SEIZING THE HEAVENS: MAKING CELESTIAL GLOBES IN THE ISLAMIC WORLD

Taha Yasin Arslan

Istanbul Medeniyet University,
D-100 Karayolu Guney Kampus, Kadikoy, Istanbul, 34000 Turkey tahayasinarslan@gmail.com

For a millennium, between the 9th and 19th centuries, astronomical instrumentation had a vital role in scientific endeavour in the Islamic world. Different types of instruments, various engravings and markings, the makers' signatures and dedications, construction dates, and artistic features provide ample evidence for assessing the level, transition, and transmission of knowledge in the period. In this manner, celestial globes are historically significant but undeservingly neglected instruments. They are the second largest group of instruments, after astrolabes, illustrative of the history of Islamic astronomy with more than two hundred extant globes. Despite its popularity throughout history, globe making procedures remain somewhat obscure. This paper presents a brief overview of the globe making tradition in the Islamic world. It deals with two main sources of information: manuals on the construction/use of globes and the extant globes. In this regard, the 10th century astronomer ʿAbd al-Raḥmān al-Ṣūfī's (d. 376/986) Book of the Constellations (Kitāb Ṣuwar al-kawākib al-thābita) and Abū ʿAlī al-Ḥasan al-Marrākushī's (second half of the 7th/13th century) From A to Z: A Compendium of Timekeeping (Jāmīʿ al-mabādī wa-l-ghāyāt fī ʿilm al-mīqāt) are highlighted as potentially the sources that were used by instrument makers. The paper raises questions regarding the influence of these works on the instrument makers and consequently on globes. The discussion on this wide-range topic, however, is limited to only a few examples as a pointer for future studies.

Keywords: Celestial globes, astronomical instruments, astronomy in the Islamic world, ʿAbd al-Raḥmān al-Ṣūfī, Abū ʿAlī al-Ḥasan al-Marrākushī, the Lahore workshop.

Celestial globes are astronomical instruments that simulate the daily motion of the sky. They can be used for observations, calculations, and demonstrations. Their sizes vary from 5 to 35 cm in diameter. There are over two-hundred extant globes from the Islamic world (for a detailed list, see Savage-Smith, 1990/1991). Most of these instruments can be categorized into three types. All carry astronomically significant great circles such as the ecliptic, the celestial equator as well as the equinoctial and solstitial colures. The categorization is mostly based on the number of stars they have. First type globes (type A) carry approximately a thousand stars (fig. 1). They almost always have the figures of the forty-eight classical constellations, although this is not exclusive to this type. Second type globes (type B) have only very bright stars, while third type globes (type C) have none (Savage-Smith 1985, 61-62). These instruments are historically significant for they help us to comprehend the level of scientific knowledge, capabilities of craftsmen and artisans of the era as well as further define cultural, religious, and political influences on scientific developments.

Texts on Celestial Globes

The two main sources for historical study of celestial globes are the extant texts and the instruments. Most important of the textual sources are manuals for making and using celestial globes. Although some books such as encyclopaedias and travel accounts may provide relevant information, they will not be investigated here. The details in manuals regarding the construction process, or instructions for use of the globe may reveal far more detailed information on essential procedures, the evolution of globes, and the transmission of knowledge abouit instrujments. For instance, the 9th century astronomer Ḥabash al-Ḥāsib (d. after 255/869) states in *the Book of Knowing the Sphere and Its Use* (*Kitab fī maʿrifat al-kura wa-l-ʿamal bihā*) (Lorch and Kunitzsch, 1985, 78): "The globe is a solid sphere, and it is made by beating and filing [two metal pieces, then forming them into hemispheres] by using a lathe, and pairing [the hemispheres]." Some of the texts will be highlighted in this paper based on their unique contribution to, or influence on, the globe making tradition.

1. The first teacher of globe making in the Islamic world was Ptolemy of Alexandria (*c.* 100-180

Figure 1. Type A celestial globe made by Jamāl al-dīn Muḥammad al-Hāshimī in 981/1573-74. Bibliothèque nationale de France, département des Cartes et plans, Ge A 326.

CE). In the third chapter of the Book VIII of the *Almagest*, Ptolemy describes the construction of a unique type of globe known as "the precession globe" (Ptolemy, 1984, 404-407). According to Ptolemy, the surface should be painted in dark colours it to imitate the night sky. The figures of the forty-eight constellations should be engraved and 1022 stars as well as the location of the Milky Way should be marked. Two rings, one for the meridian and the other for the horizon, encircle the globe. The entire assemblage stands on columns that are fixed at the bottom of the horizon ring. The ecliptic poles are marked and pierced, and the ecliptic is drawn. Using the poles, another great circle that is perpendicular to the ecliptic is drawn to mark the beginning of the ecliptic which is then divided it into 360 degrees. Neither the celestial equator nor its poles are marked or engraved. This is to prevent any deviation of the equinoxes caused by the precession over time (1° in 72.2 years).

2. One of the earliest texts on celestial globes compiled in the Islamic world was by Ḥabash al-Ḥāsib, *the Book of Knowing the Sphere and Its Use*. He was an astronomer who excelled in mathematics. He made observations, prepared astronomical tables (*zīj*), and designed and wrote on instruments. In the globe text, he deals with a globe with two rings, one for the meridian, and the other for the horizon. There are 1022 stars on the globe following Ptolemy's star catalogue However, Ḥabash's globe differs from Ptolemaic style since it has the celestial equator drawn with the ecliptic. This was not exclusive to Ḥabash's globe but became standard for almost all globes in the Islamic world. As a rare feature, lunar mansions are also engraved. Ḥabash's aforementioned statement about the constructing and joining two hemispheres is the only written record in the early Islamic era on how to make solid spheres. Despite these important details, the treatise was not comprehensive and did not become popular.

3. Quṣṭā ibn Lūqā's (d. *circa* 300/912-913), *Treatise on the Use of the Sphere with a Stand* (*Risālat al-ʿAmal bi'l-kura dhāt al-kursī*) is arguably the most popular treatise on the use of celestial globes. He was a scholar of Greek Christian origin working in the 9th-century Islamic world. He worked on astronomy, translated Greek astronomical works and compiled original treatises (Kheirandish, 2007, 948-949). His treatise deals with many applications of celestial globes both for observations and calculations in sixty-five chapters. The only difference betwen his globe and Ḥabash's seems to be the number of stars. While Ḥabash describes a type one globe, Quṣṭā prefers the second type with only dozens of stars, those can be found on planispheric astrolabes. The treatise is highlighted by Abū ʿAlī al-Ḥasan al-Marrākushī (second half of the 7th/13th century), who states that he has seen five works on the use of globes, of which Quṣṭā's is the best. The other four are the Arabic translations of the works of Autolycus of Pitane (*circa* 360 - 290 BCE) and three Alexandrian scholars; Philo (*c*. 280 - 220 BCE), Hero (*c*. 10 – 70 CE), and Theon (*c*. 335 - 405 CE) (BnF Arabe 2508, f. 112r). Quṣṭā's original text does not include a section on the construction but the Castilian translation made by scholars for Alfonso X of Castile (reigned: 1252-84 CE) has an additional chapter explaining the process in detail (For a detailed study of the text, see Samso, 2015, 63-79.).

4. A unique globe that cannot be placed in any of the three categories were designed by Abū ʿAbdallāh Muḥammad ibn Jābir ibn Sinān al-Battānī (d. 317/929-30). He made systematic observations for more than 40 years in his private observatory. The accuracy of his observations was remarkable, mostly due to his computational skills and the quality of his instruments. In chapter 57 of the *Book of Astronomical Tables* (*Kitāb al-Zīj*), he introduced a globe, simply referred as an egg (bayḍa) (Battānī, 1977, 210-13 [fols. 142r-144v]). The globe is unusual in having only five rings and does not stand on columns but is suspended. From inner to outer, these rings are a rotatable meridian ring; three rings that are of equal diameter and perpendicularly fixed to each other, the horizon, meridian, and zenith, and the outer ring from which the globe is suspended, and to which the sighting vane can be attached. Besides the usual great circles, 533 stars are marked on the sphere. There is no mention of constellation figures. Battānī mentions a detachable sighting vane for observations. Although this type was not followed in the globe making tradition, Battānī's instructions for engraving great circles and marking the positions of the stars were quite practical and might have been used in making globes of any type.

5. The most influential work on globes in the Islamic world was arguably ʿAbd al-Raḥmān al-Ṣūfī's (d. 376/986) *Book of the Constellations* (*Kitāb Ṣuwar al-kawākib al-thābita*). Ṣūfī worked on astronomy, made observations, and compiled comprehensive treatises, mostly on the use of astronomical instruments. His manual for the use of astrolabes, for instance, consists of 1760 chapters and

is the most comprehensive book of its kind in the history of astronomy. His most famous treatise, the *Book of the Constellations*, deals with the forty-eight classical constellations. The figure of each constellation is illustrated both as seen in the sky and on the globe. The figures were decorated with corresponding stars. An accompanying star table provides values for the ecliptic longitude and latitude of the stars and their brightness. The values are taken from Ptolemy's catalogue but adjusted 12° 41′ for the time difference between the two astronomers. However, when Ṣūfī is not satisfied with Ptolemy's original values, he provides new ones that he obtained from his own observations (Dekker, 2012, 29-47). Each constellation has a relevant text that describes the position of the stars relative to their corresponding constellation figure.

6. ʿAbd al-Raḥmān al-Ṣūfī also compiled a treatise on the use of globes titled *On the Explanation of Operations with the Sphere* (*Fī sharḥ al-ʿamal bi-l-kura*). This work contains 157 chapters and is more comprehensive than Quṣṭā's treatise. Although it does not have a chapter on how to make globes, the instructions for use reveal that Ṣūfī's globe has a detached quadrant with a 90-degree scale that can be used for several operations including determining the horizontal and ecliptic coordinates and measuring the altitudes or azimuths of the Sun and stars. Furthermore, the meridian ring is pierced for each degree so it can be fixed at different latitudes.

7. The most detailed instructions on globe making were given by the 13th century astronomer Marrākushī in *From A to Z: A Compendium of Timekeeping* (*Jāmīʿ al-mabādī wa-l-ghāyāt fī ʿilm al-mīqāt*). He was originally from the Maghrib but active in Cairo around the second half of the 13th century. Almost nothing is known about his life. His sole work, *Jāmīʿ al-mabādī wa-l-ghāyāt*, is arguably the most important work on astronomical instrumentation in the Islamic world. It respectively deals with computational methods (book I), constructing dozens of instruments which range from sundials to astrolabes and sine quadrants (book II), and using numerous instruments for observations and calculations (book III). The last volume is a questionnaire with 101 questions and answers (book IV). Most of the texts on instruments in the book are texts of prominent astronomers such as Qusṭā ibn Lūqā, Abū Rayḥān al-Bīrūnī (d. *circa* after 444/1053), and Abū Isḥāq Ibrāhīm ibn Yaḥyā al-Naqqāsh al-Zarqālī (d. 493/1100) but heavily revised by Marrākushī himself. The others are his original contributions. At least forty complete or partial copies of this voluminous work survive.

The fifth chapter of the second volume deals with spherical instruments. Marrākushī categorizes spherical instruments into three: celestial globes, spherical astrolabes, and the comprehensive instrument (*al-shāmila*) which is a hollow hemisphere fitted with rotating plates, an invention of the 10th century polymath Abū Maḥmūd Ḥāmid ibn al-Khiḍr al-Khujandī (d. 390/1000). He then provides a step by step guide with details for the process of globe making (BnF Arabe 2508, 13r-16v):

- Make a copper or wooden sphere. Unfortunately, he does not give any details on how to construct the sphere.
- Find its diameter using a drawing compass. Here, Marrākushī proposes a complex geometric application method which involves designation of reference points, drawing concurrent circles, and creating a great circle using the intersection points between these concurrent circles. This process might also be an indication of the use of a one-piece sphere which was not common before the 17th century. Otherwise, one could easily have measured the diameter of the globe across the open end.
- Construct two copper rings with their inner diameters equal to the diameter of the globe. One of the rings should be twice wider than the other. The wider one is for the horizon and the other one is for the meridian.
- Divide the horizon ring into four 90-degree scales (fig. 2).
- Construct a copper semi-circular piece and three copper columns for making the stand. The tips of the columns and two ends of the semi-circular piece are fixed at the bottom of the horizon ring.
- Divide the meridian ring as it was done for the horizon ring.
- Punch holes on every one-degree division of two of the four quarters of the meridian ring.
- Construct two latches to pin the meridian ring at any desired latitude.
- Construct a copper quadrant with a 90-degree scale that is the same diameter as the meridian ring.
- Using this quadrant, mark two opposite points on the globe for the celestial poles.
- Once the poles are marked, using a turning

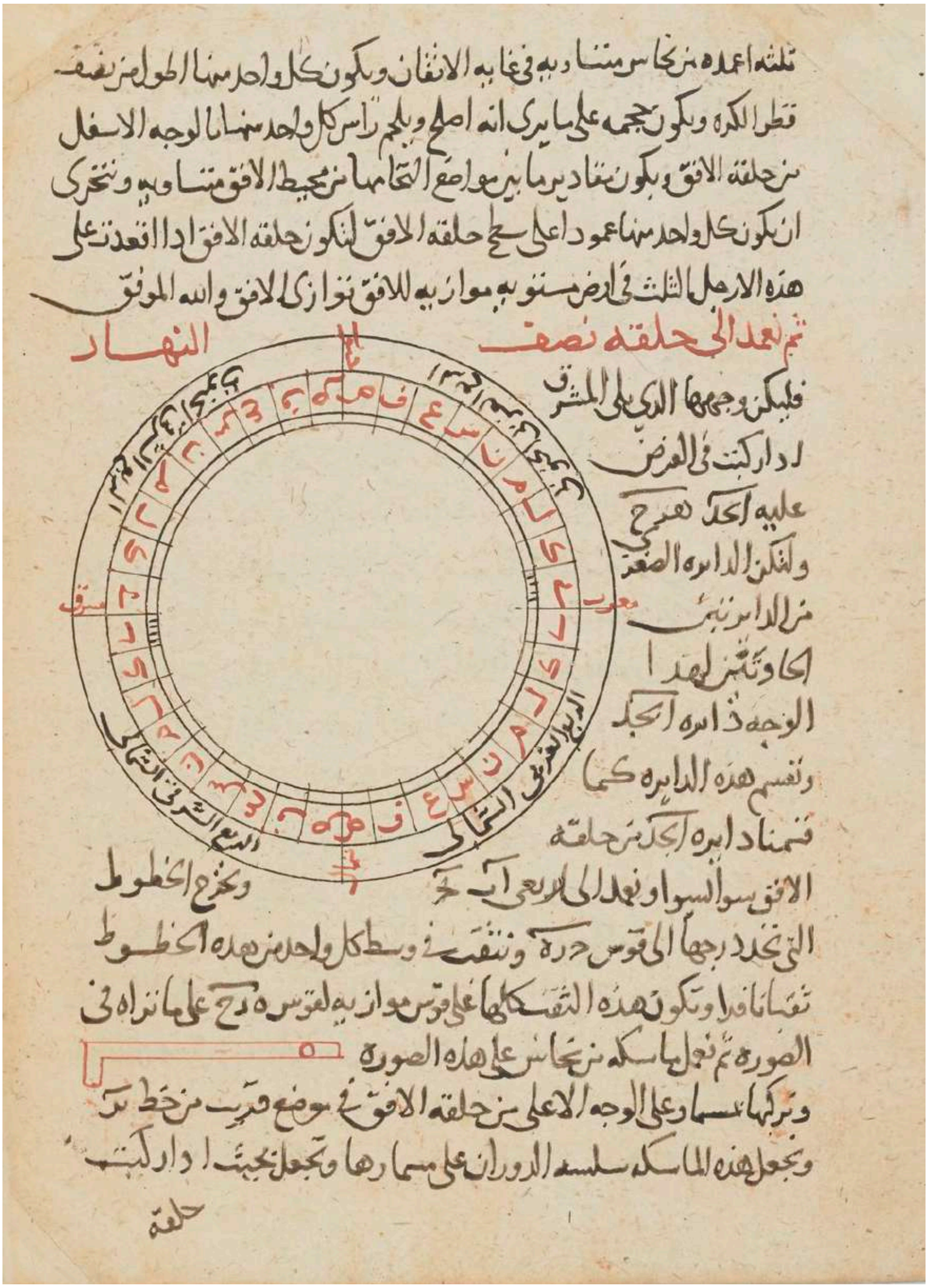

Figure 2. An extract from Marrākushī's work showing the horizon ring with four 90-degree scales, ms. Paris, Bibliothèque nationale de France, département des Manuscrits, Arabe 2508, 14v.

lathe, draw the celestial equator and later divide it in 360 degrees. Marrākushī's advice for the use of a turning lathe is to increase the accuracy of the engraving.

- Using the scale on the equator, fix the legs of the drawing compass to the degree of the obliquity of the ecliptic and use the compass to designate the ecliptic poles on the globe.
- Draw the ecliptic by using a turning lathe.
- Draw six great circles that divides the ecliptic into twelve equal divisions.
- Divide each of the divisions into 30-units as the signs of the zodiac.
- Pierce the celestial and ecliptic poles.
- Fix the meridian ring on the ecliptic poles and using the scales on the ecliptic and the meridian ring, locate and mark the stars.

Marrākushī's goal was not to propose a new model but to provide guidance for making the most accurate and easy-to-use standard globe. His contributions to globe making tradition may seem simple but they are exceptionally helpful for understanding the basic processes. At the same time as he proposed new ideas for construction, such as making a quadrant to designate and draw celestial and ecliptic poles and circles, he also used his predecessors' methods. For instance, employing the meridian ring to mark the positions of stars is a method initially described by Ptolemy. Although not mentioned in this chapter, ʿAbd al-Raḥmān al-Ṣūfī's parameters were also used for the star positions.

The Instrument Makers and Extant Celestial Globes

These seven treatises are the main textual sources for the entire globe making tradition in the Islamic world. However, finding out whether these texts had any influence on the actual construction processes, deterining any patterns of influence, and mapping the changes and transmission of knowledge about instrumentation is a rather hard task. In addition to the literature review, one needs to conduct a thorough study of both instrument makers and extant instruments. Biographical information on the makers and engraving on the globes might reveal details that connect these instruments with the textual sources.

Historical accounts point to Ḥarrān, a city today in south-east Turkey, as the epicentre of early instrument making in the 9th and 10th centuries. Ṣūfī even mentions that he has seen several globes made in Ḥarrān (BnF Arabe 5036, f. 4b). Unfortunately, none of these globes survive and there are no details about the workshops, their employees, or sale records. This is even more mysterious for globe making until the second half of the 16th century. Cities like Damascus, Cairo, Toledo, Istanbul, and Isfahan were all quite active in the instrument making, but no details seem to be available regarding the workshops.

For the 17th and 18th centuries, we are better informedormative. This is a period when astronomical instruments gained significantly in artistry, especially in Safavid Iran and Mughal India. Although other workshops in Lahore or Isfahan existed, due to the accuracy and beauty of their production, a family of artisans in Lahore became the central figures in globe making during this period. Their workshop operated for over a century through four generations: Shaykh Allāhdād Asṭurlābī Humāyūnī Lahūrī (fl. 975/1567-68), his son Mullā ʿĪsā (fl.1009-13/1600-05), Mullā ʿĪsā's two sons Qāʾim Muḥammad (fl. 1034-45/1624-36) and Muḥammad Muqīm (fl. 1030-70/1621-60), Qāʾim's son Ḍiyāʾ al-Dīn Muḥammad (fl. 1047-91/1637-81) and Muqīm's sons Ḥāmid (fl. 1065-1102/1654-91) and Jamāl al-Dīn (fl. 1077-1102/1666-91). Thirty-three extant celestial globes bear their signatures. They perfected the lost wax method, for making one-piece spheres. Unfortunately, we do not have an inventory of their library or tools in the workshop to present concrete evidence for the transmission of knowledge (For the most comprehensive information on the Lahore family, see Sarma, 2018).

Regarding the extant globes, without even needing a thorough examination, one can see that the figures of the constellations are often clearly related to Ṣūfī's *Book of the Constellations*. A careful study of the positions of the stars on the globe further help us to understand which catalogue was used in the making of it. Indeed, if the changes to the values, similar to thse made by Ṣūfī to Ptolemy's values, can be calculated, one can even date the globe. This information can be obtained more easily as in the case of a globe by Muḥammad ibn Maḥmūd ibn ʿAlī al-Tabarī in 684/1285-86. The globe is in the Khalili Collection of the Islamic Art, London. An inscription by the maker states that he obtained the values of the star positions and the figures of the constellations from Ṣūfī's *Book of the Constellations*. Unfortunately, he does not reveal how he engraved the star positions on the globe using these values.

Ṣūfī's book may have been the primary, if not the only, source for the figures but the shapes of the constellation figures differ significantly from one globe to another. These differences mainly depend on which copy of Ṣūfī's book was used in the

Figure 3a-3b. A comparison of the figures of the constellation Cepheus from two different copies of ʿAbd al-Raḥmān al-Ṣūfī's Book of the Constellations (Kitāb Ṣuwar al-kawākib al-thābita). *Paris, Bibliothèque nationale de France, département des Manuscrits, Arabe 2492, 136v (3a, on the left) and Arabe 5036, 38r (3b, on the right).*

process. Since the figures do not need to fit into a strict frame, the copiers often introduced their own cultural characteristics into their interpretation of the illustrations. Human figures may look more local or wear clothes and headwear that are familiar to the copier's region instead of following the original source (fig. 3a-3b). Consequently, when a globe maker uses a regional copy, the globe would have features that allow us to pinpoint its location. Therefore, careful investigation of globes provides valuable data to map both the exchanges and localizations of knowledge even if the instrument was not signed or dated. But this is a task beyond the scope of this paper.

Conclusion

Unmistakable similarities in the figures make it easier to show Ṣūfī's influence. However, it is very difficult, perhaps impossible, to spot the construction methods of more standard engraving such as the great circles or star indicators. Did the makers use a turning lathe to engrave the ecliptic or other great circles as Marrākushī advised? Did they make a quadrant with a 90-degree scale to designate the celestial and ecliptic poles? Did they use Battānī's or Marrākushī's methods to mark the stars on the globe? Even if they used a lathe or constructed an auxiliary quadrant, is it possible to know whether they obtained the idea from Battānī's or Marrākushī's works without that they explicitly mention them?

Some craftsmen and artisans may have constructed globes either by replicating an existing model or employing traditional learning passed from master to pupil. However, the globe making tradition stretches all around the Islamic world and continued and was intermittent. So the process needs to be examined in two aspects. Firstly, beating, filing, and seaming two copper sheets to produce two-piece spheres; secondly melting and casting copper ingots to make a one-piece sphere. These, with the construction of rings and columns are the basic processes of globe making. None of them requires astronomical knowledge rather skills of a craftsman. So, this may have been a usual process for makers without any specific influence for centuries. On the other hand, knowing how and where to mark the stars or what to engrave (i.e. figures of the constellations, great circles…) on the sphere demand a certain level of astronomical knowledge which can be obtained almost exclusively from the texts if the maker is not copying a globe at his disposal. The accuracy of many of the extant globes, especially those made in Lahore, encourages us to argue that some globe making manuals must have been used in the process. Considering there has been no newer nor more comprehensive works produced either on the constellation after Ṣūfī or on general globe making after Marrākushī and that both works were copied and widely used in the Islamic world, it is natural to assume that these two works may have provided all the information a craftsman or an artisan needed for several centuries. We hope that future studies will reveal more concrete evidences for this.

Bibliography

Al-Battānī Muḥammad ibn Jābir, ed. and trad. Nallino C. A., 1977, *Opus astronomicum* (*Kitāb al-Zīj*). Reprint of the edition, Milano 1899-1907. Hildesheim and New York, Olms.

al-Marrākushī Abū ʿAlī al-Ḥasan, *From A to Z: A Compendium of Timekeeping* (*Jāmīʿ al-mabādī wa-l-ghāyāt fī ʿilm al-mīqāt*), ms. Paris, BnF, département des Manuscrits, Arabe 2508.

al-Ṣūfī's ʿAbd al-Raḥmān, *Book of the Constellations* (*Kitāb Ṣuwar al-kawākib al-thābita*), ms. Paris, BnF, département des Manuscrits, Arabe 5036.

Dekker E., 2013, "Islamic Celestial Cartography", dans *Illustrating the phaenomena : celestial cartography in Antiquity and the Middle Ages*. Oxford, Oxford university press.

Kheirandish E., 2007, "Qusṭā ibn Lūqā al-Baʿlabakkī", dans *The Biographical Encyclopedia of Astronomers, Springer Reference*, Thomas Hockey et al. (eds.), New York, Springer, p. 948-949.

Lorch R., Kunitzsch P., 1985, "Ḥabash al Ḥāsib's Book on the Sphere and its Use". *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften 2*, p. 68–98.

Ptolemy C., trad. Toomer G. J., 1984, *Almagest*. London, Duckworth.

Samso J., 2015, "Qusṭa ibn Lūqā and Alfonso X on the celestial globe". *Suhayl*, volume 5, p. 63-79.

Sarma S. R., 2018, *A Descriptive Catalogue of Indian Astronomical Instruments*. Dusseldorf.

Savage-Smith E., 1985, *Islamicate Celestial Globes: Their History, Construction, and Use, with a chapter on iconography by Andrea P. A. Belloli*. Washington, Smithsonian Institution Press.

Savage-Smith E., 1990/91, "The classification of Islamic celestial globes in the light of recent evidence". *Der Globusfreund*, 38–39, p. 23-29.