

The renaissance of astronomy in Baghdad in the 9th and 10th centuries

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by: [David A King](/authors/david-king) (/authors/david-king)

[Note of the editor] This article was published in 2003 as: David A. King, "The renaissance of astronomy in Baghdad in the ninth and tenth centuries: A list of publications, mainly from the last 50 years" at www.davidaking.org (<http://www.davidaking.org>) ([link \(http://www.davidaking.org/Baghdad.htm\)](http://www.davidaking.org/Baghdad.htm)). We are grateful to Prof. King for permitting republishing on the [Muslim Heritage \(http://www.muslimheritage.com/\)](http://www.muslimheritage.com/) website.

Introductory remarks

"The ancients distinguished themselves through their chance discovery of basic principles and the invention of ideas. The modern scholars, on the other hand, distinguish themselves through the invention of a multitude of scientific details, the simplification of difficult (problems), the combination of scattered (information), and the explanation of (material which already exists in) coherent (form). The ancients came to their particular achievements by virtue of their priority in time, and not on account of any natural qualification and intelligence. Yet, how many things escaped them which then became the original inventions of modern scholars, and how much did the former leave for the latter to do!" The poet, litterateur and maker of astronomical instruments Hibat Allâh al-Baghdâdî (Baghdad, ca. 1120), partly quoting the astronomer-mathematician Abû Ja'far al-Khâzin (Rayy, ca. 980), as translated by Franz Rosenthal, "Al-Asturlâbî and as-Samaw'al on Scientific Progress", *Osiris* 9 (1950), pp. 555-564, esp. p. 559.

"The legacy of the translation movement in Islamic societies was profound and manifold, but it is historically inaccurate to talk about it in isolation from the Arabic scientific and philosophical tradition which fostered it throughout its existence. One should avoid generating the false impression that the translations, once executed in a receptive phase, caused the development of Arabic philosophical and scientific thinking during a subsequent creative phase of this tradition." Dimitri Gutas, *Greek Thought, Arabic Culture* (see §1), p. 192.



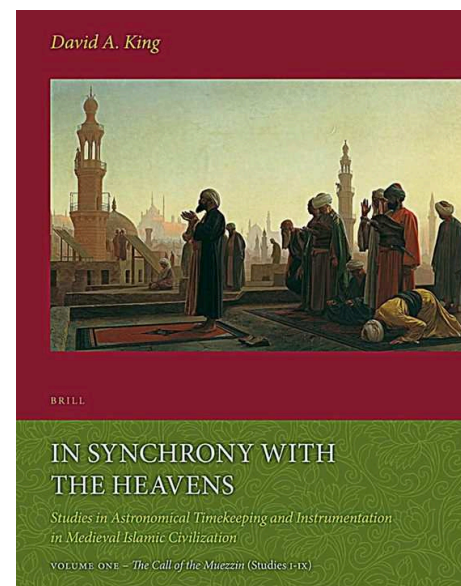


From Left: Professor Salim Al-Hassani, **Professor David King**, Professor Jeffrey Hoffman, Professor Hamid Al-Naimiy and Professor Martin Barslow from Second International Conference in Sharjah ([Source \(http://muslimheritage.com/node/2343\)](http://muslimheritage.com/node/2343))

No concerted effort has been made in Frankfurt – or anywhere else, for that matter – to document the history of astronomy in eighth-, ninth- and tenth-century Baghdad. Rather, most of the studies listed below just evolved naturally as a result of the fact that most of what we specialists study in relation to astronomy in medieval Islam and medieval Europe began right there and then. Also, we can only claim to have scratched the surface of this subject. Many texts originally from this milieu have been listed by F. Sezgin in his bio-bibliographical survey of Arabic literature up to ca. 1100 (see below). Most of the original manuscripts used by the Frankfurt team were discovered in libraries around the world in the 1970s and 80s.

The reader should be aware of the existence of earlier studies by such scholars as the Sédillots *père et fils*, C. A. Nallino, H. Suter, O. Neugebauer, D. Pingree, E. S. Kennedy, and P. Kunitzsch. Some of them could not possibly be left out of this bibliography for sentimental reasons, even though they predate, say, 1980. For the newcomer to this field, the best place to start is Kennedy *et al.*, *Studies* (§1). For bio-bibliographical information on Muslim scientists go to Sezgin, *GAS*, V-VII (till ca. 1100); Suter, *MAA*, Matvievskaia & Rosenfeld, *MAMS*, and *Cairo ENL Survey* (all periods); and Ihsanoglu *et al.*, *Ottoman Scientific Literature* (Ottoman Empire) (all listed in §1).

https://fbcdn-sphotos-d-a.akamaihd.net/hphotos-ak-xpa1/v/t1.0-9/q81/s720x720/10929009_822687087825967_2236720576690481569_n.jpg?



[oh=25724ec1bec81bbe4a19b8abc83553a8&oe=55933283&_gda_ =1431333253_b948c979155cfe7d1b9a0600b9555106](https://fbcdn-sphotos-d-a.akamaihd.net/hphotos-ak-xpa1/v/t1.0-9/q81/s720x720/10929009_822687087825967_2236720576690481569_n.jpg?)) There has been a tendency amongst scholars – even specialists in the history of Islamic science – to be pre-occupied with the Graeco-Arabic translation movement, as if it were the only aspect of Islamic science that was of any ultimate concern. Fortunately one scholar, David Pingree, has been concerned also with the Indian and Iranian influence in early Islamic astronomy. Many of the studies listed below deal with an "Islamic astronomy" in the 9th century that was already a respectable discipline in its own right, but this phenomenon occurred at the very same time as the main translations of such works as the *Almagest* became available. Perhaps we should not call it "Islamic astronomy", but rather "astronomy in Islamic civilization", for a substantial number of the contributors were not Muslims, but rather Christians, Jews or Sabians; these were, however, always a minority on the overall scene. Some of the Muslims involved were Arabs, but a substantial number, even a majority, were originally of Iranian or Central Asian origin. Call it what you will, "Islamic astronomy" used methods and materials that were ultimately of Greek or Indo-Iranian origin, but it also produced with remarkable speed a corpus of new methods and materials, including all sorts of tables computed specifically for Baghdad. So, for example, we note that the astronomical handbook with tables prepared for Caliph al-Ma'mūn ca. 825 and known as the *Mumtahan Zij* appeared on the scene at the same time as the first real translation of the *Almagest*. The *Mumtahan Zij* is already an Islamic work, quite different in style and content from the *Almagest*. Also, at the same time, there appeared a cluster of other works that have come to light only in recent years: these deal with astronomical instrumentation and the application of astronomical procedures to aspects of Islamic religious ritual: the lunar

calendar, the astronomically-defined times of Muslim prayer, and the sacred direction (qibla) towards the Kaaba in Mecca. Since much of later Islamic astronomy was devoted to such themes, it is an error to think that even later Islamic astronomy was heavily dependent on any Greek tradition. Already by the 9th century it was "Islamic", and such it remained for a millennium thereafter. The fact that there existed an important tradition of translations of Greek works and commentaries thereon *within* Islamic astronomy but without overpowering influence on it – the amount of influence was dependent on time, on location and on the personalities involved – should be taken into account. In any case, since the Graeco-Arabic translation movement has received considerable attention it seems appropriate now to take a broader look at Islamic astronomy. Certainly a serious study of the birth and early development of Islamic science is still a task for the future.

The reader should also be aware that this is not a bibliography of Islamic astronomy as such; also, many works on early Islamic mathematics could have been included but have not been. (Bibliographies of the history of Islamic mathematics tend to overlook astronomy, even though the history of Islamic mathematical methods cannot be written without taking astronomical works into consideration.) Similar bibliographies could be prepared – but not in Frankfurt at this time – for, say, studies of al-Bīrūnī, of regional schools of Islamic astronomy, of astronomy in al-Andalus, of astronomy in the service of Islam, *etc.*

A rich bibliography on transmission is in Richard P. Lorch, "Greek–Arabic–Latin: The Transmission of Mathematical Texts in the Middle Ages", *Science in Context* 14 (2001), pp. 313-331.

[Please click here \(http://web.archive.org/web/20130930124150/http://facstaff.uindy.edu/~oaks/Biblio/Intro.htm\)](http://web.archive.org/web/20130930124150/http://facstaff.uindy.edu/~oaks/Biblio/Intro.htm) for useful link for the bibliography of Islamic mathematics and astronomy is:

[Another link \(http://web.archive.org/web/20040405133326/http://www.uni-frankfurt.de/fb13/ign/instrument-catalogue.html\)](http://web.archive.org/web/20040405133326/http://www.uni-frankfurt.de/fb13/ign/instrument-catalogue.html) providing a list of new studies on Islamic astronomical instrumentation is:

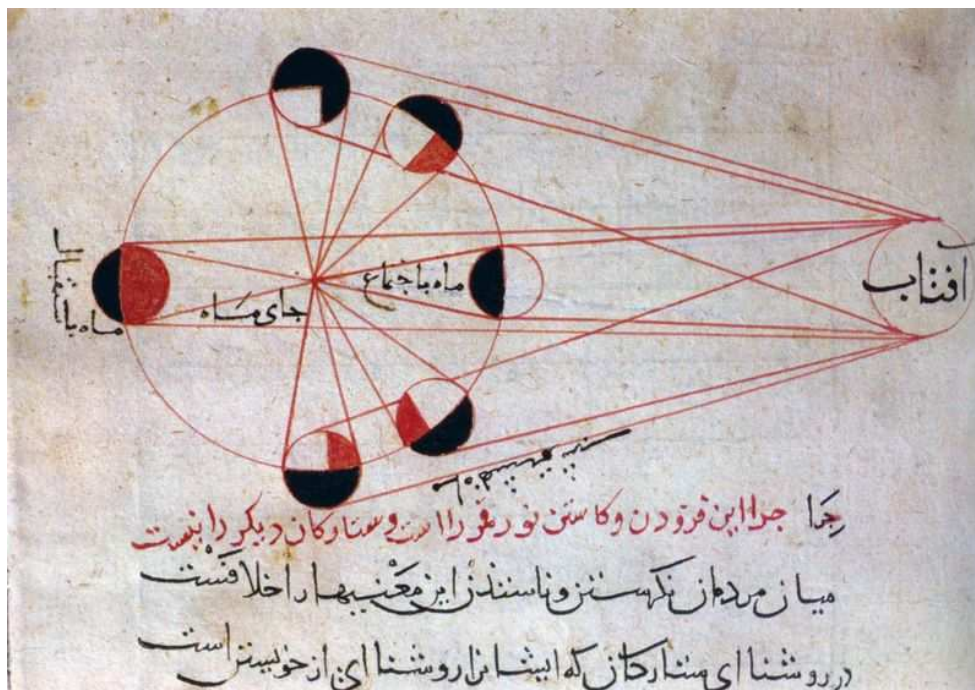
The abbreviations of personal names refer to members and guests (asterisked) of the Frankfurt Institute for the History of Science, past and present:

- BS – Burkhard Stautz
- BvD – Benno van Dalen
- DAK – David A. King
- FC – François Charette
- JH – Jan Hogendijk (Utrecht)
- PS – Petra Schmidl
- MV* – Mercè Viladrich (Barcelona)

For the numerous publications of Fuat Sezgin and his colleagues at the Institute for the History of Arabo-Islamic Sciences in Frankfurt [please click here \(http://web.archive.org/web/20030110202158/http://www.uni-frankfurt.de/fb13/igaiw/publication/mathematic.html\)](http://web.archive.org/web/20030110202158/http://www.uni-frankfurt.de/fb13/igaiw/publication/mathematic.html).

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(http://www.muslimheritage.com/uploads/Lunar_eclipse_al_Biruni.jpg)

Illustration by al-Bīrūnī of different phases of the moon, from *Kitāb al-taḥīm*. Source: Seyyed Hossein Nasr, *Islamic Science: An Illustrated Study*, London: World of Islam Festival, 1976. (Source (<http://www.muslimheritage.com/article/al-biruni>))

1. General and basic works on Islamic astronomy, including collections of articles

[Note: For more general works and also for published conference proceedings see King & Samsó, "Islamic Astronomical Handbooks and Tables" (cited below), pp. 98-105.]

(<http://www.muslimheritage.com/article/using-astrolabe>) Aaboe Festschrift: J. Lennart Berggren and Bernard R. Goldstein, eds., *From Ancient Omens to Statistical Mechanics: Essays on the Exact Sciences Presented to Asger Aaboe, Acta Historica Scientiarum Naturalium et Medicinalium* (Copenhagen) 39 (1987). [Contains a few articles on Islamic topics.]

AIOS: *Arabische Instrumente in orientalistischen Studien*, Fuat Sezgin et al., eds., 6 vols., Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1990-91, repr. as *Islamic Astronomy and Mathematics*, vols. 85-90 (1998), with 6 further volumes *ibid.*, vols. 91-96 (1998). [Reprints of studies on Islamic instruments from the 19th and early 20th century: a monumental total of over 5,000 pages.]

'Abbās al-'Azzāwī, *Ta'rīkh 'ilm al-falak fi 'l-'Irāq wa-'alāqāṭhi bi-'l-aqtār al-islāmiyya wa-'l-'arabiyya fi 'l-'uhūd al-tāliya li-ayyām al-'Abbāsiyyīn min sanat 656 H = 1258 M ilā sanat 1335 H = 1917 M* [= *A History of Astronomy in Iraq and its relations with Islamic and Arab regions in the period following the Abbasids, from 1258 A.D. to 1917 A.D.*], Baghdad: Iraqi Scientific Academy (al-Majma' al-'ilmī al-'Irāqī, 1958. [A curious work, not without utility. The author was completely unaware of any Western sources. His bio-bibliographical survey of numerous Muslim astronomers is partly based on manuscripts that were available to him in Iraq.]

J. Lennart Berggren, *Episodes in the Mathematics of Medieval Islam*, New York, etc.: Springer, 1986. [The only general work on mathematics in Islamic civilization to take seriously the fact that much of the source material is to



be found in astronomical sources.]

Cairo ENL Survey: David A. King, *A Survey of the Scientific Manuscripts in the Egyptian National Library*, (American Research Center in Egypt, Catalogs, vol. 5), Winona Lake, Ind.: Eisenbrauns, 1987. [A supplement to the standard bio-bibliographical sources.]

DSB: Dictionary of Scientific Biography, 14 vols. and 2 supp. vols., New York: Charles Scribner's Sons, 1970-80. [Contains numerous articles on Muslim scientists.]

EHAS: Encyclopedia of the History of Arabic Science, Roshdi Rashed, with Régis Morelon, eds., 3 vols., London: Routledge, 1996. [Contributions of varied quality. Also available in French (Paris: Seuil, 1997) and in Arabic (Beirut, 1997).]

El2: The Encyclopaedia of Islam, new edn., 11 vols. and supplements, Leiden: E. J. Brill, 1960 to present. [The standard reference work for Islamic Studies, also available in French.] See in addition to occasional articles on Muslim scientists the following selected thematic articles:



(<http://www.muslimheritage.com/node/791>) "Anwâ" (aspects of folk astronomy), "Asturlâb" (astrolabe), "Ilm al-hay'a" (here: astronomy generally), "Ilm al-hisâb" (arithmetic), "Kamar" (moon), "Kibla" (religious and astronomical aspects of the sacred direction), "Kutb" (celestial pole), "Layl and Nahâr" (aspects of folk astronomy), "Makka. iv: as centre of the world" (sacred geography), "Manâzil" (lunar mansions), "Matâli" (right and oblique ascensions), "Matla" (astronomical risings and settings), "Mayl" (declination and obliquity), "Mikât. ii. astronomical aspects" (astronomical timekeeping), "Mintaka" (ecliptic, zodiac and obliquity), "Mizwala" (sundial), "Nudjûm" (stars); "Nudjûm, 'Ilm ahkâm al-" (astrology), "Rîh" (winds in the folk-astronomical tradition), "Rub" (quadrant), "Samt" (direction), "Shakkâziyya" (universal astrolabic projections), "Shams" (sun), "Ta'rikh. 2. Era chronology in astronomical handbooks" (calendrics in zîjes), "Tâsa" (magnetic compass), "Zîdj" (astronomical handbooks and tables).

Gerhard Endreß, "Die wissenschaftliche Literatur", Kapitel 8 in *Grundriß der Arabischen Philologie*, Band II: Litteraturwissenschaft, Helmut Gätje, ed., Wiesbaden: Dr. Ludwig Reichert, 1987, pp. 400-506. [A very useful overview.]

Goldstein, *Studies*: Bernard R. Goldstein, *Theory and Observation in Ancient and Medieval Astronomy*, London: Variorum, 1985. [Reprints of 24 studies.]

Goldstein Festschrift: Astronomy and Astrology from the Babylonians to Kepler -- Essays Presented to Bernard R.

Goldstein on the Occasion of his 65th Birthday, Peter Barker, Alan C. Bowen, José Chabás, Gad Freudenthal and Tzvi Langermann, eds., to be published in a special issue of *Centaurus* in 2003. [Contains some articles on Islamic astronomy.]

Hartner, *Studies*, I-II: Willy Hartner, *Oriens-Occidens – Ausgewählte Schriften zur Wissenschafts- und Kulturgeschichte – Festschrift zum 60. Geburtstag*, Hildesheim: Georg Olms, 1968 (I), and *Oriens-Occidens – Ausgewählte Schriften zur Wissenschafts- und Kulturgeschichte, Band II*, Yasukatsu Maeyama, ed., Hildesheim, etc.: Georg Olms, 1984 (II). [Reprints of numerous studies.]

Hartner Festschrift: PRISMATA – Naturwissenschaftsgeschichtliche Studien – Festschrift für Willy Hartner, Yasukatsu Maeyama and Walter G. Saltzer, eds., Wiesbaden: Franz Steiner, 1977. [Contains some articles on Islamic science.]

Leo A. Mayer, *Islamic Astrolabists and Their Works*, Geneva: Albert Kundig, 1956, with a supplement in *Aus der Welt der islamischen Kunst*, Richard Ettinghausen, ed., Berlin: Gebrüder Mann, 1959, pp. 293-296, both repr. in *AIOS* (§1), XII [= *IMA* (§1), vol. 96], pp. 141-285, and 291-294. [The standard work; lists several makers from Abbasid Iraq.]

Oklahoma 1992 and 1993 Conference Proceedings: Tradition, Transmission, Transformation: Proceedings of Two Conferences on Pre-modern Science Held at the University of Oklahoma, F. Jamil Ragep & Sally P. Ragep, with Steven J. Livesey, eds., Leiden, New York & Cologne: E. J. Brill, 1996. [Contains some articles on Islamic science.]

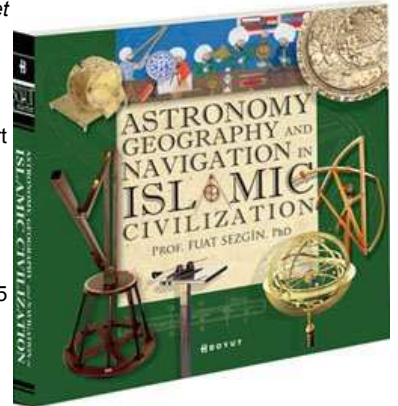
Ihsanoglu *et al.*, *Ottoman Scientific Literature: Ekmeleddin Ihsanoglu et al., Osmanlı astronomi literatürü tarihi – History of Astronomy Literature during the*

Ottoman Period, 2 vols., Osmanlı matematik literatürü tarihi – History of Astronomy Literature during the Ottoman Period, 2 vols., Osmanlı coğrafya literatürü tarihi – History of Geographical Literature during the Ottoman Period, (Studies and Sources on the History of Science, Series No. 7, 8, 9), Istanbul: Research Centre for Islamic History, Art and Culture (IRCICA), 1997, 1999, and 2000, respectively. [A monumental bio-bibliographical survey of Ottoman scientific literature, in Turkish.]

Islamic Geography: Islamic Geography, Fuat Sezgin, with Mazen Amawi, Carl Ehrig-Eggert and Eckhard Neubauer et al., eds., 278 [!!!] vols. to date, Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1992 to present. [Facsimile reprints of early writings, mainly 19th- and early-20th century.]

Islamic Mathematics and Astronomy: Islamic Mathematics and Astronomy, eidem, eds., 112 [!!!] vols to date, Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1997 to present. [Reprints of texts and studies mainly from the 19th and early 20th centuries.]

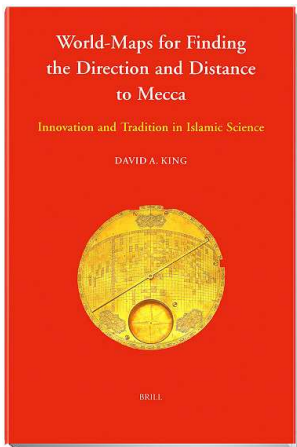
Kennedy, "Zij Survey": E. S. Kennedy, "A Survey of Islamic Astronomical Tables", *Transactions of the American Philosophical Society*, N. S., 46:2 (1956), pp. 123-177, repr. with separate pagination, n.d. [ca. 1990]. [Lists some 125 medieval astronomical handbooks with tables of the kind known as zijes. This work inspired most of the research on Islamic mathematical astronomy over the next 50-odd years. See now the interim report by King & Samsó (§1), and the new zij project described in §3a.]



Kennedy, *Studies*: E. S. Kennedy, *Astronomy and Astrology in the Medieval Islamic World*, (Variorum Collected Studies Series: CS600), Aldershot & Brookfield, Vt.: Ashgate-Variorum, 1998. [Reprints of 19 studies.]

Kennedy et al., *Studies*: E. S. Kennedy, Colleagues and Former Students, *Studies in the Islamic Exact Sciences*, David A. King and Mary Helen Kennedy, eds., Beirut: American University of Beirut, 1983. [Reprints of 69 studies, including several based on early Iraqi sources.]

Kennedy Festschrift: From Deferent to Equant: Studies in the History of Science in the Ancient and Medieval Near East in Honor of E. S. Kennedy, David A. King and George Saliba, eds., *Annals of the New York Academy of Sciences* (500), 1986. [Contains contributions from 34 leading experts in the field and represents the state of the art in the mid 1980s.]



King, *SATMI*: David A. King, *Studies in Astronomical Timekeeping in Medieval Islam*, 12 pts., in press with E. J. Brill, Leiden. Parts I-VI and X-XII are to appear with the title *The Call of the Muezzin*.

King, *Studies*, A-C: David A. King, *Islamic Mathematical Astronomy*, London: Variorum, 2nd revised edn., Aldershot (U.K.): Variorum, 1993 (A); *Islamic Astronomical Instruments*, London: Variorum, 1987, repr. Aldershot: Variorum, 1995 (B); and *Astronomy in the Service of Islam*, Aldershot (U.K.): Variorum, 1993. [Reprints of 18+22+14 articles.]

King & Samsó, "Islamic Astronomical Handbooks and Tables": David A. King and Julio Samsó, with a contribution by Bernard R. Goldstein, "Astronomical Handbooks and Tables from the Islamic World (750-1900): An Interim Report", *Suhayl – Journal for the History of the Exact and Natural Sciences in Islamic Civilisation* (Barcelona) 2 (2001), pp. 9-105. [A supplement to Kennedy, "Zij Survey" (see above), preliminary to the publication of the results of the zij project described in §3a.]

Paul Kunitzsch, *Untersuchungen zur Sternnomenklatur der Araber*, Wiesbaden: Otto Harrassowitz, 1961. [A standard work.]

Kunitzsch, *Studies*: Paul Kunitzsch, *The Arabs and the Stars*, Northampton: Variorum, 1989. [Reprints of 24 studies. See also Kunitzsch's numerous other publications on star-catalogues and star-names.]

Kunitzsch Festschrift: Sic itur ad astra. Studien zur Geschichte der Mathematik und Naturwissenschaften. Festschrift für den Arabisten Paul Kunitzsch zum 70. Geburtstag, Menso Folkerts and Richard P. Lorch, eds., Wiesbaden: Otto Harrassowitz, 2000. [Contains several relevant contributions to our subject.]

Langermann, *Studies*: Y. Tzvi Langermann, *The Jews and the Sciences in the Middle Ages*, Aldershot, etc.: Ashgate-Variorum, 1999. [Reprints of 10 studies.]

Lorch, *Studies*: Richard P. Lorch, *Arabic Mathematical Sciences – Instruments, Texts, Transmission*, Aldershot: Variorum, 1995. [Reprints of 18 studies.]

Matvievskaia & Rosenfeld, *MAMS*: Galina P. Matvievskaia and Boris A. Rosenfeld, *Matematiki i astronomi musulmanskogo srednevekovya i ikh trudi*, 3 vols., Moscow: Nauk, 1983. [A new, updated version of Suter, *MAA*, in Russian. An English translation has been published in 2003 by IRCICA, Istanbul.]

Nallino, *Scritti*, V: Carlo A. Nallino, *Raccolta di scritti editi e inediti*, vol. V: *Astrologia – Astronomia – Geografia*, Roma: Istituto per l'Oriente, 1944. [A study of fundamental importance.]

Pingree Festschrift: A Festschrift in honour of David Pingree, edited by Charles Burnett, Jan Hogendijk and Kim Plofker, Leiden: E. J. Brill, in press. [Contains

several studies relevant to our topic.]

Sabra, *Studies*: Abdelhamid I. Sabra, *Optics, Astronomy and Logic -- Studies in Arabic Science and Philosophy*, Aldershot (U.K.): Variorum, 1994. [Reprints of 17 studies.]

Saliba, *Studies*: George Saliba, *A History of Arabic Astronomy – Planetary Theories during the Golden Age of Islam*, (New York University Studies in Near Eastern Civilization, XIX), New York: New York University Press, 1994. [Reprints of 15 articles, dealing mainly with planetary theory.]

Julio Samsó, *Las ciencias de los antiguos en al-Andalus*, Madrid: MAPFRE, 1992. [The first general work on science in Muslim Spain.]

Samsó, *Studies*: *idem*, *Islamic Astronomy and Medieval Spain*, Aldershot: Variorum, 1994. [Reprints of 20 studies.]

Samsó: see also the many studies of the Millás-Vernet–Samsó Barcelona school, some of which are listed at www.ub.es/arab (<http://www.ub.es/arab>).

Samsó: see also King & Samsó above.

Aydin Sayili, *The Observatory in Islam*, (Publications of the Turkish Historical Society, Series VII: No. 38), Ankara, 1960, repr. New York: Arno, 1981. [A brilliant study, not yet superseded.]

Schoy, *Beiträge*: Carl Schoy, *Beiträge zur arabisch-islamischen Mathematik und Astronomie*, Fuat Sezgin *et al.*, eds., 2 vols., Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1988. [Reprints of many early studies.]

Sezgin, GAS: Fuat Sezgin, *Geschichte des arabischen Schrifttums*, 12 vols. to date, Leiden: E. J. Brill, 1967 onwards, from 2000 onwards Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, especially V: *Mathematik*, 1974, VI: *Astronomie*, 1978, VII: *Astrologie, Meteorologie und Verwandtes*, 1979; X-XII: *Mathematische Geographie und Kartographie im Islam und ihr Fortleben im Abendland*, 2000. [The basic bio-bibliographical research tool for all Arabic literature up to ca. 1100. For additional materials relevant to the Baghdad scene see the reviews listed below.]

Sezgin: see also *Islamic Astronomy and Mathematics*; *Islamic Geography*; and all publications of the Institut für Geschichte der Arabisch-Islamischen Wissenschaften, Frankfurt am Main.

DAK, reviews of Sezgin, GAS, V and VI, in "Notes on the Sources for the History of Early Islamic Mathematics", *Journal of the American Oriental Society* 99 (1979), pp. 450-459; and "Early Islamic Astronomy", *Journal for the History of Astronomy* 12 (1981), pp. 55-59. [These identify some new manuscript sources.]

Suter, *Beiträge*: Heinrich Suter, *Beiträge zur Geschichte der Mathematik und Astronomie im Islam*, Fuat Sezgin *et al.*, eds., 2 vols., Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1986. [Reprints of many early studies.]

Suter, MAA: *idem*, "Die Mathematiker und Astronomen der Araber und ihre Werke", *Abhandlungen zur Geschichte der mathematischen Wissenschaften* 10 (1900), and "Nachträge und Berichtigungen", *ibid.* 14 (1902), pp. 157-185, repr. Amsterdam: The Oriental Press, 1982, and again in *idem*, *Beiträge*, I, pp. 1-285 and 286-314. [This has been the main bio-bibliographical reference for Muslim scientists for the past century.]

Manfred Ullmann, *Die Natur- und Geheimwissenschaften im Islam*, Leiden: E. J. Brill, 1972. [A valuable resource, especially for astrology.]

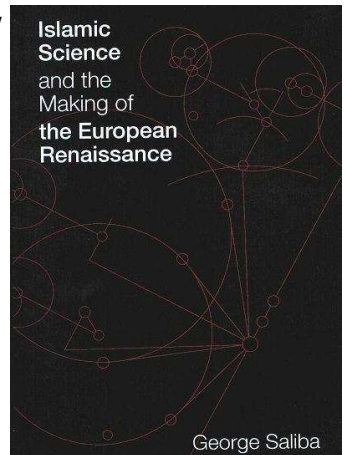
Daniel M. Varisco, "Islamic Folk Astronomy", in *Astronomy across Cultures: Astronomy across Cultures – The [!] History of Non-Western Astronomy*, Helaine Selin, ed., Dordrecht, etc.: Kluwer, 2000, pp. 615-650. [A useful survey of many aspects of the subject.]

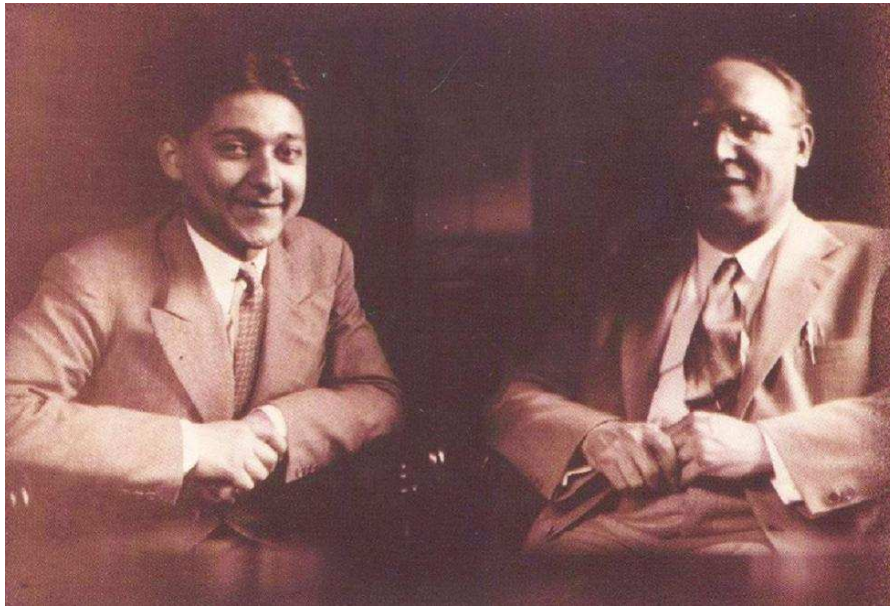
Varisco, *Studies*: *idem*, *Medieval Folk Astronomy and Agriculture in Arabia and the Yemen*, (Variorum Collected Studies Series: CS585), Aldershot & Brookfield, Vt.: Ashgate – Variorum, 1997. [Reprints of numerous studies.]

Vernet, *Estudios*: Juan Vernet, *Estudios sobre historia de la ciencia medieval*, Barcelona: Universidad de Barcelona (Facultad de Filología) & Bellaterra: Universidad Autónoma de Barcelona (Facultad de Filosofía y Letras), 1979. // Vernet, ed., *Textos y estudios*, A-B: *idem*, ed., *Textos y estudios sobre astronomía española en el siglo XIII*, and *Nuevos estudios sobre astronomía española en el siglo de Alfonso X*, Barcelona: Instituto de Filología, Institución "Milá y Fontanals", Consejo Superior de Investigaciones Científicas, 1981 and 1983. // Vernet, ed., *Historia de la ciencia árabe*: *idem*, ed., *Historia de la ciencia árabe*, Madrid: Real Academia de Ciencias Exactas, Físicas y Naturales, 1981. // Vernet, *Studies*: Juan Vernet, *De 'Abd al-Rahmān I a Isabel II – Recopilación de estudios dispersos sobre Historia de la Ciencia y la Cultura Española ofrecida al autor por sus discípulos con ocasión de su LXV aniversario*, Barcelona: Universidad de Barcelona, Instituto "Millás Vallicrosa" de Historia de la Ciencia Árabe & Promociones y Publicaciones Universitarias, S.A., 1989. [Mainly concerned with science in al-Andalus.]

Vernet *Festschrift*: *From Baghdad to Barcelona. Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet*, Josep Casulleras and Julio Samsó, eds., (*Anuari de Filologia* (Universitat de Barcelona) XX (1996) B-2), 2 vols., Barcelona: Instituto "Millás Vallicrosa" de Historia de la Ciencia Árabe, 1996. [Contains contributions from 28 leading experts in the field and represents the state of the art in the mid 1990s.]

See also Dimitri Gutas, *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early 'Abbāsīd Society (2nd-4th/8th-10th centuries)*, London & New York: Routledge, 1998, which provides part of the background for studies on early Islamic science.





Aydin Sayili and George Sarton ([Source \(http://www.muslimheritage.com/node/828\)](http://www.muslimheritage.com/node/828))

2 Overview articles

Carlo Alfonso Nallino, "Sun, Moon, and Stars (Muhammadan)", in *Encyclopaedia of Religion and Ethics*, James Hastings, ed., 12 vols., Edinburgh: T. & T. Clark, 1921, vol. XII (1921), pp. 88-101. [The best account of Islamic astronomy and astrology ever published.]

Ahmad Dallal, "Islamic Science, Medicine, and Technology": *idem*, "Science, Medicine, and Technology – The Making of a Scientific Culture", in *The Oxford History of Islam: The Oxford History of Islam*, John L. Esposito, ed., Oxford & New York: Oxford University Press, 1999, pp. 154-213. [Treats astronomy within the context of the entire Islamic scientific endeavour.]

Bernard R. Goldstein, "The Making of Astronomy in Early Islam", *Nuncius: Annali di Storia della Scienza* (Florence) 1 (1986), pp. 79-92. [On responses to Greek and Hindu astronomical traditions in early Islam.]

Bernard R. Goldstein, "Astronomy and the Jewish Community in Early Islam", *Aleph* 1 (2001), pp. 17-57. [A survey of Jewish involvement in astronomy in the early centuries of Islam.]

DAK, "Islamic Astronomy", in Christopher Walker, ed., *Astronomy before the Telescope*, London: British Museum Press, 1996, pp. 143-174. [An overview for the non-specialist reader.]

George Saliba, "Astrology/Astronomy, Islamic" in *Dictionary of the Middle Ages*, 13 vols., New York: Charles Scribner's Sons, 1982-89, vol. I, 1982, pp. 616-624, repr. in *idem*, *Studies* (§1), no. 2. [An overview for the non-specialist reader.]

George Saliba, "The Role of the Astrologer in Medieval Islamic Society", in *Bulletin d'études orientales* (Damascus: Institut Français de Damas), 44 (1992), pp. 45-67 and 6 figs. [A useful overview.]

DAK, "Science in the Service of Religion: The Case of Islam", *impact of science on society* (UNESCO), no. 159 (1991), pp. 245-262, repr. in King, *Studies* (§1), C-1. [An overview for the non-specialist reader.]

Ahmed Dallal, "Islamic Paradigms for the Relationship between Science and Religion" (unpublished, accessible on Internet). ["Science" is restricted to astronomy, further restricted to solar, lunar and planetary models. No mention is made of "astronomy in the service of Islam", or of the folk science cultivated by the legal scholars of Islam.]

See also Howard R. Turner, *Science in Medieval Islam – An Illustrated Introduction*, Austin: University of Texas Press, 1995. [Useful for schools and junior colleges.]

3 Current projects in Frankfurt

3.1 Medieval Islamic astronomical handbooks

A project to document all of the medieval Islamic astronomical handbooks known as *zīj*es, of which over 200 were compiled between 750 and 1850, conducted by Benno van Dalen, and supported by the German Research Organization (DFG) during 2000-2004. Particular attention is given to parameters underlying tables, which usually provide a clear indication of initiative or borrowing. See further

www.rz.uni-frankfurt.de/~dalen/ (<http://www.rz.uni-frankfurt.de/~dalen/>), then [params.htm](#) and [programs.htm](#).

This project was inspired by E. S. Kennedy's 1956 *Zij Survey* (§1), to which now add the interim report in King & Samsó (§1).^{*} A major publication by Benno van Dalen is anticipated. On the methodology see already his studies: "A Statistical Method for Recovering Unknown Parameters from Medieval Astronomical Tables", *Centaurus* 32 (1989), pp. 85-145; and *Ancient and Mediaeval Astronomical Tables: Mathematical Structure and Parameter Values*, Utrecht: Universiteit Utrecht, 1992.

^{*} This article was prepared on the occasion of the *Encyclopaedia of Islam* reaching the letter "Z" but turned out to be too long to be accepted for the article "Zidj".

3.2 Medieval Islamic and European astronomical instruments

A project to catalogue all medieval astronomical instruments, both Islamic and European, conducted by David A. King, and supported by the German Research Organization (DFG) during 1992-96 and 1996-2002. See further DAK, "Medieval Astronomical Instruments: A Catalogue in Preparation", *Bulletin of the Scientific Instrument Society* 31 (Dec., 1991), pp. 3-7, and for an overview of the potential of medieval instruments as historical sources see DAK, "Astronomical Instruments between East and West", in Harry Kühnel, ed., *Kommunikation zwischen Orient und Okzident*, Vienna: Österreichische Akademie der Wissenschaften (*Sitzungsberichte, Phil.-Hist. Klasse*, vol. 619), 1994, pp. 143-198.

For a table of contents (from 1991) and a list of publications relating to medieval instruments, see:

www.uni-frankfurt.de/fb13/ign/instrument-catalogue.html (<http://www.uni-frankfurt.de/fb13/ign/instrument-catalogue.html>).

Additional funding and new collaborators will be necessary to complete this project.

4 Astronomy in Baghdad in the 9th and 10th centuries – specialized studies

[Note: On the sources known before ca. 1975 see Sezgin, GAS, V-VII (cited in §1).]

4.1 The foreign sources of Islamic astronomy

[Note: Start with Nallino, Scritti (§1). Various articles listed in other sections of this bibliography deal with materials from lost Indian and Iranian works.]

David Pingree, "The Fragments of the Works of Ya'qūb ibn Târiq", *Journal of Near Eastern Studies* 26 (1968), pp. 97-125, and "The Fragments of the Works of al-Fazârî", *ibid.* 29 (1970), pp. 103-123. [Reconstructions of the earliest astronomical writings in Arabic, now lost, from citations in later sources.]

David Pingree, "The Greek Influence on Early Islamic Mathematical Astronomy", *Journal of the American Oriental Society* 93 (1973), pp. 32-43, and "Indian Influence on Sasanian and Early Islamic Astronomy and Astrology", *The Journal of Oriental Research* (Madras) 34-35 (1964-66/1973), pp. 118-126. [Studies of major importance.]

Abdelhamid I. Sabra, "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement", *History of Science* 25 (1987), pp. 223-243, repr. in *idem*, *Studies*, I. [An important study.]

George Saliba, "Arabic Science and the Greek Legacy", in *Vernet Festschrift* (§1), I, pp. 19-37. [A useful overview.]

Richard P. Lorch, "Greek–Arabic–Latin: The Transmission of Mathematical Texts in the Middle Ages", *Science in Context* 14 (2001), pp. 313-331. [Contains a rich bibliography.]

George Saliba, "Early Arabic Critique of Ptolemaic Cosmology: A Ninth-Century Text on the Motion of Celestial Spheres", *Journal for the History of Astronomy* 25 (12994), pp. 115-141. [Text by Muhammad ibn Mūsâ, mid-9th-century Baghdad.]

Paul Kunitzsch, *Der Almagest. Die Syntaxis Mathematica des Claudius Ptolemäus in Arabisch-lateinischer Überlieferung*, Wiesbaden: Harrassowitz, 1974; *Ibn al-Salâh, Zur Kritik der Koordinatenüberlieferung im Sternkatalog des Almagest*, Göttingen: Vandenhoeck & Ruprecht, 1975; *Claudius Ptolemäus – Der Sternkatalog des Almagest – Die arabisch-mittelalterliche Tradition*, 3 vols., Wiesbaden: Otto Harrassowitz, 1986-1991. [Standard works.]

Paul Kunitzsch, "Über das Frühstadium der arabischen Aneignung des antiken Gutes", *Saeculum* 26 (1975), pp. 268-282.

Paul Kunitzsch, "Arabische Astronomie im 8. bis 10. Jahrhundert", in P. L. Butzer and D. Lohrmann, eds., *Science in Western and Eastern Civilization in Carolingian Times*, Basle: Birkhäuser, 1993, pp. 205-220. [An important essay.]

Dimitri Gutas, *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early 'Abbâsîd Society (2nd-4th/8th-10th centuries)*, London & New York: Routledge, 1998. [An important new study, with a rich bibliography.]

4.2 Islamic mathematical astronomy

See the overview article of King & Samsó in §1 and the description of the *zij* project in §3a.

[Notes: The only surviving version of the only surviving version of the astronomical handbook of *al-Khwārizmī*, a Latin translation of an Andalusī recension, was published by *H. Suter* in 1914, with a translation of the text and commentary by *O. Neugebauer* in 1962 (see below). *The Mumtahan Zij of Yahyā ibn Abī Mansūr and the Zij of Habash* remain unpublished, although *J. Vernet* and *M.-Th. Debarnot* have published overviews of the *Escorial* manuscript of the former and of the *Istanbul* manuscript of the latter (see below).

Most 19th- and early-20th-century studies are reprinted in the multi-volume *Islamic Mathematics and Astronomy* (§1).

There are numerous investigations of early Islamic materials in Kennedy et al., *Studies*, including papers on different aspects of the solar, lunar and planetary astronomy in the 9th-century *zīj*es of *Yahyā ibn Abī Mansūr and Habash*, and studies based on (the then) newly-developed computer-assisted analyses of medieval tables. Interested persons should get hold of the book.]

The Verified Astronomical Tables for the Caliph al-Ma'mūn – Al-Zij al-Ma'mūnī al-mumtahan by *Yahyā ibn Abī Mansūr* ... , Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1986. [Facsimile of the unique manuscript of a later recension of this work preserved in El Escorial.]

Juan Vernet, "Las Tabulae Probatae", in *Homenaje a Millás-Vallicrosa*, 2 vols., Barcelona: Consejo Superior de Investigaciones Científicas, 1959, II, pp. 501-522, repr. in *idem*, *Estudios* (§1), pp. 191-212. [The first and last serious study of this fundamental work.]

Heinrich Suter et al., eds., *Die astronomischen Tafeln des Muhammed ibn Musa al-Khwārizmī* ... , in *Kgl. Danske Vidensk. Skrifter*, 7. R., *Hist. og filos. Afd.*, 3:1 (1914); and Otto Neugebauer, *The Astronomical Tables of al-Khwārizmī*, in *Kgl. Danske Vidensk. hist.-fil. Skrifter* (Copenhagen) 4:2 (1962). [The Latin text and tables of the only surviving version, followed by an English translation of the introduction and a commentary.]

Bernard R. Goldstein, *Ibn al-Muthannā's Commentary on the Astronomical Tables of al-Khwārizmī*, New Haven, Conn.: Yale University Press, 1967. [Relates to the *original* (lost) version of al-Khwārizmī's astronomical handbook.]

The Book of the Reasons behind Astronomical Tables (Kitāb fi 'ilal al-zījāt) by 'Ali ibn Sulaymān al-Hāshimī, Fuad I. Haddad, E. S. Kennedy and David Pingree, eds., Delmar, N.Y.: Scholars' Facsimiles & Reprints, 1981. [An important source of information on the earliest Islamic *zīj*es, by an author active ca. 890, probably in Baghdad.]

E. S. Kennedy and Hala Salam, "Solar and Lunar Tables in Early Islamic Astronomy", *Journal of the American Oriental Society* 87 (1967), pp. 492-497, repr. in Kennedy et al., *Studies* (§1), pp. 108-113. [Deals with the *Mumtahan Zij* and the *Zij of Habash*.]

E. S. Kennedy and Walid Ukashah, "al-Khwārizmī's Planetary Latitude Tables", *Centaurus* 14 (1969), pp. 86-96, repr. in Kennedy et al., *Studies* (§1), pp. 125-135.

E. S. Kennedy, "The Solar Equation in the *Zij* of Yahyā ibn Abī Mansūr", in *Hartner Festschrift* (§1), pp. 183-186, repr. in Kennedy et al., *Studies* (§1), pp. 136-139.

E. S. Kennedy, "Parallax Theory in Islamic Astronomy", *Isis* 47 (1956), pp. 33-53, repr. in Kennedy et al., *Studies* (§1), pp. 164-184. [Includes Abbasid sources.]

E. S. Kennedy and Nazim Fares, "The Solar Eclipse Technique of Yahyā ibn Abī Mansūr", *Journal for the History of Astronomy* 1 (1970), pp. 20-38, repr. in Kennedy et al., *Studies* (§1), pp. 185-203.

Jamil Ali as-Saleh, "Solar and Lunar Distances and Apparent Velocities in the Astronomical Tables of Habash al-Hāsib", *Al-Abhāth* (Beirut) 23 (1970), pp. 129-177, repr. in Kennedy et al., *Studies* (§1), pp. 204-252.

BvD, "Al-Khwārizmī's Astronomical Tables Revisited: Analysis of the Equation of Time", in *Vernet Festschrift*, (§1), I, pp. 195-252. [Includes a detailed investigation of what is original to al-Khwārizmī in the only surviving version of his major work.]

A. P. Caussin de Perceval, "Le livre de la grande table Hakémite", *Notices et extraits des manuscrits de la Bibliothèque nationale* 7 (An XII [= 1804]), pp. 16-240, with separate pagination in the separatum. [This ground-breaking publication of the Arabic text with French translation of the introduction to the *Zij* of Ibn Yūnus (Cairo, ca. 990) contains several dozen observation accounts, mainly of eclipses and planetary conjunctions, by astronomers in 9th-century Baghdad. These, and other, Islamic observation accounts have been investigated in a series of studies by F. R. Stephenson and his colleagues at Durham University.]

Rida A. K. Irani, *The Jadwal al-Taqwīm of Habash al-Hāsib*, unpublished Master's dissertation, American University of Beirut, 1956. [Describes some extremely sophisticated tables of auxiliary trigonometric functions from mid-9th-century Baghdad. Should be reworked and published!]

Aydın Sayılı, "The Introductory Section of Habash's Astronomical Tables Known as the "Damascene Zij", *Ankara Üniversitesi Dil ve-Tarih-Cografya Facültesi Dergisi* 13:4 (1955). [An important study.]

Marie-Thérèse Debarnot, "The *Zij* of Habash al-Hāsib: A Survey of MS Istanbul Yeni Cami 784/2", in *Kennedy Festschrift* (§1), pp. 35-69. [An important study of one of the most astronomical productions of 9th-century Baghdad.]

Marie-Thérèse Debarnot, ed. and trans., *al-Bîrûnî: Kitāb Maqālīd 'ilm al-hay'a. La trigonométrie sphérique chez les Arabes de l'est à la fin du X^e siècle*, Damascus: Institut Français de Damas (Publication no. 114), 1985. [al-Bîrûnî is a rich source for the developments in spherical trigonometry in 9th- and 10th-century Baghdad.]

Régis Morelon, "Eastern Arabic Astronomy between the Eighth and Eleventh Centuries", in *EHAS* (§1), I, pp. 20-57; and "L'Astronomie arabe à Bagdad au IXe siècle", *Medioevo: Rivista di Storia della filosofia medievale* (Padua) 23 (1997), pp. 325-335. [Both disappointing and tending to ignore research by other scholars.]

Régis Morelon, *Thâbit ibn Qurra – oeuvres d'astronomie*, Paris: Les Belles Lettres, 1987. [Text, translation and commentary on the works of one of the most significant Baghdad astronomers ca. 900.]

Richard P. Lorch, ed., *Thâbit ibn Qurra, On the Sector-Figure and Related Texts*, Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften (*Islamic Mathematics and Astronomy*, vol. 108), 2001. [The work by the 13th-century scholar Nasîr al-Dîn al-Tûsî on this subject is far better known, but it was the last serious work on the subject, and Thâbit's is one of the first.]

DAK, "al-Khwârizmî and New Trends in Mathematical Astronomy in the Ninth Century", *Occasional Papers on the Near East* (New York University, Hagop Kevorkian Center for Near Eastern Studies) 2 (1983), 43 pp. [Presents some newly-discovered materials which form the basis of many of our later studies. Whilst it has since been shown that some of these materials attributed to al-Khwârizmî in our sources are in fact due to his contemporaries, they are particularly important for the light they shed on the "Islamicization" of astronomy in this early period.]

JH, "Al-Khwarizmi's Tables of the "Sine of the Hours" and the Underlying Sine Table", *Historia scientiarum* 42 (1991), pp. 1-12. [Reconstruction of the earliest trigonometric table in Arabic.]

F. Jamil Ragep, "Al-Battani, Cosmology, and the Early History of Trepidation in Islam", in *Vernet Festschrift* (§1), pp. 267-303.

F. Jamil Ragep, *Nasîr al-Dîn al-Tûsî's Mem-oir on Astronomy* (al-Tadhkira fî 'ilm al-hay'a), 2 vols., New York, etc.: Springer, 1993. [The introduction contains a discussion of the early history of cosmography in 8th- and 9th-century Baghdad.]

Bernard R. Goldstein and F. W. Sawyer, III, "Remarks on Ptolemy's Equant Model in Islamic Astronomy", in *Hartner Festschrift* (§1), pp. 165-81. [See especially p. 167 for a discussion of Habash and the equant model for Venus.]

Paul Kunitzsch and Richard Lorch, "Abû Nasr and Habash on *matâli' al-sam'*", *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* (Frankfurt) 9 (1994), pp. 43-82. [On a sophisticated topic of spherical astronomy.]

DAK, "Universal Solutions in Islamic Astronomy", in *Aaboe Festschrift* (§1), pp. 121-132, repr. in King, *Studies* (§1), C-VI. [Includes early Iraqi material.]

J. Lennart Berggren and Glen Van Brummelen, "Abû Sahl al-Kûhî on Rising Times", *Sciamvs – Sources and Commentaries in Exact Sciences* (Kyoto, Hokuto, Japan) 2 (2001), pp. 31-46, and *idem*, "Abû Sahl al-Kûhî on the Distance to the Shooting Stars", *Journal for the History of Astronomy* 32:2 (2001), pp. 137-151. [The author spent time in Baghdad in the 10th century.]

Paul Kunitzsch, "The Star-Table in the *Mumtahan Zij*" (in Arabic), to appear in *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* (Frankfurt). [A study of the earliest surviving star-table in Arabic.]

4.3 Lunar crescent visibility

4.3.1 Early studies by E. S. Kennedy and his colleagues and students include:

E. S. Kennedy, "The Lunar Visibility Theory of Ya'qûb ibn Târiq", *Journal of Near Eastern Studies* 27 (1968), pp. 126-132, repr. in Kennedy *et al.*, *Studies* (§1), pp. 157-163.

E. S. Kennedy, "The Crescent Visibility Theory of Thâbit ibn Qurra", *Proceedings of the Mathematical and Physical Society of the United Arab Republic* (1960), pp. 71-74, repr. in Kennedy *et al.*, *Studies* (§1), pp. 140-143. [See now the new study by Morelon listed in §4b.]

E. S. Kennedy and Muhammad Agha, "Planetary Visibility Tables in Islamic Astronomy", *Centaurus* 7 (1960), pp. 134-140, repr. in Kennedy *et al.*, *Studies* (§1), pp. 144-150. [Includes early Abbasid materials.]

E. S. Kennedy and Mardiros Janjanian, "The Crescent Visibility Table in Al-Khwârizmî's *Zij*", *Centaurus* 11 (1965), pp. 73-78, repr. in Kennedy *et al.*, *Studies* (§1), pp. 151-156. [As Kennedy noted, the table described is from al-Andalus, not from Baghdad.]

4.3.2 More recent studies include:

JH, "New Light on the Lunar Visibility Table of Ya'qûb ibn Târiq", *Journal of Near Eastern Studies* 47 (1988), pp. 95-104. [Baghdad ca. 750. Uses sophisticated Indian mathematical methodology.]

DAK, "Some Early Islamic Tables for Determining Lunar Crescent Visibility", in *Kennedy Festschrift* (see §1 above), pp. 185-225, repr. in King, *Studies* (§1), C-II. [Contains early Iraqi material, including al-Khwârizmî's table for Baghdad.]

JH, "Three Islamic Lunar Crescent Visibility Tables", *Journal of the History of Astronomy* 19 (1988), pp. 29-44. [Contains new insights on materials presented in the paper by DAK listed above.]

4.4 Astronomical timekeeping and the regulation of the times of prayer

4.4.1 Early studies by E. S. Kennedy and his colleagues and students include:

Mark Lesley, "Bîrûnî on Rising Times and Daylight Lengths", *Centaurus* 5 (1957), pp. 121-141, repr. in Kennedy *et al.*, *Studies* (§1), pp. 253-273. [al-Bîrûnî is a rich source of information on early Islamic techniques.]

Marie-Louise Davidian, "al-Bîrûnî on the Time of Day from Shadow Lengths", *Journal of the American Oriental Society* 80 (1960), pp. 330-335, repr. in Kennedy *et al.*, *Studies* (§1), pp. 274-279. [al-Bîrûnî is a rich source of information on early Islamic techniques.]

Yusuf Id, "An Analemma Construction for Right and Oblique Ascensions", *The Mathematics Teacher* 62 (1969), pp. 669-672, repr. in Kennedy *et al.*, *Studies* (§1), pp. 495-498.

Nadi Nadir, "Abû al-Wafâ' on the Solar Altitude", *The Mathematics Teacher* 53 (1960), pp. 460-463, repr. in Kennedy *et al.*, *Studies* (§1), pp. 280-283.

E. S. Kennedy, "al-Bîrûnî on the Muslim Times of Prayer", in *The Scholar and the Saint ...*, P. J. Chelkowski, ed., New York, N.Y., 1975, pp. 83-94, repr. Kennedy *et al.*, *Studies* (§1), pp. 299-310. [al-Bîrûnî is a mine of information on early practices. On these definitions see now King, *SATMI*, IV.]

4.4.2 A more recent study is:

DAK, *Studies in Astronomical Timekeeping in Medieval Islamic Civilization*, 12 pts., in press with E. J. Brill, Leiden. Contains:

I: A Survey of Tables for Regulating Time by the Sun and Stars (previously unpublished). [Contains all known material from early Baghdad.]

II: A Survey of Tables for Regulating the Times of Prayer (previously unpublished). [Contains all known material from early Baghdad.]

III: A Survey of Arithmetical Shadow-Schemes for Time-Reckoning (an earlier version was published in 1993). [Includes material from early Baghdad.]

IV: On the Times of Prayer in Islam (previously unpublished). [Focuses on developments in 8th-century Baghdad.]

VI: Universal Solutions in Medieval Islamic Astronomy (earlier versions published in 1987-88). [Includes all known early Baghdad materials.]

VII: An Approximate Formula for Timekeeping (750-1900) (previously unpublished). [Follows the colourful history of a formula from 8th-century Baghdad in the Islamic world and in Europe for over a millennium.]

XII: When the night sky over Qandahar was lit only by stars [Text of a lecture delivered in Frankfurt, Nov., 2001, previously unpublished; deals with newly-discovered tables for timekeeping by night, computed in Qandahar ca. 1000, inspired by earlier developments in Baghdad.]

4.5 Astronomical instruments – general

See the description of the project in §3b above.

[**Note:** Most 19th- and early-20th-century works on this subject are reprinted in *AIOS* (§1).]

BS, *Mathematisch-astronomische Darstellungen auf Instrumenten: idem, Untersuchungen von mathematisch-astronomischen Darstellungen auf mittelalterlichen Instrumenten islamischer und europäischer Herkunft*, Bassum (D): Verlag für Geschichte der Naturwissenschaften und der Technik, 1997. [Includes investigations of the star-positions on several early astrolabes, including the earliest astrolabes from Baghdad.]

DAK, *Studies in Astronomical Timekeeping in Medieval Islamic Civilization*, 12 pts., to be published by E. J. Brill. Contains:

VIII: Astronomical Instrumentation in the Medieval Islamic World (previously unpublished; an Italian translation of an earlier version was published in 1991). [The entire story begins in and around Baghdad.]

FC, *Mathematical Instrumentation in Fourteenth-Century Egypt and Syria – The Illustrated Treatise of Najm al-Dîn al-Misrî*, Leiden: E. J. Brill, 2003. [In this study of a Mamluk treatise describing over 100 different varieties of astronomical instruments, the early history of the instrument-types is investigated and often traced back to 9th- and 10th-century Baghdad.]

4.6 Astronomical instruments – the astrolabe

DAK, *A Catalogue of Medieval Astronomical Instruments*. I: Eastern Astrolabes to ca. 1550, not yet published. [Contains descriptions of two dozen astrolabes from Iraq and Iran during the period 800-1000.]

BS, "Die früheste bekannte Formgebung der Astrolabien", in *Ad radices – Festband zum fünfzigjährigen Bestehen des Instituts für Geschichte der Naturwissenschaften Frankfurt am Main*, Anton von Gotstedter, ed., Stuttgart: Franz Steiner, 1994, pp. 315-328. [Discusses the design of the earliest known Islamic astrolabe from 8th-century Baghdad, showing that it is identical to the sole surviving Byzantine astrolabe dated 1062.]

DAK, "The Origin of the Astrolabe according to the Medieval Islamic Sources", *Journal of the History of Arabic Science* 5 (1981), pp. 43-83, repr. in *idem*, *Studies* (§1), B-III. [Uses some early Iraqi sources.]

Bashîr Faransîs and Nâsir al-Naqshabandî, "Al-Asturlâbât fî Dâr al-âthâr al-'arabiyya fî Baghdâd", *Sumer* (Baghdad) 13 (1957), pp. 9-33 and 5 pls., repr. in *AIOS* (§1) XII [= *IMA* (§1), vol. 96], pp. 302-331. [Describes and illustrates five astrolabes, whose present fate is uncertain. The most important of these is now described in detail in the next entry.]

DAK, "The Oldest Known Astrolabe, from 8th-Century Baghdad", to appear. [A detailed description made from defective photos of a tiny astrolabe preserved (at least until April, 2003) in the Archaeological Museum, Baghdad.]

Bernhard Dorn, "Drei in der Kaiserlichen Öffentlichen Bibliothek zu St. Petersburg befindliche astronomische Instrumente mit arabischen Inschriften", *Mémoires de l'Académie Impériale des Sciences de St.-Petersbourg*, VIIe série, 9:1 (1865), pp. 1-150 and 2 figs., repr. in *AIOS*, I, pp. 345-498. [Describes in an appendix one astrolabe from 10th-century Baghdad, whose present location is unknown.]

[Francis R. Maddison], *A Supplement to a Cata-logue of Scientific Instru-ments in the Collec-tion of J. A. Billmeir, Esq., C. B. E.*, London: Frank Partridge & Sons, 1957. [Describes an astrolabe and an unsigned rete by Khaffî, Baghdad, ca. 875.]

DAK, "Early Islamic Astronomical Instruments in Kuwaiti Collections", in Arlene Fullerton & Géza Fehérvári, eds., *Kuwait: Art and Architecture – A Collection of Essays*, Kuwait (no publisher stated), 1995, pp. 76-96. [Contains a description of the earliest dated astrolabe, by Nastûlus, and a spectacularly beautiful astrolabe by the well-known astronomer al-Khujandî, both from 10th-century Baghdad.]

Paul Kunitzsch, *Glossar der arabischen Fachausdrücke in der mittelalterlichen europäischen Astrolabliteratur*, Göttingen: Vandenhoeck & Ruprecht, 1983. [The standard work.]

Paul Kunitzsch, "Al-Khwârizmî as a Source for the *Sententie astrolabii*", in *Kennedy Festschrift* (§1), pp. 227-236, repr. in *idem*, *Studies* (§1), IX.

Paul Kunitzsch, "Al-Sûfî and the Astrolabe Stars", *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* (Frankfurt) 6 (1990), pp. 151-166. [Provides a basis for the study of all Islamic astrolabe retes.]

Richard P. Lorch, *al-Farghânî, On the Construction of the Astrolabe*, edition, translation and commentary, in preparation. [Baghdad, ca. 850.]

Richard P. Lorch, edition, translation and commentary on al-Sijzî's treatise on the astrolabe, in preparation. [al-Sijzî (d. ca. 1020) seems to have spent time in Baghdad; his treatise surveys the contributions of Baghdad astronomers of the 9th and 10th centuries.]

DAK, "The Neglected Astrolabe", in Menso Folkerts, ed., *Mathematische Probleme im Mittelalter - Der lateinische und arabische Sprachbereich*, (Wolfenbütteler Mittelalter-Studien, Band 10), Wiesbaden: Otto Harrassowitz, 1996, pp. 45-55. [Identifies all of the additions to the standard astrolabe that were developed in the 9th and 10th centuries, mainly in Baghdad.]

J. Lennart Berggren, "Abû Sahl al-Kûhî's Treatise on the Construction of the Astrolabe with Proof: Text, translation and Commentary", *Physis* 31 (1994), pp. 142-252. [An important treatise from 10th-century Baghdad.]

DAK, "Bringing Astronomical Instruments Back to Earth: The Geographical Data on Medieval Astrolabes (to ca. 1100)", in *Between Demonstration and Imagination: Essays in the History of Science and Philosophy Presented to John D. North*, Arjo Vanderjagt & Lodi Nauta, eds., Leiden: E. J. Brill, 1999, pp. 3-53. [Includes data from all available astrolabes up to ca. 1100, including those from 8th-, 9th-, and 10th-century Baghdad.]

George Saliba, "A Sixteenth-Century Drawing of an Astrolabe made by Khaffî Ghulâm 'Alî b. 'Îsâ (c. 850 A.D.)", *Nuncius – Annali di Storia della Scienza* (Florence) 6 (1991), pp. 109-119. [Two instruments made by Khaffî in Baghdad and preserved in Oxford are here supplemented by a third, discovered in a faithful drawing in a 16th-century manuscript preserved in the Uffizi.]

FC + PS, "Scientific Initiative in 9th-Century Baghdad: al-Khwarizmi on the Astrolabe and Related Treatises", to appear. [Text, translation and commentary on the earliest surviving Arabic treatises on the astrolabe and quadrant.]

DAK + FC, "A Survey of Medieval Islamic Tables for Constructing Astrolabes". Forthcoming. [Contains the first description of the tables of al-Farghânî in Baghdad ca. 850, and traces the development of subsequent tables of the same kind for a millennium.]

DAK, "A Remarkable Italian Astrolabe from ca. 1300 – Witness to an Ingenious Tradition of Non-Standard Astrolabes", to appear in a *Festschrift* for Mara Miniati to be published as a special issue of *Nuncius – Annali di Storia della Scienza* (Florence) in 2003. [Describes the only known European example of a tradition of special astrolabes (based on a mixed north-south stereographic projection) that was introduced in Baghdad in the late 9th or early 10th century.]

4.7 Astronomical instruments – the quadrant

MV, "Medieval Islamic Horary Quadrants for Specific Latitudes and Their Influence on the European Tradition", *Suhayl – Journal for the History of the Exact and Natural Sciences in Islamic Civilisation* (Barcelona) 1 (2000), pp. 273-355. [Surveys a tradition that started in Baghdad in the 9th century and lasted in Europe until the 17th century.]

Richard P. Lorch, "Some Early Applications of the Sine Quadrant", *Suhayl – Journal for the History of the Exact and Natural Sciences in Islamic Civilisation*

(Barcelona) 1 (2000), pp. 251-272. [Based on treatises from 9th-century Baghdad.]

DAK, "A *Vetustissimus* Arabic Text on the *Quadrans Vetus*", *Journal for the History of Astronomy* 33 (2002), pp. 237-255. [The *quadrans vetus*, an instrument for finding the time of day from the solar altitude for any latitude, first appeared in Europe in the late 12th century. A newly-discovered manuscript source establishes its origins in 9th-century Baghdad. See the next entry for a more detailed and more extensive study.]

DAK, *Studies in Astronomical Timekeeping in Medieval Islamic Civilization*, 12 pts., to be published by E. J. Brill. Contains:

IXa: On the Early History of the Universal Horary Quadrant for Timekeeping by the Sun (previously unpublished, but see previous entry for a summary). [The instrument was invented in Baghdad in the 9th century.]

4.8 Astronomical instruments – miscellaneous

JH, "The Contributions by Abu Nasr ibn 'Irâq and al-Saghâni to the Theory of Seasonal Hour Lines on Astrolabes and Sundials", *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* (Frankfurt) 14 (2001), pp. 1-30.

Richard P. Lorch and Paul Kunitzsch, "Habash al-Hâsib's Book on the Sphere and its Use", *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* (Frankfurt) 2 (1985), pp. 68-98, repr. in Lorch, *Studies* (§1), XIII. [9th-century Baghdad.]

E. S. Kennedy, Paul Kunitzsch and Richard P. Lorch, *The Melon-Shaped Astrolabe in Arabic Astronomy*, (*Boethius: Texte und Abhandlungen zur Geschichte der Mathematik und der Naturwissenschaften*, Band 43), Stuttgart: Franz Steiner, 1999. [A study of a treatise by Habash al-Hâsib, Baghdad, ca. 850, on an ingenious astrolabe based on a projection preserving direction and distance to the centre, and including text, translation and commentary.]

FC + PS, "A Universal Plate for Timekeeping with the Stars by Habash al-Hasib: Text, Translation and Preliminary Commentary", *Suhayl – Journal for the History of the Exact and Natural Sciences in Islamic Civilisation* (Barcelona) 2 (2001), pp. 107-159. [A treatise on a remarkable instrument from 9th-century Baghdad - text, translation and commentary.]

DAK, "14th-Century England or 9th-Century Baghdad? New insights on the elusive astronomical instrument called *Navicula de Venetiis*", to appear in a special issue of *Centaurus* in 2003, in honour of Bernard R. Goldstein. [The *navicula* is the most sophisticated instrument for timekeeping from the European Middle Ages, precursor of the better-known *Uhrtäfelchen* of Regiomontanus. Its origins in 9th-century Baghdad are here investigated, in the light of a more complicated instrument described in the previous entry.]

DAK, "New Light on the *Zij al-Safâ'ih* of Abû Ja'far al-Khâzin (II): a remarkable astrolabic instrument from late-10th-century Rayy, engraved with astronomical tables to serve an equatorium, preserved in an example from early-12th-century Baghdad", in preparation. [A preliminary description based on photos of an instrument thought to have been lost in WWII was published in 1980 (see DAK, *Studies*, B-XI). This is here revised and expanded following the rediscovery of the instrument, more complete than was revealed by the old photos, in the vaults of the Museum für Indische Kunst in Berlin.] [A third study of the *Zij al-Safâ'ih* – a task for the future – will have to take into consideration the lengthy treatise Abû Ja'far al-Khâzin relating to this instrument but also dealing with all manner of problems in mathematical astronomy: a manuscript of this has recently discovered in a library in India. This third study will be the equivalent of a couple of doctoral dissertations.]

DAK, *Studies in Astronomical Timekeeping in Medieval Islamic Civilization*, 12 pts., to be published by E. J. Brill. Contains:

IXb: On the Early History of the Universal Horary Dial for Timekeeping by the Sun and Stars (previously unpublished). [Presents the evidence that the device was most probably invented in Baghdad in the 9th century.]

4.9 Determination of the sacred direction (qibla)

[**Note:** There are several early studies by Carl Schoy that are not listed here. Also the writings of al-Bîrûnî, especially the *Tahdîd*, as translated by E. S. Kennedy, are a rich source on early techniques. See King, *World-Maps* (§4I) for further bibliographical details.]

E. S. Kennedy and Yusuf Id, "A Letter of al-Bîrûnî: Habash al-Hâsib's Analemma for the Qibla", *Historia Mathematica* 1 (1973), pp. 3-11, repr. in Kennedy *et al.*, *Studies* (§1), pp. 621-629.

DAK, "The Earliest Islamic Mathematical Methods and Tables for Finding the Direction of Mecca", *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* (Frankfurt) 3 (1986), pp. 82-149, with corrections listed *ibid.* 4 (1987/88), p. 270, repr. in King, *Studies*, C-XIV. [Based on newly-discovered texts from 9th-century Baghdad.]

E. S. Kennedy, "Applied Mathematics in the Tenth Century: Abu 'l-Wafâ' Calculates the Distance Baghdad-Mecca", *Historia Mathematica* 11 (1984), pp. 193-206, repr. in *idem*, *Studies* (§1), IV. [Not only the direction to Mecca, but also the distance to Mecca was of interest to early Muslim astronomers.]

JH, "Al-Nayrizi's Mysterious Determination of the Azimuth of the Qibla at Baghdad", *Sciamvs – Sources and Commentaries in Exact Sciences* (Kyoto, Hokuto, Japan) 1 (2000), pp. 49-70. [A surprising account of the way in which a small error in a highly sensitive mathematical operation produced a seriously incorrect result.]

See also §4I-4m below.

4.10 Mathematical astrology

For the basic concepts the newcomer should consult R. Ramsey Wright, transl., *The Book of Instruction in the Elements of the Art of Astrology by ... al-Bīrūnī*, London: Luzac & Co., 1934, pending a new edition currently in preparation.

4.10.1 Early studies by E. S. Kennedy and his colleagues and students include:

E. S. Kennedy, "The Sasanian Astronomical Handbook *Zij-i Shāh* and the Astrological Doctrine of "Transit" (*mamarr*)", *Journal of the American Oriental Society* 78 (1958), pp. 246-262, repr. in Kennedy *et al.*, *Studies* (§1), pp. 319-335.

E. S. Kennedy and B. L. van der Waerden, "The World-Year of the Persians", *Journal of the American Oriental Society* 83 (1963), pp. 315-327, repr. in Kennedy *et al.*, *Studies* (§1), pp. 338-350.

E. S. Kennedy, "The World-Year Concept in Islamic Astrology", in the *Proceedings of the International Congress of the History of Science, Ithaca, N.Y., 1962*, repr. in Kennedy *et al.*, *Studies* (§1), pp. 351-371.

E. S. Kennedy and Haiganoush Krikorian-Preisler, "The Astrological Doctrine of Projecting the Rays", *Al-Abhāth* (Beirut) 25 (1972), pp. 3-15, repr. in Kennedy *et al.*, *Studies* (§1), pp. 372-384. [Deals with tables associated with al-Khwārizmī.]

4.10.2 Other important studies include:

David Pingree, *The Thousands of Abū Ma'shar*, London: The Warburg Institute, University of London, 1968. [A brilliant reconstruction of an important lost work by the leading astrologer of 9th-century Baghdad.]

E. S. Kennedy and David Pingree, *The Astrological History of Māshā'allāh*, Cambridge, Mass.: Harvard University Press, 1971. [The first astrological world-history in Arabic, compiled in 8th-century Baghdad.]

Ana Labarta, ed., *Mūsā ibn Nawbajit, Al-Kitāb al-Kāmil, Horóscopos históricos*, Madrid & Bellaterra, 1982. [Another work of the same kind.]

JH, "The Mathematical Structure of Two Islamic Astrological Tables for Casting the Rays", *Centaurus* 32 (1989), pp. 171-202, and "Mathematical Astrology in the Islamic Tradition" (dealing with houses, rays and progressions), to appear in the proceedings of a conference "New perspectives on science in medieval Islam" held at the Dibner Institute, Cambridge, Mass., during Nov. 6-8, 1998. [Deals with some Abbasid material.]

DAK, "A Hellenistic Astrological Table Deemed Worthy of Being Penned in Gold Ink: the Arabic Tradition of Vettius Valens' Auxiliary Function for Finding the Length of Life", to appear in *Pingree Festschrift* (§1). [On a remarkable table from 9th-century Baghdad.]

Bernard R. Goldstein, "The Book on Eclipses of Māshā'allāh", *Physis* 6 (1964), 205-13. [A Hebrew version, ascribed to Abraham ibn Ezra, of an early astrological work, not extant in the original Arabic.]

C. Burnett and A. al-Hamdī, 'Zadanfarrukh al-Andarzaghār on Anniversary Horoscopes', *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften*, 7, 1991/2, pp. 294-398.

C. Burnett, "Al-Kindī on Judicial Astrology: "The Forty Chapters"", *Arabic Sciences and Philosophy*, 3, 1993, pp. 77-117.

4.10.3 Finally, in both senses, some important new editions of early Islamic astrological works:

Abu Ma'shar, *The Abbreviation of the Introduction to Astrology*, together with the Medieval Latin translation of Adelard of Bath, ed. and transl. C. Burnett, K. Yamamoto and M. Yano, Leiden: Brill, 1994.

Abū Ma'shar al-Balkhī, Liber intoductorii maioris ad scientiam judiciorum astrorum, ed. Richard Lemay, 9 vols., Naples: Istituto Universitario Orientale, 1995-96.

The Liber Aristotilis of Hugo of Santalla, eds C. Burnett and D. Pingree, Warburg Institute Surveys and Texts 26, London: Warburg Institute, 1997.

Scientific Weather Forecasting in the Middle Ages: The Writings of Al-Kindi, ed. and transl. Gerrit Bos and C. Burnett, London: Kegan Paul International, 2000.

Abū Ma'shar, On Historical Astrology. The Book of Religions and Dynasties (On the Great Conjunctions), K. Yamamoto and C. Burnett, 2 vols., Leiden: E. J. Brill, 2000.

Abu Ma'shar on Historical Astrology, The Book of Religions and Dynasties (On the Great Conjunctions), ed. and transl. K. Yamamoto and C. Burnett, 2 vols, Leiden: Brill, 2000.

Paul Kunitzsch, "The Chapter on the Fixed Stars in Zarādusht's *Kitāb al-mawālīd*", *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* (Frankfurt) 8 (1993), pp. 241-249.

Hermes, Liber de stellis beibeniis, Paul Kunitzsch, ed., in *Hermetis Trismegisti Astrologica et Divinatoria* (Corpus Christianorum, Continuatio Medievalis,

4.10.4 Note also:

Al-Qabīsi, *Introduction to Astrology*, ed. and transl. C. Burnett, K. Yamamoto and M. Yano, Warburg Institute, Studies and Texts, London: Warburg Institute, 2003 (in press).

Kūshyār ibn Labbān's Introduction to Astrology, ed. and transl. M. Yano, Tokyo: Institute for the Study of Languages and Cultures of Asia and Africa, 1997.

Kūshyār Ibn Labbān's Introduction to Astrology, M. Yano, ed., Tokyo: Institute for the Study of Languages and Cultures of Asia and Africa, 1997. [An important introductory work.]

4.11 Geodetic measurements

Raymond P. Mercier, "Geodesy" in J. B. Harley and David Woodward, eds., *The History of Cartography*, vol. 2, book 1: *Cartography in the Traditional Islamic and South Asian Societies*, Chicago, Ill. & London: University of Chicago Press, 1992, pp. 175-188. [An important overview. There were problems with the later reception of the Abbasid results – see further Ragep, *al-Tūsī's Tadhkira* (§4b).]

Y. Tzvi Langermann, "The Book of Bodies and Distances of Habash al-Hāsib", *Centaurus* 28 (1985), pp. 108-128. [Includes an account of the first Muslim geodetic measurements by Habash, Baghdad, ca. 825.]

DAK, "Too Many Cooks ... – A Newly-Rediscovered Account of the First Islamic Geodetic Measurements", *Suhayl – Journal for the History of the Exact and Natural Sciences in Islamic Civilisation* (Barcelona), 1 (2000), pp. 71-99. [The account of the judge appointed by the Caliph al-Ma'mūn to oversee the measurements.]

4.12 Mathematical geography and cartography

Hans von Mzik, ed., *Das Kitāb Sūrat al-ard des ... al-Khuwārizmī ...*, Leipzig: Otto Harras-sowitz, 1926 (repr. in *Islamic Geography* (§1), vol. 11 (1992)). [An important contribution to early Abbasid mathematical geography; based on the unique manuscript in Strasbourg.]

Kennedy & Kennedy, *Islamic Geographical Coordinates*: E. S. Kennedy and Mary Helen Kennedy, *Geographical Coordinates of Localities from Islamic Sources*, Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1987. [Data collected from over 70 different sources and organized according to place-names, increasing longitudes and latitudes, and sources.]

E. S. Kennedy, "Suhrāb and the World-Map of Ma'mūn", in *Aaboe Festschrift* (§1) pp. 113-119. [Describes the coordinate grid used on the first Arabic world-map, from early-9th-century Baghdad.]

Fuat Sezgin, *Geschichte des arabischen Schrifttums*, X-XII: *Mathematische Geographie und Kartographie im Islam und ihr Fortleben im Abendland*, Frankfurt am Main: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 2000. [A monumental study that goes beyond the usual framework and format of the GAS volumes to provide a complete historical overview of Islamic cartography, starting in the 9th century, and its influence in Europe.]

DAK, *World-Maps for Finding the Direction and Distance to Mecca: Innovation and Tradition in Islamic Science*, Leiden: E. J. Brill, and London: Al-Furqan Islamic Heritage Foundation, 1999. [Deals with 17th-century Iranian world-maps, based on mathematical techniques first developed in Baghdad in the 9th and 10th centuries. This early origin was only hypothesized, not proven. See now the review by Jan Hogendijk in *Historia Mathematica* 30 (2003), pp. 85-93, and also the next entry, on some new materials confirming the early origin.]

DAK, *Studies in Astronomical Timekeeping in Medieval Islam*, Leiden: E. J. Brill, in press, especially:

X: Architecture and Astronomy: The Sacred Direction in Islam (reprints of earlier studies and new text). [Part Xc contains new information on the mathematics underlying the map-grids discussed in the previous entry, firmly establishing its original inspiration (by a solution to the qibla-problem involving ellipses) at the latest by the 10th century.]

4.13 Sacred folk geography

DAK, *The World about the Kaaba – The Sacred Folk Geography of Medieval Islam*, to be submitted to E. J. Brill, Leiden. [Contains some Abbasid material and presents a reconstruction the three schemes of sacred geography devised by Ibn Surāqa in Basra in the late 10th century. A summary is in the article "Makka. iv. As centre of the World" in *El*₂ (§1).]

4.14 Folk astronomy

PS, *Volksastronomische Abhandlungen aus dem mittelalterlichen arabisch-islamischen Kulturraum*, doctoral dissertation in preparation (Institute for History of Science, Johann Wolfgang Goethe University, Frankfurt). [Some 13th-century Yemeni treatises on folk astronomy are full of surprises: references to a *sāhib al-waqt* in Mecca ca. 900, responsible for timekeeping; records of the astronomical alignment of the Kaaba; and information about the development in the 8th century of the definitions of the times of prayer which later became standard.]

4.15 Sacred cosmology

Anton Heinen, *Islamic Cosmology: A Study of as-Suyûti's al-Hay'a al-saniya fi-l-hay'a al-sunnîya*, Beirut Texts and Studies (Orient-Institut der Deutschen Morgenländischen Gesellschaft), Band 27, Beirut (for Franz Steiner Verlag, Wiesbaden), 1982. [Identifies the origins of the Islamic tradition in the work of the 10th-century scholar Abu 'l-Shaykh, a companion of the tradition-specialist Abû Dâ'ûd, apparently in Basra. The materials collected by al-Suyûti are mainly 7th-century in origin.]

4.16 Miscellaneous

E. S. Kennedy, "al-Khwârizmî on the Jewish Calendar", *Scripta Mathematica* 27 (1964), pp. 55-59, repr. in Kennedy *et al.*, *Studies* (§1), pp. 661-665

DAK, "A Medieval Account of Algebra before al-Khwârizmî", *al-Masaq: Studia Arabo-Islamica Mediterranea* 1 (1988), pp. 25-32. [The report relates to 7th-century Mecca, and is partly based on fantasy.]

Menso Folkerts, *Die älteste lateinische Schrift über das indische Rechnen nach al-Hwârizmî*, Munich: Beck, 1997. [Based on a newly-discovered manuscript. The original Arabic is lost.]

Paul Kunitzsch, "The Enterprise of Science in Islam: New Perspectives", in the proceedings of a conference "New perspectives on science in medieval Islam" held at the Dibner Institute, Cambridge, Mass., during Nov. 6-8, 1998, pp. 3-21. [On the early history of the so-called Hindu-Arabic numerals in Islamic civilization.]

Régis Morelon, "Fragment arabe du premier livre du Phasesis de Ptolémée", *Journal for the History of Arabic Science* 5 (1981), pp. 3-22.

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