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सरस्वती श्रुतिमहती महीयताम्।
Sarasvatī ***Śrutimahatī*** Mahīyatām

—Abhijñānaśākunta

ON THE LIFE AND WORKS OF RĀMACANDRA VĀJAPEYIN

Sreeramula Rajeswara Sarma

Sanskrit writers are usually anonymous. Even when we know their names, we know very little about their lives. In the case of famous names like Kālidāsa, Varāhamihira[1] or Bhāskara,[2] myth and legend predominate over historical facts. However, as far as writers on astronomy are concerned, we know at least their dates with some certainty, because they usually mention the epochs of their works. The picture of astronomers of the medieval period is becoming more and more focussed through the efforts of David Pingree, who has traced the family relationships and *guru-paramparās* of several writers.[3] In the following pages, I shall discuss the life and activities of a medieval "scientist" named Rāmacandra Vājapeyin, who made valuable contributions to ritual geometry and astronomical instrumentation.

Born in a family of *yājñikas* or ritualists, Rāmacandra or Rāma[4] was a prolific writer of independent treatises and learned commentaries on a wide range of subjects like *Śrauta, Śulba, Svaraśāstra, Jyotiḥśāstra,* and *Vaidyaka.* Fortunately, we are in a position to describe his life in somewhat greater detail, because he gives some information about himself and his ancestors in each of his works.[5] He is proud to be a resident of the hallowed Naimiṣāraṇya (*Naimiṣīya, Naimiṣastha, Naimiṣāraṇyavāsa*) and never tires of repeating this fact in all his writings.[6] The Naimiṣāraṇya of the *Mahābhārata* and of the Purāṇas survives today as Nīmkhār (27°22′ N; 80°29′ E), famous still for its sacred tanks and numerous temples.[7] But in Rāma's time, Naimiṣa denoted a larger area and not just a town. This area falls in the modern Sitapur district, on the left bank of the river Gomatī, not far from the capital city of Lucknow.

In the *Yantraprakāśa,* where the astronomical instruments have to be calibrated for a specific terrestrial latitude or where astronomical data needs to be given in relation to a specific location, Rāma gives a more precise information about his place of residence as Pātrapuñjanagara situated at

27° N latitude within the Naimiṣa.[8] I identify this Pātrapuñjanagara with a small hamlet by the name of Patauñja (27°26′ N; 80°29′ E), some 9 km north of Nīmkhār. In the Census of 1981, Patauñja had a population of 970 souls.[9] But until 1670 it had been a stronghold of the Ahban Rajputs who founded it in the twelfth century.[10] At the time of Rāmacandra in the fifteenth century, this area was known as Katehar and formed part of the Śarqī kingdom of Jaunpur.[11]

Rāma belonged to Vatsa gotra.[12] His great-grandfather was named Śrīdhara. Rāma describes him as a jewel adorning the Mālava region (*mālavadeśamaṇḍanamaṇiḥ*).[13] Elsewhere he refers to him as Śrīdhara Mālava[14] (i.e. of Malwa), a designation which would be meaningful only outside Malwa. It is therefore likely that Śrīdhara migrated from Malwa to Pātrapuñja in the Naimiṣa in the first half of the fourteenth century and became the chief *Purohita* of the Ahban chiefs at the latter place. Rāma reports that ārīdhara possessed many occult powers (*pratyaya*) which are unattainable to ordinary mortals; he even saw Śiva in a trance.[15]

Śrīdhara had a son called Śivadāsa or Śivadāsa Miśra, whose son Sūryadāsa mastered the Vedas and maintained the three sacred fires.[16] He was a great ritualist, bristling with *yājñika* titles like *Samrāṭ, Sthapati* and *Agnicit.*[17] In his *Śulbavārttika,* Rāma states that his father Sūryadāsa studied the science of *Śulba* at the feet of Tripurāri from Śrīparvata.[18]

Sūryadāsa and his wife Viśālākṣī had four sons called respectively Rāmacandra, Lakṣmaṇa, Harṣa and Bharata. About Lakṣmaṇa we know nothing except that he performed sacrifices. Harṣa wrote a tract entitled *Aṅkayantracintāmaṇi* on magic squares.[19] The youngest son Bharata calls Rāma his teacher. He wrote a commentary called *Saralā* on Rāma's *Samarasāra.*[20]

The most famous of the four sons is obviously the eldest, Rāmacandra. It is not known when exactly he was born. The earliest of his dated works is the *Yantraprakāśa* composed in 1428. If we assume that he was about 30 years old at this time, then he may have been born at the beginning of the fifteenth century. In this work, he does not add any *yājñika* titles to his name. These are added in his later works, and give us an idea of his progress in the *yājñika* hierarchy. However, in the colophons of the last two chapters of the *Yantraprakāśa,* he styles himself *Mahāmāheśvara* and *Ācārya.*[21]

Rāma studied all the traditional subjects like the *Vedāṅga, Pūrva-* and *Uttara-Mīmāṃsā, Sāṁkhya, Nyāya, Vyākaraṇa, Sāhitya* and *Purāṇa.* [22] In particular, his father Sūryadāsa imparted to him the knowledge of *Śulba.*[23] He had two other teachers: Vidyākara and Kṣīrasvāmin. Vidyākara and his father Śambhukara appear to be great performers of sacrifices; both enjoy

the title "*samrāṭ*". Rāma must have learnt the theory and practice of sacrifices, including *Śulba*, from Vidyākara for he salutes him at the beginning of each of the several sections of his *Karmapradīpikā* as also at the commencement of his *Śulbavārttika*.[24]

The other teacher, Kṣīrasvāmin of Kashmir, also a *Mahāmāheśvara* and *Ācārya*, taught him mathematical astronomy (*gaṇita*).[25] Evidently it was this Kṣīrasvāmin who was instrumental in Rāma's composing the *Yantraprakāśa*, as Rāma pays homage to Kṣīrasvāmin at the beginning of the work.[26] Elsewhere in the same work, there are references to a Guru, without the name. A stanza that occurs as a refrain at the conclusion of each chapter informs us that Rāma composed that particular chapter by the great grace of the teacher (*guru-guru-kṛpayā*).[27] This guru must be Kṣīrasvāmin himself. More important still is a statement that he wrote a commentary on an unnamed work of his Guru and that in this commentary he described automata with human figures (*nṛyantra*) more elaborately.[28] This Guru too must be Kṣīrasvāmin. This would suggest that Kṣīrasvāmin composed a book exclusively on instruments or a *Siddhānta* in which instruments are discussed among other topics. However, neither the Guru's text nor the pupil's commentary are extant.

There is yet another scholar who inspired Rāma, but he was not his teacher. He bore the strange name Jaṭāmān or Jaṭāma. Rāma refers to him in the following verse, towards the conclusion of his *Kuṇḍākṛti*.

śrīmadratnapurādhipena mahitaḥ śrī-Rāmacandreṇa yo
bhāradvājakulāmbudher vidhur iva śrīmaj-Jaṭāmad-dvijaḥ /
bandhūnāṃ pariṇītaye 'bhyupagato 'sau mālavo naimiṣaṃ
tenargvedavideritena racitā Rāmeṇa kuṇḍākṛtiḥ //[29]

Accordingly, a Brahmin by name Jaṭāmān[30], who was a resident of Malwa, belonged to Bhāradvāja-gotra, was a great scholar of the *Ṛgveda*, and who was honoured by King Rāmacandra of Ratnapura, visited Naimiṣa once for the wedding of a relative. Inspired (*īrita*) by him, Rāma composed the *Kuṇḍākṛti*. A similar verse occurs at the end of the *Śāṅkhāyana-Gṛhyapaddhati:*

ṛgvedāmbunidhau munir ghaṭabhavaḥ śrīmaj-Jaṭāma-dvijaḥ
śrīmad-ratnapuradyulokamaghavā-śrī-Rāmacandrārcitaḥ /
āyād bandhuvivāhakarma .[31]

Here the verse breaks off without providing the operative part of the sentence, but there cannot be any doubt that here too the missing portion would have stated that this Jaṭāmān inspired our Rāma to compose the *Śāṅkhāyana-Gṛhyapaddhati*.

These verses are important for another reason too. This Jaṭāmān is a

resident of Malwa. He was honoured by Rāmacandra, king of Ratnapura. Probably he was the chief *Purohita* of this king and normally resided at Ratnapur. On the occasion of a relative's wedding, he visited Naimiṣa, stayed there for some time and inspired Rāma to compose the *Kuṇḍākṛti* and the *Śāṅkhāyana-Gṛhyapaddhati*. Now marriages usually take place among people originating from the same geographical area, though living in separate parts of the country. Therefore, Jaṭāmān came from Malwa to Naimiṣa for establishing marriage alliance with *mālavas* settled in Naimiṣa. Rāma's family is one such. They belonged originally to Malwa; may even have been residents of Ratnapura. We have seen above that Rāma describes his great-grandfather Śrīdhara as "the jewel adorning the Mālava region." It is reasonable therefore to assume that this Śrīdhara migrated in the first half of the fourteenth century from Ratnapura in Malwa to Pātrapuṇanagara in Naimiṣa and that a century later Brahmins from Ratnapura maintained contacts with the *mālava* Brahmins settled in Naimiṣa. Śrīdhara and his descendants are then *mālavas*, original inhabitants of Malwa but now migrants, and that they kept up the historical memory of their original place of residence as a personal appellation. In his own commentary on the verse from the *Kuṇḍākṛti*, Rāma explains the term *mālava* employed in the verse as *mālavīya-dvijakula-kamalabandhuḥ*.[32] Thus the term *mālavīya* too is attested as early as 1449.

Rāma is primarily a *yājñika*, i.e. an expert in the theory and practice of Vedic sacrifices. His father Sūryadāsa and he must have officiated at the sacrifices performed by the ruling princes of Pātrapuñja. Already in 1428, Rāma describes himself as "honoured by Mahārāja Śrī Harasiṃhadeva."[33] This Harasiṃha ruled over Katehar from at least 1399.[34] But, as mentioned already, Rāmacandra does not add any *yājñika* title to his name in the *Yantraprakāśa* composed in 1428, nor in the *Śulbavārttika* written in 1434. Later, in the *Prāyaścittapaddhati* (its date is not known), he calls himself *agnicit*. As his younger brother Bharata explains, one is called *agnicit* when one has constructed and sacrificed at the falcon-shaped altar (*suparṇaciti*).[35] Again in the *Śulbasūtravṛtti* (written after 1434), he styles himself "*Somasut*."[36] By the time he wrote the *Vājapeyapaddhati* (before 1449), he has performed the *Vājapeya* sacrifice and calls himself Rāmacandra Vājapeyin.[37] By 1449 he also performed the *Bṛhaspatisava*.[38] In the colophon to the *Suparṇacitipaddhati*, which he completed in this year, he assumes the full regalia of titles like his father: *Samrāṭ-sthapaty-agnicid-Rāmacandra*.[39]

It is interesting that in Rāmacandra's milieu great store is laid not only on performing sacrifices but also on the titles resulting from them. Some of these titles, e.g. *Vājapeyin*, became surnames in the later period. Other kinds of appellations like *Mālavīya* which later became surnames are also attested

for the first time in this period. But the practice of having the same surname for all the male members of the family did not establish itself yet. Notice that in Rāmacandra's family, Śrīdhara had the title *Mālava* or *Mālavīya*, his son Śivadāsa was a *Miśra* and Rāmacandra himself was *Vājapeyin*.

Besides performing Vedic sacrifices like the *Suparṇaciti* and *Vājapeya*, Rāma also practiced non-Vedic cults of various kinds, as his great-grandfather Śrīdhara did. Towards the end of the *Yantraprakāśa*, he states that even as a child he meditated upon Sāvitrī, that once in front of the image of Śrī Bhavānī in Kāśī he experienced the touch of some divine person, that his teacher initiated him into secret knowledge and helped him accumulate unlimited Śaivite energy, and that therefore the goddess Sarasvatī constantly shines through his pure intellect.[40]

A more curious fact is the following. In *Yantraprakāśa* 1.8, Rāma exhorts the readers to cultivate the company of the good in order to acquire secret knowledge (*sadrahasya*).[41] In the commentary thereon, Rāma explains that a special name (*viśiṣṭanāma*) of his lay hidden in this verse.[42] Since the verse is repeated six more times in the *Yantraprakāśa*, viz. at the end of each of the six chapters,[43] and since the commentary alludes each time to the special hidden name,[44] this special name seems to be of great significance to Rāma. In the commentary on 1.8, Rāma explains that the name is obtained by combining the first syllable of the first foot, the second of the second foot, the third of the third foot, the fourth of the fourth foot, again the fifth syllable of the fourth foot, the sixth of the third foot, the seventh of the second foot and the eighth of the first foot. The name thus obtained is *A-psa-raḥ-pri-ya-rā-ma-sya*, "of Rāma, the lover of heavenly nymph(s)." Devasthali wonders if that "Apsaras was the name of his wife."[45] If so there is no need to hide this appellation. However, it is doubtful that such a name was borne by a woman of the *śrotriya* family, for Apsarases, though celestial, were not quite virtuous. There are two possible interpretations. It is the general belief that performance of Vedic sacrifices results in the pleasurable company of the heavenly nymphs in the after-life. Through the expression "*apsaraḥpriya*", Rāma is alluding to such a future possibility. The other possibility, which appears more likely, is that Rāma is claiming that, through his occult powers, he enjoys the love of heavenly nymphs in this life.

We have seen that Rāma's chief interest lay in the performance of Vedic sacrifices. But since ritual geometry (*Śulba*) and measurement of time are essential ancillaries to the Vedic sacrificial science, he made a mark in these areas too. During the twenty odd years between 1428 and 1449, Rāma composed some sixteen works : eight independent treatises, four auto-commentaries and four commentaries on others' writings.[46] These works are as follows.

I. Independent Treatises

1. *Yantraprakāśa* with commentary (1428 AD).
2. *Śulbavārttika* with commentary (1434 AD).
3. *Nāḍīparīkṣā* (1442 AD).
4. *Kuṇḍākṛti* with commentary (1449 AD).
5. *Karmadīpikā* in several volumes on Vedic sacrifices.
6. *Śāṅkhāyana-Gṛhyapaddhati.*
7. *Samarasāra* with commentary.
8. *Karaṇacintāmaṇi* (not extant).

II. Autocommentaries

1. On the *Yantraprakāśa* (1428 AD).
2. On the *Śulavārttika* (1434 AD).
3. On the *Kuṇḍākṛti* (1449 AD).
4. On the *Samarsāra.*

III. Commentaries on others' works:

1. On the *Kātyāyana-Śulbaśūtra.*
2. On the *Śāradātilaka* (not extant).
3. On the *Pāṭīgaṇita* of Śrīdhara[47] (not extant).
4. On an unnamed work by his Guru in which apparently astronomical instruments are discussed[48] (not extant).

Rāma's magnum opus is undoubtedly the *Karmapradīpikā* or *Karmapradīpikāpaddhati*[49] on the performance of various *Śrauta* sacrifices.[50] This work consists of several independent sections (or manuals) with their own beginnings and concluding parts. It is not definitely known how many sections there are, but the following seven (arranged alphabetically) have been noticed by Aufrecht in his *Catalogus Catalogorum* : (i) *Ādhāna-paddhati*, (ii) *Cayana°*, (iii) *Jyotiṣṭoma°*, (iv) *Prāyaścitta°*,[51] (v) *Vājapeya°*,[52] (vi) *Suparṇaciti°*,[53] and (vii) *Somakarma°*.[54] According to Eggeling, the *Prāyaścittapaddhati* follows mainly the *Kātyāyana-Śrautasūtra*. The dates of these sections could not be ascertained, but they seem to have been composed at different periods between 1434 and 1449. Rāma also wrote, on domestic rituals, the *Śāṅkhāyana-Gṛhyapaddhati* in five chapters about the year 1449 AD.[55]

Śulba-śāstra, the science of constructing the sacrificial altars, is ancillary to the Vedic ritual. Indeed the *Śulbasūtras* are treated as appendices to the *Śrautasūtras*. Particularly in the school of Kātyāyana, the *śulba* is regarded

as a *pariśiṣṭa* of the *Śrautasūtras*. Therefore, it is no wonder that Rāma turns his attention to the *Śulba-vidyā*, to which he made significant contribution.

As Sadashiv L. Katre has shown in an excellent article some sixty years ago,[56] Rāma wrote three separate works dealing with the *Śulba*. The first of these is the *Śulbavārttika* in 515 verses which he composed in 1434.[57] Just as Kātyāyana's *Vārttika* explicates and supplements Pāṇini's *Aṣṭādhyāyī* and Patañjali's *Mahābhāṣya* thereon, so is Rāma's *Śulbavārttika* is intended to explicate and supplement the *Kātyāyana-Śulbasūtra* and Karka's *bhāṣya* thereon. Like the original *Sūtra*, the *Vārttika* is also divided into six *kaṇḍikās*. In this work, Rāma strives to provide definitions to each concept and proofs (*upapatti*) to each construction.[58] On this *Vārttika*, Rāma wrote a voluminous commentary with copious citations from several authorities.

Some time after 1434, Rāma wrote a commentary with the title *Śulbasūtravṛtti* on the *Kātyāyana-Śulbasūtra*, where he refers to his own *Vārttika*.[59] Some 150 years later, in 1589, Mahīdhara also wrote a commentary on the *Kātyāyana-Śulbasūtra* where he acknowledges his indebtedness to Rāma's commentary.[60] Mahīdhara also makes occasional references to a *Vārttika* which, in all probability, may be the same as the one composed by Rāma.

Another contribution to sacrificial literature by Rāma is the *Kuṇḍākṛti*,[61] dealing with the construction of fire pits of various geometrical shapes, which he wrote along with a commentary called *Kuṇḍalakṣyavivṛti* in 1449.[62] The commentary is available in a shorter and a longer version.

Lakṣmaṇa Deśikendra's *Śāradātilaka*, though a work on *Tantra*, deals with the construction of *kuṇḍas* in the third chapter. Rāma wrote a commentary on this work. This commentary is not extant, but Rāma is said to cite it frequently in his commentary on the *Kātyāyana-Śulbasūtra*.[63]

A slender work that found great response, also in modern times, is the *Samarasāra* in 85 verses. It teaches how to draw various arrangements of letters (*cakra*) which are said to ensure victory on the battlefield. The *Samarasāra* is modelled after the *Narapatijayacaryā* (1177) of Narapati, and is one of the earliest works on this subject.[64] Its popularity can be gauged by the 260 manuscripts that survive of this work.[65] Rāma's younger brother Bharata wrote a commentary named *Saralā*. In some manuscripts, this is mentioned as a joint work by Rāma and Bharata.[66]

Rāma's younger brother Harṣa wrote a book of similar nature called *Aṅkayantracintāmaṇi*. It teaches the method of drawing magic squares of the order four for the magic sums of 24, 26, 28, 32, 54, 64, 100. These magic squares are supposed to ward off diseases, calamities and ensure the well being of pregnant women, new-born infants, and the like. It is interesting

to note that both Rāma in his *Samarasāra* and Harṣa in this work employ the *Kaṭapayādi* system of representing numbers, which is very popular in Kerala. These are the earliest datable instances of the use of this system in northern India.

According to S. B. Dikshit, Rāma wrote a *karaṇa* called *Karaṇacintāmaṇi*, but no manuscript of this work has been noticed so far, nor could any reference to this work be traced.[67]

Unconnected with any of the above-mentioned works is Rāma's exercise in medicine under the title *Nāḍīparīkṣā*, i.e. testing or examination of the pulse, written in 1447.[68] Reading the pulse for diagnosis was unknown to the traditional Āyurveda. It has not been mentioned in the works of Suśruta, Caraka or Vāgbhaṭa. According to Jolly, pulse reading was mentioned for the first time in the *Cikitsākalikā* of Tiśaṭa whom Jolly assigns to the twelfth century. In the thirteenth century Śārṅgadhara discusses pulse rather briefly in his *Saṁhitā* at 1.3.1-12. The first medical writer to give a detailed account of the pulse reading is Bhāvamiśra in his *Bhāvaprakāśa* of 1558. Since then pulse reading is included among the eight methods of diagnosis. Therefore, it is thought that pulse reading was introduced into India during the Muslim rule.[69] Given this chronology of pulse reading in India, the significance of Rāma's *Nāḍīparīkṣā* becomes quite obvious, as it is the second or third work of this kind to be written in India.

Rāma, a *yājñika* of high standing, could not have practiced medicine. Did his interest in *nāḍī-parīkṣā* (pulse reading) emanate from his interest in *Svarbala* where emphasis is laid on the two *nāḍīs* called *Iḍā* and *Piṅgalā* ?[70] Whatever the answer be, one thing stands out in connection with both the *Samarasāra* and the *Nāḍīparīkṣā* : they are the earliest works in their respective fields. We do not know what the origin of the *Svarodaya* or the *Svaraśāstra* is, but it is presented for the first time in King Someśvara's encyclopaedic work *Mānasollāsa* written in 1129.[71] The *Narapatijayācaryā* deals with this subject in an elaborate manner in 1177. Chronologically speaking, Rāma's *Samarasāra* seems to be the next work on this subject. These two cases show Rāma as a pioneer in new fields. The same pioneering spirit can be discerned more clearly in the *Yantraprakāśa*. Until the early medieval period, astronomical instruments were described in a class of works called *Siddhāntas*. Contact with Islamic astronomy led to the production of Sanskrit works exclusively devoted to instruments. The first such work was composed by the Jaina monk Mahendra Sūri under the title *Yantrarāja* in 1370.[72]

Rāma's *Yantraprakāśa* composed in 1428 together with a commentary is the second Sanskrit work solely devoted to astronomical instruments.[73]

It is also his earliest dated work. Though dealing with astronomical instruments, this work is also connected with the Vedic sacrifice as Rāma himself states expressly: the primary purpose of the astronomical instruments described in this work is to measure time, and determining the correct time is important in the performance of a sacrifice.[74]

At the beginning of the work Rāma explains that observational instruments are indispensable for astronomy:

tanur netrair nyūnā nṛpatirahitā rājanagarī
sarasyo niṣpadmā yuvatir api kāntena rahitā /
niśā niḥśītāṃśuḥ sarid api tathā cakrarahitā
tathā jyotirvidyā bhavati viphalā yantrarahitā // 10//[75]

"Like body without eyes, like royal capital without the king, lakes without lotuses, young woman sans lover, the night devoid of the moon, a river minus cakravāka birds; the science of astronomy becomes fruitless without instruments."

Though his main forte is the ritual, his works on mathematics and astronomy are especially valuable for us. His mathematical contribution pertains to the realm of ritual geometry, i.e. construction of sacrificial altars and fire-pits of specific geometrical shapes. On sacrificial alters, he wrote the *Śulbavārttika* along with a voluminous commentary as well as a commentary on Kātyāyana's *Śulbasūtras*. His *Kuṇḍākṛti* and his commentary on the *Śaradātilaka* deal with the construction of fire-pits.[76] In all these works, he does not merely enunciate the rules of construction, but constantly endeavours to provide improved methods and more accurate values. Thus he teaches a new method of squaring the circle where the difference between the area of the circle and that of the square is negligible.[77] While the value of the square-root of 2 given in the *Śulbasūtras* (1.4142156863) is correct up to five decimal places only, Rāma gives a more accurate value (1.414213502) which is correct up to seven places of decimals.[78] More important still are the mathematical proofs (*upapatti*) which he seeks to give for geometrical propositions.[79]

In the field of astronomy, Rāma's *Yantraprakāśa* has a unique place. Aside from exercising his poetic skill by employing a variety of metres with special preference to longer metres like the *Śārdūlavikrīḍita, Sragdharā* and *Mandākrāntā*, Rāma describes in this work the method of construction and use of some forty varieties of astronomical instruments, perhaps the largest ever described in any Sanskrit work. Arab astronomers, who were the first to compose exclusive manuals on astronomical instruments, did not reach this number, perhaps with the exception of Abul Hasan of Morocco. Besides the large number, what really distinguishes the *Yantraprakāśa* is Rāma's

genuine interest in instrument-making. Indian astronomers, in general, were not interested in the practical aspects of instrument construction and give the barest details, with the result that it is often difficult to visualise the instrument much less to construct it on the basis of the description.[80] In comparison, Rāma's descriptions, especially in his commentary, are considerably more detailed. He first describes the basic design and then mentions the variants that are possible.

At the beginning of the account of the astrolabe, Rāma describes the tools (*karaṇa*) employed by the astrolabe maker. In comparison to his Islamic and European counterparts, the Indian artisan used very few tools, but even these find rarely a mention in Sanskrit or other texts, nor are they represented in sculpture or painting. Therefore Rāmacandra's account of the astrolabe maker's tool-kit is particularly valuable.[81]

The major part of the *Yantraprakāśa*, i.e. the first four of the total six chapters, is devoted to the astrolabe, an instrument known from Hellenistic antiquity. But it reached its perfection in the Islamic world and from there it was transmitted to Europe and India. It was introduced into India in the fourteenth century during the reign of Fīrūz Shāh Tughluq, who encouraged Mahendra Sūri to compose the first manual in Sanskrit on this instrument.[82] Mahendra calls the astrolabe *Yantrarāja*, "king of instruments" which name he also gave to his manual. Rāmacandra uses a different name, *Sulabhā-yantra*, but his treatment is substantially based on Mahendra's work and its commentary by Mahendra's pupil Malayendu Sūri.

The fifth chapter of the *Yantraprakāśa* is devoted to two shadow instruments, the gnomon (*śaṅku*) and staff (*yaṣṭi*), and the trigonometric problems connected with their use. The sixth and final chapter discusses some thirty-six varieties of instruments which provide valuable information on the history of astronomical instruments in India. The instruments discussed here can be classified into the following categories: (i) traditional instruments as taught by Brahmagupta and Bhāskara, (ii) the same with improvements, most likely by Rāma himself, (iii) those inspired by Islamic models, and (iv) instruments mentioned here for the first time, which must have been invented in India after Bhāskara during the twelfth and thirteenth centuries, or designed by Rāma himself.

It is beyond the scope of this article to discuss these instruments in greater detail, except to say that Rāmacandra's descriptions throw an entirely new light on many aspects of the history of astronomical instrumentation in India.[83]

The main purpose of this discussion of the life and works of Rāmacandra Vājapeyin is to examine the context and the milieu in which

"scientific" activity took place in fifteenth century India. It is clear that science did not exist in a vacuum; it was often the hand-maiden of religion. But the division into science and non-science is only a recent development. Rāmacandra did not suffer from this modern dichotomy. For him the investigation into an accurate solution of the quadrature of the circle, or finding out a more accurate value of $\sqrt{2}$, or the study of astronomical instruments—even those coming from the Yavanas—was not incompatible with his deep faith in the efficacy of the Vedic sacrifices; in fact these were closely interrelated in his *Weltanschauung*. When I described him as a "medieval scientist" at the commencement of this article, it is to stress that Samrāṭ-Sthapati-Agnicit Rāmacandra Vājapeyin, *Apsaraḥpriya* and at same time *Naimiṣāraṇyavāsin*, lived fortunately in a more unified realm of discourse than many of us do today.

May this account of the life and works of Rāmacandra Vājapeyin of Naimiṣāraṇya serve as a small tribute to Professor Ram Karan Sharma who also combined in himself diverse realms of activity as scholar, administrator, vice-chancellor, President of the International Association of the Sanskrit Studies, and, above all, as an eminent teacher in the East as well as in the West.

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References & Notes

1. The Jaina tradition makes him a younger brother of Bhadrabāhu; cf. "Bhadrabāhu-Varāha-Prabandhaḥ" in : Rājaśekhara Sūri, *Prabandhakośa*, pp. 2-4; see also variant versions of this legend in Merutuṅgācārya, *Prabandhacintāmaṇi*, pp. 118-119; Jinavijaya Muni (ed), *Prabandhacintāmaṇi-sambaddha-purātana-prabandha-saṃgraha*, pp. 90-91. On the other hand, there is another tradition, perpetuated by the *Jyotirvidābharaṇa* of Pseudo-Kālidāsa which makes him one of the nine jewels (*nava-ratnas*) at the court of Vikramāditya, also a mythical personage.
2. A very popular legend seeks to explain that his book on arithmetic was named after his luckless daughter *Līlāvatī*. I propose to trace the origin of this legend in a forthcoming paper.

3. See David Pingree, *Jyotiḥśāstra : Astral and Mathematical Literature;* idem, *Census of Exact Sciences in Sanskrit.*
4. His full name is Rāmacandra, but he often contracts it to Rāma—one of the earliest recorded cases of name-shortening?
5. Cf. Devasthali, "Harṣa, the Author of the Aṅka-yantra-cintāmaṇi and Relatives"; Katre, "Three Works by Rāma Vājapeyin pertaining to Kātyāyana's Śulbasūtra"; idem, "Exact Date of Rāma Vājapeyin's Nāḍīparīkṣā (Saṃvat 1499)"; see also CESS, A-5, 467b-479a.
6. For example, cf. the beginning of his *Kuṇḍākṛti*:
iṣṭāpūrter aṅgam ādyaṃ yad āhur
yasyonatvādhikyato bhūri doṣāḥ /
kuṇḍaṃ sāṅgaṃ bhūribhedaṃ tad atra
brūte Rāmo naimiṣastho vicārya //
7. Nevill, *Sitapur, A Gazetteer*, pp. 197-199.
8. *Yantraprakāśa* BORI MS 975/1886-92, *f*10*v*; *atra naimiṣāntarvarti-pātrapuṅjanagare <gaṇakānāṃ> sukhārtham saptavimśaty-akṣāṃśānām ...*; astrolabe gazetteer *f*12*r*; *śrīmati naimiṣāraṇye pātrapuṅjanagare <akṣāṃśāḥ>* 27.
9. *Uttar Pradesh District Census Handbook*, No. 43, Sitapur Series 22.
10. Nevill, *Sitapur, A Gazetteer*, pp. 121, 137.
11. Ibid., p. 12.
12. For example, cf. *Yantraprakāśa* 1.48:
Vatsasyāste maharṣeḥ prayatatarakule sarvavidyāvidagdhaḥ
sadbuddhir śaivadāsir budhanalinaraviḥ Sūryadāso 'gnihotrī /
tatsūnū Rāmacandro gurugurukṛpayādhyāyam ādyaṃ supadyair
vaiśālākṣeya ādhād dyuguṇagaṇanajaṃ cāruyantraprakāśe //
Rāma uses this verse at the conclusion of each chapter of the *Yantraprakāśa* with suitable modifications in the last two lines.
13. Ibid, 1.3:
āsīn mālavadeśamaṇḍanamaṇiḥ śrī-Śrīdharācārya ity
udgīto bhuvane samādhisamaye sākṣātkṛtomāpatiḥ /
śrī-Vatsānvayasāgarāmṛtakaraḥ śrutyabdhikumbhodbhavaḥ
kaivalyāvagater avāptamanujālabhyākhilapratyayaḥ //
14. *Śulbavārttika* 81:
sūnoḥ Śrīdharamālavasya ḍivadāsākhyād urukhyātitaḥ
samrāḍ agnicid āpa yasya janakaḥ śrī-Sūryadāso janim /
yanmātur yaśasā diśo daśa Viśālākṣyā valakṣā vyadhāt
ṣaṣṭhīṃ śulbajakaṇḍikāṃ sa viśadāṃ Rāmo vasan naimiṣe //
cited by Katre, "Three Works by Rāma Vājapeyin," p. 74.
15. *Yantraprakāśa* 1.3 cited in n. 13 above.
16. Ibid, 1.4:
sūnuḥ saṅkramadarpaṇo guṇagaṇasyāsyābhavat kovido
vikhyātaḥ Śivadāsamiśra it tatputro vibhāti kṣitau /
vedāmbhonidhipāragaḥ pṛthuyaśaḥ śrī-Sūryadāsābhidho
vaṃśyāmbhoruhavṛndavāsaramaṇiḥ śrautāgnisevāarataḥ //
17. For example, the colophon of Rāmacandra's *Suparṇacitipaddhati* reads thus: *iti samrāṭ-sthapaty-agnicit Sūryadāsātmaja-naimiṣīya-samrāṭ-sthapty-agnicid Rāmacandrakṛtā Suparṇa-citipaddhatiḥ sampūrṇā*, cf. Rajendralal Mitra, *Notices of Sanskrit Manuscipts*, Vol. 4, No. 1460.
18. *Śulbavārttika* 6.73:
śrīparvatāntikacara-Tripurāribhaṭṭaiḥ
sūtre 'tra lambhitapathāḥ pitṛpūjyapādāḥ /

yāvantam artham avadan vihitaḥ prapañcas
tasyaiva vārttikapadaiḥ svaidhiyā mayāyam //
cited by Katre, "op. cit., p. 74.
19. Cf. Devasthali, "Harṣa, the Author of the *Aṅkayantracintāmaṇi* and his Relatives"; Sarma, "Magic Square for 2004," *Indian Journal of History of Science* 39.1 (2004) 143-44.
20. Cf. CESS, A-4, 287a-288b; A-5, 250b-251a. At the beginning of his commentary on Rāma's *Samarasāra* , Bharata states that Rāma was his teacher :
abhivandya Rāmacandraṃ guruṃ taduktasvaragrantham /
vivṛṇomi yathāprajñaṃ tadabhimatārthānusāreṇa //
At the end of the same commentary, he mentions that he is Rāma's younger brother.
granthakṛto Rāmasya bhrātā Bharato laghur vidvān /
ṭīkām enām akarot tadgranthārthaprakāśinīṃ saralām //
Cf. the manuscript at the Department of Sanskrit, Aligarh Muslim University.
21. *iti mahāmaheśvarācārya-Hīrasvāmi-śiṣya-mahāmaheśvarācārya-sauryadāsi-śrī-Rāmacandra-kṛta-yantraprakāśasya svakṛtaṭīkāyāṃ śaṅku-yaṣṭiyantra-siddhir nāma paṇcamo 'dhyāyaḥ / ....iti mahāmaheśvarācārya-śrī-Rāmacandra-viracitāyāṃ svaviracita*(sic!)*-yantraprakāśaṭīkāyāṃ kutūhalayantraprakāśano nāma ṣaṣṭho 'dhyāyaḥ samāptaḥ/*
22. *Yantraprakāśa* 6.75:
mīmāṃsādvayamūlayā phaṇipatiprodgītabhāṣāmṛtā-
sārābhyukṣitapāṇinīyadharaṇau sāhityabījotthayā /
sāṃkhyanyāyapurāṇapallavitayā śrī-Rāmadhīvīrudhā
vedāṅgādiphalaiḥ saduktikusumaiḥ ko vā na santuṣyate //
23. See n. 18 above.
24. Cf. the beginning of the *Karmapradīpikā, Prāyaścittapaddhati*, India Office Catalogue, **I**, 446 :
samrāḍo 'gnicito natvā Vidyākaraguroḥ pade /
Rāmāḥ paddhatim ādhatte pryaścittapradīpikām //
Beg. of *Karmapradīpikā, Vājapeyapaddhati*, India Office Catalogue, I. 427:
Vidyākaragurūn natvā sarvavidyākarāgriṇaḥ /
Rāmaḥ paddhatim ādhatte vājapeyakrator vidhau //
Kātyāyana-Śulba-Vārttika, 1.1:
Rāmo Vidyākaragurūn natvā śrī-Sūryadāsātmajaḥ /
kātīyaśulbe karkoktau kurute ślokavārttikam //
as cited by Katre, op. cit., p. 73.
Beginning of *the Śulbavārttika-Vivaraṇa*, a ṭīkā on the above:
śrī-āambhukarasamrājaḥ sūnuṃ Vidyākaraṃ gurum /
praṇamya Rāmo vyākhyāti svakṛtaṃ śulbavārttikam //
as cited by Katre, op. cit., p. 75.
25. *Śulbavārttika*, 6.75:
Hīrasvāminam īḍe kāśmīrācāryam āpya gaṇitavidhim /
yasmād dhīmatpravarān mayedam uddhāritaṃ śāstram //
quoted by Katre, op. cit., p. 74.
26. *Yantraprakāśa* 1.6 :
natvā Hīrasvāminam anugrahāt tasya labdhaviśadamatiḥ /
kurve'tha Viśālākṣītanayo yantraprakāśam aham //
27. See n. 12 above.
28. See n. 48 below.
29. This verse refers to three different persons, all in instrumental case (*rāmacandreṇa; tena+ṛgdevedavidā, rāmeṇa*) and is badly transmitted. It is highly corrupt in the Berlin manuscript, Chambers 274. On its basis, Weber drew the following conclusions in his Catalogue at I.1086: "Nach v. 72 war der Verf[asser] des Schriftchens ... rgvedavid,

gehörte dem Geschlecht des Vatsa an, stammt aus Mālwa (resp. dem Naimiṣāraṇya), lebte in Ratnapura, und verfasste es Saṃvat 1506." Narahari, "The Date and Works of Naimiṣastha Rāmacandra," too mixes up these three persons when he states: "we learn that the work *Kuṇḍākṛti* was composed in Saṃvat 1506 (1449 A.D.) by Rāmacandra, a Mālava brāhmin of Ratnapura, belonging to Bhāradvāja-gotra..." The fact is that Rāmacandra who lived at Ratnapura is a king of the city; Rāmacandra or Rāma the subject of this study belonged to Vatsa gotra; it is Jaṭāmān who belonged to Bhāradvājagotra and is ṛgvedavid. It is Jaṭāmān too who was honoured at the court of Ratnapura and not our Rāma of Naimiṣa. Such errors are repeated in several manuscripts catalogues and consequently also in CESS A-5, p. 467b.

30. In most MSS and printed versions the verse reads *jaṭāma-dvija*, "a brahmin named Jaṭāma". Jaṭāma makes no sense to me and I prefer to read *jaṭāmad-dvija*, "a brahmin named Jaṭāmān". Jaṭāmān would be one who has long uncombed locks of hair. It could be a nickname given to him when he started to let his hair grow!
31. Cited by Weber, Berlin Catalogue, I.133.
32. Devasthali, p. 500, n. 31, citing India Office Catalogue, No. 3154.
33. Colophon of his commentary on the *Yantraprakāśa* reads thus at the end of Chapter Four : *iti śrīsauryadāsi-mahārāja-śrī-Harasiṃhadevapūjya-naimiṣāraṇyavāsi-vaiśālākṣeya-Rāmacandra-viracitāyām.*
34. Cf. H. Beveridge (tr), *The Tārīkh-i-Mubrakshāhī by Yāhyā bin Aḥmad bin 'Abdullah Sirhindi*, pp. 175, 185, 190, 192, 194, 197, 207, where he is referred to as Rāi Har Singh.
35. Bharata in his commentary *Saralā* on Rāmacandra's *Samarasāra* 85: *agnicit suparṇa-citikāratvāt.* There were also Brahmins who performed the *Supaṇaciti* three times and bore the title *triragnicit.* Thus a manuscript of Rāma's *Prāyaścittapaddhati* (India Office Catalogue, I.446) was copied in AD 1620 for an Acala, son of *triragnicit-samrāṭ-sthapati-dīkṣita-Vāmana.*
36. The colophon to this work reads thus: *iti naimiṣīya-somasud-Rāmacandra-kṛtāyāṃ śulbasutravṛttau...*; cf. Katre, op. cit., p. 76.
37. Colophon : *iti samrāṭ-sthapaty-agnicit-Sūryadāsātmajasya Viśālākṣīsūno Rāmacandra-Vājapeyinaḥ kṛtau karmapradīpikāyāṃ paddahtau vājapeyakratuḥ samāptim agāt.* India Office Catalogue I.427.
38. *Vājapeya* together with *Bṛhaspatisava* would entitle one to call oneself "*samrāṭ*" as Bharata explains in his commentary on *Samarasāra* 85: *samrāṭ bṛhaspatisavagarbhavājapeyayājitvāt.* See also Thite, "A propos of the Vajapeya."
39. See n. 17 above.
40. *Yantraprakāśa* 6.72 :
    sāvitrī śiśunaiva yac ciram abhūd dhyātā mayā bhaktitaḥ
    kāśyāṃ sparśam adāc ca kaścana suro yacchrībhavānyāḥ puraḥ /
    śaivojo 'pi ca paryacāyayad alaṃ yad dīkṣayā śrīgurus
    tattadvaibhavato mamāmalamatau śrībhāratī bhāsate //
41. Ibid, 1.8:
    ↓ ajñair jñātuṃ sadrahasyam ↑
    ↓apsaḥgāc chītatāṃ manāk / ↑
    ↓ jñātvorahsu cirāt sadbhiḥ ↑
    ↓ saṃsṛjyaṃ priyam itsubhiḥ //↑
42. *tenātra ślokasya prathamapādādyākṣareṇa dvitīyapādadvitīyākṣareṇa tṛtīyapādatṛtīyākṣareṇa caturthapādasya caturthākṣareṇa punaḥ pañcamākṣareṇa punas tṛtīyapādaṣaṣṭhākṣareṇa punar dvitīyapādasaptamākṣareṇa punar ādyapādāṣṭamākṣareṇātmano viśiṣṭaṃ nāmoktam /*
43. *Yantraprakāśa* 1.91; 2.63; 3.65; 4.74; 5.64; 6.72.
44. Commentary on *Yantraprakāśa* 1.91 : *vyākhyā nāmaprakaṭanaṃ ca tad eva.*
45. Devasthali, p. 501.

46. Of these sixteen, four are not extant; of the rest, only two and odd are published, viz. *Kuṇḍākṛti, Samarasāra* and a part of the commentary on the *Kātyāyana-Śulbasūtra.* The following comments on his writings are therefore mainly based on the information from manuscript catalogues and, in some cases, the manuscipts themselves, esp. of the *Yantraprakāśa* and of the *Samarasāra* as listed in the Bibliography.
47. Cf. *Yantraprakāśa*, BORI MS *f* 29*r* : *pāṭīgaṇite yathā visaṅmāt padatas tyaktvā ...* [*Pāṭīgaṇita* of Śrīdhara, sūtras 25-26] *etad asmābhis taṭṭīkāyāṃ vyhyātam iti nehocyate /*
48. Cf. *Yantraprakāśa*, BORI MS *f*68 *v*: *triprakāro nṛyantravidhiḥ / vistṛtaṃ caitad gurukṛta-granthaṭīkāyām asmbhir iti neha pratanyate /*
49. Also known as *Karmadīpikā* or *Karmadīpikāpaddhati.*
50. On *Paddhatis*, cf. Alfred Hillebrandt, *Ritual-litteratur, Vedische Opfer und Zauber*, Strassburg 1897, p. 39 : "A class of writings closely related to the *Prayogas* are the *Paddhatis* which also deal with the entire ritual of their schools or with single sections thereof. The only difference, it seems to me, is that the *Paddhatis* follow more the text of the *Sūtras* and paraphrase their contents rather than serve the practical needs of a sacrificial act."
51. See Eggeling, *India Office Catalogue*, No. 1360.
52. Ibid, 91b.
53. Rajendra Lal Mitra, *Notices of Sanskrit Manuscripts*, vol. 4, No. 1460.
54. Ibid, vol. 5, No. 1727.
55. Weber, Berlin Catalogue, I.133.
56. Katre, "Three works by Rāma Vājapeyin".
57. The date of composition is mentioned in 6.76 (cited by Katre, op.cit., p. 74):
    candranandamanusaṃmitavarṣe 1491 vaikrame vyadhitavārttikam etat /
    ṣaṭśaratriśaśisaṃmitaśāke 1356 kṣetrasiddhividhaye kavi-Rāmaḥ //
58. Cf. *yac ca Karkācāryeṇa yady api vyākhyātam asmābhiś copapattidarśanena vārttikaiḥ prapañcitaṃ ... Śulbasūtravṛtti*, as cited by Katre, op. cit., p. 76.
59. Published, *Kātyāyana Śulva Sūtra*, with the Commentary by Rāma, ed. G. Thibaut (the first two Kaṇḍikās only), *The Pandit*, NS, 4 (1882). CESS, A-5, 469a mentions a *Śulbasūtrārthasaṃkṣepa* by Rāma in 8 folios. It is not certain whether it is an independent work or whether it is a part of any of the three above-mentioned works.
60. *Kātyāyana-Śulbasūtra*, with the Bhāṣyas by *Karka* and Mahīdhara, Mahīdhara's commentary, concluding verse 3:
    viduṣāṃ sukhabodhāya vyadhād buddhyanusāratah /
    bhāṣyaṃ Rāmakṛtāṃ vṛttiṃ sūtrāṇy ālocya tattvatah ///
61. In the 140 and odd MSS listed by David Pingree, the work is variously called as *Kuṇḍāhuti, Kuṇḍakārikā, Kuṇḍanirṇayaśloka, Kuṇḍanirmāṇaśloka, Kuṇḍaprakāśikā, Kuṇḍamaṇḍapalakṣaṇa, Kuṇḍamaṇḍupavidhi, Kuṇḍalakṣaṇa, Kuṇḍavarṇana, Kuṇḍasiddhi* and so on. The commntary, however, survives only in 84 MSS. Cf. CESS A-5, 469a-473b. The date is mentioned in verse 74:
    rasagaganatithipramāṇavarṣe gatavati vikramabhūmipasya kālāt /
    kratuvidhiphaladāyake makhejye kṛtir iyam astu mayārpitā sureśe //74//
62. This work was published from Bombay in 1877, along with 19 similar tracts under the title *Kuṇḍagranthaviṃśati.*
63. Aufrecht, I. 642: *Śāradātilaka-ṭīkā* by Rāma Dīkṣita, Oudh 1876, 32. Datta, *The Science of the Śulba*, p. 11, states that Rāma quotes from this commentary in his commentary on the *Kātyāyana- Śulbasūtra.*
64. Cf. Pingree, *Jyotiḥśāstra*, p. 78.
65. Cf. CESS, A-5, 473b-478b.
66. For example, in Bihārilāla Vāsiṣṭha's edition of the *Samarasāra*, the *ṭīkā* begins thus :
    natvā bhaktyā maheśānaṃ sarvasiddhividhāyakam /
    vyākhyā samarasārasya saṃgrahākhyā prakāśyate //

ṭīkā samarasārasya rāmeṇa bharatena ca /
yākāri tatsaṃgraho 'tra yathāyogaṃ vidhīyate //

67. S.B. Dikshit, *Bhratīya Jyotiṣa* (in Hindi), p. 625, n. 2.
68. Katre, "Exact Date of Rāma Vājapeyin's Nāḍīparīkṣā (Saṃvat 1499)."
69. Cf. Kutumbaiah, "The Pulse in Indian Medicine."
70. Rāma discusses *Svarabala* in *Yantraprakāśa* 6.64-666; *Samarasāra* 39-42.
71. *Manasollāsa*, vol. 1, pp. 126-130.
72. Cf. Sarma, "Yantrarāja : The astrolabe in Sanskrit."
73. Available only in two manuscripts: Bhandarkar Oriental Research Institute, No. 975/1886-92, and Asiatic Society of Bengal, No. G. 1363. The latter, however, has large gaps. Nṛsiṃha Daivajña in his commentary (AD 1621) on the *Siddhāntaśiromaṇi*, pp. 445 ff., quotes large extracts from this work. The date of composition was mentioned in the work, cf. BORI MS, *f*20*r*: *atha Saṃvat 1485 Śāke 1350 yatra granthotpattikāle caitraśukla-pratipadi naimiṣāraṇyāntargata-pātrapuñjanagare ...; f*15*v*: *Śākaḥ kheṣutrividhu (1350) rahitaḥ.*
74. *Yantraprakāśa* 1.9:
jyotiḥśāstraṃ savanasamayāvedakatvāc chrutīnām
aṅgaṃ mukhyaṅṃ dṛśam abhidadhur labdhavarṇāḥ purāṇāḥ /
kālo yantraiḥ karabadaravaj jṇāyate yat tad etac
chāstre sāraṃ budhajanamude vacmi sadyantrajātam //
75. Cf. Mahendra Sūri, *Yantrarāja*, 1*A*:
yathā bhaṭaḥ prauḍharaṇotkaṭo 'pi śastrair vimuktaḥ paribhūtim eti /
tadvan mahājyotiṣanistuṣo 'pi yantreṇa hīno gaṇakas tathaiva //
76. See in this connection, R.P. Kulkarni, *Engineering Geometry of Yajña-Kuṇḍas and Yajña-Maṇḍapas*; R. C. Gupta, "*Agni-kuṇḍas*—A Neglected Area of Study in the History of Ancient Indian Mathematics."
77. *Kātyāyana-āulbasūtra* 3.4 teaches that, for squaring a circle, the square should be built on a side of 13*d*/15. Rāma says that a side of 8*d*/9 will give a more accurate value:
vṛttavyāsaṃ navāṃśe vā parihṛtyātha tāṃ vadet /
karaṇīcaturasrārtham alpam evāntaram bhavet //
quoted by Mahīdhara in his commentary on *Kātyāyana-Śulbasūtra* 3.4.
78. Cf. Datta, *The Science of the Śulba*, pp. 11-12. See also C.N. Śrīnivaseingar, *The History of Ancient Indian Mathematics*, p. 14; R.P. Kulkarni, *Geometry according to Śulba Sūtra*, p. 104.
79. *Śulbavārttika* 1.3:
upapattiṃ vinā śāstraṃ na hṛdi sthiratāṃ vrajet /
atas tām eva me vaktum ayam yatno vijṛṃbhatām //
cited by Katre, "Three Works by Rāma Vājapeyin," p. 73.
80. Cf. Sarma, "Astronomical Instruments in Brahmagupta's Brāhmasphuṭasiddhānta," p. 68 f.
81. *Yantraprakāśa* 1.12-13 describes the basic tools of the astrolabe maker.
82. Cf. Sarma, "Sulṭān, Sūri and the Astrolabe" ; "Yantrarāja: Astrolabe in Sanskrit".
83. I have discussed this in some of my papers on instruments, notably in "Astronomical Instruments in Mughal Miniatures."