

Introduction of Persian Astronomy into India

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Abstract (received: 12/10/2008 - accepted: 08/12/2008)

The Islamic astronomy including the Persian astronomy was thoroughly introduced into India from the 14th century AD or so. Firstly, the astrolabe was introduced at the time of Fīrūz Shāh Tughluq, and a Sanskrit work entitled *Yantra-rāja* (1370 AD) was composed by Mahendra Sūri. At that time, some Sanskrit astronomical (or astrological) works were also translated into Persian. The astrolabe became quite popular in India, and Padmanābha wrote the second Sanskrit work on the astrolabe in 1423 AD. During the Delhi Sultanate period and the Mughal Empire period, Islamic astronomy and Hindu Classical astronomy influenced each other. I would like to discuss the introduction of the astrolabe into India and the development of astronomy in India in this period.

Keywords: Indian astronomy, Persian astronomy, astrolabe, Fīrūz Shāh Tughluq, Mahendra Sūri, Padmanābha.

Iran and India

According to modern linguistics, the origin of Iranians and that of Indo-Aryans are the same, and there are several similarities between Avestan language in ancient Iran and Vedic language in ancient India. And also, there is a community of Pārsīs (Zoroastrians) in India.

What I am going to discuss in this paper is not these ancient cultures, but the introduction of Islamic astronomy including Persian astronomy into medieval India. In medieval India (particularly Delhi Sultanate dynasties and Mughal Empire), Persian language was used as an official language, and there are several Indian historical documents in Persian. Some interesting astronomical works in Persian were also produced in India.

A brief history of Indian astronomy

The history of Indian astronomy can roughly be divided into the following periods.

- (i) Indus valley civilization period.
- (ii) Vedic period (ca. 1500 BC – ca. 500 BC).¹
 - (ii.a) Ṛig-vedic period (ca. 1500 BC – ca. 1000 BC).
 - (ii.b) Later Vedic period (ca. 1000 BC – ca.500 BC).
- (iii) Vedāṅga astronomy period.²
 - (iii.a) Period of the formation of the Vedāṅga astronomy (sometimes between the 6th and 4th centuries BC).
 - (iii.b) Period of the continuous use of the Vedāṅga astronomy (up to sometime between the 3rd and 5th centuries AD).³
- (iv) Period of the introduction of Greek astrology and astronomy.
 - (iv.a) Period of the introduction of Greek horoscopy (the 2nd (?) or 3rd century AD).⁴
 - (iv.b) Period of the introduction of Greek mathematical astronomy (sometimes around the 4th century AD?).
- (v) Classical Siddhānta Hindu astronomy period (end of the 5th century – 12th century AD).⁵
 - (vi) Coexistent period of the Hindu astronomy and Islamic

1. See Dikshit, Sankar Balakrishna, (*English Translation of) Bharatiya Jyotish Sastra* (History of Indian Astronomy), Translated by Prof. R.V.Vaidya, Part I, *History of Astronomy during the Vedic and Vedanga Periods*, Published by the Government of India, Delhi, 1969 [This book was originally written in Marathi, and published in Pune, 1896. Its Hindi translation *Bhāratiya Jyotiṣa* (translated by Śivanātha Jhārakhaṇḍī) was published in Lucknow, 1957]; Ōhashi, Yukio, “Development of Astronomical Observation in Vedic and Post-Vedic India”, *Indian Journal of History of Science*, 28(3), 1993, pp. 185 – 251.

2. See idems.

3. See Ōhashi, Yukio, “The Legends of Vasiṣṭha – A Note on the Vedāṅga Astronomy”, in Ansari, S.M. Razaullah (ed.): *History of Oriental Astronomy*, Kluwer Academic Publishers, Dordrecht, 2002, pp. 75 – 82.

4. See Pingree, David (ed. and tr.), *The Yavanajātaka of Sphujidhvaja*, 2 vols., Harvard Oriental Series, vol. 48, Harvard University Press, Cambridge, Mass., 1978.

5. See Dikshit, Sankar Balakrishna, (*English Translation of) Bharatiya Jyotish Sastra* (History of Indian Astronomy), Translated by Prof. R.V. Vaidya, Part II, *History of Astronomy during the Siddhantic and Modern Periods*, published by the Government of India, Delhi, 1981; Ōhashi 1994.

astronomy (13/14th – 18/19th century AD).¹

(vii) Modern period (Coexistent period of the modern astronomy and traditional astronomy) (the 18/19th century onwards).²

The Coexistent period of the Hindu astronomy and Islamic astronomy

During the previous Classical Siddhānta Hindu astronomy period (end of the 5th-12th century AD) of Indian astronomy, several astronomical treatises were written in Sanskrit.

After the establishment of Islamic dynasties in North India, the coexistent period of the Hindu astronomy and the Islamic astronomy (13/14th-18/19th century AD) began. This period is roughly divided into two subdivisions, namely the Delhi Sultanate period and the Mughal Empire period (see Appendix of this paper).

Actually, the earliest Sanskrit work which mentions a kind of the information of Islamic calendar is the *Kālacakra-tantra* (an esoteric Buddhist work, probably written in the 11th century AD), where the year of Hijra is mentioned with two years' error. However, the calendrical system of the *Kālacakra-tantra* is basically based on the Classical Hindu astronomy, and the influence of Islamic mathematical astronomy is not found there. The *Kālacakra-tantra* is the source of the Tibetan astronomy.³ And also, there is a possibility that certain knowledge of Islamic astronomy was introduced into India by al-Bīrūnī (ca. 973-1050 AD) who studied Indian culture including

1. See Ansari, S.M. Razaullah, "On the Transmission of Arabic-Islamic Astronomy to Medieval India", *Archives Internationales d'Histoire des Sciences*, 45 (No.135), 1995, pp. 273 – 297; Rahman, A. (ed.), *History of Indian Science, Technology and Culture AD 1000 – 1800*, (History of Science, Philosophy and Culture in Indian Civilization, vol. III, Part 1), Oxford University Press, New Delhi, 1998.

2. See Ansari, S.M. Razaullah, *Introduction of Modern Western Astronomy in India during 18-19 Centuries*, Department of History of Medicine and Science, Institute of History of Medicine and Medical Research, New Delhi, 1985, (also included in Sen and Shukla (1985/2000)); Kochhar, Rajesh and Jayant Narlikar, *Astronomy in India, A Perspective*, Indian National Science Academy, New Delhi, 1995.

3. See Ōhashi, Yukio, "Remarks on the Origin of Indo-Tibetan Astronomy", in Selin, Helaine (ed.): *Astronomy across Cultures*, Kluwer Academic Publishers, Dordrecht, 2000, pp. 341 – 369.

astronomy deeply,¹ but there is no extant Indian source material which shows al-Bīrūnī's influence at that time.

The first Sanskrit work where Islamic astronomy is explained in detail was produced during the reign of Fīrūz Shāh Tughluḳ (1351-1388 AD), the third Sultan of the Tughluḳ dynasty of India. At this time, some Sanskrit works on Hindu astronomical sciences were also translated into Persian by the order of Fīrūz Shāh. These events mark the real beginning of the coexistent period of Hindu and Islamic astronomy.

Cultural exchange during the reign of Fīrūz Shāh Tughluḳ

Introduction

The time of Fīrūz Shāh Tughluḳ was the real beginning of the cultural exchange between Muslims and Hindus in the field of astronomy. The astrolabe was introduced into India, and a Sanskrit work on the astrolabe was produced by Mahendra Sūri at the request of Fīrūz Shāh. I shall discuss this topic in the subsequent sections. And also, several Sanskrit works were translated into Persian during his reign. There are several Persian historical documents on Fīrūz Shāh's reign (see Elliot and Dowson, III, 93–388). Among them, there is an anonymous manuscript in Persian entitled *Sīrat-i Fīrūz Shāhī* (1370 AD) (accession No. HL-99 Khuda Bakhsh Oriental Library, Patna) (see Muḳtadir, 28–33). A facsimile of this unique manuscript was published in 1999 (Panta) with an introduction by S.H. Askari.

Persian translation of Sanskrit works

According to the *Tārīkh-i Fīrishtah* (ca. 1611 AD) of Fīrishtah, Fīrūz Shāh conquered Nagarkot (in present-day Himachal Pradesh), found a library of Hindu books, consisting of 1300 volumes, in a temple there, ordered one of those books, which treated of philosophy, astrology and divination, to be translated into Persian by 'Izz al-Dīn Khālīd Khānī, and called it *Dalā'il-i Fīrūz Shāhī* (see Briggs, I, 263).

1. See Sachau, Edward C. (tr.), *Alberuni's India*, London, 1910; reprinted: Oriental Books Reprint Corporation, New Delhi, 1983.

According to the *Muntakhab al-Tawārīkh* (1595 AD) of al-Badāyūnī (or commonly known as al-Badāonī), it “is moderately good, neither free from beauties nor defects” (see Ranking, 332). According to the *Ṭabaḳāt-i Akbarī* (ca. 1594 AD) of Niẓām al-Dīn Aḥmad, “it is a book containing various philosophical facts both of science and practice” (see De, 249).

The manuscript *Sīrat-i Fīrūz Shāhī* (f. 151 v.) reads as follows:

«... چنانکه دلائل فیروز شاه که آنرا از هندوی به زبان فارسی ترجمه فرموده است، در احکام باریدن باران و گرد آمدن ابر و احکام کسوفات و خسوفات و قرانات کواکب و انتقالات ایشان از برجی برجی چه دلیل کند، و بیشتری دلائل احکام نجوم از آن معلوم میشود.»

“As there is the *Dalā'il-i Fīrūz Shāh* (Book of the Reasons of Fīrūz Shāh), which was translated from Hindu's language to Persian, on the laws of falling of rain and assembling of cloud, the laws of solar eclipses and lunar eclipses, and that what kind of reason is meant in conjunctions of stars and their transitions from zodiacal sign to sign, much of the reasons of the laws of astronomy (*nijūm*) becomes known from it.”

According to some catalogues, there are some manuscripts of the *Tardjamah-i Bārāhī* (Translation of Varāha[-mihira]'s work), which is a Persian translation made by ‘Abd al-‘Azīz Shams Bahā’ Nūrī at the request of Fīrūz Shāh from the *Brhatsamhitā*, an encyclopaedic work on natural phenomena etc. in Sanskrit,¹ of Varāhamihira (6th century AD) (For the information about Persian translation², see Storey, 38; Rahman, 275). It may be that this is more or less related to the *Dalā'il-i Fīrūz Shāh*, but I have not yet seen the *Tardjamah-i Bārāhī*.

The *Sīrat-i Fīrūz Shāhī* mentions some other related books, one of

1. For its Sanskrit text with an English translation, see: Bhat, M. Ramakrishna (ed. and tr.), *Varāhamihira's Brhatsamhitā*, 2 parts, Motilal Banarsidass, Delhi, 1981-82.

2. Jalali, S. Farrukh Ali; S.M. Razaullah Ansari, “Persian Translation of Varāhamihira's Brhatsamhitā”, *Studies in History of Medicine and Science*, 9(3-4), 1985, pp. 161-169.

which (*Kitāb-i Sārwālī*) seems to be a Persian translation of a Sanskrit astrological work, *Sārāvalī* (ca. 800 AD) of Kalyāṇa-varman.

The water clock

According to the *Tārīkh-i Fīrūz Shāhī* of Shams Sirādj 'Afīf, a water clock (*tās-i g'harīyālah*, طاس گهڑیالہ, where the letter “ر” (ڑ) is an Urdu letter of retroflexed “r”), was placed in the Court in Fīrūzābād (in Delhi) (For its Persian original text, see Husain, 254–260; For its English summary, see Elliot and Dowson, III/338; Sarma, 2008, 125–135). The book *Tārīkh-i Fīrūz Shāhī* itself is written in Persian, and the word “*tās*” means copper bowl in Persian, but the word “*g'harīyālah*” is a derivative of Sanskrit word “*ghaṭī*” which means 1/60 of a day (i.e. 24 minutes) as well as a small water pot. Here also cultural exchange between Muslims and Hindus can be seen.

The water clock of Hindus was called “*ghaṭī-yantra*”, where the word “*yantra*” means instrument, and was a copper bowl with a small hole at its bottom. The bowl is placed on water in a large vessel, water slowly flows into the bowl through the hole at its bottom, and the bowl sinks in a *ghaṭī*. This type of water clock was commonly used in India, and there are several accounts of its actual use (see, for example, Ōhashi 1994, 273–279). It may be mentioned here that the description of this kind of water clock is also found in the memoir of the 1st emperor of the Mughal empire Bābur (see Beveridge, A.S., 516–517), and also in the *'Ā'īn-i Akbarī*, a detailed record of the reign of the 3rd emperor Akbar, of Abu'l-Fadl (see Blochmann and Jarrett, 3/17–18).

Introduction of astrolabe into India

During the reign of Fīrūz Shāh Tughluq, astrolabe was introduced into India from the Islamic world. This fact is recorded in *Sīrat-i Fīrūz Shāhī*. It (f. 152 r., see Fig.1) reads:

«اسطرلابِ تامِ کہ آن منسوب است بہ اسطرلابِ فیروز شاہی و بر
بالاترین بامِ منارۂ فیروز آباد نصب کردہ اند، بہ اختراع و تصنیف و ارشاد و
تألیفِ خاصِ حضرتِ سلطنتِ خلد اللہ ملکہ مرتب شدہ.»

ترجمه شد و اسطرلاب است مصنفه خاص اسطرلابی اربعه لیس
 قلم است اسطرلاب است و بکرمصر شهری میکنند که در آن کاراید و این
 بهعت علم کاراید و اسطرلابی دیگر از نقره شمایی و جنوبی در آن
 مقطره کشیده اند و منطبقه و عتکبوت ان شمایی جنوبی که اکثر
 کرده و اسطرلابی دیگر برنجی شمایی و جنوبی مرض معنی اسطرلابی
 از زر و نقره شمایی در آن حدود مروج و دوحه و ارباب منقبات
 و ساعات و ترف کواکب و مبروط ایشان منطبقه و بکرمصر ان شهر
 یکن طبعی در اسطرلاب است و کرمصل سطرلاب و ساعت و اینچهره است
 میدا توان کردن اندرین مجر و ارتعاش گرفتن ساعات و طاس حاصل
 میشود چون ساعت و طاس معلوم سطرلاب نیز معلوم کرد و اینچهره
 برایی و اینچهره اوقات نماز و طالع وقت و ساعت گذشته و باقی
 مانده ارد و شرح وقتی بود اسطرلاب است که ان منسوب است با سطرلاب نیز در
 ورمالارین بام مساره فرود آمد نصب کرد و انداخته و تصنیف و
 ارتداد و تالیفها خاص حضرت سلطنت جلدرانده ملکه مرتب شده و باعتر
 ان صنعت یعنی بود که بعضی حکما جمع مایون انها کردند که در عهد
 ذوالقرنین سکندر روی اسطرلابی در سکندریه ساخته اند اما ان اسطرلاب
 شمایی جنوبی نیست موصی ثری تا بنه ان جده کاه است بود در
 و
 برتال جامع علوم اسلامی

Fig. 1. *Sīrat-i Fīrūz Shāhī* (f. 152 r)

“The perfect astrolabe is considered as the astrolabe of Fīrūz Shāh and has been placed on the highest roof of the minaret in Fīrūzābād was well arranged by the special innovation, writing, guidance and authorship of His Majesty of the Kingdom, may his kingdom be eternal by the protection of Allāh.”

According to its subsequent description, some scholars told the king Fīrūz Shāh about the astrolabe made in Alexandria at the time of Alexander¹ which was a “northern astrolabe” (*uṣṭurlāb-i ṣhimālī*). Then another astrolabe which was made according to the writing of savants at the time of Alexander was brought to the King. It was “northern and southern” (*ṣhimālī wa janūbī*). The King told as follows (f. 152 v, see Fig. 2):

«از اشکال و اوضاع این اسطرلاب که از تصنیف حکمای عهد سکندر به ما رسیده است و جنوبی و شمالی است و به غور آن رسیده‌ایم و دقایق آن ما را معلوم و مفهوم گشته، می‌توانیم که از این قیاس کنیم و همان مصنوع حکماء متقدم را در این صنعت مقتدا سازیم و اسطرلاب تام چنانکه در اسکندریه شنیده پردازیم که هم شمالی باشد و هم جنوبی.»

“From the form and conditions of this astrolabe on which the writing of savants at the time of Alexander has come down to us, which is southern and northern, into which we have made investigation, and details of which have become known and understood by us, we can analogize from it, and conform us to the same product of ancient savants in this workmanship, and we may construct the perfect astrolabe as heard in Alexandria which is northern as well as southern at the same time.”

1. Actually, it must not be a historical fact that the astrolabe was made at the time of Alexander the Great, because astrolabe had not been invented at his time.

که موضح ان فرها گشته است تنها ام در ان ایام از تصنیف حکما و عمده
 سکندر اسطرلاب پیش بر سلطنت رسد که شام و جزیره و در درازگی
 ان منبع بلین فرمود و باستقصا نظر کرد بونور عقل و دما که حاکم
 بر سما ان جامی درین مصطلح را عطا کرده است بد قان وضع ان اطلاع کامل
 حاصل گشت باطن جابون بر تری اسطرلاب نام حکما که در اسکندریه تسان
 داده بودند یا بل شد ز نمودار اشکال و اوضاع این سطرلاب که از
 تصنیف حکمای عمده سکندر و ما رسیده است و جزیره و شمالست و
 و نیز ان رسیده ایم و وقایع ان ما را معلوم و مفهوم گشته می توانیم که ازین
 قیاس کنیم و همان صنوع حکما متقدم را درین بصورت مقتدا سازیم و
 اسطرلاب نام خوانند در اسکندریه شنیده و نیز داریم که هم شامی است
 و هم جزیره سیرین کار عزم مصمم شده و حکما و مخان و محاسبان و فمندان
 هند را و صنایع این عمل را جمع کرد و فرمود

کنون کان همه ما د تهای مر است	نزدکی زنه تا غایبی مر است
حکیمان که فرزند ارم از پیش و نم	حکمت در افان گشته علم
مرا نیز و نند از خاص و عام	که دارم درین علم دستی تمام
جوابی بدو که در دور کار	شاید نماید ز فرما کار

س چون ابر اسطرلاب از کت و مدارت و معظرات ان نیز بر

Fig. 2. *Sīrat-i Fīrūz Shāhī* (f. 152 v)

The “northern astrolabe” is the usual astrolabe. The centre of its disc corresponds to the celestial North Pole, and the concentric circles of the Tropic of Cancer, the equator and the Tropic of Capricorn (which is the rim) are drawn. It is useful in the northern hemisphere. The “southern astrolabe” is the opposite, and its centre corresponds to the celestial South Pole. The “perfect astrolabe” must be the combination of these two kinds of astrolabe. We shall see in the next section that Mahendra Sūri also described a similar astrolabe called “*phanīndra-yantra*”.

Early Sanskrit works on astrolabe

The *Yantra-rāja* of Mahendra Sūri

In 1370 AD, a Sanskrit work entitled *Yantra-rāja* was composed by Mahendra Sūri at the request of Fīrūz Shāh Tughluq. It is a detailed monograph of the newly introduced astrolabe.¹ The Sanskrit word “*yantra-rāja*” stands for astrolabe. The name “*yantra-rāja*” literally means “king of instruments”. This work is the earliest Sanskrit work on the astrolabe. This work has a commentary (ca.1377-82 AD) written by Malayendu Sūri, a disciple of Mahendra Sūri, which has been published² and there exists an unpublished commentary of it (1540 AD) written by Gopirāja.

The *Yantra-rāja* (I.3) reads:

“Treatises on instruments have been written in several ways from their own viewpoint in their own language by *Yavanas*. Having churned them like oceans, I give the nectar-like essence in its entirety.”

The word “*Yavana*” originally meant Greek in ancient India, but it also means Western foreigner, and it must refer to Muslim here. So, Mahendra Sūri must have seen Arabic or Persian literature on the astrolabe.

1. For its Sanskrit text, see Raikva, Kṛṣṇaśaṅkara Keśavarāma (ed.), *Yantra-rājah (tathā Yantra-śiromaṇih)*, Nirnaya-sagar Press, Bombay, 1936. Also see Sarma, S.R., “Yantrarāja: The Astrolabe in Sanskrit”, *Indian Journal of History of Science*, 34(2), 1999, pp. 145–158; also included in Sarma 2008, 240–256.

2. In Raikva, op. cit.

Mahendra Sūri explained the construction of the astrolabe and related mathematical astronomy in detail.

Besides the usual “northern astrolabe” which Mahendra Sūri called “*saumya-yantra*” (The word “*saumya*” means northern.) in Sanskrit, Mahendra Sūri also described the “*phaṇīndra-yantra*”, which is a combination of “northern astrolabe” and “southern astrolabe” (*yāmya-yantra*). The *Yantra-rāja* (III.20) reads:

“Among the variations of the mixture of them (northern astrolabe and southern astrolabe), in the case of “*phaṇīndra-yantra*”, three circles (the Tropic of Capricorn, the equator and the Tropic of Cancer) should be drawn just like the northern [astrolabe]. From the last [circle] of Cancer, [whose radius is] divided by 30, the remaining two circles (the equator and the Tropic of Capricorn) should be drawn just like the southern [astrolabe].”

The rim of this instrument corresponds to the Tropic of Capricorn, and the equator and the Tropic of Cancer are drawn inside just like the usual “northern astrolabe”. The radius of the instrument (that is the radius of the outermost circle of the Tropic of Capricorn) is assumed to be 30 units. Then the innermost circle of the Tropic of Cancer is now considered to be the rim of (small) southern astrolabe whose radius is 30 (small) units. Then the equator and the Tropic of Capricorn are drawn inside just like the southern astrolabe. So, this “*phaṇīndra-yantra*” has 5 concentric circles, instead of 3 concentric circles in the usual “northern astrolabe”. This is certainly a combination of the “northern astrolabe” and the “southern astrolabe”, but it might not have been so useful. Anyway, this “*phaṇīndra-yantra*” must have been related to the “perfect astrolabe” (*uṣṭurlāb-i tām*) of Fīrūz Shāh.

From the *Yantra-rāja*, we know that Mahendra Sūri understood the principle of the astronomy very well, and made great contribution to make it understandable to Indian scholars.

The *Yantra-rāja-adhikāra* of Padmanābha

The second Sanskrit work on the astrolabe was composed by Padmanābha. Padmanābha was a Hindu astronomer who wrote some

works on astronomical instruments in Sanskrit. Padmanābha was a son of Nārmada, who was also an astronomer, and Padmanābha was the father of Dāmodara, who composed two handy astronomical works, the *Bhaṭṭa-tulya* (1417 AD) and the *Sūrya-tulya* (1417 AD).

It is relatively well known that Padmanābha composed the *Dhruva-bhramaṇa-yantra-adhikāra* (chapter two of his *Yantra-ratnāvalī*), whose several manuscripts are extant. Here, the “*dhruva-bhramaṇa-yantra*” is the name of the instrument, and the word “*adhikāra*” means chapter. This is a description of a kind of nocturnal, where time can be obtained from the direction of α and β Ursae Minoris. This must be Padmanābha’s own invention. Padmanābha is also known to have composed a small work *Dik-sādhana-yantra*, whose single manuscript is preserved in Baroda (Vadodara).

Padmanābha also composed the *Yantra-rāja-adhikāra* (chapter one of his *Yantra-kiranāvalī*). The relationship between the *Yantra-ratnāvalī* and the *Yantra-kiranāvalī* is yet to be investigated. Only one chapter of each work is known to be extant.¹

The *Yantra-rāja-adhikāra* is the second extant Sanskrit work on the astrolabe. Padmanābha mentions the year “1345 Śaka” (= 1423 AD) in this work. So, this work must have been composed around this year. The astrolabe mentioned in this text is just opposite to the ordinary “northern” astrolabe, the centre of which is the celestial North Pole. The centre of Padmanābha’s astrolabe is the celestial South Pole. It means that Padmanābha’s astrolabe was the “southern astrolabe”. So, it is convenient in the southern hemisphere, but is inconvenient in the northern hemisphere including India. It may be that the astrolabe

1. As far as I know, the *Yantra-rāja-adhikāra* had not been studied by modern historians of astronomy when I started my research on the history of astronomical instruments as a research scholar of Lucknow University (India) under the guidance of late Professor Kripa Shankar Shukla (1918-2007), the then retired professor of mathematics of Lucknow University (see Ōhashi, Yukio, “Prof. K.S. Shukla’s Contribution to the Study of the History of Hindu Astronomy”, *Gaṇita Bhāratī*, 17, 1995, pp. 29 – 44), in 1983. I found that two manuscripts of the *Yantra-rāja-adhikāra* are preserved in Lucknow University, one is in Tagore Library (central library of the university), and one is in the Department of Mathematics and Astronomy. Then I started to study this text and incorporated its partial study in my Ph.D. thesis submitted to Lucknow University. I published its complete text and an English translation in 1997 (See Ōhashi 1997).

consulted by Padmanābha was the southern type of astrolabe, which might have been one type among the several astrolabes introduced into India during the Tughluq dynasty (1320-1413 AD) or the subsequent period.

The contents of the *Yantra-rāja-adhikāra* consists of three sections:

1. The construction of the astrolabe, in 12 chapters;
2. The star table, in 7 chapters;
3. The use of the astrolabe, in 11 chapters.

Significance of Padmanābha's *Yantra-rāja-adhikāra* is that he explained the principle of the astrolabe using Hindu traditional mathematics. This fact shows that the astrolabe was well understood by Hindu astronomers soon after its introduction.

These early Sanskrit works are the evidence that Islamic astronomy was successfully introduced into India at the time of the Tughluq dynasty and the subsequent periods.

The *Yantra-prakāśa* of Rāmacandra

Soon after the composition of the *Yantra-rāja-adhikāra* of Padmanābha, Rāmacandra, a Hindu astronomer, wrote the *Yantra-prakāśa*, where several astronomical instruments are described, around 1428 AD. Its manuscripts are extant in Calcutta and Pune. It consists of 6 chapters, and its first 4 chapters are devoted to the astrolabe. The description of the astrolabe in this work is largely influenced by Mahendra Sūri's *Yantra-rāja* with Malayendu Sūri's commentary (see Ōhashi 1997, 289-290). From this fact, we know that the monumental work of Mahendra Sūri produced at the request of Fīrūz Shāh Tughluq was well circulated among Hindu astronomers.

Astrolabe-makers in India

During the 16th and 17th centuries in India, several excellent astrolabes were made. The family of Allāh-Dād (fl.1567 AD) in Lahore was a well known family of astrolabe-makers.¹ Several

1. See Nadvi, Syed Sulaiman, "Some Indian Astrolabe-Makers", *Islamic Culture*, 9(4), 1935, pp. 621-631; Idem, "Indian Astrolabe-Makers", *Islamic Culture*, 11(4), 1937, pp. 537-539; Abbott, Nabia, "Indian Astrolabe Makers", *Islamic Culture*, 11(1), 1937, pp. 144-146;

specimens of Indian astrolabes are extant.¹

Conclusion

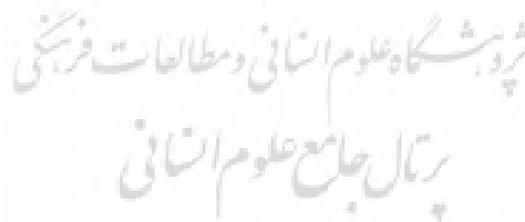
The time of Fīrūz Shāh Tughluq was the beginning of the exchange of Islamic astronomy (expressed in Arabic and Persian) and Hindu astronomy (expressed in Sanskrit) in both directions. Particularly, the astrolabe was well understood by Indian scholars soon after its introduction into India.

Since then, several interesting works on astronomy were produced in India, in Persian and Sanskrit. It should be noted that there are several unpublished manuscripts (in Persian and Sanskrit) in Indian libraries, and they are waiting future research.

My paper is only a short introduction. I hope readers of this paper are interested in this subject, and try to investigate further.

Acknowledgements:

I am grateful to the authorities of the Khuda Bakhsh Oriental Library (Patna), Tagore Library and Department of Mathematics of Lucknow University (Lucknow), and several other libraries in India and Japan, who allowed me to consult valuable works.



Sarma, S.R., "The Lahore Family of Astrolabists and their Ouvrage", *Studies in History of Medicine and Science*, 13(2), New Series, 1994, pp. 205–224; also included in Sarma 2008, 199–222.

1. See, for example, Sarma, S.R., *Astronomical Instruments in the Rampur Raza Library*, Rampur Raza Library, Rampur, 2003.

Appendix: Development of Astronomy during Delhi Sultanate and Mughal Empire periods in North India

Firstly, it will be convenient to mention some of the names of Islamic astronomers some of whose works were well studied by medieval Indian astronomers.

The Islamic astronomy is based on the *Almagest* of Ptolemy, the most distinguished Greek astronomer of the 2nd century AD, and also accepted certain influence of Indian (Classical Hindu) astronomy. Of course, Islamic astronomers made several new contributions.

Some of the well known early Islamic astronomers (up to the 12th century or so) are: al-Khwārizmī (d. ca. 850 AD), who is famous as a mathematician; al-Farghānī (9th century), who is well known as Alfraganus in Latin; al-Battānī (ca. 858-929 AD), who is well known as Albategnius in Latin; al-Šūfī (903-986 AD), whose book on the constellations were well studied in India also; Ibn Yūnus (d. 1009 AD), who made observations in Cairo (Egypt), Ibn al-Haytham (ca. 965-ca. 1039 AD), who is known as Alhazen in Latin and is famous for his study of optics; al-Bīrūnī (973-ca. 1050 AD), who studied Indian culture deeply; al-Zarqālī (1029-1087 AD), who made observations in Toledo (Spain) and whose astrolabe was studied in the court of Sawai Jai Singh in India also; ‘Umar Khayyām (ca. 1048-ca. 1131 AD), who is famous as a poet and was one of the compilers of the Jalālī calendar (an Iranian solar calendar).

Islamic astronomy was transmitted to Europe during the 12th and 13th centuries or so. For medieval Indian astronomers, the works of later Islamic astronomers (in the Īlkhānid dynasty, the Tīmūrid dynasty, etc.) were more influential.

The astronomical work (1221 AD) of Chaghmīnī, a Iranian astronomer, was well read (see Storey, 50-51).

The most important astronomer of the Īlkhānid dynasty was Nasīr al-Dīn Ṭūsī (1201-1274 AD) who made an observatory in Marāghah in 1259 AD, compiled the famous astronomical tables *Zīj-i Īlkhānī* in 1272 AD, and wrote several works (see idem, 6-7 and 52-60). Quṭb al-Dīn Maḥmūd Shīrāzī (1236-1311 AD), a disciple of Ṭūsī, was also a great astronomer (see idem, 64).

Mention may also be made of Ibn al-Shāṭir (1305-75 AD) at Damascus (Syria), who made a great contribution to planetary and lunar theories.

The most important astronomer of the Tīmūrid dynasty was Ulugh Beg (1393-1449 AD), who made an observatory in Samarkand, and made an influential collection of astronomical tables (usually called *Zīj-i (jadīd-i) Sulṭānī(-i Gūrkānī)* or *Zīj-i Ulugh Beg*) in 1437 AD (see idem, 67-72). This work was well studied in India also.

There were several associates and successors of Ulugh Beg. Ghiyāth al-Dīn Jamshīd al-Kāshī (or Kāshānī), who associated with the observatory of Ulugh Beg, wrote some works on mathematics and astronomy (see idem, 72-73). Qāḍīzādahi Rūmī, who also associated with the observatory of Ulugh Beg (see idem, 8, 67), wrote a commentary on the astronomical work of Chaghmīnī. Kūshjī (d. 1474/5 AD) was one of the successors of Ulugh Beg, and became a director of the observatory (see idem, 9-10, 75-77). His work was also well read in India.

The mathematical and astronomical works of Bahā' al-Dīn al-'Āmilī (died at Iṣfahān in 1622 AD) was also well studied in India (see idem, 11-14, 86-87).

As the main theme of this paper is the introduction of the Persian astronomy into India, the following short summary is mainly limited to North India and some other Islamic areas. It may be noted here that there were some other traditions of Hindu mathematics and astronomy in South India.¹

2. Delhi Sultanate period (1206-1526 AD)

Early period: Ghulāmshāhīyān (Slave dynasty) (1206-90) and Khaljī dynasty (1290-1320):

(2.1) According to Storey (50), an anonymous Persian translation entitled *Sirr-i maktūm* translated from an astrological book of Rāzī (d.

1. Warren, John, *Kala Sankalita*, Madras, 1825; Sarma, K.V., *A History of the Kerala School of Hindu Astronomy (in perspective)*, (Vishveshvaranand Indological Series 55), Vishveshvaranand Institute, Hoshiarpur, 1972; idem, *Science Texts in Sanskrit in the Manuscripts Repositories of Kerala and Tamilnadu*, Rashtriya Sanskrit Sansthan, Deemed University, New Delhi, 2002.

1209 AD) was made by order of Iltutmish (reign 1210/11-36), a Sultān of the Ghulāms̄hāhīyān. It may be that Islamic sciences were transmitted into India from the early stage of the Delhi Sultanate period, but exchange of sciences between Muslims and Hindus had not yet been carried on.

According to Storey (52) and S.A. Khan Ghorī, the *Zīj-i Nāṣirī* of Maḥmūd ibn ‘Umar was produced in the mid 13th century. It seems to be the earliest collection astronomical tables in Persian produced in India.

(2.2) The time of the Tughluḳ dynasty (1320-1413):

The *Yantra-rāja* (1370 AD) of Mahendra Sūri, which is the first Sanskrit work on the astrolabe was produced at the time of Fīrūz Shāh. And also, some Sanskrit works on Hindu astronomical sciences (such as the *Bṛhat-saṁhitā* (6th century AD) of Varāhamihira) were translated into Persian by the order of Fīrūz Shāh (see the above main part of this paper).

It may be mentioned here that in Bahmanī Dynasty in the Deccan (outside the main territory of the Delhi Sultanate dynasties at that time), king Fīrūz Shāh Bahmanī (reign 1397–1422 AD) ordered to build an astronomical observatory on the summit of the pass near Daulatabad (in present-day Maharashtra) in 1407 AD, but it was left unfinished due to the death of Ḥakīm Ḥasan Gīlānī, the astronomer (see Briggs, II, 239).

(2.3) Later period: Sayyid dynasty (1414-51) and Lodī dynasty (1451-1526):

In the field of Hindu astronomy during the Delhi Sultanate period, one *siddhānta* (fundamental treatise of astronomy) in Sanskrit was produced. It is the *Sundara-siddhānta* (also called *Siddhānta-sundara*) (1503 AD) of Jñānarāja. Some interesting *karaṇas* (handy practical works of astronomy) in Sanskrit were also produced in this period. One is the *Karaṇa-kautuka* (1496 AD) of Keśava. Keśava compared the position and velocity of planets according to three schools of Hindu Classical astronomy, namely, the Brāhma school, Ārya school and Saura school, and tried to determine the best astronomical constants which agree with the actual observation. This was a great progress at that time, when the tradition of the schools was considered

to be very important. Keśava's son Gaṇeśa (b. 1507 AD) was also a great astronomer, and his *Graha-lāghava* (1520 AD) is a quite popular *karana*.

Mention may be made of the cylindrical sundial in India which was first mentioned in the *Yantra-prakāśa* (1428 AD) of Rāmacandra as the "*kaśā-yantra*" where the word "*kaśā*" means whip and the word "*yantra*" means instrument. However, Rāmacandra's description is very brief. The first detailed work on the cylindrical sundial in Sanskrit is the *Kaśā-yantra* (late 15th century AD) of Hema.¹ The celebrated astronomer Gaṇeśa (b. 1507 AD) also wrote a Sanskrit work on the cylindrical sundial entitled *Pratoda-yantra* where the word "*pratoda*" also means whip.² Later, in the Mughal Empire period, Nityānanda mentioned the cylindrical sundial in his *Siddhānta-rāja* (1639 AD) as the "*cābuka-yantra*", and Munīśvara summarized the Gaṇeśa's description in his *Siddhānta-sārvabhauma* (1646 AD) as the "*pratoda-yantra*". Munīśvara's description of the cylindrical sundial was separately copied sometimes, and its manuscripts are entitled *Pratoda-yantra* or *Cābuka-yantra*. Here, the Sanskrit word "*cābuka*" is a loanword from Persian "*chābuk*" which means whip. From this fact, we can suppose that some loanwords from Persian were popularly used in Sanskrit at that time. It is not known whether the Indian cylindrical sundial was influenced by similar instruments in the Islamic world or was invented independently in India.

3. Mughal Empire period (1526 - 1858 AD)

(3.1) From the time of Bābur to the time of Aurangzeb (1526-1707):

(3.1.1) The time around the reign of Bābur (1526-30):

The Mughal Empire was founded by Bābur. Bābur's memoir *Bābur-nāmah* (originally written in Chagatai (Turkic) language) is an

1. For its Sanskrit text with an English Translation, see Ōhashi, Yukio, "The Cylindrical Sundial in India", *Indian Journal of History of Science*, 33(4), 1998, Supplement, S 147 – S 205.

2. For its Sanskrit text with an English translation, see Ōhashi, op. cit.

important source material of his activity.¹ Bābur mentioned the astronomical observatory of Ulugh Beg (1393-1449 AD) in Samarkand, where he visited in 1498 AD, and noted some other observatories known to him (see Beveridge, A.S., 79).

(3.1.2) The time around the reign of Humāyūn (1530-40 and 1555-56):

Muṣliḥ al-Dīn Lārī Anṣārī (d. 1571 at Constantinople) wrote a Persian commentary on the *Risālah dar Hay'at* of Kūshjī (d. 1474/5 AD), and dedicated it to Humāyūn (see Storey, 77; Rahman, 336).

Humāyūn was interested in astronomical instruments, and it seems that the family of Allāhdād (fl. 1567 AD) in Lahore, a well known family of astrolabe-makers, have commenced under the patronage of Humāyūn.

(3.1.3) The time around the reign of Akbar (1556-1605):

According to S.A. Khan Ghori, Mullā Chānd, a friend of Humāyūn and a court astronomer of Akbar, made a simplified version of Ulugh Beg's table. The work of Mullā Chānd is entitled *Tashīl-i Zij-i Ulugh Begī*.

At the time of Akbar, the *Pārasī-prakāśa*, a Persian glossary and Persian grammar in Sanskrit, was composed by Bihārī Kṛṣṇa-dāsa Mīśra.² From this fact, we know that some people seriously tried to exchange cultures including astronomy between Muslims and Hindus.

At the instance of Akbar, the *Līlāvātī* (1150 AD), a famous arithmetical work in Sanskrit,³ of Bhāskara (b. 1114 AD) was translated into Persian by Fayḍī, a court poet of Akbar and an elder brother of Abulfaḍl (see Storey, 4-5).

Abulfaḍl (1551-1602 AD), a consultant of Akbar, wrote two very important records of the reign of Akbar and related topics, namely the *Akbar-nāmah*⁴ and the *'Ā'in-i Akbarī*¹. Valuable information about

1. For its English translation, see Beveridge, A. S.

2. For its Sanskrit text, see Bhaṭṭācārya Vibhūtibhūṣaṇa (ed.): *Pārasī-prakāśa*, Sarsvatī Bhavana Granthamālā, vol. 95, Varanaseya Sanskrit Vishvavidyalaya, Varanasi, 1965.

3. For its English translation, see Colebrooke, Henry Thomas (tr.), *Algebra, with Arithmetic and Mensuration, from the Sanskrit of Brahmagupta and Bhāscara*, London, 1817, reprinted: Saendig Reprint Verlag, Vaduz, Lichtenstein, 1973.

4. For its English translation, see Beveridge, H. (tr.), *Akbar-nāmah*, 3 vols., Royal Asiatic Society, Calcutta, 1902-1939; reprinted: Ess Ess Publications, New Delhi, 1973.

science and technology at that time is found in these works.

In 1584 AD, Akbar established a new solar calendar “*Tārīkh-i Ilāhī*” (Divine), which was based on the Persian solar calendar. The main compiler of this calendar was Fathullāh *Shīrāzī* (d. 1589 AD), who joined the court of Akbar in 1583 AD, and was a great scientist and engineer (see Beveridge H., II, 15-18; III, 644-645; Blochmann and Jarrett, II, 1-31; Alvi & Rahman, 17-23).

The *'Ā'in-i Akbarī* (Mode of governing of Akbar) has some valuable descriptions of Islamic and Hindu astronomies and related topics, such as a section of eras and astronomers (see Blochmann and Jarrett, 2/1-31), a section of cosmology and astronomy (see Blochmann and Jarrett III, 11-28), a section of the description of the earth (see idem, III, 29-125), etc.

In the field of Hindu astronomy, Raṅganātha (son of Ballāla)² wrote a commentary (1603 AD) on the *Sūrya-siddhānta* (ca. 10th-11th century AD), one of the most popular treatise of astronomy in Sanskrit. This is the most popular commentary on the *Sūrya-siddhānta*, and an English translation of the *Sūrya-siddhānta* which is probably the most popular book on Hindu traditional astronomy in English is also based on this version.³

(3.1.4) The time around the reign of Jahāngīr (reign 1605-27):

Jahāngīr was interested in natural history, and there are several interesting descriptions of animals and plants, and also astronomical phenomena in his memoir.⁴

(3.1.5) The time around the reign of Shāh Jahān (1628-58):

1. For its English translation, see Blochmann, H. and H.S. Jarrett (trs.) *The Ā'in-i Akbarī*, 3 vols, (originally published in 1873-1894; vol.1 was translated by Blochmann, and vols. 2 and 3 were translated by Jarrett), Second Edition, Royal Asiatic Society, Calcutta, 1927 (actually 1939)-1949; reprinted: Oriental Books Reprint Corporation, New Delhi, 1977-78.

2. As there were two astronomers named “Raṅganātha” in this period, they are distinguished by their respective father’s name.

3. For the English translation, see Burgess, Ebenezer (tr.) *The Sūrya Siddhānta, a text-book of Hindu astronomy*, (originally published in the *Journal of the American Oriental Society*, 6(2), 1860, 141 - 498), Reprint edited by Phanindralal Gangooly with an introduction by Prabodhchandra Sengupta, Calcutta, 1935; reprinted: Motilal Banarsidass, Delhi, 1989.

4. See Alvi, M.A.; A. Rahman; *Jahāngīr – the naturalist*, National Institute of Science of India, New Delhi, 1968; Rogers, Alexander and Henry Beveridge (tr. and ed.), *Tūzūk-i-Jahāngīrī, or Memoirs of Jahāngīr*, 1909-14.

Some new *siddhāntas* in Sanskrit were composed during this period. Nityānanda wrote the *Siddhānta-sindhu* (1628 AD), and the *Siddhānta-rāja* (1639 AD) in Sanskrit under the reign of Shāh Jahān.

At the same time, Farīd al-Dīn Mas'ūd ibn Ibrāhīm Dihlawī (d. 1629 AD), a court astronomer of Shāh Jahān, composed the *Zij-i Shāh Jahānī* (1629 AD) in Persian (see Storey, 89; Rahman, 306-307).

It may be interesting to note that there were two rival Hindu families of astronomers at that time as follows:

Munīśvara (b. 1603 AD) (son of Raṅganātha (son of Ballāla), see above) wrote the *Siddhānta-sārva-bhauma* in 1646 AD. This work basically follows the *Sūrya-siddhānta*. He was criticized by Raṅganātha (son of Nṛsimha) (see below). Munīśvara also wrote some other astronomical and mathematical works, such as a commentary on the *Siddhānta-śiromaṇi* (1150 AD) of Bhāskara (b. 1114 AD).

Raṅganātha (son of Nṛsimha) wrote some astronomical works, and criticized Munīśvara, and was then criticized by Gadādhara (nephew of Raṅganātha (son of Ballāla), and cousin of Munīśvara). Raṅganātha (son of Nṛsimha)'s brothers Divākara (b.1606 AD) and Kamalākara (see below) were also astronomers.

Kamalākara (son of Nṛsimha) wrote the *Siddhānta-tattva-viveka* in 1658 AD. This work basically follows the *Sūrya-siddhānta*. He also wrote a commentary on the *Sūrya-siddhānta*.

In the field of Persian literature, 'Aṭā'ullāh "Rushdī" (or "Rashīdī"), the eldest son of Ustād Aḥmad (see Storey, 14-15) (architect of Tāj Maḥal made by Shāh Jahān)¹, translated the *Bīja-gaṇita* (1150 AD), a famous algebraic work of Bhāskara (b. 1114 AD) in Sanskrit² into Persian in 1634/35 AD, and dedicated it to the Muḡhal emperor Shāh Jahān (see Storey, 5, 15-16; Rahman, 391-392). His younger brother Luṭfullāh "Muhandis" was also an astronomer and mathematician (see below).

(3.1.6) The time around the reign of Aurangzeb (1658-1707):

Luṭfullāh "Muhandis", a son of Ustād Aḥmad (architect of Tāj Maḥal), wrote the *Tardjamah-i Kitāb-i Šuwar-i Kawākib* (1640 AD), a

1. For he and his sons, see Chaghtai, M. Abdullah, "A Family of Great Mughal Architects", *Islamic Culture*, 11(2), 1937, pp. 200 – 209.

2. For its English translation, see Colebrooke, op. cit.

Persian translation of the book on constellations of al-Şūfī, and the *Taḳwīm-i Lutfī* (1673/4 AD) on almanac, and also some other mathematical works such as an abridged Persian translation (1681 AD) of al-‘Āmilī’s mathematical work (see Storey, 11-12, 16, 41-42, 92; Rahman, 324-325, 404-405). His sons Imām al-Dīn Ḥusayn and Khayrullāh were also astronomers and mathematicians (see below).

‘Iṣmatullāh (d. 1732 AD) wrote an Arabic commentary (ca. 1670 AD) on al-Ṭūsī’s Arabic version (1265 or 1271 AD) of Ptolemy’s *Almagest*, and a commentary (ca. 1675 AD) on al-‘Āmilī’s astronomical work (see Storey, 86-87; Rahman, 316-317).

(3.2) Later Mughal Period (1707-1858):

(3.2.1) Around the 18th century:

After the death of the emperor Aurangzeb, the Mughal Empire more or less declined, but astronomical activities did not decline. The most eminent figure of this period is Savāī Jaya Simha (or Sawai Jai Singh in usual English spelling) (1699-1743 AD), Mahārāja of Amber (later shifted to Jaipur).¹

Savāī Jaya Simha constructed five traditional astronomical observatories, among which four still exist, in the first half of the 18th century.² Some astronomical works in Sanskrit and Persian were composed at his court. Among them, one of the most important works is the *Zīj-i jadīd-i Muḥammad Shāhī* (1728 AD) in Persian³ (see Storey, 93-94; Rahman, 348-350; Sharma, 234-253). And also, at his court, Jagannātha translated al-Ṭūsī’s Arabic version (1265 or 1271 AD) of Ptolemy’s *Almagest* into Sanskrit as the *Samrāt-siddhānta*⁴, and al-Ṭūsī’s Arabic version (1248 AD) of Euclid’s *Elements* into Sanskrit as the *Rekhā-gaṇita*.

1. “Mahārāja” is a kind of local king, and Savāī Jaya Simha constructed a new city, which was later named “Jaya-pura” (or Jaipur in usual English spelling), near his original place Amber.

2. See Kaye, G.R., *The Astronomical Observatories of Jai Singh*, *Archaeological Survey of India*, Calcutta, 1918; Sharma.

3. For the Persian text with an English translation of its preface, see Hunter, William, “Some Accounts of the Astronomical Labours of Jayasinha, Rajah of Ambhere, or Jayanagar”, *Asiatick Researches*, vol. 5, 1797, pp. 177 – 211.

4. For its Sanskrit text, see Sharma, Ram Swarup (ed.), *Samrāt-siddhānta*, 2 vols., Indian Institute of Astronomical and Sanskrit Research, New Delhi, 1967.

Jagannātha also composed his own *Siddhānta-kaustubha*¹. Its enlarged version is known as *Siddhānta-samrāt*², which is different from the translation of the *Almagest*. In the *Siddhānta-samrāt*, a description of al-Zarqālī's astrolabe is also included (see Sarma, 223-239).

By this time, Nayanasukha-upādhyāya (fl. 1729 AD), who also associated with the court of Savāi Jaya Sīnha (see Sharma, 274-275), translated the *Bīst Bāb dar 'Uṣṭurlāb*, a famous work on the astrolabe composed by al-Ṭūsī in Persian, into Sanskrit as the *Yantra-rāja-vicāra-vimśādhyāyī*³. He also translated the Arabic version of the *Spherics* of Theodosius (ca. 1st century BC) as the *Ukarā* into Sanskrit⁴, and a part of al-Birjandī's commentary on the *Tadhkira* of al-Ṭūsī into Sanskrit.⁵

By this time, sons of Luṭfullāh "Muhandis" were also active as follows:

'Imām al-Dīn Ḥusayn, the eldest son, composed several works on astronomy and mathematics including Arabic glosses (ca.1725 AD) on Qāḍīzādah-i Rūmī's commentary on the astronomical work (1221 AD) of *Chaghmīnī*, and a commentary (ca.1725 AD) on the astronomical work of al-'Āmilī (see Rahman, 316). 'Imām al-Dīn Ḥusayn wrote a biographical work *Tadhkirah-i Bāghistān*, which contains valuable information about astronomy and astronomers.⁶

1. For its Sanskrit text, see Pingree, David (ed.), "Siddhāntakaustubha of Jagannātha Paṇḍita (Original Version)", *Indian Journal of History of Science*, 39(2), 2004, Supplement, S1-S74, 39(3), 2004, Supplement, S75-S99.

2. For its Sanskrit text, see Caturveda, Muralīdhara (ed.), *Siddhānta-samrāt*, Sāgarikā-samiti, Sāgara-viśvavidyālaya, Sagar, 1976.

3. For its Sanskrit text, see Bhaṭṭācārya, Vibhūtibhūṣaṇa (ed.), *Yantrarāja-vicāravimśādhyāyī by Nayanasukha Upādhyāya*, Sarsvatībhavana Granthamālā, Vol.115, Sampurnanand Sanskrit Vishvavidyalaya, Varanasi, 1979.

4. For its Sanskrit text, see Bhaṭṭācārya, Vibhūtibhūṣaṇa (ed.), *Ukarā*, Sarsvatībhavana Granthamālā Vol.104, Sampurnanand Sanskrit Vishvavidyalaya, Varanasi, 1978.

5. See Kusuba, Takanori and David Pingree, *Arabic Astronomy in Sanskrit, Al-barjandī on Tadhkira II, Chapter 11 and its Sanskrit Translation*, Brill, Leiden, 2002.

6. See Ahmad, Nazir, "Imam-ud Din Husain Riyadi, the grandson of Nadir-ul-'Asr, ustad Ahmad, the Architect of the Taj Mahal, and his *Tadhkira-i-Baghistan*", *Islamic Culture*, 30(4), 1956, pp. 330 – 350; and 31(1), 1957, pp. 60 – 87; Murtaza, Hafiz Ghulam, "The Works of Imam-ud-din Ar-Riyadi the Grandson of the Architect of the Taj Mahal", *Islamic Culture*, 34(4), 1960, pp. 270 – 293.

Khayrullāh, the second son, according to Rahman (285), was appointed to be a director of the observatory at Delhi, but, according to Sharma, it is doubtful. Khayrullāh wrote some works on astronomy and mathematics including a Persian translation (1747 AD) of al-Ṭūsī's Arabic version of Ptolemy's *Almagest* and a Persian translation (1731/2 AD) of al-Ṭūsī's Arabic version of Euclid's *Elements* (see Storey 1, 37, 95; Rahman, 285, 386).

According to Rahman (320), Khwādjah Bahādur Ḥusayn Khān, who served Aurangzeb and later went to Deccan with Niẓām al-Mulk, wrote the *Zij-i Niẓāmī* in Hyderabad, where the method of finding dates from various calendars including the date of accession of Āṣaf Jāh II (reign 1762-1803 AD) is mentioned (see Storey, 100; Rahman, 320).

It may be mentioned here that there is an anonymous Sanskrit work on Islamic astronomy composed in 1764 AD, the *Hayata[-grantha]*¹. The word "hayata" is of course Sanskrit transliteration of "hai'at" or astronomy in Persian.

There is also a Persian treatise entitled *Dar 'ithbāt-i hay'at-I djadīd* (on the proof of the modern astronomy) composed in India between 1770 and 1772 AD by an Iranian scholar Abū Ṭālib ibn Ḥasan Ḥusaynī Ṣafavī. Its manuscript exists in Gharb Library (Hamadan, Iran), and has been published.²

(3.2.2) Around the 19th century:

There is a voluminous work entitled *Jāmi'-i Bahādur Khānī* (1833 AD) (published in 1835 AD) of Ghulām Ḥusain (1790-1862 AD)³,

1. For its Sanskrit text, see Bhaṭṭācārya, Vibhūtibhūṣaṇa (ed.), *Hayata*, Sarsvatī Bhavana Granthamālā, Vol. 96, Varanaseya Sanskrit Vishvavidyalaya, Varanasi, 1967.

2. Safavī, Abū Ṭālib ibn Ḥasan Ḥusaynī, "Dar 'ithbāt-i hay'at djadīd" edited by Ḥusain Ma'sūmī Hamadānī, *Ma'ārif*, vol. 1, no. 2, Iran University Press, Tehran, pp. 117-185. I am grateful to Prof. Mohammad Bagheri who provided me with this information, and kindly sent its copy to me. There is another manuscript of it in Rampur Raza Library (See *Catalogue of Persian Manuscripts of Rampur Raza Library*, I, 347).

3. See Ansari, S.M.Razaullah; S.R. Sarma, "Ghulām Ḥussain Jaunpūrī's Encyclopaedia of Mathematics and Astronomy", *Studies in History of Medicine and Sciences*, 16(1-2), New Series 1999/2000, pp. 77 – 93; Idem, "Ghulām Ḥussain Jaunpūrī and his *Zij-i Bahādur Khānī*", *Studies in History of Medicine and Sciences*, 14(1-2), New Series 1995/96, 181 – 188. *Jāmi'-i Bahādur Khānī* has been reprinted in Iran, with an introduction by Farid Ghassemilou, in Deputy of Research-Islamic Azad University, Tehran, 2007.

which is probably the last comprehensive Persian traditional mathematical and astronomical work written in India (see Storey, 19-20, 99; Rahman, 387). He also compiled the *Zīj-i Bahādur Khānī* (1838 AD) (published in 1855 AD), an astronomical table (see Storey, 99; Rahman, 309). According to Bagheri (5), this Zīj was the main source for the traditional calendar makers of Iran for a certain period.

There is also an interesting Persian work on modern astronomy written in India, the *Ḥadā'iq al-Nujūm* (1837 AD)¹ (published in 1837, 1841 and 1843 AD) of Rājah Ratan Sing'h (1782-1851 AD) (see Storey, 99-100; Rahman, 350).

From the above brief sketch, it is clear that both of the Sanskrit literature and Indo-Persian literature on astronomy are very important, and much more research work is needed.

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1. See Ansari, S.M. Razaullah, “The First Comprehensive Book in Indo-Persian on Modern European Astronomy”, in Chen, K-Y., Orchiston, W., Soonthornthum, B., and Strom, R. (eds.): *Proceedings of the Fifth International Conference on Oriental Astronomy*, Chiang Mai University, Chiang Mai, 2006, 81 – 90.

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