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SULṬĀN, SŪRI AND THE ASTROLABE

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The study and the manufacture of the astrolabe received a great impetus in the second half of the fourteenth century under Sulṭān Fīrūz Shāh Tughluq, who actively promoted exchanges and innovations in science and technology. The contemporary chronicle *Sīrat-i Fīrūz Shāhī* has a long account on the production of astrolabes at the court of Fīrūz. Fīrūz Shāh also encouraged Mahendra Sūri to compose the first ever Sanskrit manual on the astrolabe. An attempt is made here for the first time to glean coherent information from the *Sīrat-i Fīrūz Shāhī* concerning the astrolabe and to compare this information with what is available in Sanskrit sources.

Keywords: Al-Bīrūnī, *Asṭurlāb-i Fīrūz Shāhī*, climate, Fīrūz Shāh Tughluq, geographical gazetteer, golden minaret, Mahendra Sūri, Malayendu Sūri, north-south astrolabe, stereographic projection

0.1 In its construction, the astrolabe combines science, technology and art as no other product of the medieval world does. Hailed as the "King of Astronomical Instruments" in India[1] and as "The Mathematical Jewell" in England[2]—these are the outermost limits of its geographical spread—, the astrolabe occupied in medieval science a position analogous to that of the personal computer today. "Like a modern electronic computer," says John North, "the astrolabe in the Middle Ages was a source of astonishment and amusement, of annoyance and incomprehension. Imprecise as the astrolabe may have been in practice, it was undoubtedly useful, above all in judging time."[3]

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[1] Thus the Jaina monk Mahendra Sūri in 1370 AD, see 6.1 below.

[2] So reads the title of John Blagrave's book on the astrolabe published from London in 1585.

[3] J. D. North, "The Astrolabe," *Scientific American*, 230 (January 1974) 96-106, esp. 106; reprinted in: idem, *Stars, Minds and Fate: Essays in Ancient and Medieval Cosmology*, London-Ronceverte 1989, pp. 211-220.

0.2 It is not known precisely when the astrolabe was invented or by whom. But the principle of stereographic projection[4] on which its construction is based, is attributed to Hipparchus who lived about 150 BC. By the sixth century AD, almost all the main components of the astrolabe were fully developed.[5] The Islamic World, however, deserves the credit for preserving this knowledge, elaborating upon it and then disseminating it westwards up to England and eastwards up to India.[6]

0.3 The astrolabe (Arabic *asṭurlāb*), or more correctly the planispheric astrolabe (*asṭurlāb saṭḥī* or *musaṭṭaḥ*),[7] contains a two-dimensional projection of the heavens. Its principal parts are the following. The rete or spider (*'ankabūt*) is a perforated or open-work plate containing the ecliptic and a star map with pointers indicating the positions of some bright stars. Beneath the rete are to be found a series of plates called tympans (singular *ṣafiḥa*, plural *ṣafā'iḥ*), which are specific to a particular terrestrial latitude and display stereographic projections of the local horizon, equal altitude circles or almucantars (*al-muqanṭara*), azimuth circles (*as-sumūt*), hour curves etc. When the rete is correctly set and made to rotate upon the tympan of a particular latitude, the astrolabe stimulates the motion of the heavens above the localities situated on that latitude. The rete as well as the series of the tympans are nested in the hollow space of a heavy circular plate

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[4] In a stereographic projection, every circle on the sphere is represented also as a circle on the plane of projection, and the angle between any pair of curves remains unchanged.

[5] The earliest detailed description of the astrolabe, which is still available, emanates from John Philoponus, who wrote an extensive work in Greek on the construction and use of the astrolabe in about 530 AD. For an English translation of this work, see R. T. Gunther, *The Astrolabes of the World*, Oxford 1932, Vol. I, pp. 61-81.

[6] The literature on the astrolabe is voluminous. But the best technical introduction to the instrument can be found in Willy Hartner, "The Principles and Use of the Astrolabe" and "Asṭurlāb" reprinted in his *Oriens-Occidens*, Vol. I, Hildesheim 1985, pp. 287-318; and J. D. North, op. cit. For an important Indian contribution to the literature, see M. P. Khareghat, *Astrolabes*, (M. P. Khareghat Memorial Volume II), ed. Dinshaw D. Kapadia, Bombay 1950. On the history of the astrolabe in India, see Sreeramula Rajeswara Sarma, "Astronomical Instruments in Mughal Miniatures," *Studien zur Indologie und Iranistik*, Hamburg, 16-17 (1992) 235-276, esp. 237-241; idem, "Indian Astronomical and Time-Measuring Instruments: A Catalogue in Preparation," IJHS, 29.4 (1994) 507-528, esp. 518-522; idem, "*Yantrarāja*: the Astrolabe in Sanskrit," ibid, 34 (1999) 145-158. See also Yukio Ohashi's important study, "Early History of the Astrolabe in India," IJHS, 32 (1997) 199-295.

[7] as distinct from two other late but insignificant variants, viz. the linear and the spherical astrolabes, cf. Hartner, op. cit., pp. 317-318.

with an upraised rim, called mater (*umm*). On the back of the mater, a diopter with two sighting vanes (*libna*) is pivoted to the centre. This diopter, styled alidade from *al-'iḍādah,* is the observational part of the instrument, with which the heights or altitudes of the heavenly bodies are measured.

1.1 When was the astrolabe introduced into India? In his *Indica,* Al-Bīrūnī claims to have dictated a manual on the astrolabe in Sanskrit verse.[8] No manuscript of such a text has come down to us, nor is this claim taken seriously today.[9] Nevertheless, it is quite possible that he may have brought the astrolabe with him and explained its principles to his Hindu interlocutors at Multan. Al-Bīrūnī did write several tracts on the astrolabe in Arabic. The most celebrated is the *Exhaustive Study of the Possible Methods for the Construction of the Astrolabe.*[10] This text is still unpublished but a few parts have been studied and translated. E. S. Kennedy describes the text thus:

> Amid the plethora of medieval treatises on the astrolabe, this is one of the few of real value. It describes in detail not only the construction of the standard astrolabe but also the special tools used in the process. Numerical tables are given for laying out the families of circles engraved on the plates fitting into the instrument. Descriptions are also given of the numerous unusual types of astrolabes that had already developed in Bīrūnī's time. As for the underlying theory, not only are the techniques and properties of the standard stereographic projection presented, but also those of non-stereographic and non-orthogonal mapping of the sphere upon the plane.[11]

1.2 Besides this, Al-Bīrūnī devoted a number of other works to the discussion of various types of the astrolabe. For instance, the *Easy Method for the Correction of the Astrolabes and the Use of its Northern and Southern Compound Devices* describes a special type of composite astrolabe that can be used both for the

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[8] *Alberuni's India,* tr. Edward Sachau, first Indian reprint: New Delhi 1964, vol. I, p. 137: "Most of their books are composed in *śloka,* in which I am now exercising myself, being occupied in composing for the Hindus a translation of the books of Euclid and of the Almagest, and dictating to them a treatise on the construction of the astrolabe, being simply guided herein by the desire of spreading science."

[9] That there were limitations to Al-Bīrūnī's knowledge of Sanskrit was demonstrated by David Pingree, "Al-Bīrūnī's Knowledge of Sanskrit Astronomical Texts" in: Peter J. Chelkowski (ed), *The Scholar and the Saint,* New York 1975, p. 67-81.

[10] For the full Arabic title and other bibliographical information, see Ahmad Saeed Khan, *A Bibliography of the Works of Abu'l-Raiḥān Al-Bīrūnī,* New Delhi 1982, no. 46, p. 21.

[11] *Dictionary of Scientific Bibliography,* vol. II, New York 1970, pp. 152-53 (s. v. Al-Bīrūnī).

[12] Ahmad Saeed Khan, op. cit., no. 47, pp. 21-22.

northern and the southern celestial hemispheres.[12] Therefore, we will not be much wrong in assuming that the astrolabe was introduced into India in the eleventh century, most probably by Al-Bīrūnī. There is no evidence, however, that Hindu or Jaina astronomers in north-western India, or on the Gujarat coast, responded to this new device immediately.[13]

1.3 But after the establishment of the Delhi Sultanate, Muslim scholars migrated to India in great numbers from Central Asia and these must have brought astrolabes and used them in India for calendrical and astrological purposes. By the mid-fourteenth century, the instrument was sufficiently well known among the Muslim elite of northern India to be mentioned in a work of fiction. Ikhtisan, a minister of Sulṭān Muḥammad bin Tughluq Shāh (1324-1351), mentions the use of the astrolabe for measuring time and for determining auspicious moments in his romance *Basāṭīn al'Uns.*[14]

2.1 The use and the manufacture of the astrolabe received an impetus under Sulṭān Fīrūz Shāh Tughluq (1351-1388) who actively promoted exchanges and innovations in science and technology. He was deeply interested in medicine, natural sciences and technology. His canal building activities, the engineering skills employed in the transportation of the massive Aśokan pillars,[15] his endowments for hospitals[16] and educational institutions have been extensively discussed by modern scholarship.[17] However, his interest in astronomy and

[13] Apparently some contemporaries of Al-Bīrūnī believed that the astrolabe, as also the gnomon, the celestial globe and the armillary sphere, were invented in India. Al-Bīrūnī denounces this view in strong terms and explains the Greek origin of the instrument as well as its name. Cf. *The Exhaustive Treatise on Shadows by Abu al-Rayḥān Muḥammad b. Aḥmad al-Bīrūnī*, tr. E.S. Kennedy, Aleppo 1976, Vol. I, pp. 11-121; Al- Bīrūnī, *In den Gärten der Wissenschaft: Ausgewählte Texte aus den Werken des muslimischen Universalgelehrten*, übersetzt und erläutert von Gotthard Strohmaier, Leipzig 1991, p. 102.

[14] Iqtidar H. Siddiqui, "Basāṭīn al 'Uns: A Source of Information on the Sultanate of Delhi under the early Tughluq Sultans," *Quarterly Journal of the Pakistan Historical Society*, 36.4 (1988) 293-302.

[15] Cf. J. A. Page, *A Memoir on Kotla Firuz Khan Delhi*, Memoirs of the Archaeological Survey of India, No. 15, Delhi 1937.

[16] Cf. R. L. Verma, "Sulṭān Fīrūz Shāh Tughluq: the medieval Indian Hakim" in : B. V. Subbarayappa (ed), *Scientific and Technological Exchanges between India and Soviet Central Asia (Medieval Period)*, New Delhi 1985, pp. 140-147.

[17] Cf. Mohammad Habib and Khaliq Ahmad Nizami (ed), *A Comprehensive History of India*, Vol. V: The Delhi Sultanate (AD 1206-1526), New Delhi 1970; reprint: 1982, pp. 585-604.

astronomical instruments has not been properly studied, save for a few oft-repeated clichés. The reason for this neglect lies in the peculiar nature of the sources, and also the historians' general ignorance about the basic tools of astronomy and time-keeping.

2.2 Firūz was greatly interested in the astrolabe. Under his direction, astrolabes were manufactured perhaps for the first time in India. Contemporary chronicles like Shams Sirāj Afif's *Tārīkh-i Fīrūz Shāhī* and the anonymous *Sīrat-i Fīrūz Shāhī* make frequent references to the Sulṭān's preoccupation with this instrument. The latter text, in particular, contains precious technical information about the manufacture of astrolabes at his court. This work was completed in 772 AH/1370 AD, and survives in a unique manuscript which was copied in December 1598, and which is now preserved in the Khuda Bakhsh Oriental Public Library of Patna.

2.3 Unfortunately, however, the *Sīrat* has not been published so far. The late Professor Syed Hasan Askari prepared an English translation of this text which too remains unpublished. Because of the highly technical nature of the section on the astrolabe, corresponding to ff.151a-161a in the manuscript, there are many imperfections in the English translation. With the kind help of the Janab S. A. K. Ghori Saheb, I have compared this translation with the Persian original and extracted some coherent data on the astrolabe manufacture, which I shall present in the following pages. The main purpose of this exercise is to demonstrate the singular importance of the *Sīrat* for the history of the astrolabe in India and, hopefully, thus to induce some competent scholar of Persian to undertake an annotated translation of this section of the *Sīrat*.

3.1 This chronicle narrates that the Sulṭān had the following five astrolabes manufactured under his direct supervision:

i. A silver astrolabe for the latitudes of the seven climates *(iqlīm)*,
ii. a north-south astrolabe in silver,
iii. a north-south astrolabe in brass for the latitudes of the seven climates,
iv. a northern astrolabe in gold and silver, and
v. a very large and very splendid north-south astrolabe in brass, designated as *Asṭurlāb-i Fīrūz Shāhī*.

3.2 Before going into the details regarding the last mentioned astrolabe, it will be necessary to say a few words on the types mentioned here. Classical geography divides the inhabited portion of the hemisphere into seven climes or climates in such a manner that the maximum duration of daylight at the middle of each climate is half an hour longer than in the previous one.[18] When the *Sīrat* says that the astrolabe nos. 1 and 3 are meant for the latitudes of the seven climates, it implies that the astrolabes contain a number of tympans (*ṣafā'iḥ*) for different latitudes falling in the seven climates, or at least one *ṣafīḥa* for each climate.

3.3 Again, three of the five astrolabes are said to be both northern and southern, while the fourth was only northern (and perhaps also the first one). In a northern astrolabe (*asṭurlāb shumālī*), the stereographic projections on the rete and on the tympans are so drawn that the north celestial pole becomes the centre of the astrolabe and the outermost periphery is formed by the Tropic of Capricorn. Therefore, on the rete of this astrolabe, the positions of only such stars can be shown that lie to the north of the Tropic of Capricorn. Those lying to the south and visible to an observer in the northern temperate zone of the earth can, however, be shown in the rete of the southern astrolabe (*asṭurlāb janūbī*), where the south celestial pole forms the centre and the Tropic of Cancer the outermost periphery.[19]

Quite early, Muslim astronomers thought of combining the features of both the types in one, so that it can display the stars belonging to northern and southern celestial hemispheres.[20] Such a combined or composite astrolabe is called *asṭurlāb shumālī wa janūbī*. As we have mentioned before, Al-Bīrūnī composed a manual on this variety of astrolabe.

3.4 However, the practical utility of such a north-south astrolabe is not very great. First, unless the astrolabe is very large, it will be difficult to include on it many stars from both the hemispheres, but then the larger the astrolabe the greater the difficulty in handling it. Furthermore, double projections on the rete and the tympans will reduce the accuracy of the lines. Thus, both the southern astrolabe and the north-south astrolabe are theoretical curiosities without much practical relevance. This is reflected also in the extant astrolabes, almost all of which are northern. Not a single exclusively southern astrolabe has been noticed so far,

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[18] Cf. *'Āin-i-Ākbarī of Abul Fazl-i-'Āllami,* Vol. III, tr. H. S. Jarrett, rev. Jadunath Sarkar, Calcutta 1948, pp. 50-125

[19] Cf. Yukio Ohashi, op.cit.

[20] Cf. David A King, "Astronomical Instrumentation in the Medieval Near East" in: idem, *Islamic Astronomical Instruments*, London 1987, p. 5.

while there may be one or two north-south astrolabes. Perhaps for this very reason of rarity, and perhaps also because its construction involves a certain amount of ingenuity, Fīrūz was fascinated by the north-south astrolabe

3.5 The author of the *Sīrat* invests the manufacture of the north-south astrolabe with a legendary aura. The astronomers at the Sulṭān's court, says he, discovered once a north-south astrolabe manufactured by Alexander's scientists. Fīrūz studied this astrolabe carefully and decided to produce similar astrolabes himself. Be that as it may, the Sulṭān did not need the chance discovery of Alexander's north-south astrolabe. He must surely have had access to the much more recent treatises on the north-south astrolabes by Al-Bīrūnī.

4.1 Having decided to produce a north-south astrolabe,[21] the chronicle goes on to say, the Sulṭān summoned wise philosophers (*hukāmā*), astronomers (*munajjamān*), arithmeticians (*muhāsabān*), geometricians (*muhandasān*) and craftsmen (*sannāa*) from all over Hindustan to assist him in his job.

4.2 This north-south astrolabe was to have such large dimensions that the conventional geometrical tools like the rulers (*mistar*), compasses (*parkarha*), set-squares (*'usbādah*) and the common engraving tools could not be employed in its manufacture. Therefore, new tools had to be improvised, as the following couplet in the *Sīrat* informs us:

> Every instrument that was available before him
> Was further refined in his own time.

4.3 With these new tools, a large north-south astrolabe was manufactured and was given the grand designation *Asṭurlāb-i Fīrūz Shāhī*. The *Sīrat* provides a fairly long description of this instrument. When shorn of the usual hyperbole,[22] this description is valuable in the absence of the real astrolabe which is no more

[21] The *Sīrat* consistently calls this north-south astrolabe "*tamm*", meaning "whole astrolabe". Literally, of course, a north-south astrolabe can be considered a "whole astrolabe" but in astrolabic literature "*tamm*" is a technical term used exclusively for astrolabes having 90 almucanter circles.

[22] In the *Catalogue of the Arabic and Persian Manuscripts in the Oriental Public Library at Bankipore*, vol. 7: Indian History, Patna 1921, second impression: Patna 1977, p. 33, Maulana Abdul Muqtadīr states that in this chronicle "A strong tendency to eulogy and exaggeration is shown throughout. The narrative is florid, overloaded with pious effusions, generally ending in a compliment to the king."

extant. The account occasionally reads as if it is a quotation from a manual. The description is also valuable because it was composed soon after the manufacture of the astrolabe. It will be shown presently that the astrolabe is dated 12 *Sha'bān* 771 AH while the book was completed a year later in 772 AH.

4.4 The *Sīrat* begins with a conventional enumeration of the components of the astrolabe by saying that the *Asṭurlāb-i Fīrūz- Shāhī* consisted of twelve parts, viz. ring (*ḥalqa*), shackle (*'urwa*), cord (*mismār*), throne (*kursī*), mater (*umm*), outer rim (*ḥajra*), tympans (*ṣafā'iḥ*), rete (*'ankabūt*), alidade (*'iḍādah*), pin (*qutb*), sighting vanes (*libna*), horse-shaped wedge (*faras*).

4.5 Thereafter the *Sīrat* goes on to describe the back (*ẓahr*) of the astrolabe. It mentions the graphs for sines (*jayb*) and cosines (*qaus*), and the arcs of solar declination (*mayl-i aftāb*), which were presumably engraved in the two upper quadrants. Then three kinds of shadow squares are enumerated, with gnomons measuring respectively seven feet (*ẓill-i haft qadmī*), twelve digits (*ẓill-i asābi'a*), and six and half feet (*ẓill-i shashnim qadmī*). These are well known types, discussed among others by Al-Bīrūnī,[23] and are actually tables of tangents and co-tangents for different angles. However, normally only the first two types of shadow squares are displayed in the lower half of the astrolabe.

The back is also said to contain much astrological data in concentric semi-circles around the shadow squares. Here were shown the "limits" (*ḥudūd*), "faces" (*wujūh*), trigons (*muthallatha*), their regents, exaltations (*sharaf*), dejections (*hubūt*) etc.[24] The astrological data also included a fourfold division of the lunar mansions according to Indian astronomers, namely blind, one-eyed, both-eyed, and clear-sighted. This corresponds to the classification as *andha, mandākṣa, madhyākṣa* and *sulocana* in Sanskrit astrological texts.[25] Furthermore, the back of the astrolabe is said to contain "a table of the position of the constellations" from 12 *Sha'bān* 771 to 1 *Ramaḍān* 907.

4.6 On the front side (*wajh*), the astrolabe contained three tympans (*ṣafā'iḥ*). On each side of these three tympans and on the inner side of the mater,

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[23] Khareghat, op. cit., pp. 7-10.

[24] For the explanation of these astrological terms, see Hartner, op. cit., pp. 304-306; Khareghat, op. cit., 11-15.

[25] Cf. for example, Rāma Daivajña, *Muhūrtacintāmaṇi*, Bombay 1933, 2.22.

stereographic projections were drawn for seven different terrestrial latitudes. Each of these latitudes pertained to a separate climate. The *Sīrat* furnishes the names of towns, their climates, latitudes and the duration of the maximum daylight, as shown in the table below.

Pl. No.	Town	Climate	Latitude	Maximum Daylight Hours
1a	Tilang	I	[18°]	13;06
1b	Ajmer	II	26°	13;40
2a	Delhi	III	20;39°	13;05
2a	Mosul	IV	36°	14;30
3a	Bukhāra	V	39°	14;48
3b	Kashghar	VI	44°	15;22
Umm	Balghar	VII	49°	16;04

4.7 After mentioning the particulars for each plate, the *Sīrat* adds the names of other adjacent towns with their latitudes. Thus we have here a kind of geographical gazetteer of some sixty towns, among which seventeen are Indian. Generally, the gazetteer is engraved on the inner side of the mater. But in the Fīrūz-Shāhī astrolabe the inner side of the mater contained a projection for the seventh climate. The gazetteer, on the other hand, is apparently distributed in seven groups on the seven projections pertaining to the different climates. That is to say, on the second side of the first tympan which is calibrated for the latitude of Ajmer, the following information is engraved: the name of town (Ajmer), climate (II), latitude (26°), maximum duration of the daylight in hours (13;40), and also the names of nine other towns together with their latitudes which lie in the second climate. Likewise, on the first side of the second tympan, calibrated for Delhi in the third climate, the names and latitudes of ten other towns are mentioned. This seems to be a more meaningful method of recording the geographical gazetteer.[26] However, this part of the manuscript of the *Sīrat* is extremely faulty. The latitudes given for many towns are quite wide off the mark.

26 There are at least two extant Indian astrolabes which follow this method: (i) Indo-Persian Astrolabe, dated 1616 AD, in the collection of the Sampurnanand Sanskrit University, Varanasi; cf. Sarma, "Kaṭapayādi System on a Sanskrit Astrolabe," op. cit, p. 275; and (ii) Gurumukhī astrolabe dated VS 1907/AD 1850 in a private collection in London.

This is so even in the case of Delhi, for which the *Sīrat* assigns the latitude of 20;39 degrees and the maximum daylight of 13;5 hours, while the correct figures as available in contemporary Sanskrit sources are 28;39 degrees and 13:49,36 hours respectively.

4.8 Since this is a north-south astrolabe, the projections on the tympans were made both for the northern and southern celestial hemispheres. First of all, says the *Sīrat,* five concentric circles were described on the tympans to represent the five diurnal circles (*madārāt-i panigāna*) of the Equator, Capricorn, Aries, Libra and Cancer. The correct sequence should be Capricorn, Aries, Cancer, Libra, and Capricorn. In fact, the circles of Aries and Cancer coincide with the Equator. Therefore, in effect, the five concentric circles represent successively the Tropic of Capricorn, Equator, Tropic of Cancer, Equator, Tropic of Capricorn.[27] Then the altitude circles (*muqanṭarāt*) were drawn both for the northern and southern celestial hemispheres.

4.9 Finally, the rete (*'ankabūt*). The *Sīrat* says that the position of eighteen fixed stars were marked on it, according to their coordinates on 12 *Sha'bān* 771 (=10 March 1370)[28] and on 21 *Sha'bān* 839 (= 9 March 1436), "so that the astrolabe may be used for 136 years from the time of manufacture." We may recall that the table of constellations on the back of the astrolabe was said to be valid from 12 *Sha'bān* 771 to 1 *Ramadān* 907 (= 9 March 1502). This is the duration of 136 lunar years.

4.10 Thus the *Sīrat* mentions three dates, separated from one another by 68 lunar (66 solar) years. The first is undoubtedly the date of the manufacture of this astrolabe and the 18 star positions marked on the rete correspond to their co-ordinates on 10 March 1370. But when the *Sīrat* adds that the positions on 21 *Sha'ban* 839 (= 9 March 1436) were also marked and that the instrument can be used for the 136 years starting from the time of manufacture, it seems to imply that the star positions were marked for three different dates; 10 March 1370;

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[27] Cf. the contemporary Sanskrit manual *Yantrarāja*, p. 60, where this sequence is given correctly. This text will be discussed in 5.1 ff. below.

[28] I have used CALH Calendar Conversion Programme, Historical Edition, version 1.2, November 1996, developed by Benno van Dalen for converting the *Hijrī* dates into Julian dates and Pancanga vers. 2.0 developed by M. Yano and M. Fushimi for converting the Indian *tithis*.

9 March 1436; and 9 March 1502. Now it is most unusual to display three different positions for each of the18 stars and thus to construct 54 star pointers. It is possible that the rete of the astrolabe displayed star positions only of the date of manufacture, viz. 10 March 1370, and the table engraved on the back of the astrolabe or the manual composed in Persian at this time explaining the construction and use of this astrolabe contained the co-ordinates of these 18 stars on the afore-mentioned three dates.[29] It appears that here also the anonymous author of the *Sīrat* is quoting indiscriminately from the inscriptions on the astrolabe as well as from the manual. This hunch is strengthened by his statement at the end of the section on astronomy and astrolabes, where he says:

> Here from every chapter something has been extracted and offered by way of samples. The full texts on this branch of knowledge, written under emperor's desire and also the astrolabes constructed under his direction are preserved in the royal library.

5.1 Sulṭān Fīrūz's real achievement, however, lay not in mastering the principles of the astrolabe, nor in getting it manufactured — though both are creditable in themselves — but in disseminating the science of the astrolabe in India among the Jainas and Hindus.[30] The Persian sources are silent on this aspect but fortunately there survives a Sanskrit text on the construction and use of the astrolabe, entitled *Yantrarāja,* which was produced in 1370 AD under the auspices of Fīrūz. This was the first ever manual on the astrolabe in Sanskrit and was composed by the Jaina monk Mahendra Sūri. His pupil Malayendu Sūri wrote a commentary on it.[31]

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[29] Due to the precession of the equinoxes, the longitudes of the stars increase by about 1° in 66 solar years. As will be shown below in 7.2, Mahendra Sūri accepts a rate of precession of 1° in $66\frac{2}{3}$ solar years.

[30] I mention the Jainas first because they had good relations with the Delhi Sulṭāns. They also acted as intermediaries in the intellectual exchanges between the Islamic learning on the one hand and Sanskrit scholarship on the other.

[31] Mahendra Sūri's *Yantrarāja,* together with the commentary by Malayendu Sūri, ed. Kṛṣṇaśaṅkara Keśavarāma Raikva, Bombay 1936. On this text and others of this genre, see S. R. Sarma, "Yantrarāja: the Astrolabe in Sanskrit" (n. 6 above); see also Sadashiva L. Katre, "Sultān Firūz Shāh Tughluq: Royal Patron of a Contemporary Sanskrit work," *Journal of Indian History,* 45 (1967) 375-367.

5.2 It is well known that Fīrūz got a number of Sanskrit texts on medicine, astronomy and astrology translated into Persian.[32] This could have been possible only if he had gathered at his court Jaina and Hindu scholars, besides Muslim scholars. The *Sīrat* reports about these translations,[33] but it does not mention that any Jainas or Hindus were associated with this activity. Only once does the *Tārīkh-i Fīrūz Shāhī* state that the Sulṭān summoned Brahmins and Jainas to decipher the writings on the Aśokan pillar but none could do so.[34]

6.1 Be that as it may, Mahendra Sūri was so impressed by the versatile functions of the astrolabe that he called it *Yantrarāja*, the king of astronomical instruments. At the beginning of his work which is also styled *Yantrarāja*, he says that the Muslims have written many manuals on the astrolabe in their language. Having extracted their essence, just as one extracts nectar after churning the milky ocean, he is presenting this work in Sanskrit.[35] We do not know exactly what these Arabic/Persian sources were which Mahendra Sūri consulted, but they certainly must have included Al-Bīrūnī's various Arabic writings on the astrolabe.

6.2 Malayendu informs us that his teacher Mahendra Sūri was the foremost astronomer at Fīrūz's court. He concludes his commentary on each of the five chapters with a common colophon stanza, which translates thus:

> Master Mahendra Sūri, the great Sūri, was the foremost (*praṣtha*) among all the astronomers at the court of the illustrious Fīrūz, the lord of the Muslims. In this commentary on the *Yantrarāja* composed by Malayendu Sūri, who is like the honey-bee at the lotus feet of the said master, the first chapter entitled *Gaṇitādhyāya* is concluded.[36]

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[32] One of the texts thus translated was Varāhamihira's *Bṛhatsaṃhitā*, and this translation is still extant. Cf. S. Farrukh Ali Jalali and S. M. Razaullah Ansari, "Persian Translation of Varāhamihira's Bṛhatsaṃhitā," *Studies in History of Medicine and Science*, 9 (1985) 161-170.

[33] Cf. Sreeramula Rajeswara Sarma, "Translation of Scientific Texts under Sawai Jai Singh," *Sri Venkateswara University Oriental Journal*, 41 (1998) 67-87.

[34] Cf. Sreeramula Rajeswara Sarma, "Palaeographic Notes," *Aligarh Journal of Oriental Studies*, 3.2 (1986) 125-140.

[35] Mahendra Sūri, *Yantrarāja*, 1.3.

[36] *Yantrarāja*, p. 54:

śrīperojaśakendrasarvagaṇakapraṣṭho mahendraprabhur
jātaḥ sūrivaraḥ tadīyacaraṇāmbhojaikabhṛṅgadyutā /
sūriśrīmalayendunā viracite 'smin yantrarājāgame
vyākhyāne gaṇitābhidhaḥ prathamako 'dhyāyaḥ samāptiṃ gataḥ //

The printed edition reads *gaṇakaiḥ pṛṣṭo* which makes no sense. I follow the reading in Ms no. 37 of the Department of Sanskrit, Aligarh Muslim University.

6.3 Like the *Sīrat,* Malayendu's commentary also furnishes a geographical gazetteer of 77 towns together with their latitudes, of which some sixty are Indian.[37] Here a special mention is made of "Hissār-Fīrūzābād founded by the illustrious King Fīrūz [at the latitude] 29° 48'." Sulṭān Fīrūz did indeed construct a fort at Hissar and called it Hisār-Fīrūzah around 1355, and from there on laid his famous canal system.[38] Delhi is mentioned under the twin names Dillī and Yoginīpura, and is assigned to the latitude 28° 39'. Again, whenever a concrete example is needed to illustrate a rule, this latitude of Delhi is taken as the basis for such calculations.[39] All of this goes to show that Malayendu was at the court of Fīrūz, obviously in the company of his teacher Mahendra.

7.1 But the most significant fact is the following. In the *Yantrarāja,* Mahendra furnishes a catalogue of thirty-two astrolabe stars together with their longitudes and latitudes.[40] In the commentary, Malayendu adds that the epoch for this catalogue is "*Saṃvat* 1427 *Caitra sudi* 15 corresponding to the thirteenth lunar day of *Sha'bān* in the Arabic year 771."[41] Now

VS 1427 *Caitra sudi* 15 = 12 March 1370 Tuesday
AH 771 *Sha'bān* 13 = 11 March 1370 Monday.

Thus there is a difference of one day between the Vikrama and Hijrī dates. However, since the lunar day in Islamic calendar begins at sunset, 13 *Sha'bān* begins at the sunset on Monday and lasts up to the sunset of Tuesday. Therefore the two dates coincide during the daylight hours of Tuesday, 12 March 1370.

7.2 Furthermore, there are two separate tables in the commentary containing the co-ordinates for the 32 stars respectively for *Saṃvat* 1427 *Caitra sudi* 15 (=12 March 1370) and *Saṃvat* 1494 *Śaka* 1359 *Caitra sudi* 15 (=21 March 1437).

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37 *Yantrarāja,* pp. 18-19. These are tabulated and compared with Ulugh Beg's lists by David Pingree, "History of Mathematical Astronomy in India," *Dictionary of Scientific Biography,* vol. XV, New York 1978, pp. 626-627.

38 Cf. Mohammad Habib and Khaliq Ahmad Nizami (ed), *A Comprehensive History of India,* Vol. V: The Delhi Sultanat, pp. 587-588.

39 See, for example, *Yantrarāja,* pp. 16-18.

40 Ibid, I. 22-39. Cf. David Pingree, op. cit.,p. 628.

41 *Yantrarāja,* p. 35: "*Saṃvat 1427 varṣe caitraśudi 15... yathā taddine arabī terīṣaṃ 771 sabānacandra 13 abhūt.*" The printed edition reads the lunar date wrongly as 213 while the Aligarh MS reads it correctly as 13.

In the second table the longitudes have an increment of 1° added for precession.[42] In this context, Mahendra Sūri declares that the rate of precession is 720/800 minutes of the arc in one year, which works out to 1° in $66\frac{2}{3}$ years.[43] Now it becomes clear why the *Sīrat* speaks of different sets of star co-ordinates at an interval of roughly 66 years.

7.3 The *Sīrat* states, it may be recalled, that the star positions marked on the *Asṭurlāb-i Fīrūz Shāhī* pertain to 12 *Sha'bān* 771. I am unable, at present, to account for the discrepancy of one day between 12 *Sha'bān* of the *Sīrat* and the 13 *Sha'bān* of Malayendu Sūri. Nevertheless, this near identity between the epoch of Mahendra Sūri's star catalogue and that of the star positions engraved on the *Asṭurlāb-i Fīrūz Shāhī* cannot have been accidental. If Fīrūz had merely encouraged Mahendra Sūri to write a book on the astrolabe, the latter could have chosen any date as the epoch. But if the Sulṭān commissioned his Muslim astronomers on the one hand and Mahendra Sūri (together with his pupil and assistant Malayendu Sūri) on the other to compose books respectively in Persian and Sanskrit on the astrolabe, and further had ordered that his artisans manufacture a grand astrolabe employing therein the star positions calculated jointly by the Muslim and Jaina astronomers, then and only then will it be possible to have an identical date for all the three activities.

7.4 Then again, while 12 or 13 *Sha'bān* has no special significance in the Islamic calendar, *Caitra sudi* 15 is the beginning of the new year in Vikrama calendar in the North Indian *purṇimānta* system. Therefore, there is a greater chance of the epoch date being chosen by Mahendra Sūri rather than by the Muslim astronomers.

7.5 Even if it was not, the coincidence in the dates show that there was a systematic and close co-operation between Muslim and Jaina/Hindu astronomers at the Sulṭān's court. This would also suggest that manuals may have been composed in Persian and Sanskrit, and that astrolabes may have been manufactured accordingly with legends in both Arabic/Persian and Sanskrit. The Persian manuals and astrolabes are no more extant. What exists is only the somewhat garbled account of *the Sīrat.* But the best record that still survives of the Sulṭān's

[42] Ibid, pp. 36-43.

[43] Ibid, I. 40.

endeavours with the astrolabe is undoubtedly the Sanskrit text and commentary by the two Jaina Sūris, Mahendra and Malayendu.

8.1 We have seen that the *Sīrat* attaches great importance to the north-south composite astrolabe (*asṭurlāb shumālī wa janūbī*). Mahendra's *Yantrarāja* also dwells on this variant. It describes how to construct not only the northern astrolabes (*saumya-yantra*), but also the southern astrolabes (*yāmya-yantra*) as well as north-south composite astrolabes (*miśra-yantra*).[44]

8.2 In his commentary, Malayendu provides elaborate tables for constructing the north-south astrolabe. Here he supplies the eccentricities and radii, in northern and southern hemispheres, at six degree intervals of altitudes, for the following localities.[45]

S.No.	Town	Latitude	Maximum Daylight in *ghaṭīs*
1	Tilaṅga	18°	32;44
2.	Tryambaka	21°	33;34
3	Aṇahillapattana	24°	33;48
4	Tīrabhukta	27°	34;10,54
5	Dillī	28;39°	34;34
6	Nepāla	31°	35;06

8.3 We have mentioned that Fīrūz got a number of technical books on medicine, astronomy, astrology translated from Sanskrit into Persian and that this activity must have involved a close cooperation between Muslim scholars and Jaina/Hindu Sanskritists. It is gratifying that this cooperation should bear fruit in the reverse direction as well, when Mahendra Sūri composed the manual on the astrolabe, after having extracted the essence from many Arabic/Persian books on this subject. Neither the astrolabes manufactured at Fīrūz's command, nor the Persian manual composed at his instance survive today. But his efforts at disseminating the science of the astrolabe bore two different kinds of fruits respectively among Muslims and Jainas/Hindus of India.

[44] Ibid, Ch. III.

[45] Ibid, pp. 19-25.

8.4 Fīrūz's first attempts to manufacture astrolabes was avidly emulated by the Muslims. Astrolabe manufacture reached its zenith under the Mughals, especially during the reigns of Shāh Jahān and Aurangzeb in the seventeenth century.[46] On the other hand, the encouragement Fīrūz extended towards writing manuals on the astrolabe was taken up enthusiastically by Jainas/Hindus, who produced some fifteen works in the next four centuries.[47] Even so, Mahendra's *Yantrarāja* remained unsurpassed in popularity. Among the Indian *Jyotiṣīs* it enjoyed the same kind of high reputation as Nasīr al-Dīn al-Ṭūsī's celebrated Persian manual on the astrolabe in twenty chapters, popularly known as the *Bīst Bāb,* did among the Islamic astronomers.[48]

9.1 While the section on the astrolabes in the *Sīrat-i Fīrūz-Shāhī* is thus extremely valuable for the history of the astrolabe in India, only one sentence from this entire section gained certain amount of currency, generating a myth about Fīrūz's interest in the astrolabe. It is necessary to set this myth right. At the very beginning of the description of the *Asṭurlāb-i Fīrūz-Shāhī,* the *Sīrat* states that this astrolabe "was fixed on the top of the highest minaret of Fīrūzābād." While describing the manuscript in his catalogue, Maulana Abdul Maqtadīr lays special emphasis on this sentence: "The author says that... an astrolabe invented by the emperor himself, was constructed by his order and placed on highest minārah of Fīrūzābād."[49] Since then, nearly every one who writes on Fīrūz Shāh Tughluq mentions this fact as if it is of great scientific significance. To quote one typical instance, where this

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[46] See Sreeramula Rajeswara Sarma, "The Lahore Family of Astrolabists and their Ouvrage," *Studies in History of Medicine and Science,* 13.2 (1994) 205-224.

[47] Some of these texts were discussed in Sreeramula Rajeswara Sarma, "Astronomical Instruments in Mughal Miniatures,"*Studien zur Indologie und Iranistik,* 16-17 (1992) 235-276, esp. 238-241. See also, idem, "*Yantrarāja:* the Astrolabe in Sanskrit," IJHS, 34 (1999) 145-158.

[48] This is evident from the large number of manuscripts of this text. Ninety-nine manuscripts are listed in David Pingree, *Census of Exact Sciences in Sanskrit,* Series A, Volume 4, Philadelphia 1981, pp. 393-395; Volume 5, Philadelphia 1994, pp. 296-97. The one-hundredth manuscript is in the Department of Sanskrit of Aligarh Muslim University; cf. Sreeramula Rajeswara Sarma, *A Catalogue of Sanskrit Manuscripts. (A) Jyotiḥśāstra, preserved in the Department of Sanskrit, Aligarh Muslim University* (Typescript), No. 37, dated *Saṃvat* 1910 *Jyeṣṭha* kṛ 1 (which date corresponds to 23 May 1853). Moreover, the entire fifth chapter of this work is engraved on a large astrolabe, now preserved in the Science Museum, London; cf. Sarma, "Yantrarāja: the Astrolabe in Sanskrit," p. 154, Fig. 3.

[49] *Catalogue of Arabic and Persian Manuscripts in the Oriental Public Library at Bankipore,* Vol. 7: Indian History, Patna 1921, pp. 28-33.

statement is further embellished: "He got constructed a special type of astrolabe and fixed it on the highest minaret of Fīrūzābād, where it, along with some other instruments, served as an astronomical observation post."[50]

9.2 But from what has been said about the construction of the astrolabe, it must be obvious that it is not an automatic recording device, much less an "astronomical observation post," whatever this latter expression might mean. The astrolabe has to be held and manipulated by the astronomer. He holds it in his right hand and adjusts the alidade with the left hand in order to take the altitude of the sun in the daytime or that of a prominent star at night. Then he "feeds" the altitude so obtained into the astrolabe by rotating the star map to the appropriate position. Then the star map together with the latitude plate on which it rests simulates the heavens at the place of observation at that moment. Now the astronomer can take various kinds of readings from the front of the astrolabe. All of this, it must be reiterated, has to be done manually by the astronomer. Then again, as the *Sīrat* itself reports, this special astrolabe contains three latitude plates with projections for seven different towns (see 4.6 above). That is say, this astrolabe was fabricated for use in different localities and not just in Delhi alone.

9.3 In these circumstances, setting the astrolabe upon, or suspending it from, a lofty minaret would by itself serve no purpose unless the astronomer also stands there at least to read it. Thus for a fourteenth century Sulṭān to fix a rare astrolabe on the top of the highest minaret of Fīrūzābād and subject it to the vagaries of the north Indian weather would be as pointless as for a twentieth century prime minister to install a personal computer atop the Qutb Minar. For both these instruments have to be read by the user and manipulated by hand. Moreover, like the personal computer today, the astrolabe was an expensive and precious instrument of the Middle Ages, and it was handled with care.[51]

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[50] O.P. Jaggi, *History of Science and Technology in India*, Vol. VII: *Science and Technology in Medieval India*, Delhi 1977, p. 44. The same sentence is reproduced, without any attribution, by Pervin T. Nasir, "Muslim Contributions in Astronomy: Astrolabe Making during the Mughal Period," *Papers presented at the International Conference on Science in Islamic Polity: Islamic Scientific Thought and Muslim Achievements in Science*, Islamabad 1983, vol. 2, pp. 55-61, esp. p. 58.

[51] While describing the astrolabe manufacture at Isfahan, Sir John Chardin narrates how carefully the Persians treat the astrolabe: "... the Persians always keep astrolabes in cases or bags so that the air of Persia does not rust, dirty, or eat away the body, as it does in our Western countries; even among the common people each keeps his astrolabe like a jewel." Cited in: A. J. Turner, *The Time Museum, Catalogue of Collection*, Vol. I, Part 1: Astrolabe-related Instruments, Rockford 1985, p. 25, n.73.

9.4 Therefore, we must seek a rational explanation for this dubious sentence and not take it literally and then, in order to substantiate it, hypothesize that the astrolabe invented by Fīrūz is of special kind that took automatic recordings. There has never been such a variant in the history of the astrolabe nor does the *Sīrat* confirm such an interpretation. This chronicle merely states that it was just a plane astrolabe on which projections for the northern and southern celestial hemisphere were drawn. Such models were known to Al-Bīrūnī and others.

10.1 A likely solution to this problem is to be found in another contemporary chronicle of Fīrūz's reign, namely, the *Tārīkh-i Fīrūz Shāhī* by Shams Sirāj Afīf. This chronicle was written some eighteen years after the completion of the *Sīrat*. A comparison of the two chronicles suggests a possible rational answer to the conundrum. In Book IV, chapter 18 of the *Tārīkh*, Afīf speaks of the technical inventions and innovations introduced by Fīrūz.[52] In this connection, he mentions various types of standards or banners (*nishānaḥ*). First there is the mention of a pair of very large standards. Each of these were made of one maund of iron and were tied to the elephants with thick ropes. These elephants marched on either side of Fīrūz when he went out for hunting and the standards were visible up to a distance of three *kos*. The *Tārīkh* then goes on to state that Fīrūz also caused a *nishānah* called *aṣturlāb* to be suspended near/from the golden minaret (*minārah-i zarrin*). Thus what the Sulṭān caused to be suspended from a minaret cannot be the real astrolabe, the best and the elaborate one he got made, but a *nishānah*, a banner on which the astrolabe was painted or depicted. Why did he do it? Obviously to proclaim his great love for the instrument. Where was the banner hung from? Not from any random minaret but from the *minārah-i zarrin*, the golden minaret.

10.2 Before yet another myth is built up around this golden minaret, the *Tārīkh* fortunately explains what it was: it was the Aśokan pillar, which the Sulṭān got transported from Topra in 1356 and set up within his citadel at Fīrūzābād (i.e. the present-day Firoz Shah Kotla, not very far from the Indian National Science Academy) on the top of a three-storeyed building erected specially for this purpose, next to his Friday mosque. Afīf repeatedly mentions that Fīrūz called this pillar his golden minaret.

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[52] *Tārīkh-i Fīrūz-Shāhī*, ed. Maulvi Wilayat Husain, Calcutta 1890, pp. 269-270.

10.3 This pillar may also have been the highest minar in Fīrūzābād then, but there is not much space on its top to set up an "observation post" nor for the Sulṭān and his astronomers to stand there and take readings with the astrolabe. All that the Sulṭān can do from the minaret is to hang a banner with an astrolabe depicted on it in order to proclaim that the astrolabe was his favourite scientific instrument, that he mastered the principles of its construction and use, and that he got several astrolabes manufactured in his kingdom. The Sulṭān was fascinated enough by the massive polished stone pillar that he erected a special building for setting up the pillar upon it. Antiquarian though he was, he had no way of knowing that the pillar was caused to be carved and inscribed by Rājā Priyadarśī Aśoka more than sixteen hundred years earlier but he could not have chosen a more appropriate place for the symbolic act of displaying his astrolabe banner.

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