astronomical instruments
IN THE
SALAR JUNG MUSEUM

By Dr. Sriramula Rajeswara Sarma

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THE ASTRONOMICAL INSTRUMENTS
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By

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Cover picture :
ASTROLABE
by ALLAHDAD
of 975/1567 A.D.
Front view (Acc. No. 113/1/XXXV).

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PREFACE

This comprehensive account on **"THE ASTRONOMICAL INSTRUMENTS IN THE SALAR JUNG MUSEUM"**, was the result of a detailed study of the collections undertaken by Dr. Sreeramula Rajeswara Sarma during the years 1991 (June and December) , and 1995 (March). Dr. Sarma readily accepted our invitation to deliver the Salar Jung Memorial Lecture on this very topic during the 109th Birthday Celebrations of Nawab Salar Jung III (18th March, 1995). He gave the manuscript with select illustrations for publication. This paper was originally published in the **SJM BI-ANNUAL RESEARCH JOURNAL, XXXI-XXXII (1994-1995)** at pages 153-189. In view of the topical interest and reference value of this important contribution, it is felt appropriate, to bring it out as a separate monograph for the benefit of the scholarly world.

Dr. Sarma hailed from Ulichi Village, Prakasam dt. (A.P) and holds an M.A. (Sanskrit) from Visvabharati, Santiniketan and D.Phil. from Marburg. He is presently Chairman, Dept. of Sanskrit, Aligarh Muslim University, Aligarh. He also served as Visiting Associate Professor of History of Mathematics, Brown University, Providence, USA (1992-93) and Visiting Professor at Universite de Paris III (1994-September-October).

The present monograph is an important one, and for the first time, brings to light the rare Astrolabes of the Salar Jung Museum. We learn that Dr. Sarma is also preparing a Catalogue on the Astrolabes of the British Museum. We are deeply beholden to Dr. S.R. Sarma for this valuable contribution.

Dr. I.K. SARMA

LIST OF ILLUSTRATIONS

Fig. 1: Lahore Family of Astrolabists and their Instruments in the Salar Jung Museum.

THE ASTRONOMICAL INSTRUMENTS IN THE SALAR JUNG MUSEUM

By Dr. S. Rajeswara Sarma

In connection with a project of preparing *A Descriptive Catalogue of Indian Astronomical and Time-Measuring Instruments*[1], the author had occasion to study the astronomical instruments preserved in the Salar Jung Museum of Hyderābad. Before any discussion of the importance of this collection consisting of six astrolabes and four celestial globes, it is necessary to give a brief introduction to these two types of instruments. Both these instruments were invented originally in Hellenistic antiquity, but they reached their perfection in the Islamic world. From there they were transmitted westwards to Europe and eastwards to India. In the Islamic world, they were the two most popular astronomical instruments, and the usual mode of describing a good astronomer was to say that he was an expert in the use of the astrolabe and the celestial globe.

ASTROLABE

The most common type of the astrolabe[2] is the one known as the planispheric astrolabe or flat astrolabe *(Latin: astrolabium planisphaerum; Arabic: asturlāb sattī or musattah or dhāt al-safiha)*. It consists of a heavy circular plate called mater, with a raised rim all around, into which are received a number of thin plates called *Safiha*. On the mater is usually engraved a list of towns with their geographical coordinates. The mater is endowed with a crown-like projection *(Kursī)*, often highly ornate, to which are attached a shackle, a ring and a cord for suspending the instruments. The *Safiha* Plates contain stereographic projections of altitude circles, azimuth circles, horizon, hour lines etc., pertaining to a specific terrestrial latitude. In order that the astrolabes can be used at different localities

having different latitudes, they are generally provided with more than one plate, each plate being engraved for a separate latitude. At the centre of the plate is written the latitude for which the plate is calibrated and also the duration of the longest day at this latitude. The astrolabe contains a host of numerical values engraved on its surface in abjad notation.

A raticulated or open work plate, pivoted to the centre of the astrolabe, rotates freely over the latitude plates. It is called Ankabūt (i.e. spider) in Arabic and rete (i.e. net) in Latin. In English, it is customary to use the Latin word rete. It contains projections of the ecliptic, devided into 12 signs of the Zodiac, and also of the positions of about 30 principal fixed stars. Leaving the minimum of space needed for the ecliptic circle and the star pointers, the rest of the plate is cut out in such a way that, through these perforations, the engraved lines of the Safiha can be read. These pierced retes often exhibit very beautiful designs. By rotating the rete upon the Safiha of a particular latitude, the altitudes and azimuths of various stars at that latitude at a given time can be ascertained.

At the back of the astrolabe, a narrow bar called alidade is pivoted to the centre by means of a pin (qutb), so that it rotates freely, its ends touching the graduated circumference. At both ends of the alidae, there are sighting vanes with minute holes through which heavenly bodies are sighted and their altitudes measured. The pin is held in position by a wedge called *faras* (horse) because it usually has the shape of the horse's head.

With the astrolabe, one can measure time both in the day and in the night. One can measure time in seasonal hours or in equal hours. One can also ascertain the Muslim prayer times. From its dial can be read directly the ascendant (sanskrit, *lagna*), i.e. the point on the ecliptic or the sun's apparent path which is rising above the eastern horizon for any given time. The ascendant is necessary for casting the horoscope. The front side with the rete rotating upon the

stereographic projections of the Safiha plate can be used as an analogue computer for solving problems in spherical trigonometry. The astrolabe can also be used in land survey, e.g. in measuring the heights and distances of buildings and other objects.

In short, in medieval times, the astrolabe enjoyed a reputation comparable to, or even greater than, that of the modern computer. When one held an astrolabe in one's hand, it was thought that one held all the mysteries of the universe.

The astrolabe may have been introduced into India in the eleventh century by Al-Bīrunī, but its manufacture appears to have commenced only in the fourtheenth century under the patronage of Sultān Fīrūz Shāh Tughluq[3]. The Sīrat-i Firūz-Shāhi reports that different types of astrolabes were manufacture at his Court. Firūz also induced Mahendra Sūrī, a Jaina monk, to compose the first ever manual in Sanskrit on the construction and use of this instrument in 1370. Impressed by its versatile functions, the Sūri called it *Yantrarāja*, "the king of astronomical instruments", and it is by this name that the instrument is known in India[4]. Following him, Hindu and Jaina astronomers began to use the the astrolabe and composed more than a dozen manuals in Sanskrit in the next five centuries.

But no specimen manufactured in India in the fourteenth or in the fifteenth century is extant today. The earliest specimens we know of were made by Allāhdād of Lahore, the royal astrolabist of emperor Humāyūm, who was himself a great expert in the use of the astrolabe and the celestial globe[5]. Under his patronage, Allāhdād – and later on his descendants for the next three generations – manufactured a large number of astrolabes. This Lahore family of astrolabe makers played a very curcial role in the development of scientific instrumentation in India during the sixteenth and seventeenth centuries. Today we know of more than one hundred instruments signed by seven members of this family belonging to four successive generations. There are also many unsigned instruments which can be attributed

to this family on stylistic grounds. These instruments are now scattered in various parts of the world : India, Pakistan, Iraq, Kuwait, Egypt, Turkey, France, Germany, the Netherlands, Britain, Canada and the United States of America[5]. Astrolabes were made outside this family as well, but not in such great quantities. There is also a large number of astrolabes having labels in Sanskrit language and in Devanāgarī script.

CELESTIAL GLOBE

While the astrolabe is an observational and computational instrument, the celestial globe (Arabic al-kura) is purely meant for teaching and demonstration[6]. On the globe are marked the positions of a large number of stars, together with the ecliptic, equator, arctic circles etc. On Islamic globes, usually the positions of some 1018 stars are marked accordding to the coordinates given in Ulugh Beg's tables. Besides the stars, which are indicated by inlaid silver points of varying sizes according to the magnitude of the star concerned, about 48 constellation figures including the figures of the 12 signs of the Zodiac are engraved in outline.

The globe is set up on a stand, consisting of a graduated horizontal ring, supported by three or four legs. Perpendicular to the plane of the horizontal ring runs another graduated ring, representing the meridian. The axis of the globe is affixed to the meridian ring in such a way that it has an inclination equal to the local latitude. By turning the globe to the appropriate degree of the ecliptic, the position of the starry heavens at that locality at a given day can be replicated, as is done today in a planetarium.

Celestial globe is a relatively late-comer to India[7]. It seems to have been introduced into India by Humāyun. Celestial globes were also manufactured by various members of the Allāhdād family the earliest known specimen being the one crafted by Allahdad's grand-

son Qaim Muhammad[8] in 1622. Globes were also manufactured by others, and there is a small number with labels in Sanskrit language and Devānagarī script.

THE SALAR JUNG MUSEUM COLLECTION

The six astrolabes and the four celestial globes preserved in the Salar Jung Museum have not been studied before. In 1935, Syed Sulaiman Nadwi published an article entitled "Some Indian Astrolabe Makers" in the Islamic Culture. In this article, Nadwi enumerated eight astrololabes and four celestial globes manufactured by four different members of the Lahore family of astrolabists. Nadwi wrote that an astrolabe manufactured by Allāhdād in 975 AH was then in the library of Sir Salar Jung Bahadur of Hyderabad and reproduced the inscription[9].

Some fifty years later, in 1986, Professor Gerard L'E. Turner of Oxford, who is the Secretary of the Scientific Instrument Commission of the International Union of History & Philosophy of Science, toured India to see the scientific instrument collections here. In a privately circulated report,[10] he noted that in the Salar Jung Museum "There are only a few scientific artefacts, the most important being a group of six astrolabes and four celestial globes, all Islamic. The museum attributes them to the family of Alladad of Lahore, one being dated A.H. 975 (A.D. 1567/8)."

Professor Turner kindly drew my attention to this collection during the International Congress on History of Science at Hamburg in 1989. Two years later, when I embarked on a survey of the extant astronomical and time-measuring instruments of India, I naturally made this collection the starting point of my survey. I had studied these ten instruments for the first time in June 1991. Again in December of the same year, I saw the instruments once more in the company of Professor Dr. David king, Director of the Institute of History of Science, Johan Wolfgang Goethe University, Frankfurt.

who is a foremost authority on Islamic astronomical instruments. I am greatly benefited by his comments and also his notes which he made available to me.

This collection of astronomical instruments is important in several respects. It contains Allāhdad's exquisitely crafted astrolabe of A.D. 1567 (Catalogue No.1), which is not only the earliest dated astrolabe manufactured in India, it is in fact the earliest dated Indian scientific instrument known to us. Besides this astrolabe, the museum also holds a representative collection of astrolabes and globes made by four of the seven members of Allāhdād's family. In fact, six of the ten instruments in this museum are made by various members of this family. (Phs. 23-24). As will be shown below, the astrolabe with a zoomorphic rete created by Allāhdād's grandson Muhammad Muqīm in A.D. 1637(Catalogue No.2) is also a unique piece.

Until now no astrolabe or celestial globe made in Deccan was known. Therefore, it was assumed that this art was confined only to the Western and northern parts of India. In this respect, the celestial globe (Catalogue No.7) manufactured by Muhammad Fadlullah, son of Muhammad Murād, son of Muhammad Musa the astrolabist of Aurangabad, dated A.D. 1808, is highly interesting. It is the only known piece made in Deccan. While the star positions in other Islamic globes are usually marked according to the coordinates determined by Ulugh Beg in his tables, the star positions on this globe are marked according to the coordinates in the Zīj Jadīd-i Asafia, compiled by Husain Khan Rizwi in Hyderabad. It is worth investigating if any other astrolabes or globes manufactured by Fadlullah, or by any other member of his family, are still extant.

All the instruments in this collection are in a good state of preservation. However, the astrolabes appear to have been repaired at a late date by the same craftsman, who replaced the missing alidades, pins and screws with new but crude ones. Thus, instead of alidades with sighting vanes, the astrolabes are now equipped with crude sighting tubes, which are clearly later additions. Likewise, in some cases, the pins holding the several parts of the astrolabes have been replaced by screws and rivets.

Of the two Mughal celestial globes in this collection, the globe by Diyā al-Dīn (Catalogue No.7) does not have the original meridian ring, consequently it cannot be mounted properly. The other one, by Hāmid (Catalogue No.8), lacks the entire stand. It is now mounted on a nineteenth century stand. Nevertheless, this is an important collection with many unique pieces to its credit. In the entire southern India, there is no other collection of historically valuable scientific instruments comparable to this one at the Salar Jung Museum.

THE CATALOGUE

1. ASTROLABE, BY ALLĀHDĀD 975 A.H./A.D. 1567

Acc. no. 113/1/XXXV (Phs. 1 to 3)

This is the earliest extant astrolabe manufactured in India[11]. In fact, it is the earliest dated scientific instrument of India that is extant today. At the Museum of History of Science, Oxford, there is one more astrolabe produced by this astrolabist, but it does not bear a date[12]. On both these astrolabes, he signs his name as Ustād Allāhdād Asturlabi Lāhūri, thus proclaiming himself as a resident of Lahore. His descendants, in all their creations, give their complete genealogy starting from Allāhdād. Here they usually mention the patriarch as Shaykh Allāhdād Asturlābi Humāyuni Lāhuri. The attribute asturlabi humāyuni can only mean that he was the royal astrolabe maker to Humāyūn. Though the only dated instrument by him, namely the astrolabe here, is manufactured in 1567, i.e. eleven years after Humāyūn's death, this does not go against the assumption that he may have made astrolabes (perhaps even celestial globes) in Humāyūn's life-time.

This astrolabe measures 199 mm in diameter and has a thickness of 11 mm. This is a rather large and heavy piece. It could not have

been meant for the daily use of a common astronomer, but only as an ostentatious piece used by a high nobleman.

The astrolabe is suspended by a circular ring with a diamond-shaped cross-section. To this is attached a shackle. Its upper part has a trefoil shape with a triangular cross-section. The lower part of the shackle is rivetted to the top of the throne or Kursī. The Kursī is high and solid, with seven labes on either side. The lower-most is longer and more prominent and is pierced by a hole, a feature that recurs in several astrolabes. On the front a geometrical pattern is engraved on the surface of the Kursī. With one or two exceptions, all other astrolabes produced in the family have pierced or fretwork Kursīs, and none have such a surface decoration with a geometrical pattern. Indeed Allāhdād's second astrolabe at Oxford has an equisitely pierced Kursī.

The rim of the mater measures 12 mm in width and carries two scales. The outer one is graduated in groups of 5° and labelled clockwise from 5° to 360° in abjad notation. The inner scale is graduated in single degrees of the circle. On the inner side of the mater, there is a geographical gazetteer of 96 cities, engraved in two sets of five concentric circles. For each entry, five cells are envisaged to carry respectively the names of cities (al-bilād), their longitudes (al-tūl), latitudes (al-'ard), their orientation towards Macca (al-inhirāf) and the duration of the longest day (al-sāat). The majority of the cities are from the Middle East, starting from Mecca at 21;40° N and reaching up to Samarqand at 39;37° N latitude. But there are also a few Indian cities, and this number grows with each successive descendant. Surprinsingly enough, the last two cells meant for the inhirāf and the longest day are left blank. In the case of Najaf, except the name all other cells are empty. In the astrolabe at Oxford, all these values are given for some 157 towns. Allāhdād's successors also provide such gazetteers of towns, but they give only the latitudes and longitudes.

On the rete, there is a complete equinoctial bar which is counter-changed at the centre, but the solstitial bar runs only in the upper half of the rete. Large arcs of the circle representing the equator are shown both within and below the exliptic. The latter is devided in groups of 6° and in 2° but not labelled. The names of the signs are engraved. There are 28 star-pointers on the rete. These exhibit an archaic pattern of tiger's claws, sometimes with two or three lobes. This style is not emulated by any other member of the family. Even in his second astrolabe, now at Oxford, Allāhdād adopts a floral tracery to connect the star pointers, and this becomes the hallmark of the retes manufactured not only in this family but of all Mughal astrolabes in general.

There are 5 plates or tympans containing stereographic projections for nine different latitudes. The plates bear numbered altitude circles for each 2° and therefore the astrolabe belongs to the nisfī or bipartite category. The azimuth circles are drawn only below the horizon for each 10° and numbered. Besides the curves for seasonal hours, there are also additional curves for the hours since sunset and before sunrise, both up to the meridian. The prime vertical, the horizon curve, and the additonal hour curves are inlaid with silver. This is an unusual feature, not to be met with anywhere in the extant astrolabes. The plates serve the following latitudes:

Plate no.	latitude	longest day	location
1a	21;40	13;02 h	(Mecca)
2a	27	14;34	
3a	28	14;40	
4a	28;30	12;49	(Delhi)
2b	30	13;57	
1b	33;25	14;12	(Baghdad)
5a	34;0	14;17	
5b	39;37	14;52	(Samarqand)
3b	45	15	
4b	horizons		

Although Allāhdād calls himself a Lāhūri, it is intriguing that there is no plate for the latitude of Lahore either in this astrolabe or in the one at Oxford. It is also strange that the latitude of what is probably Delhi is widely off the mark. Plate no.4a mentions it as 28;20°, but in the geographical gazetteer it is mentioned as 28;15°. But the more accurate value 28;39° was known as early[13] as 1370. Remarkable is also the fact that the five plates exhibit slightly different colouration, suggesting that they were cut from different sheets of brass with varying proportion of copper. The rete also appears to contain in more copper than the rest of the components. (See the Appendix).

On the back, the upper half of the rim is graduated, as in the front, in groups of 5° and then in single degrees. The former are labelled in abjad notation from 5° to 90° and then from 90° to 5°. In the lower half of the rim, there is a circular scale of shadows.

The back is devided into four quarters. In the upper left quadrant, there is a trigonometric grid with horizontal parallels for each degree. This is the so-called sine quadrant, where the angles of altitude can be converted automatically into the corresponding sines.

In the upper right, there is a solar quadrant or zodiac quadrant with quarter circles for each 30° or single Zodiacal sign. These arcs are equi-distant, whereas in the persian astrolabes they are stereographically projected. Moreover, in Persian astrolabes, graphs for equal hours at various localities are plotted upon these arcs. Allāhdād omits such equal hour graphs on both his astrolabes and engraves just the arcs. Later on, his decendants began to plot sigmoid graphs for the meridian solar altitude at Lahore and Agra, the two imperial capitals. Such graphs appear to have been introduced for the first time by Allāhdād's son Īsa.

In the two lower quadrants are engraved the shadow squares for 12 digits and 7 feet respectively. An elaborate astrological table is

incorporated within these squares, featuring triplicities, influence of the ascendant on various human conditions and faces. The maker's inscription is engraved below the shadow squares and reads as follows:

San'at Ustād Allāhdād Asturlābī Lahūrī fi sanah 975, "made by Master Allāhdād, the astrolabist of Lahore, in the year 975 (Hijri = 1567-8 A.D.)".

The original alidade, pin and horse are missing. These are replaced by crude substitutes. Now there is a straight alidate with turtle-head-shaped ends and a five-lobed central part. A cylindrical sighting tube is attached to the sights. The pin and the horse are replaced by a modern screw and a rivet.

2. ASTROLABE BY MUHAMMAD MUQIM 1047/1637

Acc. No.114/1/XXXV (Pls.4 and 5)

Muhammad Muqim is the second son of Mullā or Hafiz Īsa and a grandson of the patriarch Allāhdād. He is the most prolific astrolabe maker of this family. I have counted some 37 astrolabes and one celestial globe made during the course of fifty years between A.D. 1609 and 1659. There are also about eight unsigned astrolabes which may be attributed to him. However, in none of these creations does he ever repeat himself. Muqim produced a number of large sized astrolabes, and also the world's smallest astrolabe. This miniature astrolabe has a diameter of just 43 mm, with five finely engraved plates. The kursi was cut a jour incorporating the phrase Allah-u Akbar. This delicate piece fits nicely into the palm and thus illustrates the saying that the astrolabe represents the universe in one's own palm. Neither the large ones nor this very small piece are really convenient for actual use but must have been highly prized collector's items at the Mughal Court.

The present astrolabe is a large piece measuring 256 mm in

diameter 13 mm in thickness. It is suspended by a large ring with a diamond-shaped cross section. To this is attached a small shackle; its upper part is circular, and the lower part is rivetted to the top of the kursi.

The kursi is high and is intircately pierced with several interlinking triangles and vines. The top of the kursi terminates in a trefoil design. Both sides of the surface of the fretwork of the kursi display leaves and tendrils in shallow engraving with a slightly different colouration[14].

The rim of the mater measures 12 mm in width. The outer circle is graduated in groups of 5° and labelled clockwise from 5° to 360° in abjad notation. The inner part of the rim is graduated is single degrees of the circle. On the inner side of the mater is an elaborate gazetteer of 160 towns with their longitudes and latitudes, engraved in five concentric circles (48 + 40 + 32 + 24 + 16).

On the rete, there is a complete equinoctial bar which is counter-changed at the points where it intersects the ecliptic. The ecliptic circle is divided into signs and labelled. It is further divided into groups of 5° and in single degrees. Like the other productions of Muqim, this rete too exhibits an intricate floral pattern, with circular loops of vines, tendrils, leaves, buds and flowers. More important still is the fact that of the 45 star pointers as many as 28 are zoomorphic. That is to say, they display the animal shapes of the respective constellations, as conceived in the Hellenistic or Beduin traditions[15]. For example, Sirius, the dog star (alpha Canis Majoris) is shown with a dog's head, or Pegasus by a horse. Here Muqim cuts the outline of the desired shape upon which he engraves the appropriate lines for the eyes etc.

We shall describe below the zoomorphic shapes and explain their significance, in a regular sequence starting from the east and proceeding in the anti-clockwise direction. For each star, we shall provide first (i) the Arabic name of the star as engraved on the

astrolabe, (ii) its literal translation, (iii) the scientific name and (iv) modern English/European name, which in most cases was derived from the Arabic name and then describe the zoomorphic shape in which the star is represented.

The first major constellation south of the ecliptic is the sea-monster Cetus, transliterated as *al-qaytus* in Arabic. The Greeks though of it is a whale, but in the Islamic world, it assumed a more fantastic shape with "a snarling dog's head, bird's feet, and a feathered fish tail[16]." Such a shape is drawn fully on Mughal globes[17]. But the full form cannot be shown on the rete of the astrolabe. Therefore Muqim just depicts the fish tail with the two fins (northern and southern) and the dog's head, placing the appropriate stars in these parts. The pointed edges of the tail fins become the pointers to the stars called respectively after these. At the intresection of these two tail fins, there is also a handle (mudir) with which the rete can be rotated.

1. *dhanab al-qaytus-i sh [umālī]*, (northern tail of Cetus, Iota Ceti), shown as the tip of the northern fin of the fish tail.
2. *dhanab al-qaytus-i j[anūbī]* (southern tail of Cetus, Beta Ceti, Deneb Kaitos), shown as the tip of the southern fin of the fish tail.
3. *fum al-qaitus* (mouth of Cetus, Gamma Ceti), snarling dog's mouth.
4. *al-ghūl* (actually ra's al-ghūl, head of the ghoul, Beta Persi, Algol), a demon's head with two horns.
5. *Tall yi masāf [at] al-Nahr* (valley or expanse of the river [Eridanus], gamma Eridani), the river is shown as an arc, from which projects the thin star pointer.
6. *'ayn al-thawr* (eye of the bull, alpha Tauri, Aldebaran), a well executed bull with slender horns and an engraved eye.

The next four stars depict the two hands and the two feet of Orion. The hands are skilfully represented, the three last fingers folded, and the index finger outstreched to form the star pointer. The feet are depicted through tapering shoes.

7. *Rijl-i yusra* (left foot [of Orion], Beta Orionis, Rigel), shoe.
8. *Yad-i yusra* (left hand, gamma Orionis, Belletrix), hand.
9. *Rijl-i yumna* (right foot, kappa Orionis, Saiph), shoe.
10. *Yad-i yumna* (right hand, alpha Orionis, Betelguese), hand.
11. *Shi 'ra-yi yamani* (the shouthern Shi ra, alpha Canis Majoris, Sirius), dog's head.
12. *Shi 'ra-yi sha' ami* (the northern Shi'ra, alpha Canis Minores, Procyon), dog's head.
13. *Minkhar al-shuja'* (the nose of the serpent, sigma Hydrae), snake's head.
14. *Ra's al-asad-i shamali* (the nothern head of the lion, mu Lionis), Lion's head.
15. *Zahar-i dubb-i akbar* (back of the Great Bear alpha Ursae Majoris. Dubhe), outline of the grizly or serrated back.
16. *qa'idat al-batiya* (bottom of the cup, alpha Carater), a bucket with vertical serrations.
17. *Janah al-ghurrab* (for janah al-ghurrab al-aysar, left wing of the raven, gamma Corvi. Algorab), pointed stylized wing.
18. *Simak-i a'zal* (zlpha Virginis, spica) hand.
19. *Al-fakka* (alpha Coronae Borealis, Alphecca), crown, more like a bucket.
20. *'unuq al-hayya* (neck of the serpent, alpha Serpentis), open mouthed snake's head.
21. *Al-jathi* (kneeling man, i.e. Herculus, alpha Herculis), human face.

22. *Al- hawwa* (actually ra' s azl - hawwa' , the head of the serpent charmer, alpha Ophiuchi, Ras Alhaque), human face
23. *Al - waqi* (actually al - Nasral - waqi', the falling eagle, alpha Lyrae, Vega) bird's beak .
24. *Minqar al - dajaja* (the bird' s beak, beta Cygni), chicken. .
25. *Al - ta'ir* (short for al - Nasr al - ta' ir, the flying eagle, alpha Aquilae, Altair), eagle's head with a curved beak and an engraved eye .
26. *Mankib al - faras* (shoulder of the horse, beta Pegasi) horse's head and shoulder, excellently executed and engraved.
27. *Surrat al - faras* (the navel of the horse, delta Pegasi / alpha Andromedae, Sirrah) . This star is common to the two constellations Pegasus and Andomeda. Here it is named after Pegasus but represented with Andromeda's face with demure eyes.
28. *Janah al - faras* (wing of the horse, gamma pegasi, Algenib), slightly projecting triangle, apparently the tip of the wing.

Emulating his father, Muqim's son Jamal al - Din also produced in 1077/1666 a zoomorphic rete in an astrolabe with a diameter of 250 mm, but it lacks the elegance of his father's workmanship[18].

A still larger astrolabe with a diameter of 352 mm and a zoomorphic rete is preserved in Jai Singh's Observatory at Jaipur[19]. This is a very elegant astrolabe with a gilded surface. R . T . Gunther, the author of the Astrolabes of the World[20], was so fascinated by its rete that he decorated the covers of his work with a silhoutte of the rete in gold. This astrolabe is neither dated nor signed. However, because of its close similarity with the astrolabe at Hyderabad, it may be attributed to Muqim.

We know of no other astrolabes which can be compared to these three in the wealth of zoomorphic representation. The design of the rete, consisting of interconnecting vines with circular loops, supporting flowers, buds, leaves and nodes, and interspersed with animal and bird figures, belongs, to the same artistic tradition as can be found in the border designs of contemporary Mughal miniature paintings[21]. Again, of these three astrolabes, the anonymous astrolabe at Jaipur is undoubtedly mor elegantly crafted than the one in Hyderabad. However, the latter bearing the signature of Muqim and date is historicaly more valuble.

This astrolabe by Muqim contains four plates. One of these is cimpletely blank on both sides and is obviously a replacement for a lost original. The other plates contain equal altitude circles for each degree, and therefore this astrolabe is called a *tamm* or complete astrolabe. The azimuth curves are drawn below the horizon for each 5°. In addition to the unequal hour lines, some plates have curves for the hours since sunset, others also for the hours before sunrise. The three inscribed plates serve the following latitudes:

plate no	latitude	longest day
1a	18°	3/9 h
1b	21	13;22
2a	23;30	13;21
3a	36	14;54
3b	39	14;14

Plate 2b is for coordinate conversion (safiha-yi mizan-yi 'ankabut) with altitude circles for each 2° and azimuth circles for each 5°. Probably the missing plate bore projections for the latitudes of 27° and 32°.

On the back, the upper half of the rim is graduated, as in the front, the groups of 5° and then in single degrees. The former are labelled

in abjad notation from 5° to 90° and then from 90° to 5°. The upper left quadrant has a sine graph containing horizontal parallels for each degree of argument. In the upper right, there is a solar quadrant with quarter-circles for each six degrees of solar longitude. Upon these are drawn two meridian altitude curves for the latitudes of 27° [Agra] and 32° [Lahore]. In the two lower quadrants, there are shadow squares, the scales of which are extended on the rim as well. Within these shadow squares is a scale for lunar mansions and various other astrological scales. The maker's signature is engraved in two parts, inside the half-circle close to the centre and below the half circle near the rim and reads as follows:

San 'at Muhammad Muqim ibn 'Isa ibn Allāhdād Astrolabi Humayuni Lahuri and fi sanah 1047 hijri,

'made by Muhammad Miqim son of 'Isa son of Allāhdād, the astrolabe maker to Huhammad Miqim, of Lahore, in the Hijri year 1047 [= 1637 - 38 A.D.].

The original alidade, pin, and horse are missing. These are replaced respectively by a crude sighting tube attached to a straight alidade with a three-lobed central part, a screw and a bolt.

3. Astrolabe by Diya' Al-Din Muhammad of 1651-52

Acc. No. 112/2/xxxv (Pls. 6 & 7)

Diya', al-Din Muhammad is the son of Qa'im Muhammad who was Muqim's elder brother. Diya' al-Din inherited his father's skill in casting celestial globes and his uncle Muqim's virtuosity in crafting astrolabes. He is the most prolific and versatile member of the family. He produced some 32 astrolabes and 16 celestial globes between the years 1645 and 1680. He also attempted a number of unsual varieties of astrolabes and globes, which were discussed by theoreticians but rarely executed in practice.[22] His astrolabe at the Salar Jung Museum is a neatly crafted piece and exhibits some unusual technical features.

The astrolabe measures 262 mm in diameter and has a thickness of 13mm. It is suspended by a ring and a shackle. A semi circular loop is attached to the ring, which appears to be a later addition. The kursi is worked *a jour* but it is somewhat solid and lacks the filigree-like delicacy of his other creations.

The rim of the mater has a width of 11 mm and bears three scales. The innermost one is graduated in 1/3 degrees, the middle one in single degrees and the outermost scale in groups of 3° and labelled clockwise from 3° to 360°. On the inner side of the mater, a geograhphical gazetteer of 160 localities is engraved with their longitudes and latitudes in four concentric rings (64 + 48 + 32 + 16).

The equinoctial bar on the rete is complete and is counter-changed at the centre and at the two points of intersection with the ecliptic. The ecliptic is divided into signs, each sign is futher divided in groups of 6° and then in single degrees. The rete displays a large number of star pointers, repesenting the positions of as many as 52 stars. These pointers are joined by a tracery of a highly accomplised floral pattern, which is almost symmetrical. There is a handle on the outer periphery of the rete at a place nearly midway between the north and west points.

There are six plates, serving eleven different latitudes. The equal altitude circles are drawn for each degree, making it is *tamm* astrolabe. Azimuth circles are drawn below the horizon for each 6°. More important, in addition to the usual hour curves for measuring time in terms of hours (= 60 minutes), there are also curves to measure time in *ghatis* (= 24 minutes) since sunset. On some of these plates, the duration of the longest day is given both in hours and ghatis. Thus:

plate no	latitude	longest day	
1a	17°	13;07 h	32;37 gh
1b	19°	13;15	

2a	21°	13;16,56	33; 12,20
3a	27°	13;43	34;27
2b	29°	13;58, 56	34; 52,20
4a	30°	14;8	
3b	32	14; 8	35;20
5a	35	14.22	35;55
6a	40°	14;52	
4a	44°	15;18	
5b	0°/90°		
4b	Coordinate conversion		
6b	horizons		

At the Mughal court, the traditional Indian ghati of 24 minutes as well as the middle eastern hour of 60 minutes were employed, the former in common measurement of time and the latter in scientific work. In this astrolabe, Diya al-Din gives expression to his dual system of time-measurement.[13]

Diya' al-Din has a predilection for multiple projections, i.e., engraving the projections for two or three latitudes on the same side of a plate. Thus in this astrolabe, plate 4a has a double projection to serve two latitudes, viz., 30° and 44°. Likewise, plate 5b is engraved for the latitudes of 0° and 90°. Plate 6b bears four sets of half-horizons while 4b is fashioned for the conversion of the coordinates.

On the back, the upper half of the rim is calibrated as in the front in groups of 3°, but labelled from 3° to 90° and then from 90° to 3°, in single degrees and then in 1/3°. In the upper left quadrant there is a sexagessimal grid with radial lines at each 6° and also at 45°.

In the upper right quadrant, Diya' displays his fondess once again

for intericate constructions. The solar quadrant contains quarter-circles for each 3° of solar longitude and midday curves for latitudes 15°, 19°, 21°, 29°, 32°, 35°, and 40°.

In the lower half, there is an astrological table just below the centre. This is surrounded by a semi-circular scale for the lunar masions. These two are enclosed within a double shadow square.

The maker's signature is engraved in the space between the astrological table and the scale for the lunar mansions and reads as follows:

'amal Diyā' al-Dīn Muhammad ibn Mullā Qā' im Muhammad ibn Hafīz 'Isa ibn Shaykh Allāhdād Asturlābī Humayuni.

"the work of Diyā' al-Dīn Muhammad son of Mullā Qā' im Muhammad son of Hafiz 'Isa son of Shaykh Allāhdād, the astrolabe maker to Humāyūn."

The year of manufacture is given in three eras at three different places: below shadow squares *sanah 1062 Hijri;* to the east of the shadow square *sanah 1021 khadīvī* and to the west *sanah 1063 Rūmī* (all corresponding to A.D. 1651-52).

The alidade is replaced by a sighting tube of crude workmanship, so also the pin and the horse.

4. ASTROLABE BY HAMID OF 1069/1658.

Acc. no 114/21xxxv (Plts. 8 and 9)

Muqīm's son Hamid represents the last phase and the decline of the instrument making in this family. Compared to his immediate predecessors, Hāmid's surviving oeuver is rather meagre: eleven astrolabes and two globes. The Salar Jung Museum has the distinction of possessing three items by Hāmid: an astrolabe of 1958, a celestial globe of 1683 and a manuscript copied by him on 17 September 1678. This manuscript contains the text of the Bist Bab, the most popular work on the astrolabe in twenty chapters by Nasir-

al-Din al-Tūsi.[24] The diameters of Hāmid's eleven astrolabes range between 89 to 140mm. These are handy instruments and were meant for daily use by commone.rs and not presentation pieces for the high nobility.

The astrolabe at the Salar Jung Museum has a diameter of 112 mm and a thickness 7 mm. The ring and shackle have a diamond-shaped cross section. The *kursi* is a slightly tapering rectangle with three lobes on either side at the upper corners. The top culminates into a trefoil to which the shackle is attached. The *kursi* is solid and unadorned.

The rim of the mater is graduated into single degrees and into groups of 6° and labelled from 6° to 90° in each qudrant separately in a clockwise direction. On the inner side of the mater is a geographical gazetteer with sixty localities, engraved in two concentric annuli (36 + 24).

The rete is every unusual in its composition. The equinoctial and solstitial bars are complete. The former is counterchanged at the ecliptic. Within the ecliptic circle, there are small circular protrusions on which the zodiac signs are labelled numerically 0 - 11 in *abjad* notation. There are also protrusions to mark the limits of the signs. each sign is divided in groups of 6° and labelled. There are 27 star pointers, some of which are set up on triangular arches. There is a prominent handle with a crown-like cross section.

There are five plates with projections for eight different latitudes. On these, the altitude circles are drawn for each 6° and azimuth circles for each 10° below the horizon. There are additional curves for the hours since sunset. The following latitudes are served by the five plates.

plate No	latitude	longest day
1a	18°	13;4,36 h
2a	20	13;42;56
2b	23	13;25, 4

3a	25	13;33;36
3b	27	13;42,46
1b	29	13;51,36
4a	32	14; 8, 0
4b	36	14 27, 10
5a	coordinate Conversion	
5b	horizons	

On the back, the rim is graduated in groups of 6° and then in single degrees. The degrees are labelled in the usual fashion from 6° to 90° and then from 90° to 6°. In the upper left quadrant is a sine graph with horizontal parallels. The solar quadrant on the right, strangely enough, has a meridian altitude curve for 20° latitude. There is a double shadow square in the lower half and also a scale for lunar mansions. the maker's inscription is engraved partly above the semi-circular scale for the lunar mansions and partly below the shadow squares and reads thus:

sān'at aqall al-'ibad Hāmid ibn Muhāmmad Muqīm ibn 'Isa ibn Allāhdād Asturlābi Lāhūri Humāyūni fi ta' rīkh 21 rab [i]' l-awwal sanah 1069.

"made by the least of the servants [of God] Hamid son of Muhammad Muqim son of 'Isa son of Allāhdād Asturlabi Lahuri Humayuni on the date 21 of the month Rab [i]' l-awwal of the year 1069 [Hijri = 17 December 1658].

The alidade is straight and appears to be original, but a cylindrical sighting tube was atached to it later on. The pin and the wedge also appear to be original. the wedge combines the forms of a serpent and a horse, with a slit for the mouth and a hole for the eye at the back of the head.

5. ASTROLABE UNSIGNED, UNDATED

Acc. No. 112/1/xxxv (Phs. 10 and 11)

It measures 133 mm in diameter and has a thickness of 6 mm. width of the rim of the mater is 8 mm. On the inner side of the mater, there is a gazetteer of towns including Golconda, Bidar, Bijapur, Ahmednagar, Daultatabad, Rajmahal etc. Therefore the astrolabe must be of Indian manufacture.

There are 30 star pointers on the rete. The astrolabe has three plates containing projections for 5 different latitudes and one tablet of horizons.

On the back, there is a sine cosine graph on the left, a solar quadrant on the right, with curves of midday solar altitudes for two unspecified latitudes. There is a shadow square in the lower half. Here also the original alidade seems to have replaced by a copper sighting tube.

6. ASTROLABE BY SARRAJ DAMASHQI OF 623/1226

Acc. No. 113/2/xxxv (Pls. 12)

The other astrolabes by this instrument maker from Damascus are extant. The first is at the Raza Library of Rampur and is dated 626 A.H/A.D. 1229.[25] The other was manufactured in 628 A.H./ A.D. 1231 and is preserved at the National Maritime Museum, Greenwich.[26] These astrolabes by Sarraj Damashqi are much older than any of the extant astrolabes manufactured in India. These must have been brought to India by travelling scholars.

This kufic astrolabe has a diameter 114 mm and a thickness of 6 mm. It is suspended by a large right and a smaller shackle. The *kursi* is low and plain with three lobes on either side, the last lobe pierced with a large perforation.

The rim of the mater is divided in groups of 5° each and labelled.

It is further subdivided into single degrees. On the rete, there is a complete equinoctial bar which is not, however, counter-changed. The ecliptic is divided into signs and labelled. the signs are further divided into groups of 6°but are not numbered. There are nineteen dagger-shaped star pointers. Two handles are located on either side at about 30° below the east-west line.

There are two plates with projections for four different latitudes. A fifth projection is engraved on the inner-side of the mater instd of the gazetteer. While in all Indian astrolabes, there is a projecting bit in the rim of the mater called *mumxika* which fits into a corresponding indent in the plates, here the situation is the reverse. The plates have projecting metal strips that go into a hole under the rim. The following latitudes are served by the projections:

Plate no	latitude
1b	20
3a	21
1a	24
2a	38
2b	37

On the back there is sine-cosine grid in the upper left quadrant, a sine graph in the upper right quadrant, and a horary quadrant in the lower left. The rim of these three quadrants is graduated in 5° and labelled from 5° to 90° to measure the altitudes. The lower right right quadrant is occupied by a shadow square. The maker's signature is engraved at the bottom of the lower left quadrant.

The original alidade was replaced by a copper sighting tube.

7. CELESTIAL GLOBE BY DIYA AL-DIN OF 1074/1663

Acc. No., 113/xxxv (Pls. 13)

Qā' im Muhammad perfected the art of casting the celestial globes in one poece through the eire perdue or lost wax method. Diya' al-Din excelled in this art and produced many celestial globes, perhaps

the largest number manufactured by a single individual[27].

The diameter of the present globe measures 160mm. The height of the stand is 120 mm. The horizontal ring, 14 mm thick and 12 mm wide, is supported by three stout S-shaped legs. The ring is further supported by a half circle that runs below the globe. In the horizontal ring and in the lower half circle, there are indents through which the meridian ring must have passed but it is now lacking. Therefore, the globe cannot be set upon properly. Its axis rests now on the horozontal frame.

The globe is cast as a single hollow sphere without any seams, but there are two ovoid plugs measuring 20 X 25 and 50 X 55 mm respectively, of a different colouration with greater copper content. In the globe there are holes at the two poles of the equator and at the two poles of the ecliptic, so that it can be made to revolve either around the poles of the equator or around the poles of the ecliptic.

The horizontal ring, the equator and the ecliptic are marked with double bands of lines on which each degree is marked and groups of 5° are numbered. Single lines mark the tropics and the arctic circles. Six great circles run perpendicular to the ecliptic, dividing it into 12 signs. Some 48 constellation figures are finely engraved. Noteworthy is the spectacular Argo Navis (*safinah*) which looks more like a Mughal palace than a ship. About 1018 star positions are marked on the globe by inlaid silver points of three magnitudes.

The maker's inscription reads as follows:

'a mal aqall al - 'ibād Diyā' al - Dīn Muhammad ibn qā' Muhammad ibn Mullā 'Isa ibn Shaykh Allāhdād Humāyuni Axurlābi. Lahuri 1074 Hijrī.

"the work of the least of the servants [of God] Diya' al-din Muhammad son of Aq'im Muhammad son of Mulla 'Isa son of Shaykh Allāhdād, the astrolabe maker to Humayun, of Lahore [in the year] 1074 Hijri [= 1663 A.D.]."

In the Museum of History of Science at Oxford, there is a globe which Diya' al-Din made in the same year.[28] The sizes are different, but the stands are alike. Here also the meridian ring is missing. this seems to be weakest part of the Mughal globes.

8. CELESTIAL GLOBE BY HAMID OF 1094/1683

Acc No. 114/xxxv (Ph. 14)

Only two globes by Hāmid are known. The other one, a small piece of 99 mm diameter and dated 1065 A.H./A.D. 1655, is in the Whipple Museum of History of Science at Cambridge.[29] There is no stand, nor are any constellation figures engraved on the globe. In contrast, the one at the Salar Jung Museum is about twice as large.

This globe, with a diameter of 170 mm, is cast as a single hollow sphere with no seams visible but with two circular plugs of diameters 65 and 50 mm respectively, one near each pole. The ecliptic and equator are marked by double bands of lines on which each degree is marked and groups of 6° are numbered. Both the ecliptic and the equator are divided by six great circles each that cut across them perpendicularly and converge at their respecive poles. Tropics are marked by double lines and arctic circles by single lines. Some 36 constellation figures are engraved in outline and labelled but no Zodiac figures are so represented. About 1018 stars positions are marked by inlaid silver points of three maginitudes. In each constellation figure, the serial number of the star is given.

The maker's inscription reads as follows:

'amal aqall al 'ibād Hāmid ibn Muhammad Muqīm ibn' Īsa ibn Allāhdād Asturlābī Lāhurī Humāyunī,

"the work of the least of the servants [of God] Hāmid son of Muhammad Muqīm son of 'Īsa son of Allāhdād, the astrolabe maker to Humayun, of Lahore [in the year] 1094 Hijri [=A.D. 1683]."

At present the globe is set upon a stand which clearly does not belong to it. This stand seems to be an early nineteeth century make of European inspiration and closely resembles the one in a globe manufactured by Fadlullah in A.D. 1808 (which will be discussed next).

In the stand, the horizontal frame is supported by two semicircular arcs which pass through a solid bit of an ovoid shape. The meridian ring also passes through it. The stand is supported by three curved legs. Between these legs, a mirror is affixed in which the lower side of the solid bit is reflected. The height of the stand up to the horizontal ring is 320 mm. The horizontal ring and the meridian ring are not calibrated. The latter cannot be adjusted to the local latitude. Therefore the axis of the globe is merely resting on the horizontal ring.

9. CELESTIAL GLOBE BY MUHAMMAD FADLULLAH OF 1223/1808

Acc. No. 112/xxxv (Ph. 15).

The globe has a diameter of 170 mm. It is cast as a single piece of holow sphere with no seams and no plugs. Ecliptic and equator are indicated by single lines on which each degree is marked. Tropics and arctic circles are also marked with single lines. Six great circles each cut perpendicularly across the ecliptic and the equator. Some 48 constellation figures are finely engraved. Star positions are indicated by engraved asterisks.*

The height of the stand is 270 mm. The stand shows clear European influence. The horizontal frame is supported by two semicircular arcs which pass through a solid spherical bit. The meridian ring also passes through this piece rather tightly, but it can be shifted so that the inclination of the axis of the globe can be changed according to the local latitude. The axis of the globe is screwed at both ends to the meridian ring. The spherical bit is

supported by three curved legs between which rests a magnetic compass on a triangular platform. The horizontal ring is calibrated in degrees and groups of 5° are numbered.

The inscription reads as follows:

.....nanābiq jīz jadīd-i asafia Bahādur Husain Khān Rizwī Haiderābād samia Muhamma Fadlullah ibn Muhammad murād ibn Muhammad Mūsā Asturlabi matubattin Awarangābād..... 9 Ramdān 1223 Hijri, "..... according to the *Jadid-i asafia* by Bahādur Husain Khān Rizwī compiled at Hyderabad..... the globe was manufactured by Muhammad Fadullah son of Muhammad Murad son of Muhammad Musa, the astrolabe maker, resident of Awarangabad on the ninth day of Ramdan in the year 1223 Hijri [= 29 October 1808 A.D.]."

This is clearly the only extant Islamic astronomical instrument manufactured in southern India. This Fadlullah seems to be an astrolabist at the Nizam's court. Unlike in other globes where the star positions are marked accoriding to the coordinates given in the *Zīz* of Ulugh Beg, here they are marked according the *Zīz jādid-i Asafia*, alsIo known as *Zīz Nizāmī*, compiled by Husain Khan Rizwi at Hyderabad.[30] Fadlullah comes from a long line of astrolabists, but none of their creations have survived save this globe.

10. CELESTIAL GLOBE UNSIGNED UNDATED

Acc. No. xxxv 112/3/(Ph. 16)

The last instrument in the collection of this museum is an unsigned undated celestial globe with a diameter of 155 mm. There is no stand. The globe is cast as a single hollow sphere without visible seams or plugs. At the two poles of the equator and also at the two poles of the ecliptic, there are rather large holes. Both the equator and the ecliptic are marked with double bands of lines on which each degree is shown and the arctic circles by single lines. Six great

circles cut perpendicularly across the ecliptic dividing it into 12 signs, which are labelled. But there are no star positions indicated on the globe.[31]

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The persent Director, Dr. I.K. Sarma invited me to deliver the Salar Jung Memorial Lecture on "The Astronomical and Time-Measuring Instruments at the Salar Museum" during the 109th Birthday Celebrations of Nawab Salar Jung Bahadur III on 18 March 1995. This paper is a revised version of the Salar Jung Memorial Lecture. The invitation also gave me an opportunity to study and photograph the instruments once more. I am highly obliged to Dr. I.K. Sarma for the invitation and for the warm-hearted hospitality.

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NOTES & REFERENCES

(1) S.R. Sarma, on the significance and the methodology of this project, see my "Indian Astronomical and Time-Measuring Instruments: A Catalogue in Preparation," *Indian Journal of History of Science*, 29.4 (1994) 507-528.

(2) The best technical introduction to the astrolabe can be found in Willy Hartner, "The Principles and Use of the Astrolabe" in: *idem*, *Oriens-Occidens*, (Vol. I), (Hildesheim 1985), pp. 287-318; and J.D. North, "The Astrolabe," *Scientific American*, 230 (January 1974) 96-106. See also M.P. Khareghat, *Astrolabes* (M.P. Khareghat Memorial Volume II), ed. Dinshaw D. Kapadia, (Bombay 1950).

(3) S.R. Sarma, on the history of astrolabe in India, see my "Astronomical Instruments in Mughal Miniatures," *Studien Zur Indologie und Iranistik*, 16-17 (1992) 235-276; and "Sultan, Suri and the Astrolabe," to appear in *Medieval India 3: Professor Mohammad Habib Commemoration Volume*.

(4) This is also the name of the text written by him in Sanskrit, on which his pupil Malayendu Suri wrote a commentay. The text and the commentary are edited by K.K. Raikva, and published from Bombay in 1936.

(5) Cf. my "The Lahore Family of Astrolabists and their Ouvrage," *Studies in History of Medicine and Science*, 13.2 (1994), PP. 205-224.

(6) For an excellent introduction to the celestial globe see, Emilie Savage Smith, *Islamicate Celestial Globes: Their History, construction and Use* (Washington, D.C, 1985).

(7) S.R. Sarma, on the history of the celestial globe in India, see my "From al-kura to Bhagola; on the Dissemination of the Celestial Globe in India," *Studies History of Medicine and Science*, 13.1 (1994) 69-85; and also S.R. Sarma, S.M.R. Ansari & A.G. Kulkarni, "Two Mughal Celestial Globes," *Indian Journal of History of*

Science, 28.1 (1993) 80-8.

(8) Preserved in the Stonyhurst College Library near Blackburn, Lancashire, England, cf. *Savage-Smith, op. cit.,p.224*.

(9) *Islamic Culture*, 9 (1935) 621-631, esp. 627. Since then the literature locates this astrolabe in the "*Library of Sir Salar Jung Bahadur*," though this is no more the case.

(10) "*Report on a Tour of Indian Museums of Science*, including some university departments and colleges, (British Council, 16 February to 10 March 1986), p.3.

(11) This astrolabe is listed as no.1120 in Sharon Gibbs, Janice Anderson, Derek de Sola Price, *A Computerized Checklist of Astrolabes*, (Yale University, New Haven 1973), (henceforth CCA).

(12) CCA 1089. Cf. Francis Maddison, *A Supplement to a Catalogue of Scientific Instruments in the Collection of J.A. Billmeir*, Esq., C.B.E., Exhibited by the *Museum of the History of Science* (Oxford, Oxford-London 1957), No.159, pp. 20-21, pl. XVIII. See also R.G.W. Anderson, *Science in India: A Festival of India Exhibition at the Science Museum*, (London, Catalogue, London 1982) Object No.126, p.35, fig.9. A third astrolabe (CCA 2530), unsigned and undated, also at the Museum of history of Science, Oxford, is generally attributed to Allahdad, cf. Maddison, op. cit., No.159A, p.21.

(13) Cf. K.K. Raikva (ed), *Mahendra Süri's Yantrarāja*, p.18 et passim.

(14) Such surface ornamentation can be seen also in the Kursi of the astrolabe preserved at the *Museum of History of Science, Oxford*, which Muqim manufactured in the year 1053/1643, cf. R.T. Gunther, *The Astrolabes of the World, (Oxford 1932)*, vol. I, Pl. XLVII, p. 199.

(15) Cf. Owen Gingerich, "Zoomorphic Astrolabes and the

Introduction of Arabic Star Names in Europe" in: David A. King and George Saliba (ed), *From Deferent to Equant: A volume of studies in the History of Science in the Ancient and Medieval Near East in Honor of E.X. Kennedy (=Annals of the New York Academy of Sciences*, vol. 500), (New York 1987), pp. 89-104.

(16) Savage-Smith, *op. cit.*, p.187.

(17) *Ibid*, p.188, fig. 75.

(18) Cf. Gingerich, *op. cit.*, p. 102. I saw the photographs with Perofessor David King.

(19) See G.R. Kaye, *The Astronomical Observatories of Jai Singh*, (Calcutta 1918, reprint: Delhi 1973), p.16, figs.5 and 7; see also my "Portable Instruments at Jaipur Observatory," to appear in the *Proceedings of the International Symposium on Indian & Other Asiatic Astronomies*, (B.M. Birla Science Centre, Hyderabad, and B.M. Birla Planetarium, Jaipur, 1991).

(20) Oxford 1932, se also Vol. I, pp. 203-205.

(21) In particular, this design may be compared to a border design on a folio from the late Shah Jahan Album of about 1650, reprodeced in Pratapaditya Pal *Indian Painting: A Catalogue of the Los Angeles County Museum of Art Collection*, Vol.I, (Los Angeles 1993), p.276.

(22) See my "The Safiha Zarqaliyya in India," to appear in the *Festschrift for Professor J. Vernet, Barcelona;* and *"The Lahore Family of Astrolabists and their Ouvrage,"* (note 5 above).

(23) However, of the Six *hour-ghati* equations, half are not correct. Thus 13;07 h equal 32;47, 30 gh and not 32;37 gh. 13;58, 56 h equal 34;57, 20 gh and not 34;52, 20 gh. Again 13;43 h are tantamount to 34;27, 30 gh and not to 34;20 gh. This is rather surprising because the hours and *ghatis* have a simple ratio of 60 : 2.5 : 1. In the anonymous astrolabe with the zoomorphic rete at Jaipur also, such equations are given in three cases, only one of which is correct.

(24) Cf. *Catalogue of the Persian Manuscripts in the Salar Jung Museum and Library*, (Hyderabad, Vol. IX, Hyderabad 1988), Ms. no. 3877: Bīst Bāb, with an anonymous commentary, copied by Hamid Asturlabi ibn Muhammad Muqīm on 10 Sha'ban 1087/17 September 1678.

(25) CCA 3765, cf. Padmakara Dube, "Astrolabes in the State Library Rampur," *The Journal of the United Provinces Historical Society*, 4.1 (October 1928) 1-11, pl. I - IV.

(26) CCA 1042.

(27) Cf. my "From al-kura to Bhagola: on the Dissemination of the Celestial Globe in India" (n. 7 above).

(28) Cf. Savage-Smith, op. cit., no. 28, p. 231.

(29) Ibid, No.68, p. 252.

(30) This author, Khwaja Bahadur Husain Khān came with his grandparents from Bukhara during Shahjahan's reign, served Awrangzeb for a while and then moved to Deccan with Nizam-ul mulk Asif Jah who ruled Hyderabad from 1761 to 1803. In the Zij there are frequent quotations from the Sūryasiddhānta, Siddhāntasiromani and references to authorities like Cintamani, Gangabhatta, Bhāskaracārya, Chagmini, Kushyar ibn Laban, al-Biruni, Tusi, Euclid and Ptolemy. A manuscript copy is at the State Central Library (Riyadi - 112, 236b). Cf. Wazir Hasan Abdi, "Enrichment of Methematical Sciences in India through Arabic and Persian" in: B.V. Subbarayappa and S.R.N. Murthy (eds), *Scientific Heritage of India*, (Bangalore 1988), pp. 63-77, esp. 69.

(31) Emilie Savage-Smith classifies such globes as Class-c, cf. op. cit., Nos. 91-124, pp. 263-275. *The Museum of Indology, Jaipur*, has also a similar globe, on which just the great circles are marked and the Zodiac signs are named but in Devanāgarī script.

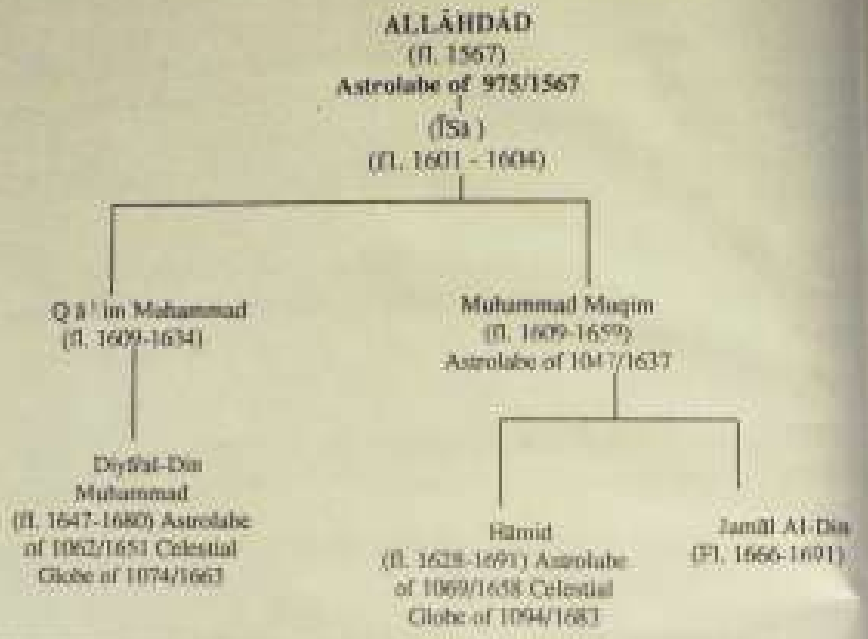
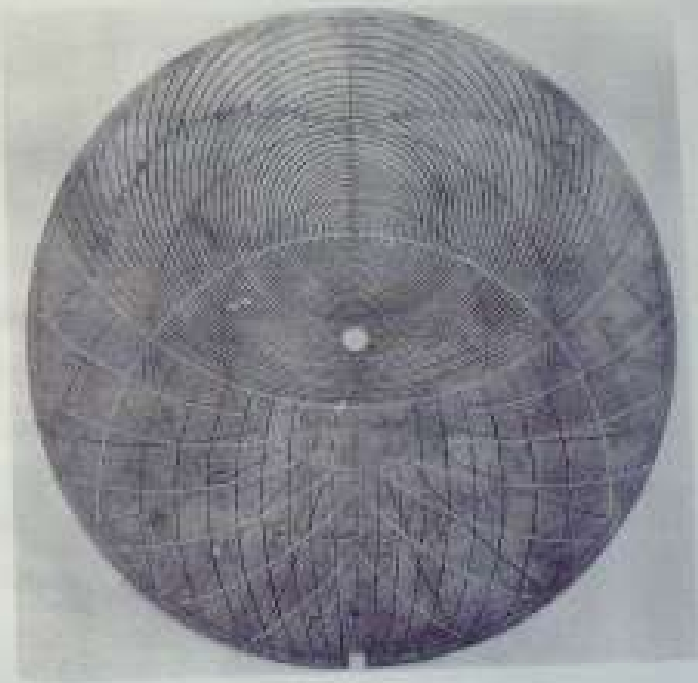


Fig. 1 The Lahore Family of Astrolabists and their Instruments at the Salar Jung Museum, Hyderabad.

Ph.1 Astrolabe by Allahdad of 975/1567 front
(Acc.No. 113/1/XXXVI)

Ph.2 Astrolabe by Allahdad of 975/1567.
[back as above]



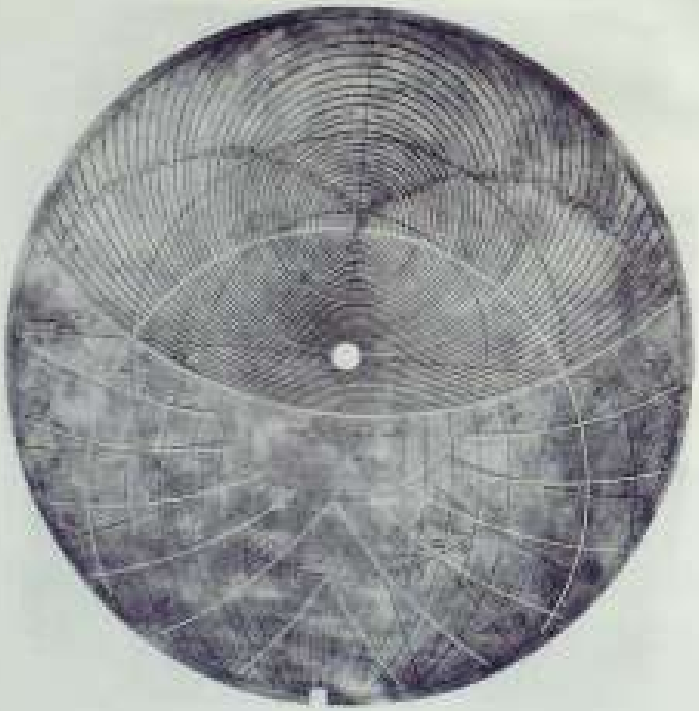
Ph.3 Astrolabe by Allahdad of 975/1567. Rete

Ph.4 Astrolabe by Muqim of 1047/1637,
front [Acc.No.XXXV/114/1]

Ph.5 Astrolabe by Muqim of 1047/1637,
back [Acc.No.XXXV/114/1]

Ph.6 Astrolabe by Diya'al - Din of 1062/1651, front [Acc.No.XXXV/112/2]

Ph.7 Astrolabe by Diya'al - Din of 1062/1651 [Back]



Ph.8 Astrolabe by Hamid of 1069/1658, back [Acc.No.XXXV/114/2]

Ph.9 Astrolabe by Hamid of 1069/1658, Rete [Acc.No.XXXV/114/2]

Ph.10 Astrolabe unsigned and undated
front [Acc.No.XXXV/112/1]

Ph.11 Astrolabe unsigned and undated.
back [Acc.No.XXXV/112/1]

Ph.12 Astrolabe by Sarraj Damashqi of 624/1226,
front [Acc.No.XXXV/113/2]

Ph. 13 Clestial Globe by Diya'al - Din of 1074/1663
[Acc.No.XXXV/113]

Ph.14 Celestial Globe by Hamid of 1094/1683 [Acc.No.XXXV/114]

Ph.15 Celestial Globe by Muhammed Fadlullah of 1223 AH/1808 A.D.
[Acc.No.XXXV/112]

Ph.16 Celestial Globe unsigned and undated
[Acc.No.XXXV/112/3]

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