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INDIAN LITERATURE ON MATHEMATICS DURING 1400—1800 A.D.

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The available Indian literature on mathematics during 1400-1800 A.D. can be broadly classified into two main categories. In the first category belong the Sanskrit works, or the works written in scripts of the regional Indian languages. Though the scripts are different, the language of these scripts is mainly Sanskrit and bears Indian tradition both in content and character. The major portion of these works are commentaries on the works of *Sūrya Siddhānta, Āryabhaṭīya, Līlāvati, Bijagaṇita, Siddhānta Śiromaṇi*, and some other well-known works of the ancient period, and contribute little to the knowledge of mathematics. The commentators of this period were perhaps content with the preservation and transmission of knowledge from one generation to the other. Their studies gave some impetus to the studies of the scholars like Mādhava, Parameśvara, Nīlakaṇṭha, Śaṅkara, Jyeṣṭhadeva, Acyuta Piśāraṭi, etc., for about 500 years starting from fourteenth century A.D. These scholars made some break-through by introducing the idea of series in calculating the value of *pi*, sine-table, discovery of the sine and cosine series and made many other innovations. The second category of mathematical literature constitute the Persian and Arabic works developed mostly under the patronage of the Mughal rulers. These were mainly written for readers of Persian who knew no other language and had no access in standard Sanskrit, Persian and Arabic mathematical works. Many standard mathematical works were brought here from outside India. Some scholars tried to translate or write commentaries on the available works without trying to correlate with the available Indian knowledge. A few scholars like Munīśvara, Kamalākara, Jagannāth Paṇḍit tried to make a synthesis of the available knowledge but their contribution appears to be negligibly small. The real contribution lies in the effort of Raja Jai Singh who used the observatories at Delhi, Jaipur, Mathura, Banaras and Ujjain to prepare accurate astronomical tables. In the paper, an attempt has been made to make analysis of these two categories of mathematical literature in the period.

The Indian literature on Mathematics during the period 1400—1800 A.D., as available now in different oriental libraries, can be broadly classified into two different categories. To the first category belong the sanskrit works, or the works written in scripts of the regional Indian languages. Though the scripts are different, the

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language of these manuscripts is mostly Sanskrit and bears Indian tradition both in content and in character. The second category of mathematical literature consists of Persian and Arabic works produced mostly under the patronage of the Mughal rulers. An attempt has been made to make an analysis separately of these two categories of mathematical literature.

1. WORKS IN SANSKRIT LITERATURE

Thousands of works were written in the period. A few of the prominent works by well-known scholars have been summerized to have an idea of the type and trend of mathematical literature.[1]

Gaṅgādhara (*c.* 1400), the son of Govardhana and grandson of Divākara, was an inhabitant of *Jambusāgāranagar*. His commentary *Gaṇitāmṛtasāgarī* is a commentary on the *Līlāvatī* of Bhāskarācārya. It appears almost verbatim of the original work.

Mādhava (*c.* 1400) of Saṅgamagrāma near Cochin was a well-known scholar in astronomy and mathematics.[2] He is referred to as *golavid* by his student Parameśvara and Nīlakaṇṭha. His *Veṇvāroha* gives a method for the computation of the moon and *Sphuṭacandrāpti* accounts for calculation of true moon. He is also known to have written *Lagnaprakaraṇa* and *Mahājñānāyaṇa prakaraṇa*. Apart from these works, a number of these verses of Mādhava are quoted by later astronomers like Nīlakaṇṭha, Somayājī, Nārāyaṇa (commentator of the *Līlāvatī*), Śaṅkara (commentator of *Tantra Saṃgraha*), etc.

Parameśvara (*c.* 1430), a resident of South Malabar in Kerala, was the student of Rudra, Nārāyaṇa and Mādhava. He is well-known for his lucid commentaries and knowledge in mathematics and astronomy. Among his works, the *Bhaṭadīpikā* (commentary on *Āryabhaṭīya* of Āryabhaṭa-I), *Karmadīpikā* (comm. on the *Mahābhāskarīya* of Bhāskara I), *Parameśvarī* (commentary on the *Laghubhāskarīya* of Bhāskara-I), *Siddhāntadīpikā* (comm. on the *Mahābhāskarīyabhāṣya* of Govindasvāmi), *Vivaraṇa* (commentary on the *Sūryasiddhānta* and *Līlāvatī*), *Dṛggaṇita* (*dṛk* system), *Goladīpikā* (spherical geometry and astronomy), *Grahaṇamaṇḍaṇa* (computation of eclipses), *Grahāṇavyākhyādīpikā* (on the rational of the theory of eclipses), *Vākyakaraṇa* (on the methods of the derivation of the several astronomical tables) besides others are well-known. Parameśvara was a practical astronomer and realised the limitations of previous scholars in the calculation of eclipses and devised correction for finding mean position of the sun, moon, apsis, node, etc.

Nīlakaṇṭha Somasutvan (*c.* 1443—1543) was a student of Parameśvara and is well-known for his contribution to mathematics and astronomy. He is the author of *Āryabhaṭīyabhāṣya*, *Tantra Saṃgraha* (*tantra* collection), *Grahaṇanirṇaya* (computation of lunar and solar eclipses), *Golasāra* (quintessence of spherical astro-

nomy). *Siddhāntadarpaṇa* (mirror of the laws of astronomy), *Candracchāyāgaṇita* (computation concerning moon's shadow), *Candracchāyāgaṇitaṭikā*. He has quoted profusely from the *Vedāṅgajyautiṣa*, *Āryabhaṭīya*, *Pañcasiddhāntikā*, *Bṛhajjātaka*, *Bṛhatsaṃhitā*, *Sūryasiddhānta*, *Siddhāntaśekhara*, *Laghumānasa*, etc. He is mainly an astronomer and well-known for methods of determining corrections, rational of eclipse correction, procedures for observation of planets with instruments and for their computation using the data obtained from the observation.

Yallaya (1482), son of Śrīdharācārya, was the pupil of Sūrya.[3] He is well-known for his works *Āryabhaṭīya*, *Vyākhyāna*, (commentary on the *Āryabhaṭīya* of *Āryabhaṭa*), *Jyotiṣadarpaṇa*, *Kalpavallī* (commentary on the *Sūryasiddhānta*), *Laghumānasa Kalpalatā* (a commentary on the *Laghumānasa of Mañjulācārya*), and *Gaṇitasaṃgraha* (a treatise on arithmetic).

Śaṅkara Vāriar (*c.* 1500-1560), the brother and student of Nīlakaṇṭha is the author of *Laghuvivṛti*, a scholarly commentary on the *Tantrasaṃgraha*. Śaṅkara seems to have well-versed in astronomy and in following his brother Nīlakaṇṭha. It is expressed by Nīlakaṇṭha in some of the passages that he had complete faith in his brother in studies of mathematics and astronomy. He wrote another work, *Kriyākramakarī*, an elaborate commentary on the *Līlāvati* of Bhāskara II giving rational and proof of the theorems and formulae. The work is more or less identical with the *Karmapradīpaka* of Nārāyaṇa, only difference is that Śaṅkara's work is more elaborate.

Jyeṣṭhadeva (*c.* 1500—1600) is a well-known Kerala scholar on mathematics and astronomy. His *Yuktibhāṣā* (rational explanation) was written to provide the basic equipment needed for the study of computation of planetary movemets as depicted in the *Tantrasaṃgraha*. The work is divided into two parts, the first comprising of arithmetic, geometry and algebra and the second exclusively devoted to the astronomy, spherical trigonometry and allied subjects. It gives the raional or derivation of all theorems and formulae then in use among the astronomers.

Cakradhara (*c.* 1500), son of Varuṇa, wrote his *Yantracintāmaṇi*, a treatise on astronomical instruments in four chapters, viz. *Yantroprakaraṇasādhana*, *Tripraśnādhikāra*, *Grahānayanādhikāra* and *Prakīrṇādhyāya*. He also produced a commentary on his own *Yantracintāmaṇi*.

Jñānarāja (*c.* 1503) was the son of Nāganātha of Pārthapura. He is well-known for his *Siddhānta-sundara* dealing with astronomy. The *Sphuṭādhyāya* chapter contains sine table. His *Sundarasiddhāntabīja* is another work on algebra which was written as a sequel to Bhāskara II's *Bījagaṇita*.

Gaṇeśa Daivajña (*b.* 1507), the son of Keśava Daivajña of Nandigrāma (Nandod, Gujrat), was an influential teacher and the author of not less than seven

works, viz. *Bṛhattithicintāmaṇi* (treatise on the preparation of lunar calendar), *Laghucintāmaṇi* (abridgement of bigger work), *Buddhivilāsinī* (commentary on the *Līlāvatī* of Bhāskarācārya), *Dhruvabhramaṇa Yantra vyākhyā* (commentary on the *Dhrubabhramaṇa Yantra* of Padmanābha), *Grahalāghava* (simplification of Planetary computation), *Pratodayayantra* (special class of astronomical instruments, *Cābuka Yantra, Sudhirañjana Yantra* and *Siddhāntaśiromaṇi vyākhyā* (a commentary on the *Siddhānta Śiromaṇi of Bhāskara* II).

Sūryadāsa (*c.* 1541), son of Jñānarāja, wrote two commentaries, viz. *Gaṇitāmṛtakūpikā*, a commentary on the *Līlāvatī* of Bhāskara II, and *Sūryaprakāśa-Bījavyākhyā*, a commentary on the *Bījagaṇita* of Bhāskara II.

Raṅganātha (*c.* 1578) son of Ballāla and father of Munīśvara wrote a commentary on the *Sūryasiddhānta*. The commentary is well-known for its style and lucidity.

Dinakara (*c.* 1578) wrote three works. His *Candrārkī* deals with true place of the sun and moon in astronomy in 33 verses. His *Kheṭasiddhi* describes methods for finding the true place of the planets. He also wrote commentary to his own *Candrārkī*.

Acyuta Piṣāraṭi (*c.* 1580), a non-Brahmin astronomer, mathematician of Kerala, was a student of Jyeṣṭadeva. He, for the first time in Indian astronomy, incorporated the correction in the *Sphuṭanirṇaya* and explained its rational elaborately in his work, *Rāśigolasphuṭanīti* (ed. by K. V. Sarma, Adyar Library, Madras, 1955). The correction was first introduced in Western astronomy by Tycho Brahe at about the same time. His *Karaṇottama* (ed. by Raghavan Pillai, TSS 213, Trivendrum, 1964) deals with astronomical computation. He wrote commentaries on *Sūryasiddhānta, Veṇvāroha* of Mādhava and on his own *Sphuṭanirṇaya* and *Karaṇottama*.

Viśvanātha Daivajña (1580) son of Divākara Daivajña was a powerful teacher and commentator. He comes of an astronomer family which traces his ancestry back through a long line of astronomers in Maharashtra. He wrote as many as ten commentaries besides other works on almanacs. The works are *Sūryasiddhāntodāharaṇa* (commentary on the *Sūryasiddhānta*), *Grahakautukodāharaṇa*, (commentary on the *Grahakautuka* of Keśava Daivajña), *Grahalāghavodāharaṇa* (commentary on the *Grahalāghava* of Gaṇeśa Daivajña), *Karaṇakutūhalodāharaṇa* (commentary on the *Karaṇakutūhala* of Bhāskara II), *Mākarandodāhāraṇa* (commentary on the *Tithipatra* of *Makaranda*), *Rāmavinododāharana* (commentary on the *Rāmavinoda* of Rāma Daivajña), *Śiromanyudāharaṇa* (commentary on the *Siddhāntaśiromaṇi* of Bhāskara II), *Somasiddhāntaṭikā, Vaśiṣṭhasiddhāntaṭikā* and others.

Nṛsiṃha Daivajña (1586), son of Kṛṣṇa Daivajña and grandson of Divākara Daivajña Golagrāma (Maharashtra), wrote these commentaries, viz, *Vāsanā Vārtika*,

(commentary on the *Siddhāntaśiromaṇi* of Bhāskara II), *Saurabhāṣya* (commentary on the *Sūryasidhānta*) and *Tithicintāmaṇiṭikā* (commentary on the *Tithicintāmaṇi* of Gaṇeśa Daivajña).

Nilakaṇṭha Jyotirvid (*c.* 1587), son of Ananta, was the Chief Paṇḍit of the Court of Akbar (1556-1605). He wrote *Grahakautuka, Grahalāghavaṭīkā, Makarandavivṛti* (commentary on the *Tithipatra* of *Makaranda*), *Saranikaṣṭhaka, Subodhiniṭīkā* (commentary on the *Jaiminiyasūtra*), *Tithiratnāvalī.*

Dhuṇḍirāja (1590) son of Nṛsiṃha was the inhabitant of Parthapura. He wrote as many as four works, viz. *Ayanatattva, Grahamaṇi* (short astronomical treatise), *Makarandodāharaṇa* (commentary on the *Tithipatra* of Makaranda) and *Pañcāṅgaphala* (on calendar).

Gaṅgādhara (1590), son of Nārāyaṇa, flourished in late half of the sixteenth century wrote *Manoramā*, a commentary on the *Grahalāghava* of Gaṇeśa Daivajña.

The *Karaṇapaddhati*[3a] (1596) is an important astronomical work in ten chapters written by anonymous Kerala Brahmin family of Śivapura[4]. The text is edited in Trivandrum Sanskrit series no. 126. Apart from usual elements and formulae characteristics of Hindu astronomy, the work gives the values of *pi*, sine, co-sine and tan series. This also used the idea of indeterminate equations to calculate *māhāhāra* and *mahāguṇa* required in connection with the calculation of the mean motions of planets.

Kṛṣṇa (*c.* 1600) was the son of Vallāla of Dadhigrāma (Vidarbha). He belonged to a prominent family of *jyautiṣa*, patronised by the King of Vidarbha. The family moved from Vidarbha to Benaras in the sixteenth century. He was the student of Viṣṇu who was the pupil of Nṛsiṃha, the nephew of Gaṇeśa of Nandigrāma and was patronised by Jahangir (1605-1627) according to his younger brother Raṅganātha. He wrote three works, viz. *Bījāṅkura* (commentary on the *Bījaganita* of Bhāskara II), a commentary on the *Jātakapaddhati* of Śrīpati, and a commentary on the *Līlāvatī* of Bhāskara II.

Divākara Daivajña (1603), son of Nṛsiṃha Daivajña, was the resident of Golagrāma (Maharashtra). He wrote *Makarandavivaraṇa* (commentary on the *Tithipatra* of Makaranda), *Pātasāriṇiṭīkā* (a commentary on the *Pātasāriṇi* of Gaṇeśa Daivajña), *Rāmavinoda prakāśapaddhati*, and *Tattvacintāmaṇi.*

Munīśvara (b. 1603), son of Raṅganātha and a cousin of Nārāyaṇa, was the main astronomer in the court of Shahjahan (1628-59). He wrote *Marīci*, a commentary on the *Siddhāntaśiromaṇi* of Bhāskara II, *Nisṛṣṭārthaduti*, a commentary on the *Līlāvatī* of Bhāskara II, *Pāṭīsāra*, a work on mathematics and geometry, *Siddhāntasārvabhauma*, an astronomical work and his own commentaries on it. He had a controversy with *Kamalākara* and tried to refute some of the latter's contribution.

Rāma Daivajña (1615), son of Madhusūdana was the resident of Parthapura. He wrote a commentary entitled *Yantracintāmaṇiṭīkā* (commentary on the *Yantracintāmaṇi* of Cakradhara).

Kamalākara (*c.* 1616-1700), son of Nṛsiṃha Daivajña, was the descendent of Viśvanātha family of Golagrāma. He was born in Benaras. His brothers, Divākara and Raṅganātha, were also noted astronomers in Benaras in mid-seventeenth century. He was the court astronomer of Jahangir (1605-1627). He composed his work *Siddhāntatattvaviveka* in 1658 A. D. He was a follower of *Sūryasiddhānta* and tried to refute some of the views of the Bhāskara II and Munīśvara. Though *Siddhāntatattvaviveka* is mainly a work on astronomy, he made contribution to trigonometry by giving several correct relations between chords and its corresponding arcs in his section of *Spaṣṭādhyāya*. Some of the passages of the *Siddhāntatattvaviveka* are evidently copied from the *Elements*. Other instances of resemblence can also be identified with particular propositions of *Elements*. On the whole, there is absolutely no doubt that Kamalākara had knowledge of Euclid's *Elements*. His other works are *Grahagolatattva*, *Grahāsaraṇi*, *Kairasyudāharaṇa* (commentary on the *Līlāvatī* of Bhāskara II), *Manoramā* (commentary on the *Grahalāghava* of Gaṇeśa Daivajña), *Sauravāsanā* (commentary on the *Sūryasiddhānta*) and *Śeṣavāsanā*, a supplement to the author's *Siddhānta-Tattvaviveka*. Kamalākara combined traditional Indian astronomy with elements of Aristotelian physics, Euclidean geometry and Ptolemaic astronomy as presented by Ulug Beg.

Malayendusūri (*c.* 1659) wrote a commentary on the *Yantrarāja* of Mahendrasuri (*c.* 1320). It is a guide to the preparation of an instrument by means of which the times of day and night may be accurately ascertained. The work in 5 chapters are *Ghaṭanā*, *Gaṇita*, *Yantraracanā*, *Yantraśodhana*, and *Vicārana*. Malayendu Sūri wrote another work *Yantrarājaracanā* which is also useful in the preparation of *Yantrarāja*.

Jayasiṃha (died in 1667), the ablest General under emperor Aurangzeb (1659-1709), was also a great patron of learning. His descendent Sawai Jayasiṃha or Jayasiṃha II became the prince of Amber in Rajasthan and stabilised his Kingdom in 1708. The prince was greatly interested in mathematics particularly in astronomy. Paṇdit Jagannātha, the versatile scholar in Sanskrit worked under his patronage, and within a short time mastered in Persian and Arabic languages. A table known as *Dṛkpakṣasāraṇi* was prepared under his order. The table was used for finding lunar days according to the motion of the planets determined by means of astronomical observations. Another work, *Yantrarāja* was also compiled by him which contains directions for preparation of universal sundial.

Paṇḍit Jagannātha (*c.* 1667-1750) flourished under the patronage of King Jayasiṃha (1693-1743) of Amber. He was a great scholar of Sanskrit and acquired great proficiency in Persian and Arabic. He translated Euclid's *Elements* from the Arabic version Tahirir-u-Uqlidas by Nasīr-ud-dīn at-ṭusi (1201) under the

name of *Rekhāgaṇita*. His other works are *Samrāṭ Siddhānta*, a Sanskrit version of Ptolemy's *Almagest* and *Siddhānta Sārvabhauma* which contains partly *Samrāṭ Siddhānta* and partly Hindu astronomy.

Nayanasukhopadhyāya (*c.* 1730) is the author of *Ukarākhya-grantha*, a treatise on spherical trigonometry. This was prepared from an Arabic translation of a Greek work of anonymous author. The Arabic translation was perhaps done by Qusta b. Luqa. Nayanasukha took the help of the Abid for its translation into Sanskrit. The manuscript copy is available in the Calcutta Sanskrit College.

2. Tradition And Trend Of Mathematical Literature In Sanskrit

The present survey shows that the major portion of these works are commentaries on the works of *Sūryasiddhānta, Āryabhaṭīya, Līlāvatī, Bījagaṇita, Siddhānta-śiromaṇi* and some other well-known works of the ancient and medieval period. The other works contain some improved results in trigonometry and methods for finding the position of the sun and the moon, duration of eclipses, rational explanation and the corrections on them. These works have been mostly produced by six well-known families or traditional schools in *Jambusāgaranagara, Dadhigrāma* (Vidarbha), *Nandigrāma* (Gujrat), *Pārthapura* (Pathari, Parbhani, District, Maharashtra), *Golagrāma* (Maharashtra) and followers of the traditional schools which are as follows :

(a) *Jambusāgaranagara* :
Divākara - Govardhana - Gaṅgādhara

(b) *Dadhigrāma* (Vidarbha)
Rāma - Trimalla + Gopirāja
Trimalla—Vallāla
Vallāla—Rāma + Kṛṣṇa + Govinda + Raṅganātha + Mahādeva
Govinda—Nārāyaṇa
Raṅganātha—Munīśvara.

(c) *Nandigrāma* (Gujrat)
Kamalākara Daivajña—Keśava—Gaṇeśa
Keśava—Rāma—Nṛsiṃha.

(d) *Pārthapura* (Maharashtra)
Nāganātha—Jñānarāja—Sūryadāśa
Nṛsiṃha—Dhuṇḍirāja (1575)
Madhusūdana—Rāma Daivajña (*c.* 1615)

(e) *Golagrāma* (Maharashtra)
Divākara Daivajña—Viṣṇu + Kṛṣṇa (1500 *C.*) + Mallāri + Keśava + Viśvanātha
Kṛṣṇa—Nṛsiṃha + Śiva
Nṛsiṃha + Divākara + Kamalākara + Gopinātha + Raṅganātha.

(f) *Kerala*

Mādhava—student, Parameśvara
Parameśvara—son Dāmodara
Dāmodara—Pupils, Nīlakaṇṭha Somasutvan+Jyeṣṭhadeva
Jyeṣṭhadeva—Pupil, Acyuta Piṣāraṭi—Pupil, Nārāyaṇa Bhattātiri.

The works produced by these scholars reflect fully the Indian tradition of writing commentaries or explanations which at times appear verbatim of the original work, sometimes with some insight into the ancient material without any change in content and character. In the process some success has been achieved in algebra through the application of continued fraction, in trigonometry with the help of the series, in arithmetic through the use of symbols, *pāṭī* and dust.

For example, Mādhava used the idea of series for calculating the circumference of the circle to be 28, 27, 43, 33, 88, 233 (13 figures) for a radius of 9×10^{11}, which gives the value of *pi* (= 3. 14159265359) correct to 11 places of decimals. In radian measure the radius of the circle came out to be $\frac{21600 \times 9 \times 10^{11}}{282743388233}$ =3438′44″48‴. From this the 24 *mahājyās* or sine or cosine table correct to 7 or 8 places of decimals were calculated by applying sine and cosine series by Mādhava much before Newton. Nīlakaṇṭha gave the value of the circumference of the circle of diameter 113 to be 355 which gives the value of *pi* as 3. 1415929 (correct to 6 places of decimals). Some synthesis of available astronomical knowledge was tried by Munīśvara, Kamalākara and Jayasiṃha, for they had some opportunity to be familiar with Persian or Arabic version of Greek materials but it appears that these scholars were unaware of the development of mathematics in the south. To what extent these scholars and some muslim scholars under the Mughal rules have been effective to draw materials from the Persian/Arabic literature can be seen from our survey of Indo-Persian Literature[5].

3. Indo-Persian/Arabic Literature During The Period

'Abd al-' Azīz ibn Shams prepared a Persian version *Tarjumah-ī Bārāhī*[6] of the *Bṛhat Saṃhitā* of Varāhamihira for Firoz Shah Tuglaq (1351 - 1388 A. D.). Out of the 104 chapters (*bābs*) in the original, only eight were left out in the translation. He might have written another Persian work, *Nujūm al - Hind wa Sań'at - i - uṣturlāb* on Indian astronomy and construction of astrolabe. The date of compilation is not available.

Muṣliḥu'd - dīn al - lārī al - Anṣāri flourished during the reign of Humāyūn (1530 - 40). Later he joined the Court of Mirzā Shāh Ḥusain Arghun (1556), the ruler of Sind. He wrote a commentary on 'Alā'ud - dīn 'Alī Qūshji's *Risālah dar Hai' at* entitled *Sharḥ Risālah i Qūshji*. The manuscript is available in the Bankipur Library and State Central Library, Hyderabad.

The *Līlāvatī* gained a wide popularity in India and was held in esteem in the time of Akbar (1556 - 1605). It is under his order, Abul Faizī, his court poet, prepared a Persian translation *Tarjamah - i - Līlāvatī* in 1587 A. D. (A. H. 995 - 6). This is mentioned in *Āīn - i - Akbari.*

Mullāchānd was also the court astronomer of Akbar. He wrote a work on astronomical table, *Tashīlāt.* This is referred by *Farīd - ud Dīn in Zīj - u - Shāhja hānī* and Jai Singh Sawā'i in *Zīj - i - Muḥammad Shāhī.*

'Atāu'llah Qārī (Qadiri?) flourished during the reign of Barhān Niṣām Shāh, ruler of Aḥmadnagar (1591 - 1595). His *Risāladar Ma'rifat i A'māl i Rub'mujayya - i Āfāqī* dealing with sine quadrant,. The manuscript is available in the State Central Library, Hyderabad and Azad Library, Aligarh.

A Persian translation of the *Bījagaṇita* entitled *Tarjamah i Bīj* was made in India in 1634 - 35 A. D. by 'Aṭāullāh Rashīdī, son of Ustad Aḥmad Nādīr, the builder of Taj. He was originally a resident of Lahore and had his education under his father and Makramat Khan, well-known for his knowledge in mathematics. This was dedicated to Shahjahan (1628 - 1659). The Persian version was translated into English by Edward Strachey in 1813 A. D. From the translation it appears that it is not a faithful translation of the *Bījagaṇita* but is a mixture of text, commentary and some interpolations. The same author wrote perhaps two other works, viz, *Khasinatril A'dad* dealing with arithmetic, algebra, and applied geometry. Some discussion is also available on some astronomical problem. The other work is *Khulasah-i-Baz* dealing with arithmetic, mensuration and algebra in verse form. The manuscript copies are available in Bankipur and British Museum.

Farīd'd-dīn Mas'sūd, son of Ḥāfis Ibrāhim Munajjim was the court astronomer of Shahjahan. He was considered as a great scholar in mathematics, astronomy, geometry, etc. He wrote perhaps two works, viz. *Sirāju'l Istikhrai and Zīj -i Shāhjahān ī* in 1629 A. D. The former deals with eras, calculations of dates and principles of computation of almanacs. The latter is on calendars and astronomical tables. The manuscripts of both the works are available in the State Central Library, Hyderabad.

Lutfu'llah Muhandis, the brother of Atā'ullāh Rashidi (*c.* 1634) and the second son of Ustad Aḥmad, was also well-known for his interest in mathematics and other sciences. His *Muntakhab* is a short versified translation of Bahā'ud - dīn Āmulī's mathematical work *Khulāsatu'l Hisāb* and was written in Persian in 1681 A. D. The copies of the manuscripts are available in the Asiatic Society of Bengal, Bankipur, British Museum, Azad Library (Aligarh) and Salarjang Library, Hyderabad. His *Risāla dar Jawab i - Sawāli* on geometry in question answer form and *Risalah - i - Arsmatiqi* on properties of numbers are still available in the Rampur Library and Saidiyah Library (Hyderabad). He wrote *Taqwīm Lutfī,* on almanac

and *Tarjuma Kitāb Suwar i Kawākib*—,a commentary on the celebrated astronomical work *Suwaru'l Kawākib*. The manuscript is available in Rampur Rida Library, U. P. and Azad Library Aligarh.

Hāji Khalu'llah, son of Amanu'llah and brother of Mulla Murshid Makramat Khan in the beginning of seventeenth century A. D. (died in 1649) wrote a commentary on the work of mathematics entitled *Sharḥ i Kitāb - i - Haji Kalil*. A copy is available in the Rampur Library.

Sh. Muḥammad (seventeenth century A. D.), son of Sh. Muḥammad Said, flourished under emperor Aurangzeb (1659 - 1709). He wrote in Arabic *Sharḥas Sirājīyyah*, an incomplete commentary on a Sajavandi's algebrical treatise known as Sīrajīyah. The manuscript is available in the Asiatic Society of Bengal.

Dharma Nārāyan ibn Kalyānmal Kayath wrote a Persian commentary in 1663 - 64 at Etawah on the *Līlāvatī* under the title *Badā'i - i Funūn* and dedicated to Alamgir (1659 - 1709). The copies of manuscripts are listed by C. A. Storey. This shows that the *Līlāvatī* received recognition among the Mughal emperors. Manuscript copies of Faizi's version are found deposited in the British Museum (one copy), India Office Library (three copies) and John Rylands Library in Manchester (one copy) to mention a few. Another version *Dastūr al - Ḥisāb : Tarjuma - i - Līlāvatī* was prepared by Amīn Shaikh Muḥammed Said in 1678 The incomplete Manchester copy has been translated by Winter and Mirza, the work contains a selection of examples taken from the *Līlāvatī*. The examples include problems on investigation of mixture, rule of three, inverse proportion, compound proportion etc. and concern primarily business translation.

Khwāja Bahādur Ḥusain Khān Bahādur flourished during the reign of Aurangzeb and later went to the South with Qulich Khān. He learnt astronomy and astrology under S. 'Alavī Khān Zubadatu'l Munajjimin Ṭāliqāṇī. He is known for his two works, viz. *Sharḥ - i Zīj - i Nizāmī* (commentary on *Zīj - i Nizāmī*) and *Zīj - i Nizāmī* (astrological and astronomical table). The scholar has made studies of both Indian and non-Indian works. The copies of both the works are available in the State Central Library.

Nand Rām, son of Hiranand Ka'isth flourished during the reign of Mughal emperor Aurangzeb (1659 - 1709) and wrote a work on accountancy, *Ain - i - Siyaq* in 1680 One copy of the manuscript is available in the State Central Library, Hyderabad. M. Husain s. o. Khalīlullah (*d.* 1696) was born at Bijāpur and studied under M. Zubair at Bijāpuri. He was appointed principal of Madrasah - Maḥmūd in Bidar by Aurangzeb in 1686. He produced *Ujalatur Rub* in Arabic which deals with application of quadrant for recording various astronomical data. The manuscript is available at Saidiyah Library, Hyderabad.

Rājā Jayasiṃha (1693 - 1743) flourished under the patronization of Maḥammad

Shāh (1719 - 1748) and tried to rectify and improve the almanacs already constructed by his predecessors[7]. He started organising new observations with the help of the Muslim, Hindu and European experts. After seven years of observations in Delhi, Jaipur, Mathura, Benaras, and Ujjain, he deputed Padre Manoel with some competent hands to Europe who brought back with them the astronomical tables of De la Hire. These materials are compiled in his *Zīj - i Jadīd - i Muḥammad Shāhī*, which was completed in 1727. The manuscript is available at the Oriental Library, Bankipur and British Museum. Under his patronization, Samrāṭ Jagannātha translated Ptolemy's *Syntaxix* as *Siddhāntasāra Kaustubha*, Euclid's *Elements as Rekhāgaṇita*. Kewal Ram (Gujrathi Brahmin) translated De la Hire's table as *Jai Vinod Vibhag Sāraṇī*, *Ulugbeg's* tables as *Tārā Sāraṇi*. Puṇdarik Ratnākara, a Maharastrian Brahmin wrote *Jai Singh Kalpardrum* dealing with *Purāṇic* facts.

Muḥammad Zaman Fayyad, son of M. Sadiq al - Anbalaji ad-Dehlawi wrote in 1718 his *Ghayat - i Juhdu'l Ḥisāb*. The manuscript is available in the Bankipur and Rampur Libraries. He was a native of Ambala and later on resided at Delhi. He wrote several other books in mathematics and astronomy. His *Tahrīru'l Ashkāl li Hal - i Sharh - li Ashkālu't Ta'sis li Ṭusī* is a super commentary on the commentary by Tusi on the *Ashkalu't Ta 'sis*, a geometrical work of Shamsu'd Din M b. Ashraf Husaini. The manuscript is available in the Rampur Library.

'Imāmu'd - dīn Ḥusain (*b.* 1701), the eldest son of Luṭfu'llāh Muhandis was a well-known astronomer. He wrote many works on astronomy of which mention may be made of *at - Ta' līqāt 'alā Sharhi'l - Mulakhkhaṣi'l Chagmini* (commentary) on the *Al - Mulakhkhas fi'l - Hai'al of Qāḍī Zādah ar - hūmī* and *At - Taṣrīhfi sharhi' Tashriḥ* (commentary on *Taṣrīḥu'd - dīn Aftāk* of Bahā'ud - din 'Āmūlī).

Mirzā Khairullāh Muhandis (*c.* 1700 - 1740), the second son of Luṭfalla Muhandis of Lahore and nephew of 'Ata' Allāh Rushdī (*c.* 1634), was astronomical adviser to Jayasiṃha (fl. 1693 - 1743) and wrote a *Sharḥ* on the latter's *Zīj i Muḥammad Shāhī*. He also translated a copy of *Almagest* and wrote a commentary on it. A manuscript of *Almagest* with his commentary is available at the Raza Library, Rampur.

Abu'l Khairu'llah, son of Luṭfu'llah Muhandis was appointed the head of the observatory at Delhi by emperor Mohammad Shāh in 1718. His *Taqrību't Taḥrīr*, is a Persian translation of Naṣīrud-din's Arabic version on Ptolemy's *Almagest*. He compiled with the help of Nizāmu'd-dīn al-Barjandi's commentary on Ṭusī's above work. The manuscript is available at the Bankipur Library. He wrote another commentary on the *Zīj-i-Muḥammad Shāhī*.

Mulchand, son of Harihar Prasad, flourished during the reign of Muḥammad

(1719-1748) ruler of Delhi. His *Ḥisab Nāmāh*, a treatise on arithmetic was written in Delhi. One copy of the manuscript is available in State Central Library.

Anand Ram Mukhlis, son of Rajah Mardi Ram of Allahabad, flourished during the reign of Muhammad Shah (1719-1748). His work *Dasturu'l Amal* chiefly dealing with accountancy was written in first half of eighteenth century in Persian. It contains informations on weights and measures, zodiacal signs, Hindu science and *śāstras* in tabulated forms. He quoted profusely about his teacher Mirza Bedi in the work.

Inderman, a native of Hisar wrote his *Dastur-i-Ḥisāb* in 1767. It is a treatise in five *maqulah* and a *Khatimah*. One copy is available at Bankipur Library.

Muhammad Barkat flourished in Lahore in 1782 A.D. and was well-known for his *Sharḥ Taḥrīr-u usuli'l Handasat-i wa'l-Ḥisāb*, a commentary in Arabic on the first book of *Euclid* and *Al-Hashiyah'ala Uqlidas*, a gloss on the *Euclid*. The manuscripts are available in the Osmania University Library.

Khwajah Muḥammad was a native of Hyderabad and dedicated his arithmetical work, *Mir'atu'l Ḥisāb* in 1786 to Mumtazu'd Daulah M. A. 'Zamu'd-dīn Khan Bahādur Muzaffar Jung, commander in chief of Nizāmud Dīn Mir. Nizam 'Alikhan Fath Jung, ruler of Hyderabad. The manuscript is available at the Azad Library, Aligarh, State Central Library, Rampur Library and Mashriqi Kutub Khanah Salar Jung, Hyderabad. He wrote also a commentary *Sharh-i-Khulāṣatu'l Ḥisāb* on the *Khulāṣtu'l Ḥisāb of Baha'u-d-Din 'Amuli'*. The manuscript is available in the State Central Library.

Raushan 'Ali (flourished second half of the eighteenth century) was born at Jaunpur. He taught at Calcutta Madrasah and Fort William College. He wrote a number of works in mathematics and other subjects. Some of these works are *Risalah fi Jabr wa Muqab-lah* (on algebra), *Risalah-i Hisāb* (a treatise on arithmetic) *Tarjumah-i Khulasatu'l Hisāb* (a translation of Bahā'ud-dīn Ānuli's mathematical treatise). The manuscript is available in Rampur Library.

Karim Baksh made a selection from a larger treatise, *Umudu'l Ḥisāb* for a Deccan Prince Arastu Jah. Three copies of the manuscripts are available in the Sa Idiyah Library, Hyderabad.

Nawab Shamsu'ul Umara Fakhru'd-dīn Khān Bahādur (b. 1785) was a descendent of Faridu'd-dīn Mas'ud al Ajudhani. His grandfather migrated to Hyderabad and was appointed an officer under Asaf Jah Nizam, first founder Nizam of Hyderabad (died in 1748). He took interest in propagating western knowledge to India. He wrote two works, viz. *Risālah der Bayan i Amal-i Qite*, a treatise on the cons-

truction of the sector and *Sham su'l Handasah*, a work on geometry, mensuration and trigonometry. Both these manuscripts are available in State Central Library, Hyderabad.

M. Ḥusain Isfahani Landani, son of S. 'Abdu'l-'Azim Isfahani Landani, flourished during the days of Asifu'lmulk Sikandar Jāh Bahādur. He wrote his *Risālah-i Haī'at-i Angrezī* in 1797 on European astronomical system specially English and French. The manuscript is available in State Central Library, Hyderabad and Rampur Library, U.P.

Sayyid Nuru'l Asfiyah Aurangabad (*c.* 1800) was born at Aurangabad. He lived for a considerable time with Nawab ali Khān at Karnal and later on shifted to Hyderabad and joined the service under Nawab Shamesu'ul Umara. He wrote *Risālah-i-Nuru'l Ḥisāb*, a treatise on arithmetic. The manuscript is available in the State Central Library, Hyderabad.

Sh. Aḥmad b.m. Maghribi Tilimsani al-Ansari as-Sa'imi (*c.* 1814) was attached as collector in the Department of Revenue of Madras. He composed several treatises on mathematics and astronomy. His *A' zamu'l-Ḥisāb* is a treatise on mathematics, now available in the State Central Library. The *Zubdatu'l Ḥisāb* is another mathematical treatise available in Asiatic Society in four chapters dealing with arithmetic, measurement, finding an unknown quantity and some essentials relating to arithmetic. He perhaps wrote another work *Mir'atu'l-'Alam* on mathematics. The manuscript is available in the State Central Library.

Abu'l Qāsim (Ghulam Ḥusain), son of Fath M. Al-karbala-i wrote his *Jami'i Bahādur Khānī* in 1834. He was born at Jaunpur in 1790-91 and had his lesson in mathematics under his father and some contemporary scholars in mathematics. He spent most of his time with the princes of Benaras and Murshidabad. The work is devoted to mathematics and astronomy in six chapters, viz. science of geometry, optics, arithmetic, practical geometry dealing with the measurement and division of circle, etc., heavenly bodies, horoscope and calendar. The copies of manuscripts are available in the Asiatic Society of Bengal, State Central Library, Salarjung Library, Hyderabad. He wrote several other works, viz. *Sharzhala Taḥrīr-i Uqlīdas* (commentaries on *Euclid*) and *al-Mijisṭī* (commentary on *Almagest* of Ptolemy). *Anīsu'l-Aḥbāb fī Bayān-i Masā'il-i Usṭurlāb* (commentary on the Bahāu'd-dīn 'Āmulī's treatise on *Sufaiḥah*), *Iṣṭilāḥātu't Taqwīn* (on compilation of almanacs) and *Zīj-i-Bahādur Khānī* (on astronomical tables).

4. Trend of Indo-Persian Literature

The Persian and Arabic literature were produced mostly under the patronage of Mughal rulers. Many standard works were brought from outside India. Some of these are *Khulāṣtu'l Ḥisāb* of Bahā'ud-dīn 'Āmūlī (*c.* 1547-1621) written originally in Arabic in Iran, *Taḥrir-i-Uqlidas al Mijisti*—Arabic version of Euclid's *Elements*

and Ptolemy's *Almagest* by Nasīru'd-dīn aṭ-ṭusi etc. besides some others on accountancy, which attracted attention of many Indian scholars.

Attempt has been made to translate and write commentaries on these texts. Similar attempts have been tried to make translations of *Bṛhatsaṃhitā, Līlāvatī,* and *Bījagaṇita* in the period, but very few attempts have been made to make a comparison with the available knowledge in Sanskrit sources. These were written mainly for readers of Persian who knew no other language and had no access in standard Sanskrit, Arabic and Persian treatises in mathematics. Only a partial attempt has been made by Munīśvara and Kamalākara, Jagannātha Paṇḍit and Rājā Jayasiṃha to make a synthesis of the available Indian knowledge and that of Ptolemy and Euclid. The real success has been achieved by Rājā Jayasiṃha who used the services of great Sanskrit scholars having knowledge of Sanskrit, Persian, Arabic and European works which helped him to modernize the observatories in Delhi, Jaipur, Mathura, Banaras, Ujjain and left two almanacs in Sanskrit and one work in Persian.[7]

5. Conclusion

To sum up, the present survey gives an idea of the Indian literature on mathematics during the period. It is by no means complete. The account gives both Hindu and Islamic traditions in India as well as their activities in the form of writing commentaries on older Indian and some Persian texts, which helps us to some extent to assess the trend of literature. The activities of the Indian scholars in mathematics and astronomy also attracted the attention of European scholars, viz. Giovanni Dominique Cassini (1691-1699), Le Gentil (1772), Robert Barker (1777), Joseph Tieffenthaler (1785-1789), Bailey (1878), William Jones (1790), Samuel Devis (1790-1792) and John Bentley (1799), who tried to make an assessment of Indian activities by writing translation of the texts, writing articles in French, Latin, German language. Sen[8] has made a resumé of these activities. But the assessment of the actual contribution in the period deserves more intensive research. This is very important because this will help us to assess correctly the proportion of cultural interdependence in the field of mathematical knowledge.

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