is devoted to calculate the inverse procedure, that is, the altitude from the shadow. Instructions are different depending on whether we deal with a horizontal or vertical shadow:

a) horizontal shadow: we have to count on the sine line, the distance of which to the diameter is 12, starting from the major chord, as much as the number of digits. Then, we make a marking and put the thread over the marking and, finally, we have to calculate the corresponding degrees on the graduation of the external circle.

b) vertical shadow: we have to count, starting from the diameter, over the chord, the distance of which to the major chord is 12. Then we make a marking and put the thread on it. The value of the altitude will be read on the graduation of the external circle.

If we work with shadows in feet we have to use 6 2/3 instead of 12.

[23] Fol. 57 r.

[24] See Calvo, 1993 p. 104; Kennedy, 1976, vol. I p. 78, vol II, p. 35.

[25] Fol. 57 v.

Chapter 15[26] describes how to convert shadows from one another. The factor of conversion is 144.

Chapter 16[27] is devoted to find the altitude from the shadow as in chapter 14. In fact, the instructions are basically the same in both chapters.

6.2 Determination of the solar altitude for the moments of **al-zawāl, al-ẓuhr** *and* **al-ʿaṣr**

Chapter 17[28] is devoted to calculate the moments of the diurnal prayers. First of all we have to know the solar altitude at midday. The author says that the moment when the solar altitude at this day begins to decrease corresponds to the beginning of the *zawāl,* which is the first moment for the *ẓuhr* prayer. As for the *waqt al-ikhtiyār* (the moment of preference), it arrives when the shadow has decreased a cubit.

To determine the altitude of the sun for the moments of the *ẓuhr* and *ʿaṣr* prayers the instructions are (see fig. 4):

- We have to know the meridian shadow, that is the *zawāl* shadow, by placing the thread in the Capricorn quadrant according to the meridian altitude and, then, we have to find its intersection with the sine, the distance of which to the diameter is 12. We have to put there a marking.
- The number of chords between the marking and the major chord gives the fingers corresponding to the *zawāl* shadow.
- We add three chords to this value and we make a second marking.
- We put the thread on this marking and we obtain the solar altitude corresponding to the *ẓuhr* prayer in the graduation of the external circle.

To obtain the value of the solar altitude for the *ʿaṣr* prayer, the instructions are:

- We have to add 12 chords to the marking corresponding to the *zawāl* shadow and to make a marking on the chord obtained.
- Then, we put the thread over this marking and we have the value of the altitude for the *ʿaṣr* prayer on the graduation of the external circle.

[26] Fol. 58 r.
[27] Fol. 59 r.
[28] Fol. 59 v.

- Then, we have to count 24 chords from the first marking (corresponding to the *zawāl*) to obtain the altitude of the end of the *ʿaṣr* prayer.

These instructions make clear that the formulae involved in the calculations are:

$$S_z = S_m + \frac{1}{4} n \qquad S_{pa} = S_m + n \qquad S_{fa} = S_m + 2n$$

These are the values to calculate the corresponding shadows usually used in al-Andalus. We find them, for instance, in Ibn Bāṣo's treatise on the universal plate[29].

6.3 Determination of the equation of daylight

Chapters 18 and 19 are devoted to the determination of the arcs of daylight and night from the degree of the ecliptic, that is to say, from the solar longitude, λ.

Chapter 18[30] gives instructions to determine the *taʿdīl murī qaws al-nahār* (the equation of the index for the arc of daylight) where the objective is to determine the equation of the day for the solstices. The text says that this is a general procedure to obtain the arc of daylight. In fact, this implies to calculate the maximum value of the equation of daylight, and, therefore, the value of the maximum arc of daylight for a given latitude.

The equation of daylight, *e,* corresponds to the difference between half the arc of daylight and 90 degrees:

$$e = |D - 90|$$

If we perform this calculation for the solstices we have that the declination equals the obliquity of the ecliptic

$$\delta = \varepsilon$$

The instructions given in the text are (see fig. 5):

- To put the thread on the quadrant of Cancer according to the latitude φ.

[29] See Calvo, 1993, pp. 104-105.
[30] Fol. 60 r.

- Then, we have to put a marking on the quadrant of Aries according to the maximum declination (i.e. the obliquity of the ecliptic, ε). The chord determined by this marking is called *watar al-mayl,* declination chord (chord HI)**.** The intersection of this chord and the thread is determined by point B in the in figure 5.
- Then, we put the thread on the extreme of this chord (H) and the bead (*murī*) in the intersection of the thread with the sine line determined by B, which is point C'. The text says that, once we have done this, we have equalized the arc of daylight. The reason is that, when the bead is put on the thread on this point, we can put the thread according to the right ascension of any degree of the sun and we obtain automatically the value of the equation of the arc of daylight as the arc determined by the chord intersecting with the thread.

In figure 5, if we put the thread according to the right ascension α = GL, the bead will be at point S and the equation will be determined by chord MN and, therefore, e = GM.

The geometric demonstration allows us to obtain the formula underlying these instructions:

In OHA $\quad OA = R \sin \varepsilon$
In OAB $\quad \tan \varphi = AB/OA \Rightarrow AB = OA \tan \varphi \Rightarrow AB = R \sin \varepsilon \tan \varphi$
In OC'D $\quad OC' = AB / \cos \varepsilon \Rightarrow OC' = R \sin \varepsilon \tan \varphi / \cos \varepsilon$

$$OC = OC' = R \tan \varepsilon \tan \varphi$$

The circle determined by this radius (OC' = OC) determines the value of the arc of daylight.

In ONS $\quad \sin \alpha = ON/OS = ON/OC \Rightarrow ON = OC \sin \alpha$

$$ON = R \tan \varepsilon \tan \varphi \sin \alpha$$

$\sin e = ON/R \quad \Rightarrow \quad \sin e = \tan \varepsilon \tan \varphi \sin \alpha$
When $\delta = \varepsilon \quad \Rightarrow \quad \alpha = 90^\circ$ and, therefore,

$$\sin e = OC = \tan \delta \tan \varphi$$

Chapter 19[31] describes how to determine the *taʿdīl qaws al-nahār* from the declination for any day of the year.

[31] Fol. 60 v.

The first instruction is to equalize the bead as explained in the preceding chapter. This means that we have to put the bead on the thread according to the value of the radius

$$OC = OC'$$

The next instruction is to put the thread on the limb according to the value of the right ascension, α. The chord passing through the bead (*murī*) determines the value of the *taʿdīl* (equation of the day, chord MN in fig. 5).

The underlying formula is again

$$\sin e = \tan \varepsilon \tan \varphi \sin \alpha$$

The author gives another possibility using the declination instead of the right ascension. In this case the instructions are (see fig. 6):

- First, we have to determine the chord corresponding to the value of the declination, δ (chord AF).
- Then, we have to put the thread in the quadrant of Cancer according to the value of the latitude and find the intersection between the thread and the chord (point B).
- Next, we have to find the intersection of the thread and the sine line determined by B (point C).
- We have to put the bead on the thread according to this distance OC.
- Finally, we have to put the thread over the diameter. The chord determined by the bead (point C') will give the two points of rising and setting of this day.

From these instructions on the text we can obtain the underlying formula used in this case. In the figure:

In OAF $\sin \delta = OA/R$ => $OA = R \sin \delta$
In OAB $\tan \varphi = AB/OA$ => $AB = OA \tan \varphi$
$AB = R \sin \delta \tan \varphi$
In OCD $\cos \delta = CD/OC$ => $OC = CD/ \cos \delta$
$CD = AB$ => $OC = R \sin \delta \tan \varphi / \cos \delta = R \tan \delta \tan \varphi = OC'$

And, since

$$\sin e = OC'/R$$

therefore,

$$\sin e = \tan \delta \tan \varphi$$

It can also be formulated as

$$\cos D = - \tan \delta \tan \varphi$$

where D is the half arc of the day, or

$$D = 90 + e$$

The text says that the two extremes of the chord determine the rising and setting points of the sun in this day and that the amount of degrees between these two points in the direction of Capricorn corresponds to the value of the arc of daylight and the rest, in the half of Cancer, corresponds to the arc of night.

6.4 Calculations related to the time elapsed of the day

Chapter 20[32] gives the equivalence of one equinoctial hour to 15 degrees. This means that, in order to obtain hours one has to divide the degrees of the arc of the day or night into 15. The result will be hours and fractions.

Chapter 21[33] determines the altitude of the sun from the time elapsed since sunrise, *T*.

The instructions are that from the rising point one has to count as much as *T*. Then, one has to make a marking on the corresponding chord and on its intersection with the diameter of the plate.

The formula involved is

$$h = \arcsin [\cos T \cos \delta \cos \varphi + \sin \delta \sin \varphi]$$

Chapter 22[34] explains the inverse procedure, i.e., to determine the time elapsed since sunrise from the altitude of the sun, according to the formula

$$T = \arccos \frac{\sin h - \sin \delta \sin \varphi}{\cos \delta \cos \varphi}$$

Chapter 23 explains how to calculate the *taʿdīl* to know the time elapsed since sunrise from the altitude and the contrary

[32] Fol. 61 r.
[33] Fol. 61 v.
[34] Fol. 62 r.

The involved formula is

$$\text{vers } t = \text{vers } D - \text{vers } D \text{ sen } h / \text{sen } hm$$

7. Abridged reference

7.1 Remainder of the topics studied. Trigonometric formulae involved

Chapter 13: $HS = n \cot h$

Chapter 14: $VS = n \tan h$

Chapter 15: $HS \cdot VS = 144$

Chapter 16: $h = \arctan \frac{n}{HS}$ $h = \text{arc cotan} \frac{n}{VS}$

Chapter 17: $S_z = S_m + \frac{1}{4} n$ $S_{pa} = S_m + n$ $S_{fa} = S_m + 2n$

Chapter 18: $OC = R \tan \varepsilon \tan \varphi$

Chapter 19: $\sin e = \tan \varepsilon \tan \varphi \sin \alpha$ // $\sin e = \tan \delta \tan \varphi$

Chapter 20: 1 equinoctial hour = D/15

Chapter 21: $h = \arcsin [\cos T \cos \delta \cos \varphi + \sin \delta \sin \varphi]$

Chapter 22: $T = \arccos \frac{\sin h - \sin \delta \sin \varphi}{\cos \delta \cos \varphi}$

Chapter 23: vers t= vers D – vers D sen h /sen hm

7.2 Symbols

HS: horizontal shadow

CS: vertical shadow

n: gnomon, shadow graduated scale

h: altitude

S_z: shadow at the moment of the *ẓuhr* prayer

S_m: meridian shadow

S_{pa}: shadow at the beginning of the *ʿaṣr* prayer

S_{fa}: shadow at the end of the *ʿaṣr* prayer

R: radius of the plate

ε : obliquity of the ecliptic

φ: local latitude

e: equation of the day (|D-90|)

α: right ascension

δ: declination

D: half arc of the day

T: time elapsed since sunrise

8. Concluding remarks

As we have seen, the main contents of the treatise are transformations of coordinates and timekeeping or *mīqāt* that are the main objectives of the treatises aimed at *muwaqqits* almost at the same time that this institution appears for the first time in Egypt and Syria. Among these contents one missing is the determination of the *qibla* which in turn is found in Ibn Bāṣo's treatise on the universal plate.

As it is clear, this plate makes it possible to solve in a rather simple way problems related to the timekeeping, such as the religious prescriptions, but avoiding the trigonometric calculations involved although these calculations are implicit in the use of the instrument.

For the treatment of *mīqāt* in Ibn Bāṣo's treatise, there are some coincidences with what we find in Ibn Bāṣo's treatise on the universal plate and what was in use in al-Andalus and the Maghrib at the time: we find analogous procedures and parameters in treatises on *mīqāt* compiled for instance by Ibn al-Bannā'[35], who was active some years after the death of Ibn Bāṣo and who was very influenced by Andalusian astronomers such as Ibn al-Zarqālluh, an astronomer that was also influential on Ibn Bāṣo's work.

From the analysis of the instructions given in the treatise it is clear that it does not always give the precise information.

One clear example is that the author does not specify the value of the obliquity of the ecliptic that he is considering, although this value is not needed, since there are two circles that are traced according to it: the declinations circle and the ascensions circle that can be used when this parameter is needed.

In the description of the instrument these two circles are introduced in a rather vague way, but a study of the chapters on the use reveals how they are traced on the plate: the circle of declinations has a radius of value (R sin ε) and the circle of ascensions has a radius of value (R cos ε) where R is the radius of the plate, divided into 60 parts, and ε is the value of the obliquity of the ecliptic adopted by the author.

But this seems to be a rather technical question and the treatise tends to avoid them in order to make it useful for non specialists.

The way in which the exposition is offered gives some idea of who was the target of this treatise: like the treatises on *tawqīt bi-l-ḥisāb* that we find in the Maghrib in the following centuries, the potential user is the non

[35] On Ibn al-Bannā' see Djebbar & Aballag and Calvo, 2004b

specialist needing a tool containing instructions relatively easy to follow although, as it is clear, the underlying theory was not.

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Fig. 1 Ms. 5550, fol. 55 r
National Library, Tunis.

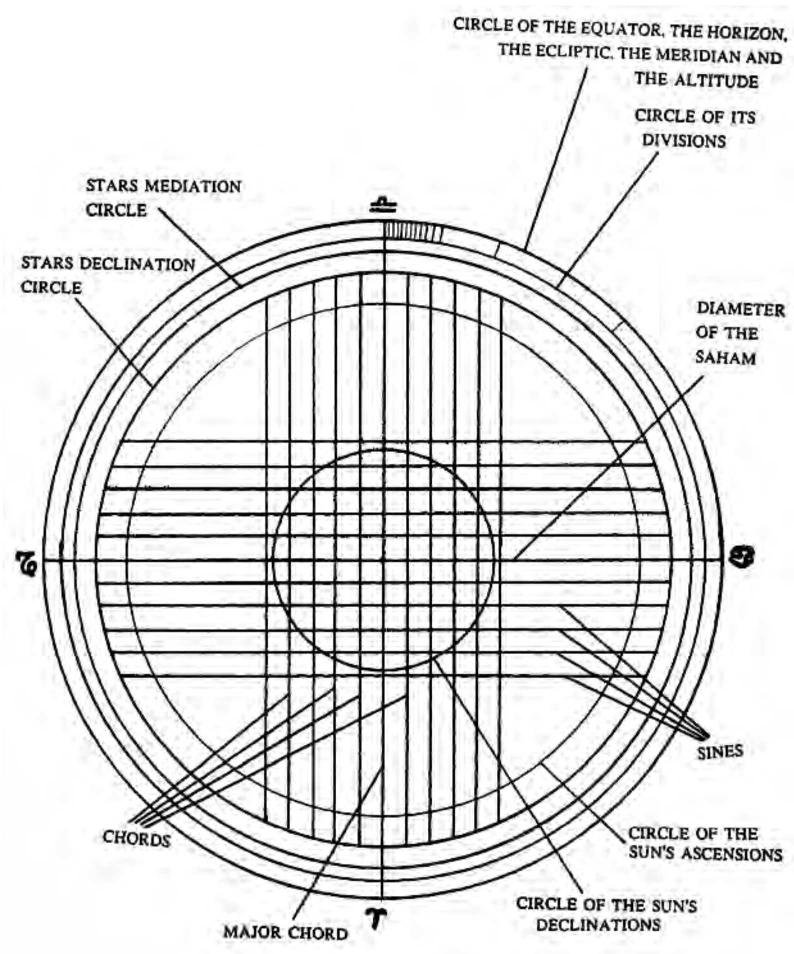

Fig. 2 Elements of Ibn Bāṣo's plate of sines.

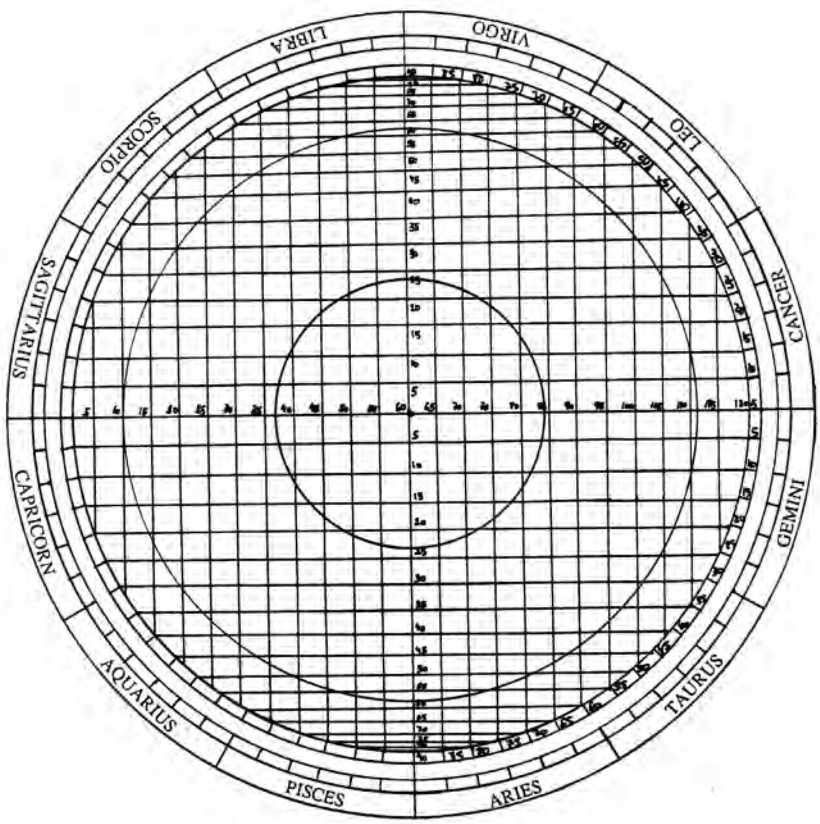

Fig. 3 Reconstruction of Ibn Bāṣo's plate of sines.

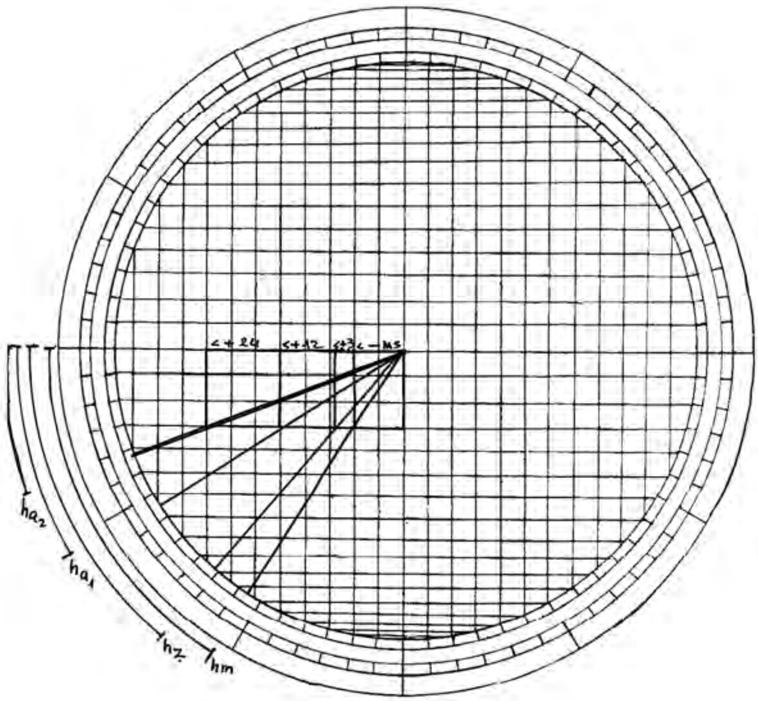

Fig. 4 Determination of the moments
of the *ẓuhr* and *ʿaṣr* prayers from the meridian shadow.

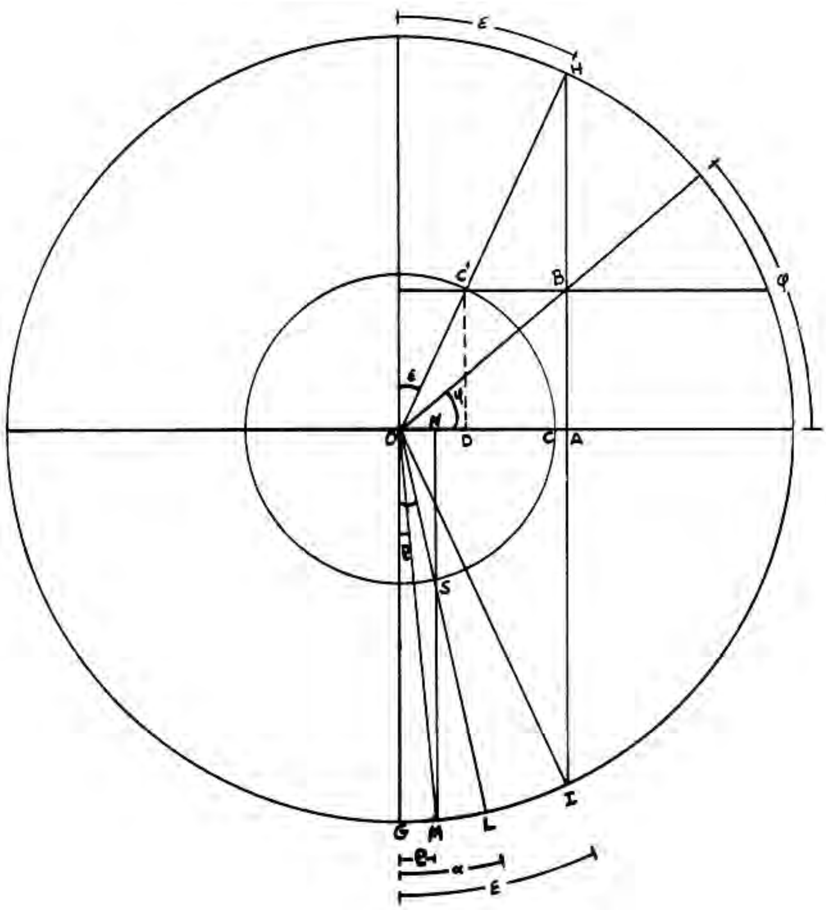

Fig. 5 Determination of the equation of the day, *e*, from the right ascension, *α* (chapter 18).

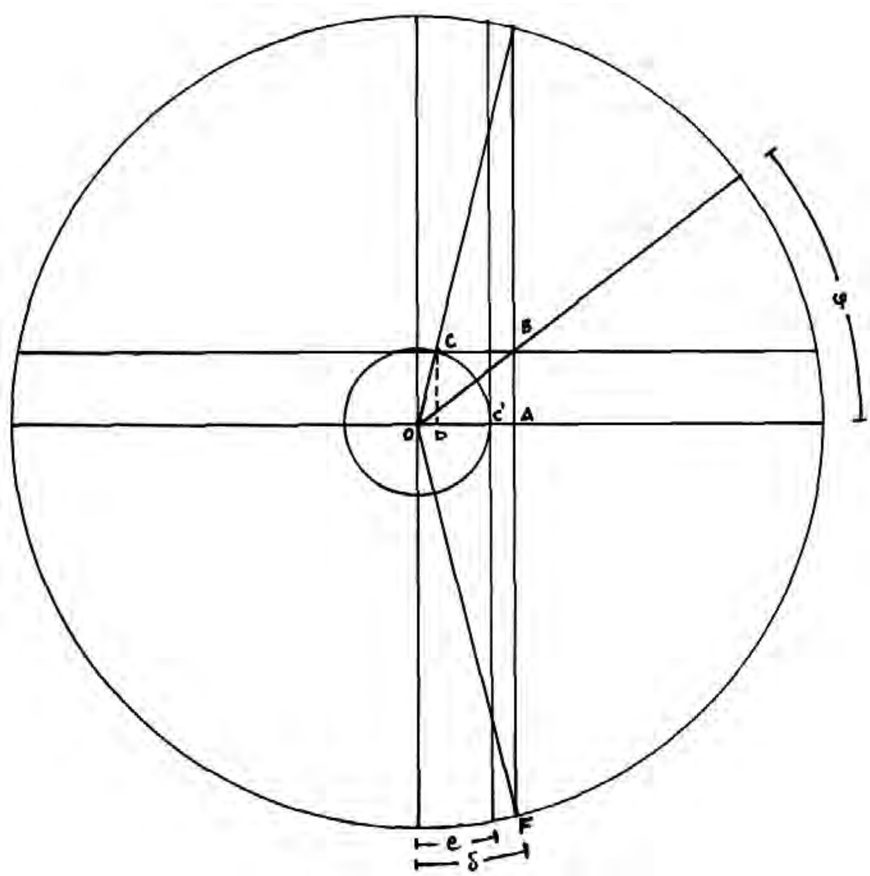

Fig. 6 Determination of the equation of the day, *e*, from the declination, δ (chapter 19).

Bin Waḥshiyya's 93 Alphabets and Mathematics

Harald Gropp

1. Introduction

Abū Bakr bin Waḥshiyya claims to have lived in the ninth or tenth century AD and to have translated several books from the "Nabatean" into Arabic.

The best known of these books is the so-called *Nabatean agriculture*, discussed in detail by [2]. Not so well known is his book on *ancient and occult alphabets* (see [5]) which contains 93 alphabets, among them many strange and unknown ones.

One manuscript of this book on alphabets was found in Cairo 200 years ago by the Austrian Joseph Hammer, later von Hammer-Purgstall, who in 1806 translated it into English and published it [5]. In 1637 the German Jesuit Athanasius Kircher collected Arabic manuscripts in Malta, among them maybe also Bin Waḥshiyya's manuscript on ancient alphabets.

Among the 93 alphabets we find Hebrew, Greek, Syriac, and some other "known" alphabets; the rest consists of more or less hieroglyphic symbols dedicated to peoples, scientists, planets, and constellations. The Latin alphabet does not occur among them.

From the point of view of the history of mathematics the most interesting alphabets in this book are the three so-called Indian alphabets consisting of variations of the 9 digits from 1 to 9.

In this short paper I shall investigate several aspects of this book concerning the history of mathematics. In general, the book is not much estimated by orientalists of today nor was it by European scientists 200 years ago. However, it may obtain interesting information on mathematics, languages, scripts, and cryptography in the Islamic world and their relations to society in general.

2. Bin Waḥshiyya and his book

2.1 The book on 93 alphabets

Bin Waḥshiyya's book on alphabets has the following titlepage in the printed version of [5]:

> ANCIENT ALPHABETS AND HIEROGLYPHIC CHARACTERS EXPLAINED; WITH AN ACCOUNT OF THE EGYPTIAN PRIESTS, THEIR CLASSES, INITIATION, AND SACRIFICES, IN THE ARABIC LANGUAGE BY AHMAD BIN ABUBEKR BIN WAHSHIH; AND IN ENGLISH BY JOSEPH HAMMER, SECRETARY TO THE IMPERIAL LEGATION AT CONSTANTINOPLE. LONDON… 1806

In his preface the author explains as follows:

> Praise to God, and health to his servants, who have pure hearts. Amen! My object is to collect the rudiments of alphabets used by ancient nations, doctors and learned philosophers in their books of science, for the use of the curious and studious, who apply themselves to philosophical and mystic sciences.
>
> Each alphabet is represented in its old shape and form, the original name of it recorded, and the power of the characters written underneath with red ink in Arabic letters, to the end that they may be better distinguished.
>
> I have arranged the work in chapters, and entitled it *The long desired Knowledge of occult Alphabets attained*. With the aid of God!

Hammer remarks in his translator's preface as follows:

> Since writing the above, I have discovered that this rare book was not unknown to Kircher, who in his work on the Hieroglyphics, under the first paragraph, *Occasio hujus operis*, says: "... quos inter principem sane locum obtinet *Aben Vaschia*." Then again page 109 in the text naming his Arabic authors – "*Gelaledden*, *Aben Regel*, et *Aben Vahschia*..." And then: "Nam *Aben Wahschia* – primus Aegyptios libros in linguam Arabicam transtulit, quem nos Melitae inter spolia Turcorum repostum singulari Dei providentia arabicum reperimus."
>
> Now through these quotations shew that the manuscript was not, as I supposed, unknown, yet they enhance the value of it by the worth attached to it by a man like Kircher. [...]
>
> Kircher found his copy at Malta amongst the Turks, and I this at Cairo amongst the Arabs.

2.2 Joseph Hammer

Concerning the story how he found his manuscript Hammer gives a quite short report in the beginning of his preface of [5]:

> The original of this translation was found at Cairo, where it had escaped the researches of the French *Savans*, who, though successful in collecting many valuable Oriental books and manuscripts, failed in their endeavours to procure a satisfactory explanation of the Hieroglyphics.

In his *Lebenserinnerungen* we can read a bit more:

> Die Zeit meiner Abreise rückte heran. [...] Mein Gastfreund Rosetti bedauerte, daß er die wenigen arabischen Manuskripte, die er besessen, den Franzosen überlassen hatte und gab mir zum Abschied das einzige, welches sie ihm nicht abgelockt hatten, weil er es für das kostbarste hielt und nich daran zweifelte, daß in ihm der Schlüssel zum Lesen der Hieroglyphen enthalten sei. Es war das Buch Bin Wahshihs über unbekannte Alphabete, das ich auf der Seefahrt nach England übersetzte und welches später der Orientalist Wilkins herausgab. ([6], p. 114)

2.3 A short description of the book

Quite interesting are the 3 alphabets on the pages 6, 7, and 8 which are called Indian alphabets (see below).

By the way, the Latin alphabet does not occur at all among the 93 alphabets. However, the Greek alphabet on page 15 is not identical to our modern Greek alphabet. For instance, it consists of L and R instead of the corresponding Greek letters.

There are many other alphabets dedicated to persons with Greek sounding names. Two examples are the alphabets of Syourianos, the philosopher (on page 36) and the alphabet of Philaos, the philosopher (on page 37). However, also more prominent philosophers occur like "Plato, the Greek philosopher" whose alphabet (a tree alphabet) is shown on page 46.

Further alphabets are named after the 7 planets starting with the alphabet of Saturn (page 47) and after the 12 zodiacal constellations.

2.4 Early discussions of the book

After the translation and publication by Hammer in 1806 the discussion of the European orientalists lead to a negative evaluation of the book. It was mainly argued that the whole book is not that old and not a translation from a "Nabatean" language. The idea that the whole book is rather an "invention" of an author that lived much later than is stated in the book seems to be still the general opinion of the experts. As an early example, how the discussion went, let me cite from A. von Gutschmid's paper [4] of 1861:

> [...] Da aber die günstige Auffassung Chwolson's ziemlich viel Beifall gefunde hat, da Männer wie Bunsen, Ewald, Spiegel, so sehr sie auch in ihren Ansichten über das Alter un den Grad der Authentizität jener Schriftwerke auseinandergehen, doch darin übereinstimmen, dass hier wirkliche Reste einer eigenen Nabatäischen Literatur vorleigen, da man endlich, wie ich höre, schon anfängt, Ibn Wahshijjah's Uebersetzungen als Quellen zu citeren, so halte ich nicht nur für sehr an der Zeit, sondern geradezu für Pflicht, mit dem Urtheile, welches ich mir in dieser Frage gebildet habe, vor die Oeffentlichkeit zu treten.

2.5 Athanasius Kircher's stay in Malta

As Hammer himself remarks (compare above) he was probably not the first European who found this Arabic manuscript. Athanasius Kircher (1602-1680), a polymath of the seventeenth century, born in Geisa near Fulda in Germany, spent the first half of his life in Germany in the typical Jesuit education centers. In the second half of his life Kircher was the professor of mathematics of the Collegium Romanum in Rome. At the very beginning of his stay in Roma he made a longer voyage to the south of Italy and to some islands in the Mediterranean. His main motivation was the investigation of volcanoes and other geological and mineralogical studies. For further information on the life and work of Kircher see [3].

During this voyage Kircher's stay in Malta was of particular importance. Kircher arrived in Malta on May 31, 1637 and left the island on February 1, 1638. Hence he spent there exactly 8 months. It is not clear whether Kircher had already intended to look there for old manuscripts or whether he found them "by chance". Anyhow, his work "Oedipus II" contains a list of many authors in "Catalogvs Avthorvm". Among several Arabic authors the name "Aben Vaschia" occurs.

The Maltese Abela met Athanasius Kircher and reported that he grumbled of the shortage of books, but carried away precious manuscripts to Rome.

There are two letters between Cardinal Francesco Barberini and Fabio Chigi (1599-1667), the Apostolic delegate in Malta (1634-1639), and later Pope Alexander VII (1655-1667).

On October 10, 1637 Barberini writes to Chigi discussing Kircher's return to Rome and Kircher's successor to Malta:

> It does not seem that Fr. Kircher was quite happy with his stay in Malta ([1], p. 312, letter 232a)

On February 1, 1638 Chigi writes to Barberini discussing Kircher's return to Rome and mentions a few manuscripts which Kircher brought to Rome "con la opportunità del ritorno del padre Atanasio Chircherio [...] alcuni pochi manuscritti" ([1], p. 351, letter 257a).

3. Mathematical and final remarks

At the end let me just focus on two interesting aspects of Bin Waḥshiyya's book which should lead to a new discussion concerning the question for authenticity and ancient age of this book (and its translation).

The fact that the Latin alphabet does not occur is perhaps explainable if the book was written in a century and in an area far away from places where the Latin alphabet was used and known. Moreover, the Latin letters which occur among the letters of the Greek alphabet could explain an uncertain knowledge of Latin letters and a certain mix-up of these two alphabets.

As far as mathematics is concerned, to me the most interesting alphabets are the so-called three "Indian alphabets". The basis for the letters in these alphabets are the nine symbols which today represent the Eastern Arabic numerals from 1 to 9 in the countries between Egypt and Iraq and Iran. These 9 "numbers" form the first 9 letters of such an Indian alphabet, followed by the same symbols with one dot on top of them as letters 10 to 18, followed again by these symbols with two dots as letters 19 to 27. The 28th letter is the number 1 with three dots. My explanation is that these "Indian" alphabets were discussed as such before the introduction of the Indian numerals into the Islamic world.

The detailed discussion of the big rest of the 93 alphabets is left to Egyptologists (many letters look hieroglyphic like, at least at the first sight) and to experts on Greek culture concerning the many Greek names related to most of the alphabets.

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[1] Vincent BORG, *Fabio Chigi, Apostolic delegate in Malta (1634-1639)*, Città del Vaticano, 1967.

[2] Mohammed EL-FAIZ, *L'agronomie de la Mésopotamie antique*, Leiden – New York – Köln, 1995.

[3] Harald GROPP, "Athanasius Kricher (1602-1680) – Kombinatoriker in der Lullschen Tradition", in *Rechenbücher und mathematische Texte der frühen Neuzeit*, Schriften des Adam-Ries-Bundes Annaberg-Buchholz, Band 11, R. Gebhardt (ed.), Annaberg-Buchholz, 1999, pp. 249-256.

[4] Alfred von GUTSCHMID, "Die Nabatäische Landwirthschaft und ihre Geschwister", *Zeitschrift der Deutschen morgendländischen Gesellschaft* 15 (1861), 1-110.

[5] Joseph HAMMER, *Ancient Alphabets and hieroglyphic characters explained*, London, 1806.

[6] Joseph von HAMMER-PURGSTALL, *Erinnerungen aus meinem Leben* (17774-1852), Wien – Leipzig, 1940.

On Jābir b. Aflaḥ's Criticisms of Ptolemy's *Almagest*[*]

José Bellver

In this paper I intend to draw some conclusions from my ongoing study of the initial chapters of Jābir b. Aflaḥ's *Iṣlāḥ al-Majisṭī*.[1] Although we do not possess a great deal of information on the author from external sources such as bio-bibliographical repertories, the *Iṣlāḥ al-Majisṭī* itself can be used to shed light on the motivations behind its composition and on the character and background of the author. I shall endeavour to summarize these here.

Jābir b. Aflaḥ al-Ishbīlī, known as Geber filius Afflay Hispalensis in medieval Western Europe, was a mathematician and theoretical astronomer who most probably flourished in Seville during the first quarter of 12th century.[2] Jābir b. Aflaḥ is a leading figure in medieval astronomy thanks to the *Iṣlāḥ al-Majisṭī*, his *magnum opus* which was translated into Latin and Hebrew.[3] The *Iṣlāḥ al-Majisṭī* can be considered a unique work in medieval Islamic astronomy in the West for a number of reasons.

[*] The present paper has been prepared within the research programme "Science and Society in the Western Mediterranean in the Late Middle Ages", sponsored by the Spanish Ministry of Education and Science (HUM2004-02511) and FEDER.

[1] The best introduction to Jābir b. Aflaḥ is R. P. Lorch (1975), "The Astronomy of Jābir b. Aflāḥ", *Centaurus*, Vol. 19, pp. 85-107, which was reprinted in R. P. Lorch (1995a), *Arabic Mathematical Sciences: Instruments, Text, Transmission*, Variorum, Aldershot, VI.

[2] See Lorch (1975), pp. 85-6.

[3] During this research we mainly considered the only three extant Arabic manuscripts in Arabic script: Mss. Escorial 910 [henceforth referred to as Es^1], Escorial 930 [henceforth referred to as Es^2] and Berlin 5653 [henceforth referred to as B.]. In some sections of the *Iṣlāḥ al-Majisṭī*, Mss. Escorial 910 and Berlin 5653 differ, while Ms. Escorial 930 follows one or the other. On the *Iṣlāḥ al-Majisṭī*'s manuscripts, see Lorch, R. P. (1995b), "The Manuscripts of Jābir's Treatise", in R. P. Lorch (1995a), *Arabic Mathematical Sciences: Instruments, Text, Transmission*, Aldershot, VII.

Firstly, the only topic dealt with in the work is Ptolemy's *Almagest*. This is the first of only a few occasions that this occurs in western Islamic astronomy.[4] In this sense, it is worth recalling a later work by Ibn Rushd, *Mukhtaṣar al-Majisṭī*,[5] which is a summary of the *Almagest* but a far less ambitious text than Jābir b. Aflaḥ's *Iṣlāḥ al-Majisṭī*.

Secondly, Jābir b. Aflaḥ focuses only on theoretical astronomy, since he is interested primarily in the underlying mathematical structure of the *Almagest*. This distances him from the great majority of astronomers of his time, since even the most theoretical astronomers, who ultimately dedicated their work to depicting more accurate models, had only practical purposes in mind. I refer here, for example, to astronomers such as Ibn al-Zarqālluh, who developed trepidation models in order to obtain more accurate astronomical tables.

Thirdly, Jābir b. Aflaḥ bases the *Iṣlāḥ al-Majisṭī* exclusively on the *Almagest* and does not refer to, or even consider, any enhancements of Ptolemaic astronomy made by later astronomers. In the Introduction to his work, he mentions only Greek mathematicians such as Euclid and Menelaus.

Finally, Jābir b. Aflaḥ occasionally introduces criticisms of certain errors –or, at least, points that he considered to be errors– found in the *Almagest* and provides the necessary corrections. Given the historical context of the *Iṣlāḥ al-Majisṭī*, in which some criticism was made from the point of view of philosophical cosmology, in addition to improvements to the astronomical models presented in the *Almagest*, Jābir b. Aflaḥ's criticisms warrant closer study to determine their exact nature.

Therefore, the unique character of the *Iṣlāḥ al-Majisṭī* derives from the fact that it is not, or at least not exclusively, a compendium, nor is it a commentary on or criticism of the *Almagest*, but rather a corrected re-edition of the *Almagest* in the form of a handbook.

These initial impressions of the *Iṣlāḥ al-Majisṭī* are reinforced by Jābir b. Aflaḥ's Introduction, in which he summarizes the aims of the work.[6] First of all, he considers the position of astronomy within the sciences as a whole. He points out that astronomy, due to the eternally regular nature of its contents and to its clear and certain methodology, is second in importance only to the religious science *par excellence*, which is the science of Law or *Sharīʿa*. Even though the framework of his

[4] For a list of the Arabic commentaries on the *Almagest*, cf. F. Sezgin (1978), *Geschichte des arabischen Schrifttums*, Band VI, Leiden, pp. 90-4; Ḥājjī Khalīfa, *Kashf al-Ẓunūn ʿan asāmī al-kutub wa-l-funūn*, 3 vols., Tehran, 1967 (3rd ed.), vol. II, col. 1094-6.

[5] Cf. J. Lay (1996), "*L'Abrégé de l'Almageste*: un inédit d'Averroès en version hébraïque", *Arabic Sciences and Philosophy*, Vol. 6 (1996) 1ª parte, pp. 23-61.

[6] For this quotation, cf. Mss. Es[1] ff. 2v-4r, Es[2] ff. 1v-3v and B. ff. 1v-3r.

classification is clearly a product of Islamic thought, he bases it on Ptolemy's Introduction to the *Almagest*, in which the contents and methodology of astronomy are described in similar terms.[7]

Jābir b. Aflaḥ then defines the science of astronomy (*ʿilm al-hay'a*, lit. 'science of structure'), which "consists of [the study of] the motions of the Sun, the Moon and the stars (*nujūm*)[8] and the knowledge of their spheres (*aflāk*)",[9] and points out that the main source for studying this science is Ptolemy's *Almagest*, a book that "is sufficient in order to master this science since it gathers together all of its content".[10] Therefore, we can infer from these quotations and from the content of the *Iṣlāḥ al-Majisṭī* that Jābir b. Aflaḥ considers *hay'a* to be mathematical astronomy and not cosmology.[11]

The central role played by the *Almagest* in astronomy led him, as he claims in his Introduction, to study the entire work in order to master this scientific discipline. However, he considered it to be a very difficult proposition for students. In his analysis, Jābir b. Aflaḥ considers five main problems faced by students of the *Almagest*. He makes the following points:

- The *Almagest* mixes theoretical and practical contents, but the practical contents (i.e. the operations) dilute the theoretical contents and make the work harder to understand.
- Throughout the *Almagest*, Ptolemy uses Menelaus' Theorem, which is difficult to master.
- Ptolemy refers to works by Menelaus and Theodosius, which are complicated and abstruse, and therefore dissuades students from studying the *Almagest*.
- Ptolemy oversimplifies his discussion in various sections of the book, which can confuse students.
- The sentences of the translated text do not seem to be ordered correctly, which prolongs the study of the book unnecessarily.

We can see from these criticisms that Jābir b. Aflaḥ evaluates the *Almagest* from a pedagogical point of view. This analysis leads him to

[7] See *Almagest* I.1. For Toomer's translation, cf. G.J. Toomer (1984), *Ptolemy's Almagest*, London [henceforth referred to as PtA], pp. 35-36.
[8] Ptolemy considers the word 'star' to include stars, planets and sometimes the Sun and the Moon. Cf. PtA p. 37, n. 8. Jābir b. Aflaḥ seems to follow Ptolemy by considering the planets as stars.
[9] Cf. Mss. Es[1] f. 2v, Es[2] f. 1v and B. f. 1v.
[10] *Ibidem*.
[11] For a discussion on the concept of *hay'a* in the Andalusian astronomical tradition prior to Jābir b. Aflaḥ, mainly as used by *qāḍī* Sāʿid in his *Ṭabaqāt al-Umam*, see J. Samsó (1994b), "Biṭrūjī and the *hay'a* tradition" in J. Samsó (1994a), *Islamic Astronomy and Medieval Spain*, Variorum, Aldershot, XII, especially pp. 1-5. This paper was first presented at the International Symposium for the History of Arabic Science held in Granada (April-May, 1992).

produce an enhancement (*iṣlāḥ*) of the *Almagest*, always with his pedagogical purpose in mind. Thus, he states that once he had mastered the contents of the *Almagest*, he continued "the research and reflection to fulfil the desire to learn this enormous science and to move closer to understanding this immense book".[12] These improvements were the basis of what was to be his most significant work, the *Iṣlāḥ al-Majisṭī*.

Jābir b. Aflaḥ structures his re-edition across different lines of argument, which he describes in his Introduction. First, he devises a trigonometric introduction to the *Almagest*, in which he combines the spherical trigonometry and plane trigonometry needed to understand his rewriting of Ptolemy's work. His spherical trigonometry is based on different ratios of four elements including Sinus' Theorem and the Rule of the Four Quantities, while he desists from using Menelaus' Theorem. However, his plane trigonometry is the same as that used by Ptolemy.[13]

Next, Jābir b. Aflaḥ removes from his *Iṣlāḥ al-Majisṭī* any practical content that appeared in the *Almagest*. Therefore, no reference to actual data such as eclipses suitable for calculations and dates appears in the *Iṣlāḥ al-Majisṭī*. The book is therefore stripped of its calculations and simplified to a great extent.

Finally, he attempts to make up for the shortcomings of the *Almagest* by providing demonstrations where needed and clarifying the more obscure points in the text.

However, his re-edition focuses not only on the way in which the *Almagest*'s content is presented but also on the content itself, since he also introduces a number of corrections to Ptolemy's astronomy. In the final part of his Introduction to the *Iṣlāḥ al-Majisṭī*, Jābir b. Aflaḥ lists the errors found in Ptolemy's book and the sections of his own work in which the corrections can be found.[14]

Since his most famous criticism of Ptolemy –related to the order of the planets, in which he considers Mercury and Venus to be above the Sun– has profound consequences in Ptolemaic cosmology, Jābir b. Aflaḥ could easily be seen as a forerunner of the Andalusian philosophers of the 12th century, who criticized the incongruence of Ptolemaic astronomy from the point of view of Aristotelian Physics. We therefore come to the question of what type of criticisms Jābir b. Aflaḥ makes of Ptolemy's *Almagest*. To answer this question I studied the criticisms found in the books of the

[12] Cf. Mss. Es^1 f. 3r, Es^2 f. 2r and B. f. 2r.
[13] On Jābir b. Aflaḥ's trigonometry, see R. P. Lorch (1995c), "Jābir ibn Aflaḥ and the Establishment of Trigonometry in the West" in R. P. Lorch (1995a), *Arabic Mathematical Sciences: Instruments, Text, Transmission*, Aldershot.
[14] Cf. Mss. Es^1 ff. 3v-4r, Es^2 ff. 3r-3v and B. ff. 2v-3r.

Iṣlāḥ al-Majisṭī devoted to the Sun, the Moon and the eclipses, i.e. Books IV and V, which are the first to appear in his list of errors.

Jābir b. Aflaḥ's first criticism[15] concerns *Almagest* IV.2[16], where Ptolemy discusses the Hipparchian method for finding the lunar anomaly period using four lunar eclipses which must fulfil a series of conditions regarding the lunar position in each and the time elapsed between pairs.[17] However, these conditions do not determine only a single lunar anomaly period, so further considerations must be made in order to identify the correct one. However, in doing so, Ptolemy unnecessarily complicates his explanation. Jābir b. Aflaḥ adds some further conditions to Ptolemy's initial ones. Although the method presented by Ptolemy is fairly accurate, it is greatly simplified by the conditions added by Jābir b. Aflaḥ. In addition, Jābir b. Aflaḥ makes a very severe criticism of Ptolemy's knowledge of Geometry. This is obviously a minor correction of Ptolemy's astronomy and is not related to cosmology.

The second criticism focuses on *Almagest* V.10[18], where Ptolemy discusses whether the second and third lunar anomalies influence the syzygies. Although Jābir b. Aflaḥ claims that Ptolemy's demonstration is correct, he also points out an inconsistency between the correct demonstration and the abridged solution that is used to introduce the demonstration.[19] At this point, he suspects that this discrepancy is the fault of the translators, so he is careful to point out that he has consulted copies of the *Almagest* translations by al-Ḥajjāj and by Isḥāq b. Ḥunayn, although he found only minor differences. This criticism shows that Jābir b. Aflaḥ made a very close reading of the *Almagest*.

His next criticism concerns *Almagest* VI.5, where Ptolemy deals with the ecliptic limits in which, given a mean syzygy, solar and lunar eclipses can take place.[20] Therefore, he needs to obtain a mean syzygy from an apparent one in which a minimum eclipse can take place, although, in an intermediate step, he also requires the true syzygy. Jābir b. Aflaḥ[21] points out that Ptolemy adds the difference between the mean and true syzygies to the Moon's nodal distance during the apparent syzygy, thus obtaining the true nodal distance during the apparent syzygy and not the true syzygy

[15] Cf. Mss. Es[1] ff. 39v-42v, B. ff. 38v-42r and Es[2] ff. 43v-48r.

[16] Cf. PtA 174-9 and O. Neugebauer (1975), *A History of Ancient Mathematical Astronomy*, 3 vols., Berlin – Heidelberg – New York [henceforth referred to as HAMA], pp. 71-3.

[17] See J. Bellver (2006), "Jābir b. Aflaḥ on the four-eclipse method for finding the lunar period in anomaly", *Suhayl*, Vol. 6 (2006), pp. 159-248 for an edition, translation and study of this criticism.

[18] Cf. PtA pp. 239-43 and HAMA pp. 98-99 and 1234.

[19] Cf. Es[1] ff. 50r-51r, Es[2] ff. 57r-58v and B. ff. 49v-50v.

[20] Cf. PtAT pp. 282-7, HAMA pp. 125-9 and 1240 and O. Pedersen (1974), *A survey of the Almagest*, Odense [henceforth referred to as Pedersen], pp. 227-30.

[21] Cf. Es1 ff. 56v-58v, Es2 ff. 67v-70r and B. ff. 58v-60v.

as he claims. He then shows that this difference must be added to the nodal distance during the true syzygy and corrects the entire method. Unlike Ptolemy, Jābir b. Aflaḥ uses spherical trigonometry instead of plane trigonometry. Again, Jābir b. Aflaḥ reveals himself to be an extremely careful reader. As previously, the criticism is not related to cosmology.

His next criticism refers to *Almagest* VI.7 to VI.9, in which Ptolemy develops his method for calculating the magnitude and phases of lunar eclipses.[22] The method for solar eclipses is the same, once the lunar parallax has been accounted for. Ptolemy uses two tables to obtain the eclipse magnitude and phases: one when the Moon is in its apogee and the other when the Moon is in its perigee. Next, the results obtained with both tables are interpolated for a given anomaly using an interpolation table. Jābir b. Aflaḥ proposes an original method through which he avoids using tables and interpolation.[23] He also offers a criticism and correction of Ptolemy's interpolation method, in addition to his novel suggestion. However, his correction of Ptolemy's method in fact reproduces the same method that can be found in the *Almagest*. Since he quotes inaccurately from Isḥāq b. Ḥunayn's translation of the *Almagest* we can conclude that this criticism is due only to an error in the manuscript that he used. Nevertheless, he makes very strong criticisms of Ptolemy, although these are not related to cosmology.

The three subsequent criticisms also focus on sections VI.7 to VI.9 of the *Almagest*, in which Ptolemy again discusses solar eclipses.[24] However, before explaining his criticisms on this point, Jābir b. Aflaḥ discusses his method for dealing with the effect of parallax on solar eclipses. His method is very similar to that of Ptolemy, although it is much clearer and shows some slight variations. However, he also commits an error of his own, since he does not take into account the additional solar motion when considering the effect of lunar parallax and epiparallax in solar eclipses. The Mss. Escorial 910 and Berlin versions differ on this point: from the point of view of astronomy, the Berlin version is the correct one.

In his first criticism of solar eclipses, for which Ptolemy determines the true conjunction from the apparent one, Jābir b. Aflaḥ states that Ptolemy uses the meridian for deciding whether to add or subtract a temporal correction, but this is not actually the case. This is likely to be another error of transmission, since his corrected method is in fact the same as Ptolemy's.

[22] Cf. PtAT pp. 294-310, Pedersen pp. 231-235 and 1240 and HAMA pp. 134-139.
[23] Cf. Es[1] ff. 62r-64r, Es[2] ff. 74v-77r and B. ff. 64r-66r.
[24] Es[1] ff. 64v-67r, Es[2] ff. 78r-80v and B ff. 66v-68v.

Jābir b. Aflaḥ also criticizes Ptolemy for stating that the immersion and emersion phases of a solar eclipse are only equal when the mid-eclipse is on the meridian. Ptolemy is only considering the motion of the ecliptic through the horizon, not the motion of the Moon in its inclined orbit. Instead, Jābir b. Aflaḥ considers that the immersion and emersion phases of a solar eclipse are only equal when the eclipse is on the mid-heaven of the ascendant. Therefore, he is only considering the motion of the Moon through its inclined orbit, not the motion of the ecliptic through the horizon. However, the correct solution should take into account both motions. Therefore, his criticism is correct, but his solution is not.

Jābir b. Aflaḥ's final criticism of the solar eclipse theory concerns Ptolemy's determination of the lunar parallax in latitude. In fact, this criticism is derived from another manuscript error, since Jābir b. Aflaḥ's solution is the same as Ptolemy's and the corresponding quotation from the *Almagest* appearing in the *Iṣlāḥ al-Majisṭī* is clearly inaccurate.

The final criticism found in Books IV and V of the *Iṣlāḥ al-Majisṭī* deals with *Almagest* VI.11 to VI.13, in which Ptolemy studies a method for calculating the inclination of eclipses on the horizon, which was probably used to obtain astrometeorological predictions.[25] Ptolemy simplifies the method greatly by using plane trigonometry and approximations. Jābir b. Aflaḥ provides a corrected solution that instead uses spherical trigonometry.

Conclusions

First of all, it must be pointed out that the author's principal aim is to re-write the whole of Ptolemy's *Almagest* essentially for pedagogical purposes. The *Iṣlāḥ al-Majisṭī* must be considered in this light if it is to be placed in its correct context. Jābir b. Aflaḥ's criticisms of the *Almagest* are secondary to his fundamental pedagogical purpose.

However, in the context of medieval western astronomy, this is a remarkable event. The fact that he intended to rewrite the *Almagest* presupposes that Jābir b. Aflaḥ understood the work in its entirety. This places Jābir b. Aflaḥ among the very few medieval astronomers who could lay claim to this achievement, particularly if we consider that early medieval astronomy can be seen as a series of attempts to understand it.

The corrections postulated in Jābir b. Aflaḥ's criticisms of the *Almagest* have nothing to do with cosmology. Jābir b. Aflaḥ certainly cannot be considered alongside critics of Ptolemy such as the Andalusian

[25] Cf. PtA pp. 313-320, HAMA pp. 141-144 and 1244-1246.

philosophers of the 12th century, who were mainly concerned with the physical suitability of Ptolemaic models.

Rather, Jābir b. Aflaḥ wishes to correct some inconsistencies found in the *Almagest,* which can be classified in various types. First, he points out technical, astronomical errors that can be largely attributed to a lack of thoroughness. Such mistakes include the one highlighted by Jābir b. Aflaḥ when dealing with the limits of an eclipse.

Second, he identifies inconsistencies between what Ptolemy states in one part of the *Almagest* and his actual procedures when he requires prior statements as a premise for further developments in other sections. This type of error is indicated by his criticism of Ptolemy's stated order of the planets, although this was not considered here.

Third, he makes criticisms which do not refer to errors *per se*, but to what could be termed "inelegant" demonstrations in the *Almagest*. These are shown by his criticism of the four-eclipse method for finding the lunar period in anomaly.

Finally, he also points out errors –at least, he considers them to be errors– that are in fact due to missing sections in the manuscript of the *Almagest* he used when he wrote the *Iṣlāḥ al-Majisṭī*. I was surprised to discover that problems due to the manuscript of the *Almagest* he used play a major role in the compilation of these "errors" in the *Iṣlāḥ al-Majisṭī*. These include the error considered when dealing with lunar eclipses.

In any case, these errors are only of a mathematical, technical nature. While some may have had profound cosmological implications and a strong influence on later astronomers, the errors themselves are minor corrections to geometrical errors or inconsistencies. Jābir b. Aflaḥ does not wish to change the premises upon which Ptolemy's astronomy is built.

From reading the books of the *Iṣlāḥ al-Majisṭī* devoted to the lunar theory and to the theory of syzygies and eclipses, certain conclusions on the author can be drawn.

First, Jābir b. Aflaḥ is primarily a mathematician. He makes this point in his Introduction to the *Iṣlāḥ al-Majisṭī*, since he states that "We strove using our previous experience in the art of Geometry and our ease with it until […] we understood all the contents of this book on astronomy (*ʿilm al-hay'a*)".[26] He is probably a professor of mathematics, if we consider his knowledge of Geometry and his concerns with pedagogical issues.

Even though he does not take into account astronomers after Ptolemy, Jābir b. Aflaḥ clearly has some knowledge of their work since he

[26] Cf. Es[1] f. 3r, Es[2] f. 2r and B. f. 2r.

mentions the literature of tables[27] and mentions an unnamed contemporary astronomer in his discussion of the order of the planets.[28]

Some of the errors he points out demonstrate that he is an extremely careful reader of Ptolemy's *Almagest*, since he highlights points that were overlooked even by Neugebauer and Toomer.

Even though Jābir b. Aflaḥ is reediting the *Almagest*, he is not merely a copyist, since he understands all of the contents he presents in his *Iṣlāḥ al-Majisṭī*. Moreover, although he follows the *Almagest* closely, he occasionally provides improved methods –such as his method for calculating lunar eclipses, for example– so he deserves to be considered as a creative and original theoretical astronomer.

The number of criticisms that can be attributed to his incomplete copy of the *Almagest* shows that the *Iṣlāḥ al-Majisṭī* was not corrected by any other astronomer before being published. This suggests that Jābir b. Aflaḥ worked alone or, at least, that he was the most proficient astronomer of his close circle.

The mistake he commits by neglecting the additional solar motion when considering the effect of the lunar parallax and epiparallax on solar eclipses shows that he never calculated a solar eclipse. Therefore, we can conclude that he was not a skilled practical astronomer.

Of the extant Arabic manuscripts in Arabic script, the Berlin manuscript is the closest to Jābir b. Aflaḥ's hand, as it is the most accurate from an astronomical perspective, as shown by the mistake found in Ms. Escorial 910 in the discussion of solar eclipses. It is fairly unlikely that MS. Escorial 910 would be Jābir b. Aflaḥ's second rewriting of the *Iṣlāḥ al-Majisṭī*, as it is now extant.

[27] Cf. Es[1] f. 3v, Es[2] f. 3r and B. f. 2v.
[28] Cf. Es[1] f. 80v, Es[2] f. 98v and B. f. 82v.

Transmission of Knowledge

Embedding Scientific Ideas as a Mode of Science Transmission*

George Saliba

Introduction

At a different occasion I had attempted to survey the results that have already been reached regarding the transmission of scientific ideas from the world of Islam to the scientists of the European Renaissance.[1] In that survey, I included some of those details which have been well known in the literature since the late fifties of the last century, while I added others that were either less known, or have been more recently explored and documented. I used the discipline of astronomy as a template to record the transmitted ideas and hoped that other people, who work on other disciplines, would do the same, all in an effort to paint a fuller picture of the situation that prevailed around the Mediterranean during the sixteenth and seventeenth centuries.

Problems of Detecting Contacts

In the field of astronomy, which happens to be the most fecund of all the scientific fields, tracing the transmission of astronomical ideas from the Islamic world to Europe proves to be rather challenging for two main reasons: When texts were plainly and admittedly translated from Arabic into Latin, and that happened mainly during the Middle Ages, sometime

* The first version of this paper was delivered at a conference *A Shared Legacy: Islamic Science East and West*, which was hosted by the University of Barcelona in April 2007, for whose support and facilities to attend this conference is here gratefully acknowledged.

[1] See my most recent book *Islamic Science and the Making of the European Renaissance*, MIT Press, 2007.

between the tenth and the fourteenth centuries, the problem that was hardest to answer was: why some texts were translated while others were not? Why were the works of Muḥammad b. Mūsā al-Khwārizmī (d. c. 850) translated, his Indian arithmetic, his algebra, as well as his astronomical tables, while the astronomical tables and other mathematical works of his contemporary, and in many ways just as brilliant, Ḥabash al-Ḥāsib (d. c. 870) were not?

In the case of the Renaissance the situation becomes much more complex. For by that time, that is, after the fifteenth and during the sixteenth centuries, we rarely find Arabic books that were explicitly translated into Latin, as was the case in medieval times. Of course we are not talking about the conscious efforts by people like Andreas Alpagos who undertook the challenge to re-translate the works of Avicenna in particular, for those were simply revisions of translations already completed before. Nor are we talking about the very few attempts that were made during the seventeenth century to translate one book here or one treatise there as was the case during the earliest stages of what later became the tradition of Orientalism. Those attempts are a category by themselves for they were mainly executed with an archaeological purpose in mind and were mostly motivated by the curiosity that became notorious during the later colonial period, and prepared the ground for the fictitious Orient that was finally created in the European mind, an Orient that became the hallmark of Orientalism.[2] The complex issues that began to appear in the Renaissance, and were rarely recognized before, had to do with a completely different kind of transmission of scientific ideas. The phenomenon I wish to single out, and which I would call embedding rather than transmission, is that of a transmission process through which Renaissance scientists, and sometimes also humanists, read texts in the original Arabic, grasped the ideas contained in those texts, and then incorporated those ideas in their own works. Of course, their resulting works were produced in Latin.

During this process, detecting lines of transmission, especially in the case of humanistic texts, becomes much more difficult, and at times even contentious. Issues of whether Dante read the *Miʿrāj* stories of prophet Muḥammad before he wrote his *Divine Comedy* or not, give only one sample of such difficulties. And if true, such a process of embedding could be barely detected in the works of Dante, notwithstanding the disputes that surround it and still stir up much debate. This very process of

[2] See Edward Said, *Orientalism*, Pantheon, 1978.

embedding may in fact be a forerunner of what seems to have happened at a much larger scale during the Renaissance.

Those who work with scientific texts are slightly more fortunate than their fellow humanists simply because it is slightly easier to prove the process of embedding in scientific texts than it is in humanistic ones. It is the very nature of those scientific texts that allowed someone like Neugebauer, Kennedy and generations of the latter's students after him to pronounce immediately that what they saw in the lunar model of Copernicus (d. 1543) was in fact a case of embedding the lunar model of Ibn al-Shāṭir (d. 1375). And yet, we can still hear people arguing for the case of independent discovery, and that one should not yet talk of embedding or transmission of the ideas of Ibn al-Shāṭir by or to Copernicus without demonstrating the exact route by which Ibn al-Shāṭir's ideas reached Copernicus. Independent discovery is in fact a plausible argument, and we have many examples of such occurrences in the history of science. But the case of Ibn al-Shāṭir's lunar model, the story of coincidence is slightly more complex. To start with, it is a geocentric model unlike the other Copernican models, not only because it fits better with an Aristotelian cosmology, but because the moon is in fact an earthly satellite. Second, Ibn al-Shāṭir's model was designed to solve in one stroke two major problems in the Ptolemaic lunar model: (a) it solved the equant-like behavior of the Ptolemaic model, and (b) it resolved the distortion that the Ptolemaic model introduced to the apparent size of the lunar disk at quadrature. Third, Ibn al-Shāṭir's model was also designed to dispense with the concept of prosneusis that had bedeviled the Ptolemaic model and had caused much controversy in Islamic astronomy. When all those factors are taken into consideration it becomes clear that all those purposes that motivated Ibn al-Shāṭir's model, and the multiple layers of technical intricacies it resolved, make it highly unlikely that two people would coincidentally come upon it unless they were both seeking to resolve all those problems of the Ptolemaic model and from within the same Aristotelian cosmology. To think that the same complexities and the same motivations could be attributed to Copernicus in order to explain his adoption of Ibn al-Shāṭir's lunar model complicates the story of independent discovery, not to say that it makes it incredible. Let us at least say that one's imagination has to be stretched a little in order to believe that such coincidences could occur.

The fact that we still do not know the exact route by which Copernicus knew of Ibn al-Shāṭir's lunar model, before he decided to adopt it, and yet we can make such claims of indebtedness on the part of Copernicus, is only a feature of the nature of scientific texts that allow such conjectures.

As we just said, the scientific intricacies of Ibn al-Shāṭir's model and its complexity and multiple purposes, as well as its demonstrable equality with that of Copernicus, angle for angle, sphere for sphere, and the historical fact that Ibn al-Shāṭir died exactly a hundred and sixty-eight years before Copernicus, make the story of independent discovery much less likely. And yet it is not impossible to imagine.

Had the story stopped with the lunar model, this particular case of embedding would have remained a tantalizing conjecture, and we would have all continued to wait for the day when we could indeed account for what is sometimes called "the smoking gun" that would demonstrate the route through which Copernicus came to know of Ibn al-Shāṭir's work.

The plot thickened, however, when it was found out that Copernicus also used a mathematical theorem, now commonly known as the Ṭūsī Couple, which was discovered by another astronomer, Naṣīr al-Dīn al-Ṭūsī (d. 1274), who lived even another hundred years earlier than Ibn al-Shāṭir. As it turned out, Copernicus did not only use this theorem, but offered to prove it. It was in the proof that he reproduced the same geometric points that were used by Ṭūsī before. One could still stretch his imagination and say that it was a series of coincidences. But then there was a "smoking gun" in this case. There was one geometric point that indicated the center of the smaller sphere in the Ṭūsī Couple where Ṭūsī had designated it with the Arabic letter "*zain*". All other points were the same, that is the Arabic letters used by Ṭūsī were duplicated, point for point, with their Latin phonetic equivalents by Copernicus. For this particular point, Copernicus used the Latin letter "F", instead of the expected "Z". This single variation could only mean that he, or someone helping him, obviously misread the Arabic "*zain*" for an Arabic "*fā'*". In fact the two letters are very similar in the Arabic script, and, depending on the manuscript that he or his assistant were working from, it would be very easy to mistake a "*fā'*" for a "*zain*". Thus the likelihood that Copernicus would have his own random selection of alphabetic designators to mark the same points that were marked by Ṭūsī with the same phonetic equivalences is very slim indeed, and in light of that one has to begin to loose faith in the theory of independent discovery.

But when it was further found that Copernicus also used the same model for the upper planets that was used by Ṭūsī's colleague and friend Mu'ayyad al-Dīn al-ʿUrḍī (d. 1266), of course after making the easy mathematical shift from geocentrism to heliocentrism, and this time neglecting to prove the lemma that was devised by ʿUrḍī and proven by him for the purpose, the problem of independent discovery became even harder to maintain. This lapse in Copernicus's construction of 'his own' mathematical model for the upper planets prompted Kepler to write to his teacher Maestlin and inquire about this particular proof of this rather simple theorem, now dubbed as the ʿUrḍī lemma, and Maestlin duly complied with his request.[3] One can see how complex scientific texts could allow us to reach such conclusions regarding the embedding of scientific ideas even if we had no clue regarding the route through which Copernicus must have known about these earlier results.

The coup de grace came when Copernicus reached the construction of his model for the planet Mercury. There too, Ibn al-Shāṭir had constructed a model of his own that avoided the equant problem of Ptolemy's model, but preserved the essential features of the Ptolemaic observational results, namely, that the planet Mercury should have one apogee in the constellation of Libra and two perigees at ± 120º on either side of it. The very problem of two perigees came about from the Ptolemaic observational problem where it was thought that Mercury had its maximum elongations from the sun at those two points, i.e. it appeared to the observer, on the earth, to have the largest epicycle at those points. In order to achieve all these cosmological purposes and remain faithful to the Ptolemaic observational results, Ibn al-Shāṭir had to use the Ṭūsī Couple within the construction of the model in order to allow Mercury's epicycle to expand and contract, so that it would look small at apogee, and large enough at the two perigees. This was relatively simple for Ibn al-Shāṭir since the Ṭūsī Couple was specifically designed to take care of such cases of expansion and contraction while remaining within the conceptual domain of Aristotelian cosmology. Put simply, the Ṭūsī Couple was developed specifically to obtain linear motion, the expansion and contraction in this case, as a result of the Aristotelian required uniform circular motion.

Now, in his own construction of the Mercury model, Copernicus adopts the same technique as Ibn al-Shāṭir, that is, he used the same Ṭūsī Couple for the same expansion and contraction purposes that were used by Ibn al-Shāṭir. And he also accounted for the equant in exactly the same way it was accounted for by Ibn al-Shāṭir. But here again there was another "smoking gun". In adopting Ibn al-Shāṭir's very complicated model Copernicus got confused between the absolute size of Mercury's epicycle and the size it would *appear* to an observer on earth, and made the absurd statement that the model would yield a maximum elongation at a distance of 90º from the apogee. He apparently forgot that size depended on two

[3] See Anthony Grafton, "Michael Maestlin's Account of Copernican Planetary Theory." *Proceedings of the American Philosophical Society* 117, no. 6 (1973): 523–550.

variables: the absolute size of the object, and the distance of the object from the observer. For although Mercury's epicycle does in fact reach its maximum expansion at 90º away from the apogee, for an observer at the earth it would still not look as big as the contracted epicycle which would be brought closer by the motion of the model to the observer at 120º on either side of the apogee. When Swerdlow noted this discrepancy in Copernicus's construction of the Mercury model, as he translated Copernicus's earliest astronomical treatise, the *Commentariolus*, he had this to say about it:

> "There is something very curious about Copernicus's description. [...] Copernicus apparently does not realize that the model was designed, not to give Mercury a larger orbit (read *epicycle*) when the Earth (read *center of the epicycle*) is 90º from the apsidal line, but to produce the greatest elongations when the Earth (read *center of the epicycle*) is ± 120º from the aphelion (apogee)."[4]

He then went on to say:

> "This misunderstanding must mean that Copernicus did not know the relation of the model to Mercury's apparent motion. Thus it could hardly be his own invention for, if it were, he would certainly have described its fundamental purpose rather than write the absurd statement that Mercury "*appears*" to move in a larger orbit when the Earth is 90º from the apsidal line. The only alternative, therefore, is that he copied it without fully understanding what it was really about. Since it is Ibn ash-Shāṭir's model, this is further evidence, and perhaps the best evidence, that Copernicus was in fact copying without full understanding from some other source, and this source would be an as yet unknown transmission to the west of Ibn ash-Shāṭir's planetary theory." [italics mine][5]

The series of "coincidences" mentioned before, as well as the misreading and "misunderstanding" just mentioned, makes it clear that Copernicus was not working independently of the Arabic texts that had been written in the previous two centuries or so. The fact that we can assert such claims demonstrates the power of scientific texts which allow us to determine indebtedness, incorporation, embedding, direct and indirect transmission, etc., without necessarily knowing the manner in which those contacts took place. Similar cases in humanistic texts would be much harder to establish.

Other instances of such embeddings are a little easier to establish in the opposite direction, that is, when we know the Arabic texts that were read by Renaissance scientists, but we still do not know exactly how they were

[4] Nowel Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory: A Translation of the Commentariolus with Commentary." *Proceedings of the American Philosophical Society* 117, no. 6 (1973): 423–512, esp. p. 504

[5] *Ibid.*

used by those scientists in their Latin habitat. I have had occasion to study Arabic manuscripts that were read by one of Copernicus's younger contemporaries, Gillaume Postel (1510-1581). One of those manuscripts is preserved at the Vatican Library, while the other at the Bibliothèque Nationale de France. Both manuscripts have Postel's handwritten annotations on their margins. I used those manuscripts for an article, which I published on the internet, in order to raise the question: whose science was Arabic science in Renaissance Europe?[6] In that article I demonstrated how someone like Postel would read Arabic astronomical manuscripts one day, annotate them, and in some instances even correct them, and the next day he would deliver his lectures at the Institut Royal, now College de France, obviously in Latin. Just think of the complexity of ideas being originally in Arabic, themselves written to challenge Greek astronomy, and after being digested by Postel were embedded in his lectures which were obviously delivered in Latin.

I used that example to question the applicability of such concepts as Arabic science, Latin science, Greek science and the like when we know, as in the example of Postel, how ideas were actually constructed through many layerings of those languages, religions, and cultures to which those sciences are usually ascribed. In it I called for a new historiography of science that accounts for such instances of embeddings as Postel's and Copernicus's.

One More Incorporation: The Case of Ighnāṭius Niʿmatallāh (d. c. 1590) and the Gregorian Reform of the Calendar

Now that we have shed a badly needed light on the poorly studied phenomenon of embedding as a mode of transmission that was apparently quite common during the Renaissance, a phenomenon that did not involve specific texts being translated as was done during the Middle Ages, we can then approach the Renaissance with a much more open mind. Once we do that, we are likely to find many more contacts than the ones we have already mentioned. In what follows, I will focus on one particular instance where transmission was not specifically sought out by Renaissance orientalists, as was done by Postel and others, but by a fortuitous offer by an occidentalist, if you wish, who simply managed to have his ideas incorporated by Renaissance scientists, also without producing fully translated texts from the original Arabic.

6 George Saliba, "Whose Science is Arabic Science in Renaissance Europe?," http://www.columbia.edu/~gas1/project/visions/case1/sci.1.html

The occidentalist in question was a colorful character by the name of Ighnāṭius (Ignatius) Niʿmatallāh (Niʿmeh), known variously as Niʿmeh in the Eastern sources or Nehemias in the Latin ones. He was a patriarch of the Syriac Jacobite church and was raised to the see of the Antiochian patriarchate in the year 1557.[7] While still in Diyār Bakr (modern Diyarbakir in South East Turkey), this patriarch seems to have earned the confidence of the local Ottoman governor of the district. The Ottoman rule itself was at that time still on the ascension. It had been barely one hundred years since the successful conquest of Constantinople, the capital of the Byzantine Empire. And with its fall the Ottoman conquest ushered in the defeat of the last vestiges of Byzantine presence in Asia Minor. One could safely say that at the time Christian Ottoman relations were not at their best. In addition, and even without the ascension of the Ottomans, the Christians in that area were living in a political turmoil that had been worsening vis à vis their Muslim neighbors since the incursions of the crusaders between the 11th and 13th centuries, and reached an abyss amongst the Christians themselves when the fourth crusade 1204-1205 was redirected and finally launched against the capital city of Byzantium.

Thus by the middle of the sixteenth century, religious sensitivities and interfaith suspicions and intrigues had been ripening for centuries. It was not surprising, therefore, that the local Muslims were suspicious of a Christian patriarch like Niʿmatallāh gaining favor at the local governor's court, ostensibly as the governor's private physician on account of his expertise in Islamic medicine. Niʿmatallāh's expertise was not totally off the mark. Other independent facts corroborate this expertise, and in a future study, devoted to this man, I will demonstrate that the first printing of Avicenna's Arabic text of the *Canon* by the Medici's Oriental Press, in 1593 in Florence, used one of the manuscripts which were brought along to Italy by this same Patriarch. His relatively advanced medical scholarship, however, could not protect him from jealousies and intrigues at the Diyār Bakr court. Thus in a gesture of reconciliation, and probably intending to protect his private physician, the local governor took off his own turban one evening and placed it on the head of the patriarch, while

[7] The information on this Patriarch derives from several sources, most important among them is a note written by Yūḥannā ʻAzzô, the secretary of the Antiochian Syriac Patriarchate. This biographical note was used as an introduction to ʻAzzô's Arabic translation of the Syriac autobiographical letter that was sent by patriarch Ighnāṭius Niʻmeh (short for Niʿmatallāh) to his parishioners in Diyār Bakr (probably from Rome towards the end of the sixteenth century). See Yūḥannā ʻAzzô, "*Risālat al-batriyark Ighnāṭius Niʻmeh*," *al-Mashriq*, vol 31 (1933) pp. 613-623, 730-737, 831-838. A less reliable biographical note was added by Louis Cheikho, in a previous issue of the same journal to his article "*al-Ṭā'ifa al-mārūnīya wa-l-ruhbānīya al-yasūʿīya fī l-qarnayn al-sādis ʿashar wa-l-sābiʿ ʿashar*", *al-Masriq*, vol. 19 (1921), p. 139.

declaring that his own physician had by this gesture just converted to Islam. Conversion has a tremendous power, and many a sinful person was saved by the very act.

Historical reports tell us that the governor's gesture went well with his Muslim audience. But they also tell us that the very act of a patriarch converting to a different religion, whether Islam or otherwise, infuriated his own Christian parishioners, who now clamored for his head. Sensing a danger for his life, the hapless patriarch managed to appoint his nephew to his patriarchal see (apparently still had some clout among his Christian followers for such an act of nepotism), and to escape with his life in the year 1576 AD. In addition he apparently managed to haul along a relatively large collection of Arabic manuscripts. Concrete evidence of his escape still survives in a note appended to a manuscript, which is now kept, together with the rest of the patriarch's manuscripts, at the Laurentiana Library in Florence, Italy. The note says that he, "the lost soul, by the name of Patriarch Niʿmeh, finished resolving the problems in this manuscript while he was being tossed by the sea waves on his way to Venice, in the year 1888 of the Greeks (= 1577 AD)."[8]

Further background should at least partially explain the reasons why the Patriarch ventured on this dangerous trip in the first place, and should give us a clue as to what he expected to achieve with it. The decision taken by the Eastern Orthodox churches to split off from the Church of Rome in 1054 AD was unwelcome by the Vatican, and thus no effort was spared to re-integrate those churches back under the papal flag. The Syriac Antiochian church was one of those Eastern churches whose re-unification with the Church of Rome was at least promised by the Patriarch. That promise itself may have facilitated his reception at the papal see, when he finally arrived at Rome.

Thus far his motivation for taking the trip may be understandable. But what remains to be problematic is the reason why he decided to bring along a large number of Arabic manuscripts, mostly scientific ones, and what was he planning to do with those books. As we shall soon see, this problem remains unresolved unless we change our vision of the intellectual life during the Renaissance, and begin to appreciate the extent to which Islamic culture, and Islamic science in particular, had been

[8] Much of the information regarding the life of the Patriarch in Italy comes from the excellent work of John Robert Jones, *Learning Arabic in Renaissance Europe (1505-1624)*, Ph.D. dissertation, London University, 1988. This particular note is appended to the Laurentiana manuscript OR 177, fol. 79r. Several other Arabic manuscripts in the Laurentiana collection are clearly marked as having been owned by this Patriarch Iġnāṭius.

sought after during that time. So what was the Patriarch hoping to do with those books?

In hindsight, we now know that there was a good market for them in northern Italy, along the corridor that stretched from Venice in the North East down to Florence and eventually to Rome. The sources report that sometime during the Patriarch's trip from Venice to Rome, in the company of the converted Turk Paolo Orsini as his interpreter, the Patriarch made the acquaintance of the cardinal, and future Duke of Tuscany, Ferdinand de Medici, who was apparently considering the establishment of a press, later known as the Medici Oriental Press.[9] The Patriarch's books were definitely useful for the enterprise. We are told that Ferdinand struck a deal with the Patriarch in which the Patriarch would receive a monthly stipend of 25 scudes, and a life-long free access to his books, if he consented to deliver those books to a governing board of the press that was then headed by Raimondi, and who later became the owner of the same press.

All of these facts could not simply be happy circumstances. What is the likelihood of the convergence of such characters as a patriarch, traveling to Venice with a considerable load of Arabic books; a business/cleric/and future Duke from the banking family of the Medicis, interested in setting up an oriental press towards the end of the sixteenth century; and a Pope, interested in re-uniting the Eastern churches under the papal flag? The only explanation that could connect all those facts together is to assume that there was a lively intellectual and business environment in sixteenth century Italy that valued the sciences of, and possible business with, the Islamic world. A word of this interest must have already reached the Islamic lands so that the Patriarch could smell a commercial prospect for his books. The re-unification of the churches must have only been an excuse to facilitate the trip, for we know that nothing of the sort happened, and that a very small group of Eastern Christians had a long and checkered history with the Papacy who, at various stages of their history, all the way from the great schism of the eleventh century till the nineteenth century, split off and re-united themselves with the papal authority several times over.

[9] The information regarding the relationship between the Patriarch and Ferdinand de Medici and the matter of the press comes from, among others, John Robert Jones, *Learning Arabic*, *op. cit*, John Robert Jones, *The Arabic and Persian Studies of Giovan Battista Raimondi (c. 1536-1614)*, M. Phil dissertation, Warburg, London, 1981, and [John] Robert Jones, "The Medici Oriental Press (Rome 1584-1614) and the Impact of its Arabic Publications on Northern Europe," in *The 'Arabick' Interest of the Natural Philosophers in Seventeenth-Century England*, ed. G. A. Russell, Brill, Leiden, 1994, pp. 88-108. More information on this press and the role played by Ignatius Ni'meh, can be found in G. J. Toomer, *Eastern Wisedome and Learning*, Oxford University Press, Oxford, 1996.

At the Patriarch's arrival in Rome the reigning Pope, Gregory XIII (1572-1585), had other reasons to rejoice at meeting him. Not only did the Pope want to test the grounds for a campaign against the Turks,[10] but he also wanted to revive the Catholic church from the debilitating attacks it had received at the hands of the protestants. A patriarch from the Turkish lands of Islam, ostensibly wishing to re-unite his flock with the Pope's, would be very useful to the Pope, and a learned one to boot, who could be employed in the papal committee that was to achieve the single most famous act of this pope, namely, the Gregorian Reform of the Julian calendar, which eventually reestablished the Catholic church's authority, at least symbolically, in protestant lands.[11] Eastern orthodox churches, in countries where the Gregorian calendar is accepted by political authorities for civic purposes, still refuse to follow the ecclesiastical injunctions of this calendar, differing with it most notably over the Easter cycle. One should not underestimate the symbolism of this rejection as a means to safeguard the independence of the Eastern churches from that of Rome.

For the moment, I wish to leave aside the incorporation of the Patriarch's ideas into the production of the books at the Medici Oriental Press, for I would like to treat that issue at much greater length at a different occasion. But for now, let it be said that the first batch of printed Arabic books that this press issued from Florence, which were supposed to benefit the missionaries who were to proselytize in Arabic-speaking Islamic lands, included some four important scientific books, including Avicenna's *Canon* and a hybrid text of the revised *Elements* of Euclid. The manuscript copies for both of these books came from the Patriarch's library.[12] I note in passing that I find it hard to believe that anyone would deliberately use Euclid's *Elements* in order to proselytize among Muslims who had been using this book for almost a full millennium at the time. My contention is that the press had a European market in mind, and used the missionary work to avoid being censored by the Inquisition for producing Arabic books in the very heart of Christendom.

Now that I lay the matter of the Patriarch's role in the Medici Oriental Press aside, I wish to devote the rest of this paper to the Patriarch's role in the Gregorian calendar reform itself. Not much is known about the details

[10] For Gregory's interest in a Turkish campaign, see the *Catholic Encyclopedia*, *s.v.* Gregory XIII.
[11] See, for example Jones, *Learning Arabic*, p. 42, where he says: Ignatius "Ni'matallah brought more than political influence to Europe. He was educated in the lingua franca of the Middle East, Arabic, and he was familiar with the medicine, mathematics and astronomy of the region. Joseph Scaliger referred appreciatively several times in his great Chronology, *De Emendatione Temporum* to a learned correspondence he had entered into with Ni'matallah; and the Pope appointed him to the commission for calendrical reform."
[12] Jones, "The Medici Oriental Press" *op.cit.*

of the deliberations that led to the reform of the Julian calendar in 1582, under Gregory XIII. We do not know who proposed what, at what time, and for what reasons. We also do not know the particular expertise the Patriarch brought to the committee, other than his being well versed in the secular sciences of the Islamic world. But few tidbits have already come to light, and through them we can still trace the general theme of the embedding of the Islamic legacy into the intellectual environment of Renaissance Europe.

We are particularly fortunate that the Vatican had the wisdom to convene a conference at the 400th anniversary of the Gregorian reform, and that the proceedings of the conference are now in print for all to consult.[13] And although none of the conferees devoted a paper to the role of the patriarch in the making of the Gregorian reform, several of them have hinted to that role. I will only single out those who have made remarks that help us understand the phenomenon of embedding of scientific ideas or remarks that warrant further research. I only have the chance to highlight those remarks here and not to go into them in any great detail.

In the article, "Christoph Clavius and the Scientific Scene in Rome," Ugo Baldini had occasion to refer to the report, *Ratio Corrigendi…*[14] that was submitted by the calendar committee, on the 14th of September in the year 1580, to Pope Gregory XIII, regarding their proposed reform of the calendar. The important part of the report is that it included the names of the members of that committee.

> "Among the nine signatures we find the names of three prominent prelates. The first is Cadinal Guglielmo Sirleto who was the prefect of the congregation and co-ordinator of its works. Next comes Bishop Vincenzo Lauri of Mondovì who was perhaps the co-ordinator of the group before Sirleto. In the third place we find the name of the Patriarch Ignatius of Antioch. It is certain that the three of them were well acquainted with astronomy and we have direct evidence of this in the case of the Patriarch."[15]

Notice that the name of the famous Christoph Clavius is not among the top three signatures of the report. By the direct evidence of the Patriarch's knowledge of astronomy, Baldini means the existence of a

[13] *Gregorian Reform of the Calendar: Proceedings of the Vatican's Conference to Commemorate its 400th Anniversary (1582-1982),* edited by G. V. Coyne, S. J., M. A. Hoskins, and O. Pedersen, Vatican, 1983.

[14] *Ratio corrigendi fastos confirmata, et nomne omnium, qui ad Calendarii Correctionem delecti sunt oblate SS.mo D.N. Gregorio XIII*. According to Baldini this report exists only in two Latin manuscripts: one at the Vatican Library *Cod. Vat. Lat.* 3685, 1-10, and the other at the Biblioteca Casanatense, Rome, 649, 164-167. See Baldini's remarks about these manuscripts in *Ibid*, p. 155, n.1.

[15] *Ibid*, p. 137.

correspondence between the Patriarch and Clavius in which, according to the Laurentiana manuscript OR. 301 where the original Arabic of this correspondence is kept, he says that

> "Patriarch Ignatius maintained that the idea of a variable tropical year was due to observational and instrumental errors, also adding that a whole series of near-eastern observations (708 A.D. to 1472) showed the length of the year to be constant. He alludes to these observations by listing, sometimes the authors, sometimes the places where they had been made."[16]

Baldini goes on to say that "this series of observations does not seem to have been sufficiently researched in studies on Islamic astronomy."[17]

What Baldini's testimony really means is that the Patriarch was considered among the top three knowledgeable persons on the committee, that the committee was composed of a chosen few (nine members), and that the Patriarch contribution to this committee was that he was well grounded in Islamic astronomy and that he brought along with him from Diyār Bakr very important information the committee needed to know. One can imagine what kind of information that could be when we know that any ecclesiastical calendar had to consider, at a minimum, the best values if could have for the lengths of the solar year and the lunar month, and the manner in which those values were determined. So the Patriarch's list of observations which led to a fixed solar year was crucial for the calendar's deliberation.

Furthermore, the concept of the solar year itself involves decisions whether this year was a sidereal or a tropical year, and the relationship between the two was governed by a third concept, namely, that of precession. What was well known by then was that the Ptolemaic value for precession was considerably off the mark, and that this very value was indeed corrected by the observations that were performed during Islamic times in more than one Islamic capital. So what did the calendar committee do with such parameters? Baldini goes on to say that the committee "almost completely abandoned … the Ptolemaic linear theory, according to which there was a constant rate of precession of 1° per century. It had proved unable to account for the observations made by Muslim astronomers in 9^{th} century Baghdad…"[18] Of course, the variation in the value of precession had necessitated debates over a third concept, namely that of trepidation. And the models proposed for this trepidation

[16] *Ibid*., p. 162, n. 55.
[17] *Ibid*.
[18] *Ibid*, p. 148.

had a long history that stretched all the way from ninth century Baghdad till the time of Copernicus and the time of the committee itself.

Here again the Patriarch had a crucial intervention brought to the committee's attention, and later on to the Pope himself as we are told by Baldini when the subject of those trepidation models was discussed. In Baldini's words:

> "Each one of these models led to a different theory of the tropical year. The linear precession of Ptolemy gave a constant value of the length of the year which was known to be wrong. This had become clear already to Muslim astronomers working from the 9th century onwards in Baghdad and elsewhere, as the Patriarch Ignatius explained to the Pope in a letter (1579) and in a later report on the Compendium (12 March 1580) in which he maintained that the year had a constant, although non-Ptolemaic value."[19]

The Patriarch was therefore already involved in the minute technical details of the committee's deliberations, and his position was apparently clearly expressed in letters as the one whose copy is still preserved at the Laurentiana, according to Baldini. More importantly, he was apparently instrumental in convincing the committee to abandon the obsolete values of Ptolemy and adopt instead the latest, up to date values that were determined in Islamic times. This in itself is the best illustration I can think of to elucidate the concept of embedding ideas as a means of science transmission.

Other participants in the commemorative conference also noted the interjections of Patriarch Ignatius Naʿmatallāh in the committee's deliberations and appreciated the full scope of his role in the calendar reform.

In his own article on the Papal Bull of 1582 that aimed to promulgate the reformed calendar, August Ziggelaar had occasion to address the persons who gave this Bull the authority it had and the calendar the shape it finally took. Of course, the lion's share in promulgating the Bull had much to do with the very dynamic personality of Pope Gregory XIII himself, and with his power of persuasion. But the Calendar's authority rested with the nine men who went through the minute technical deliberations. But more importantly, Ziggelaar reveals that not all the members were in one voice supporting the results that were reached and circulated by the Pope in his letter to all catholic princes.[20] Notable among the dissenting voice was that of Patriarch Niʿmatallāh and for very

[19] *Ibid*.
[20] *Ibid*. p. 201.

technical reasons. They are the same reasons contained in the Laurentiana manuscript, which has been repeatedly mentioned so far.

Because of the importance of that dissent, Ziggelaar devoted a whole section to describing it in his article, under the title "The Criticism by Patriarch Ingatius."[21] In it he lists the substantial points that were raised by the Patriarch. For apparently the Patriarch, like Clavius, had studied the very details of the new calendar and on his own had come to the following conclusions:

> "(1) The anticipation of the equinoxes cannot be as much as one day in 134 years because at the time of the Council of Nicea it was on 21 or 20 March and it had not yet gone back to 10 March; (2) from many observations in the East one concludes that the sun anticipates one day in 132 years; (3) the idea of leaving out ten leap days during 40 years should be rejected; (4) adjustments at the turn of the centuries is too irregular; (5) the moon gains one day, not in 304, but in 276 years; (6) the 14th of the lunation, according to the calculation of the *Compendium* by mean motions, differs sometimes two to four days from the true motion so that we could sometimes celebrate Easter with and sometimes before the Jews; (7) for the same reason Easter may sometimes be celebrated a month late. Finally, the Patriarch promised to present within a very few days the result of the research in his books, according to the commission of his Holiness."[22]

Ziggelaar tells us that the Patriarch kept his word, and his critique of the calendar is apparently still preserved, in Karshuni, in the Laurentiana manuscript, which has been referred to several times already. The present author had not yet seen this manuscript and thus has to depend on the reports about it summarized in Zigglaar's and other articles in the proceedings of the Gregorian Reform conference. Apparently the critique of the Patriarch did not stop with the seven points listed above. He went on to discuss other defects in the proposed reform that was being circulated by the Pope. For example, he contended that

> "it is not the conjunction of the sun and moon which marks the beginning of the month but the day when the moon becomes visible minus 24 hours and this according to the horizon of Jerusalem and as calculated by mean motions. Thus the 14th day will be full moon but the *Compendium* makes full moon fall on the 16th day. The *Compendium* believes that the mean motion of the sun is irregular and hence the length of the year variable. But this has to be attributed to the instruments of observation. A long series of observations in the East, from 708 to 1472,

[21] *Ibid*. p. 215.
[22] *Ibid*. p. 216.

> establish that the length of the year is 365 days, 5 hours, 48 minutes, 53 5/12 seconds."[23]

All this reveals the amount of scrutiny the Patriarch was able to bring to the effort of the reform. And more was to come.

> "On f. 22r Ignatius reveals the "greatest error" of the *Compendium*: "that it has not understood the first day of the month of the Jews." It counts the 14th day from noon, whereas the day of the Jews begins at sunset. Also, if conjunction takes place shortly before sunset, the next day will invariably be the first day of the month. It thus results that the month always begins more than one day too early in the *Compendium*. If we also take the anomaly of the moon's motion and the longitude difference between Rome and Jerusalem into account, the real full moon may occur up to five days later than calculated. Summarizing, Ignatius repeats that the *Compendium* makes the lunation begin one day too early and from noon, as astronomers do, but not as the Jews do. Ignatius joins a few tables to find Sunday letters according to several assumptions and he also adds thirty tables to find the new moons according to the opinion of the Holy Fathers and that of the *Compendium*."[24]

Apparently the Patriarch's reservations were taken very seriously, especially by the senior mathematician on the committee Clavius himself. For according to Ziggelaar

> "In his *Explicatio* Clavius asserts that the reform agrees completely with those rules of the Christians in the East which Patriarch Ignatius showed the commission in Rome, in particular that Easter may be celebrated immediately after the 14th day of the lunation. Ignatius is among the members who signed the report of the commission dated 14 September, 1580."[25]

The final adoption of the reform was not a straightforward matter, and could not be assumed as finalized as soon as the *Compendium* was issued. It was in fact a long process, and some may even remember that as early as 1514 Copernicus himself was supposed to have participated in a proposed solution for the calendar reform.[26] The criticisms and the discussions that followed the first announcements of the Gregorian reform necessitated, several times, a return to the drawing table. At one point, the Paris faculty of theology's response to the *Compendium* in 1577, judged that "astronomers are contemptible, dangerous and ignorant people."[27] But particularly the Patriarch's criticisms seem to have found a listening ear, for in the final formulation of the calendar reform, the commission

[23] *Ibid*. p. 216-7.
[24] *Ibid*. p. 217.
[25] *Ibid*. p. 217-8.
[26] Noel Swerdlow and Otto Neugebauer, *Mathematical Astronomy In Copernicus's De Revolutionibus*, Springer, NY, 1984, p. 8.
[27] *Gregorian Reform of the Calendar*, op. cit. p. 234, note 25.

> "agreed on a few guide-lines, called "hypotheses": if full moon occurs after six p.m., it is assigned to the next day. At new moon however, there is no need of so much precision. This seems to be the result of all the criticism by Ignatius."[28]

And yet in the final reform formulation, as promulgated in 1582, the problem of the new moon falling after 6 pm being relegated to the next day was not formally accepted, but was found to be most correct if followed in practice. Ziggelaar concludes that "perhaps the criticism of Ignatius was accepted in practice, though never overtly."[29]

Having a scientifically valid calendar, and accepting to keep within it the influence of the church tradition, like keeping Easter tagged to Passover, and the Vernal Equinox on March 21, as it was during the Nicean Council when Easter rules were established, instead of 25, which was being proposed at the time of the Gregorian reform, is one thing, and having it accepted universally by all churches East and West is another matter. Of all the committee members, Clavius was the most conscious of the political hoops the calendar had to go through after it was finally pronounced in the bull *Inter gravissimas* in 1582. He already anticipated that, especially in the Eastern churches, who incidentally never signed onto this reform at least as far as the date of Easter was concerned. In that respect, he must have known that the presence of the Patriarch on the committee would become a political asset. In fact, as early as 1581, he began to deploy that political asset as could be easily detected in his use of the name of the Patriarch in order to smooth the passage of the calendar in the Eastern churches. He must have been even worried about the Eastern Christians who were still affiliated with the Papal see, like the Maronites of Lebanon and the Melkites of Lebanon, Syria and Palestine, a sizeable number of whom did not participate in the boycott of the Roman church in 1054, just as much as he was worried about the Orthodox Christian churches who never fully adopted this reform as we just saw.

We have already said before that this particular pope, Gregory XIII, had his own ambitions vis à vis the East, both in its Turkish face, against which he was trying to mount another crusade, and its Christian face as he was trying to re-unify the Eastern churches that had split off some five centuries before. After all, he welcomed Patriarch Niʿmatallāh in Rome, and assigned him a stipend from the papal treasury for the sole hope that the Patriarch would bring his Syrian church back under the papal flag as he promised he would do. It was also this Pope who had already sent several Jesuit emissaries during the 1570's to Lebanon, Syria, Palestine

[28] *Ibid*. p. 218.
[29] *Ibid*. p. 221.

and Egypt probably to attempt to proselytize among the Muslims, but most importantly to give aid to the few Eastern Christians who still swore allegiance to the Pope.

One of those emissaries who came to Lebanon several times in 1578 and throughout the 1580's was a Jesuit by the name of Giambattista Eliano, who did indeed investigate the conditions of the Eastern Christians who were still in union with the Pope, and particularly the Maronites of Lebanon who had their own liturgy, different from that of Rome, and who never saw eye to eye with the Orthodox Christians who persecuted them as heretics when Orthodoxy was declared the religion of the Byzantine Empire during and after the schism of 1054. It was this fellow Jesuit, Eliano, who was the correspondent of Clavius, and to whom Clavius wrote in regard to the calendar:

> "About the calendar, which is already finished, you should not be anxious, because the Pope plans to let two very able men come from there, and the patriarch has also subscribed to our calendar and admitted that it is very good. I hope that it will soon be published, because the Pope is quite eager."[30]

Clavius continued to defend the Calendar Reform well after it was announced in the bull of 1582. He did so, for example, in his voluminous *Explicatio*,[31] which was published in 1603. And in his correspondence with cardinal Vincenzo di Lauro, who was himself involved in the calendar reform and at one point appointed by the Pope to participate in and later head the committee that considered the proposal of Luigi Giglio for the reform,

> "Clavius also told [Lauro] how Patriarch Ignatius of Antioch appeared at the meeting of the commission with books from the East and it was verified that the measures planned by the commission were in full agreement with these texts."[32]

This is as close as I have been able to get to the inner working of that committee, and to the role played by Naʿmatallāh in the Gregorian reform. I will return to this point below when I assess this role and connect it with the general theme of this paper, namely the various modes of transmission of science from East to West. For now, it should have become clear how crucial that role was, and how intimate the relationship between the Patriarch and Clavius had become during the time when they both worked on the reform committee.

Before I conclude this paper I wish to use this information that we have already gathered about the Patriarch and Clavius in order to answer a

[30] Letter quoted in part by Ziggelaar in *ibid*. p. 231.
[31] Chrisotopher Clavius, *Romani calendarii a Gregorio XIII restituti explication*, Roma, 1603.
[32] Quoted by Ziggelaar, in *Gregorian Reform, op. cit*. p. 232.

question that was raised by my dear friend and colleague Eberhard Knobloch in his admirable work on Clavius and his knowledge of Arabic sources. I am referring here to Knobloch's article with the same title that was published as part of the proceedings of a conference that took place in 2001.[33] In this splendid article, Knobloch reviews in the most masterly fashion the intricate relationship Clavius had with a dozen authors of Arabic mathematical texts, and examines very carefully Clavius's interaction with those authors, texts, and the ideas contained in those texts. While discussing the relationship between Clavius's work on Euclid's *Elements*, and Ṭūsī's work on the same, Knobloch quotes Clavius's preface of his 1589 edition of Euclid's *Elements* as saying:

> "We learned long ago that the Arabs demonstrated the same principle. Though I diligently looked for the demonstration a long time, I could not see it, because it is not yet translated from the Arab [*sic*] into Latin. Hence I am obliged to imagine it by myself."[34]

Knobloch goes on to say:

> "In the edition of his works Clavius replaced this section by the remark: "I never got the permission to read it though I continuously asked for it the owner of the Arabic Euclid." We do not know anything about this person who must have been able to read Arabic and who did not give the book to Clavius."[35]

After admitting that he did not know of the person who could read Arabic and who was an acquaintance of Clavius, Knobloch continues to identify the Euclidian text that Clavius was talking about. In that instance he says:

> "The Arabic Euclid must have been Pseudo-aṭ-Ṭūsī which appeared in Rome in 1594. But Clavius's remark in his edition of 1589 proves that he knew this fact by hearsay already many years before the printed publication of the Arabic text appeared."[36]

Knowing what we now know of the life and works of Patriarch Niʿmatallāh, you can say that this whole article was written just to answer my friend Knobloch's puzzles. I think we now know who was the person intended by Clavius who could read Arabic but did not give Clavius the permission to see the book. I think that he was none other than the Patriarch. And the Eucledian text that Clavius had heard about was none other than the text that Niʿmatallāh brought along, which is now still

[33] Knobloch Eberhard, "Christoph Clavius (1538-1612) and his knowledge of Arabic sources". In: *Gesuiti e università in Europa (secoli XVI – XVIII) Atti del Convegno di studi Parma, 13-15 dicembre 2001, a cura di Gian Paolo Brizzi e Roberto Greci*. Bologna 2002, pp. 403-420.
[34] *Ibid*. p. 419.
[35] *Ibid*. p. 420.
[36] *Ibid*.

preserved at the Laurentiana, and which was itself used as the base for the 1594 edition that was published by the Medici Oriental Press.

We only need to remember that the Patriarch arrived in Rome in 1577, and was immediately appointed by the Pope to work on the committee for the Gregorian Reform. The Medici Oriental Press did not begin to publish the Arabic works that the Patriarch brought along until the early 1590's, some ten years or so after the work on the Gregorian Reform was finished and promulgated with the Bull *Inter gravissimas*. Between the time when Clavius came to know of the Patriarch, in the late 1570's, and the time the Press began to function, the Patriarch had, in all likelihood, not yet reached the deal with the Medici's to join the board of the press under the leadership of Raimondi, and had not yet secured his livelihood of the 25 monthly scudes and life-time access to his books that he was promised if accepted to give his books to be used by the press. During that period of anxiety, and knowing how valuable those books were, otherwise he wouldn't have taken them along in his perilous journey, the Patriarch was probably a little stingy with strangers wishing to consult them. That could explain his refusal to give Clavius the permission he needed.

Conclusion

In light of this multilayered evidence, I hope we can now safely say that Renaissance Europe was in fact in need of the sciences that were already relatively well developed in the Islamic world. The Patriarch knew that, and thus brought his scientific books along, and Clavius and the Pope knew that as well, and thus immediately made use of this learned man who offered his services at the right time. Clavius had already heard of the various Arabic sources that he used, and were elegantly gathered by Knobloch, through their Arabic translations. He was apparently eager to learn more, as was also concluded by Knobloch when he collected all the Arabic material that Clavius had heard about, and wished to pursue. In some instances he had to come up with solutions of his own which were already found in the Arabic sources, as Knobloch says. But in all instances, Clavius was a living example of a very competent scientist, a younger contemporary with Copernicus, like his French colleague Guillaume Postel, of the kind of fertile cross breeding that was taking place between the worlds of Islam and Renaissance Europe.

But most important for us is the manner in which Arabic scientific ideas were embedded into the Latin scientific tradition of the time. Ideas seem to have seeped in, as if by osmosis, without much fanfare and without the traditional modality of transmission of science where we can easily detect the routes between original Arabic books and their Latin translations. Aren't we slightly better prepared now to understand how Copernicus could have known about the earlier Islamic astronomical works? And aren't we better equipped to understand the intellectual climate of the Renaissance and the desperate need Renaissance scientists must have had for scientific texts from the Islamic world.

Spiritual Medicine in the Muslim World with Special Emphasis on Rāzī's Book

Mohsen Javadi

Abstract

Although Aristotle and to some degree Plato used medicine as a model of method in their ethics, Muslim philosophers developed the idea and even articulated an approach to ethics known as spiritual medicine which accords with various parts of medicine. They took the first part of their spiritual medicine to be the explanation of different parts of the soul (corresponding to the explanation of parts of the body in medicine), because they thought that only by grasping the soul as a whole can we find suitable cures for spiritual sicknesses. The second part of the spiritual medicine was related to spiritual nourishment, which was taken to be accomplished through virtuous actions. Good actions make the soul better and this in turn will make the soul more ready to do good actions exactly the same as is the case in the nourishment of the body. The third step in spiritual medicine, corresponding to the diagnosis of different bodily illnesses, was to recognize different vices of the soul. The cure is the same as in the case of bodily cures: firstly by good nutrition, that is virtuous deeds, and then by medicine, that is by obliging the sick person to act in the direction of the opposite vice, and finally by burning the ill part of the soul.

Abū Bakr Muḥammad ibn Zakariyyā al-Rāzī was born in 864 in Rayy, near present-day Tehran and died there in 925. He was physician, philosopher and chemist and the author of more than two hundred works and was called "the unsurpassed physician of Islam".[1]

[1] For a detail study on his works and life see: Goodman, Lenn E., "Muḥammad ibn Zakariyyā al-Rāzī", in *History of Islamic Philosophy*, (eds) Seyyed Hossein Nasr and Oliver Leaman , pp. 198-215.

His principal books on medicine have been published but most of his philosophical treatises have been lost or remain unpublished; but fortunately we have two important books related to his moral philosophy, namely, his *Philosophical Autobiography* and his *Spiritual Medicine*. There are some essays on medical ethics, one of which is a letter of him to his friend of which only one manuscript exists. Contrary to his *Spiritual Medicine*, which is well known and also has been translated to English[2], his book on medical ethics, which is published under the title of *Ethics of the Physician*, is unknown and neglected by many who study his views.

Reviewing the outlines of his medical ethics on the basis of his *Ethics of the Physician*, we will concentrate on his famous book *Spiritual Medicine* to explain an approach to or attitude toward ethical studies in Islamic literature. This approach is usually known as the medical approach to ethics (the Arabic phrase would literally be the *hospital* approach) and has its own principles which distinguished it from other approaches to ethical studies,[3] like a theoretical one that can be found in Fārābī, or like a tradition-based ethics that can be found in Ashʿarī. This line of ethical consideration was more practical than other attitudes and, indeed, like medicine, is based on experiment and most of its discussions are parallel to the discussions of medicine.

Preliminary discussions

a. Since ethics as such is neither an exact nor a natural science, its study cannot be suitable for a journal dedicated to the study of the history of natural and exact sciences, but my paper may be deemed relevant insofar as it provides a study of the influence of medicine as a natural science upon the structure and different discussions of ethics as a philosophical science and which gave rise to the emergence of an interdisciplinary branch of knowledge, namely, spiritual medicine.

Using medicine as a model for analyzing ethical problems was known to Greek philosophers. Plato and most notably Aristotle used medicine as a model of method in their ethics,[4] but Muslim philosophers developed the idea and went further so as they took the end of both disciplines as health, and they articulated their entire discussion of ethics in accord with

[2] Al-Rāzī, *The Spiritual Physic of Razes*, trans. by A. J. Arberry (London, 1950)

[3] For a detailed study on this approach see: Muḥammad ʿAbed Jaberi, *Al-ʿaql al-akhlāqī al-ʿarabī*, Beirut: Markaz al-dirāsāt al-ʿarabiyya, 2001, pp. 291-315.

[4] Werner Jaeger in his excellent paper cited different uses of medicine by Aristotle. See: Jaeger, Werner, “Aristotle’s Use of Medicine as Model of Method in His Ethics”, *The Journal of Hellenic Studies*, Vol. 77, part 1 (1957), pp. 54-61.

various parts of medicine. The purpose of this paper is to explain the different aspects of this usage with special emphasis on Rāzī's spiritual medicine.

b. Since the beginnings of Islam, Muslims attached importance to medicine. The Prophet himself repeatedly consulted doctors and asked people to seek cures for the sick from the hand of the physician rather than the magician. Subsequently, it was natural for medicine to be a central part of Islamic culture. The development of medicine as a science in Islamic civilization has two stages: the stage of translation and the stage of excellence and genuine contribution. During the first stage, Syrian and Persian scholars faithfully translated the ancient literature from Greek and Syriac into Arabic. The works of Hippocrates (460-370 BC) and Galen (131-210 AD) were among those translated into Arabic and had a marvelous influence on Muslim physicians. In addition to the original books of these two leading figures of medicine, there was a lot of the secondary literature as the heritage of two important centers of medicine at that time, Alexandria (*Iskandariyyah*) and Jundishapur, which was also translated into Arabic. As we know, both schools were influenced by Galen, whose approach to medicine, in contrast to that of Hippocrates, had a philosophical tone. The influence of Galen on Muslim scholars was not restricted to his medical books but most of his philosophical writings, especially his epitomes of Plato's works, are translated and referred to by Muslim thinkers.

Influenced by this tradition, Muslim physicians developed a large and complex medical literature exploring and synthesizing the theory and practice of medicine well grounded in a philosophical context. Indeed, their medicine, unlike contemporary medicine, cannot be separated totally from rational and philosophical methods and teachings.

In this atmosphere it was not surprising that people often believed that good doctors would also be good philosophers. One of Galen's books, which were translated into Arabic very early, had the name of *The Outstanding Physician Must also Be a Philosopher*.

Early Muslim physicians in general and Rāzī in particular heeded the counsel of Galen's book and worked industriously in both branches of knowledge. Avicenna and Ibn Rushd and most importantly Rāzī are just three prominent figures of this tradition, being physicians and at the same time philosophers. All of them have different medical and philosophical books. They contributed to the development of an integrated study of medicine and philosophy, especially moral philosophy and philosophical psychology *ʿilm al-nafs*. They usually used medicine as a methodological paradigm for ethical studies and, on the other hand, used philosophical theories to explain some of their medical concepts. Here we will not engage in the details of this relationship between philosophy and medicine and its advantages and disadvantages, but we will concentrate on different aspects of the uses of medicine as a model in generating the medical approach to ethics in Islamic literature.

Since medicine was regarded as a natural science from the start, and on the other hand ethics was enumerated among the branches of philosophy, it is important to see how a natural science can be a model for philosophical knowledge.

Medicine was an example of a useful and successful science the status of which was never in doubt, but there was and still is controversy about the importance and usefulness of ethics as an independent science in addition to jurisprudence, which was and still is the main subject of study in the Islamic sciences. According to an influential view (of such theological sects as the *Ashʿarites*), all we need for the guidance of human beings can and must be found in the commands and prohibitions of God, which are embodied in the *sharīʿa* or Islamic Law[5]. According to this idea, it follows that there is no need for a philosophical branch of knowledge called ethics. The comparison of ethics to medicine provides the philosophers with an implicit reply to such opponents by suggesting that ethics has a clinical character and can be used to alleviate moral illness, which is beyond the scope of Islamic Law, which merely details divine prescriptions without giving advice about how to treat the causes of non-compliance.

c. The linkage of ethics and medicine in the Muslim world was so strong that some scholars, such as Ibn Ḥazm in his *marātib al-ʿulūm* (classes of sciences), divided medicine into corporeal medicine and spiritual medicine, and also there are many ethical books that have the name of medicine in their titles. Kindī, the first Muslim philosopher, wrote a book with the title *Spiritual Medicine* which unfortunately is lost. But surely the most influential book in generating this medical approach was written by one of the greatest physicians of the world, namely Abū Bakr Muḥammad ibn Zakariyyā Rāzī.

After Rāzī some of the scholars, like Ibn Ḥazm, used this or a similar title (e.g., *Medicine of the Soul*) in their ethical books. Although the expression ‘spiritual medicine’ did not become too common, the idea became influential, in such a manner that we can find it employed in many books that do not explicitly bear a title of this sort.

[5] Javadi Mohsen, “Moral Epistemology in Muslim Ethics”, *Andisheh Dini*, 11 (1383/ 2004).

Comparing ethics to medicine as mentioned above is rooted in Plato's dialogues and notably in Aristotle's ethical books[6], but the sources that inspired Muslim scholars were Galen's interpretations and synopses of them, especially his epitome of Plato's *Timaeus*, which was read and used by many Muslim philosophers in Arabic translation prior to the translation of the works of Plato and Aristotle. Rāzī also explicitly refers to this book in his works.

More influential than Galen's works on their own, however, is the fact that the idea of a medical analogy was also indicated by several verses in the Noble Qurʿān and narrations in the ḥadīth literature which speak of the diseases of the heart (the Islamic name of the soul) and its health.

The Medical Ethics of Rāzī

Medical ethics must not be confused with spiritual medicine because the former is simply a branch of applied ethics and focuses primarily on the relations of physicians with the patients whom they are treating. The name *medical ethics* in contemporary usage includes what some call bioethics as well as the professional ethics of the physician.[7] Theoretical discussions like the study of the concept of death are central parts of contemporary medical ethics. Medieval Muslim physicians, however, put their professional ethics in their medical books or in the treatises and books with the title of *The Ethics of the Physician* and did not use the title *medical ethics*. Most of the theoretical discussions in contemporary medical ethics must be found in the philosophical and ethical works of these authors. So, if we want to provide a study of the medical ethics of Rāzī or other prominent figures of medieval Islam we must take into account his philosophical and ethical books. Unfortunately, Rāzī's medical ethics in general and his professional ethics in particular have not been studied and discussed in depth. I think his works can provide us with good materials to evaluate some accusations which have been made against him, like his denial of the eternal and non-material soul.

At any rate, the final purpose of medical ethics, especially in its old conception, was to provide a good moral and social context for the

[6] Some of the studies on this topic are: W. Jaeger, "Greek Medicine as Paideia", c. 1 of *Paideia,* Vol. III (New York: Oxford Univ. Press, 1944), p. 3-45; J. Longrigg, "Philosophy and Medicine: Some Early Interactions", *Harvard Studies in Classical Philology* 67 (1963), p. 147-75; G. E. R. Lloyd, "Aspects of the Interrelations of Medicine, Magic, and Philosophy in Ancient Greece", *Apeiron* 9/1 (May 75), p. 1-17; G. E. R. Lloyd, "The Role of Medical and Biological Analogies in Aristotle's Ethics", *Phronesis* 13/1 (1968), p. 68-83.

[7] See: William Ruddick, *Medical Ethics in Encyclopedia of Ethics*, (eds) Lawrence C. Becker and Charlotte B. Becker, London: Rutledge, 2001, p. 1062.

success of the cure. Indeed, there are some special moral and social issues that no physician can afford to neglect. Ultimately, these moral failures can affect the reputation of the physician and even in some cases can prevent him from doing his job.

In his introduction, Dr. ʿAbd al-Laṭīf says that he was working on the study of Rāzī's philosophical books and suddenly encountered a letter of him to one of his friends that is an important source for Rāzī's professional ethics. Dr. ʿAbd al-Laṭīf, finding no other manuscript, decided to edit the book on the basis of only one manuscript. The book originally is a letter that Rāzī wrote to one of his friends who was invited to be a special physician of the king. He enumerates his professional duties especially in regard to the treatment of the king and his court and explains how he has responsibility to be a confident and to treat alike a poor and rich man. He asks his friend to improve his moral character in addition to his knowledge and to be good tempered in his behavior with patients. He urged his friend to avoid abusing the opportunity for curing women for the sake of sexual pleasures or the cure of the well known people as a means to establish one's reputation. He sees these actions as a threat to his professional work.[8] Muslim scholars provide a rich source for this line of study and fortunately there is a good historical introduction to the English translation of one of the most famous books of medieval Muslim medical ethics namely that of al-Ruhāwī.[9] In summary, in his introductory chapter al-Ruhāwī describes medical ethics as follows:

> "To collect material about the ethics which the physician must cultivate, and the manner in which the physician must strengthen his moral character. I have mentioned some things about the ways in which the physician must treat his body, that which he must do first himself so that he may treat ill and healthy persons, and also some instructions, injunctions, and treatments regarding the care of the patient, his servants, and his nurses." [10]

Spiritual Medicine or the Medical Approach to Ethics among the Muslims

Before explaining the spiritual medicine of the Muslims in general, it is important to mention that *spiritual medicine* has another meaning that is in an opposite direction to the meaning which we are to explain. The word

[8] ʿAbd al-Laṭīf Muhammad al-ʿAbd, *Akhlāq al-Ṭabīb*, Maktabeh Dar al-Torath, Cairo, 1977.
[9] Levey, Martin, "Medical Ethics of Medieval Islam with special Reference to Al-Ruhawi's 'practical Ethics of the Physician'", *Transactions of the American Philosophical society*, New Series Vol. 57, No. 3, 1967, pp. 1-100.
[10] Ibid, p. 18.

is used to refer to some psychic treatments given for the cure of the body using spiritual exercises. Because there is an interaction between soul and body, some diseases of the soul may affect the body and the reverse. This can be regarded as another form of the relationship between medicine and ethics, for since there is an interaction between their subject matters, body and soul, likewise there will be a relationship between the sciences that study them: medicine and ethics.

Indeed there was and still is a discipline in Islamic literature that deals with the diagnosis of spiritual ills through physical conditions. This science is called *ʿilm al-firāsa*, which Rāzī himself dealt with in his famous book *Al-Ḥāwī,* and another Rāzī, Fakhr al-Dīn, wrote a book on this discipline. The basis of this discipline is the direct relation of the body to the soul so that by examining pulse, temperature, aches and other bodily conditions, the physician can determine the spiritual maladies of the patient. However, we will concentrate in what follows not on this but on *spiritual medicine* in the sense of the diagnosis and treatment of illnesses of the soul.

In his introduction to the book *Spiritual Medicine*, Rāzī writes that this book is a companion and parallel to the *Kitāb al-Manṣūri,* the purpose of which was to study corporeal medicine, and thereby he claims to succeed in discussing the health and illnesses of both body and soul.[11]

In his famous *Kitāb al-taʿrīfāt* (The Book of Definitions), Jurjānī defines spiritual medicine as "the knowledge of the perfections of the soul and its blights and its diseases and the way of keeping it in good condition or returning it to health after its being sick."[12]

To explain spiritual medicine clearly it is necessary to say something about the human soul, because it is the cornerstone of all ethical studies in the Muslim world in general and spiritual medicine in particular. The main characteristic of spiritual medicine is the acceptance of an independent substantial entity which has its own specific conditions of health and illness. It can have some interaction with the body but cannot be reduced to it or its functions. Spiritual medicine is harmonious with the common idea among Muslims that human beings have two aspects or dimensions: an inward and unobservable aspect, which is the subject matter of spiritual medicine, and a physical and observable dimension that is the subject of corporeal medicine. Indeed the word *akhlāq* (ethics), which is the plural of the word *khulq,* refers to inward dispositions in

[11] Al-Rāzī, *al-Ṭibb al-Rūḥānī*, ed. M. Mohaghegh, Tehran, 1999, p.83. All citations from Rāzī's *Spiritual Medicine* are from this edition.
[12] Jurjānī, *Kitāb al-taʿrīfāt*, (Tehran: Nase Khosro), p. 60.

contrast to the word *khalq* which refers to apparent bodily conditions of the person.

Rāzī in different places of his book asserts that the subject matter of his book is the soul rather than body. Even if one does not accept the existence of the soul, Rāzī claims that there is a minimal amount of ethics that can be observed, since one will seek to avoid future pains by controlling desires for present pleasures. However, this is only a superficial level of ethics, and in order to be effective at any deeper level an acceptance of the existence of the eternal incorporeal soul is required. At this deeper level one seeks to control one's desires in order to avoid not only future pains in this life, but those that may occur in the hereafter as well.[13]

In another place, he says that we must not be among those people who benefit minimally from morality, i.e. those who use self control only as much as they need to manage their worldly affairs, but instead we must benefit from it the highest level, namely controlling ourselves for the sake of the felicity of the eternal soul[14].

The second characteristic property of spiritual medicine as outlined by Rāzī is a clinical approach to ethical studies. Like a physician, he tries to understand the original and principle cause or causes of the diseases of the soul and after that tries to find the different manifestations of this cause in a variety of situations, and finally tries to find the general and special cures for each disease. He says the main cause of illnesses in the realm of the soul is the failure to restrict the appetites through reason[15] and this failure results in different illnesses in each of the human faculties.

This clinical approach to ethics can be seen from the titles which he gave to his discussions, such as "On the removal of disappointment"[16] and "Preventing rage" [17] and the like.

Due to the influence of this approach and in the light of religious prescriptions for the health of the soul, we can trace spiritual medicine in the later ethical books of Muslim scholars. It is for this reason that Muslim ethical books often begin with a brief discussion of the soul. As an example, we cite the starting points of Ṭūsī in his famous ethical book *The Nasirean Ethics*, where he says:

> "The human soul is a simple substance whose function is to perceive intelligibles by its own essence and to regulate and control the body.

[13] Al-Rāzī, *al-Ṭibb al-Rūḥānī*, p. 92.
[14] Ibid, p. 99.
[15] Ibid, p. 101.
[16] Ibid, p. 131.
[17] Ibid, p. 123.

> Such a substance is not a body nor is it corporeal, nor is it sensed by any of the senses." [18]

Then he gives his reasons to prove the existence of the soul, its substantiality, its simplicity, its not being corporeal and its power to perceive by essence and to act by means of the bodily organs, and finally its hiddenness from our senses.

Although there is a diversity of views among Muslims about the original status of the soul, and some scholars, like Mulla Sadra, believe in the material generation of the soul (although he affirms that it has the potentiality to go beyond matter and to become a non-material entity), others, like Avicenna, believe that the soul from its beginning is a non-material entity and is only imprisoned in the human body[19].

At any rate, both groups, as mentioned earlier, hold that the soul and body have some interactions and sometimes, for returning the body to its health, we need spiritual prescriptions, and on the other hand sometimes, for treating our souls, we need some medical treatments. But the 'spiritual medicine' as a special approach of ethics is to understand the diseases of the soul and their treatments, just as is the case for corporeal medicine.

Indeed, the adjective *spiritual* here refers to the essential character of the subject matter of ethics, but in the previously mentioned usage, which is also common in our modern times, it refers to the quality of the treatments for the healing of the body. This is the reason why nearly all Muslim philosophers take up the task of proving the existence of the soul and explaining its powers in their ethical works.

In the beginning of his book, Ṭūsī says:

> "Every science has a subject matter which is investigated in that science. Thus in the case of medicine, it is human bodies from the standpoint of sickness or health. The subject matter of ethics is the human soul, from the stand-point of sickness or health. Although the existence of the body is apparent, but the existence of the soul as a non-material substance is in need of proof. The proper place for proving the soul in the view of most philosophers, like Avicenna, is physics (*ṭabīʿāt*). *ʿIlm al-nafs* (the science of the soul) belongs to this part of philosophy, that is, physics, because, although the soul is not considered to be material, yet it operates through the natural organs and is affected by them." [20]

[18] Naṣīr al-Dīn Ṭūsī, *The Nasirean Ethics*, transl. by G. M. Wickens, London, 1964, p. 36.
[19] For a detail study on Avicenna's view on the soul see *Medieval Islamic Philosophical Writings*, (ed) Muhamad Ali Khalidi, Cambridge University, 2005, p. 27-59.
[20] Ibid, p.35.

The Parallel Structure of Corporeal Medicine and Spiritual Medicine

The first similarity is with regard to the standpoint of the study of ethics. As we know, assuming a physical substance (body) as its subject matter, medicine studies it from the standpoint of its sickness and health. Spiritual medicine, in turn, studies the sicknesses and health of the psychical substance (soul).

The second parallel is related to the practical character of ethics. Although medicine, as a science, has a cognitive status, its final aim is only realized when it is put into practice. Spiritual medicine holds the same point for ethics, and has claimed that it is not of any use unless it is put into practice.

In other words, ethics, like medicine, is an art, rather than a pure science. As Aristotle says, we try to know what courage is in order to become courageous, exactly as in the case of medicine, in which we seek an understanding of the healthy condition of the body in order to maintain our health in practice. The practical ends are not reached only by a theoretical enterprise.

The third similarity is in the key concepts that the proponents of spiritual medicine use: the concept of health and disease. As we know, the health of the body was measured by the situation of its constitution or temperament, which is the result the combination of its powers. The body is healthy if it is in a moderate state, not being dominated by any one of the four humors: yellow bile, black bile, phlegm, and blood. Moral philosophers used the same concept to explain the health of the soul: it is in a healthy condition if it is in a just and moderate condition. The same analogy can be found in the European Middle Ages, due to which the terms melancholic, sanguine, and phlegmatic derive from the terms for the humors. Different faculties of the soul (rationality, lust and irascibility) can lead to mental disease when not in proper balance with the others. Health is attained when a mean between extremes is achieved both in physical and spiritual health.

The fourth use is related to the taxonomy of the sciences. The proponents of spiritual medicine, following the physicians, divided ethical discussions into two important parts: how we can preserve the health of the soul if it already exists and how we can restore a sick soul to health.

Parallel to the division of medicine into prophylactic and curative measures, nearly all ethical books have the same division. As an example, see the titles of related discussions in Miskawayh's *The Refinement of*

Character[21] "The preservation of the health of the soul," and "The restoration of health to the soul when health is missing."

The fifth parallel pertains to the way physicians preserve health through good nutrition, the consumption of the proper foods in appropriate quantities.

Ṭūsī says:

> "When the soul is good and virtuous [...] its owner is obliged to take thought for those things which invoke the retention of these conditions. Now, just as, in medicine, the rule for preserving the body's health is to use that which is wholesome to the constitution, so the rule for preserving the health of the soul is to prefer association and intercourse with such persons as are congenial and collaborative in respect of the aforementioned qualities. Nothing has a greater effect on the soul than a companion or close friend.
>
> Among the means of preserving the health of the soul is a strict adherence to the obligations of praiseworthy acts, whether of the class of speculative or that of activities".[22]

He then explains the detailed applications of this way to preserve the health of the soul.

The sixth similarity which is the most important is related to the treatments used in ethical treatises. In this regard, Ṭūsī says:

> "Just as, in the science of physical medicine, sickness is removed by an opposite, so in psychical medicine, too, one must remove vices by the opposite of those vices".[23]

It is remarkable that this form of ethical studies is not restricted only to early scholars but we can find it in the later scholars. Narāqī (d. 1791), whose famous book *Jamʿat al-Saʿādāt* on ethics is still used as a textbook in Iranian universities, writes:

> "We have explained that corporeal medicine is a paradigm for spiritual medicine, and the rule for the treatment of corporeal illnesses is to know the genus of the disease, first of all, and then the causes and manners of their treatment. Treatments can be general or particular to a specific disease. The same is the case for spiritual medicine. In this book we will discuss these matters in several chapters".[24]

We will conclude our discussion by pointing out a difference between the cases of physical and spiritual medicines. In the case of the bodily diseases, we feel pain that directs our attention to it and motivates us to

[21] Miskawayh, Aḥmad ibn Muḥammad, *Tahdhīb al-Akhlāq* (The Refinment of Character), tr. Constantine K. Zurayk, Beirut, 1969, p.155.

[22] *The Nasirean Ethics*, p.113.

[23] Ibid, p. 122.

[24] Mulla Mehdi Naraqi, *Jamʿat al-Saʿādāt,* vol. 1, ed. Sayyid Muhammad Kalantar, Qom: Ismaʿiliyan, 1383/2004, p. 95.

find a cure for it. In the case of the diseases of the soul, however, often the situation is different, and our feelings act to the contrary, producing pleasures instead of pains, so that we neglect any attempt to cure them. Another reason that it is difficult to assess our own moral failings is the natural love of self, because of which one tends to see oneself as good. These two factors lead Rāzī to discuss methods for ascertaining our own moral illnesses in a separate chapter.[25] This also reminds us of a famous treatise of Galen, i.e. *How a Man may discover his own Vices*.

[25] Al-Rāzī, *al-Ṭibb al-Rūḥānī*, p.101.

A New Source for the History of Medicine: an Arabic Medical Handbook from the 10th Century

Lena Ambjörn

Background

Medieval medicine, with its centre in the Arab-Islamic region, is an important link between the scholastic medical discussion of Late Antiquity and the development of modern Western medicine. In spite of its importance, and although an extensive bulk of texts has been preserved, this part of the History of medicine has not received the attention it deserves. Problems connected with identifying manuscripts and noting them in catalogues, the handwritten form, the Arabic language and the relative lack of multi-disciplinarily trained scholars to interpret, edit and translate the texts are all factors that contribute to the fact that a rich treasure of source material has, to a large extent, remained unprocessed, and that our knowledge of how the medical tradition of Late Antiquity was cultivated and developed in the Arab-Islamic culture is still vague and fragmentary[1].

An overall aim of the project *A new source for the History of Medicine: an Arabic Medical handbook from the 10th century*[2] is to make a hitherto neglected Medieval medical text known and more easily accessible to researchers from various fields, particularly historians of science and medicine, but also philologists and linguists. The text in question is *al-Muʿālajāt al-Buqrāṭīya* (*Hippocratic treatments*, henceforth MB), by the

[1] For a recent survey of the field, see Pormann, P. E. and Emily and Savage-Smith. *Islamic Medicine*, 2007.

[2] The project is funded by the Swedish Research Council and carried out at the Centre for Languages and Literature, Lund University, Sweden.

10th-century physician Abū l-Ḥasan Aḥmad b. Muḥammad al-Ṭabarī[3]. The potential importance of the text was noted at the beginning of the last century by Hirschberg, and some initial studies were made: Hirschberg himself studied the book on eye-diseases (book 4)[4], and two chapters on skin diseases were translated[5] due to which Abū l-Ḥasan al-Ṭabarī was recognised as the discoverer of the *Acarus scabiei*[6]. A fragment of Galen's book on ethics (the Greek original is lost) has been identified in the introduction[7]. Apart from this, the work has not been studied.

Sezgin, who published a facsimile copy of the most complete of the extant textwitnesses in 1990, has emphasized the need for further study of MB, which, according to his view, "... holds a specific place in the general as well as in the Arab-Islamic history of medicine. It supplies ample and original material for future research, and may even conceal some unexpected surprise. [...] We also draw attention to the considerable importance of the book with regard to the history of medical literature insofar as it preserves valuable traces of numerable books written by Greek, Harranian, and Arab physicians."[8]

These expectations are confirmed already by a first reading of MB. The text, no doubt, conveys a wealth of information that will contribute to a more differentiated picture of various aspects of medieval medicine – from minute details concerning therapeutic strategies and the construction of surgical instruments to remarks that throw light on a wider social context.

The handbook

MB is divided into ten books (*maqālāt*), which are further divided into altogether 473 chapters (*fuṣūl* or *abwāb*) of various length. After a general introduction (book 1, 50 chapters), the author describes –from head to foot, or, more accurately, from head to intestines– external ailments that

[3] Ibn Abī Uṣaybiʿa (IAU), vol. I, p. 321; Sezgin, F. *Geschichte des arabischen Schrifttums* (GAS), vol. III, pp. 307f.; Ullmann, M. *Die Medizin im Islam*, p. 140. I am most grateful to Prof. Dr. Sezgin for drawing my attention to this material.

[4] Hirschberg, J. *Handbuch der gesamten Augenheilkunde*. Vol. 13: *Geschichte der Augenheilkunde*. Leipzig 1908, pp. 1071f. Reprinted in: *Augenheilkunde im Islam*. Ed. F. Sezgin. Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften 1986, vol. 3, pp. 115ff.

[5] Rihab, M. "Der arabische Arzt aṭ-Ṭabarī. Übersetzung einzelner Abschnitte aus seinen ʿHippokratischen Behandlungen'". In: Archiv für Geschichte der Medizin, 19 (1927), pp. 123-168.

[6] Friedman, R. "At Tabari: Discoverer of the Acarus Scabiei", in: Medical Life (New York), 45 (1938), pp. 163-176.

[7] Stern, S. M. "Some fragments of Galen's On Dispositions in Arabic", in: The Classical Quarterly 50 (1956) pp. 91f. and 97.

[8] MB, vol. I, p. VII.

affect the scalp and the skin of the face (book 2, 35 chapters), the internal organs of the head, i.e. the brain (book 3, 43 chapters), the eyes (book 4, 54 chapters), the nose and the ears (book 5, 34 chapters), the oral cavity, the teeth, the tongue and the larynx (book 6, 58 chapters), the skin of the body (book 7, 60 chapters), the respiratory organs and the heart (book 8, 38 chapters), esophagus and the gastric ventricle (book 9, 52 chapters) and, finally, the affections of the liver, the spleen and the intestines (book 10, 49 chapters).[9]

MB is attributed to Abū l-Ḥasan Aḥmad b. Muḥammad al-Ṭabarī. According to Ibn Abī Uṣaybiʿa, Abū l-Ḥasan was a physician in the service of the Būyid ruler Rukn ad-Dawla (r. 932–976)[10]. He had studied medicine with the same teacher as ʿAlī b. al-ʿAbbās al-Majūsī, known in the Latin-speaking world as Haly Abbas[11]. The bio-bibliography information on Abū l-Ḥasan is scarce, but thanks to his own remarks in MB ("I saw in Baṣra [...] I saw people in Mosul", etc.) it is possible to map, approximately, the area in which he was active, to get an idea of the people he met and worked with, the medical and philosophical literature he had studied, the cases he was confronted with in his clinical work, and many other things. The most frequently mentioned place is Baṣra, which was obviously a central location for Abū l-Ḥasan's professional activity. He mentions seeing his teacher, Abū Māhir Mūsā Ibn Sayyār, treat patients in Baṣra, and comments on practices at the Bīmāristān of Baṣra. He mentions being sent to Ahwāz to treat the founder of Būyid rule in Baghdad, Muʿizz ad-Dawla[12] (r. 945Ā967), and that he lived for a while "in a place called Kurat Fasā."[13] Besides this, the first five books of MB confirm that he visited the following cities: Abadan, Baghdad (also referred to as Iraq), Kūfa, Mosul, Rayy, Sīrāf (modern Taheri) and Wāsiṭ, and that he travelled the road between Iṣfaḥān and Ahwāz.[14]

In MB, Abū Māhir Mūsā b. Sayyār, the teacher of both Abū l-Ḥasan al-Ṭabarī and al-Majūsī, is frequently mentioned. The references are often introduced by phrases such as "I saw Mūsā b. Sayyār treat the ailment x

[9] Since 1990, MB is available as a *facsimile* edition of manuscript (MS) Malik Milli 4474, copied in 1479 CE. This MS is the most complete of the preserved text-witnesses. 21 MSS have been identified, most of which are only fragments. See Sezgin, GAS III, p. 308, and MB, vol. I, p. VII. The MB *facsimile* is printed in two volumes and comprises totally 694 pages. Vol. I contains books 1-5, and vol. II books 6-10. The entire table of contents has been typed, which facilitates access to the work.
[10] IAU I p. 321.
[11] The work of the latter was to gain great influence in Europe, and his *Kitāb al-Malakī* (*Liber Regis*), twice translated into Latin, is regarded as one of the most important medieval encyclopedic works on medicine. *K. al-Malakī* and MB do not display any significant correspondence, neither of disposition nor of contents. There is a survey of the chapters of *K. al-Malakī* in Ullmann, *Medizin*, pp. 145ff.
[12] MB 3:31 (vol. I, p. 145)
[13] MB 2:36 (I 90).
[14] For this journey, during which the author observed a particular kind of snake, see MB 5:7 (I 251).

by the measure y". The connections, in which Abū l-Ḥasan refers to his teacher show that both teacher and student were actually practitioners with clinical experience, not merely scholastic theorists. The clinical perspective, the personal tone and the author's sincere wish to supply his colleagues and students with practically useful information is characteristic for MB. That MB is easy to handle and practical to use in clinical work does not, however, mean that the author disregards medical theory. On the contrary, he says that the very reason he produced the book is that he believes that the art of medicine has lost its scientific standard and been reduced to a simple practice of bloodletting performed without any theoretical basis. That he starts the book by demonstrating, by means of logic, that medicine is a both "useful and necessary" art, and furthermore the most noble of all arts, is a formal approach that agrees well with Galen's view that it is the employment of deduction and logic that distinguishes qualified *ars medica*, with its focus on causal connections, from simple symptom-based healing.

Besides the recurrent references to his teacher, the author of MB mentions many Greek, Roman, Persian and Arab physicians, from Hippocrates, Plato and Aristotle via Galen and his commentators, to his own 10th century contemporaries. The main medical authority is, of course, Galen, to whom the author refers more frequently than to any other person.[15]

Several book-titles are mentioned, and since Abū l-Ḥasan frequently quotes his predecessors, the text can be expected to contain fragments of lost works. Fragments from Galen's book on ethics have been mentioned above, and another example is the summary of some of the contents of a book attributed to an eye-doctor by the name of Dhuhayl (?) al-Kaḥḥāl, a book of which Abū l-Ḥasan has a high opinion.[16] Quotations are also used as starting points for critical discussions of ideas with which Abū l-Ḥasan does not agree. These discussions deserve particular attention and systematic study.

MB contains plenty of case histories and clinical observations, often explicitly from the author's own experience. One rather dramatic case throws light on the status of female physicians: The author tells about Bint Isrā'īl from Rām Hormuz, a female doctor whom he met at the court of Muʿizz ad-Dawla in Ahwāz. Bint Isrā'īl was one of the physicians involved in treating the emir who suffered from a melancholic disorder

[15] The more than 50 references to Galen, and the less frequent ones to Hippocrates and Rufus, are distributed evenly throughout the first five books which constitute the *corpus* of this paper. References to Aristotle and Plato are concentrated to book 1, the general, philosophically biased introduction.

[16] MB 4:49 (I 226).

that was difficult to diagnose and had deteriorated due to mistakes made by three doctors who had all been severely punished: two died and one left the medical profession for good. The assignment, thus, was dangerous, but the treatment suggested by Bint Isrā'īl proved successful. Abū l-Ḥasan at first disregarded her professional opinion, taking for granted that she prescribed remedies "as female [healers] do, without discrimination and knowledge". When confronting her, however, he realized that she was a skilled physician who had studied the books of Hippocrates and Galen and was well acquainted with all aspects of the profession.[17]

Further examples of case histories are found in 2:3 (I 60; the author discusses a 15 year old male patient who had become bald); 2:6 (I 63; a *warrāq* in Ahwāz treated for an affection in the scalp); 2:13 (I 71; two patients, a man and a woman, affected by lice); 3:25 (I 129; two cases of wrong treatment of lethargy); 3:28 (I 136; treatment of a cerebral affection); 3:31 (I 143; an example of how the doctor discusses a melancholic affection with the patient); 3:41 (I 169; a case in Kūfa); 3:42 (I 171; two cases in Rayy); 4:16 (I 201; two cases of visual disorder); 5:7 (I 251; the treatment of nose-bleed); 5:24 (I 265; female patient with an insect in the ear); 5:31 (I 269; an observation concerning a man who had been hanged by his ears so that the cartilage had broken).

Surgical procedures are described, discussed and sometimes criticised. Examples are found in 4:19 (I 202); 4:20 (I 203); 4:22 (I 204f.); 4:39 (I 224); 5:12 (I 255).

With all deference to surgery, the main therapeutic strategy in MB is to restore the humoral balance in the body by means of drugs, foodstuffs and an appropriate general regimen. A very large number of medically active substances (plants, minerals and animal products), including foodstuffs, are mentioned, and the text contains an extensive bulk of prescriptions of complex drugs of various kinds: pills, pastes, ointments, oils, decoctions, bandages, clysmata, etc., as well as instructions on how to administer these medicaments. As for the general regimen, the author gives recommendations concerning physical exercise, baths and massage, sexual habits, sleeping habits, and intake of food and drink.

[17] For this episode, see MB 3:31, vol. I, p. 145f.

Preliminary results: Personal names[18]

The personal names found in MB, books 1 – 5, are listed below in (Latin) alphabetical order. The index works as follows: "3:31 (I 148)" means MB, Book 3, chapter 31, found in vol. I, p. 148 of the *facsimile* edition.

Abū ʿAbdullāh al-Yazīdī 3:31 (I 145)
Abū Bakr ibn Saʿīd 5:24 (I 265)
Abū Bakr ibn Abī Saʿīd bi-l-Baṣra 3:31 (I 148)
Abū Jaʿfar al-Karkhī fī l-ʿIrāq 3:42 (I 170)
Abū Ḥakīm al-mutaṭabbib 3:31 (I 145)
Abū l-Ḥasan al-Mafrūjī, rajul min al-kuttāb 4:9 (I 189)
Abū l-Ḥusayn Ḥashāsha (?) 2:34 (I 89)
Abū Isḥāq b. Ibrāhīm b. Baksī 4:28 (I 213)
al-Muʿtaṣim (r. 833–842) 2:7 (I 65)
Abū Nūḥ al-mutaṭabbib min Fārs 3:31 (I 145)
Abū l-Qasam al-maʿrūf bi-l-muʿawwaj al-raqaba 4:39 (I 227)
Abū l-Qasam al-Yazīdī 4:53 (I 241)
Abū Sā'ib (?), *qāḍī fī Baghdād* 3:35 (I 157)
Abū Zakariyā 3:31 (I 148)
al-ʿAkarī (?), *ṣāḥib k. al-ʿayn* 4:1 (I 175); 4:22 (I 204)
Alexander [*the Great*] 1:22 (I 20, the Alexandrian calendar)
Alexander [in his *Kunnāsh* known as *rāḥat al-ṭabīb*] 2:6 (I 62); 4:14 (I 199f.)
Alexander Aphrodisias [in his *Kunnāsh* known as *ʿArūs*] 4:42 (I 229); 4:43 (I 231)
ʿAlī al-Kaḥḥāl[19] 4:27 (I 211f.); 4:37 (I 220); 4:37 (I 221); 4:38 (I 222); 4:53 (I 241)
al-Āmidī, *ṣāḥib k. al-ʿayn*[20] 4:9 (I 188, 189); 4:16 (I 201); 4:52 (I 239, 240)
Andromachos 1:50 (I 53); 3:31 (I 141)
Arānes see *al-Hindī*
Archigenes[21] 4:1 (I 175); 4:12 (I 195); 4:45 (I 233); 4:46 (I 233); 4:52 (I 238)
Aristotle 1:1 (I 4); 1:2 (I 6), 1:4 (I 7); 1:8 (I 9); 1:10 (I 10); 1:11 (I 11); 1:13 (I 12); 1:14 (I 12); 1:17 (I 13); 1:20 (I 16); 1:21 (I 16, 18, 19, 20); 1:22 (I 20f.); 1:23 (I 22f.); 1:24 (I 25f.); 1:27 (I 29); 1:32 (I 32); 1:36 (I 36); 1:38 (I 37); 1:39 (I 39); 1:40 (I 41); 1:41 (I 42); 1:42 (I 42); 1:43 (I 43); 1:46 (I 43); 1:50 (I 53); 3:27 (I 131); 3:28 (I 137); 3:40 (I 167); 4:14 (I 200); 4:51 (I 237); 4:52 (I 240)

[18] The results presented here are based on books 1-5 (not on the entire work). References to more or less specific groups of people, such as "the people in the mountains", "the Ṣābians" or "the physicians in Basra" are not included here.
[19] GAS III 337-340; Ullm. 208f.; Wood, C. A. *Memorandum Book of a Tenth-Century Oculist for the Use of modern Ophthalmologists: A Translation of the Tadhkirat of Ali ibn Isa of Baghdad*. Chicago 1936, repr. Birmingham, Classics of Medicine Library, 1985.
[20] Probably Aëtius of Amida, see GAS III 164f., Ullm. 84f.
[21] GAS III 61-63; Ullm. 69f.

Bint Isrā'īl al-mutaṭabbib (sic) *min Rām Hormuz* 3:31 (I 145f.)
Bukhtīshū[22] 3:27 (I 134); 4:16 (I 201)
Buqrāṭ see *Hippocrates*
Dioscurides 4:32 (I 217); 4:45 (I 233); 4:53 (I 241)
Dhubāba (?) 2:23 (I 82); 3:25 (I 129)
Dhuhayl (?) al-Kaḥḥāl 4:39 (I 226)
Epicurus 1:21 (I 18)
Euclid 4:54 (I 244)
Galen i (I 2); 1:1 (I 4); 1:2 (I 6), 1:9 (I 10); 1:22 (I 20f.); 1:24 (I 25f. (etik)); 1:29 (I 30); 1:30 (I 31); 1:31 (I 31); 1:32 (I 32); 1:48 (I 45); 1:50 (I 48); 2:2 (I 59, 60); 2:5 (I 61); 2:6 (I 62f.); 2:7 (I 64); 2:9 (I 66); 2:10 (I 68); 2:14 (I 72); 2:18 (I 74); 2:26 (I 84f.); 2:34 (I 89); 2:35 (I 90); 3:7 (I 100, 101); 3:8 (I 102); 3:19 (I 112, 113); 3:22 (I 122); 3:23 (I 125); 3:27 (I 131, 134); 3:28 (I 137); 3:31 (I 141, 144, 146); 3:33 (I 153); 3:37 (I 159, 160); 3:38 (I 163); 3:39 (I 164); 3:40 (I 167, 168); 4:1 (I 175); 4:2 (I 177); 4:8 (I 186); 4:9 (I 188); 4:11 (I 191); 4:12 (I 193); 4:13 (I 197); 4:26 (I 210); 4:28 (I 213); 4:32 (I 217); 4:37 (I 221); 4:39 (I 224, 225); 4:45 (I 233); 4:46 (I 233f.); 4:52 (I 238 passim., 239, 240); 5:1 (I 247); 5:8 (I 253); 5:14 (I 259).
Jurjis[23] 2:7 (I 65); 2:8 (I 66); 2:11 (I 68); 4:12 (I 196); 4:26 (I 210); 4:46 (I 234).
Ḥāmid b. al-ʿAbbās 2:7 (I 64)
al-Ḥārith b. Kalada[24] 2:1 (I 56).
al-Hindī, *Arānes yuʿraf bi-* 4:32 (I 217).
Hippocrates i (I 2); 1:23 (I 21); 1:50 (I 46); 2:8 (I 66); 2:19 (I 77); 2:20 (I 79); 2:33 (I 89); 3:1 (I 94); 3:7 (I 100f.); 3:22 (I 124); 3:23 (I 125); 3:27 (I 131, 134); 3:31 (I 146); 3:32 (I 151); 3:39 (I 164); 3:40 (I 167); 3:41 (I 169); 4:1 (I 175); 4:9 (I 188); 4:11 (I 191); 4:12 (I 195); 4:14 (I 200); 4:52 (I 238, 240).
Ḥubaysh[25] 2:5 (I 62)
Ḥunayn b. Isḥāq[26] 2:6 (I 63); 4:1 (I 175); 4:12 (I 195).
ʿIbdān (?) *bi-l-Baṣra* 2:26 (I 85); 2:29 (I 88)
Ibn Abraz (?) *bi-l-Wāsiṭ* 2:7 (I 64)
Ibn al-Azraq, *fī Māristān al-Baṣra* 2:13 (I 71)
Ibn al-Duhnī (?) 5:7 (I 252).
Ibn Ḥamdān 3:31 (I 149)
Ibn al-Laws (?), *insān min al-barbar* 4:12 (I 196)
Ibn Māsawayh, *Yuḥannā*[27] 2:2 (I 59); 3:31 (I 148); 4:42 (I 229); 4:43 (I 231)

[22] GAS III 210f.
[23] See GAS III (209) 210.
[24] GAS III 203; Ullm. 19f.
[25] GAS III 265; Ullm. 119.
[26] GAS III 247-256; Ullm. 115-119.
[27] GAS III 231-236; Ullm. 112-115.

Ibn Māssah[28] 2:5 (I 62); 4:28 (I 213); 4:52 (I 239, 240).
Ibn Naṣr (?) *fī l-Bīmāristān* 2:1 (I 57)
Ibn Sayyār, *Mūsā*[29] 1:21 (I 19); 2:1 (I 57): 2:3 (I 60); 2:6 (I 63); 2:7 (I 64); 2:13 (I 69); 2:14 (I 72); 2:23 (I 82); 3:1 (I 94); 3:2 (I 95); 3:7 (I 100); 3:9 (I 105); 3:20 (I 118); 3:22 (I 123); 3:30 (I 140); 3:32 (I 152); 3:33 (I 154); 3:40 (I 168); 3:42 (I 170f.); 4:5 (I 182); 4:11 (I 192); 4:12 (I 195); 4:13 (I 199); 4:50 (I 237); 5:6 (I 251).
spec. Abū Māhir [Mūsā b. Sayyār] 3:31 (I 145, 148); 4:13 (I 197, 198); 4:14 (I 200); 4:16 (I 201); 4:22 (I 204); 4:37 (I 221); 4:41 (I 229); 4:46 (I 234); 4:53 (I 241); 5:13 (I 256).
spec. Abū ʿImrān Mūsā b. Sayyār 1:21 (I 19); 2:1 (I 56); 2:2 (I 58); 4:11 (I 192); 4:12 (I 195); 4:42 (I 230); 4:50 (I 237).
spec. Abū ʿImrān b. Mūsā b. Sayyār 4:36 (I 220)
Ibrāhīm b. Baksī 3:31 (I 149); 4:14 (I 200)
ʿIlkān (?) *al-mutaṭabbib* 2:11 (I 68).
ʿĪsā, *ṣāḥib Ibn Māsawayh* 3:31 (I 148)
Isḥāq b. Ḥunayn[30] 4:1 (I 175)
John of Alexandria, *Philoponos* see *Yaḥyā al-Naḥwī*
Kriton[31] 2:1 (I 56); 2:7 (I 64, 66); 2:20 (I 80); 2:27 (I 86)
al-Muhandis 4:14 (I 199)
Muʿizz ad-Dawla (r. 945-967) 3:31 (I 145)
al-Muʿtaṣim (r. 833-842) 2:7 (I 65)
an-Nuʿmānī (?) *bi-l-Baṣra* 4:37 (I 221)
Oribasius 4:32 (I 217)
Plato 1:8 (I 9), 1:13 (I 12); 1:23 (I 22f.); 1:24 (I 25); 1:25 (I 26); 1:26 (I 27); 1:31 (I 31f.); 1:32 (I 32); 1:43 (I 43); 1:49 (I 45); 1:50 (I 49); 1:50 (I 50); 1:50 (I 53); 4:28 (I 213); 5:26 (I 267)
Proklos[32] 1:14 (I 12 ult.); 1:24 (I 25); 1:25 (I 26); 1:27 (I 29); 1:47 (I 44)
Ptolemy 1:10 (I 10)
Pythagoras 1:21 (I 18); 1:23 (I 22); 1:39 (I 38)
Qusṭantīn 4:23 (I 206, the author of a *Kunnāsh* in Syriac)
Rufus 2:6 (I 63); 2:13 (I 71); 2:19 (I 76); 3:27 (I 134); 3:30 (I 139); 4:8 (I 186); 4:12 (I 195); 5:14 (I 259)

[28] GAS III 257; Ullm. 122f.
[29] The MB references vary between "Ibn Sayyār", "Mūsā b. Sayyār"; "Abū Māhir Mūsā b. Sayyār", "Abū Māhir", "Abū ʿImrān Mūsā b. Sayyār", "Abū ʿImrān", and (once) "Abū ʿImrān b. Mūsā b. Sayyār".
[30] GAS III 267; Ullm. 119.
[31] GAS III 60; Ullm. 71.
[32] Ullm. 91, 95.

Sābūr b. Sahl[33] 2:5 (I 61)
al-Sāhir[34] 4:26 (I 210)
Salmawayh al-Ḥarrānī[35] 1:21 (I 19)
Sayyār [explicitly] the father of *Ibn Sayyār* 4:12 (I 195)
Socrates 1:24 (I 25);1:31 (I 31); 1:50 (I 53)
Thābit b. Qurra[36] 2:1 (I 56); 4:27 (I 212)
ʿUmar b. نعف ? 3:31 (I 149)
Wahb, "yahūdī yuʿraf bi-Wahb"; contemporary with the author of MB 3:31 (I 145)
al-Yahūdī[37] 2:1 (I 58)
Yaḥyā al-Naḥwī (John Philoponos; John of Alexandria)[38] 1:20 (I16); 1:24 (I 25)

To this list two hitherto unidentified names should be added: ترطلوس (?; contemporary with Galen) 2:7 (I 64); and العرم () 4:27 (I 212).

[33] GAS III 244; Ullm. 300f.; Kahl, *O. Sābūr ibn Sahl. The Small Dispensatory*: Translated from the Arabic together with a Study and Glossaries. Leiden 2004.
[34] GAS III 227; Ullm. 124.
[35] GAS III 227; Ullm. 112.
[36] GAS III 260f.; Ullm. 123f.
[37] See GAS III 206; Ullm. 24.
[38] GAS III 157; Ullm. 89ff.

Science in *Adab* Literature

Paul Lettinck

Introduction

A long standing topic of discussion among orientalists has been the question whether science in medieval Islamic society was a marginal activity, restricted to small elite circles and not rooted in society, or whether it was well assimilated and widely accepted in society. The former position, called the 'marginality thesis' was adopted by, for instance, von Grünebaum.[1] This thesis was attacked by, for instance, Sabra.[2] His position became known as the 'appropriation thesis'. Also Gutas opposed the marginality thesis.[3]

That scientific knowledge was recommendable not only insofar as it was useful for religion and Muslim society, but also as an intellectual pleasure and as a recognition of the beautiful order and arrangement of God's creation, was testified by the philosopher al-Āmirī (d. 992).[4] It is this attitude to science which one also finds in *adab* literature. Books belonging to this kind of literature contain material about a variety of subjects, considered from various points of view, such as religious, scientific, historical, literary, etc. They contain knowledge and at the same time entertainment for educated people. Here we consider two *adab* works: (an extract of) *Faṣl al-Khiṭāb* by al-Tīfāshī (d. 1253) and *Mabāhij al-fikar wa-manāhij al-ʿibar* by al-Waṭwāṭ (d. 1318).

[1] Von Grünebaum, G.E., "Muslim World View and Muslim Science" in: *Islam. Essays in the Nature and Growth of a Cultural Tradition*, London 1955, 2nd ed. 1961, repr. Westport, Conn. 1981, 111-126.
[2] Sabra, A.I., "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: a Preliminary Statement" in: *History of Science* 25 (1987), 223-243.
[3] Gutas, D., *Greek Thought, Arabic Culture*, London 1998.
[4] The relevant passage from al-Āmirī is quoted in F. Rosenthal, *Das Fortleben der Antike im Islam*, Zürich 1965, translated as *The Classical Heritage in Islam*, London and New York 1975, pp. 63-70.

The book of al-Tīfāshī as we have it discusses astronomical and meteorological subjects. The passages on astronomy give the usual Aristotelian cosmological picture of the world in a simplified version for non-specialists. The passages on meteorological subjects explain these phenomena in agreement with Aristotle's theory of the double exhalation, and it appears that they are based to a large extent on Ibn Sīnā's interpretation of this theory.

The book of al-Waṭwāṭ consists of four sections, which deal with the heaven, the earth, animals and plants respectively. One chapter of the first section deals with meteorological phenomena and presents a survey of the explanations current in his time, such as could be found in the works of al-Kindī and Ibn Sīnā.

One will probably not find new and original scientific ideas in the *adab* literature, but one gets an impression of how besides knowledge of Qur'ān, ḥadīth, poetry and literary prose, scientific knowledge was a part of the education of a certain class of people, also of those whose special interest was not science. It also appears that the subjects of science were not restricted to those which were useful for religion and Muslim society. Science was an integrated activity in society, pursued for intellectual satisfaction and pleasure in knowledge, and most groups in that society held that there was nothing in it that would be incompatible with Islam as a religion.

Al-Tīfāshī and his work

Al-Tīfāshī[5] was born in 1183 in Qafsa, the present Gafsa (Tunesia). At that time the country was ruled by the dynasty of the Almohads. The Tīfāshī family was in favour with the Almohad caliphs. Their name is derived from Tīfāsh, a village near Gafsa, but that was not their native place. After his elementary education al-Tīfāshī went to Tunis, and then at the age of fourteen, to Egypt and subsequently to Damascus for further education. He returned to Gafsa, where he married, got three children and became a judge (*qāḍī*). He was forced to give up this job when it was discovered that he stored wine in his house. Then he decided to leave Gafsa. He embarked to Alexandria with his children (his wife had already died). His ship was wrecked in a storm and his children drowned; he himself was saved by Bedouins, who brought him to Alexandria. Then he lived at the court in Cairo, under the protection of the Ayyubid sultan of

[5] This sketch of al-Tīfāshī's life and works is taken from the introduction to *Surūr al-nafs bi-madārik al-ḥawāss al-khams* by the editor Iḥsān ʿAbbās. See also Brockelmann, C., *Geschichte der arabischen Literatur*, Leiden 1937-1949, vol. I p. 652 and Suppl. I p. 904.

Egypt, al-Kāmil Muḥammad al-Malik. Al-Kāmil liked the company of scholars and literary men; he received them in his palace, let them sleep in his bedroom, and subsidized their living. From Cairo al-Tīfāshī travelled to various places throughout the Middle East. Among others, he visited the court of Muḥyīddīn al-Ṣāḥib, a representative of the Zanjid sultan Muʿizz al-Dīn Sanjarshāh in Jazīrah (northern Iraq). It is probably there that he wrote the work *Faṣl al-Khiṭāb*, making use of the books in the library of this Muḥyīddīn.

After this period of travelling he settled down in Cairo, a centre of culture and commerce where people from all parts of the world gathered. There he learned many things, for instance about gems, resulting in his well known book about gems and minerals *Azhār al-afkār fī jawāhir al-aḥjār* (Flowers of Thought about the Precious Stones). He died in Cairo in 1253.

Al-Tīfāshī was an attractive, clever and elegant person, and also social and kind-hearted. He was inquisitive and interested in new experiences, an eager observer of nature and society. He loved wine and wrote about it. He read many books, but what he wrote was also based on stories told to him by others and on his own observations and experiences, of which he was quick to make notes; what was told to him he checked by observation and experiment. Nevertheless he followed current ideas which included much superstition; for instance, he devoted a large part of his *Faṣl al-Khiṭāb* to astrology.

Arabic sources mention eighteen books written by al-Tīfāshī, a few of them still extant. His most well known books are the one on gems and minerals mentioned above, and *Nuzhat al-albāb fīmā lā yūjad fī kitāb* (Entertainment of the hearts about what one cannot find in any book),[6] a collection of anecdotes and poems about sexual matters, such as pimps, prostitutes, and the conditions for adultery.

Al-Tīfāshī also wrote the extensive work *Faṣl al-Khiṭāb fī madārik al-ḥawāss al-khams li-ūlī l-albāb* (Decisive Discourse on the Perceptions of the Five Senses for Intelligent People). This work is not extant as a whole, but we have an extract from it, made by Ibn Manẓūr. This Ibn Manẓūr is well known as the author of the Arabic dictionary *Lisān al-ʿarab.* His fuller name is Muḥammad ibn Mukarrram Jamāl al-Dīn, known as Ibn Manẓūr. His grandfather moved from Tunis to Cairo where his father Mukarram was born, two years after the birth of al-Tīfāshī. Mukarram was favoured by the sultan al-Kāmil, who called him *malik al-ḥuffāẓ* (king

[6] This book was translated into French in 1971 as *Les délices des coeurs*, and in 1988 parts of it were translated into English as *The Delight of Hearts: Or What You Will Not Find in Any Book* by Winston Leyland.

of those who have memorized the Qur’ān), because after hearing eleven verses one time, he could memorize them all. He was often visited by al-Tīfāshī. Mukarram’s son Muḥammad was born in 1232. He acquired an extensive knowledge of language, grammar, history and literature. He wrote summaries or extracts of many works, such as *Kitāb al-Aghānī*, and *al-Yatīma* of Thaʿālibī.

When Ibn Manẓūr was still a child he heard al-Tīfāshī talk to his father about a huge book which had taken almost his whole life to write, with the title *Faṣl al-Khiṭāb fī madārik al-ḥawāss al-khams li-ūlī l-albāb*. This title struck him as an insolence, for *faṣl al-khiṭāb* was something given by God to the prophet David. When al-Tīfāshī died, Ibn Manẓūr was twenty-two years old, and he forgot about the whole matter, until he remembered the book when he was sixty. Then he got hold of the book at one of al-Tīfāshī’s friends, and started to make an extract from it. He gave it the title *Surūr al-nafs bi-madārik al-ḥawāss al-khams* (Enjoyments of the Soul by the Perceptions of the Five Senses).[7] According to al-Safadī the extract consisted of ten sections. What is extant is two sections, entitled: *Nuthār al-azhār fī l-layl wa-l-nahār* (Fragments of Flowers about the Day and the Night) and *Ṭall al-asḥār ʿalā l-jullanār fī l-hawā’ wa-l-nār* (Morning Dew on the Pomegranate Blossom about the Air and the Fire).

Ibn Manẓūr’s editing of al-Tīfāshī’s text consisted of the following: he omitted what he considered to be a repetition; he also omitted verses that he considered scabrous or jocular; he reordered the texts, and divided each section into ten chapters; one time he added a poem and two times he changed verses of a poem. He did not change anything in the ‘lies of the astrologers’.

The book *Surūr al-nafs* as we have it discusses the following subjects: night, day, sun, moon, stars, seasons, thunder, lightning, rain, winds and fire. These subjects are discussed from various points of view: natural philosophy (science), pseudo-science (*e.g.* astrology, oneiromancy, *i.e.* dream interpretation), religion, language, literature, etc. Poems and pieces of prose are quoted in which these subjects are mentioned. The sources from which the quotations come are often mentioned, but not always. Some of them are: Aristotle, Pseudo-Aristotle (*Theology*), al-Jāḥiẓ (*K. al-Ḥayawān*), Ibn Qutayba (*K. al-Anwā’*), Marzūqī (*Azmina wa-amkina*), Ibn Sīnā *(al-Qānūn*), Abū Maʿshar, Kushyār, al-Bīrūnī (*K. al-Tafhīm*), Ibn Dāwūd *(K. al-Zahr*), Thaʿālibī (*al-Yatīma*), and the *dīwān*s of various poets, such as Ibn Muʿtazz.

[7] Al-Tīfāshī, *Surūr al-nafs bi-madārik al-ḥawāss al-khams*, revised by Ibn Manẓūr, edited by Iḥsān ʿAbbās, Beirut 1980.

Al-Tīfāshī's book, of which *Surūr al-nafs* is an extract, belongs to the kind of *adab* literature which intends to explain knowledge for a general educated audience and at the same time shows the pleasure one may derive from knowledge for its own sake. It exhibits the various ways and forms in which poets, natural philosophers, geographers, encyclopedists, etc. talked about natural phenomena. Later similar works would be composed by al-Nuwayrī (*Nihāyat al-ʿarab fī funūn al-adab*), al-ʿUmarī (*Masālik al-abṣār fī mamālik al-amṣār*), al-Waṭwāṭ (*Mabāhij al-fikar wa-manāhij al-ʿibar*).

We present a survey of the passages of *Surūr al-nafs* that deal with astronomical and meteorological subjects, discussed from the point of view of science or natural philosophy.

The passage on astronomy gives the usual Aristotelian cosmological picture of the world; it is a simplified picture for non-specialists; it does not go into details of planetary motions and it does not mention anything of the Ptolemaic model for these motions.

The transformation of one element into another is not described as a change of one the four qualities (hot, cold, dry, wet), as was done by Aristotle, but simply as a change in density: when fire becomes denser, it becomes air, etc

The cosmology of the heaven is Ibn Sīnā's cosmology of nine revolving celestial spheres, each with its intellect, soul and body.

The passages on meteorological subjects (lightning and thunder, rainbow and halo, rain, snow, etc.) explain these phenomena in agreement with Aristotle's theory of the double exhalation. According to this theory, the heat of the sun dissolves two exhalations from the earth: a dry warm kind of smoke (*dukhān*), dissolved from the earthy parts, and a wet, warm vapour (*bukhār*), dissolved from the watery parts (sea, lakes and rivers). All phenomena in the atmosphere are explained as being effects of these two vapours. This theory was adopted by most Islamic scholars. Some of them, such as Ibn Sīnā, added further descriptions and explanations that are not found in Aristotle. It appears that the passages from *Surūr al-nafs* are based to a large extent on Ibn Sīnā's explanations of meteorological phenomena. For example, the phenomenon of the halo is explained as follows:

> "If the cloud is between the observer and the luminous object, while the latter is around its highest position, then you will see a halo; this is a circle, in the middle of which one sees the moon, surrounded by a white ring which is secluded by the darkness of a moist cloud. Sometimes a cloud is situated below another cloud; then another halo arises from it,

> which is larger than the one caused by the cloud above it and is similar to it as seen from the observer." [8]

The rainbow is explained as follows:

> "If the observer is between the cloud and the luminous object, while the latter is in a low position, near the horizon, then he sees half a circle with various colours; it is necessarily half a circle, since the luminous object is at the horizon. This is called a rainbow. The extension (width) of the rainbow varies in accordance with the height of the luminary above the horizon. Since the luminary should be near the horizon one seldom sees the rainbow at midday in summer, in contrast to the winter. One can imagine this occurring only when there is behind the smooth cloud something dark, another cloud or something else, so that it will be possible for the smooth cloud to transmit what is impressed on it to the observer via a transparent medium, the cloud acting as a mirror." [9]

In the section about the philosophers' opinion about air a passage is quoted from Book I of Ibn Sīnā's *al-Qānūn*,[10] where he states that the air we breathe is the atmospheric air, which is not the same as the element air. The atmospheric air is a mixture or elemental air, water in the form of vapour, particles of dust and smoke, and fire.[11] The (atmospheric) air may undergo a change and become obnoxious for human health. Such a change may be substantial or it may be a change of qualities. In the former case the air becomes spoiled, just as stagnant water may become spoiled and putrid. In the latter case the extent in which the air has the qualities dry, moist, hot and cold changes. Then Ibn Sīnā mentions the various influences of putrid air and of hot, cold, moist and dry air on the condition of the human body.

Al-Waṭwāṭ's *Mabāhij al-fikar wa-manāhij al-ʿibar*

The author of this work is Muḥammad ibn Ibrāhīm ibn Yaḥyā ibn ʿAlī al-Anṣarī, known as Waṭwāṭ; his *laqab* is Jamāl al-Dīn al-Kutubī. He was born in Egypt in 1235, where he seems to have spent his whole life. He made his living as a copyist of manuscripts, which gave him the

[8] The issue of multiple haloes is mentioned by Ibn Sīnā, see *Kitāb al-Shifāʾ, al-Ṭabīʿiyyāt 5*, ed. A. Muntaṣir, S. Zāyid, A. Ismāʿīl, I. Madkūr, Cairo 1964, pp. 48 ff.
[9] The cloud acting as a mirror is a feature typical for Ibn Sīnā, see *Kitāb al-Shifāʾ, al-Ṭabīʿiyyāt 5*, pp. 50 ff.
[10] Ibn Sīnā, *al-Qānūn*, Bulāq 1294, Book I, p. 90.
[11] Cf. Ibn Sīnā, *Kitāb al-Shifāʾ, al-Ṭabīʿiyyāt 4*, ed. M. Qāsim, I. Madkūr, Cairo 1969, p. 204.

opportunity to collect books and to develop a broad knowledge in many fields. He died in 1318.

The title of his book *Mabāhij al-fikar wa-manāhij al-ʿibar* (The Pleasures of Thoughts and the Ways of the Lessons) is also given as *Manāhij al-fikar wa-mabāhij al-ʿibar* in the manuscripts, as well as in the texts that mention the book. The subject matter is considered from two points of view, that of *adab* –this includes the poems and *adab* fragments which the author has found concerning the subjects under discussion– and that of science –this includes the scientific matters mentioned by the author about his topics.

There is an abstract of the *Mabāhij* under the title *Nuzhat al-ʿuyūn fī arbaʿat funūn* (Pleasures for the eyes in four disciplines). This abstract mainly omits the *adab* part and only contains the scientific part. It only exists in manuscript form. An article about it has been published by Kāmil al-Ghazzī.[12]

A facsimile edition of the *Mabāhij* has been published by Fuat Sezgin in 1990.[13] The book consists of four sections, entitled The Heaven and its Adornments, The Earth and What is Connected With it, The Animals and Their Natures, and The Plants and Their Cultivation. An edition of the third section, about animals, was published in 2000 by ʿAbd al-Razzāq Aḥmad al-Ḥarbī.[14] For this section al-Waṭwāṭ used the following sources: for the scientific aspect he used *K. al-Ḥayawān* of al-Jāḥiẓ, *K. al-Ḥayawān* of Aristotle, *K. al-Ḥayawān* of Aḥmad ibn Abī al-Ashʿath and the works of ʿAbd al-Laṭīf al-Baghdādī; for the aspect of *adab* and language he used many sources, such as the *dīwān*s of poets, and general works of *adab*. He especially mentions *ʿUyūn al-akhbār* of Ibn Qutayba, *al-ʿUmda* of Ibn Rashīq, *al-Gharīb al-muṣnaf* of Abū ʿUbayd, *al-Mujmal* of Ibn Fāris, *al-Awā'il* of Abū Hilāl al-ʿAskarī, *Kitāb al-maṣāyid wa-l-muṭārid* of Kashājim. He also took information from some books on history, such as *Kitāb murūj al-dhahab* of al-Masʿūdī and *al-Kāmil* of Ibn al-Athīr, and from works on philosophy and *tafsīr*.

Chapter 5 of the first section deals with the meteorological phenomena. After an exposition of the four elements and the way they are ordered in spherical layers around the center of the universe, first special attention is paid to the elements fire and air. About fire it is stated that it has a resemblance to human beings, a resemblance that does not exist between

[12] Kāmil al-Ghazzī, "Kitāb Nuzhat al-ʿuyūn fī arbaʿat funūn", in: *Majallat al-majmaʿ al-ʿilmī al-ʿarabī* (Damascus), vol. 9 (1929), pp. 681-687.
[13] Jamāl al-Dīn al-Waṭwāṭ, *Manāhij al-fikar wa-mabāhij al-ʿibar*, ed. Fuat Sezgin, Publications of the Institute for the History of Arabic-Islamic Science, Series C, Vol. 49, 1-2, Frankfurt am Main, 1990.
[14] Muḥammad b. Ibrāhīm al-Waṭwāṭ, *Mabāhij al-fikar wa-manāhij al-ʿibar*, ed. ʿAbd al-Razzāq Aḥmad al-Ḥarbī, Al-dār al-ʿarabiyya li-l-mawsūʿāt, 2000.

the other elements and human beings. This resemblance consists in the fact that human beings come into being and live in the same environment where also fire comes into being and lives, and they perish and die where also fire perishes and dies. This became known to the people who work in shafts and mines. Whenever they are about to enter a shaft in the earth or a cave, they carry in front of them a burning wick at the tip of a lance, and if the fire remains burning, they enter, and if the fire is extinguished, they do not enter.

Air is discussed as being the material of wind. Since Aristotle has stated that wind is not moving air, but moving dry exhalation, the problems that arise if one adopts this explanation give rise to many rather confusing explanations by Greek and Arabic commentators. Al-Waṭwāṭ says that, according to Aristotle, wind is flowing air and air is wind that is stagnant. The air is set in motion by the rising of much vapour, which pushes it into various directions. Another explanation is that wind is a motion caused by the dry and wet exhalations. After having risen they return independently with a motion that is hitting the air and stirring it up; this return is either due to the heaviness that comes to them when they get to the cold layer of the atmosphere, or due to the fact that they are obstructed from penetrating into the higher air because of the speed with which this layer of air is moving. This explanation is clearly taken from Ibn Sīnā.[15]

Sometimes wind occurs due to the expansion of the parts of the air that are made less dense by the heat that occurs to them, so that they flow and move. This alternative explanation is also mentioned by Ibn Sīnā.[16] It is also the explanation of wind by al-Kindī.[17]

Snow is caused by moist vapour. When the higher air between the heaven and the clouds becomes very cold, it freezes the rain that descends from the clouds and changes it into snow. It can also happen that the atmosphere becomes very cold by a wind that cools it down so that the air, which is mixed with watery vapour, freezes before it condenses into clouds. Then it falls down, while the sky is bright, as oblong snow, since its parts coalesce with each other due to the cold wind –this is called *zamharīr*. This special type of snow was discussed by al-Kindī.[18]

Other meteorological phenomena discussed are thunder and lightning, shooting stars, thunderbolts and the rainbow. Al-Waṭwāṭ mentions the phenomenon that the rainbow is half a circle when the sun is at the

[15] Ibn Sīnā, *Kitāb al-Shifā', al-Ṭabī'iyyāt 5*, p. 58.
[16] Ibn Sīnā, *Kitāb al-Shifā', al-Ṭabī'iyyāt 5*, p. 59.
[17] al-Kindī, "On the reason why in some places it almost never rains" in *Rasā'il* II 70-75.
[18] al-Kindī, "On the causes of snow, hail, lightning, thunderbolts, thunder and *zamharīr*" in *Rasā'il* II 80-85.

horizon and becomes less than half a circle when the sun is rising until it completely disappears when the sun is at a certain height. He also says that according to some people observing the rainbow is like observing something in a mirror. Therefore the rainbow is only seen behind a smooth cloud, which acts as the dark backside of a glass mirror. This is clearly based on Ibn Sīnā, like the similar passage in al-Tīfāshī's work (see above note 9).

From the few examples discussed here we conclude that scientific knowledge was considered to be a part of the education of 'civilized' people, not only of those whose special interest was philosophy and science. Also, the subjects of science discussed were not restricted to those which were useful for religion and Muslim society. Science was also pursued for intellectual satisfaction and pleasure in knowledge, as is made clear by some of the titles of the works discussed here. The examples also show the influence of Ibn Sīnā: his explanations are quoted without his name being mentioned; apparently his ideas were more of less common knowledge. A further study of the scientific aspects of *adab* literature seems recommendable.

Recovering Truncated Texts: Examples from the Euclidean Transmission

Gregg de Young

Introduction

One problem that may confront the historian working with medieval documents and manuscripts is the truncated text from which one or more folios have been removed.[1] This removal may be accidental, as when initial or final folios fall out after repeated usage of the manuscript. Or the removal may be deliberate, as when a reader wishes to keep available one or more segments of the manuscript and simply removes them from the codex. Anyone who has ever found a crucial article razor-bladed from a journal knows something of the frustration that can be caused by the truncated manuscript. If the manuscript exists only in a unique copy, the missing folios often present an insoluble puzzle – what were the contents of this section?

Initially, it may seem a hopeless question. And in many cases, it is hopeless. But in a few rare instances, either the missing segment is located, maybe even in another library,[2] or in other equally rare cases, the lacuna can be restored, either in whole or in part, from quotations in later treatises. It is the latter situation that is the focus of this paper.

In this study, I consider two examples of truncated texts from the Arabic transmission of the *Elements*. The first is the commentary on the *Elements* by al-Anṭākī (died 326 AH / AD 938). The commentary is

[1] The truncated text and other editorial difficulties are discussed in Roshdi Rashed, "Conceptual Traditions and Textual Tradition: Arabic Manuscripts on Science," in Y. Ibish, ed., *Editing Islamic manuscripts on Science* (London: al-Furqān Islamic Heritage Foundation, 1420 / 1999), pp. 15-57, especially pp. 33-45.

[2] A remarkable case from the Arabic Euclidean transmission is the discovery of the segment from missing from book VII in Tehran, Malik 3586 in another library – Tehran, Dānishgāh 2120.

known today in a unique copy, beginning with the commentary on book V.[3] My second example is the commentary by al-Nayrīzī (died ca. 328 AH / AD 940). For a long while, the treatise was known also only in a unique copy containing books I-VI and a few lines from book VII.[4] The portion containing comments of Simplicius on the definitions of book I is missing from this manuscript. Recently, Brentjes described a second manuscript of the treatise which is now in a library in Qūm, Iran.[5] This second manuscript, however, ends with book V, so that the commentary remains truncated until the present moment.[6] Using the Qūm manuscript, Rüdiger Arnzen has been able to remove several of the lacunae in the section dealing with the definitions and postulates.[7]

While on a research trip to India, I came upon a previously unstudied Arabic commentary on Euclid.[8] This treatise is also truncated, being incomplete at both ends. It initially caught my attention because it contains quotations ascribed to al-Ḥajjāj.[9] The commentary contains also numerous quotations ascribed to al-Anṭākī, to al-Nayrīzī, to Ibn al-Haytham, as well as comments attributed to Ibn Hūd, al-Baghdādī, al-Dimashqī and several other mathematicians from the early period of the Arabic/Islamic transmission. A subset of these quotations, those from al-

[3] Oxford University, Bodleian Library, ms. Huntington 70. The title page identifies it as part two of the treatise. This designation seems probable because the text begins without any introduction other than the bismallah.

[4] In this study I have relied on the printed edition of the Arabic text in R. O. Besthorn *et al*., *Codex Leidensis 399,1. Euclidis Elementa ex interpretatione al-Hadschdschadschii cum commentariis al-Narizii* (Copenhagen, 1893-1932). The Arabic text has been reprinted in A. S. Saʿīdān, *Handasat Uqlīdis fī aydin ʿarabiyyah* (Amman: Dār al-Bashīr, 1411 / 1991). An English translation has begun to appear in A. Lo Bello, *The Commentary of Al-Nayrizi on Book I of Euclid's Elements of Geometry* (Leiden: Brill, 2003).

[5] Qūm, Kitābkhāna-I ʿUmūmī 6525. I have not been able to see a copy of this manuscript. It was cited by S. Brentjes, "The Relevance of Non-Primary Sources for the Recovery of the Primary Transmission of Euclid's Elements into Arabic," in F. J. Ragep and S. Ragep, eds., *Tradition, Transmission, Transformation* (Leiden: Brill, 1996), pp. 201-225, at p. 203, note 13.

[6] A Latin version, usually ascribed to Gerard of Cremona, extends beyond the limits of the known Arabic text. The Latin text was edited in M. Curtze, *Anaritii in decem libros priores Elementorum Euclidis Commentarii* (Leipzig: B. G. Teubner, 1899) on the basis of only one manuscript (Krakow 569). A more recent edition, using additional manuscripts, has begun to appear. P. M. J. E. Tummers, *The Latin Translation of Anaritius' Commentary on Euclid's Elements of Geometry, Books I - IV* (Nijmegen: Ingenium, 1994).

[7] R. Arnzen, *Abu l-Abbas an-Nayrizis Exzerpte aus (Ps.-?) Simplicius' Kommentar zu den Definitionen, Postulaten und Axiomen in Euclids Elementa I* (Essen: Rudiger Arnzen, 2002).

[8] Oriental Manuscripts Library and Research Institute [formerly Andhra Pradesh State Central Library], Riyāḍī 2. A copy made from this manuscript after it became truncated exists in Osmania University Library, acq. no. 375, call no. QA 510 Ash-R.

[9] G. de Young, "The Arabic Version of Euclid's *Elements* by al-Ḥajjāj ibn Yūsuf ibn Maṭar: New Light on a Submerged Tradition," *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften*, 15 (2003): 125-164.

Anṭākī and al-Nayrīzī, form the focus for my investigation of truncated manuscripts from the Arabic Euclidean tradition.

Methodology

The quotations from al-Anṭākī and from al-Nayrīzī in the Hyderabad commentary extend beyond the limits of the currently extant Arabic manuscripts for these two early commentaries. References to al-Anṭākī appear regularly from the beginning of book III, while a few references from al-Nayrīzī appear in books IX and X. These quotations seem to offer the possibility of extending our knowledge of the missing segments from these two early Arabic commentaries on Euclid. But this possibility could only be realized if the quotations were close to the original version of the treatise. The greater the discrepancy between quotation and truncated text, the more circumspect one must be when generalizing from the quotations.

In order to assess the degree of editing to which these quotations might have been subjected, I compared them, when possible, to the surviving portion of the (now truncated) text from which they were ostensibly drawn. My plan also called for inclusion of Ibn al-Haytham quotations in this comparison. Since multiple manuscripts of Ibn al-Haytham's commentaries exist, a study of these quotations offered a means to assess more completely the degree of editing imposed on the earlier commentaries by the author of the Hyderabad commentary.

General Features of the Commentaries

The author of the Hyderabad commentary quotes from many earlier sources. Most of these sources are quoted only in his discussion of Euclid's definitions and premises. When commenting on the theorems, the author quotes from only a few sources –mostly from al-Anṭākī, along with a handful of quotations from al-Nayrīzī, and sometimes "someone else," who is still not identified. There are also statements attributed to the author himself (*qāla al-mu'allif*). They occur almost exclusively in the context of his commentary on the definitions and premises.

When commenting on definitions and premises, the author begins by quoting the Euclidean text of the statement. The diction used in these quotations indicates that he is utilizing a treatise close to the "Group B" manuscripts of the Arabic primary transmission of Euclid.[10] These

[10] For the general division of the Arabic manuscript tradition into two different Groups, see G. De Young, "The Arabic Textual Traditions of Euclid's *Elements*," *Historia Mathematica*, 11 (1984): 147-160.

manuscripts that have become contaminated with readings from the transmission of the *Elements* attributed to al-Ḥajjāj. For example, book V, definitions 7 and 8 are given using the terminology and diction of Group B manuscripts. But the order in which the definitions appear in the Hyderabad commentary is inverted from the typical Group B order. This reversal in ordering also appears in Escurial, ms. Árabe 907 and in Rabat, Khizānah al-Mālakiyyah 1101. (These two manuscripts from Group A have also been influenced by the transmission of al-Ḥajjāj.) Similarly, definitions 13-16 exhibit both a distinctive difference in diction and an alteration in ordering between Group A and Group B manuscripts. The Hyderabad commentary follows the diction of Group B, although its ordering of these definitions does not completely match either of the major primary transmission groupings. On the other hand, the two definitions of perturbed ratios of equality that was interpolated into Group A manuscripts as definitions 24 and 25 (and into some Group B manuscripts, where they are attributed to Thābit) are also quoted in the Hyderabad commentary.

When commenting on the propositions, the author's procedure is to give the number of the proposition, followed by a statement listing the propositions on which the Euclidean demonstration depends. He does not, however, quote either the enunciation of the proposition or its demonstration. Thereafter follow his comments, some of which are drawn from earlier authors. It is rare to find comments attributed to more than one earlier commentator under a single proposition. In books V and VII-X, the commentary frequently concludes with a "numerical example".[11] In book X, there are often two numerical examples for each proposition– one for rational numbers and one for irrational values.

Not all the comments are explicitly attributed to an earlier commentator, however. Editorial comments, for example, that detail differences between the transmission of al-Ḥajjāj and Isḥaq are not referred to a specific source. Although some of the other mathematical comments are explicitly attributed, there are several cases in which the author refers comments to "someone else" or states that "another has said". I have not been able to identify these anonymous references. Presumably the author is here quoting from memory or has not taken the time to check the original sources available to him and therefore provides only an incomplete citation. The majority of comments, however, are not referred to anyone.

[11] The function of these examples is not completely clear. Perhaps they are intended as a kind of concrete specification to supplement the highly abstract arguments of Euclid (which are never quoted directly in the commentary).

The commentator routinely spells out the letter names used as labels to identify specific geometric entities. The copies of the earlier commentaries, however, use independent letter forms for these labels. The choice of style used in referring to geometric entities seems to be primarily a matter of scribal preference.

Diagrams are carefully produced with straight-edge and compass. They are typically placed at the left-hand margin of the text, set into more or less rectangular openings in the text. The right-hand edge of the opening is often not vertical but instead takes roughly the shape of the edge of the diagram figure. Thus, it appears that the standard construction technique used was to stop copying at a particular line and draw the figure immediately below the left side of the last copied line of text. The copyist then continued copying and used the edge of the diagram as a rough margin. Not every proposition is provided with a diagram. One could speculate that diagrams were somehow seen as heuristic and that they were included whenever the commentator felt that they would be beneficial to a student.

Like the Hyderabad commentary, al-Anṭākī quotes each definition before launching into his commentary on it. These definitions and premises are generally quoted following the diction typical of Group B manuscripts. In the commentary on the propositions, al-Anṭākī begins with the proposition number, sometimes written as a numeral and sometimes written in words. It may be accompanied by the term "proposition" (*shakl*), but often is not. He then quotes the enunciation of the proposition, typically in the diction of Group B, followed by the list of propositions on which Euclid's demonstration depends. After these elements, al-Anṭākī launches into his discussion of the proposition and its demonstration. Sometimes it is necessary to introduce one or more supplementary propositions to demonstrate important points that Euclid left implicit. These lemmas and added propositions (termed *muqaddima* and *ziyāda* respectively) usually come before any other commentary. When a numerical example is present, it is more likely to be given immediately after the list of propositions used in Euclid's demonstration although it is sometimes at the end of the proposition. (Surprisingly, al-Anṭākī gives only a few numerical examples in Euclid's arithmetical books – books VII-IX.) Within book X, al-Anṭākī gives only one numerical example for each proposition and it is almost always in terms of irrational values. These irrational values, though, do not match the values used in the Hyderabad commentary. Only in book V do the numerical examples in the two commentaries have the same values. At the end of each proposition and its discussion, al-Anṭākī places the list of propositions on which Euclid's demonstration rests. The copyist regularly uses individual Arabic letters to refer to geometric entities within the demonstrations or discussions.

Al-Anṭākī's diagrams are typically placed at one of the margins, in an opening in the text. Overall, there does seem to be a preference for the left margin, but it certainly is not as strong as in the case of the Hyderabad commentary. There are also examples of diagrams being placed in the middle of the line, with text on either side, as in the latter part of book IX where diagrams comprise only a single line and its letter labels. Construction technique appears generally similar to those described for the Hyderabad commentary. In general, there is a strong impression that the diagrams are less carefully produced. Lines to not always meet precisely, and some diagrams appear more free-hand sketches than careful geometric constructions. There are copyist errors in some diagrams. The diagram for proposition V,3, for example, has an extra line, which the copyist (or perhaps a later reader) has "crossed out". Not all propositions are supplied with diagrams.

The commentary of al-Nayrīzī was once believed to be constructed around quotations from the revised version of al-Ḥajjāj.[12] The extant portion appears to be an edited version of the *Elements* so that it is difficult to know to what extent the diction may represent that of al-Ḥajjāj. In addition to re-stating the Euclidean text, the treatise also contains numerous comments from the late antique Greek commentators Heron of Alexandria (fl. 2nd century AD)[13] and Simplicius (fl. 6th century AD).[14] When quoting these Greek commentators, al-Nayrīzī begins by citing the name of the commentator.[15] There are also quotations attributed explicitly to al-Nayrīzī, as well as comments attributed to "the commentator" (*al-mufassir*). Some notes are unascribed or incompletely ascribed, introduced using phrases such as "in other texts".

The printed edition of al-Nayrīzī is provided with diagrams for each proposition. These often differ in labeling and / or orientation from those occurring in the quotations in the Hyderabad commentary. Unfortunately, we cannot know whether this variation is significant without an inspection

[12] This information is contained in an introductory epistle to *Codex Leidensis 399.1*. Engroff showed that this assertion is probably incorrect and that the entire treatise has apparently been edited by al-Nayrīzī. See J. Engroff, *The Arabic Tradition of Euclid's Elements: Book V* (Cambridge: Harvard University PhD dissertation, 1980 [unpublished]), pp. 5-20.

[13] F. Sezgin, *Geschichte des arabischen Schriftums, Band V: Mathematik* (Leiden: Brill, 1974), pp. 151-154..

[14] F. Sezgin, *Geschichte des arabischen Schriftums, Band V: Mathematik* (Leiden: Brill, 1974), pp. 186-187.

[15] On a few occasions, the reference is to the followers of Heron (*madhhab Ayran*).

of the diagrams in the manuscripts themselves, since editors in the past frequently felt no qualms about redrawing diagrams to comply with their own prejudices concerning the intent of the diagram's author.

Complications

Initially I had assumed that the methodology outlines above would be relatively simple to carry out since the raw materials (in the form of microfilm and printed copies) were close at hand. The project had not advanced far, however, before it became clear that there are unexpectedly more parallels between the Hyderabad commentary and some of the earlier commentaries, extending considerably beyond the explicit citations. Many passages from the commentaries of Ibn al-Haytham or al-Anṭākī are quoted, sometimes in somewhat edited form, without an ascription to the original author. When discussing Euclid's premises, a comment ascribed to "the author" (*al-mu'allif*) is almost always a quotation from Ibn al-Haytham. I have no explanation why the commentator ascribes some comments directly to Ibn al-Haytham and others to "the author". (Most of the comments ascribed to "the author" occur in the context of the premises, although there are a few examples in comments on the propositions. These latter comments are apparently either the author himself speaking or they are from a still unidentified source.) And comments drawn from al-Anṭākī, whether referring to premises or propositions, very often carry no ascription at all, even when the comment is virtually a verbatim rendition of the earlier commentary. Appendix II gives one example showing how closely unascribed material in the Hyderabad commentary follows the diction of al-Anṭākī's treatise. On the other hand, I have found no examples of material quoted from al-Nayrīzī's commentary without an explicit ascription in the Hyderabad commentary.

It quickly became apparent, however, that one cannot rely on the attribution of quotations in the Hyderabad commentary. The commentary of al-Nayrīzī, for example, contains not only the discussion by the commentator himself but also statements attributed to Simplicius and to Heron. When quoting these sources, the author of the Hyderabad commentary often lumps them together and refers them to al-Nayrīzī. A comment on definition I, 5, for example, is attributed to "the author" in the Hyderabad commentary, but the same comment is attributed to Simplicius in the commentary of al-Nayrīzī. Quotations from Heron are typically identified as such in the Hyderabad commentary, although in at least one instance (proposition III, 7) a discussion attributed to Heron by al-Nayrīzī is ascribed to al-Nayrīzī himself in the Hyderabad commentary. An alternative demonstration for proposition I, 46 (I, 47 in the standard Greek edition) is attributed to al-Nayrīzī in the Hyderabad commentary but could not be located in the commentary as edited by Heiberg and Besthorn.

The case of al-Anṭākī does not initially appear so complex, since there are not multiple attributions within his commentary that could become confused when quoted within the Hyderabad commentary. However, there remains a problem of editing – sometimes the quotation is very close to the wording of the surviving manuscript and sometimes it is scarcely more than a paraphrase. Even in cases of closest congruence, there are a surprising number of what appear to be copying errors – a word omitted, for example, or an apparent grammatical alteration (as from *allatī* to *alladhī*, for example), or the misreading of a word by a copyist. However, when making careful comparisons between the two treatises, one finds that the "better" or more easily understandable readings are far more randomly distributed than initially anticipated. Often one is left with the impression that both the copyist of al-Anṭākī's commentary and the copyist of the Hyderabad commentary were remarkably careless and ignorant of their subject matter or that the commentaries have both been subjected to some sort of editing process.

There is also an occasional re-arrangement of material quoted from the earlier commentators. Such re-arranging occurs most frequently, in the case of al-Anṭākī, when a lemma or preliminary principle (*muqaddima*) which he placed prior to a specific proposition is moved by the author of the Hyderabad commentary to follow the introduction to the specific proposition itself.

There are three quotations (labeled as additions) in the Hyderabad commentary attributed to both al-Nayrīzī and al-Anṭākī. These quotations are a microcosm illustrating many of the complications that beset this study, for the additions exhibit a remarkably diverse degree of editing or manipulation of the text. The first quotation is in proposition III, 12. This addition, in its quoted form, presents essentially the work of al-Nayrīzī. The unusual technical vocabulary, especially the use of *ʿalāma* instead of the more usual *nuqṭa*, is especially striking. Another important difference that we note is that the Hyderabad commentary edits out nearly all the references to previous propositions found in al-Nayrīzī's commentary. The Hyderabad commentary includes a diagram not present in the modern edition of al-Nayrīzī's text. And in the diagram for the second part of the proposition, there is a line inserted in the edition of al-Nayrīzī which does not appear in the Hyderabad commentary.

The second quotation is in proposition III, 13. This addition is ascribed to Heron in al-Nayrīzī's commentary. It consists of two parts, each having the possibility of variant positions which are given in different orders. The diction in the Hyderabad commentary, though, is certainly not identical to the version recorded in al-Nayrīzī's commentary. The diagrams for this proposition in these two commentaries are the same in structure, but they are oriented differently and have their labels rearranged. If the printed version has been faithful to the manuscript, this rearranging would seem an indication of editing somewhere in the transmission.

The third quotation is in proposition IV, 3. Here the Hyderabad commentary is difficult to relate to al-Nayrīzī's commentary because there are so many differences between them. These three examples indicate, in summary form, some of the major difficulties inherent in the attempt to recover truncated texts based on quotations in later texts. Appendix III compares these quotations in tabular form to show their relation to the text of al-Nayrīzī more readily. The varying degrees of correspondence between the quotations and al-Nayrīzī's commentary prompt us to wonder how closely these quotations might reflect also the presentation of this material in al-Anṭākī's commentary –a question that cannot at present be answered at present.

There are seven citations of al-Nayrīzī in books IX and X. They are of special interest because the Arabic text of al-Nayrīzī's commentary breaks off at the beginning of book VII. The Latin version attributed to Gerard of Cremona, however, extends through book X. So perhaps these Arabic quotations will allow us some access to the content of his commentary. The additions attributed to al-Nayrīzī in IX, 1 correspond, at least in general content, to similar material in the Latin version.[16] The addition to IX, 6 does not seem to correspond to material reported in Gerard's Latin. The addition to IX, 7 is ascribed to al-Nayrīzī, but there is no report of an addition to this proposition in the Latin version. There are four further citations of al-Nayrīzī in discussion of the definitions of book X. None of these correspond to anything found in Gerard's Latin version. The lack of correspondence between the Hyderabad commentary and the Latin translation is difficult to interpret. The relation between the Arabic and the Latin transmission of this treatise has been discussed by Brentjes, who has suggested that Gerard's Latin is not based directly on the surviving Arabic transmission of al-Nayrīzī.[17]

[16] Curtze, pp. 196-198.

[17] S. Brentjes, "Two Comments on Euclid's *Elements*? On the Relation between the Arabic Text attributed to al-Nayrizi and the Latin Text attributed to Anaritius," *Centaurus* 43 (2001): 17-55.

General Observations

This study began by asking whether the attributed quotations in the Hyderabad commentary can contribute to filling the lacunae in earlier truncated commentaries. Before an answer can be proposed, it is essential to ascertain whether editing might have occurred when these quotations were incorporated into the Hyderabad commentary. As a first step toward ascertaining the purity of the quoted material, I compared quotations ascribed either to al-Anṭākī or to al-Nayrīzī with the same material in the unique copies of the extant portions of these commentaries. Based on previous studies of commentators quoting the Arabic primary transmission of the *Elements*, I expected to find fairly close agreement between the earlier commentaries and the quotations in the Hyderabad commentary. I discovered that, when quoting from Euclid himself, there is close agreement, both in arrangement and in diction, with the primary transmission. When the author of the Hyderabad commentary quotes from the secondary transmission, though, there was often less agreement than anticipated.

There are some 135 quotations explicitly attributed to al-Anṭākī in the Hyderabad commentary. Of these, twenty occur in books III and IV and so represent a potential contribution toward recovering the lost portion of al-Anṭākī's commentary. The quotations from al-Anṭākī discuss both the definitions and the propositions. Initially, I found it surprisingly difficult to locate the original position of attributed material drawn from al-Anṭākī's commentary on the definitions. The original location of the quotations from his commentary on propositions was much easier to find. In part, this situation arises because the Hyderabad commentator quotes from many sources in his discussion of the premises of each book and he selects only segments from most of these sources. In the case of commentary on the propositions, however, he typically quotes the entirety of the comment by al-Anṭākī. Apart from some editing (usually at the beginning of the passage in order to integrate it into the flow of the Hyderabad commentary) and some modifications to the diction of the text (surprisingly frequent elision by homoeoteleuton, for example), the quoted portions from al-Anṭākī's commentary are very often given in their entirety.

To get another impression of the accuracy of the quotations in the Hyderabad commentary, I examined the approximately 50 passages ascribed to Ibn al-Haytham. It quickly became apparent that all the quotations attributed to him come from his *Sharḥ Muṣādarāt Kitāb*

Uqlīdis.[18] Thus, these quotations are found only in the discussion of the definitions and premises – there are only two indirect references to Ibn al-Haytham in the comments devoted to the propositions. A careful comparison of these quotations in the Hyderabad commentary and several manuscripts of the commentary of Ibn al-Haytham, revealed two important facts. First, the attributions to Ibn al-Haytham do not represent the full extent of the commentator's use of Ibn al-Haytham's treatise. As mentioned in the previous section, the large majority of comments attributed to "the author" are actually quotations from Ibn al-Haytham. Following up on this discovery, I re-examined the unattributed comments in the propositions of book V in the Hyderabad commentary and discovered that many were actually quotations from al-Anṭākī, although they lacked an explicit attribution.

Second, it is apparent that some editing has taken place when material was incorporated into the Hyderabad commentary. The editing is of two kinds. There are the minor adjustments needed to obtain a grammatical fit to the context in which the quotation is being inserted. And there is sometimes elision or condensation when the material is inserted into the Hyderabad commentary. This condensation, in turn, is of two kinds. Most often it is on the order of a phrase or a sentence which may be omitted through homoeoteleuton, but sometimes it can stretch to omission of paragraphs (the commentator often omits Ibn al-Haytam's recapitulation statements) and even pages of commentary. The latter occurs when Ibn al-Haytham, for example, comments on several features of a definition but the commentator wants to include only specific comments and so omits entire sections found in Ibn al-Haytham's treatise.

Another general observation arising from this study is that the author of the Hyderabad commentary seems to rely on specific commentaries in each book. For example, we have already noted that many of the Hyderabad commentary's notes on the definitions and postulates are borrowed from Ibn al-Haytham, although the commentator brings in material from a wide array of writers, especially concerning the premises of book I. In the commentary on the propositions, however, we find only a few sources used regularly. In the commentary on the propositions of book I, the most frequently cited source is al-Nayrīzī, along with Heron and Simplicius whose work is quoted (or at least reported) by al-Nayrīzī. A majority of these quotations seem to have undergone significant editing, since both the text and the diagrams in the Hyderabad commentary differ

[18] Two manuscripts have been published in facsimile (Bursa and Istanbul, Fatih). See F. Sezgin, ed., *Sharh Musâdarât Uqlîdis / Commentary on the Premises of Euclid's Elements* (Frankfurt: IGAIW, 2000). I have relied heavily on these published sources, as well as Tunis, Bib. Nat., ms. 16167.

from the printed edition of al-Nayrīzī's commentary. Beginning with book II, however, explicit citations of al-Nayrīzī are much less frequent; there are no references at all to al-Nayrīzī in books VII and VIII.

References to al-Anṭākī first appear in book III, and remain the dominant cited source from book V until book X. Within book X, however, al-Anṭākī is cited and quoted less frequently. The source of the many unattributed comments in book X is still not determined. I do not know how to interpret the complete lack of reference to al-Anṭākī in the first two books of the commentary. Could it be that when the commentary was composed, the commentary had already become truncated?

Cautious Conclusions

We began this study by asking whether the quotations from the Hyderabad commentary could be used to restore at least some parts of now-truncated earlier Arabic commentaries on Euclid by al-Anṭākī and al-Nayrīzī. The time has now come to try to draw together these disparate bits of evidence to attempt an answer to the question. Like the question itself, the answer seems to grow more complex with time. The existence of the various complicating factors noted in the earlier section warns us that considerable circumspection is needed in analyzing our data.

Because quotations in the Hyderabad commentary often exhibit variations in diction from the same material in the manuscript of the earlier commentary, it is unlikely that they can help us to recover the precise wording of al-Anṭākī's earlier commentary. Nevertheless, I believe that the attributed quotations could be used to recover –at least partially– the structure and general content of the now truncated sections of some of the earlier commentaries. The presence of many unattributed quotations (both for al-Anṭākī and for Ibn al-Haytham) and the fact that quotations are very often complete imply that the commentator typically quoted his source in blocks without extensive editing or alteration of the quotations. It is still difficult, however, to postulate without reservation a definite identification for any of the unattributed comments. Perhaps after more extensive statistical analysis of the content of the earlier commentary and detailed philological study of its terminology it might be possible to hazard some guesses about al-Anṭākī's possible authorship of the comments of book III and IV not referred to a specific source.

The quotations from al-Nayrīzī pose considerably greater difficulty. Not only do we have some quotations that cannot be located in the surviving literature, but even the quotations that can be identified appear to have undergone substantially more editing than was the case of the quotations from either al-Anṭākī or Ibn al-Haytham. This editing includes not only the diction, but extends even to re-arranging the material (Appendix III). Moreover, I have not been able to discover any instance in which an unattributed quotation in the Hyderabad commentary can be referred to al-Nayrīzī. Without some additional evidence, it seems to me that these quotations can not help us very much with regard to the missing sections of al-Nayrīzī's commentary.

Even though the results of our study may be somewhat less impressive than we had originally hoped, these quotations do provide at least a limited window into the truncated text of al-Anṭākī. Nevertheless, a number of caveats are in order.

One should not assume that a manuscript of the original commentary is more likely to be free from copying errors or intentional modifications than are the quotations preserved in a secondary commentary. Since in this study we are using unique manuscripts, the degree of modification introduced during copying is difficult to ascertain. Whenever possible, it is preferable to examine multiple manuscripts in order to avoid being misled by copyist errors.

There is, I think, a natural tendency to assume that the closer in time a manuscript copy is to the autograph text, the more pristine is the text that it transmits. In order to validate this assumption, one would need to be able to assess the antecedents of each copy and evaluate their textual purity. Since this cannot be done, it is essential to keep an open mind on whether variations between the manuscript of the original commentary text and the material quoted in the later commentary represent intentional or unintentional modifications by copyists of either text or by editors of the text. Philological analysis, along with statistical analysis of content details may, at times, allow some clarification of the observed textual variations, but my experience is that one is usually left with an irreducible ignorance.

Naṣīr al-Dīn al-Ṭūsī's widely circulated *Taḥrīr* (Redaction) of the *Elements* incorporates material from earlier sources (mainly Ibn al-Haytham's *Kitāb ḥall Shukūk Kitāb Uqlīdis*, as well as the commentary of al-Anṭākī).[19] When using this material, al-Ṭūsī edits his source in the sense that he has streamlined the argument and deleted repetitive statements as well as altering the diction when necessary to match the style of his own treatise. This borrowing from earlier commentaries occurs without an explicit attribution. As we have seen, the Hyderabad commentary also incorporates considerable material from earlier sources,

[19] G. De Young, "The *Tahrīr Kitāb Usūl Uqlīdis* of Nasīr al-Dīn al-Tūsī: Its Sources." To appear in *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften.*

some of it with explicit citation, but more often without an attribution. As more secondary transmission documents are subjected to careful scrutiny, we may perhaps find additional sources that may help to restore the truncated texts in the Arabic transmission.

Appendix I

Tabulated proposition comments, books III-V

In these tables, I catalog each comment found in the Hyderabad commentary. If it is explicitly attributed, I note that fact by the author's initial or name in column 2. If it is not explicitly attributed, there is nothing in column 2 unless the material can be found in the extant portion of al-Anṭākī's or al-Nayrīzī's commentary. If an unattributed comment matches what is found in one of the earlier commentaries, that author's initial is placed in square brackets. The tables show that the majority of comments are unattributed. But in book V, a large majority of these unattributed comments turn out to be drawn from the commentary of al-Anṭākī.

III, 1	A	Addition (converse of the proposition)
III, 2		Logical objection
III, 5 & 6		Logical objection
	Heron	Muqaddima
III, 7	N	Addition
III, 8	N	Addition
III, 9	Thābit	Alternate demonstration
	A	Addition
III, 10	Thābit	Alternate demonstration
III, 11	Thābit	Alternate demonstration
III, 12	N + A	Muqaddima
		Alternate demonstration
III, 13	N + A	Addition
III, 14		Proof "according to what we added in proposition 13"
III, 15		Logical objection
III, 16		Alternate demonstration
	A	Addition
	A	Addition
		Addition
III, 19		Three cases

		Porism
		Porism
III, 20		Correcting a logical lacuna
		Another demonstration
		Addition
		Extension of previous addition
III, 21	A	Addition
III, 22		Addition (?)
III, 24		Alternate demonstration
		Alternate demonstration
III, 25	A	Addition
III, 32		Porism
		Alternate demonstration
		Alternate demonstration
		Alternate demonstration
III, 35		Addition (?)
		Porism (3 cases)
III, 37		Converse of the proposition (?)
III, 47 (?)		Another diagram (or approach)
IV, 1	N	Addition
	A	Addition
	A	Addition
IV, 2		Alternate demonstration
	A	Addition
	A (?)	Addition
		Another ("easier") demonstration
		Porism
IV, 3	N + A	Addition
		Logical objections (2)
	A	Addition
IV, 4		Logical objection
	A	Addition
IV, 5	Thābit	Demonstration
	Thābit	Comment / gloss
	N	Demonstration
	N	Addition
		Another demonstration
		Another approach
	A	Addition
		Converse of the addition
		Extension (?)
		Converse of the extension
		Extension (?)

		Converse of the extension
		Porism (?)
IV, 8		Alternate demonstration
IV, 9		Another method (?)
IV, 10	A	Addition
IV, 11	A	Addition
IV, 12		Comment / gloss
	A	Addition
IV, 13		Note (proposition ordering)
		Comment
	Heron	
		Extension beyond the pentagon
IV, 14		Comment / gloss
		Converse of the proposition
		Porisms (2)
		Extension (?)
IV, 15		Note (proposition ordering)
IV, 16		Comment (method of previous proposition "easier")
IV, 17		Comment / gloss
		Porisms (2)
	Thābit	Extension to hexagon
		Alternate approach
		Converse of alternate approach
		Comment / gloss
	N	Comment
IV, 18		Extensions (4)
		Comment
V, 1	[A]	Comment
	[A]	Converse
		Numerical example
		Alternate demonstration
V, 2	[A]	"Converse of previous proposition"
	[A]	Porism
		Proof in terms of parts
		Alternate demonstration
V, 3	[A]	Extension beyond doubling
	[A]	Converse
	[A]	Numerical example
	[A]	Porism
V, 4	A	Muqaddima
		Numerical example
V, 5		Comment
	[A]	Converse (not identified as converse in Hunt. 70)

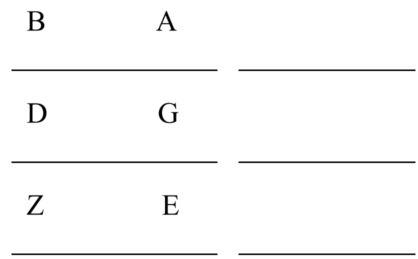
V,5		Commentary
	[A]	Converse (not identified as converse in Hunt. 70)
	[A]	Numerical example
V, 6	[A]	Generalizing Euclid's proof
V, 7	[A]	Converse (called "ziyāda" in Hunt. 70)
	[A]	Numerical example
V, 8	A	Muqaddima
		Demonstration (Euclid?)
	[A]	Porism
	[A]	Numerical example
V, 9	A	Muqaddima
	[A]	Extension
	[A]	Porism
		Numerical example
V, 10	[A]	Numerical example
V, 11	[A]	Another approach
	[A]	Numerical example
V, 12	[A]	Comment / gloss
	[A]	Numerical example
V, 13	[A]	Numerical example
V, 14	[A]	Numerical example
V, 15		Numerical example (values differ from Hunt. 70)
V, 16	N	Addition
V, 17	[A]	Numerical example
	N	Addition
V, 18	N	Addition
	[A]	Numerical example
V, 19	[A]	Converse (not identified as such in Hunt. 70)
V, 20	A	Muqaddima (converse of the proposition)
	[A]	Extension beyond 3 magnitudes
	[A]	Extension to 5 magnitudes
	[A]	Numerical example
V, 21	[A]	Comment and extension beyond 3 magnitudes
V, 22	[A]	Extension beyond 3 magnitudes
V, 23	[A]	Extension beyond 3 magnitudes
V, 24	[A]	Comment / gloss
	[A]	Numerical example
V, 25	[A]	Comment / gloss
	[A]	Numerical example
		Alternate demonstration

Appendix II

Tabular comparison of Al-Anṭākī and Hyderabad, Riyāḍī 2

In the following table, I set out in tabular form the statements of proposition V, 11 and the corresponding statements in Hyderabad, Riyāḍī 2. The result reveals an unattributed comment in the Hyderabad commentary that clearly is quoted from the commentary of al-Anṭākī.

al-Anṭākī	**Hyderabad, Riyāḍī 2**
Proposition 11: Two magnitudes whose ratio is equal to a ratio, their ratios are equal to one another.	
He used in the demonstration of this proposition the condition (*sharīṭa*) of multiples in proportionals (*al-munāsiba*) and the intellectual premise (*muqaddima ʿaqliyya*) that things equal to one and the same <thing> are equal to one another. And it is clear according to what was said about it.	He used in this proposition the first principle concerning the condition (*al-qaḍiyya al-ulā fī sharīṭa*) of multiples and things equal to one and the same thing are all equal to one another and it was shown according to what he said concerning it.
And it is possible that we prove it (*nubarhina ʿalayhi*) without abridgement (*bi-lā ikhtiṣār*) of the multiples but rather, strengthening them (*yaqwī-hā*).	And it is possible that we prove it (*nubarhina ʿalayhi*) without (*dūna*) taking (*akhadha*) the multiples, but rather by taking the ratios.
And so he speaks thusly:	And so he says:
The ratio of A to B is as the ratio of G to D and the ratio of G to D is as the ratio of E to Z.	The ratio of A to B is as the ratio of G to D and the ratio of G to D is as the ratio of E to Z.

al-Anṭākī	**Hyderabad, Riyāḍī 2**
So I say that the ratio of A to B is as the ratio of E to Z.	I say that the ratio of A to B is as the ratio of E to Z.
[There is no diagram in Hunt. 70]	
The proof of that is that the ratio of A to B is as the ratio of G to D.	Its proof is that the ratio of A to B is as the ratio of G to D.
Now, according to the condition of multiples, it is when we take for magnitudes A, G <and> B, D, for each pair of them, equimultiples, the multiples of A, G either together exceed the multiples of B, D or are equal to them or are less than them.	Now, the condition of the multiples is when we take for magnitudes A, G <and> B, D, for each pair of them, equimultiples, the multiples of A, G either exceed the multiple of B, D or are equal to them or are less than them.
Likewise also, the ratio of G to D is as the ratio of E to Z.	Likewise also, the ratio of G to D is as the ratio of E to Z.
Then, if we take for magnitudes G, E equimultiples and for magnitudes D, Z equimultiples, according to the condition of multiples, the multiples of G, E either equal to the multiples of D, Z or exceed them or are less than them.	And if there be taken for magnitudes G, E equimultiples and for magnitudes D, Z equimultiples, the condition of the multiples is <that> the multiples of G, E either are equal to the multiples of D, Z, or they exceed them, or are less than them.
Thus the multiples of A and E either are <together> equal to the multiples of B and Z or together exceed them or together are less than them.	Thus, the multiples of A, E either are equal to the multiples of B, Z or together exceed them or together are less than them.

al-Anṭākī	**Hyderabad, Riyāḍī 2**
Thus the ratio of A to B is as the ratio of E to Z.	Thus the ratio of A to B is as the ratio of E to Z.
That is what we wanted to show.	That is what we wanted to show.
Its example from numbers: A, three; B six; G, two; D, four; E, five; Z ten.	Its example from number is that we make A three and B six and G two and D four and E five and Z ten.
	Thus the ratio of three is of six is as the ratio of five is of ten and the two of them are as the ratio two is of four.
	Its demonstration is completed.

Appendix III

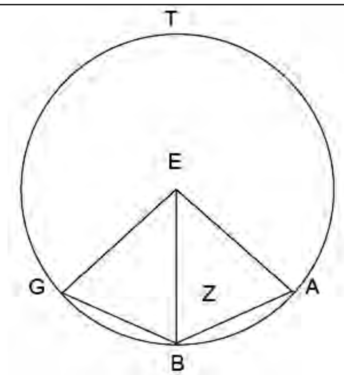
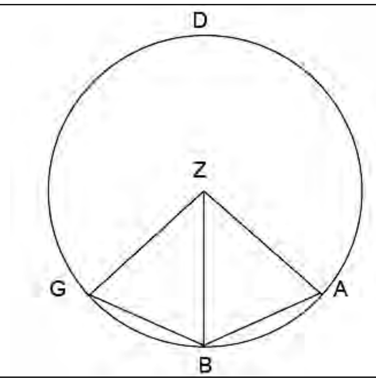
Tabular comparison: al-Nayrīzī and Hyderabad, Riyāḍī 2

In the following tables, I translate the three propositions ascribed to al-Nayrīzī and al-Anṭākī in Hyderabad, Riyāḍī 2. Each proposition is matched to the other statement by statement in order to exemplify the variation between the two treatises.

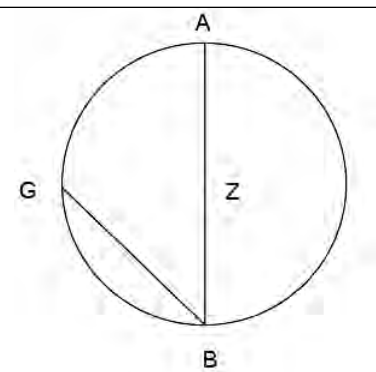
In this first table, I provide a close parallel translation of proposition III,12 comments recorded in the Hyderabad commentary and in the commentary of al-Nayrīzī.

Al-Nayrīzī	**Hyderabad, Riyāḍī 2**
Heron said: We introduce a lemma (*muqaddima*) needed in proposition twelve:	There is found, for al-Nayrīzī and al-Anṭākī, a lemma (*muqaddima*) needed in it, namely:
A straight line does not cut the circumference of a circle at more than two points (*ʿalāmatayn*).	A straight line does not intersect a circle at more than two points (*ʿalāmatayn*).
For if it be possible, let straight line AG cut circle DAG[20] at more than two points – I mean at points (*ʿalāmāt*) A, B, G.	For if it were possible, let ABG, <a straight line> falling outside the center of circle ABG, intersect circle ABG at points (*ʿalāmāt*) A and B and G.

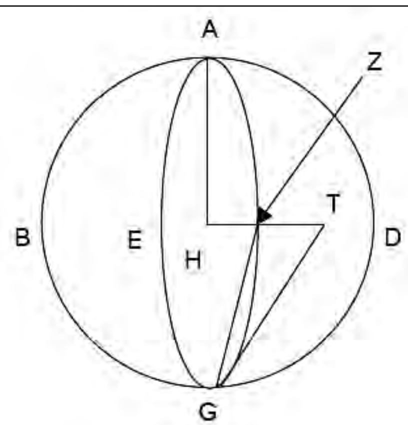
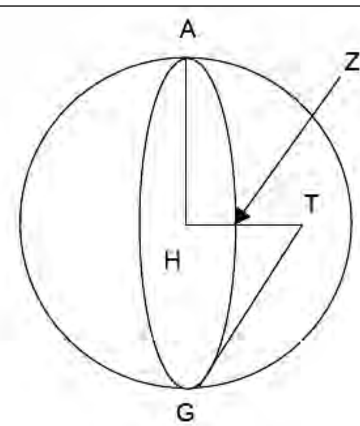
[20] The diagram in the printed edition labels the circle TAG, although the text reads DAG.

Al-Nayrīzī	**Hyderabad, Riyāḍī 2**
	
We determine (*nastakhriju*) the center, just as its determination (*istikhrājuhu*) was shown in demons-tration (*burhān*) one of [book] three. Let it be point E.	
We connect lines EA, EB, EG.	We extend from the center lines AZ, ZB,[21] ZG.
	Now, line ZA is like line ZG, so angle A is equal to angle G.
	Also, line ZA is equal to line ZB, so angle A is equal to angle ZBA.
Now, on account of [the fact] that line ABG is a single straight line	
and angle EBA is exterior (*khārij*) <to> triangle EBG, so on account of demonstration (*burhān*) 16 of <book> I, angle EBA is greater than angle EGB.	But angle ZBA, the exterior <angle> of triangle ZGB, is greater than the interior <angle> which lies opposite it, namely angle G.
But angle EBA was equal to angle EAB. That is shown on account of demonstration 5 of <book> I.	But angle ZBA was equal to angle A.
Thus angle EAB is, therefore, greater than angle EGB.	Thus angle A is greater than angle G.

[21] The copyist has written AB.

Al-Nayrīzī	Hyderabad, Riyāḍī 2
Because[22] side EG is equal to side EA, so, on account of <demonstration> 5 of <book> I, angle EAB is equal to angle EGB.	
But it was greater than it.	But angle A was equal to angle G.
This is a contradiction – <it is> an impossibility.	This is a contradiction – it is not possible.
Therefore, a straight line does not cut the circumference of a circle at more than two points. That is what we wanted to show.	
Now, one may say (*qāla qā'ilan*) that the center is able to be on line AB.	So then it is possible that the center is on line ABG, falling within the circle in more than two places.
In that case, we say that if it be possible, let it be at point Z.	So let point Z, just as in the second diagram, be the center.
[There is no comparable diagram in the printed edition of al-Nayrīzī.]	
Now, on account of the fact that point Z is the center of circle ABGD, line AZ is equal to line ZB; also line ZA is equal to line ZBG.	Now, line AZ is equal to ZB, and likewise AZ is equal to ZBG.

[22] We would expect "but" (*lākin*) instead of "because" (*li-anna*).

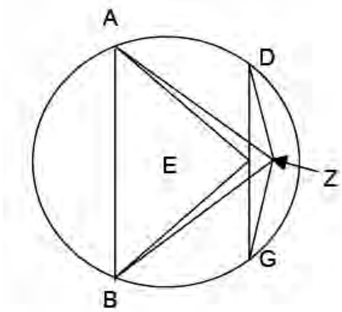
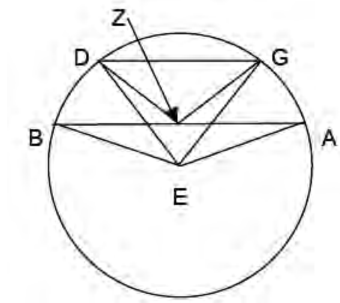
Al-Nayrīzī	Hyderabad, Riyāḍī 2
So line ZBG, then, is equal to line ZB. So, therefore, line GBZ, the greater, is equal to line ZB, the smaller.	Thus, ZB is equal to ZG, the smaller is like the greater.
This is not possible.	This is a contradiction, it is impossible.
Therefore a straight line does not cut the circumference of the circle at more than two points. That is what we wanted to show.	
Heron said also, in proposition twelve,	Then he mentioned and adduced, after this lemma, another demonstration for the desired proposition.
Whether it be possible that two circles are tangent to one another at more than one point (*ʿalāma*).	That is, whether it be possible that two circles be tangent to one another at more than one point (*ʿalāma*),
So let circles ABGD, AEGZ be tangent to one another interiorly at more than one point – I mean, at points (*ʿalāmatay*) A, G.	Let the two be tangent at two points (*ʿalāmatay*) A and G.
	

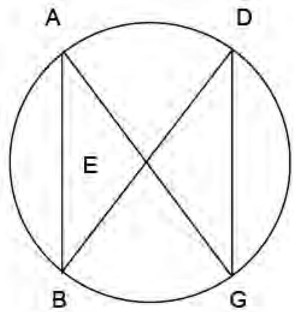
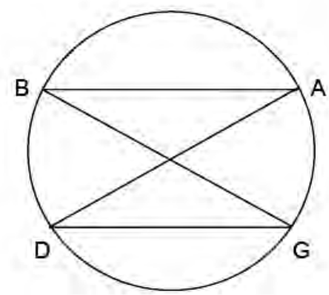
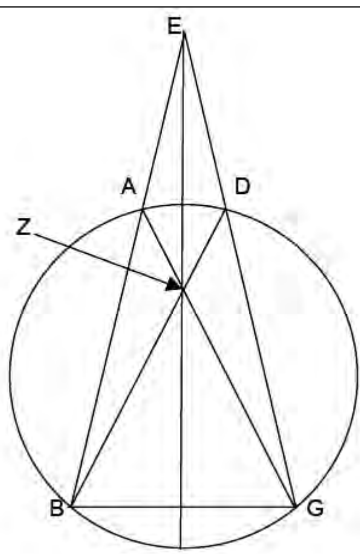
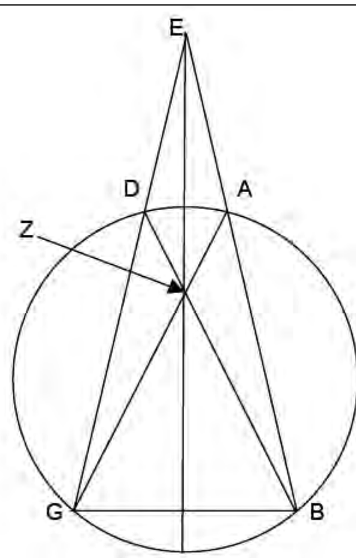
Al-Nayrīzī	**Hyderabad, Riyāḍī 2**
Let us determine (*nastakhriju*) the center of circle AEGZ, just as its determination was shown in demonstration (*burhān*) 1 of [book] III.	We determine (*nastakhriju*) the center of circles AG, BD as we showed in the demonstration (*burhān*) of the first proposition of this book.
Let it be point H,	
	Euclid specifies it in the interior of the circle.
And the center of circle ABGD. We postulate (*nunazzilu*) that it to be outside circle AEGZ at point (*ʿalāma*) T.	Now, if it be possible, the center of the outer circle is exterior to the inner circle. Let it be T.
Thus, we say that the center does not fall outside, for if it were possible,	
We connect between points (*nuqṭatay*) H, T, which are the two centers, by line HT.	We connect points (*nuqṭatay*) T, H which two are at the center, by line HT.
Then, it is clear on account of demonstration (*burhān*) 11 from [book] III, that line HT, if extended in both directions together, passes through the place (*mawāḍiʿ*) of tangency. It therefore passes through points A, G.	Now it has been shown in proposition 11 from this book that line HT, which is extended in both directions, falls on the two points (*nuqṭatay*) of tangency, namely points A, G.
So we extend it such, therefore, such that the locale (*waḍʿa*) of this line is as the locale of line AHTG.	So let it be extended such that this line, then, falls just as does line AHTG.
Therefore, line AHZG cuts circle AEGZ at more than two points (*ʿalāmatayn*).	Therefore, line AHTG cuts circle AZG at more than two points (*ʿalāmatayn*).
But we have shown that it is not possible.	This is a contradiction.

Al-Nayrīzī	**Hyderabad, Riyāḍī 2**
Therefore, the center of circle ABGD does not fall outside circle AEGZ.	
On the example of this we may show that it does not fall on arc AZG.	
For if <possible>, let it be like point (*nuqṭa*) Z.	Likewise, if we specify the center of the outer circle to be on the circumference of the inner at point (*nuqṭa*) Z;
	We extend line ZH passing through the two centers.
	And so it will, if extended in both directions, pass through the two points of tangency, namely points A, G.
Thus line AHZG, a single straight line, cuts the circumference of circle AEGZ at more than two points (*ʿalā-matayn*) – I mean at points (*ʿalāmāt*) A, Z, G.	Thus line AHZG falls on the circumference of circle ADZ in more than two places (*mawḍiʿayn*).
That is not possible.	This is a contradiction.
So it is not possible, therefore, that the center of circle ABGD fall on the circumference of circle AEZG.	And so let us set out that it is not possible to find two circles tangent to one another which cut one another in the same place, since if that were possible it would not be possible a priori (*min qabla*) that the two be tangent because tangency precedes intersecting <according to> nature (*ṭabʿ*).
But we have shown that it also does not fall outside it. Therefore, it falls within it, just as the Mathematician (*al-Riyāḍī*) said.	
That is what we wanted to show.	That is what we wanted to show.

In proposition III,13 the differences between the comment attributed to al-Nayrīzī and al-Anṭākī as recorded in the Hyderabad commentary and that found in edition of al-Nayrīzī are more pronounced. I translate only the basic stages of the argument, omitting the details of the proofs, in order to give the flavor of the differences. The parts of the two comments are arranged differently in the original texts. I have paired similar comments in this table so that differences in diction can be easily observed. To indicate comments that are not in their original place, I place the text in italic typeface and indicate the respective ordering using numbers in curly brackets.

Al-Nayrīzī (Heron)	**Hyderabad, Riyāḍī 2**
As for the addition of Heron in this proposition:	And al-Nayrīzī and al-Anṭākī added additions,
it may be shown that the center of the circle falls between lines EZ, GD.	
He drew for that a picture (*ṣūra*) of circle ABGD and extended in it lines AB, GD equal to one another.	
He said that the center of this circle falls between lines AB, GD.	
It cannot be otherwise. For if it be possible, let it fall first on <one of> lines AB, GD. We postulate (*nunazzilu*) that it falls on line GD at point (*ʿalāma*) E. [Then follows an argument leading to a contradiction.] {1}	*We say that the center is on line AB, such as point (nuqṭa) Z.* [Then follows a demonstration leading to a contradiction.] {2}

Al-Nayrīzī (Heron)	**Hyderabad, Riyāḍī 2**
	
And on this example it may be shown that it does not fall on line AB.	
I say also that it is not outside (*khārijan*) one of lines AB, GD. For if it be possible, let it be outside line GD. [Then follows an argument leading to a contradiction.] {2}	*The center, namely point (nuqṭa) E, is outside the two chords falling in the circle, namely chords AB, AG.* [Then follows a demonstration.] {1}
Heron showed also that the center of circle ABGD falls between lines AB, GD, which are equal to one another, without the technique of an indirect proof.	It may be shown also that the center of the circle falls between lines AB, GD, which are equal to one another, without an indirect proof.
Now it is permissible that lines AB, GD be either parallel or skewed to one another.	And it is so that the two lines are parallel or skewed to one another.
Let us postulate (*nunazzilu*) first that they are parallel to one another. [Then follows a demonstration.] {3}	Let us make them first parallel to one another. [Then follows a demonstration.] {3}

<table>
<tr><th>Al-Nayrīzī (Heron)</th><th>Hyderabad, Riyāḍī 2</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>And we may postulate also that lines AB, GD are not parallel to one another. We extend the lines rectilinearly until they meet. Let them meet at point E. We extend lines AG, BD to intersect at point Z and we extend line EZH.</td><td>Now if the two are not parallel to one another, we extend them until they meet one another at point E. We extend line EZTH</td></tr>
<tr><td>I say that the center of the circle is on line EH.
[Then follows a demonstration.] {4}</td><td>I say that the center of the circle is on line EH.
[Then follows a demonstration.] {4}</td></tr>
<tr><td>
</td><td>
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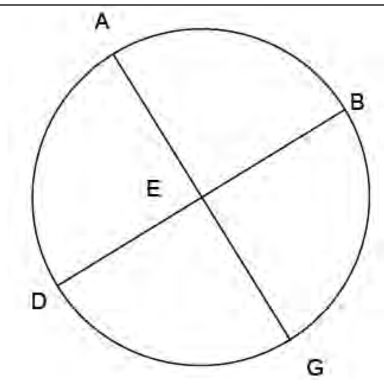
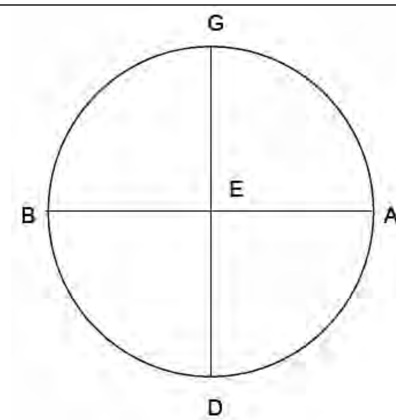
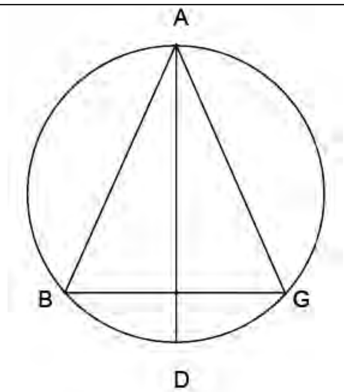
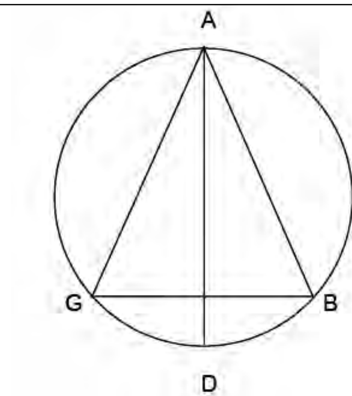
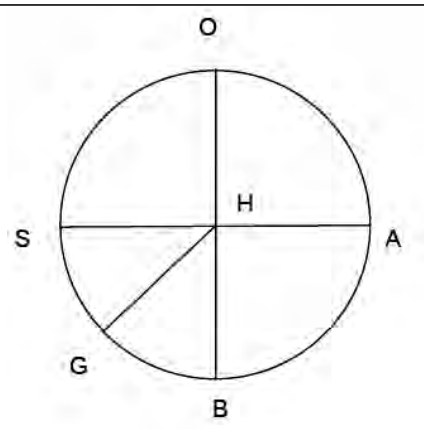
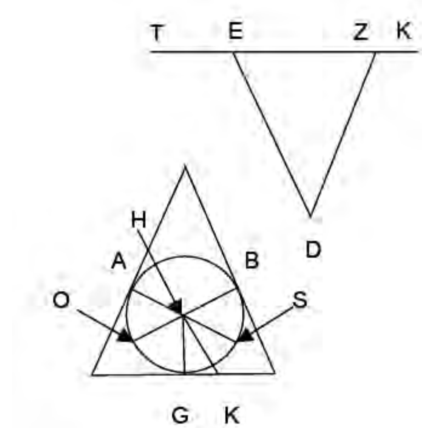
Al-Nayrīzī (Heron)	**Hyderabad, Riyāḍī 2**
He said also: Should someone say that the two equal lines intersect inside circle ABGD at point (*ʿalāma*) E. . . . We say that that the center is either at the common intersection of AG, BD . . . or it is somewhere else.	*Let them intersect inside the circle.*
Now, if it falls at point E (the common intersection), it is therefore between lines AG, BD. The issue has been resolved. {5}	*It is not impossible that the center fall at their bisection.* *Thus the center is the common portion of their intersecttion.* {6}
	
And it has been shown that it does not fall on one of lines AB, GD. [No demonstration follows.]	*And if their intersection is elsewhere than at their bisection, the center is in this case between them.* [Then follows a demonstration.] {7}
Now, someone might say that we may specify that lines AB, GD do not intersect within circle ABGD but meet at its circumference like lines AB, AD. [Then follows a proof that the center is between them on line AG.] {6}	*Let them meet also at the circumference line. I say that the center is between them.* [Then follows a demonstration that the center lies between them.] {5}

Al-Nayrīzī (Heron)	Hyderabad, Riyāḍī 2
	

In this table, I compare the material attributed to al-Nayrīzī and al-Anṭākī in proposition IV, 3 of the Hyderabad commentary with the same material in al-Nayrīzī's commentary. I have corrected an error in the diagram. In the manuscript, HS is incorrectly extended to fall on the base line along with G, K. (I have retained the unusual, and potentially confusing, double use of K in the diagram since it reflects the diction of the text itself.)

Al-Nayrīzī	Hyderabad, Riyāḍī 2
As for what Heron attacked in this proposition, it is also something to be considered. But we mention that he said:	
	Al-Nayrīzī and al-Anṭākī added to it, saying:
	That we want to construct about circle AB a triangle surrounding it having its angles equal to the angles of triangle DEZ.
	So we choose (*ʿalimnā*) on the circumference of circle AB point A and extend from it a line to the center. It is line AH.

<table>
<tr><th>Al-Nayrīzī</th><th>Hyderabad, Riyāḍī 2</th></tr>
<tr><td></td><td>We construct at point H from it an angle like angle TED, the exterior <angle> from triangle DZ, the side EZ having been extended rectilinearly to points T,[23] K, namely angle AHB.</td></tr>
<tr><td>If we extend lines AH, BH to points S, O,</td><td>We extend side AH rectilinearly to point S and similarly <side> BH to point O.</td></tr>
<tr><td>Then we construct angle BHG equal to angle DZK.</td><td>Then we construct at point H from line HB an angle like angle DZK, namely <angle> BHG.</td></tr>
<tr><td></td><td>Then we extend from points A, B, G lines tangent to the circle.</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td></td><td>Now, line BH, since there has been constructed at point H from it an angle like angle DZK, namely angle BHG, line HB falls on line HS.</td></tr>
<tr><td></td><td>And angle <B>HS is equal to angle DZK.</td></tr>
</table>

[23] The copyist has incorrectly written E.

Al-Nayrīzī	**Hyderabad, Riyāḍī 2**
	Now a situation of doubt (*tashkīk*) arises concerning it since he says that angles DZK, DZE, DEZ, DET are equal to four right angles.
	We remove (*nukhriju*) from them angles DZE, DEZ which are less than two right angles because they are two angles in a triangle. There remain angles TED, DZK which are greater than two right angles.
Line GD falls between points B, S.	
We say for that reason that AS is straight because it is the diameter of the circle. Thus angles AHG, GHS are equal to two right angles.	They are equal to angles AHB, BHS, which are equal to two right angles.
But angle AHG is equal to angles DET, DZK and angles DET, DZK are greater than two right angles.	
Thus, angle AHG is greater than two right angles. It is also less than the sum of angles AHG, GHS – two right angles.	
This is abominable (*shaniʿ*).	This is a contradiction – it is not possible.
Therefore, line HG is not constructed (*yubtanā*) on line HS in the direction of (*naḥwa*) point B.	
Now if it be said that it is superimposed on line HS, we say that then angles DET, DZK are equal to angles AHB, BHS.	And if it is said that HG falls somewhere between point B and S, as line HK – that also Is not possible because angles DET, DZK, the equals of angles AHB, AHK are greater than two right angles.

Al-Nayrīzī	**Hyderabad, Riyāḍī 2**
But angles AHB, BHS are like two right angles. Thus angles DET, DZK are two right angles.	But angles AHK, KHS are equal to two right angles. Thus, angle AHK is less than two right angles and it is equal to angles TED, DZK, which are greater than two right angles.
This also is abominable because the two of them are greater than two right angles. Thus line HG is not superimposed on line HS. And it is not constructed upon it in the direction of point B	This is a contradiction – it is not possible.
Now, if it be said that line HG is superimposed on line HO which is connected to line BH rectilinearly, we say on account of angle AHB being made like angle DET, then there remains angle DZK equal to angles BHS, SHO, which are two right angles.	
This is utterly abominable and it is more abominable if it be said it is constructed on line HO in the direction of point A. So line GH never [has] its extension between points O, S.	
Now this has been shown, the remaining figures, if we speak of them according to what the Mathematician postulates, there is no necessity for a challenge to them.	
That is what we wanted to show.	

The 1413–14 Sea Chart of Aḥmad al-Ṭanjī

Mónica Herrera-Casais

The only extant sea chart by Aḥmad b. Sulaymān al-Ṭanjī was signed in the city of Tunis in 1413–14.[1] This is the first dated Arabic sea chart of the Mediterranean that is preserved, and the oldest after the anonymous Maghreb Chart, which dates from around the first half of the 14th century. Nothing is known about al-Ṭanjī's life, except that he was originally from Tangiers and possibly settled in Tunis. He must have been an experienced professional chartmaker, as the artistry and accuracy of his piece strongly argues against its being an isolated work. He was a contemporary of Anselm Turmeda (or ʿAbdallāh al-Tarjumān, d. ca. 1424–30), a Majorcan scholar converted to Islam who became translator and maritime customs officer for the Ḥafṣid sultan Abū Fāris (gov. 1394–1434).[2] Like Turmeda, al-Ṭanjī may have been active in or around the flourishing port of Tunis, a major commercial centre of the Islamic west, where sea charts and nautical data could be obtained from all over the Mediterranean.[3]

Al-Ṭanjī's chart is carefully executed as a work of art, probably commissioned for some important person or wealthy customer. Indeed,

[1] On the chart, see Sezgin 2000-07, vol. 11, pp. 31-32, 39, 40, 136; vol. 12, pl. 36 and vol. 13, p. 13ff.; Soucek 1992, p. 264, fig. 14.2; Uçar 1987 (summarized in Uçar 2000, pp. 215-17). Colour reproductions: *Istanbul Exhibition 1994*, pl. 2; *Mediterraneum 2004*, pp. 278-79 (the neck has been left out) and 280, 281 (Mediterranean islands in detail); Özdemir 1992, pp. 122-23; Sezgin 1987, pl. 18.

[2] *Mediterraneum 2004* → M. de Epalza: "Las lenguas portuarias mediterráneas: Traducir en la «cultura de funduq» y entenderse en «lengua franca»," p. 233ff. Turmeda became also a leading figure in the religious controversy against Christianity. See the edition and translation of his *Tuḥfat al-adīb* by Epalza 1994, with biographical references, pp. 11-25 (introd.), 230-43 (text).

[3] The presence of Arago-Catalan, Pisan, Genoese and Venetian diplomats, merchants and seamen is documented in Tunis since the 13th century. Their *fondacos* (lodgings) were all located outside the walled city, near the port area of Goletta, where they remained into the Ottoman period. These lodgings functioned as centres for trade and exchange, leading to cross-cultural contacts: see Constable 2003, pp. 128-33, 191-99, 296-301.

most surviving Arabic sea charts are luxury pieces, similarly to their Majorcan counterparts, some of which are known to have been made as gifts for princes and dignitaries. In its contents al-Ṭanjī's chart is purely nautical, as it focuses on the coastline layout and practical data needed for navigation.[4] The inland territories are mostly left empty, except for the main river courses and deltas, some miniatures for cities and fauna, and an additional system of colour identification for the central Mediterranean islands.

In this paper, a series of elements in al-Ṭanjī's chart that will be identified as originally Islamic, belong to a distinctive Arabic chartmaking tradition in the Mediterranean. These elements include Arabic place names and geographical terminology, the hydrography of the territories under Islamic control, a calendar of lunar mansions and a decorative frame made of intertwined knots. Moreover, the chart presents features derived from the works of Pietro/Perrino Vesconte (fl. Venice, 1311–27), the most prolific and influential chartmaker in 14th-century Venice. Other features of al-Ṭanjī's chart are attested in the early Majorcan production from the time of Angelino Dalorto/Dulcert (fl. Palma, ca. 1325–39) onwards. These characteristics bear witness to the circulation of European sea charts as reference sources in Tunis at the beginning of the 15th century, and perhaps before this date. In the 16th century, the use of a Majorcan model by a Maghrebi chartmaker is reported by ʿAlī al-Sharafī in one of the inscriptions in his 1579 chart.[5]

General description

Al-Ṭanjī's chart is preserved in good condition at the Topkapi Palace Museum in Istanbul, where it is catalogued as Hazine 1823 (formerly Karatay no. 1407).[6] The circumstances as to how it came to the Topkapi are unknown, though some scholars claim that it was already there at the time of Sulaymān the Magnificent (gov. 1520–66). The chart is drawn on a parchment surface covering about 44.5 × 77 cm (out of about 55 × 90 cm for the whole skin).[7] The approximate scale is 1: 6 000 000.

The parchment is arranged with the neck located to the east, in contrast to the more customary practice in Mediterranean sea charts that place the

[4] The classification *náutico puro* in opposition to *náutico geográfico* is established by Rey & García 1960, ch. II.
[5] The inscription is translated into Italian by Nallino 1944, p. 538.
[6] Goodrich 1993, p. 129; Karatay 1961, vol. C1, pp. 464-65; Van de Waal 1969, p. 82 (taken from Karatay).
[7] I have not surveyed the original myself. Its dimensions vary in the modern literature: Soucek 1992, fig. 14.2 (skin 54 × 88 cm); Uçar 1997, p. 225 (chart 44.4 × 77 cm; skin 55 × 90 cm).

neck to the west. This arrangement is distinctive of some charts by Vesconte and by other early 15th-century Venetian chartmakers such as Albertin de Virga (1409),[8] an anonymous (ca. 1420) who will be discussed below, Francesco de Cesanis (1421)[9] and Giacomo Giroldi (1422).[10] One Arabic example is that of Ibrāhīm al-Mursī (Tripoli, 1461).[11] In al-Ṭanjī's chart, the neck shows a calendrical wheel combining the solar system of the Julian months with that of the twenty-eight lunar mansions to be used as chronological indicators. Each lunar mansion has its name, figure and influence period throughout the year. Most Arabic sea charts of the Mediterranean include calendrical data of this kind, which may be arranged in a wheel (for instance, in al-Mursī's chart) or tabulated form (in ʿAlī al-Sharafī's atlases, 1551 and 1571). The lunar mansions are an element of Islamic influence in the Catalan Atlas attributed to Abraham Cresques (ca. 1375).[12]

The inscriptions and decoration

Al-Ṭanjī's chart is signed and dated on two cartouches that are inserted in the two longitudinal scales. They divide each of the scales into two parts, but do not interfere with their functioning. The inscriptions are written in ornamental Maghrebi script similar to the kufic calligraphy, and differ from the regular handwriting (*naskhī*) used for the coastal place names. They face the outer borders of the chart, so that the dating (right above the frame of the wind rose) should be read with the chart oriented southwards (south at the top), and the signature with the chart oriented northwards (north at the top). These are:

صُنع بمدينة تونس عام ستّة عشر وثمانمائة

This was made in the city of Tunis in the year 816
[of the Hijra = 1413–14 d.C.],

[8] La Roncière & Mollat 1984, p. 204 (no. 11).
[9] Reprod. Kamal, *Monumenta* 4:4, p. 1417.
[10] Reprod. Kamal, *Monumenta* 4:4, p. 1420. The chart's toponymy is listed by Kretschmer 1909.
[11] On his chart, see Comes 2007; İhsanoğlu 2000, p. 11; Leitner 1982; Sezgin 2000-07, vol. 11, pp. 32-33, 40, 136 and vol. 12, pl. 37; Soucek 1992, pp. 264-65, fig. 14.3; Uçar, 2000, pp. 217-19.
[12] *L'Atles Català* (fol. II), pp. 98-99. Other main astronomical and astrological contents are studied in Samsó 2005.

من عمل العبد الفقير إلى الله أحمد بن سليمن الطِنجيّ
by the humble servant of God,
Aḥmad b. Sulaymān al-Ṭinjī (= al-Ṭanjī).[13]

The chart is enclosed in a frame decorated with intertwined knots on the northern, eastern and southern sides. This design is widely documented in Islamic art and manuscript production, particularly in Korans from al-Andalus and the Maghreb.[14] The knotted frame seems to be peculiar to the Islamic sea charts, as attested in al-Mursī's piece and the extant production of the al-Sharafī family. A frame of this kind appears with angular knots in Pīrī Re'īs' map of the Atlantic (1528–29),[15] and is modified into a chevron pattern in the 16th-century chart by Ḥājj Abū l-Ḥasan (fl. Istanbul?).[16] According to Rosselló, there are also some 15th-century Majorcan examples with frame decoration.[17] In Gabriel de Vallseca's chart (1439) the frame consists precisely of distorted Arabic letters, and in four charts by Pere Rossell (1456, 1464, 1466 and 1468) fragments of chevron adorn the graphic scales.[18]

The cartographic scope

The area shown in al-Ṭanjī's chart is mainly the Mediterranean, though the cartographic scope extends from Ireland (about 10º W) to the eastern end of the Black Sea (almost 42º E). It also reaches approximately as far south as Tarfaya (28º N), lying above the area of Cape Bojador (26º N) which defines the limit for western African coasts in 14th-century European sea charts.[19] The Canary Islands have been left out here for reasons of space, though they are usually depicted from Angelino

[13] The name is difficult to read. In the modern literature, since Karatay 1961, it is erroneously transliterated as Ibrāhīm b. Aḥmad b. Sulaymān al-Kātibī al-Tūnisī: İhsanoğlu 2000, pp. 3-4; Soucek 1992, p. 264; Uçar 1987, p. 226. Sezgin 1987 and 2000-07 give it correctly.

[14] See examples in *L'Art du livre arabe 2001*. King 2002-03, pp. 98-101 draws attention to the knots engraved on astronomical instruments.

[15] On this map, see Soucek 1992, p. 272, pl. 21; Uçar 2000, pp. 222-24. Reprod. *Istanbul Exhibition 1994*, pl. 15; Sezgin 2000-07, vol. 12, pl. 39a.

[16] On this chart, see İhsanoğlu 2000, p. 114; Sezgin 2000-07, vol. 11, pp. 33-34, 136 and vol. 12, pl. 38; Soucek 1992, p. 265, fig. 14.4; Uçar 2000, p. 227. Catalogue references: Goodrich 1993, pp. 128 (fig.), 129; Van de Waal 1969, p. 86, pl. 5. Reprod. *Istanbul Exhibition 1994*, pl. 26.

[17] Rosselló 1995, p. 297; Rosselló 2000, pp. 105-6.

[18] For a preliminary study of Vallseca's chart, see Rosselló 1995, pp. 53-56 (no. 3). On Rossell's examples, see Winter 1952, no. 2, 4, 6, 7 (with figs.).

[19] Campbell 1987, p. 411 (pp. 411-14). See *L'Atles Català* (fol. III), pp. 122-23; and expanding knowledge of the region in the mid 15th-century *Mappamondo Estense*, pp. 36, 38, 47, 50-51ff. (study), 175, 176-77 (toponymy). The sequence of places names from Ceuta to Cape Bojador in several other charts is extracted in Kamal, *Monumenta* 4:4, p. 1468; Kretschmer 1909, pp. 683-85.

Dulcert's 1339 chart onwards.[20] To the north, the shape of the continent comprises the western half of the Jutland Peninsula (above 55º N), excluding the Baltic Sea. Further north, the cartography spreads to Norwegian lands, covering the tip of southern Scandinavia (above 58ºN) which is longitudinally misplaced to the west. The Scandinavian coastline is slightly indented and flanked by islands, as in the Majorcan sea charts that follow Dulcert's models (1325–30, 1339).[21] Italian chartmakers frequently omitted not only Scandinavia but northern Europe entirely. In Islamic nautical cartography, Scandinavia reappears in Ḥājj Abū l-Ḥasan's chart, where its shape encompasses the west of Ireland.

A comparison with the Maghreb Chart: The anonymous Maghreb Chart is the oldest surviving Arabic sea chart, and perhaps one of the earliest in the Mediterranean chartmaking tradition. It has been dated to the first part of the 14th century, and is believed to have been made in Granada or North Africa (Morocco or Tunisia).[22] Campbell considers it to be a loose page from a larger nautical atlas.[23] It covers the western section of the Mediterranean, the Atlantic coastline from northern Morocco to west Jutland, and parts of the British Isles. Compared with the Maghreb Chart, the equivalent section in al-Ṭanjī's is strikingly similar, with some improvement in the shape of the Iberian Peninsula and particularly the islands of Corsica and Majorca.[24] In addition, it extends western Africa further south, depicts a sketch of Scotland with a few labels, and the whole of Ireland, while the Maghreb Chart covers only its eastern half. The silhouette of the coastline from Flanders to the Jutland Peninsula is also similarly drawn in both charts, and compressed to the west, as it appears in other 14th-century European examples. In nautical cartography, this section remains mostly unaltered until Pere Rossell's 1462 chart which presents a more accurate outline.[25]

[20] Dulcert (1339): Kamal, *Monumenta* 4:2, p. 1222; La Roncière & Mollat 1984, p. 201 (no. 7).

[21] Campbell 1987, pp. 409-10. For Scandinavia in 14th and 15th-century European cartography: Skelton 1965, pp. 160-62, 163-64; Winter 1955. For Dalorto/Dulcert (1325-30): Kamal, *Monumenta* 4:2, p. 1197.

[22] On the Maghreb Chart, see Sezgin 2000-07, vol. 11, pp. 27-31, 58; vol. 12, pl. 35 and vol. 13, p. 11ff.; Soucek 1992, pp. 263-64, fig. 14.1; Vernet 1962. Reprod. Kamal, *Monumenta* 4:3, pp. 1336 (chart), 1337 (toponymy according to Fischer's identification).

[23] Campbell 1987, p. 445 (see also pp. 418, 423, 459).

[24] Sezgin 2000-07, vol. 13, p. 13ff. superimposes the cartographic layout of the Maghreb Chart on al-Ṭanjī's (fig. 1) by computer means. He also compares the charts by Giovanni da Carignano (early 14th centuyr) and al-Ṭanjī (fig. 4), and suggests a common origin for both.

[25] Lang 1955, pp. 36-40. See also Campbell 1987, p. 414; Skelton 1965, p. 163; Winter 1952, pp. 5-6, fig. 4.

The rhumb line network

Both in the Maghreb Chart and al-Ṭanjī's, the rhumb line network crisscrossing the cartographic layout has sixteen winds or directions which is the standard number until the mid-15th century.[26] In al-Ṭanjī's chart, the rhumb lines are customarily coloured in groups of winds and middle winds in ochre, their subordinate quarters in green, and the half quarters between secondary centres in red. There is one hidden circle in the Maghreb Chart and two in al-Ṭanjī's. Here, the diameter measures 33 cm.[27] The western circle is centred near Barcelona, next to cape Llobregat, just as in the Maghreb Chart. In both charts the horizontal axis crosses above the Cantabrian coastline, showing its latitudinal displacement with respect to the location of Barcelona, which is a distinctive feature of the early charts. The eastern circle is centred on the Aegean coastline at Kuşadası Gulf, opposite the island of Samos. The two circles make contact between the gulfs of Salerno and Policastro (above 40º N).

The wind rose

Al-Ṭanjī's chart displays a single wind rose that functions as a north pointing star. It stands isolated from the rhumb line network in a decorative frame, but is placed in a prominent location, centred above when the chart is oriented to the north. The wind rose has eight spokes, with the north – south axis aligned with the imaginary central meridian of the chart. The north spoke that springs out of the core of the wind rose is coloured black, denoting a main direction, and is illuminated with golden ink. The other spokes are coloured alternately in red (four) and green (three). There are no labels for the names of the winds.

The first known wind rose in Mediterranean nautical cartography is attested in the Catalan Atlas; however, simple (Pole) Stars were used for graphical orientation some time earlier. An example of this appears in 14th-century copies of Vescontes' world map for Marino Sanudo's *Liber secretorum fidelium Crucis* (comp. 1321–22).[28] There, the eight-pointed

[26] The number of winds is doubled to thirty-two in Rossell's 1456 chart, for the first time. The new system is not observed in Italian examples before 1500: Campbell 1987, pp. 396-97; Rosselló 2000, pp. 95-96.
[27] Uçar 1987, p. 226.
[28] About ten copies are preserved from this period, some of which are reproduced in Kamal, *Monumenta* 4:1, pp. 1160, 1169, 1175 (Bongars 1611 version); also in *The History of Cartography*, vol. 1, pl. 16. The configuration of the map is heavily influenced by Islamic cartography. This aspect is studied by Drecoll 2000, pp. 40-43; Lewicki 1976; Sezgin 2000-07, vol. 10, pp. 299-300.

(Pole) Star is centred north upon a vertex of the rhumb line network that crosses the map in nautical style. This kind of star is to be seen in Dulcert's production (placed in central Europe in his 1325–30 chart, and centred in the north margin in his 1339 chart),[29] and later in Guillem Soler (1385), Batista Beccari (1426) and Joan de Viladesters (1428).[30] In the Catalan Atlas, the star is developed into an elaborate wind rose that is shown at the western end, but except for the cardinal directions, it remains independent from the rhumb line network.[31] The first wind rose to be half integrated in the system of the rhumb lines is found in Vallseca's 1439 chart.[32] His eight-pointed rose is centred north and superimposed on the chart's decorative frame. Its location and structure is the closest to al-Ṭanjī's. The three wind roses in the Catalan Atlas and the charts of al-Ṭanjī and Vallseca display a small Pole Star on top of the north spoke.

According to Campbell, wind roses are not observed in Venetian sea charts before the 15th century.[33] The first ones have sixteen winds, and are fully integrated in the rhumb line network, as in the Combitis and Pinelli-Walckenaer atlases.[34] In the second half of the 15th century, they became commonplace and increased in number and intricacy. Neither the Maghreb Chart nor al-Mursī's has wind roses.

The Danube

The entire course of the Danube, from its source to the mouth on the Black Sea, is represented in al-Ṭanjī's chart. The river is visually striking and an element of inland geographical information. It is drawn horizontally and a segment of it is hidden under the frame of the wind rose. The course is chain-shaped, with five unlabelled islands corresponding to the main cities of the Danube region, such as Ratisbon (Regensburg), Vienna and medieval Budapest (Buda). These chained islands are peculiar to Majorcan sea charts by Dulcert (1339) and Macià de Viladesters (1413), the Catalan Atlas and the Catalan world map (ca.

[29] The star is mentioned in *L'Atles Català* → Pujades: "Un mapamundi de transició de la segona meitat del segle XIV," p. 20; and Winter 1950, p. 37 (Vesconte and Majorcan charts). It is interesting to note that Dulcert might be of Genoese origin, like Vesconte, but established in Majorca: see *L'Atles Català* → Pujades: "La cartografia portolana a la Corona d'Aragó: l'escola mallorquina," p. 26.

[30] Reprod. Kamal, *Monumenta*, vol. 4:3, pp. 1320 (Soler 1385), 1322 (Soler, undated) and vol. 4:4, pp. 1453 (Beccari), 1457 (Viladesters). For Soler (undated): Mollat & La Roncière 1984, p. 202-03 (no. 9). For Viladesters (1428): Winter 1954, pp. 1-3 (with fig.).

[31] *L'Atles Català* (fol. III), pp. 114-15.

[32] Rosselló 1995, p. 54, fig. 25; Rosselló 2000, p. 96.

[33] Campbell 1987, pp. 395-96.

[34] Winter 1950, pp. 37, 38, 39-40. Reprod. Kamal, *Monumenta* 4:3, pp. 1316-19 (Pinelli-Walckenaer), 1333 (Combitis).

1450–60) from the Biblioteca Estense, which also include the whole of the Danube.[35] In general, Venetian sea charts omit river courses, with the exception of the last part of the Danube, due to its fundamental role in communications between central and Eastern Europe with the Black Sea and the Bosphorus.

For the Majorcan chartmakers, the Danube springs out of a branch of the Alps Mountains, as in the maps in al-Idrīsī's 12th-century Geography (*Nuzhat al-mushtāq*),[36] which may have been among their sources of reference. Al-Ṭanjī does not show the Alps, however, in his chart the source of the Danube is heart-shaped and apparently based on an Islamic artistic design. The delta opens up in a fan that splits into its tributaries in five coloured arms in the style of Vesconte. The influence of his work is visible in al-Ṭanjī's elaborate deltas of the other main rivers: the Nile, the Dnieper and the Rhône. The last part of the course of the Nile is also drawn with a series of small islands. Similar but simpler deltas are seen in other 15th-century Venetian examples, such as the highly refined 1409 chart by De Virga[37] and the anonymous example described below.

Affinities with an anonymous Venetian chart

Al-Ṭanjī's chart presents affinities with an anonymous Venetian piece, in terms of the wind system, visual aspects of the hydrography and the identification of some islands. The Venetian chart, preserved in the Archive of the Crown of Aragon in Barcelona, has aroused great interest among Spanish scholars. Some believe that it belonged to the Catalan monastic Order of La Mercè (founded in the first half of the 13th century), devoted to pay ransoms for Christian captives in North Africa. In his preliminary study of the chart, Rosselló dates it to around 1420 on the evidence of place name analysis, and emphasizes Vesconte's influence on its design.[38] This dating is almost contemporary with al-Ṭanjī's activity.

Both al-Ṭanjī's chart and the Venetian place the neck of the parchment in the Levant. They cover a similar cartographic scope, though the latter chart omits Scotland and Scandinavia. The structure of the rhumb line

[35] On the distinctive shape of the Danube in Majorcan nautical cartography, see Rey & García 1960, pp. 28 (fig. *Danubio en cadena*), 29; Rosselló 2000, pp. 103, 104. Toponymy of the Danube: *L'Atles Català* (fol. IV), pp. 128-29, 138; *Mappamondo Estense*, pp. 44, 136-37. For Viladesters (1413): Kamal, *Monumenta* 4:3, p. 1368; La Roncière & Mollat 1984, p. 205 (no. 12).
[36] Idrīsī, *Nuzha*, climate V: section 2.
[37] See detail in Campbell 1987, p. 445 (fig. 19.21).
[38] On the chart, see Conde 2001, pp. 88-89 (no. 19); Rey & García 1960, p. 51; and above all Rosselló 1995, pp. 49-52 (no. 2); Rosselló 2000, pp. 89, 90, 93-94, 100, 101, fig. 9. Campbell 1987, p. 419 (no. 18) has also dated it as early 15th-century.

network, with sixteen winds, is also similar in both, with two hidden circles whose centres are located on the Catalan and Aegean seashores. In the Venetian chart, the centres rest at l'Ampolla (W) and Smyrna (E), though in the Iberian Peninsula the horizontal axis is below the line of the Cantabrian Sea, between Cape Finisterre and the Low Ebro region. The deviation of the Mediterranean axis in each chart shows considerable variants in their cartographic construction. These variants, which range from relatively sophisticated mathematical conceptions to mere copying distortions, are difficult to interpret.

Both charts use similar colour codes for the geographical identification, and apparently political ascription, of the main Mediterranean islands. These had been illuminated in Vesconte's production, but it was the Majorcan chartmakers who specifically developed heraldry banners for territorial domains.[39] This was perhaps due to the Catalan maritime expansion in the western Mediterranean from the late Middle Ages. The blazoning of the Majorcan sea charts is partially registered in the Spanish *Libro del conosçimiento* (Book of the Knowledge of All Kingdoms, comp. late 14th century), a survey of armorial data which is presented in the form of a travel account.[40] In this book, some of the colours assigned to the island blazoning match those to be seen in al-Ṭanjī's chart and the Venetian. In both, Sardinia appears in red filled in with geometrical patterns; in al-Ṭanjī's chart, these patterns resemble the armorials for the Arago-Catalan Crown which was in control of the island at the time.[41] Since the end of the 14th century, Catalan rule had also extended to Sicily, which is decorated in blue (deep blue with red dots in al-Ṭanjī), one of the island's armorial colours since the Angevin rule.[42] As for the other islands, Corsica is in green, Crete in red and Cyprus in blue (deep blue in al-Ṭanjī's chart and silver blue in the Venetian).[43] Majorca is highlighted

[39] See the illumination for Crete, Rhodes and some Aegean islands in Vesconte's 1313 atlas: La Roncière & Mollat 1984, pp. 198-99 (no. 4); Kamal, *Monumenta* 4:1, p. 1149. On 14th-century nautical vexilology: Brincken 1978; Pasch 1967 & 1973; and some remarks in Campbell 1987, pp. 398-401.

[40] See concordance tables with the sea charts: *Libro del conosçimiento*, pp. 70-75.

[41] *Libro del conosçimiento*, pp. 65, 165 (*Rey de Sardeña*, no. LVI): *El rrey dende ha por senalles bastones del rrey de Aragon* (Blazon, p. 60: *palado de diez piezas de gules y oro*). On Sardinian armorials under Catalan rule: *Nobiliario de la Corona de Aragón*, vol. 1. On Sardinia in Islamic cartography, including the Maghreb Chart and al-Sharafī's atlases: Pinna 1996.

[42] Blue (*azure*) is not assigned to the Aragonese king in Sicily in the *Libro del conosçimiento*, p. 161 (*Rey de la Ysla de Ceçilia*, no. XXXI): *Et el rrey desta ysla ha por senalles vn pendon a quoarterones, los dos coartos blancos con dos agujllas prietas et los otros dos coartos a bastone*[s] *vermejos et amarillos desta manera* (Blazon, p. 58: *cuartelado en sotuer: 1º y 4º, de oro, cuatro palos de gules; 2º y 3º, de plata, un águila de sable; las águilas de estos dos cuarteles afrontadas*).

[43] *Libro del conosçimiento*, p. 163 (no. XLVI): *Et el rrey de Chipre ha por senalles vn pendon a meatades, la vna meatad cardena con flores de oro, porque es el rrey de la cassa de França, et la*

in golden ink, but lacks the king's attributes (*four pales in gules*) shown in the sea charts made on the island.[44] Except for Majorca, the silhouettes of these other islands are outlined with golden ink in al-Ṭanjī's chart.

The representation of Venice

In the 14th and 15th centuries, Venice was the most frequently depicted city in sea charts due to its power and influence in the Mediterranean.[45] For the name, al-Ṭanjī chose a transliteration of the Italian for Venice instead of the Arabic al-Bunduqīya, as did later ʿAlī al-Sharafī in his nautical atlases. In al-Ṭanjī's chart, the figure representing the city seems to be inspired by a Venetian design, and consists of a golden coloured circle divided into two halves by a river. The circle is surrounded by a ring of green dots, perhaps meaning some sort of coastal signposting for the islands. A similar figure is found in De Virga's 1409 chart where the circle is crossed by three rivers: the Adige, Brenta and Piave.[46] The design is a conventional representation of the lagoon of Venice as found in mid-14th to mid-15th century Italian nautical cartography, mainly in the Medici, Combitis and Pinelli-Walckenaer atlases. It seems to derive from the works of Vesconte (atlas ca. 1320),[47] who may have established a pattern for the geographical environment of the head of the Adriatic. The Catalan Atlas, and other Majorcan examples, such as the charts of Soler (1385), Macià (1413) and Joan de Viladesters (1428), develops the circle into a castle which reflects symmetrically in the river. This kind of vignette is adopted in the anonymous Venetian chart described above.[48]

The vignette of Tunis

The city of Tunis, where al-Ṭanjī worked, is highlighted with a castle in golden ink, and it is significant that this is the only urban vignette that appears in his chart.[49] The castle is placed next to the lagoon of Tunis, which is filled with red dots indicating danger for coastal navigation. In the 14th and 15th centuries, the flourishing maritime trade in Ḥafṣid Tunis

otra meatad blanca con çinco cruzes bermejas atales (Blazon, p. 59: *partido: 1º, de azur pleno; 2º, de plata, una cruz trífida de gules cantonada de otras cuatro cruces iguales*).

[44] *Libro del conosçimiento*, p. 165 (*Rey de Mallorcas*, no. LXII): *Et el rrey dende ha por senalles bastones atales* (Pendant, p. 60: *de oro, cuatro palos de gules*).

[45] For city views of Venice in nautical cartography, see Rosselló 1995, pp. 28-29.

[46] For their identification, see La Roncière & Mollat 1984, p. 204 (no. 11).

[47] Reprod. Kamal, *Monumenta* 4:1, pp. 1160-61.

[48] See detail in Rosselló 1995, p. 51 (fig. 22).

[49] Alongside with the castle, Soucek 1992, p. 264 identifies a golden symbol for the governing Ḥafṣid dynasty which I cannot see in my photographic printout of the chart.

must have favoured the chartmaking business which would explain al-Ṭanjī's activity. In turn, 16th-century Sfax became a corsair enclave where the al-Sharafī family of chartmakers originated. In the other Islamic sea charts of the Mediterranean, Ḥājj Abū l-Ḥasan is the only one to represent Tunis, among other cities, with a vignette. A detailed chart of the gulf of Tunis, with sailing instructions and a city view, is provided in Pīrī Re'īs' *Kitāb-i Baḥrīye* (first version 1521, second version 1526).[50]

The miniatures in Scandinavia

Al-Ṭanjī draws two miniatures in southern Scandinavia that can be identified as a falcon (a red bird) and perhaps a lynx (a four-legged black animal).[51] Miniatures of white Norwegian gyrfalcons appear in Majorcan sea charts by Dulcert (1339), Macià de Viladesters (1413), who also includes a bear and a four-legged animal, and the work of the Italian Pizigani brothers (Venice, 1367), who were influenced by the Majorcan style.[52] In addition, Viladesters' chart and the Catalan world map from the Biblioteca Estense depict a hawking scene in the area corresponding to Russia. All these miniatures, including al-Ṭanjī's, are drawn upside down, that is, face up with the charts oriented northwards.

In Majorcan nautical cartography, Dulcert (1325–30, 1339) is the first to provide legends about the extreme weather conditions, hunting practices and the gyrfalcons in Scandinavia.[53] His data is borrowed and expanded in the Catalan Atlas, where we read: *Aquesta regió de Nuruega és molt aspra e molt freda e muntanyosa, salvatgosa e plena de boschs, los habitadors de la qual més viuen de peix e de caça que de pa; avena s'i fa e fort pochs per lo gran fret; moltes feres hi ha, ço és, cervos, orsos blanchs e grifalts*. This legend from the Catalan Atlas still reappears with some variants in the Catalan world map from the Biblioteca Estense.[54] The *Libro del conosçimiento* locates the gyrfalcon in the Norwegian highlands: *Parti de Gocia et subi a las altas sierras de Nuruega, ... et en las montañas desta Nuruega crian muchas aves girifaltes, açores, ffalcones; otrosy crian muchas anjmalias fuertes: jabalies blancos et*

[50] Pīrī Re'īs, *Baḥrīye*, vol. 3, esp. fol. 327r.

[51] The lynx should not be mistaken for a lion, which is the most popular animal in medieval heraldry. Majorcan chartmakers use the lion as a symbol for Norway. See the blazoning in the *Libro del conosçimiento*, p. 159 (no. XVIII): *el rrey desta Nuruega ha por senalles vn pendon de oro con vn leon prieto* (Pendant, p. 57: *de oro, un león de sable*).

[52] Reprod. Kamal, *Monumenta*, vol. 4:2, p. 1286 (Gasparotti's 1827 copy) and vol. 4:4, p. 1483.

[53] *L'Atles Català* → Pujades: "La història de l'Atles català i l'enigma de l'autor," pp. 40-41. Winter 1955, p. 45 also draws attention to these legends.

[54] *L'Atles Català* (fol. III), p. 117; *Mappamondo Estense*, pp. 42-44 (study), 132 (legend G).

ossos blancos.[55] Some of the data in the Majorcan inscriptions is already found in the Geography of al-Idrīsī which places a small tiger (*babr*, pl. *bubūr*) in Norway, though no falcon is described.[56] Curiously enough, the interest in falcons is also attested in Quṭb al-Dīn al-Shīrāzī's (1236–1311) astronomical treatise *al-Tuḥfa al-shāhīya fī l-hay'a*, where the author explains a method for making a sketch map similar to a Mediterranean sea chart. There he mentions falcons in Ireland (*wa-aḥsan khawārij al-ṣayd wa-huwa l-mashhūr bi-ṣunqur innamā yakūn fī-hā*),[57] but his identification may have been caused by confusion with the Nordic gyrfalcon (sing. *sunqūr* / *ṣunqūr / shunqūr*; pl. *sanāqīr*).[58]

The gyrfalcon (*Falco rusticolus*), a species of Siberia, Scandinavia and Iceland, was highly appreciated as an exclusive and spectacular bird for hawking.[59] Its strength, large wingspan and distinctive white colour are outlined in the specialized literature. It was imported to the Islamic countries at great expense, and often figured among ceremonial gifts upon the exchange of ambassadors. The earliest Arabic texts on hawking describe the Nordic goshawk (*Accipiter gentiles*), a native of Lapland and Siberia, with seasonal migration south to Turkestan, which had been known to the Sasanid princes. In his *Kitāb Ḍawārī al-ṭayr* (comp. Baghdad, 8th century), al-Ghiṭrīf b. Qudāma al-Ghassānī names it as the *ṭughrīl* bird that is to be found in the lands of the Khazars, from the south Russian steppes to the Caspian Sea regions, including Khwārazm and Armenia.[60] The bird is registered as *togrines* in the Castilian *Book of Moamin* (1250) which is a mixture of al-Ghiṭrīf's work and Muḥammad b. ʿAbdallāh b. ʿUmar al-Bāzyār's *Kitāb al-Mutawakkilī* (or *Kitāb*

[55] *Libro del conosçimiento*, p. 159 (see *girifalte* in the vocabulary index, p. 186).
[56] Idrīsī, *Nuzha*, climate VII: section III → *Opus geographicum*, p. 952; *Géographie d'Edrisi*, vol. 2, p. 430.
[57] Here, *jawāriḥ* (beasts or birds of prey) should be read for *khawārij.* See the text in Kamal, *Monumenta* 4:1, p. 1142b. Sezgin 2000-07, vol. 11, pp. 319-20 and vol. 13, pp. 19ff., 392-93 discusses Quṭb al-Dīn's mapping method.
[58] On the terminology, see Viré 1977, p. 144; F. Viré: "Bayzara," *EI*² vol. 1 (1960). According to Hofmann 1957-58, p. 139, the first Nordic goshawk is mentioned in England in 1086 and the first Nordic gyrfalcon in 1159. It is interesting to note that Abeele 1994, pp. 57, 72 discusses the identification of the Latin medieval designation *falco britannius* (*sic*) with a gyrfalcon variety nesting in Scotland.
[59] On the gyrfalcon, see Abeele 1994, pp. 59-61 (also pp. 56-57).
[60] For the identification: Viré 1977, p. 140 (*ṭughril*, *ṭughrul*). See Ghiṭrīf, *Ḍawārī*, pp. 67 (n.47), 81 (n.115) (trans.). A facsimile from Ghiṭrīf's book [MS Istanbul, Topkapı Sarayı Müzesi Kütüphanesi: Ahmet III 2099] is published by F. Sezgin in Frankfurt a. M.: IGAIW, 1986. The Nordic falcons could have also reached the Caspian via trading routes. In Khwārazm, the geographer al-Yaʿqūbī (m. 897) documents the fur trade from the lands of the Bulghārs, who in turn obtained goods from remoter peoples: "Farw," *EI*² vol. 2 (1965).

al-Jawāriḥ; comp. Baghdad, mid-9th century).[61] The *Moamin* version was accomplished under the patronage of Prince Alfonso (future Alfonso X el Sabio, gov. 1252–84), and had a strong influence on the later Spanish production.[62] From the 13th century onwards, European treatises discuss the gyrfalcon at length, particularly the prestigious *De arte venandi cum avibus* (comp. Sicily, 1230–45) by Emperor Frederick II Hohenstaufen.[63] The widely read 14th-century Spanish *Libro de la caza de las aves* (Book of bird hunting, comp. 1385–86) by Pedro López de Ayala records their exports to Flanders, from where they reached the Iberian Peninsula.[64]

The inclusion of the falcon and lynx miniatures in al-Ṭanjī's chart might be connected with the tastes and practices of the Ḥafṣid rulers who were smitten for hawking and had long been acquainted with Nordic falcons. In 1262, the sovereign al-Mustanṣir (gov. 1249–77), who enjoyed hawking in a vast preserve near Bizerta, was presented with falcons from King Haakon the Old of Norway (gov. 1217–63). In the 14th century, King Magnus Eriksson of Norway and Sweden (gov. 1319–64) enjoyed a five-year papal allowance to sell falcons to the Tunisian sultans.[65] Among them, ʿUthmān (gov. 1435–88) became famous for hawking several days a week. Hunting with the aid of pet or tame carnivores (caracal lynxes or gazelle-hounds) was also favoured by the Muslim princes.[66] Reference to this chasing technique or merely to wild fauna is seen in al-Mursī's chart, where a desert predator runs after two gazelles south of the Atlas Mountains in North Africa. The 14th and 15th-century Majorcan sea charts that include data on falcons and depict hawking scenes are all luxury examples. In this context, the hunting sports are documented as well for the Arago-Catalan nobility, in particular under the rule of Joan I (gov. 1387–96), expressively known as the Hunter (*el Caçador*).[67]

[61] *Moamin* I:2, p. 13: *Otrosí cuentan de los gavilanes de tierra de Cazdria, los que son nombrados togrines, de cómo son altaneros e cómo dan salto a qual nuvada quier que vean d'aves, sean quan grandes se quiere, ca non se partirán d'ellas en todo 'l día fasta que las abatan en tierra a todas, e en estas tierras non son atales* (*tierra de Cazdria* is not identified by the editor; see *togrines* in the vocabulary index, p. 305). On the Arabic sources of *Moamin*, see Bāzyār, *K. al-Mutawakkilī*, pp. 11, 15ff. (introd.). al-Bāzyār is identified as a polymath astrologer and disciple of the famous astronomer and instrument maker Ḥabash al-Ḥāsib (fl. Baghdad, 829 and 864): *K. al-Mutawakkilī*, pp. 33-35 (introd.); *Moamin*, pp. xii-xiii (introd.).

[62] On the influence of Arabic hawking techniques in Majorca, see Bover & Roselló 2004.

[63] Frederick II, *De arte venandi*, parts II (II.R.5, p. 182), III (pp. 91-110), IV.

[64] López, *Libro de la caza*, ch. IV.

[65] Evidence for Nordic falcons in Tunisia is provided by Hofmann 1957-58, p. 140. F. Viré: "Bayzara," *EI*[2] vol. 1 (1960) draws attention to the Ḥafṣids practising falconry. On surviving hawking techniques at Cape Bon Peninsula in the mid-20th century, see Mathis 1949.

[66] F. Viré: "Ṣayd," *EI*[2] vol. 9 (1997).

[67] Cifuentes 2006, pp. 151-56.

In the Middle Ages and during the Renaissance the falcon was an element of inspiration both in Islamic and European art, appearing in manuscript painting, decorative metalwork, engraving, ceramics, tapestry and embroidery.[68]

Note on place names in North Africa

Campbell stresses the value of place names as the most reliable evidence for analysing sea charts and establishing connexions between them.[69] However, toponyms on Arabic sea charts of the Mediterranean remain unexplored, except for Fischer and Vernet's transliteration and identification of the sequence of coastal place names in the Maghreb Chart.[70] This first approach to the toponymy in al-Ṭanjī's chart is restricted to the North African shores between Ceuta and Alexandria.

In nautical cartography, al-Ṭanjī provides the most comprehensive registry of Arabic toponymy that is recorded for the Islamic territories. The density of the place names is remarkable in North Africa, and far surpasses the data compiled in earlier geographical sources of al-Bakrī (m. 1094), al-Idrīsī or Ibn Saʿīd al-Maghribī (1213–86), who describe itineraries along the coastline.[71] With respect to the Maghreb Chart, al-Ṭanjī includes additions in all regions, as can be clearly observed in the western Mediterranean islands, and naturally the British Isles and Atlantic seashores that lie beyond the scope of the Maghreb Chart. In North Africa, the latter records a total of sixty-one place names between Ceuta and Tunis, whereas al-Ṭanjī's chart contains around ninety. The increase in the toponyms suggests that other sea chart(s) may have been produced in the Maghreb or al-Andalus in the 14th century in the period of time between the Maghreb Chart and al-Ṭanjī's. As toponyms are incorporated gradually into the chartmaking tradition, al-Ṭanjī himself may have been working with some unknown Maghrebi model with more details than the Maghreb Chart. According to Campbell, the 14th century is precisely the most innovative for updating and development of place names in European sea charts.[72] The compilation process is obscure and could not have resulted from a single chartmaker working alone. Cartographers are likely to have counted on the experience of mariners, skippers and travellers; for instance, in his chart signed in Savona in 1403, Francesco

[68] Abeele 1994, pp. 42-44.
[69] Campbell 1987, pp. 415ff.
[70] Vernet 1962, pp. 5-16. He improves the identifications in Fischer 1886. Vernet's list is collected in Pinna 1996, vol. 2, pp. 112-23 (with colour plate).
[71] See especially, Idrīsī, *Nuzha*, climate III: sections 1-4 and climate IV: section 1.
[72] Campbell 1987, pp. 422-23.

Beccari expressly corrected the location of Sardinia on the advice of seafarers.[73]

In al-Ṭanjī's chart, the seashores between Ceuta and Alexandria are drawn accurately and supply precise visual information concerning capes, bays, river mouths and other landforms that are used for geographical identification and water supply on coastal navigation. One example is the rugged succession of capes between Stora, Bona and La Calle (*marsā* al-Kharaz) on the Barbary Coast, carefully depicted and named. The same applies to the hydrography, which is thoroughly described in the western Maghreb. There, a significant number of deltas and river beds are missing from Majorcan and Venetian sea charts where knowledge of the region appears to be more limited.[74] Al-Ṭanjī's contribution to the section between Tripoli and Alexandria is of special interest, particularly from the Gulf of Sirte (labelled Qāʿ al-Janūbī) to eastern Marmarica, as the sequence of place names is slightly denser than in the other Arabic sea charts and Pīrī Re'īs' *Kitāb-i Baḥrīye*.[75] There, the differences with respect to Venetian sea charts of De Virga (1409), the anonymous work described above, Cesanis (1421) and Giroldi (1422) become more pronounced. In fact, the region was not frequented by European vessels due to the barren, desert conditions of some of the areas, in addition to the local instability. Their commercial connexions with Tripoli and Alexandria were established mainly through European bases in Tunis and the main Mediterranean islands.

The geographical terminology that supplements place names shows the diverse origin of the sources that Mediterranean chartmakers were consulting. In al-Ṭanjī's chart, in North Africa and the Islamic territories, including al-Andalus, the terminology is originally Arabic (*marsā*, *ra's*, *ṭarf*, *wādī*, *jazīra*), while in regions under European control it often consists of transliterated forms from the Latin languages (*burt*, *qāb*, etc.). A parallel transliteration process occurs in Venetian and Majorcan counterparts which, for the Islamic regions, adapt the Arabic terminology and even combine it with European vocabulary. Their sources must have ranged from Arabic sea charts and geographical treatises to direct oral communication. The Catalan Atlas provides many examples of these, such as *Casar Romol* (qaṣr al-Rūm) in Ifrīqiya; or *cap de Ras Aosem* (cape Sem), next to *Marzasuse* (marsā Sūṣa) in Cirenaica.[76]

[73] English translation of Beccari's address to the reader: *Twenty-five Manuscripts*, MS 18, pp. 63-64. See reference in Campbell 1987, p. 428, fig. 19.17.
[74] See toponyms between Alexandria and Ceuta in European nautical cartography and portolan books in Kretschmer 1909, pp. 673-84.
[75] Pīrī Re'īs, *Baḥrīye*, vols. 3-4.
[76] *L'Atles Català* (fols. III-IV), from p. 106.

Conclusion

The chart by Aḥmad al-Ṭanjī signed in 1413–14 is an exciting document for the history of cartography, as it is one of the oldest and the most attractive Arabic sea chart of the Mediterranean that survives. The chart's careful execution suggests that al-Ṭanjī must have been a skilled experienced chartmaker, even though no other examples of his work are extant. Its contents bear witness to al-Ṭanjī's accurate knowledge of the coastline layout, and his mastery of detailed information on toponymy and hydrography. The chart is designed as a work of art, and seems to have been commissioned as a presentation piece. This explains the illumination of Venice and Tunis in golden ink, and the drawing of the miniature of the hawking bird, which also appears in luxurious Majorcan sea charts.

The comparison of the cartographic shape and sequence of coastal place names with those of the Maghreb Chart, the only one preserved in Arabic before al-Ṭanjī, hints at the existence of other late 14th or early 15th-century Arabic (possibly Maghrebi) sea chart(s) that are now lost. These charts must have contributed to the process of compilation and development of the Arabic nautical toponymy and hydrography. These latter elements, the calendar of lunar mansions and the decorative frame of intertwined knots are clearly distinctive of the Arabic sea charts of the Mediterranean.

In al-Ṭanjī's chart, the analysis of visual elements, such as the wind rose, the main river mouths and the figure representing Venice, reveals interaction with Venetian and Majorcan sea charts which follow the 14th-century models by Vesconte and Dulcert. Further research on al-Ṭanjī's toponymy and geographical terminology for Mediterranean Europe will most likely support this evaluation. Some elements of contact are visible in the anonymous Venetian chart (ca. 1420) from the Archive of the Crown of Aragon, which shows similar colour codes for the geographical and political identification of the central Mediterranean islands. All these features situate the 14th and 15th-century chartmaking production in a broad Mediterranean context in which the circulation of Arabic and European sea charts was favoured by commercial and cultural interplay.

Acknowledgements

This paper is part of the research project *Cartografía náutica árabe en el contexto mediterráneo (ca. 1300–1600): Influencias entre oriente y occidente* (University of Barcelona), sponsored by the Spanish Ministry of

Education and Science (HUM2005–03375/FILO). The colour microfiche from al-Ṭanjī's chart and its photographic printout at original scale were financed by *Arbor Scientiarum: Frankfurter Vereinigung für Geschichte der Wissenschaft und Technik*, thanks to arrangements made by Prof. David A. King at the Institut für Geschichte der Naturwissenschaften, University of Frankfurt.

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[77] Abbreviations: BnF = Bibliothèque nationale de France, Paris; CSIC = Consejo Superior de Investigaciones Científicas, Spain; IRCICA = Research Centre for Islamic History, Art and Culture, Istanbul; IGAIW = Institut für Geschichte der Arabisch-Islamischen Wissenschaften, Frankfurt am Main.

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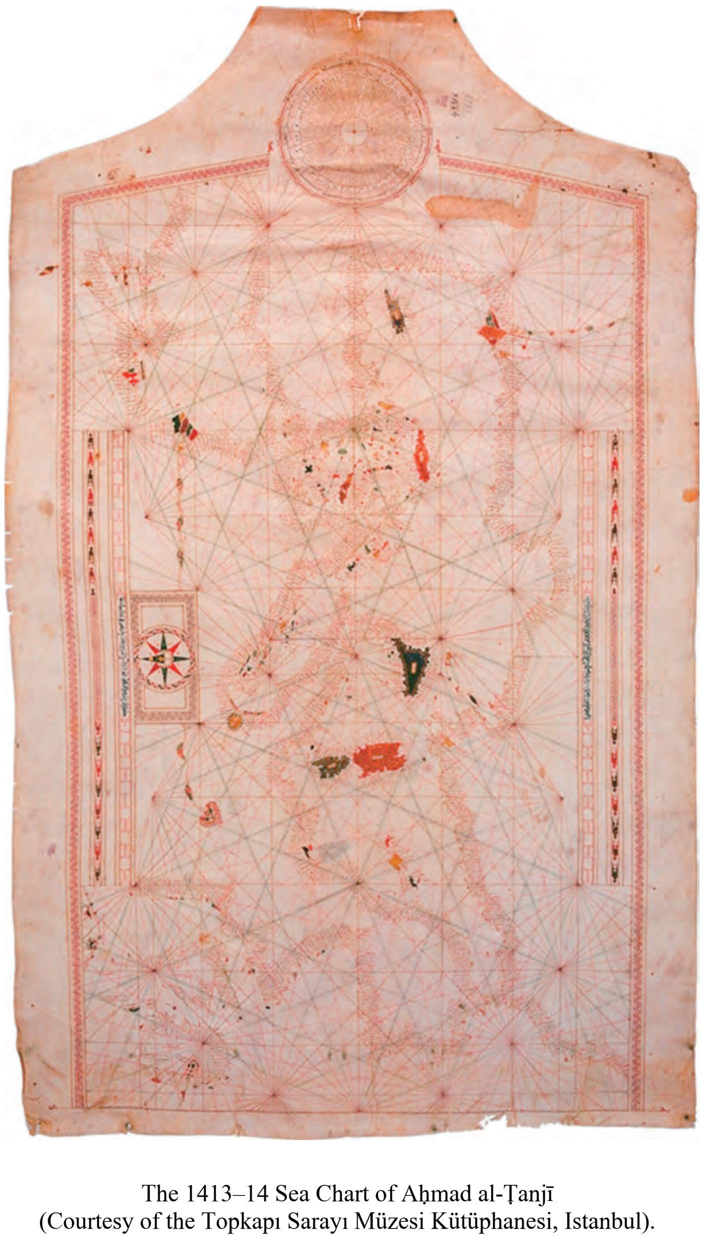
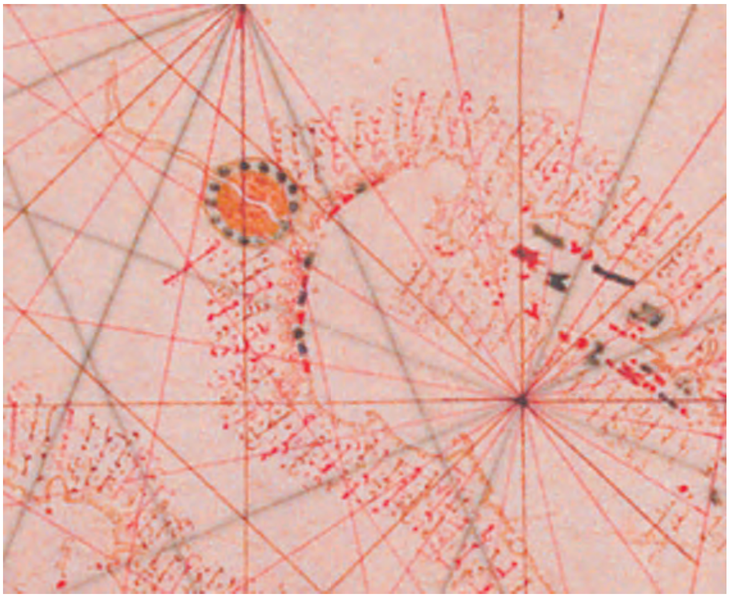


The 1413–14 Sea Chart of Aḥmad al-Ṭanjī
(Courtesy of the Topkapı Sarayı Müzesi Kütüphanesi, Istanbul).



Detail of the head of
the Adriatic, including Venice.

Detail of miniatures in
Scandinavia (oriented southwards).

The Reception of Aristotle's *Meteorologia* in the Persian World: Isfizārī's Meteorology

Mohsen Zakeri

When the Greek scientific texts started to be translated into Arabic, the science of meteorology was one of the first to evolve as a distinct discipline and was known as *ʿilm al-āthār al-ʿulwiyya*, "the science of the upper phenomena." It entered under this name into the classification of sciences by al-Fārābī (d. 339/950) in *Iḥsāʾ al-ʿulūm*, al-Khwārazmī (fl. 980) in *Mafātīḥ al-ʿulūm*, and in the *Rasāʾil of Ikhwān al-Ṣafāʾ* (end of 10th century).

From among all the classical Greek works on diverse sciences which became accessible in Arabic in the early ʿAbbāsid period and were adopted by Muslim scientists, perhaps no other subject received as much attention as *ʿilm al-āthār al-ʿulwiyya*. This interest was mainly focused on Aristotle's *Meteorologia* and the commentaries on it written in Hellenistic times, some of which became available relatively early. A vast body of literature grew around Aristotle's Meteorology in Arabic, either by way of commentaries or in independent works inspired by it. Numerous philosophers wrote on one or the other related aspect of this subject. Thus, as Paul Lettinck succinctly writes, we have expositions by al-Kindī (d. ca. 260/873), Ibn Khammār [Abū l-Khayr Ḥasan b. Suwār b. Bābā b. Bihnām (d. ca. 421/1030)], Ibn Sīnā (d. 429/1037), Ibn Bājja (d. 533/1138), and Ibn Rushd (d. 595/1198), among many others. The subject attracted also cosmographers, geographers, encyclopedists, and authors of belletristic (*adab*). Furthermore, it found its way into Muslim heresiographies as well as some compendiums on medicine.

Since a few references to Aristotle's Meteorology are found already in Jābir b. Ḥayyān (d. ca. 200/815), and since its translator Yaḥyā Ibn al-Biṭrīq (d. ca. 215/830), a prominent member of the *Bayt al-ḥikma* at

Baghdad, who worked for the caliph al-Ma'mūn, uses a polished set of technical terms, an even earlier Arabic translation is postulated. This early translation is assumed to have been done from Syriac, probably by Yaḥyā's father al-Biṭrīq, who was an active translator under the caliph al-Manṣūr (d. 156/775) (Sezgin, *GAS*, VII, 213). Accordingly it seems that the *Meteorologica* became accessible in Arabic first perhaps in the second half of the 2nd/8th century. In any event, this was only a late Hellenistic modified shorter version of the old master's work, that is to say, Muslims never had access to the full original (Sezgin, *GAS*, VII, 206). Nonetheless, this recension kept its value as a canonical work, though its propositions, which had already undergone modifications in the Hellenistic period, could not be adhered to in individual cases. The numerous errors and shortcomings of the *Meteorologica* itself and the primitive Arabic translations provided a fertile ground for Muslim scholars to revise, expand and put them right in medieval times.

The second most important classical contribution to meteorology after that of Aristotle is by Theophrastus (371-287 B.C.), who has played a significant role in the diffusion of Aristotelian thought, in particular his meteorological doctrine. Theophrastus' work, however, became known to Muslims first in the 4th/10th century through an Arabic translation from Syriac by Bar Bahlūl, or that of his contemporary Iranian Nestorian scholar Ibn Khammār. Ibn Khammār's main book is *Maqāla fī l-āthār al-mutakhayyala fī l-jaww* (Treatise on Meteorological Phenomena), but he has also one *Masā'il (Quaestiones) of Theophrastus*, and one *al-Āthār al-ʿulwiyya*, which he translated from Syriac.[1] The remains of these works have been edited and translated by Hans Daiber (1992) and Paul Lettinck (1999).

A few generations later, we witness great activity in this scientific field in the West, in the South of Spain for that matter. Ibn Bājja, the famous Avempace of Saragossa (d. 533/1138),[2] wrote commentaries on many of Aristotle's works including the *Meteorologica*. His work, more a paraphrase than a true commentary, has been edited and translated by Paul Lettinck (1999, 383-481).

Ibn Bājja's successor, the great Ibn Rushd (Averroes, 520-95/1126-98), who lived in Seville and Cordoba in the 6th/12th century, incorporated Ibn al-Biṭrīq's translation and a number of other relevant texts into his *Shorter –talkhīṣ* 'paraphrase'– and *Middle Commentaries* (Arabic in Hebrew

[1] Ibn al-Nadīm, *Fihrist*, ed. Tajaddus, Tehran 1971, 323.

[2] Ibn Bājja, Abū Bakr Muḥammad ibn Yaḥyā b. al-Sāʾigh was born in Saragossa, al-Andalus, end of 11th century; and when Alfonso seized power in Saragossa, he moved to Seville, and died in Fez.

letters). These have been edited and translated into European languages several times.

Again in Spain and around the same time, the Latin translation of Meteorology was done from the Arabic by the Italian Gerard of Cremona (ca. 1114-1187) at the cathedral in Toledo. Having been a very productive author, he translated some 70 books from Arabic. His Meteorology (= Ibn al-Biṭrīq) is edited and translated by Pieter L. Schoonheim (2000).

Not long afterwards, once again in Spain, the Jewish philosopher-doctor Ibn Ṭibbon [Samuel ben Judah (1150-1230, Granada-Marseille) translated Ibn al-Biṭrīq's version into Hebrew in 1210. He was an adherent of Maimonides (Abū ʿImrān Mūsā b. Maymūn, born of Spanish Jewish parents in Cordova in 1135 and died in 1204), whose philosophy he expounded on in many writings. Ibn Ṭibbon is also reputed for his translations of Jewish rabbinic literature from Arabic into Hebrew. It is interesting to know that the first Aristotelian work to be translated into Hebrew was the Arabic version of Aristotle's *Meteorology*. This is edited and translated by Resianne Fontaine (1995).

It was only in the middle of the 13th century that the Syrian polymath Ibn al-ʿIbrī, the famous Bar Hebraeus (622-685/1225-1286), included a Syriac version of the *Meteorology* into his magnum opus *Butyrum sapientiae* (The Cream of Wisdom), which is modeled after Ibn Sīnā's *Kitāb al-Shifā'*. This is edited and translated by Hidemi Takahashi (2004).

Now one curious thing in all these is that none of the modern editors and translators listed above seems to be aware of the existence of another line of transmission, that initiated by the Iranian scholar al-Isfizārī! Whereas the reception-history, the growth and development of the Aristotelian meteorological doctrines in Arabic, Arabic-Latin, Hebrew, and Syriac has been satisfactorily described respectively by Petraitis, Daiber, Lettinck, Fontaine, Schoonheim, and Takahashi, nothing similar can be claimed for its Persian renderings and refinements. This chapter in the literary history of *Meteorologia* has remained almost fully unexplored so far.

In the Iranian scientific tradition, the book *Meteorology* written by Abū Ḥātim Muẓaffar b. Ismāʿīl al-Isfizārī (variants: Asfizārī, Asfuzārī, Asfazārī, etc.) (ca. 437-513/1045-1119) has had a groundbreaking role. As the oldest existing work in Persian on Aristotelian meteorology, this text enjoyed widespread popularity in the Persian speaking world. Known in Persian as *Āthār ʿulwī*, it was edited by Muḥammad Taqī Mudarris Raḍawī in Tehran about seventy years ago (in 1311/1940).

Mudarris Raḍawī collected the scanty biographical notes about the author, but presented them haphazardly and uncritically. David Pingree's brief entry on Isfizārī in The *Encyclopaedia Iranica*, does not even offer the data commonly known about him. A more exhaustive survey of sources is done by Albert Napoleon Companeoni, published in Tehran University Journal, in his article "Ḥakīm Abū Ḥātim Muẓaffar Isfizārī," *Majalla-i Dānishkadih-i Adabiyāt-i Tehran* 5.1-2 (1336/1958), 166-230. Moreover, Muḥammad Abattouy has made most of the biographical information about Isfizārī readily accessible in two articles (2000, 2007).

The facts of al-Isfizārī's life and scientific achievement are well attested through his own writings (Persian and Arabic), and the testimony of his contemporaries. As for the date of his death it can be set, with some acrobatic balancing, relatively securely between 511/1117 and 513/1119 (the fist being the date of Sultan Sanjar's ascendance to the throne, to whom a book is dedicated, and the second, Shahmardān b. Abī l-Khayr Rāzī's finishing his *Nuhza-nāma*, in which he speaks of Isfizārī as deceased). He finished his *Meteorology* in the last decade of the 5th/11th century; it is addressed to Fakhr al-Malik b. Niẓām al-Mulk, who succeeded his reputed father Niẓām al-Mulk to premiership in 488/1095, and fell victim to Bāṭinid assassination in 500/1105.

The little known but prolific author Abū Ḥātim al-Isfizārī belongs to the group of distinguished scientists (mathematicians, astronomers, engineers, and philosophers) of the later half of the 5th/11th century. He was a long-time colleague of the celebrated astronomer and mathematician ʿUmar-i Khayyāmī (ca. 440-526/1048-1131), with whom he participated in the creation of the astronomical tables *Zīj al-Jalālī* at the time of the Saljūkid sultan Malikshāh (r. 465-485/1072-1092). Another of his colleagues, or followers was the renowned astronomer-mathematician Abū l-Fatḥ ʿAbd al-Raḥman al-Khāzinī, whose Arabic *Mīzān al-ḥikma* (The Balance of Wisdom), on hydrostatic balance, is in fact an encyclopedia of mechanics based on the teachings of al-Isfizārī written for Sultān Sanjar in 515/1121.[3]

Isfizārī's scientific interests include several fields of natural philosophy, above all mathematics and engineering sciences. Having been an artisan-scientist, he showed particular aptitude for constructing new sophisticated mechanical instruments. Several of his treatises expound on the mathematical principles governing the function and production of engineering devices. One of his sensational products was the so-called *Mīzān-i Arshi-midis* (Archimedes' Balance, a hydrostatic balance), which

[3] This is edited by Hāshim al-Nadwā, Hyderabad 1940. Partial English tr. by N. Khanikoff, *JAOS* 6 (1859), 1-128. Facsimile edition by F. Sezgin, Frankfurt 2001. A copy of an old Persian translation of this is kept at Āstān-i Quds-i Raḍawī. J. Vernet, s.v. "al-Khāzinī." *EI*², IV, 1186.

he created to measure the absolute and specific weights of elements. (See *EI*^{2}, s.v. "Mīzān," by Eilhard Wiedemann).

Isfizārī is said to have been a very productive author, but only a few of his scientific works survive and have been partially published and translated into European languages:

1) *Ikhtiṣār fī uṣūl Uqlīdis* (An Epitome of Euclid's *Elements*). (Paris, BN, Orient. Ar. no. 2458). Some sections of this Arabic treatise on mathematics containing geometric drawings are edited and translated into French by L. A. Sédillot, "Notice de plusieurs opuscules mathématiques qui composent le manuscrit arabe... de la Bibliothèque du Roi," in *Notices et extraits des Manuscrits de la Bibliothèque du Roi* 13 (1838), 146-48. Cf. F. Sezgin, *GAS*, V, 110.

2) *Risālat al-Shabaka* (The Treatise on Networks). This Persian text, edited by Albert Napoleon Companeoni, *MDA Tehran* 5.3 (1337/1959), 39-52, is presented to the Saljūqid ruler Abū al-Muẓaffar Birkiyāraq, who ruled from 486/1093 till 498/1104. It is a discourse on physics (natural sciences) and botany in the geoponic tradition of *al-Filāḥa al-Rūmiyya* of Cassianus Bassus Scholasticus, who is cited by name here. In the first of its twelve chapters, Cassianus' book (ed. Cairo 1293/1876), which was first translated from Middle Persian into Arabic,[4] handles astronomical and meteorological questions. Among other things, Cassianus knows the twelve-part Wind rose (the basis of meteorological observations of wind speeds and wind directions; it summarizes the occurrence of winds at a location, showing their strength, direction and frequency) (see Sezgin, *GAS*, VII, 320-21).

3) *Muntakhab Kitāb al-Ḥiyal* (An Epitome of the Book of Devices) (Arabic MS. Tehran; Brockelmann, *GAL*, SI, 383; A. Mingana, *Catalogue of the Ar. mss in John Rylands Library*, Manchester 1934, no. 347 B; or no. 419? According to Abattouy, there are also two copies in the ʿUthmāniyya University, Hyderabad). This Arabic text, on Mechanical Arts and automata, has been studied by Abattouy.[5] It is mainly a selection from the 'Book of Devices' (*Ḥiyal*) of Abū Jaʿfar Muḥammad b. Mūsā (d. 259/873),[6] a member of the renowned Banū Mūsā family in Baghdad of the 3rd/9th century. The book, based on the older Greek writings of Heron, Apollonius, Philon, and others, described some one hundred mechanical contrivances and how to use them.

[4] Ḥājjī Khalīfa, *Kashf al-ḍunūn*, Istanbul 1943, II, 1447.

[5] "Nutaf min al-Ḥiyal: A Partial Arabic version of Pseudo-Aristotle's 'Problemata Mechanica'." *Early Science and Medicine* 6 (2001), 96-122.

[6] This is translated by Donald R. Hill, *The Book of Ingenious Devices (Kitāb al-Ḥiyal) by Banū (sons of) Mūsā bin Shākir*, Dordrecht-London 1979.

The impact of *Kitāb al-Ḥiyal* is visible in Badīʿ al-Zamān Ismāʿīl b. al-Razzāz al-Jazarī's (6th/12th c.) *al-Jāmiʿ bayna l-ʿilm wa-l-ʿamal, al-nāfiʿ fī ṣināʿat al-ḥiyal* (A Compendium on the Theory and Practice of the Mechanical Arts, written in 602/1205), in the Arabic edition by Aḥmad Y. al-Ḥassan, Aleppo 1975. Donald R. Hill translated this as *The Book of knowledge of Ingenious Mechanical Devices*, Dordrecht 1974. This translation is based mainly on MS Graves no. 27 of the Bodlein Library, Oxford, which bears the title *Kitāb fī maʿrifat al-ḥiyal al-handasiyya* (Book of Knowledge of Mechanical Devices). An anonymous older Persian translation of this is also extant (C. A. Storey, *Persian Literature*, II, part 3, Leiden 1971, 445). Between 1915 and 1921, E. Wiedemann and F. Hauser published a series of seven articles in German using the Bodlein copy: "Über die Uhren im Bereich der Islamischen Kultur," in *Nova Acta Abh. der Kaiserl. Leop. Carol. Deu-tschen Akademie der Naturforscher* 100 (Halle 1915), 1-272.

4) *Muqaddima fī l-masāḥa* (Introduction to Land Surveying). This short text which describes the proper use of measuring instruments in diverse situations, remains unpublished. (MS. => K. Defteri, Lāleli, Istanbul 1310, no. 2708, 3^0 f. 19b-23b; Krause, 1936, no. 268; C. Brockelmann, *GAL*, SI, 856).

5) *Irshād dhawī al-ʿirfān ilā ṣināʿat al-qaffān* (Guide to the Learned Men in the Art of the Steelyard) is addressed to Abū Saʿīd Muḥammad b. Manṣūr b. Muḥammad (d. 495/1101). For a study of this see Abattouy (2000), who has used a Ms. at Damascus, National Library, no. 4460, 16r-23v. The manuscript Tehran, Majlis-i Sinā, no. 518, contains four *Risāla*s. The third is al-Khāzinī's *Mīzān al-ḥikma*, the eighth chapter of which, "Dar markaz-i athqāl wa-ṣanʿat qappān", in four sections (fol. 216-286), is taken from Isfizārī. Al-Khāzinī refined and finished Isfizārī's "Balance of Wisdom" to create his now classic *Mīzān al-ḥikma*, where he qualifies the scale as "the tongue of justice and the article of mediation."

6) *Aʿdād al-wifq*, known as *al-Murabbaʿāt al-siḥriyya* (Magical Squares). This is introduced by Jacques Sesiano at a conference in Tehran in a lecture "Quatre auteurs iraniens d'études sur les carrés magiques," delivered at the *Second Colloque International "la science dans le monde iranien"*, organized at Tehran University, June 7-9th, 1998; proceedings edited by N. Pourjavady and Z. Vesel, Tehran 2004.

And the last but not least,

7) *Risāla-i Āthār-i ʿulwī, yā Kā'ināt-i jaww* (The treatise on Meteorology), written before 500/1106. This is the Persian text edited by Mudarris Raḍawī based on two very defective Mss. Mudarris Raḍawī's edition is maddening in that one cannot tell which Ms. is the original,

which paraphrase, commentary, insertion, or deletion. He spends no word either on the relationship of the text with the older Greek, Syriac, Arabic, Hebrew, or Latin versions, nor on the existing commentaries on Aristotle's Meteorology.

Ever since his own days, Isfizārī's works had become very popular and generations after him frequently used his scholarly writings, in particular his book on meteorology. A younger contemporary, Shahmardān b. Abī l-Khayr Rāzī, the author of the encyclopedic work *Nuzhat-nāma-i ʿAlā'ī* (written in 513/1119) incorporated the entire text of Isfizārī's meteorology (except the introduction), because, as he says, the latter had done an outstanding job as far as the discussion of meteorological phenomena was concerned. Shahmardān's *Nuzhat-nāma*, which offers the closest version of Isfizārī's original, is edited and published by Farhang Jahānpūr, Tehran 1983. Not long after Shahmardān, Muṭahhar b. Abī l-Qāsim wrote his *Farrukh-nāma*, now lost, as a critical response to it (Ḥājjī Khalīfa, II, 1254).

Two early Persian tracts on meteorology, which depend wholly on Isfizārī, have been published together by Muḥammad Taqī Dānishpazhūh, *Du risāla dar bāra-i āthar-i ʿulwī*, Tehran 1337/1958. These are:

1. *al-Risāla al-Sanjariyya fī l-kā'ināt al-ʿunṣuriyya* (Epitome on Meteorology Dedicated to Sanjar) [that is, Sultan Sanjar b. Malikshāh, r. 511-552/1118-1157] written by the logician-philosopher Zayn al-Dīn ʿUmar b. Sahlān Sāwajī around 525/1130. Sāwajī or Sāwī uses Isfizārī as well as Ibn Sīnā's meteorology in *al-Shifā'* (Dānishpazhūh, 1-56; for his biography, see idem, *Tabṣara-i Sāwī*, Tehran, date?, and Hossein Ziai, *EIr*, s.v. "Ebn Sahlān Sāvajī," VIII, 52-53, points out that as a logician and mathematician he was influential on the formation of Suhrawardī al-Shahīd's philosophical thought).

Daiber Collection II, Ms. No. 125:

[2259] fols. 35r-v: Anonymous: *Risāla fī bayān muqaddimāt sabʿ yuḥtāju fī maʿrifat qaws quzaḥ ilā maʿrifatihā* رسالة في بيان مقدمات سبع يحتاج في معرفة قوس قزح إلى معرفتها (A Treatise on the Seven Preconditions Needed for the Understanding of Rainbows). In the main the author follows Aristotle's theory of visual rays and reflections (cf. Aristotle, *Meteorology*, III, 4-5; and H. Daiber, *Ein Kompendium der aristotelischen Meteorologie in der Fassung des Ḥunayn Ibn Isḥāq*, Amsterdam-Oxford 1975, 90-92). The text is published by Louis Cheikho, *al-Mashriq* 15 (1912), 736-ff; and translated into German by E. Wiedemann, *Gesammelte Schriften zur arabisch-islamischen Wissenschaftsgeschichte II*, D. Girke and D. Bischoff (eds.), Frankfurt/M. 1984, 746-48. A synopsis of this *Risāla* has entered al-Qazwīnī's

(d. 610/1213) *ʿAjā'ib al-makhlūqāt* (ed. Fārūq Saʿd, Beirut 1978, 144:20-145:15). Al-Qazwīnī, however, reduces the seven preconditions to four and gives his source as al-Qāḍī ʿUmar Ibn Sahlān al-Manāwī المناوي (= Zayn al-Dīn ʿUmar Ibn Sahlān al-Sāwī = al-Sāwajī; Brockelmann, *GAL*, SI, 830f.) Al-Qazwīnī's section on the rainbow (*ʿAjā'ib*, I, 100:7-13) corresponds with al-Sāwī (Dānishpazhūh, 23-27), but not with this Arabic manuscript which is perhaps part of an older, more extensive source, used by al-Sāwī in the 6th/12th century.

Another copy of the above *Risāla* is kept at Göttingen; cf. Tilman Seidensticker, *Arabische Handschriften*, Teil II. *Die Arabischen Handschriften* Cod. Ms Arab 136 bis 180 der Niedersächsischen Staats- und Universitätsbibliothek Göttingen, Stuttgart 2005, 146-47 (Nr. 176.15, fols. 190a-191b). The author is Muṣliḥ al-Dīn Muṣṭafā Ibn Yūsuf Khwājazāda al-Burūsawī (d. 893/1488). Seidensticker introduces a couple other Mss.

2. *Risāla-i āthār-i ʿulwī* (Epitome on Meteorology), written by the arithmetician Sharaf al-Dīn Muḥammad b. Masʿūd al-Masʿūdī Marwazī around 551/1155. This is edited also by Muḥammad Shafīʿ as "Risāla dar maʿrifat-i ʿanāṣir wa kā'ināt al-jaww", in *Oriental College Magazine* 4.3 (1928), 31-91. Marwazī (still alive in 582/1186) was a close associate and a disciple of ʿUmar Khayyāmī. He has fully adopted Isfizārī's comments on the rainbow. He is the author of a Persian book on astronomy called *Jahān-i Dānish* (*dar ʿilm-i hay'at* 'On Astronomy'), which he translated from his own Arabic *Kifāya fī ʿilm al-hay'a* in 549/1154 (published in *Ḍamīma-i Sālnāma-i Dabīristān-i Pahlavi*, Tehran 1314-15, 1-190). One of Marwazī's successors was the philosopher Fakhr al-Dīn Rāzī (ca. 544-606/1150-1210), who studied with him for some time in 582/1186. Fakhr al-Dīn's *Mabāḥith mashriqiyya* (Eastern Studies on Metaphysics and Physics) (ed. 2 vols. Hyderabad 1343) discusses meteorology, physics and the nature of the physical world. He explains the rainbow better and more comprehensively than his predecessors.

In addition to the above, we know of two dozens other Persian tracts on meteorology still waiting to be published, including:

3. *Dānish-nāma-i jahān*, written by Ghiyāth al-Dīn ʿAlī b. ʿAlī Amīrān al-Ḥusaynī al-Iṣfahānī in 879/1474 (Ms. Āstān Quds-i Raḍawī). Ghiyāth al-Dīn relies mainly on Ibn Sīnā and Isfizārī.

4. The Iranian Parliament Library possesses an anonymous *Shinākht-i kā'ināt jaww* (On Meteorology) (Majlis-i Shawrā-i Millī, no. 621, 20r-28r; *Fihrist-i Makhṭūṭāt Majlis*, II, 374), which is presented to the Ṣafawīd Shāh ʿAbbās I (r. 996-1038/1588-1629). This tract, which gives Isfizārī as

its source, and is in fact a refutation of the critic some earlier author had addressed against Isfizāri, documents the canonical role of our author as well as the sustained interest for meteorology at that late age.

Isfizārī's *Meteorology*, though published a long time ago, has not received the kind of attention it deserves. It is the most comprehensive book written on meteorological phenomena in Persian. From among all the recensions, compendia and translations of Aristotle's *Meteorologica* in diverse languages, Isfizārī's Persian adaptation is the only one that has not yet found its proper place in modern scholarship. It constitutes not only a significant phase in the history of dissemination of Aristotelian ideas, but considering the fact that Persian language substituted Arabic in the Eastern half of Muslim world, a very important one for that matter. Most of the authors writing on the subject after Isfizārī (Shahmardān, Sāwī, Marwazī, Ghiyāth al-Dīn, and others) are dependant on him. As such Isfizārī's contribution represents a milestone in the history of meteorology in the East. Specialists coming after him agreed that quite a number of problems related to meteorology, which Aristotle, Ibn Sīnā and other earlier scientists had left unsolved, were satisfactorily explained by Isfizārī. He was recognized as the ultimate authority in this field.

Isfizārī himself gives no names as his authorities and no direct title as his source. We do not know of any other comparable work on this subject in Persian prior to his time (except perhaps some relevant sections of Ibn Sīnā's *Dānishnāma*). A cursory comparison between the content, arrangement, and supportive arguments in Ibn al-Biṭrīq's translation and Isfizārī's composition reveals close similarities as well as differences. Just to give an example: The chapter on Winds is not in the same section in both books. In Ibn al-Biṭrīq (Petraitis 72-73; Lettinck 166-69) the winds are said to be 12 kinds, though the common people know only four of them by name. The 12 winds are delineated here (Greek original does not enumerate them). In a different context in the book (Petraitis 85) still another wind, *zawbaʿa* (pl. *zawābiʿ*) 'whirlwind', and its synonym *ṭurbīna* (Latin *turbo*, used for Greek δίνη), is introduced, rising the total to 13 winds. Isfizārī, however, states that the winds are 14 kinds, adding yet another to the above list, namely the Qur'anic *ṣarṣar* 'violent, cold wind, icy gale'. This is a good sign that he is not translating, but paraphrasing and expanding the topics he has chosen. Nonetheless, the dependence of the Persian text on the Arabic is obvious here and elsewhere, though Isfizārī's input adds constructive improvements to the subject.

In discussions about Aristotle's *Meteorologia* in oriental sources, attention has been focused on the Arabic translation from the Syriac, occasionally also on probable direct renderings from the Greek. For Ibn al-Biṭrīq, Endress postulates a Syriac copy based on a Hellenistic version (Lettinck 7). As for Theophrastus' Meteorology, Daiber (1992, 47-49) suggests that Ḥunayn b. Isḥāq (d. 260/873) was the translator of the book into Syriac and the Arabic version was created by someone from his school. Nobody has raised the possibility of a Middle Persian intermediary as a channel yet.

Despite the fact that the meteorological concepts articulated here are highly technical and not always easy to grasp, Isfizārī's text makes easy reading, suggesting that the vocabulary he uses was conventional in Persian. Nowhere in the text or elsewhere in the literature it is mentioned that Isfizārī's work is a translation from Arabic, Syriac, Middle Persian, or otherwise. The Persian text does not read like a translation from Arabic. If that was the case, we would expect to encounter the fixed Arabic technical jargon adopted into Persian. On the contrary, a cursory look at the published Arabic versions of Ibn al-Biṭrīq reveals a number of Persian technical terms borrowed directly or translated into Arabic, for example *nayzak* or *niyāzak* "meteor," *ghīm* (= *mīgh*) "cloud," *nadan* "dew," *qaws quzaḥ* (= *kamān-i rangīn* or *rangīn kamān*, in popular parlance: *kamān-i Rustam*) "rainbow," *jawf* "hollow, cavity," *niṣf al-nahār* (= *nīmrūz*) "meridian," *hāla* "halo," *sirāj* "lamps", and so forth. These terms are slightly different from the regular *muʿarrabāt*, Persian words in Arabic, also abundantly used here such as *jawhar* "matter, substance," *zamān* "time," *zībaq* "quicksilver," *zamharīr* "bitter cold," *kahrubā'* "electricity," *qirmiz*, "kermes," *mādda* "materia," *shāhiq* "high, lofty," *burj* (pl. *burūj*) [< Greek *pyrgos*], *zabarjad* "chrysolite," *ṭūfān* "typhoon; hurricane," *ābnūs* [Pahl. *āwanôs* < Aramaic *abnūsā* < Greek *ébenos*], even when some of these words are ultimately of Greek origin.

Though these examples are far too few to be conclusive in any way, the mere fact of the existence of Middle Persian terms both in the Arabic and Persian versions opens a new vista for checking the possibility of the Aristotelian Meteorology or its early Hellenistic commentaries having been translated into Middle Persian already in pre-Islamic times. The exact relationship of Yaḥyā b. al-Biṭrīq's (d. ca. 215/830) translation with the original Greek and its compendia in Syriac is still open to debate. A Syriac intermediary is only postulated for him. According to Ibn al-Nadīm, Yaḥyā belonged to a group of translators, among them al-Ḥasan b. Sahl al-Nawbakhtī and Sahl b. Hārūn, who happen to be translators from Middle Persian. Moreover, Syriac was the scientific language commonly used in the Sasanian Empire as the language of instruction and this could have paved the way for the reception of Aristotelian ideas in these territories. The list of Greek authors whose work was available in Middle

Persian is large. *Kitāb al-Aḥjār* (Lapidary) of Aristotle belongs to the late Sasanian Persian-Syriac tradition.[7] This differs from the "Mineralogy" of Theophrastus. It is certainly an Oriental compilation and contains numerous Iranian names for stones. The examination of the Middle Persian channel is important for the history of science and cultural exchange in antiquity as well as the transfer of Greek science in the ancient world.

Hans Daiber, who became interested in the impact and remains of Aristotelian *Meteorologia* in the Islamic world some forty years ago, has been behind most of the editions and translations listed above. The only lingering knot in the literary history of this book is the Iranian branch, which despite of some preliminary work, remains still inaccessible to the broader public. Daiber's desire to complete what he calls, his "Lebenswerk", has brought us together to work on a new edition based on newly emerged better manuscripts of Isfizārī's Meteorology, an English translation and commentary, as well as its interaction with the older Iranian concepts in this field.

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[7] Ed. & trans. Julius Ruska, 1912; S. H. Nasr, *Cambridge History of Iran*, ed. R. Frye, Cambridge 1975, IV, 410.

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Islamic Astronomical Instruments and Some Examples of Transmission to Europe

David A. King

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1 INTRODUCTORY REMARKS

Before we can consider some examples of Islamic astronomical instruments that became known in Europe, it is necessary to present an overview of Islamic instrumentation. This is somewhat easier than presenting an overview of medieval European instrumentation, because the Islamic sources are under better control. The general impression that medieval European instrumentation was highly indebted to Islamic instrumentation is correct, but the richness and sophistication of the Islamic tradition has become clear only in the last few years. However, the Europeans in the Middle Ages actually had a very limited idea about Islamic instrumentation and just took over what they could find. On the other hand, Europeans in the Renaissance were designing and making instruments of the same kind as Muslim astronomers and crafts-men had been involved with centuries earlier. In some cases we can see direct Islamic influence, in others European initiative. In this study I shall indicate the extent of the European debt to Islamic instrumentation, not least by showing earlier attestations of a few instruments previously thought to be of European origin.

Our knowledge of astronomical instrumentation in the Islamic world between the 8th and 19th centuries is derived essentially from two sources: (1) the instruments which survive in various museums and private collections around the world, and (2) the treatises on the construction and use of instruments that are preserved in manuscript form in libraries mainly in Europe and the Near East.[1] The surviving instruments are legion: two hundred globes, several hundred astrolabes and a few dozen each of quadrants and sundials, although most postdate the creative period of Islamic science that lasted from the 8th to the 15th century. An inventory of the instruments up to *ca*. 1500 has now been published,[2] and important new examples are continually showing up in dealers' salons. The texts exist in similar profusion, the most important of these having been compiled during the early period of Islamic science.[3] Also, some describe instruments far more interesting than the standard astrolabe or quadrant or sundial, and of which there are no surviving examples. Many more manuscripts have yet to be uncovered in the various uncatalogued

[1] This paper is mainly abridged from King, *SATMI*, vol. 2.
On Islamic instrumentation see also the volumes listed as *AIOS* containing reprints of studies mainly from the 19th and early 20th centuries, as well as various papers reprinted in Kennedy *et al*., *Studies in Islamic Exact Sciences*, and King, *Studies*, B. A useful study that pays considerable attention to transmission to Europe is Samsó, "Instrumentos astronómicos".
[2] *SATMI*, XVIII.
[3] Sezgin, *GAS*, V and VI.

collections of Arabic (and also Persian and Turkish) scientific manuscripts, particularly those in libraries in the Near East and India.

The Islamic astronomical texts, let alone such illustrations as that of the Observatory in Istanbul in the late 16th century –see Fig. 1–, bring these instruments back to life again and save us from the antiquarian attitudes so prevalent amongst scholars who deal only with instruments. The study of Islamic instruments is but a small chapter in the history of Muslim interest in astronomy for over a millennium. We also need to be liberated from the notion that Islamic instrumentation is of consequence only as a prelude to European developments. Some of these various Islamic instruments and related mathematical procedures were not influential in Europe, but to the historian of science they should none the less be of interest.

It is convenient to consider Islamic instruments in two main categories, namely, observational and non-observational instruments. Those instruments used by Muslim astronomers for observations followed closely in the tradition of the devices described by Ptolemy of Alexandria: the armillary sphere –a physical representation of specific astronomically-significant circles on the celestial sphere, such as the horizon, the meridian, the celestial equator and the ecliptic; the mural quadrant –a device for measuring the meridian altitudes of celestial bodies; and the parallactic ruler –a structure for measuring the zenith distance of a celestial body.[4]

Instruments whose primary function was not observational are mainly for solving problems of spherical astronomy, the mathematics of the rotation of the celestial sphere about the observer. The main problems are related to timekeeping, using the risings and settings of the sun and stars over the local horizon, or more commonly, the culminations of the sun and stars across the local meridian. Such instruments include: (1) the celestial sphere –a model of the universe in which the sun and stars are represented on a sphere that can rotate about the celestial axis, so that risings and settings can be simulated over any horizon; (2) analogue computers like the astrolabe (and its simplified version, the astrolabic quadrant) for representing –in two dimensions rather than three– the positions of the sun and the fixed stars with respect to the local horizon; (3) mathematical grids like the sine quadrant for obtaining numerical solutions to problems of trigonometry without calculation, and (4) sundials and other devices for measuring the time of day by means of shadows. Another variety of Islamic instrument was (5) the equatorium, a device for determining planetary positions according to geometric models of the Ptolemaic kind for the sun, moon, and planets. With the exception

[4] The fundamental study of Islamic observatories is still Sayılı, *The Observatory in Islam*.

of the astrolabic quadrant and the trigonometric grids, these instruments were known to the Muslims from Greek sources.

Two monographs dealing with Islamic instruments may revive some scholarly interest in this subject. These are, firstly, the long-awaited repertory of Islamic astrolabists and their works by A. Brieux and F. Maddison;[5] and, secondly, my recent book on aspects of Islamic instrumentation, including detailed descriptions of various groups of instruments.[6]

In the present paper, I shall concentrate on portable instruments and shall refer to a series of European instruments now known to have been conceived by Muslim astronomers.

2 CELESTIAL GLOBES

The problems of spherical astronomy can be illustrated by means of a three-dimensional celestial globe. The stars and the ecliptic, the apparent path of the sun against the background of fixed stars, are represented on the outside of a sphere of arbitrary radius which is set inside a horizontal ring representing an arbitrary horizon. The axis of the sphere is fixed in the plane of the meridian, but its inclination to the horizon can be adjusted so that the ensemble represents the heavens with respect to the horizon of any locality. One rotation of the sphere about its axis corresponds to one 24-hour period of time.

The Muslims inherited the celestial globe from the Greeks, and a description of such an instrument was available to them in Ptolemy's *Almagest*. Several Arabic treatises were written on the celestial globe over the centuries. The instrument was called in Arabic *al-kura* or *al-bayḍa* or *dhāt al-kursī*, terms meaning "the sphere", "the egg" and "the instrument resting in a horizontal frame." Some 200 Islamic celestial globes survive to this day, most post-dating *ca*. 1500.[7]

3 ASTROLABES

The theory of stereographic projection, developed by Hipparchus of Rhodes *ca*. 150 B.C., enables the same problems of spherical astronomy to be solved with equal facility and with but a slight stretching of the

[5] Brieux & Maddison, *Répertoire*, to appear. For the present, Mayer, *Islamic Astrolabists*, is indispensable.
[6] See the reference in n. 1 above.
[7] For a survey see Savage-Smith, *Islamicate Celestial Globes*.

imagination by means of a two-dimensional instrument.[8] The Muslims inherited such a device –the planisphaeric astrolabe– from their Hellenistic predecessors, and they developed it in virtually all conceivable ways.[9] The device results from a stereographic projection of the celestial sphere onto the plane of the celestial equator from the south celestial pole. This projection has the property that circles on the sphere project into circles on the plane and that angles are pre-served.

The standard astrolabe consists of two main parts, one "celestial" and the other "terrestrial". First, there is a grid called a rete, bearing pointers representing the positions of certain prominent fixed stars and a ring representing the ecliptic. Second, there is a plate for a specific latitude bearing markings representing the meridian and the local horizon. Altitude circles and an orthogonal set for the azimuth are also included on the plate. When the rete –the "celestial" part– rotates over the plate –the "terrestrial" part–, the apparent rotation of the sun and stars across the sky above the horizon of the observer is simulated. The typical medieval astrolabe contained several plates for a series of latitudes as well as various markings on the back of the instrument either for measuring celestial altitudes or for performing calculations. Muslim developments to the simple planisphaeric astrolabe are of considerable historical interest.

a) Astrolabe construction

The construction of the markings on the rete and on the plates for different latitudes can, of course, be achieved by geometry, but it can also be effected, if somewhat tediously, by calculation. One needs to know the radius of each of the altitude and azimuth circles and the distances of the centres of these circles from the centre of the astrolabe. In early-9th-century Baghdad, the astronomer al-Farghānī compiled a set of tables displaying the radii and centre distances of both altitude and azimuth circles for each degree of both arguments, for each degree of terrestrial latitude.[10] These tables, which contain over 13,000 entries, were used by astrolabists alongside geometrical construction during the following centuries, and similar but less extensive tables were prepared for specific localities by a series of later astronomers[11].

[8] The best accounts of the basics of the astrolabe are Chabàs & Bosch, *L'astrolabi* (in Catalan), and North, "The Astrolabe". For more details see *SATMI*, XIIIa: "The Neglected Astrolabe: A supplement to the standard literature on the favourite astronomical instrument of the Middle Ages", also X-4-5.

[9] On instrumentation in early-9th-century Baghdad see now Charette & Schmidl, "Al-Khwārizmī and Practical Astronomy in Ninth-Century Baghdad".

[10] For his treatise see now Lorch, *Al-Farghānī On the Astrolabe*.

[11] King & Samsó, "Handobooks and Tables", pp. 91-92.

b) Ornamental retes

The Muslims developed the retes of astrolabes into objects that were sometimes of great beauty. Stars were sometimes selected for inclusion on the retes by virtue of their positions, in order to achieve symmetry about the vertical axis. Zoomorphic representations for constellations or groups of stars, or even for single stars, were used albeit not commonly, from the 10th century onwards. Floral patterns were particularly popular on Indo-Persian astrolabes from the 16th century onwards.

It is now possible to trace the astronomical and artistic development of astrolabe retes. Particularly important were the instruments of al-Khujandī of Baghdad in the late 10th century, which broke away from the earliest rather spartan retes inherited from the Hellenistic tradition and introduced quatre-foils and zoomorphic figures – see Fig. 2;[12] those of al-Khamā'irī of Seville in the 13th century, which were imitated in the Muslim West for six centuries;[13] and the less well-known ones of Jalāl al-Kirmānī of Central Asia in the 15th century, which mark the beginning of the floriated patterns on Eastern Islamic instruments.[14]

c) On the geography of astrolabes

Geographical and astrological information was often engraved on the maters or plates of astrolabes.[15] Originally, astrolabe plates served each of the seven climates of Classical Antiquity. The first geographical table on an astrolabe –the Cairo mater by Nasṭūlus from *ca*. 900– gave only the latitudes of a series of localities, their purpose being to indicate which plate one should use for a specific locality. (Medieval texts often advocate interpolating between the results derived from two plates with a lower and a higher latitude than one's own.) Later astrolabe plates were engraved for a series of latitudes no longer corresponding to the seven climates (although these often lurk in the back-ground in a disguised form). Often the length of longest daylight at those latitudes would be included, this being another feature reminding the user of the notion of the climates. Sometimes a list of localities served by each of the plates would be included. The plates of an astrolabe often yield clues as to the provenance of the instrument because usually the plate for the latitude of the locality where the instrument was made has additional markings.

12 *SATMI*, XIIIc-9.
13 See, for example, Gunther, *Astrolabes*, no. 130.
14 *SATMI*, XIVd.
15 For more information see *SATMI*, XVI.

d) Special markings relating to religious obligations

Some of the markings introduced by Muslim astronomers on the standard astrolabe have to do with Muslim prayer.[16] Muslim ritual requires five prayers each day at times that are defined in terms of the position of the sun relative to the local horizon. These prayers begin when the sun has disappeared over the horizon at sunset, at nightfall, at daybreak, either at astronomical midday or shortly thereafter, and at mid-afternoon. The beginnings of the permitted intervals for the daylight prayers are defined in terms of shadow lengths, and the corresponding times for the night prayers are defined in terms of sunset and twilight phenomena. Most astrolabic plates for specific latitudes show special markings for the prayers at mid-afternoon, nightfall and daybreak, and the times of midday and sunset are easily determined with an astrolabe anyway.

Furthermore, it is the duty of every Muslim to face Mecca during prayer, and it is thus required to know the direction of Mecca from any locality.[17] At least for the scientists, this involved calculating the direction from the latitudes and the longitude difference. By medieval standards, the formula for finding the qibla is rather complicated; however, correct procedures were derived already in the 9th century. Especially in the Eastern Islamic world, astrolabists after about the 13th century engraved lists of localities together with their latitudes, longitudes, and qiblas on the maters of their astrolabes, or palettes of qibla directions in a quarter-circle on the backs of the instruments. After the 16th century, the latter were replaced by graphs displaying the altitude of the sun throughout the year when the sun is in the direction of Mecca in various places.

e) Additional markings

A set of scales for finding the solar longitude from the date in any one of the solar calendars (Syrian, Persian, Coptic or "Western") is a feature on the backs of certain Eastern astrolabes and virtually all Western Islamic instruments. Sometimes extensive scales for converting dates from one calendar to another were included on Western Islamic instruments. Also, astrological in-formation was occasionally engraved on the mater or back.

The other markings introduced by Muslim astrolabists on the backs of astrolabes were shadow scales and quadrants. The latter were usually sine quadrants or horary quadrants, and are best considered separately –see §4a-b below.

[16] On the times of prayer in Islam and the way in which they were regulated over the centuries see *SATMI*, II-IV, summarized in the article "Mīqāt" in *EI*$_2$, repr. in King, *Studies*, C-V.

[17]See King, *Mecca-Centred World-Maps*, pp. 47-193, and the summaries in the articles "Qibla" and "Makka: As Centre of the World" in *EI*$_2$, repr. in *idem*, *Studies*, C-IX and X, respectively,

f) Non-standard retes

The northern and southern halves of the ecliptic are projected into dissimilar arcs of the ecliptic on the rete of the standard astrolabe. This fact motivated several astronomers in the 9th and 10th centuries to devise retes on which the two halves of the ecliptic were represented symmetrically.[18] Such astrolabes required special kinds of plates, and the treatises on their use called for considerable ingenuity on the part of their inventors and dexterity on the part of their users. See further §8b.

Of considerable interest is an instrument devised by Ḥabash al-Ḥāsib in the mid 9th century and known to us only from a single manuscript. This is the so-called "melon" astrolabe, in which the meridians on the sphere are projected into radii through the South Pole in the tangential plane. The ecliptic and the altitude circles are no longer circular, hence the name of the astrolabe.[19]

g) Spherical astrolabes

An Islamic development of the planisphaeric astrolabe –see below– was the spherical astrolabe,[20] an instrument in which a spherical frame bearing mar-kings representing the ecliptic and fixed stars could be rotated over a sphere with markings for the horizon and altitude circles of any locality and the hours. The instrument has the advantage over the planisphaeric astrolabe in that it was universal, that is, it can be used for any latitude, one of two surviving pieces has markings specifically for the latitude of Tunis. A series of treatises was written on the instrument between the 10th and 17th centuries, but it does not appear to have been widely used.

h) The linear astrolabe

The ingenuity of the mathematician Sharaf al-Dīn al-Ṭūsī (*fl*. Iran, *ca*. 1200) was such that he conceived a linear astrolabe.[21] The instrument consists of a series of scales marked on a baton that represents the meridian for a specific latitude. Two of the scales represent the intersections of the declination circles and the altitude circles with the meridian. The basic idea is that any circle on the standard planisphaeric

[18] See *SATMI*, X-5.1, for references to the literature.
[19] See Kennedy & Kunitzsch & Lorch, *The Melon-Shaped Astrolabe*.
[20] On the spherical astrolabe see Seemann, *Das kugelförmige Astrolab*. On the two surviving examples see Maddison, "A Fifteenth-Century Spherical Astrolabe", and Canobbio, "An Important Fragment of a West Islamic Spherical Astrolabe".
[21] On the linear astrolabe see Carra de Vaux, "L'astrolabe linéaire ou baton d'al-Tousi", and Michel, "L'astrolabe linéaire d'al-Tusi".

astrolabe can be represented on the baton by the position of its centre and its radius. Threads are attached to the baton, and with these and the various scales, one can perform the standard operations of an astrolabe. Angles are measured by means of an additional scale of chords. The device is impractical but brilliant in its conception. No examples are known to have survived.

i) The universal plate and astrolabe

In Baghdad in the mid 9th century, Ḥabash devised a plate with markings re-presenting the horizons of various localities. He noticed that the problems relating to risings, culminations and settings of celestial bodies could be solved for all latitudes using such a plate and a rete displaying the ecliptic and fixed stars. This notion was developed further in Toledo in the 11th century. Muslim astronomers there developed a universal plate from the markings on an astrolabic plate for latitude zero and thence an astrolabe that would function for all latitudes with a single plate.[22]

The astronomer Ibn al-Zarqālluh, better known in the West as Azarquiel, appears to have developed the universal plate called *al-shakkāziya* with a regular alidade, with which some of the problems of spherical astronomy can be solved only approximately. He also devised the plate called *al-zarqālliyya* which consisted of two *shakkāziyya* grids inclined at an angle equal to the obliquity; the alidade is now equipped with a movable cursor and the combi-nation serves only to convert between ecliptic and equatorial coordinates.

The astronomer ʿAlī ibn Khalaf al-Shajjār, a contemporary of al-Zarqālluh, developed a more sophisticated and more useful instrument. Taking the basic notions –that the *shakkāziyya* plate could be used to represent in two dimensions any orthogonal spherical coordinate system, and that two such plates superposed one upon the other could be employed to solve any problem of coordinate transformation, which problems are the essence of spherical astronomy– to their natural conclusion, he invented the universal astrolabe. This instrument is known only from the 13th-century Castilian compilation entitled *Libros del saber*: the rete consists of one semicircle of *shakkāziya* markings and another comprising an ecliptic and star-pointers, and the plate is a *shakkāziyya* grid.

[22] On the universal astrolabe and plate see the article "Shakkāziyya" in EI_2 and the numerous publications of the Barcelona school there cited, including the chapter "Instrumentos universales en al-Andalus", in *Madrid MAN 1992 Exhibition Catalogue*, pp. 67-73; Puig, *al-Shakkāziyya – Ibn al-Naqqāsh al-Zarqālluh*, and *eadem*, *Los tratados de construcción y uso de la azafea de Azarquiel*; and most recently Calvo & Puig, "The Universal Plate Revisited".

The universal astrolabe of ʿAlī ibn Khalaf and his treatise on its use do not seem to have been known in the Muslim world outside al-Andalus. The same instrument appears to have been "reinvented" in Aleppo by Ibn al-Sarrāj in the early 14th century, and a unique example designed and constructed by him survives in the Benaki Museum in Athens –see Fig. 3.[23] In his treatise on a simplified version of the instrument he claims to have invented it himself, and this there is no reason to doubt. But the surviving astrolabe of Ibn al-Sarrāj is far more complicated and sophisticated than that of ʿAlī ibn Khalaf or the same instrument described in Ibn al-Sarrāj's treatise: it contains a set of quarter-plates for all latitudes, a plate of horizons for all latitudes, and other features such as a universal trigonometric grid; indeed, the instrument can be used universally in five different ways.[24] It is undoubtedly the most sophisticated astronomical instrument from the entire medieval and Renaissance periods.

In the 14th century the Granada astrolabist Ibn Bāṣo devised a modification of the *shakkāziyya* for use with a standard astrolabe rete. Each of the *zarqālliyya* and *shakkāziyya* plates and the plate of Ibn Bāṣo were also known in the Muslim East.[25]

j) The *Zīj al-ṣafāʾiḥ*

One unusual astrolabe devised by Abū Jaʿfar al-Khāzin in the 10th century contained, in addition to at least one standard astrolabic plate, a series of additional plates (*ṣafāʾiḥ*) bearing various astronomical tables of the kind usually found in astronomical handbooks (*zīj*es).[26] It appears that al-Khāzin wrote a book to be used alongside his instrument. A unique example of his *Zīj al-ṣafāʾiḥ*, constructed by the celebrated early-12th-century astrolabist Hibatallāh, was preserved in Munich until 1945, but only photographs of it were thought to have survived World War II. However, a copy of al-Khāzin's treatise survives in Srinagar, and Hibatallāh's astrolabe has recently been found in the vaults of the Museum of Indian Art in Berlin. Both await serious study. The device with all its components functions as an equatorium (see §6a).

[23] See Gunther, *Astrolabes*, no. 140; *SATMI*, XIVb-5.1; and Charette & King, *The Universal Astrolabe of Ibn al-Sarrāj…*, forthcoming.
[24] Charette & King, The Universal Astrolabe of Ibn al-Sarrāj, forthcoming. See already *SATMI*, XIVb-5.1.
[25] Calvo, *Abū ʿAlī al-Ḥusayn ibn Bāṣo ... Tratado sobre la lámina general para todas las latitudes*; and *eadem*, "A Study of the Use of Ibn Bāṣo's Universal Astrolabe Plate".
[26] See King & Samsó, "Islamic Astronomical Handbooks and Tables", pp. 42-43.

k) Geared astrolabes

A unique example of an astrolabe fitted with a geared mechanism for reproducing the relative motions of the sun and moon survives from 13th-century Iran. We also possess accounts of a similar mechanism by Nasṭūlus *ca*. 900 (see §6d) and al-Bīrūnī.[27]

l) Astrolabic clocks

A large device for time-keeping resembling an astrolabe was seen by a 14th-century historian in the home of the contemporary Damascene astronomer Ibn al-Shāṭir, and the face of an astrolabic clock in Fez originally constructed in the 13th century survives in restored form to this day. Thus these "instruments" existed, but they were certainly not common.

4 QUADRANTS

There are essentially four varieties of quadrant of concern to us here: (1) the sine quadrant –for solving numerically problems of trigonometry, usually those deriving from spherical astronomy; (2) the horary quadrant –for reckoning time by the sun, (3) the astrolabic (or almucantar) quadrant –developed from the astrolabe; and (4) the universal *shakkāziyya* quadrant –for solving problems of spherical astronomy for any latitude. Each of these was invented by Muslim astronomers but the early history of the different kinds of quadrants has only recently been investigated for the first time,[28] and the problems associated with their transmission to Europe now have to be considered afresh.

a) The trigonometric quadrant

The sine quadrant was developed in Baghdad in the 9th century and remained popular for a millennium. Originally, it was devised to solve just one problem: the determination of time as a function of solar altitude and solar meridian altitude using an approximate formula adequate for low latitudes. By the 10th century it had been developed into a kind of medieval astronomer's slide-rule, a quadrant of markings like modern graph paper with a thread fitted with a movable bead attached at the centre. With a device bearing markings resembling modern graph-paper,

[27] On al-Bīrūnī's description of a gear mechanism see Hill, "Al-Bīrūnī's Mechanical Calendar".
[28] On the quadrant in Islam see already the article "Rubʿ" in *EI*$_2$, and now *SATMI*, X-6. On the approximate formula see *ibid*., XI.

fitted with a cord attached at the centre of the quadrant and carrying a movable bead, one can solve numerically the most complicated problems of medieval trigonometry, such as, for example, the problem of determining the qibla for any locality. Often a sine grid of one kind or another would be incorporated on the back of an astrolabe.

b) Horary quadrants

The horary quadrant bears either a series of markings for the seasonal hours, which are one-twelfth divisions of the length of daylight, or for the equinoctial hours. In the first case, the markings serve all latitudes (the underlying formula –already mentioned above– being approximate); in the second case, they serve one specific latitude. When one edge of the quadrant is aligned towards the sun, a bead on a plumb-line attached at the centre of the quadrant indicates the time of day. Universal horary quadrants of this kind are common on Islamic astrolabes from the 10th century to the 19th.[29] They are inevitably associated with shadow-scales, another invention from 9th-century Baghdad.[30]

Two early horary quadrants for specific latitudes survive, one from Iran and the other from Egypt, and others are attested on the backs of astrolabes from the 10th century onwards. A simple variety of horary quadrant which I shall label zodiacal quadrant, displaying only solar meridian altitudes or solar altitudes at the afternoon prayer (and from the 16th century onwards, also the altitude of the sun when it is in the qibla) was often included on the backs of astrolabes from the 12th century onwards.

c) The astrolabic quadrant

Considerable mystery surrounds the invention of the astrolabic quadrant. The basic idea is simple: since the markings on a standard astrolabe plate are symmetrical with respect to the meridian, one uses just half of such a plate engraved on a quadrant. The rete is replaced by a cord attached to the centre of the quadrant and this carries a bead that can be moved to represent the position of the sun or a fixed star, either of which can be found from markings for the ecliptic and star positions which are now included on the quadrant itself. The astrolabic quadrant is such a handy device that by the 16th century it had generally replaced the astrolabe in most parts of the Islamic world except Morocco on the one hand and Iran and India on the other. Most surviving astrolabic quadrants are of

[29] *SATMI*, XIIa.
[30] On the development of such scales see *ibid*., XIIa, App. B.

Ottoman Turkish provenance, although we do have a few Mamluk examples from the 14th century.

Until recently, the earliest known treatises on the use of the astrolabic quadrant were those compiled in Syria in the 14th century. Yet not one of the authors of these treatises claims to have invented the instrument. A manuscript on the use of the astrolabic quadrant, which is of Egyptian origin and is datable to the 12th century, has been discovered in Istanbul, but again the author makes no claim to have invented it.

New kinds of trigonometric grids were invented in Syria in the 14th century as alternatives to the sine quadrant, and for these the astronomers who invented them have left us treatises on their use.[31] The universal *shakkāziyya* quadrant with one or two sets of *shakkāziyya* grids is a singularly useful device. A few examples of other grids survive, and they were apparently quite popular in Egypt, Syria and Turkey for several centuries. Some of these grids were of very considerable sophistication, notably the one on the back of the astrolabe of Ibn al-Sarrāj. All of these grids serve the same purpose of providing universal solutions to the problems of spherical astronomy.

5 SUNDIALS

Muslim astronomers made major contributions to the theory and construction of sundials of many different varieties.[32] The earliest Islamic sundials were horizontal with lines for the seasonal hours. Several survive from al-Andalus, and these are fitted with additional curves for the midday and mid-afternoon prayers.[33] Already al-Khwārizmī or Ḥabash in early-9th-century Baghdad pre-pared for a series of latitudes sets of tables of radial coordinates for marking the points of intersection of the hour-lines with the equinoctial and solstitial shadow-traces.[34] The earliest conical and cylindrical sundials date from the same milieu. From 10th-century Baghdad we have a set of tables for marking the hour-lines on vertical sundials inclined at any angle to the meridian. No-table advances to gnomonics, that is, the theory and construction of sundials, were made in Mamluk Egypt and Syria (13th-early 16th century); our know-ledge of these is based mainly on texts on their construction. One remarkable example survives from 14th-century Damascus. Made by the astronomer Ibn al-Shāṭir, it can be used to regulate time with respect to each of the

31 See Charette, *Mamluk Instrumentation*, pp. 209-220, *etc*.
32 On Islamic sundials see *SATMI*, X-7, and the summary in the article "Mizwala" in *EI*$_2$, repr. in *idem*, *Studies*, C-VIII.
33 On sundials in al-Andalus see King, "Three Sundials from Islamic Andalusia", and Labarta & Barceló, "Ocho relojes de sol hispanomusulmanes".
34 King & Samsó, "Astronomical Handbooks and Tables", pp. 92-94.

five daily prayers of Islam, and is undoubtedly the most sophisticated sundial from the entire medieval and Renaissance periods –see Fig. 4. Most surviving sundials date from the Ottoman period (16th-20th century) and pale in comparison to the splendid instruments that we know were constructed in the earlier centuries.[35]

6 MISCELLANEOUS INSTRUMENTS

a) Equatoria

An equatorium is a mechanical device for finding the position of the sun, moon and planets without calculation, using instead what is essentially a geometric model to represent the celestial body's mean and anomalistic motion. To use Ptolemy's models for this purpose, one simply takes the values of the mean longitude and the anomaly from the mean-motion tables standard in the astronomical handbooks and feeds these into the instrument, which then displays the true position of the celestial body. It is known that already Archimedes had a complicated equatorium, and of course the Antikythera device with highly complex gearing to reproduce the relative motions of the sun and moon represents the pinnacle of Greek mechanical engineering.[36] Already Nasṭūlus *ca*. 900 (see §6d below) had described a universal sundial of Hellenistic origin fitted with a solar-lunar gear mechanism, and we have already mentioned a mechanism of al-Bīrūnī inside an astrolabe (§3k). Alas, no medieval Islamic equatoria or planetaria survives intact, although the "astrolabic *zīj*" of Hibatallāh (§3j) shows evidence of having been fitted out as an equatorium. The original instrument on which this is based, the *Zīj al-ṣafā'iḥ* of Abū Jaʿfar al-Khāzin, was fitted with more complicated devices serving as an equatorium. Furthermore, we have at least four treatises on the equatorium, the first three being by Andalusī astronomers and dating from the period 1015-1115.[37] Considerably more sophisticated was the equatorium described by al-Kāshī in the early 15th century, which could be used even to determine planetary latitudes.[38]

[35] On some remarkable Mamluk sundials see Janin, "Le cadran solaire de la Mosquée Umayyade à Damas", also *SATMI*, XIVb-8, and Charette, *Mamluk Instrumentation*, pp. 181-208, *etc*.
[36] Price, "Gears from the Greeks".
[37] On Andalusī equatoria in general see Comes, *Ecuatorios andalusíes*, and *eadem*, chapter "Los ecuatorios andalusíes" in *Madrid MAN 1992 Exhibition Catalogue*, pp. 75-87.
[38] On al-Kāshī's instrument see Kennedy, *The Planetary Equatorium of... al-Kāshī*, and various articles thereon repr. in *idem et al*., *Studies*, pp. 448-480.

b) The magnetic compass

The earliest references to the magnetic compass in the astronomical literature occurs in a treatise compiled in the Yemen in the late 13th century and another compiled in Cairo in the early 14th.[39] Here, however, the authors of the treatises make no claim to be the first to write on the compass, and it is certain that they were not. From other 13th-century sources, we know that the compass was in limited use amongst the navigators of the eastern Mediterranean at that time: evidence of any transmission to Europe is lacking.

c) Astronomical compendia

During the 14th and 15th centuries, Muslim astronomers developed compendia, devices performing several different functions.[40] Ibn al-Shāṭir (*fl*. Damascus, *ca*. 1350) devised a compendium in the form of a box, the lid of which could be raised to serve the astronomical function of the box and its appendages for any of a series of terrestrial latitudes. This lid bears a set of astrolabic horizon markings, and a removable plate inside the box bears a universal polar sundial and a set of qibla markers for different localities. All of the other parts of this compendium, which are missing from the only surviving specimen of it now preserved in Aleppo, such as a magnetic compass for aligning the instrument in the cardinal directions and the sights for reading the time from an equatorial scale on the lid of the box, are described in a treatise on its use, preserved in Berlin and authored by Ibn al-Shāṭir himself.

The fact that the compass needle may deviate from the meridian by a certain number of degrees was first recorded in the Islamic world by the 15th-century Egyptian astronomer al-Wafā'ī, who modified this Syrian instrument into a semi-circular equatorial dial with a sighting device, compass and qibla indicator, and wrote a treatise on its use. Several Ottoman examples survive.

d) Horary devices

In 2005, a remarkable device surfaced at auction in London. It is in the form of an astrolabe with a solar / calendrical scale on the outer rim, and with a set of six lemon-shaped curves representing the solar altitude at the seasonal hours (1-6) throughout the year. The instrument is signed by

[39] Schmidl, "Two Early Arabic Sources on the Magnetic Compass".
[40] On Islamic compendia see Brice & Imber & Lorch, *The Dā'ire-yi Mu'addel of Seydī ʿAlī Re'īs*; King & Janin, "Ibn al-Shāṭir's *Ṣandūq al-Yawāqīt*"; and now *SATMI*, X-9.3.

Nasṭūlus, who was active in Baghdad during the period 890 to 930. He is known by three astrolabes, and a treatise on a universal sundial fitted with an internal gear mechanism (§3k), but textual references inform us that he also devised non-standard astrolabes and instruments for eclipse calculations.[41]

e) Qibla-indicators

The compendia of Ibn al-Shāṭir and al-Wafā'ī bore markings similar to those found on various Persian astrolabes from the 11th to 16th centuries which enabled one to find the qibla or local direction of Mecca in various localities. Simplistic maps of the world centred on Mecca, specifically intended for fin-ding the qibla approximately, were also available. In later centuries, simple qibla indicators consisting of a compass and a gazetteer of qibla values for major cities were in widespread use.

Muslim astronomers and mathematicians also achieved a cartographic solution to the qibla problem. They devised a Mecca-centred grid representing the world from Spain to China, Europe to the Yemen, using which the direction and distance of any locality to the centre could be read off without any calculation whatsoever.[42] (The first European maps of this kind date from *ca*. 1910.) The mathematics underlying the grid –the solution of the qibla problem using conic sections– is known from 10th-century Baghdad and 11th-century Isfahan. Three such world-maps are now known, all from 17th-century Isfahan: they are surely copies of a more extensive prototype, now lost. We do not know when and by whom the first such maps were conceived and executed, but the geographical coordinates underlying the positions of the 150-odd localities marked on the maps can be associated with 15th-century Central Asia.

7 SCHOOLS OF INSTRUMENT-MAKERS

The most important contributions to instrumentation were made by individuals working alone. As the leading lights in this field we may mention Ḥabash and Nasṭūlus from the 9th century and al-Khujandī from the 10th, all active in Baghdad; ʿAlī ibn Khalaf and Ibn al-Zarqālluh from the 11th, both active in Toledo; and Ibn al-Sarrāj from the 14th, working in Aleppo. The most influential authors on the other hand were al-Bīrūnī in Central Asia in the 11th century and al-Marrākushī in Cairo in the 13th, but neither was particularly original. al-Bīrūnī relied heavily on his teacher al-

[41] On this piece see King, "An Instrument of Mass Calculation made by Nasṭūlus in Baghdad ca. 900", to appear.
[42] On these see King, *Mecca-Centred World-Maps*, with new information in *SATMI*, VIIc.

Sijzī, who was familiar with developments in Baghdad in the 9th and 10th centuries, and one of al-Marrākushī's virtues is that he seems to have incorporated into his encyclopaedic work every treatise on instruments that he could find.

There were schools of astrolabists, who also made globes and quadrants, functioning in the following major centres:

- Baghdad in the 9th and 10th centuries (we have the names of the most important of these and, happily, a few of their instruments) and again in the 12th (Hibatallāh and his followers);
- Various centres in al-Andalus in the 11th century (we have a dozen instruments), and especially Cordova and Toledo in that same century for universal astrolabes and plates (for these we have texts but no instruments);
- Isfahan in the 11th to 13th (we have several instruments, especially those of Ḥāmid ibn Maḥmūd al-Iṣfahānī and his son Muḥammad);
- Marrakesh and Seville in the early 13th century (see the numerous instruments of Abū Bakr ibn Yūsuf and al-Khamā'irī, respectively, and their many imitators in later centuries);
- Damascus and Cairo in the 13th (whence the spectacular instruments of ʿAbd al-Raḥmān ibn Sinān al-Baʿlabakkī and ʿAbd al-Karīm al-Miṣrī);
- N. Iran and Central Asia in the 14th and 15th (we have several instruments by the al-Kirmānī family, of which the most important are those of Muḥammad ibn Jaʿfar al-Kirmānī known as Jalāl);
- Granada in the 14th (represented by the Ibn Bāṣo father-and-son team; a treatise by the father and several instruments by the son survive);
- Damascus in the 14th (several unusual instruments, notably by Ibn al-Shāṭir, and numerous treatises);
- Isfahan (and also Meshed) from the 16th to the 19th (several prolific astrolabists, all competent but none in any way innovative, including Muḥammad Muqīm Yazdī, Muḥammad Zamān Mashhadī, Muḥammad Mahdī, Khalīl Muḥammad, ʿAbd al-ʿAlī, Muḥammad Ṭāhir, Muḥammad Amīn and ʿAbd al-A'imma);
- Lahore from the 16th century to the 18th (at first, mainly one family stemming from Allāh-dād, and generally more adventurous than their colleagues in Isfahan); and
- Marrakesh and Meknes from the 17th (?) to the 19th (especially al-Baṭṭūṭī around 1700).

The main centres for the construction of quadrants were Damascus and Cairo in the 14th and 15th centuries (several instruments, notably by al-Mizzī, and numerous treatises preserved); and Istanbul from the 16th to the 19th (numerous late quadrants available).

8 SOME EXAMPLES OF THE INFLUENCE OF ISLAMIC INSTRUMENTATION IN MEDIEVAL AND RENAISSANCE EUROPE

We now move to medieval Europe, which had a lot to learn from the contemporaneous Islamic world. Instrumentation is one field that has been omitted in most accounts of the transmission of scientific knowledge to Europe. One reason for this is that medieval European instrumentation is less well documented than Islamic instrumentation, and the former cannot be properly understood without reference to the latter.[43] The scene is set in Fig. 5, a French miniature showing Sapientia instructing the Benedictine monk Henricus Suso.[44] Here we see escapement clocks, a European development, and a series of portable instruments, from the astrolabe on the left to the quadrant and the compendia on the right, all of which the Europeans encountered during their contacts with the Islamic world.

In this section, we consider some European astronomical instruments that have recently been shown to be of Islamic origin or at least to have earlier Islamic counterparts. My selection by no means exhausts the subject, which deserves a much deeper investigation than has been conducted so far.

a) Medieval European astrolabes

The standard French design of astrolabe retes in the 13[th] and 14[th] centuries includes a distinctive curved bar at the top of the vertical diameter: these are typified by the astrolabes associated with the school of Jean Fusoris in Paris, and one is shown in Fig. 5.[45] This bar serves to support various star-pointers. I strongly suspect that this design was brought home by a French Crusader, for we find it already on a Syrian astrolabe from 1222/23.[46] Alas, no other Islamic astrolabes with this feature are known, but other Syrian astrolabes from the 13[th] century have far more complicated decorative zoomorphic designs.[47]

Consider also the 14[th]-century French astrolabe illustrated in Fig. 6.[48] Any student of medieval European art history would recognize the *fleur-de-lys*. But one has to know of the influential astrolabe of al-Khujandī –

[43] On European astronomical instruments see Maddison, "Early Astronomical and Mathematical Instruments; Poulle, *Instruments scientifiques*; and King, *Ciphers of the Monks*, pp. 364-419. As a model publication of texts on instruments (and much else) see North, *Richard of Wallingford*.

[44] On this miniature see *SATMI*, VIII, and the literature there cited.

[45] Other examples are Gunther, *Astrolabes*, nos. 192, 193 and 198, and *Chicago AP Catalogue*, nos. 2 and 3. On Fusoris-type astrolabes see also King, *Ciphers of the Monks*, pp. 391-405.

[46] See the detailed study in *SATMI*, XIVc, and the remarks in King, *The Ciphers of the Monks*, p. 395.

[47] For the most spectacular example see Gunther, *Astrolabes*, no. 104.

[48] See already, King, *Ciphers of the Monks*, p. 394.

see Fig. 2– to recognize the ultimate source for some of the ornate decoration on this French astrolabe. The rest, namely, the three *miḥrāb*s, or prayer-niches, deco-rating the lower part of the rete, has been copied from an Andalusī astrolabe, of which we have several from the 11th century with such markings.[49]

The predominant motif of the astrolabe retes of 16th-century Flanders is a "tulip"-shaped design. There are no medieval European precedents for this, and I have wondered whether the design might have been inspired by a *basmala* written partly in mirror script, such as we find on 17th-century Iranian astrolabes but which was surely also used on earlier astrolabes. The form of the Iranian decoration is suspiciously similar to that on the Flemish retes –compare Figs. 7 and 8.

Many more examples could be cited of Islamic influence on European astrolabes of the standard variety. We now consider a remarkable European astrolabe that has hitherto defied explanation.

b) A non-standard Italian astrolabe

A tiny Italian astrolabe preserved in Oxford bears a rete with a very unusual arc of a circle for the entire ecliptic and astrolabic markings for latitude 24°: see Fig. 9.[50] (The markings have previously been described as serving latitude 37°, so that the piece has traditionally been associated with Sicily.) The only explanation for this piece is that it is a copy (of a copy) of an Islamic instrument with a rete of the mixed variety described in 9th- and 10th-century Arabic texts (see §3f), fitted with a set of plates for each of the seven climates. The Italian who made this piece seems to have had only a vague idea of what he was doing, for he included only a useless set of markings for the second climate, serving, for example, Aswan.

c) The universal astrolabe

In 1585 the English scholar John Blagrave proposed a universal astrolabe, which he called "The Mathematical Jewel" –see Fig. 10.[51] This is none other than the instrument of ʿAlī ibn Khalaf (Toledo, 11th century). It does not bear any comparison from the point of view of mathematical sophistication with the universal astrolabe of Ibn al-Sarrāj (see §3i), which can be used universally in five different ways. How did the Englishman

[49] See, for example, Gunther, *Astrolabes*, no. 118.
[50] See Gunther, *Astrolabes*, no. 169, and now *SATMI*, XIIId.
[51] Gunther, *Astrolabes*, no. 308, and, more recently, Turner, *Elizabethan Instruments*, pp. 187-190. See my remarks on other Elizabethan instruments in *Journal of the History of Collections* 15 (2003), pp. 147-150, esp. pp. 149-150.

learn of the universal projection underlying these instruments? He was probably influenced by a medieval French tradition of a single set of such universal markings, or the derivative Renaissance Flemish tradition. The European tradition was influenced by the Middle Castilian *Libros del Saber de Astronomía* of Alfonso El Sabio, which preserves for us a translation of the lost Arabic text of ʿAlī ibn Khalaf.

d) The *quadrantes vetus* and *novus*

The *quadrans vetus* is an ingenious device for reckoning time by the sun for any latitude, using an ingenious approximate formula. It first appears in Europe at Montpellier at the end of the 12th century. The horary markings on a quadrant are to be used in connection with a movable solar scale on the rim, which can be set for the latitude of the locality. A reading of the solar altitude on a given day of the year yields immediately the time since sunrise or before sunset in seasonal hours. Now several varieties of this quadrant –with fixed or movable cursor– are described in an Arabic text from 9th- or 10th-century Baghdad, which has recently been published for the first time.[52] For the latitude of the Mediterranean the formula underlying these approximate mar-kings works rather well; in Northern Europe, where the same markings, either on the *quadrans vetus* or the *quadrans novus* (see below) or on the backs of astrolabes, were widely used until the 16th century, the approximation does not work at all well.

The late-13th-century Jewish astronomer Profatius of Montpellier modified the *quadrans vetus* (whose markings are approximate) by adding a set of astrolabic horizons and ecliptic scale (which markings are exact). This unfortunate instrument, called the *quadrans novus*, was popular in Europe until the 16th century.[53] It is entirely European in its conception, because Muslim scholars had developed the much more sophisticated astrolabic quadrant (see §4c), which in some regions of the Islamic world replaced the astrolabe as the most popular instrument, but which was mainly unknown in Europe. (The European *quadrans novus* and the Islamic astrolabic quadrant are confused in much of the modern literature on instrumentation.)

[52] See King, "A *Vetustissimus* Arabic Treatise on the *Quadrans Vetus*", and the more detailed account in *SATMI*, XIIa.
[53] See Dekker, "Medieval Astrolabe Quadrant"; also *SATMI*, X-6.6 and XIIa-8.

e) Universal and latitude-specific horary dials

In 14th-century England, a little dial in the form of a ship, known as the *navicula de Venetiis*, became popular. Several examples survive, as well as treatises on the construction and use in Latin and Middle English: see Fig. 11.[54] The instrument has the potential to solve the complicated problem of finding the time of day exactly in equatorial hours from the solar altitude on any day of the year for any terrestrial latitude. Yet most of the surviving *naviculae* are made according to the over-complicated procedures outlined in the surviving texts and do not function exactly. It is, at least to my mind, in-conceivable that the genius who first devised this brilliant instrument would not have proposed a correct construction procedure and appropriate method of use to achieve an exact solution. Now Ḥabash al-Ḥāsib in 9th-century Baghdad described a yet more complicated device for timekeeping by the stars,[55] and I strongly suspect that he is behind the universal horary dial on the *navicula*, for this features the same components and the same kind of ingenious mechanical device for facilitating the solution of a complicated trigonometric problem. In addition, the (approximate) universal horary quadrant and shadow square on the back of the *navicula* are known to have originated in 9th-century Baghdad (see §4b). We are still a long way form knowing how this instrument was transmitted and who was the first to design it in the form of a ship and apply the label *navicula de Venetiis*.[56] Future investigations will have to take into consideration a contemporaneous German version of the universal horary dial that was not in the form of a ship, and which evolved into the well-known *Uhrtäfelchen*, "plate for finding the hour of day", of the 15th-century German astronomer Regiomontanus.

The horary quadrant for a specific latitude, such as the one in ivory made in Vienna in 1438 for Kaiser Friedrich III, is of a kind known from 9th- and 10th-century Baghdad. For example, there is one for latitude 33°, that is, Baghdad, on the back of the astrolabe of al-Khujandī.

f) Nuremberg compendia

In 16th-century Nuremberg there was a remarkable activity in the production of ivory compendia including universal sundials.[57] All of the astronomical components of these compendia are known from earlier Islamic sources, except the nocturnal, a simple device for timekeeping by

[54] See Brusa, "Le navicelle orarie di Venezia".
[55] Charette & Schmidl, "A Universal Plate for Timekeeping with the Stars by Ḥabash".
[56] King, "14th-Century England or 9th-Century Baghdad: New Light on the ... *Navicula de Venetiis*", and the more detailed account in *SATMI*, XIIb.
[57] Gouk, *The Ivory Sundials of Nuremberg*.

night.[58] In particular, two compendia from 14th-century Syria and 15th-century Egypt feature, in addition to a magnetic compass, a universal polar or equatorial sundial (see §6c). A possible vehicle of transmission was the Jewish scholarly community in 15th-century Sicily.[59]

g) Equatoria

Some Italian texts of the early 14th century, if not earlier, provide evidence of the design of astronomical clocks of a highly complex variety with extensive gear mechanisms to reproduce solar, lunar and planetary motions. They seem to represent an Islamic tradition for which we have no evidence from the Islamic world itself. It is known, however, that in 1232 ambassadors of the Ayyubid Sultan al-Ashraf presented to the Emperor Frederick II, whilst in S. Italy, a kind of planetarium which had "within itself the course of the planets".[60]

A 15th-century European report states that the instrument known as the sexagenarium was of contemporaneous Egyptian provenance.[61] This is a quadrant with a trigonometric grid on one side (see §4a), and a series of circular scales for computing mean longitudes and anomalies for the sun, moon, and planets on the other. The trigonometric quadrant serves not only to provide numerical solutions to problems of spherical astronomy but also to compute equations of the sun, moon, and planets. (The latter function serves only to challenge the wits of the user, because the standard auxiliary tables for computing the equations obviate the need for such tedious calculations.) While the trigonometric quadrant and associated instructions for performing computations in spherical astronomy were well-known in 15th-century Cairo, no such planetary dials are known from there. No trigonometric quadrant is mentioned by al-Kāshī, and in any case his equatorium renders such a device superfluous for calculations in solar, lunar and planetary astronomy.

h) Observational instruments

Although we have not dealt with observational instruments, it seems appropriate to conclude with a case in which European astronomers had finally "caught up" with their Muslim predecessors, not least because this is not well known. The late-16th-century Danish astronomer Tycho Brahe

[58] Oestmann, "On the History of the Nocturnal".
[59] Goldstein, "Description of Astronomical Instruments in Hebrew".
[60] *SATMI*, X-5.4.
[61] On the sexagenarium see Poulle, "Théorie des planètes et trigonométrie au XVe siècle, d'après ... le sexegenarium", p. 130, and, more recently, Aguiar Aguilar and González Marrero, *Un texto valenciano del siglo XV: el tratado astronómico del* Sexagenarium … .

fitted his new observatory with a series of observational instruments that are identical in form and similar in size (and accuracy?) to those of the Syrian astronomer Taqī al-Dīn, who in 1577 founded a new observatory in Istanbul.[62] Brahe made serious observations, and Taqī al-Dīn would have made more than he actually did, had not the Ottoman Sultan ordered the demolition of the Istanbul Observatory simply because Taqī al-Dīn had made an incorrect prediction about the outcome of a war between the Ottomans and the Safavid Persians. Inevitably the Sultan was pretty angry that the Ottomans were defeated, rather than emerging victorious, as Taqī al-Dīn had predicted for him.[63]

9 CONCLUDING REMARKS

The most spectacular technical aspects and even decorative designs in European instrumentation up to *ca*. 1550 usually have their counterparts in earlier Islamic astronomy. This does not preclude independent initiative on the part of the Europeans, but in order to properly understand European instrumentation it is important to keep in mind this potential Islamic influence. The reader must trust me that there are many more examples that could be cited.

What happened in the late 16th century and thereafter is highly significant. In Islamic astronomy, all of the problems had been solved, some many times over. Muslim astronomers kept alive the medieval tradition in various regional manifestations, even though the writings of some of the major scholars had been forgotten. Muslim craftsmen in Morocco, Iran and India continued to make astrolabes, and in Turkey to make astrolabic quadrants, in both cases until the 19th century. In Western astronomy new problems were identified and pursued with vigour, and new instruments, notably the telescope, were developed. The flame now burned on another candle.

[62] Tekeli, "Observational Instruments of Istanbul Observatory", based on her doctoral thesis and other articles.
[63] The unhappy story is related in detail in Sayılı, *The Observatory in Islam*, pp. 289-305.

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Fig. 1

Fig. 2

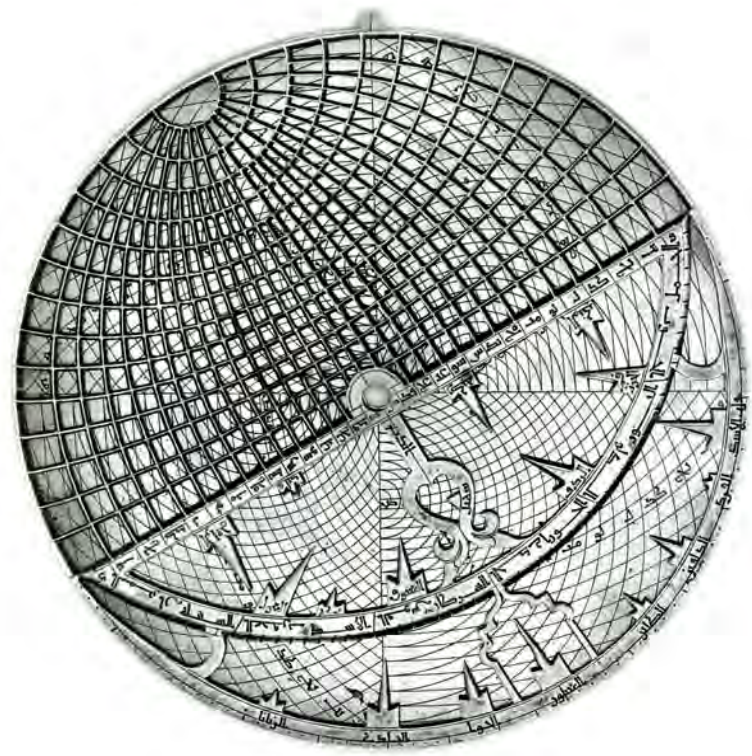
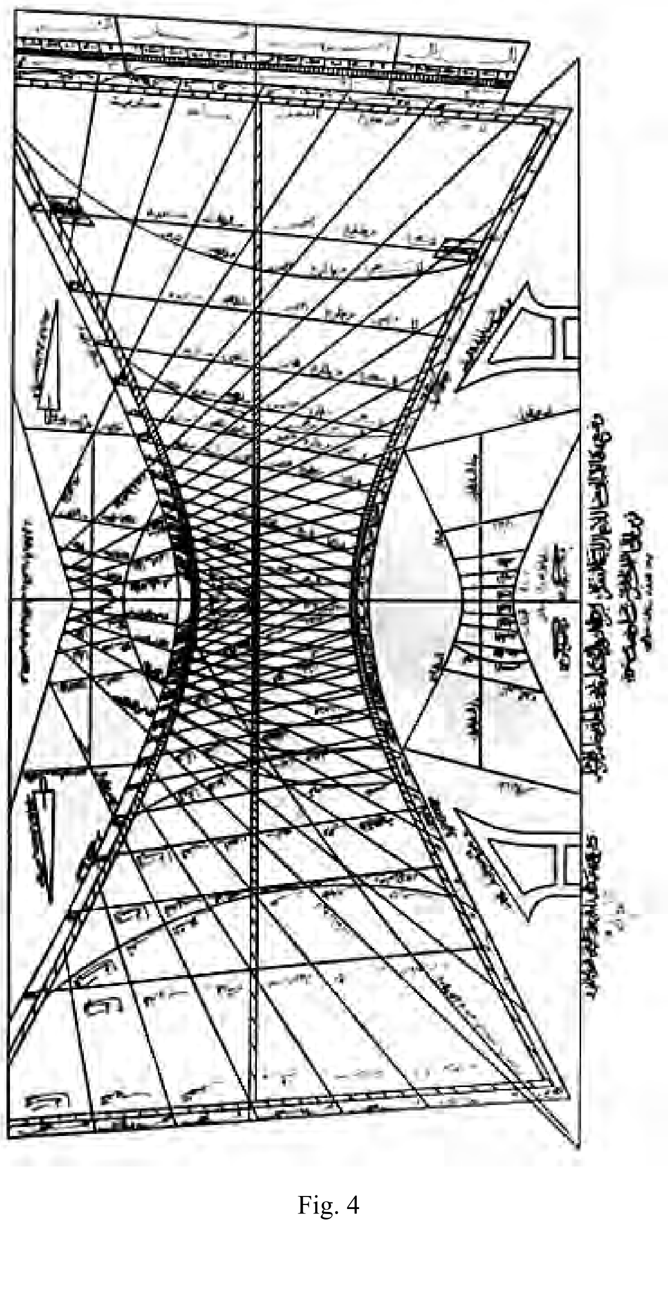


Fig. 3



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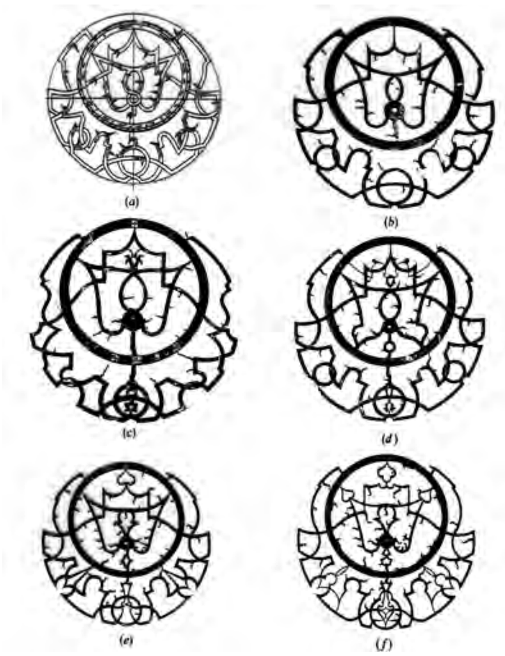

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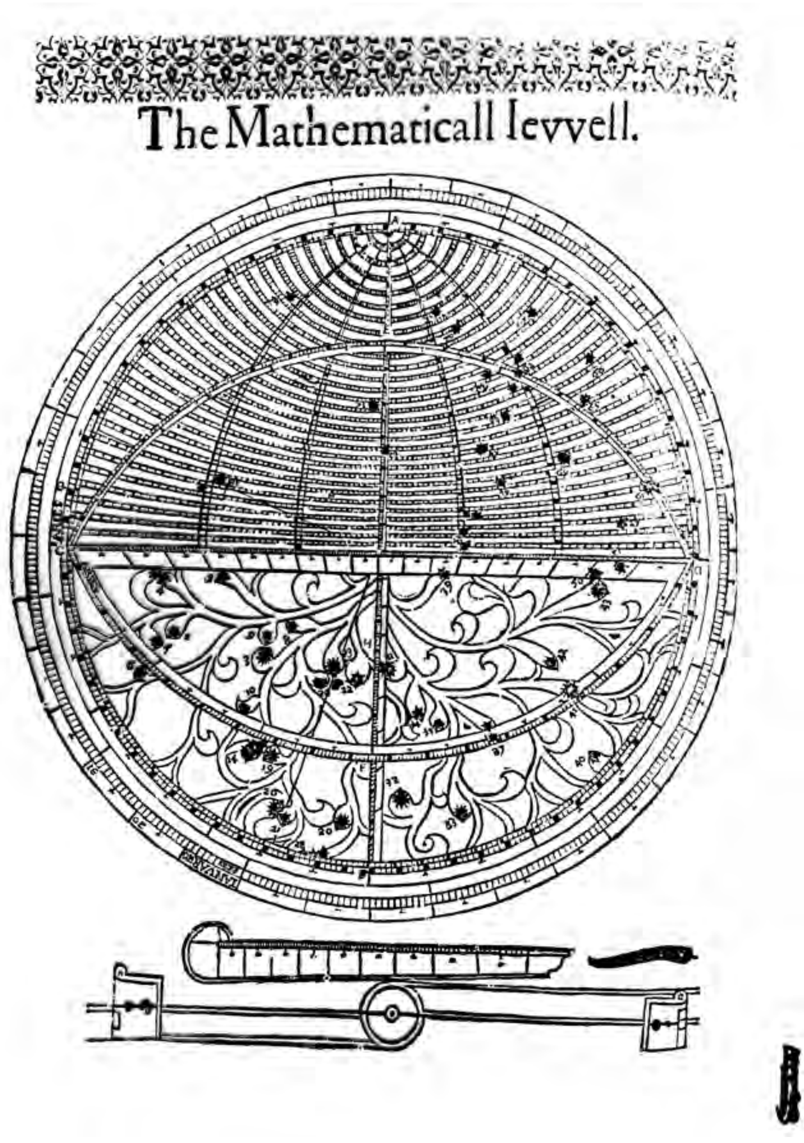

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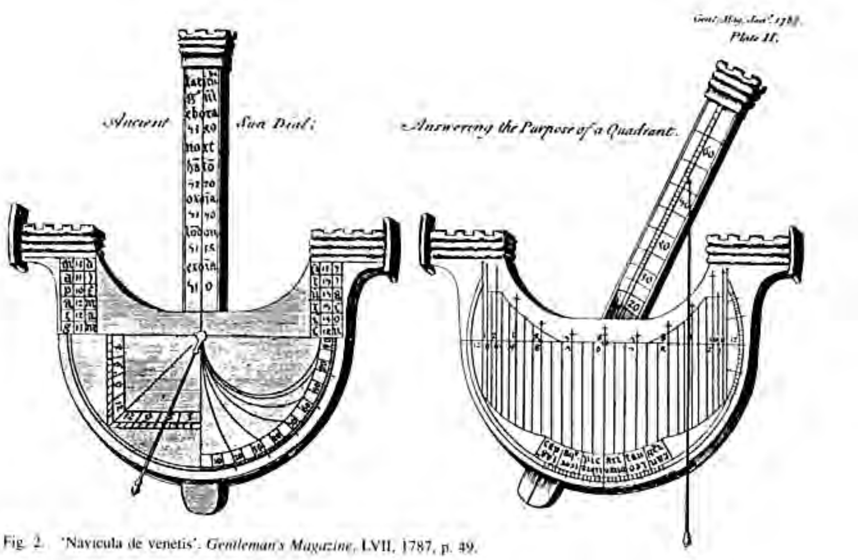

Fig. 2. 'Navicula de venetis'. *Gentleman's Magazine*, LVII, 1787, p. 49.

Fig. 11

Captions for plates

Fig. 1: An artist's view of the astronomers at the Istanbul Observatory in the late 16th century and their instruments. The Director of the Observatory is depicted holding a standard astrolabe, and most of the other instruments are well known. However, many far more interesting instruments are described in Arabic manuscripts, such as those stacked vertically on the shelves on the upper right, which are now in the University Library in Leiden. (Taken from MS Istanbul U. L. Yıldız 1404, courtesy of Istanbul University Library).

Fig. 2: The front of the magnificent astrolabe of the astronomer / mathematician al-Khujandī, made in Baghdad and dated 984/85. This instrument, a technological masterpiece and scientific work of art, reveals the progress made by Muslim astrolabists since they first encountered the basic astrolabe in the 8th century. Compare Fig. 6 below. (Museum of Islamic Art, Doha, Qatar; photo courtesy of a previous owner).

Fig. 3: The rete and one of the numerous plates belonging to the most sophisticated astrolabe ever made. The universal astrolabe of Ibn al-Sarrāj, made in Aleppo in 1328/29, well merits such a description for it can be used universally –that is, for any terrestrial latitude– in five different ways. (Courtesy of the Benaki Museum, Athens).

Fig. 4: A lithograph copy of a 19th-century reproduction of the sundial made in 1371 by Ibn al-Shāṭir for the Umayyad Mosque in Damascus. Engraved on marble, it measures about 2 m by 1m. The markings can be used to find the time with respect to each of the five daily prayers. (From the archives of the late Alain Brieux, Paris).

Fig. 5: This beautiful miniature reveals the kind of instruments that were most common in medieval Europe. It occurs in a work on mysticism divided into 24 chapters, hence the inspiration, at least for the clocks. (Courtesy of the Bibliothèque Royale Albert 1er, Brussels).

Fig. 6: A French astrolabe, probably from the 14th century. (Most medieval European astrolabes are neither signed nor dated.) Compare the design to the astrolabe of al-Khujandī shown in Fig. 2. (Courtesy of the Museum of the History of Science, Oxford.)

Fig. 7: Examples of retes from 16th-century Flanders. (By Gerard L'E. Turner).

Fig. 8: The *basmala* on the rete of an astrolabe made by Muhammad Zamān in Meshed in 1651/52. The design was surely adopted from earlier astrolabes; already Timurid astrolabes are known to have had the names of the dedicatees engraved inside the upper ecliptic on their retes. (Courtesy of the Metropolitan Museum of Art, New York).

Fig. 9: A very unusual and potentially highly sophisticated Italian astrolabe from *ca*. 1300. The underlying theory was well known to the leading astronomers of Iraq and Iran in the 9th and 10th centuries, none of whom, however, would have made a piece like this, which is useless for all practical purposes (except at the latitude of Aswan). (Courtesy of the Museum of the History of Science, Oxford).

Fig. 10: An example of the universal astrolabe of John Blagrave. Compare the more sophisticated instrument in Fig. 3. (Courtesy of the Adler Planetarium, Chicago).

Fig. 11: Drawings of the back and front of the most sophisticated instrument of medieval England. These were apparently little understood at the time, so that on most surviving examples the markings are not executed properly. The person who first conceived these markings in their proper form was a genius, and a prime candidate must be the 9th-century Baghdad astronomer Ḥabash, not least because he conceived a more complicated instrument for timekeeping by the stars. (From *The Gentleman's Magazine*, 1787).

On the occasion of the 75th +1 anniversary of the publication of Prof. J. M. Millàs Vallicrosa's seminal work *Assaig d'història de les idees físiques i matemàtiques a la Catalunya medieval* by the Institut d'Estudis Catalans, the Commission on the History of Science and Technology in Islamic Societies (International Union on History and Philosophy of Science), the Grup Millàs Vallicrosa d'Història de la Ciència Àrab (Universitat de Barcelona) and the Societat Catalana d'Història de la Ciència i de la Tècnica (Institut d'Estudis Catalans) organized a conference entitled "A Shared Legacy: Islamic Science East and West". The papers published in this volume deal with a mixture of subjects and disciplines –astronomical instruments, planetary models, geometry, medicine, time-keeping, technology and cartography– they all have the transmission of knowledge between the two shores of the Mediterranean as a common underlying thread.

A Shared Legacy: Islamic Science East and West is "probably the most important international meeting in the history of medieval science held in Barcelona since 1959" (J. Samsó in the Foreword).

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