Gerard Turner Memorial Lecture

Of Making Celestial Globes There Seems No End

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As is well-known to historians of scientific instruments, the celestial globe is the oldest form of celestial mapping, and its origins can be traced to Greece in the sixth century BC. The stars were commonly perceived – as indeed they still are by the average person looking up at the sky – as though attached to the inside of a hollow sphere enclosing and rotating about the Earth. The Earth, known from early classical antiquity to be spherical, was imagined at the centre of the celestial globe, with the stars placed on its surface.

When mapping the stars onto a three-dimensional globe, you can think of yourself either *inside* the sphere, looking up, or *outside* the sphere looking down. When the three-dimensional model of the skies presents the stars as seen from *outside* the sphere of stars, the relative positions of the stars on the globe are the reverse, east to west (or right to left), of their appearance when viewed from the surface of the earth. This outside or external view was the basic design from classical antiquity through most of the classical Islamic period, even throughout the 19th century. Modern European celestial globes, however, generally use an *internal* view, with the sequence of zodiacal signs running clockwise when viewed from above the globe, rather than anticlockwise as they appear on a globe with an external perspective.

No celestial globes from antiquity have survived, but the basic principles of their design were maintained, with some modifications and elaborations, in the Islamic world. Over 290 Islamic celestial globes are known to be preserved today.[1] The earliest dated globe was made in Valencia, Spain, in either 1085 (478H) or 1080 (472 H), depending upon how you read the inscription.[2] Globe production continued through the nineteenth century, with variants being produced even today, and the number is increasing almost as we speak. Regardless of date, only the forty-eight constellation outlines recognized in antiquity are indicated. When constellation outlines are drawn around the stars, the clothing and faces of the human figures reflect the artistic conventions common in the artisan's day when the globe was made. The stars represented on Islamic globes are those listed in the medieval star catalogs, usually 1022.

On almost every Islamic globe preserved today there is also a set of six great circles at right angles to the ecliptic. See, for example, Fig. 1, which is a globe made in 1362-3.[3] These are not meridians, but circles used for measuring coordinates in an ecliptic-based system, which dominated in the medieval period. A hole for the axis was drilled near the Pole Star. Since the positions of the stars change over time with the precession of the equinoxes (at a rate of about 1° per 70 years), the star positions on a globe (or on an astrolabe, for that matter), while correct when the globe was made, remain valid for only three-quarters of a century.

Fig. 1 *Celestial globe made in 1362 (764H) by Jaʿfar ibn ʿUmar ibn Dawlatshāh al-Kirmānī, showing Hercules hanging upside-down with his head next to the constellation of Serpentarius (Ophiuchus). To the left of the serpent's head are the constellations Boötes and Corona Borealis. Oxford, Museum of the History of Science (inv. no. 44790). Diameter 16.5 cm.*

To function as an instrument, the sphere needs to be placed in a ring assembly, permitting adjustment to different geographical latitudes, when it then represents the rotation of the heavens as seen at the latitude. Unfortunately most of the medieval globes preserved today are missing the rings. If a well-constructed celestial globe with rings were supplemented by a gnomon (or pin sundial) or quadrant providing the altitude of the Sun, it could then be used by an astronomer or astrologer to determine a range of astronomical data, including the length of the unequal day-time hour for a given day and location, or the present time elapsed at certain location, or the data needed for a horoscope.[4]

As early as the ninth century, Arabic treatises were composed on the design and use of celestial globes, not just as demonstrational devises but as instruments for calculating astronomical and time-keeping data. In the following centuries, additional treatises on the subject were composed, including one by an important court astronomer in Shiraz, ʿAbd al-Raḥmān ibn ʿUmar al-Ṣūfī (d. 986) written when nearly eighty years of age. ʿAbd al-Rahman al-Ṣūfī is better-known, however, for having composed some twenty years earlier a *Book of the Constellations of Stars* that provided tables of coordinates for 1022 stars.[5] Several globes have inscriptions acknowledging dependence on al-Ṣūfī's star catalogues. For example, the globe illustrated in Fig. 1, made in 1362 by Jaʿfar ibn ʿUmar ibn Dawlatshāh al-Kirmānī, has an engraved inscription stating:

> 'The stars were placed according to the *Book of Constellations* by Abū al-Ḥusayn ʿAbd al-Raḥmān al-Ṣūfī after increasing their longitudes by 6 degrees 3 minutes to

Fig. 2 *The constellation of Serpentarius as seen in the sky (left) and on a globe (right), as drawn in a copy of ʿAbd al-Raḥmān al-Ṣūfī's Book of Constellations made in Baghdad in 1125. Doha, Qatar, MIA MS 2.1998, fols. 50b–51a.*

Fig. 3 *A globe with stars but no constellations, unsigned and undated, made in hemispheres* c. *1250–1350. Diameter 10.7 cm. Ajaloo Museum in Tartu, Estonia.*

> our time in the year 764H [= 1362], which is also 732 in the Yazdigird calendar and 1674 of the Alexandrian era.'

While al-Sufi's treatise provided tables of co-ordinates for the 1022 major stars, the visual depictions of the constellations in his treatise had an even greater impact. For each constellation he provided two views, one as it is seen in the sky and one as it would be on a globe. In Fig. 2 the two views of Serpentarius are shown from what has been argued to be the earliest preserved copy of al-Sūfī's *Book of the Constellations of Stars,* copied in Baghdad in 1125 (519H).[6]

In terms of design, Islamic celestial globes fall into several distinct categories. The first comprises those displaying the forty-eight constellation outlines and approximately 1022 stars. These are the largest and the most elaborate artefacts. Ninety-one examples are now recorded. See Fig. 1 for a fourteenth-century example made of metal hemispheres joined at the celestial equator with soldering evident along the seam.

Those in the second category have no constellation outlines and only a selection of the most prominent stars, usually between 20 and 60. Fifty-two of this type has now come to light.[7] A particularly fine example is shown in Fig. 3, a globe now in the Ajaloo Museum in Tartu, Estonia, made *c*. 1250-1350, in hemispheres.[8] It has 53 labelled stars or star groups, indicated by inlaid silver studs, each surrounded by an engraved circle. The majority of globes in this category are metal spheres, but there are a few recorded examples of painted wooden globes of the 18th or 19th century.[9]

The third type of globe has neither constellation outlines nor any stars, but only the great and lesser circles (ecliptic, equator, tropic, and polar circles), all of which are labelled.[10] The latter design is not mentioned in any of the written sources, and evidence so far available suggests it originated in Iran in the late seventeenth or early eighteenth century. The vast majority are made in hemispheres (typical of Iranian workshops), but there are a few examples recently found that can be attributed to the Lahore workshop in India of the 18th and 19th century, for they are seamless and have other attributes distinctive to the Lahore workshops. Some 69 examples are known of this style, seven of which are wooden painted globes.

Of the 290 recorded Islamic celestial globes, the vast majority are hollow metal spheres. These were constructed in one of two ways: (1) from two hemispheres or (2) cast by the *cire perdue* (lost wax) process, in one piece and with no seam. The hemispheres from which the first type was constructed could be either cast or raised metal. For examples of

Fig. 4 *A globe made in 1639 (1049 H) by Muḥammad Muqīm Asṭurlābī Humayūnī Lāhūrī Diameter 17cm; horizon ring is not original to globe. Doha, Museum of Islamic Art, MW.146.1990.*

globes made of two hemispheres, see Figs 1 and 3.

On the basis of evidence so far available, the technique of producing a seamless hollow sphere appears to have originated in northwestern India toward the end of the sixteenth century in the city of Lahore, on the upper course of the Indus river, which at that time was the capital of a Mughal province or *ṣūba* of the same name, later to be called the Punjāb. The earliest confirmed date for such a globe is one made in 1589–90 (998H) by ʿAlī Kashmīrī ibn Lūqmān[11], and globes of this construction continued to be produced through the 19th century. The example in Fig. 4 was made in 1639 (1049H) by Muḥammad Muqīm Asṭurlabī Ḥumayuni Lāhuri, a member of an important four-generation family of instrument-makers working in Lahore. During more than a century, from 1567 to 1697 – a period that covered the reigns of the second though the ninth Mughal rulers of India – seven members of this family produced numerous planispheric astrolabes and other instruments, including twenty-one signed globes and, no doubt, a considerable number of unsigned ones as well.

All of their globes were seamless globes. The production of hollow seamless metal globes became the hallmark of all workshops in the Punjab and Kashmir areas of India through the nineteenth century. Most, though not all, have a full set of constellations, and all are of the highest quality of precision and craftsmanship. Many have been surface treated, so that the darkened surface made the silver inlaid stars very obvious and at the same time covered over evidence of the plugs that were used to correct flaws in the casting process.[12]

It was thought that it was not possible to cast a hollow seamless metal sphere until laboratory tests were carried out on a specimen of this Lahore workshop's output that had come into the collections of the then National Museum of History and Technology (now the National Museum of American History) of the Smithsonian Institution in Washington D.C. in the 1970s.[13] The Analytic and Conservation Laboratory at the museum used radiography, metallography and metal analysis, as well as a small camera dropped though a damaged area, to examine the globe and try to analyse its method of construction.[14] They found that in the globe, which had a diameter 21.7 cm, the thickness of wall varied from 0.47 mm to 1.00 mm. Radiography confirmed that the globe was cast as a hollow seamless globe by the *cire perdue* method. Seventy-four plugs were found, only a few easily visible. A large round plug, rather difficult to see, is found at the end of the constellation Eridanus, and it is located where the sprue was located—that is, where the alloy was poured into the mould. A weak area occurred around Draco, Cepheus, Hercules and Serpens, where a small part is missing, and in this region there are 17 large plugs, 7 small square ones, and 6 round ones, the latter being the location of armatures or chaplets, which still protrude on the inside (visible through broken area). Many of the plugs were hammered into place from the inside. Presumably work on the inside (as well as removal of the interior mould) was facilitated by removing a fairly large circular plug around the sprue area, which would then be replaced when the work on the inside was completed. Soft solder was employed in securing the large plugs. All of the plugs were made of the same alloy as the rest of the globe. The alloy was found to have copper as the primary component, with over 30% lead, plus zinc, tin and traces of other metals. It was probably heavily leaded to increase the fluidity. After all the plugs were in place, the globe was turned on a lathe for smoothing and polishing. The resulting precision and the uniformity in the sphericity are impressive, and this is generally true of all seamless cast globes.

The technique of producing these seamless globes continued on in Lahore and by the first half of the 19th century the workshop operated under the name Lālah Balhūmal Lāhūrī. See Fig. 5 (and cover illustration) for an example from the Balhūmal workshop.[15] All products of the Balhūmal workshop are fine examples of craftsmanship and accuracy of execution, while continuing the medieval tradition of design, except for the inclusion of meridians as well as ecliptic latitude measuring circles.

Only a few painted wood or papier-mâché Islamic globes have survived, all of them hand-drawn or painted on solid wood or papier-mâché spheres. The method that dominated globe-making in Europe — namely, laying printed paper gores over a wood or fibre core — seems not to have been practiced in the Islamic world. Of globes with constellations, we know of only five examples made of painted wood or papier-mâché spheres, all of them from the seventeenth century or later.[16]

Throughout the ten centuries of their production in the Islamic world, celestial globes – whether metal or wood – maintained the medieval tradition of displaying only the classical 48 constellations and approximately 1022 stars. None of the surviving Islamic celestial globes records the stars and constellations of the southern hemisphere first mapped by Europeans during explorations of the sixteenth century.[17]

In terms of design, however, there are three globes whose function is unknown, but appear to be in the tradition of or related in some

Fig. 5 *A celestial globe from the Lālah Balhūmal Lāhūrī workhsop in India, first half of the nineteenth century, with original rings and stand. The Nasser D. Khalili Collection of Islamic Art, SCI285. Photography courtesy of the Nasser D. Khalili Collection of Islamic Art.*

manner to a spherical astrolabe.[18] One is an early 17th-century globe made in Yazd (Iran) using two cast hemispheres, having 37 major stars, the usual great and lesser circles, and a full set of circles parallel to the ecliptic at 5° intervals.[19] It also has the unique feature of arcs drawn and labelled through the star ʿ*ayyūq* (*α Aurigae* or Capella) apparently intended to demonstrate the three methods of determining the coordinates of a star or planet for an observer at a geographical latitude of 32° North, which is that of Yazd (in Iran), where the globe was most likely produced.

The second[20] is painted paper on a wooden core and has about 60 stars or star groups indicated by small circles with radiating lines. Most puzzling is a network of half-great circles originating at the intersection of the celestial equator and the solstitial colure at the winter solstice and extending to the equinoctial colure at 5° intervals. The hemisphere thus defined is also covered by a series of parallels (parallel to the equinoctial colure) at 1° intervals, drawn in red with every 5° parallel drawn in black. The purpose of the network in unclear.

The third globe of curious design[21], made in Iran in 1797 (1212H) by Muḥammad Sharīf ibn Muḥammad Riḍā, combines properties of a celestial globe having 39 prominent stars with some unique features, such as a large hole labelled 'place of the gnomon' that might have enabled it to function as a spherical elevation or altitude dial. The design suggests an exposure on the part of the maker to some of the European spherical dials that were particularly popular in Germany in the 18th century.

Another three globes represent yet another departure from standard celestial globe design. These are all early seventeenth-century globes having a few stars poorly positioned on them and twelve circular medallions with anthropomorphic representations of the twelve zodiacal signs. One of the three[22] was made in 1603 (1012H) for the great Safavid ruler Shāh ʿAbbās I, who ruled Persia from 1587–1629. In addition to the twelve medallions containing symbols of the zodiacal signs, it has 38 stars indicated by inlaid silver points surrounded by a circle and also greater and lesser circles, unlabelled. The other two[23] are essentially identical, but unsigned and undated, though the globe made for Shāh ʿAbbās I has the unique feature of a large crescent Moon engraved on it between the north equatorial pole and the House of Aries. These globes are very difficult to photograph so that the lightly engraved zodiacal signs –such as Libra depicted as a cross-legged human figure holding a balance scale over his shoulders, or Gemini as a man sitting cross-legged with two shafts of wheat – are visible. Note that on all three globes of this type, the sequence of zodiacal signs is the reverse from that on standard Islamic globes—that is, clockwise rather than anti-clockwise when viewed from above North Pole. These delicate and decorative globes are non-functional from an instrumental point of view and may have been intended merely as ornaments or as symbols of astrological expertise.

In India in the nineteenth century a quite different form of celestial globe was produced that served astrologers as *aides-mémoire* for their art[24] - see Fig. 6A for an example. Only a few constellations were depicted (some of aberrant size), with most of the surface area covered with astrological information inscribed in a mixture of Arabic, Persian, and Urdu. The sphere is not a true celestial globe, though it has constellation images on it. Four examples of these astrologer's globes are known, two in the Nasser D. Khalili Collection of Islamic Art and two that were in private collections in the late 1990s.[25] All four are unsigned and undated and are inscribed in a mixture of Arabic, Persian and Urdu – the use of the latter indicating a workshop somewhere in north-central India. All are constructed of metal hemispheres of high-zinc brass joined along the 'ecliptic' by an internally soldered strip, suggesting that they were not made by the Lahore workshops. For examples of products from the Lahore workshops, see Figs 4 and 5.

On each of these four 'astrologer's globes', there are two gore-shaped panels assigned to each zodiacal sign, one in the northern and one in the southern half of the sphere. Each panel, beginning at the narrow point, contains matters associated with that sign, such as letters of the alphabet, season of the year, part of the day or night, unlucky days of the month, number of days the Sun resides in that sign, associated temperaments, dejections and exaltations of planets, lunar mansions, elements, direction of the compass, colour, sex, and noctural or diurnal attributes attributed to that sign. See Fig. 6B for a rendering and translation of three sections on the globe that is illustrated in Fig. 6A.

Notice the stands on these globes. They have no allowance for a meridian ring, but have a padded frame set inside them which would allow the sphere to be rapidly turned for reading without being scrapped or damaged by the stand.

Fig. 6 **A** *(left). An astrologer's globe, unsigned and undated. Diameter 20.8 cm. The Nasser D. Khalili Collection of Islamic Art, SCI51. Photography courtesy of the Nasser D. Khalili Collection of Islamic Art;* **B** *(right). A drawing with translations of inscriptions on three of the twelve northern panels on the astrologer's globe. Based on Khalili Collection SCI51.*

This type of stand is *identical* to the earliest of a large group of globes from Indian workshops have come recently onto the art market, some displaying false dates, and all of them with curious and often faulty interpretations of constellations and star positions.[26] They are distinguished by peculiar iconographic features that betray an early modern European influence as well as a misunderstanding of the significance of the original design of the celestial globe and its function. Several constellations are represented in a unique manner that is characteristic of this entire group of globes.

What apparently is the earliest example of this class of celestial globe (illustrated in Fig. 7) has an inscription giving the opening verse of the *Shahnāmah* of Firdawsī[27], followed by the name Munshī ʿAbd al-Shahīd, astrologer and divinator (*munajim wa-jaffār*), with Delhi and a date equivalent to 1656 in the last line.[28] Whether Munshī ʿAbd al-Shahīd is intended to be a maker's name or an owner's name is uncertain, but in any case, the date cannot be taken as genuine. The occurrence of Delhi on an object supposedly made during the reign of Shāh Jahān, when the city was called Shāhjahānabād, is incongruous. Moreover, the globe reproduces in detail the unusual constellations of a nineteenth-century Sanskrit map. The spacing of the constellations on the globe suggests that the maker was transferring the design from a two-dimensional model onto a three-dimensional object, and indeed the constellation designs on this globe are virtually identical to those in

Fig. 7 *A 'rabbit globe' made in India bearing a date of 1067H (= 1656), the place-name Delhi, and the name Munshī ʿAbd al-Shahīd 'astrologer and divinator'. The Nasser D. Khalili Collection of Islamic Art, SCI284. Photography courtesy of the Nasser D. Khalili Collection of Islamic Art.*

a nineteenth-century Sanskrit manuscript now in the British Museum.[29] The Sanskrit treatise *Sarvasiddhāntattaçūḍāmaṅī* or *Jewel of the essence of all sciences* was written sometime between 1833 and 1839 by Durgashankara Pathaka, an astronomer of Benares, and it presents a horoscope for the prince Nau Nihal Singh of Lahore (1821–40). This highly illustrated manuscript includes two planispheric maps of the Ptolemaic constellations, one with the autumnal equinox at the centre, the other with the vernal equinox at the centre, both of which are directly related to the designs on this globe, and this globe appears to have served as a model for the subsequent globes of this class.

On this globe bearing the name of Munshī ʿAbd al-Shahīd, the astrologer and divinator, the ecliptic, celestial equator, and solstitial colure are carefully engraved and graduated, but they are incorrectly labelled and incorrectly positioned. None of the silver (occasionally brass) inlaid stars are labelled and they are so poorly positioned that they do not correspond to any epoch. It is made of two hemispheres, joined along the ecliptic by a one-inch wide internally soldered collar; its construction, together with the ring and stands, suggests it was made by the same workshop that produced the 'astrologer's globes'.

On all examples of this large class of globes there are eight constellations that have particularly unusual iconography not to be found on any other group of globes. For example, Auriga is given a radically new interpretation, for it is depicted as a bearded man sitting cross-legged, with two small animals held in his arms. This image of Auriga is in great contrast to the usual depiction of the clean-shaven man holding reins or a staff in his hand, either standing or sitting with both knees drawn up. See Fig. 8, where Auriga as depicted on a typical globe of this class is contrasted with the standard depiction of the constellation on all other Islamic celestial globes showing constellations.

Fig. 8 **A** *(left). The constellation Auriga as seen on a typical 'rabbit globe' (Nasser D. Khalili Collection of Islamic Art SCI8;* **B** *(right). The standard depiction of the constellation Auriga on earlier globes (Washington, D.C., Smithsonian Institution, NMAH, inv. no. 330,781; unsigned and undated,* c. *1620s, attributed to Lahore workshop).*

The image of Auriga with one or more goats was part of the late medieval and early modern European tradition of celestial cartography, and at some point the notion of Auriga holding small animals must have become available in India by the early nineteenth century. A Carolingian manuscript of the astronomical poem by Aratus (d. 240BC), for example, shows Auriga standing, with a goat perched on his left shoulder and two kids held in his left arm.[30] These two animals in the European tradition appear to be representations of the large star on the western shoulder of Auriga (Capella) whose Arabic name *ʿayyūq* is of obscure meaning but may have derived from a Babylonian word for goat; two other stars on the western arm were called in Arabic *al-jadyān* (the two kids).

On all the Islamic globes of this class, however, the animals held in the arms of Auriga are not goats, but rather long-eared rabbits or hares – for which reason I informally refer to all the globes of this class as 'rabbit globes' – for they have been reproducing like rabbits and they have been flooding the antiques market in recent years – at the moment I know of at least 49 examples, one of which came to light as I was composing this essay.

Fig. 9 *A small 'rabbit globe' set within six decorative, non-functional rings. London, private collection, as of 1994.*

While some of these 'rabbit globes' are made as seamless spheres, the majority are in hemispheres. The makers went in for using unusual alloys, including one of gold and several of silver. Several names of well-known (earlier) astronomers – such Nasīr al-Din al-Ṭūsī (d. 1274) – or earlier instrument-makers appear on some of the globes. On several the ground behind the constellations, circles and labels has been cut back, producing the effect of shallow relief with cloud-bands holding the labels.

In addition to these 49 'rabbit globes', I have in recent years become of aware of 'rabbit globes' set within nonsensical rings. Eleven examples are known, and the number increases by the month. The 'rabbit globe' is set within six or seven rings or bands, the whole arrangement then suspended from a small ring attached to the outer large ring; see Fig. 9 for an example. Three of these 'instruments' are of truly monumental size, with the outside ring nearly shoulder-height next to a person and one example weighing 45 pounds. These are attractive but strictly non-functional. They appear to have been engraved by someone not understanding Arabic, and the placement of stars and the numbering of the graduations (when there are any) are nonsensical. The rings are often fancifully engraved with a

Fig. 10 *A plate with a 'rabbit globe' set at the centre and four smaller ones placed around. This non-functional 'astro-oddity' was found on the web in October 2016 for sale at the Barakat gallery.*

Fig. 11 *An 'astro-oddity' of monumental proportions, photographed in a London garden in 2000. Height* c. *120 cm. Present location unknown.*

profusion of Arabic letters and pseudo-words as well as animal forms on a ground of twisting vines. These items were said to have been purchased in places as far afield as the Yemen and a thrift shop in San Marcos, Texas.

And if that is not enough, there are multiple 'rabbit' globes set within in metal panels. Four examples of these totally non-functional objects are known, three with rectangular plates and one (see Fig. 10) found on the web where it was offered for sale by the Barakat gallery and described as 'Islamic brass astrolabe w/5 celestial globes, India, 19th –20th C'. The ones with rectangular plates were said to have been acquired in Muscat (Oman), in the Yemen, and in Zanzibar.

In addition, there are three similar fanciful objects incorporating one or more 'rabbit globe' in circular discs or octagon plates, which have surfaced since 2012 in Australia and the UK. Stephen Johnston, at the Museum of the History of Science in Oxford, coined the term 'astro-oddities' for all these objects incorporating 'rabbit globes'.

The most elaborate of all such 'astro-oddities' was brought to my attention in 2000 - see Fig. 11. The object stands almost shoulder high. None of the globes are 'rabbit globes', but rather all seem to have inexplicable circles and lines engraved on them. The configuration of the device – with one large sphere and three stationary smaller ones attached to the horizon ring – is nonsensical. Around the horizon ring of the largest sphere there is a massive inscription giving a potted history of astronomy in the Islamic world, in which it says that the first observatory was established in Damascus in 848 (214H) and mentions the early work in Baghdad and the observatories of the early Mughal rulers. It then states that this device was completed on 9 Ramadan 1011 (= 20 Feb 1603) and on that day given to ʿAbd al-Raḥīm Khān, who was commander-in-chief of the army under the Mughal ruler Akbar, who ruled 1556 until his death in 1605. It goes on to say that the army commander then showed it to the Mughal ruler Akbar, and he appreciated it.

I don't believe a word of this inscription, for all you have to do is compare this astro-oddity with the high-quality and technically accurate products of the Lahore workshop that we know made globes for Akbar and other Mughal rulers (see Fig. 4 for one made in 1639) and compare them with this piece of nonsense, and you know something is not right here.

Still today there are probably workshops in India making astrolabes and globes – clumsily executed and often incorporated into fantastical designs. About ten years ago, a source – who does not wish to be identified – said that in Lahore at that time there was workshop of instrument-makers called *Fakirkhāna* ('houses of the poor') that had been active for several generations. In Jaipur, my informant told me, there was a Hindu instrument-maker named Manwan who used tools inherited from his grandfather to make astrolabes and globes, some of them very large and occasionally of silver or gold. He was also said to have made a very large instrument of two towers with a huge astrolabe (?) between the towers. Apparently, according to my source, he sold his instruments to a film producer in Bombay who then used them to raise money for film production. Indeed, I wonder if some of these astro-oddities might have been used on Ballywood film sets as background for science fiction movies.

The identification of fakes and forgeries when studying early intrumentation is not always straight forward. For example**,** a few years ago a remarkable, large (28.6 cm diameter) and extraordinarily heavy (almost 18 pounds) wooden globe emerged on the market[31], bearing the exact same signature as one that has been in Dresden since 1592 and was made around AD 1288 by Shams al-Dīn Muḥammad ibn Muʾayyad al-ʿUrḍī, who was an astronomer at an important observatory at Maragha, in north-western Iran.[32] Great interest was shown in it by several museums, for, if genuine, it would be an important piece of evidence for the instruments used at this thirteenth-century observatory. In 1992 its then owner brought the globe to Oxford and allowed us to undertake a forensic investigation of its legitimacy. The Arabic lettering and constellation outlines, as well as the circles, were made of small irregularly cut pieces of metal, with more fluid lines in some of the constellations formed by inlaid metal wire. We were greatly intrigued by its construction. It was evident on simple observation that the sphere had been made of several very large, and heavy, pieces of wood, and we thought there was a medal rod passing through it that both served as the axis through the ecliptic poles and in some way held it together. There appeared to be no way of mounting it using the celestial poles; the wood has split in places as it dried and contracted, and there was damage to some areas. Radiocarbon dating indicated that the wood – identified as Oriental Plane Tree, *Platanus orientalis* L. – was felled between 1680 and 1950 AD—hence not thirteenth-century.[33] The analysis of the metallic components[34] indicated the alloy was dominantly copper with about 32% zinc, and the inlaid wire was produced by a technique developed in the seventeenth to eighteenth centuries. X-rays and CT scans[35] revealed that there was not a single dowel running through the axis, but in fact the two protruding pieces of metal were quite short and did not even go half-way through the first piece of wood. The CT scans also showed us that the sphere was composed of two large horizontal slabs plus composite caps of two pieces each, with no beveling or toothing or dowels or other devices to interlock the pieces. So the question became, what was holding it together. Finally, a hypodermic biopsy in a seam revealed that the glue was not the traditional glues of fish bones or resins but rather it was epoxy resin, first discovered in the 1930s by Paul Schlack of Germany in 1934 and Pierre Castan of Switzerland and patented in 1938.

This globe, however, I would suggest was not made for sale – that is, it probably was not

an intentional fake. It is, I believe, a modern copy by someone who saw the lithograph of the Dresden globe that was published in 1873[36], and the craftsman was unaware of how to make a metal globe but familiar with inlay work in wood, and so used the technique he was most familiar with to make a model or copy of what had been described and illustrated in the lithograph. In other words, it is an example of a person wishing to make a copy for his own enjoyment.

On the other hand, a modern copy of the same Dresden globe that recently came to light may have been made to deceive a buyer.[37] It is a metal globe having a seam along the ecliptic and a diameter essentially the same as the original (13.9 cm); it is carefully engraved, though lacking the damascening on the Dresden globe, and the stars are casually positioned. The rings and stand are completely modern and do not correspond to those of the original Dresden globe.

There are also modern versions of medieval globes that are not forgeries intended to deceive but rather completely honest reproductions. An outstanding example is one made by Mohammad Zakariya, a calligrapher in Washington D.C. In an Arabic inscription on the globe he stated that he made the globe in 1984, based on the design of a globe and ring-stand now in Naples that was made in 1225 (622H) by Qayṣar ibn Abī al-Qāsim ibn Musāfir al-Ashrafī al-Ḥanafī.[38] Mohammad Zakariya goes on to say in the inscription on this recent globe that he made it for an historical exhibition in a new science and technology museum being built in 1984 by Aramco in Dhahran, Saudi Arabia.

To bring to a close this discourse on the seemingly endless variety of celestial globes produced in the Middle East, I will end with an example of how difficult it is to detect a copy or a forgery based on an early globe. In 1892 the Musée du Louvre acquired a globe bearing a date equivalent to 1285 (684H) with the maker's name of Muḥammad ibn Maḥmūd al-Ṭabarī, an instrument maker known from other sources.[39] A globe bearing the identical date and maker's name came recently into the Nasser D. Khalili Collection of Islamic Art.[40] The method of construction of the one in Paris as – well as other features – reveal it to be a nineteenth-century Indian *copy* of the original globe made by al-Ṭabarī, which is the one now in the Khalili Collection. The nineteenth-century copy – now in the Louvre – is a seamless globe made using techniques not known to exist until developed in Lahore at the end of the sixteenth century, while the globe now in the Khalili Collection was made in hemispheres – in keeping with a thirteenth-century product.

It is evident that while the Indian workshop of Balhūmal continued in the nineteenth century to produce globes – very well made ones – that made no pretense of being anything other than modern instruments that continued a medieval tradition, *other* metalworkers in India in the nineteenth century produced celestial globes with dates or maker's names the purported to be from an earlier period.

The number of recorded Islamic celestial globes is continually increasing. In 1985 I knew of 130 globes of only three types. The number has now risen to 290 (possibly more, depending upon how you count them) and several variant designs have emerged. In thirty years they have far more than doubled – nearly trebled – in number. And of these, some are precise and early examples of scientific instrumentation, others were made by less skillful artisans, some are honest copies of earlier instruments, some fraudulent fakes, some of use only to astrologers, and some fancifully reworked into monumental decorative pieces of no utility whatsoever.

Notes and References

1. Francis R. Maddison and Emilie Savage-Smith, *Science, Tools & Magic* (London & Oxford, 1997), pp. 168–85, 212-13, 234-59; Emilie Savage-Smith, *Islamicate Celestial Globes: Their history, construction, and use* [Smithsonian Studies in History and Technology, no. 46] (Washington, D.C., 1985); Emilie Savage-Smith, 'Celestial Mapping' in J. B. Harley and David Woodward, eds, *The history of cartography*. *II.2: Cartography in the traditional Islamic and South Asian societies*, (Chicago, 1992), pp. 12–70; Silke Ackermann, 'Islamic globes' in Elly Dekker, *Globes at Greenwich: A catalogue of the Globes and Armillary Spheres in the National Maritime Museum, Greenwich* (Oxford, 1999), pp. 177–98; David Pingree, *Eastern astrolabes: Historic scientific instruments of the Adler Planetarium & Astronomy Museum,* Vol. II (Chicago, 2009), pp. 228–238; Sreeramula Rajeswara Sarma, *Astronomical Instruments in the Rampur Raza Library* (Rampu, 2003), pp. 61–73; Emilie Savage-Smith, 'The Classification of Islamic Celestial Globes in the Light of Recent Evidence', *Der Globusfreund*, **38/39** (1990), pp. 23–35 and plates 2–6; Elly Dekker, *Illustrating the Phaenomena: Celestial Cartography in Antiquity and the Middle Ages* (Oxford, 2013), pp. 307–336; Emilie Savage-Smith, 'Globes (Celestial and Terrestrial)' in *The Encyclopaedia of Islam—Three*, (2016), pp. 129–132.

2. It was made by a well-known astrolabe maker Ibrāhīm ibn Saʿīd al-Sahlī al-Wazzān in collaboration with his son Muḥammad; Florence, Istituto e Museo di Storia della Scienza, inv. no. 2712. See Elly Dekker, *Catalogue of Orbs, Spheres and Globes, Istituto Museo di Storia della Scienza* (Florence, 2004), pp. 112–118 ; Dekker (note 1), pp. 323–325; Savage-Smith, *Islamicate Celestial Globes* (note 1), p. 217 no. 1. An undated and unsigned globe of essentially the same time period, and of very similar design, is now in the Bibliothèque nationale de France; see Elly Dekker and Paul Kunitzsch, 'An early Islamic tradition in globe making', *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften*, **18** (2008/2009), pp. 155–211.

3. Made by Jaʾfar ibn ʿUmar ibn Dawlatshāh al-Kirmānī; diameter 16.5cm; Oxford, Museum of the History of Science, in. no. 44790. See Savage-Smith, *Islamicate Celestial Globes*, pp. 221–222 no. 7 & fig. 9; Dekker (note 1), pp. 334–335.

4. See Maddison & Savage-Smith (note 1), pp. 180–185.

5. See Dekker (note 1), pp. 282–307; Edward S. Kennedy, 'Al-Ṣūfī on the Celestial Globe', *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften*, **5** (1989), pp. 48–93; Richard P. Lorch and Paul Kunitzsch, 'Ḥabash al-Ḥāsib's Book on the Sphere and Its Use', *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften*, **2** (1985), pp. 68–98; W. H. Worrell, 'Qusta ibn Luqa on the Celestial Globe', *Isis*, **335** (1944), pp. 285–93; Richard Lorch and José Martínez Gázquez, 'Qusta ben Luca: de sphera uolubili', *Suhayl*, **5** (2005), pp. 9–62; Julio Samsó, 'Qusṭā ibn Lūqā and Alfonso X on the Celestial Globe', *Suhayl,* **5** (2005), pp. 63–79.

6. Doha, Qatar, MIA, MS 2.1998, fols. 50b-51a. For a discussion of this manuscripts, see E. Savage-Smith, 'The Most Authoritative Copy of ʿAbd al-Raḥmān al-Ṣūfī's Tenth-century *Guide to the Constellations*' in Sheila Blair and Jonathan Bloom, eds, '*God is Beautiful; He Loves Beauty*': *The Object in Islamic Art and Culture* (New Haven, 2013), pp. 122–155.

7. Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 247–263, 176 (nos. 59–90 & 130-132); Dekker (note 1), p. 308 fig.4.12.

8. E. Savage-Smith, 'An Arabic Celestial Globe in Tartu', *Tartu Ülikooli ajaloo küsimusi*, **41** (2013), pp. 221–230. The stand may be later replacement.

9. An unpublished 18th or 19th-century Turkish example is Doha, Qatar, MIA SI.13.2002.

10. Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 263–275 nos. 92–124.

11. Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 223–224 no. 10 and figs.11 and 69; the diameter is unknown, for only photographs were available for study.

12. An example of one of their globes with a purposely darkened surface, made in 1663 (1074 H) by Diyāʾ al-Dīn Muḥammad Aṣṭurlābī Humāyūnī Lāhūri, is in Oxford, Museum of the History of Science, inv. no.

57-84/25. For a discussion and illustration, see Savage-Smith, *Islamicate Celestial Globes* (note 1), p. 231 and figs. 40, 43, and 47.

13.Washington, D.C., National Museum of American History, Division of Physical Sciences, Inv. no. 330,781; acquired in 1974 from the collection of Ernst Nagel of San Francisco.

14. The results of the tests and examination were summarized in Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 93–95.

15. London, The Nasser D. Khalili Collection of Islamic Art, SCI285. The globe has a diameter of 37cm, and the height of the stand (original to the globe) is 16. cm; it is undated and unsigned but has all the distinctive features characteristic of products from the workshop of Lālah Balhūmal Lāhūrī. See Maddison & Savage-Smith (note 1), p. 242–245 cat. 140.

16. For three published examples, see Silke Ackermann 'Islamic Globes' (note 1), pp. 184 (GLBO141) and 193 (GLBO180); and Savage-Smith, *Islamicate Celestial Globes*, p. 237 no. 36 & fig. 19, p. 246 no. 56 & fig. 29, and p. 276 no. 129. In 2009 a remarkable wooden celestial globe, covered with a coat of gesso and given a bright blue ground on which gilt great circles and brightly coloured constellations were painted, was offered for sale in Paris; it appears to have an inscription suggesting it was made in 1752 (1166H) for Sultan Husayn and displays considerable European influence in the depiction of the constellation figures.

17. Some seventeenth-century European celestial globes, however, display knowledge of Arabic star-names. See Emilie Savage-Smith and Colin Wakefield, 'Jacob Golius and Celestial Cartography' in W. D. Hackmann and A. J. Turner, eds., *Learning, language and invention: Essays presented to Francis Maddison* (London, 1994), pp. 238−60; Paul Kunitzsch, 'Coronelli's Great Celestial Globe Made for Louis XIV. The Nomenclature', *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften*, **14** (2001), pp. 39–55.

18. Only two spherical astrolabes are preserved today, one by an otherwise unknown maker named Mūsā in 1480 (885H), now in Oxford, Museum of the History of Science, and the other an unsigned undated example made (possibly in the sixteenth century) for use in Tunis. For the latter, see Ernesto Canobbio, 'An Important Fragment of a West Islamic Spherical Astrolabe', *Annali dell'Istituto e Museo di Storia della Scienze di Firenze* **1** (1976), 317-41; the rotating pierced cap forming the rete is missing. A fragment of a third spherical astrolabe was put up for sale at Christie's in London in 2015.

19. Oxford, Museum of the History of Science, Billmeir coll. inv. no. 57-84/182; diameter 13.1 cm. See Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 258–259 no. 81 & fig. 22; Savage-Smith, 'Celestial Cartography' (note 1), p. 48 and fig. 2.30.

20. Damascus, Musée Nationale, inv. A.4485; diameter 22.4 cm. See Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 256–257 no. 75 & fig. 28. Francis R. Maddison suggested the unusual network of semi-great circles and parallels was intended for use in measuring the coordinates of the ecliptic, by placing the axis of the globe in a horizontal position and tilting it at an angle equivalent to the obliquity of the ecliptic.

21. The Nasser D. Khalili Collection of Islamic Art, SCI 155. For an illustration and discussion, see Maddison & Savage-Smith (note 1), pp. 256-259 cat 151.

22. Chicago, Adler Planetarium and Atronomical Museum, inv. no. A-114; diameter 14.9 cm. See Pingree (note 1), pp. 234–235; Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 249–250 no. 63 and fig. 10.

23. Cambridge, Whipple Museum of the History of Science, inv. no. 1410, unsigned, undated, diameter 12.1 cm, and Greenwich, National Maritime Museum, inv. no. GLB0142, unsigned, undated, diameter 18 cm. For the latter, see Ackermann (note 1), pp. 189–190, and for both globes, see Savage-Smith, *Islamicate Celestial Globes* (note 1), p. 259 nos. 82 and 83.

24. Emilie Savage-Smith, 'Two Astrologer's Globes' in Maddison & Savage-Smith (note 1), pp. 160–65.

25. The Nasser D. Khalili Collection of Islamic Art, SCI 51 and SCI43; see Maddison & Savage-Smith (note 1), pp. 163–165 cat 113 & 114. One of this type was in the private collection of R. Kaplan in Los Angeles as of 1997, and another was brought into Christie's in South Kensington for examination in 1989 and then withdrawn from sale (present location is unknown). The globe in Los Angeles had the names of angels and the Urdu names of the lunar mansions, which were not on the other three globes.

26. Emilie Savage-Smith, 'Appendix I: Modern Indian Globes' in Maddison & Savage-Smith (note 1), pp. 406–413.

27. Firdawsi, *The Epic of the Kings. Shah-Nama, the national epic of Persia by Ferdowsi*, translated by R. Levy, revised by A. Banani (London, 1967).

28. The Nasser D. Khalili Collection of Islamic Art, SCI284; see Savage-Smith (note 26), pp. 408–409 cat 382.

29. London, British Library, MS Or. 5259; the maps are on fols. 56v and 57r. For an illustration, see Savage-Smith, 'Celestial cartography' (note 1), p. 69 fig. 2.49.

30. Leiden, University Library, MS Voss lat.Q 79, fol. 22v; see Renee Katzenstein and E. Savage-Smith, *The Leiden Aratea: Ancient Constellations in a Medieval Manuscripts* [exhibition catalogue] (Malibu: CA: J. Paul Getty Museum, 1988), p. 23.

31. Present location unknown. It was brought to Oxford for examination in 1992. It was said to have been acquired about five or six years earlier from a Russian family who said it had been in the family for generations.

32. Dresden, Staatlicher mathematisch-physikalischer Salon. See Moya Carey, 'The Gold and Silver Lining: Shams al-Dīn Muḥammad b. Muʾayyad al-ʿUrḍi's Inlaid Celestial Globe (*c*. AD 1288) from the Ilkhamid Observatory at Marāgha', *Iran*, **47** (2009), pp. 97–108; Savage-Smith, *Islamicate Celestial Globes* (note 1), p. 220 no. 5.

33. The report on radiocarbon dating was prepared by Dr Clare Anglias at the Radiocarbon Accelerator Unit in Oxford. and the wood analysis by Peter Franklin of Plant Sciences Department. Also of assistance were Esther Cameron, of the Archaeological Institute, Tony Simcock and Lyn Forman of the Museum of the History of Science, and Dr Alan Scott of Applied Computing.

34. Carried out by Dr R.A. Jarjis using the Oxford Scanning Proton Microprobe at the University of Oxford.

35. Conducted at the Computerized Tomography Unit and X-Ray Units in the Old Radcliffe Infirmary x-ray department by Dr James Bryne, radiologist, and Amarjit Bhamra and Elizabeth Sands, radiographers.

36. Adolph Dreschsler, *Der arabische Himmels-Globus angefertigt 1279 zu Maragha von Muhammed bin Muwajid Elardhi zugehörig dem Königlichen mathematisch-physikalischen Salon zu Dresden* (Dresden, 1873).

37. Vienna, private collection Rudolf Schmidt, Islamic globe no. 1. It was acquired about 1983 from a dealer in Amsterdam.

38. Naples, Museo Nazionale; Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 218–219 no. 3.

39. Paris, Musée du Louvre, Département des antiquités orientales, section Islam, OA 6013; Savage-Smith, *Islamicate Celestial Globes* (note 1), pp. 220–221 no. 6 and fig. 6.

40. The Nasser D. Khalili Collection of Islamic Art, SCI21; Maddison & Savage-Smith (note 1), pp. 212-213 cat. 123. See also Sophie Makariou, ed., *L'apparence des cieux: astronomie et astrologie en terre d'Islam* [exhibition catalogue] (Paris: Musée du Louvre, 1998), item 54.

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