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ASTRONOMERS AND THEIR REASONS: WORKING PAPER ON JYOTIḤŚĀSTRA

PREAMBLE

For the group project on the Sanskrit knowledge systems, the scientific tradition of Jyotiṣ, Jyotiḥśāstra, a term that includes the disciplines of mathematics, astronomy and divination, presents a problem. There is a difficulty in including Jyotiṣ in the general history. Though Jyotiḥśāstra is a 'knowledge system' of the same sort as the others covered in the project, there is a noticeable separateness to its intellectual space, practical niche, and social network.[1]

Divination texts, and astrological texts especially, were among the most numerous and widespread of all literatures in Sanskrit, but despite their range of dissemination, and despite the early inclusion of Jyotiṣ in canonical lists of vidyās and śāstras (knowledges and sciences), Jyotiṣ was practiced at some remove – in method, assumptions, even in the form of textuality – from the preeminent śāstras, the sciences of language analysis (vyākaraṇa), hermeneutics (mīmāṃsā), logic-epistemology (nyāya), and moral-legal-political discourse (dharmaśāstra).[2] In this respect Jyotiṣ is more comparable to Āyurveda, the other Sanskrit "technical art."

To what extent, then, is Jyotiḥśāstra meaningfully studied in connection with the other philosophical and intellectual traditions of the śāstrīs? And how can it be included in the general history proposed in this project, or even its periodization?

In what follows I will propose a way of going about answering these questions. These proposals are necessarily preliminary and provisional, and represent only a first attempt at consideration of the problem. I feel emboldened to make synoptic claims about Jyotiḥśāstra in this period because of a special difference in the study of Jyotiṣ, by comparison to the study of the other śāstras. Because of the meticulous and comprehensive survey of the history of Jyotiṣ texts being done by David Pingree, we are in a position to make an assessment of the history of Jyotiṣ in the early modern context in a way that cannot yet be imagined for the other śāstras.[3]

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The relevant questions with which to begin are these: is there a meaningful periodization of the history of Jyotiṣ which approximately overlaps the proposed interval (1550–1750), in which distinctive and/or new activities can be identified? Furthermore, does the history of Jyotiṣ in this period run parallel to that of the other śāstras, so that they can be imagined to belong to the same larger historical development? And finally, to follow on from the studies by McRae and Bronner, is there not just newness, but a self-consciousness about newness, which can be taken to be characteristic of some Jyotiṣa texts in this period?

In the following, I will attempt to show that there is a moment at the start of the 16th Century that marks a beginning of new astronomical writing; and that in the astronomical texts produced at that time there is manifested a new concern with reconfiguring the relationship of Jyotiṣ to the philosophical śāstras, to make Jyotiṣ resemble and participate in the world of the philosophical śāstras to a greater extent. As for the last question, that of self-consciousness newness, that is a question more difficult to answer, I suspect because the astronomers had, for professional reasons, a different attitude toward temporality in general.

COLLINS AND THE MATH / PHILOSOPHY AXIS

The separateness of mathematics, astronomy and astrology from other knowledge systems is not a phenomenon unique to the Sanskrit intellectual world, especially in pre-modern periods. The sociologist of knowledge, Randall Collins, has argued that in global terms there is a differential history – though many early Greek philosophers were also mathematicians or closely related to them in their intellectual networks, most early Chinese philosophers were not, and the overlap was only partial in Muslim and medieval European networks.[4] Collins identifies a close relationship of mathematics and philosophy in the 17th Century in Europe as crucial for the emergence in Europe of what he calls "Rapid-Discovery Science."

Collins' account of Indian mathematics records its development in India as largely unconnected to the philosophical traditions. Collins claims that for India "there are no recorded contacts between philosophical and mathematical networks, and no individuals overlap both activities."[5] For the earlier period, this is confirmed by the work of Pingree, though, as Pingree points out, our information is far from complete.[6] Such scientists as Āryabhaṭa, Varāhamihira, Brahmagupta and others are not known to have taken much interest in philosophy; nor is there much interest manifested in the other direction. While this separation appears to hold for the earlier Indian history, developments in the early modern period undermine the validity of the claim for the later era.[7]

YAVANAS AND JYOTIṢ

There is another, related featured of the problem to consider here, Jyotiḥśāstra's *relative* cosmopolitanism or openness to non-Sanskritic scientific knowledge systems. A new period of Indian astronomy famously began with the appropriation, starting in the 2nd Century C.E., of Greco-Babylonian and Hellenistic astronomical and astrological models, parameters, and calculatory/interpretative systems.[8] This meant that in early Jyotiṣ literature there appeared rationales for valuing the sciences of "foreigners" (mleccha or yavana). The subsequent circulation of Jyotiṣa methods and texts into Pahlavi, Persian, and Arabic texts, with subsequent circulation histories beyond, and in turn the later śāstraic interest in Arabic and Persian astronomical and divinations systems, are also well-established.[9] To be sure, Jyotiṣ was not an intensely outward-looking, cosmopolitan intellectual tradition, but by comparison with the other Sanskrit knowledge systems, especially after the waning of the influence of Buddhist intellectuals in the Sanskrit sphere, the participation by the astronomers in a more "international" network of circulation is striking. It is probably related to the relative isolation from the other Sanskrit śāstras, again a phenomenon shared to some extent with Āyurveda. In the early modern period, an interest in Arabic/Persian astronomy and astrology, if not a uniform receptivity, only increased among Sanskrit astronomers. I will suggest that the interest in Arabic/Persian exact sciences became a significant factor in determining the direction that Jyotiḥśāstra took during this period.

PERIODIZATION – JÑĀNARĀJA'S SIDDHĀNTASUNDARA, 1503 C.E.

First then, where might we place the beginning of an early modern period for Jyotiṣ? Of course, there is no need to expect precise synchrony among the sciences we are jointly considering.[10] A date that suggests itself, somewhat earlier than the one proposed for the other sciences, is 1503 C.E., the date of the completion of the Siddhāntasundara by Jñānarāja, an astronomer who lived in Pārthapura, along the Godāvarī river.[11] The Siddhāntasundara, or "Treatise Beautiful," was the first astronomical Siddhānta, or magisterial treatise, to appear in Sanskrit in 350 years, the first after the hugely influential work by Bhāskara II, the Siddhāntaśiromaṇi.[12] To write another Siddhānta after a long gap is to recuperate the past, but at the same time to break from it, and the Siddhāntasundara pointedly defines itself by its departures from Bhāskara's work. Jñānarāja's work was circulated widely in north India, and defined the terms of a number of discussions that took place among the astronomers in Banaras in the following century.

Further support for this date, 1503, as marking the beginning of a new phase in Jyotiṣ is found in the dating of two other prominent and innovative movements in astronomy which are roughly contemporary with Jñānarāja, one in Gujarat, the other in Kerala.

GAṆEŚA DAIVAJÑA

The first of these is the astronomical school associated with Gaṇeśa Daivajña, who was born in 1507 C.E., and who lived in Nandigrāma near the coast in Gujarat.[13] Gaṇeśa was the author of the hugely popular Grahalāghava. Gaṇeśa's Grahalāghava belongs to the genre of Karaṇas, or "pragmatic expositions," rather than to the genre of Siddhāntas.[14] The Grahalāghava became the most influential karaṇa since Bhāskara's Karaṇakutūhala. Its acceptance was far greater even than that of Jñānarāja's work.[15] Gaṇeśa proposed self-consciously new systems for calculating the positions of planets and for other astronomical practices. His texts are notable for requiring no trigonometry, for the uniqueness of their planetary periods, rates of mean motion, and equations of anomaly. They provide a form of mathematical astronomy that makes redundant the traditional approach of the Siddhāntas, with its dependence on geometric, epicyclic models.[16]

Gaṇeśa's work became extensively used, especially in Western India. Some families at astronomers of Banaras were especially active in commenting and disseminating his work in the next century.[17] Gaṇeśa's work is somewhat later that Jñānarāja's, but Gaṇeśa's father Keśava, also from Nandigrāma, and also an astronomer, was a contemporary of Jñānarāja's. His principal work, the Grahakautuka, appeared in 1496.[18] Keśava had begun some of the new work that culminated in the Grahalāghava and other works. It was thus not just filial humility that made Gaṇeśa give the credit for many of his innovations to his father. In this sense the appearance of the Nandigrāma school, known as the Gaṇeśapakṣa, can be argued to be more closely contemporaneous with that of the Siddhāntasundara.

NĪLAKAṆṬHA SOMAYĀJĪ

The other prominent innovator of the same period is the astronomer Nīlakaṇṭha Somayājī, a Nambudiri Brahmin who lived from 1444–1545 (more than a hundred years!) near Tirur. He was a member of the Kerala school of astronomers, founded by Mādhava in the later fourteenth century.[19] This school ran along its own historical trajectory, though it was in some contact with developments in astronomy elsewhere. Its inclusion in a unitary history of Indian astronomy is thus problematic.[20] Furthermore, some of Nīlakaṇṭha's more interesting advances were anticipated by his paramaguru Parameśvara a century earlier, at the end of the 14th and in the early 15th century. Thus Nīlakaṇṭha is not the originator of a school, and his contribution is not so easily made to fit into a narrative of the beginning of an era. Nevertheless he is unusually innovative, and certain features of his innovations are comparable enough to developments elsewhere in the subcontinent in the period that I will include consideration of them here.

One contribution of Nīlakaṇṭha's that has received attention recently was his rather radical reformulation of the geometry of the planetary models in a substantial departure from the models standard among his predecessors.[21] But Nīlakaṇṭha is most noteworthy to us here for a work that he wrote called the Jyotirmīmāṃsā, "the analysis of astronomy."[22] Some features of this work lead us into the second section of this study, so I will pause for a moment on them here.

In the Jyotirmīmāṃsā Nīlakaṇṭha argued that the astronomical parameters and models inherited from the texts of the past were not in themselves permanently correct, but needed constantly to be improved and corrected based on a systematic practice of observation and reason. Nīlakaṇṭha was apparently the first person to make such an arguments, even though, as part of his justification of it, he attributed the argument to his astronomical predecessors.

What was also innovative in Nīlakaṇṭha's work was the way that he argued this point; that is, it is not simply that he argued for observational correction, but that he extended himself to the foundational argument as well. He made claims about why observation and reason, that is, in the philosophical parlance of the Sanskrit tradition, pratyakṣa and anumāna, are, as Pingree put it,[23] "fundamental to the proper practice of astronomy."

A hint of his approach is already signaled in the second word of his title. 'Mīmāṃsā,' analysis, is also of course the name of one of the dominant philosophical traditions of his day, Karma- or Pūrvamīmāṃsā, the system of hermeneutics that derived from the analysis of Vedic ritual texts. The title, therefore, already implies that the same sort of analytical approach should be applied to Jyotiṣ, something that had not previously been claimed in a systematic way by astronomers.

Here I will not review Nīlakaṇṭha's entire argument, but will refer only to something that might be a complication for our understanding of his work as 'progressive.' As mentioned above, in making his appeal to the idea of using observation and inference, Nīlakaṇṭha works in an intellectual world in which he needs to make these arguments on a textual basis. Thus he shows that in the writings of Kumārila Bhaṭṭa, the philosopher of the Mīmāṃsā school from the 7th century, one can find a statement about the practice of Jyotiṣ that gives sanction to the use of observation and reason in order to correct and update parameters.[24] The statement is brief, and not a topic in and of itself for Kumārila (really rather only an example mentioned in passing), but the fact of it, and the presence of commentators' interpretations, creates a sanction based in textual authority for astronomical corrections that proceed from observation. Nīlakaṇṭha also interprets a passage from the Bhāgavata Purāṇa [11.22.25] to the same purpose, and even a passage from a later Vedic text, the Taittirīya Āraṇyaka [1.2.1–2], though here he must elicit his argument from texts that do not specifically mention astronomy and its practices.

In summary, Nīlakaṇṭha's argument for why it is sanctioned, even desirable for astronomers to engage in an observation-based, regularly updated scientific practice is grounded on an appeal to properly philosophical, epistemological arguments. While some of the central arguments are hermeneutic and scholastic ones, this appeal to philosophical foundation is something new in astronomy.

In practice, Nīlakaṇṭha made some use of astronomical observations.[25] He begins the Jyotirmīmāṃsā by noting the occurrence of two recent eclipses that he has observed, and that were not predicted by Āryabhaṭa's system.[26] Nīlakaṇṭha was following the example of his paramaguru, Parameśvara, who recorded observations of eclipses between 1393 and 1402.[27] No doubt Indian astronomers had always looked at the skies, but there is something new about the orientation of Nīlakaṇṭha and Parameśvara toward observation in evidence here. More on this below.

Nīlakaṇṭha Somayājī is thus a third innovative astronomer at work in 1503, in what was effectively a separate astronomical tradition operating on the subcontinent. Further examination of the contents of Nīlakaṇṭha's innovations shows us two tendencies that can be traced elsewhere – an interest in proper philosophical argumentation, including argument by appeal to textual authority in the Mīmāṃsist mode, by appeal to logical principle and by appeal to experience in the form of observation; and an interest in finding new approaches to the use of observation as part of astronomical practice.

At the same time, the separate history of the Kerala school provides a caution against our constructing too simple a narrative for the early modern period. It would be wrong to say that Jyotiṣ was monolithic and stagnant in the late medieval period, and was suddenly and dynamically renewed at the beginning of the 16th Century. In the preceding centuries, Jyotiṣ had been varied – conceptually, practically, and regionally; and it had been undergoing its own incremental and divergent developments.[28] Nīlakaṇṭha's and Gaṇeśa's works are nevertheless strikingly innovative, and innovative in an unprecedented way. More innovation followed elsewhere, as I shall discuss below.

OBSERVATIONS

I mentioned above Nīlakaṇṭha's and Parameśvara's notable interests in the use of observations. What is also noteworthy is their reference to specific observed events, and to their own observational projects. Some evidence of a similar new orientation toward the use of observation is found in the Nandigrāma school of astronomers as well. Gaṇeśa Daivajña is reported by his commentator Mallāri to have made use of astronomical observations in Gujarat,[29] and his father, Keśava, describes himself as having observed the conjunctions of planets and stars, and to have made corrections based on these observations.[30]

Some distinctions need to be made here in the variety of ways in which observations might be used, if they are used at all. For much of the history of Jyotiṣ, aside from being used to establish local position and time, observation appears to have played at most a supporting role in astronomical practice – either as a rough check of observable phenomena against what the models predict; or as a way of more systematically confirming the validity or invalidity of a system; or even as merely an element of rhetorical strategy, as a practice to lay claim to as a way of differentiating one school of astronomy from another.[31]

Keśava employed astronomical observations in a novel way to improve astronomical parameters using 'bija-corrections.' In effect, however, the observations were used only to help him make a choice among already existing parameters found in the available astronomical schools, not to establish new parameters.[32] Gaṇeśa's use of observations resembles his father's, though the parameters are sometimes revised further. Thus there is something new in the use of observations in Gujarat in this period, though it cannot be described as a revolutionary change.[33]

In the case of Nīlakaṇṭha, it appears that the use of observation has enabled him to arrive at new parameters, though in fact most of these parameters (except for one concerning Mercury), are very close to the parameters of an existing school.[34] Again, observations have been used by Nīlakaṇṭha, and presumably also by Parameśvara, in correcting parameters, and perhaps even developing new ones, but how precisely they might have been used to do so is difficult to reconstruct.

For what none of these astronomers has done, neither in Gujarat nor in Kerala, is to lay out in their texts a system whereby observations could be incorporated into improvements of the astronomical parameters and models, even though Nīlakaṇṭha in the Jyotirmīmāṃsā is calling for such a program in general terms. Something like this was attempted nearly two centuries later, in the 18th Century, independently by another astronomer also named Keśava (fl. 1706) and by the astronomical workshop centered around the astronomer-king, Sawāī Jaisingh (reigned 1700–1743).

I would suggest that this new attention to ways of making use of observation is motivated by an awareness of Arabic/Persian astronomical practices, which by this period had become established in many parts of South Asia. Arabic astronomy is famously preoccupied with astronomical observations and the method of their incorporation into astronomical theory.[35] There is evidence that Arabic/Persian astronomy and astrology was gradually filtering into the awareness of Sanskrit Jyotiṣīs from the mid-14th Century, as I will discuss below. Here I will only mention some traces of evidence about the authors under consideration. It is evident from the terms of measurement that he uses that Parameśvara's observations were made using an astrolabe.[36] Keśava and Gaṇeśa were aware of at least some features of Arabic/Persian astrology, as Keśava wrote a text in Sanskrit on Tājika, that is Persian, astrology.[37] And Gaṇeśa produced a text on the sundial with horizontal gnomon, the Cābukayantra, an instrument which had its origins in Arabic/Persian astronomy, as its name suggests.[38]

JÑĀNARĀJA AND THE PĀRTHAPURA SCHOOL

Let us now return to the works of the Pārthapura school, that is, to the works of Jñānarāja and his two sons, Cintāmaṇi and Sūryadāsa. They were members of a family of astronomers and śāstrīs.[39] An ancestor had served at the court of the Devagiri Yādavas. In Jñānarāja's day the family was settled in Pārthapura. Jñānarāja's sons Cintāmaṇi and Sūryadāsa both wrote works on astronomy (more on both of them below), as did other family members. The astronomical works of all three have received comparatively less study than those of Parameśvara/Nīlakaṇṭha and Keśava/Gaṇeśa; none of them has been published, so I will devote a little more space to them here. The features I have remarked on for the Kerala and Nandīgrāma schools – a new concern with epistemological foundation, in both new uses of textual sources, especially philosophical ones and argumentation, and the new approach to the use of experience, together with some trace of a growing "internationalism," have their reflexes, in one form or another, in the work of the Pārthapura school.[40]

One also detects in the Pārthapura group a greater interest in accommodation to the cosmology of the Purāṇas, a feature not noticeable in the Kerala or Gujarat movements mentioned earlier. The terms in which this accommodation is accomplished involve the incorporation of properly philosophical argumentation, and of an alternative variety of observation or even what one might call experimentation. The 'purāṇicizing' tendency might be understood as further evidence of the desire to bring Jyotiṣśāstra into the mainstream of Indian intellectual developments, given how influential the Purāṇas, especially the Bhāgavata Purāṇa, had become in this period. On the other hand, it could be understood as a sign of the erosion of the separate disciplinary authority of astronomy, for the Purāṇic and the Siddhāntic cosmologies are at odds on many points. In what follows I will refer especially to the sections of the texts from authors in Pārthapura that refer to the support of the earth; for here we encounter examples of the other kinds of innovations as well.[41]

The Purāṇic accounts explain that the earth is held up by various incarnated divine beings, that is, the great serpent Śeṣa, the boar incarnation Varāha, the tortoise incarnation Kūrma, and so on. The astronomical tradition, on the other hand, has always been nearly unanimous in maintaining that the earth required no external support. Bhāskara, for example, argued that the earth had its own inherent power of self-support, and required no other supporting entity.

Jñānarāja, in seeking to rescue more of the Purāṇic point of view, breaks here with the astronomical tradition, most visibly with Bhāskara, against whom he directly argues. Purāṇic doctrines can be reconciled, he argues, if we suppose that the earth's divine supporters are stationed inside the globe, in the Pātālas, supporting the earth from its interior.[42]

In order to prove his point his point he must argue against Bhāskara's notion of an inherent power of fixity in the earth, and a secondary power in the earth to attract things to it. It is not because of an attraction power, but rather because things fall downward that we see things have it in their nature to fall to earth. This makes it necessary for Jñānarāja to posit a separate special power that inheres in creatures who live on the sides and bottom of the earth, which holds them to the globe in those places, so that they do not fall off, downward.

Implicit here is a more general principle that informs a number of Jñānarāja's arguments, having to do with the 'downness of down,' that is, with whether directionality is absolute or relational. Most earlier authors of the Siddhāntas include in their discussion of the sphericity of the earth a statement of relational directionality, that wherever one is on the globe, 'up' is over one's head, and 'down' is below one's feet. People opposite each other on the globe are mutually 'under' each other. There is no such statement in Jñānarāja.

In the interest of establishing a greater deal of authority for the Purāṇic model, Jñānarāja must thus necessarily sacrifice some of the standard cosmological views of the astronomers, even though this leads him into more complicated and potentially less arguable positions.

CINTĀMAṆI

Jñānarāja's son Cintāmaṇi, also lived in Pārthapura. His only known work is a commentary on the Siddhāntasundara of his father, Jñānarāja. The work is called the Grahagaṇitacintāmaṇi, the "Philosopher's Stone of Planetary Calculation." This lengthy work was circulated widely in Northern India, though not as widely as the Siddhāntasundara itself. It was known to the 17th century astronomers in Benares.

CINTĀMAṆI AND PRAMĀṆAŚĀSTRA

The feature of Cintāmaṇi's work worthy of note here is his preoccupation with integrating the arguments and demonstrations of astronomy with the epistemological systems of the philosophical sciences, the śāstras. The concern is especially with the vocabulary of the realist-logican school of Nyāya, but Mīmāṃsā and the grammar-philosophers are also introduced.

Cintāmaṇi categorizes and reformulates Jñānarāja's arguments in the vocabulary and format of the mainstream philosophical method – are his father's arguments inferences from positive evidence, (anumāna), or presumptive conclusions (arthāpatti), or some other mode of argument? Do the inferences fulfill the philosophers' criteria for a sound logical syllogism, having the five elements of proof (pakṣa, sādhya, hetu, sapakṣa and vipakṣa), in their proper relationships to each other? Or are there rather faulty arguments, (hetvābhāsa), defective in their concomitance relations by departure (vyabhicāra) or misidentification of cause (upādhi), or aptness of demonstration (sādhāraṇatā)? The vocabulary is not incidental, but is basic to the commentary's agenda.

A verse in Jñānarāja's work attempts to prove the sphericity of the earth by appeal to the fact that when the sun is directly over Laṅkā (which is assumed in the astronomical tradition to be on the equator, and also to be the point on the equator that establishes the prime meridian of the earth's longitude), then it is simultaneously seen as on the southern and northern horizons from the point of view of the north and south poles, respectively, and on the eastern and western horizons from the point of view of Rome and Yamakoṭi, respectively, two cities assumed to lie on the equator at 90 degrees west and east from Laṅkā.[43] "Someone might object that a desired view (viz. that the earth is a sphere) is not simply proved by proposing that it is," says Cintāmaṇi in his introduction to the verse, "but rather through the accumulation of competent proofs. In reply to this objection Jñānarāja states, in Vasantatilaka meter, as the required proof, a presumptive conclusion (arthāpatti), which emerges from the otherwise unexplainable common experience based on people's perception."[44]

This is not the end of it, however, for Cintāmaṇi next concedes, through the voice of another imaginary objector, that the argument in the verse is not persuasive, since it requires us to assume for the purpose of the proof that which it seeks to prove, for no-one has seen the people in any of these cities; "and surely the disbelievers (nāstikas) would only laugh at us, finding it quite a surprise that astronomers would seek to prove something using something else unproved."[45] In order to rescue the argument, clearly not designed by Jñānarāja to be evaluated by these analytical criteria, Cintāmaṇi then introduces the contents of a later verse, which more straightforwardly demonstrates the spherical nature of the earth by appeal to the changing elevation of the pole star for a person moving north or south. And so the commentary goes, in effect reformulating the Siddhāntasundara in syllogistic terms and retrieving arguments that cannot stand on their own.

Even the mathematical results are reformulated as syllogisms, something astronomers had not previously dreamed of doing. Consider for example the calculation of the size of the earth. In his treatise, Cintāmaṇi's father had used the example of an astronomer who measures the sunrise in his local position, and who then travels swiftly due east 10 yojanas with a sand-clock, and measures sunrise in that location the next day. He will find, says Jñānarāja, a time difference in local sunrise of $7\frac{1}{5}$ palas.[46]

The solution to the "rule of three" problem that this presents – $7\frac{1}{5}$ is to 3600 as 10 is to what? – becomes in Cintāmaṇi's commentary a standard philosopher's syllogism of this form: Earth is possessed of the property of being 5000 yojanas in overall measure (pratijñā); because there is the property of generating $7\frac{1}{5}$ palas time difference at sunrise by an interval of 10 yajanas (hetu); for wherever there is the generation of $7\frac{1}{5}$ palas time difference in an interval of 10 yojanas, there is for a time difference of 60 ghaṭikās an interval of this size, i.e. 5000 yojanas (udāharaṇa).[47]

CINTĀMAṆI AND 'EXPERIMENTS'

In the swift-moving astronomer's trip east we see a reference made to observation, as a way to prove the earth's spherical shape and manageably small size. This passage of Jñānarāja's work is a development of the sort of argument about the spherical shape of the earth made already in earlier Siddhāntas, but here there is a greater attention to the process, and the method of calculation. Unfortunately it is an experiment that will only give the predicted results on the equator. The east-west circle at northern (or southern) latitudes will not be a great circle, and hence will not be of the same circumference as the equator. Nevertheless Cintāmaṇi describes the experiment with verve:

> Travelling east for ten yojanas, [the astronomer] comes upon a fortress stronghold atop a hill, and sees there the gateway to a royal city, decorated with masses of gems brought from all over the king's domain and from the domains of his conquered enemies. Seeing the reddish reflection of the rising sun's rays on the walls of the gateway decorated with silk banners and with stone from Kashmir, and seeing that the sun has risen, his mind is filled with wonder, and with a broad smile on his face, he reflects, 'what has happened is amazing.'[48]

One also finds in Cintāmaṇi a tendency to make an appeal to common experience and behavior (laukika-vyavahāra), something that astronomers and especially philosophers had commonly done as a way of securing certain arguments. Cintāmaṇi's examples begin to resemble something like scientific experiments, though again, perhaps only thought experiments.

Cintāmaṇi and his father, for reasons of argument about the earth's support, wish to deny that the earth has a separate power of attraction. In Cintāmaṇi on this point there is reference to a quasi-Galilean experiment on the behavior of objects of different weight. An iron ball and an āmalaka fruit, of equal size, each threaded onto a string, are pulled toward the observer with equal force at the same moment. The āmalaka reaches him more quickly.[49] In another place in the text, the materials are changed. A piece of rock and a Betel nut are each threaded onto strings and at a given moment, simultaneously pulled toward the 'experimenter.' The 'experimenter' will find that the Betel nut reaches him more quickly. Hence, Cintāmaṇi concludes, lighter things are propelled more quickly than heavier things by the same amount of force. And yet we see that, in nature, heavy things fall to the earth faster. Thus it can't be the earth's attraction force that makes them fall; for if it were a force that caused the motion, the lighter thing would reach the earth faster. Instead it must be some other principle, viz. that all things fall downwards.

Another feature of the commentary worth noting is Cintāmaṇi's direct appeal to the mainstream of philosophical discussions when these become pertinent. For example, in a lengthy discussion of what it is that keeps a bird aloft when it flies or soars (a discussion occasioned by Jñānarāja's argument that the earth can be held aloft for the duration of a creation by Śeśa or others, since even an eagle can soar for a long time even while holding a heavy snake in its claws), Cintāmaṇi, among other things, refers to two different texts where Udayana, the 10th Century realist/logician, discusses the phenomenon of how things can be supported on air. The Kiraṇāvalī is directly cited,[50] and the Nyāyakusumāñjali is alluded to for its discussion of the inference of will in any flying object.[51] Thus the Nyāya-Vaiśeṣika account of the physical properties of objects, their tendency to fall down, and the physics of flight, are brought up here, in a way that one does not ordinarily find among the astronomers.

Thus Cintāmaṇi can be compared to Nīlakaṇṭha in his interest in 'philosophizing' the Jyotiṣ discipline, though he goes about it in a different way, by bringing philosophical argumentation schemes and texts directly into the astronomy sections of his own work. Cintāmaṇi is not notably an advocate of observation and correction, as Nīlakaṇṭha is, yet there is a distinctively 'experimentalist' drift to his rhetoric, even if the experiments remain only 'on paper'.

SŪRYADĀSA

Sūryadāsa (born 1508), son of Jñānarāja and brother of Cintāmaṇi, also lived in Pārthapura. Sūryadāsa was a prolific writer in a variety of genres, especially in mathematics and poetry.[52] His best known work is the

Rāmakṛṣṇavilomakāvya, a dvisandhāna work that tells simultaneously the story of Rāma and of Kṛṣṇa, if read in opposite directions.[53]

SIDDHĀNTASAṂHITĀSĀRASAMUCCAYA

Sūryadāsa was the author of the Siddhāntasaṃhitāsārasamuccaya, a "compendium of essential points about the astronomical Siddhāntas and Saṃhitās."[54] In most respects he follows the arguments of his father and brother. I mention the work here for the fifth chapter, called the Mlecchamatanirūpaṇa, the description of the views of the foreigners, in this case astronomers. Here there is an account, in 81 verses, of the cosmological, astronomical, and astrological views of the mleccha astronomers. Arabic and Persian terms are listed and translated along with the basic Aristotelian model of the organization of the elements and the proofs offered for it. The last 26 verses record equivalent vocabulary in Sanskrit and Arabic or Persian, for nakṣatras, for the twelve astrological terms or houses, for the zodiacal signs, and for other astronomical and astrological phenomena.

The Mlecchamatanirūpaṇa is, as far as I know, the earliest attempt in an astronomical text to write a doxography of Arabic/Persian astronomy and astrology.[55] There had been earlier traces of astronomical curiosity, however. As mentioned above, there was interest in the instruments used by the "yavanas." Texts in Sanskrit describing the astrolabe and its use began to appear in the 14th Century, the first securely dateable one being the Yantrarājāgama by Mahendra Suri, commissioned by the court of Fīrūz Shāh Tughluk.[56] Interest in astrology is also well-represented. Indeed, perhaps the most successful of any "knowledge system" Sanskrit text of this period is the Tājika-Nīlakaṇṭhī, produced by Nīlakaṇṭha, the Jyotiṣarāya in the court of Akbar.[57] Many other Tājika texts were written in Sanskrit, including one by Keśava, as mentioned above.

The earliest Persian-Sanskrit dictionary that we know of appeared in the late 16th century, commissioned by Akbar.[58] Subsequent dictionaries expanded the astronomical sections, but Suryadāsa's work is interesting as the earliest known example of something like the creation of a glossary for Jyotiṣ. Furthermore, the juxtapositions of technical vocabulary constitute the beginning stages of a comparative project.

Probably not long after Suryadāsa wrote his work, an anonymous author created a Sanskrit translation of a Persian text of the *ilm al hay'a* genre.[59] The work, entitled the Hayatagrantha, renders into Sanskrit a general survey of Arabic/Persian astronomy, including a treatment of the Aristotelian principles that underly it. Here again, Sūryadāsa appears to represent the beginning of a wave of activity.

I will not rehearse the entire later history of the phenomenon during the period, but Sanskrit astronomers in the 17th century are noticeably even more engaged in translation, evaluation, and consideration of the possibility of learning from Arabic/Persian astronomical models than their predecessors. The figure most worthy of note here is Nityānanda, who was active in Delhi in the days of Shah Jahan. He was the paṇḍit commissioned in the 1630's to translate the Zīj-i-Shāh-Jahānī of Farīd al-Dīn Mas'ūd into Sanskrit, which translation he named the Siddhāntasindhu. This translation of the Zīj did not meet with much acceptance, and so Nityānanda subsequently composed another work, the Sarvasiddhāntarāja, in 1639, as an "elaborate apology for using Muslim astronomy."[60] He wrote even more eclectic works as well, and his works were of great interest to Sawāī Jaisingh a little less than a century later.[61]

In the 17th Century also, two prominent Śāstrīs of Banaras, Munīśvara and Kamalākara, both active at mid-century, together with their relatives, vigorously debated the value of Muslim astronomy in their Siddhāntas and other compositions.[62] If they did not know Sūryadāsa's work, they must have had access to similar sources for some of their information.

I mention the later history of the response to astronomy in Arabic and Persian in conjunction with my discussion of Sūryadāsa's 'mlecchamata' chapter to show that it is particularly the 16th Century when this doxographic and comparative project begins to pick up momentum. What had earlier been a distinctive feature of Jyotiḥśāstra, its connection to networks of scientists outside of the Sanskrit sphere, is resumed and revivified in the early modern period. It reaches its culmination in the work of Jaisingh, about which much has been written elsewhere.[63] This engagement in a dialogue with Arabic and Persian scientists is shared by the authors of texts on Āyurveda, but it is not shared by the Śāstrīs in the mainstream of philosophical disciplines in Sanskrit, as far as I know. As liberal about the astronomy of the mlecchas as Kamalākara appears to have been, I know of no work of his in the other śāstas in which he pursues the possibilities of comparison opened up by the acquaintance he might have formed with some features of Aristotelian cosmology, for example.

We are thus left without the possibility of a simple schematic account of Jyotiḥśāstra in the period. There is, rather, what looks like a complex double movement, in which Jyotiḥśāstra moves closer to the philosophical disciplines in Sanskrit, and at the same time further away from them.

CONCLUSION

As stated at the outset, this is not intended to be a comprehensive account of Jyotiṣ, but at this point only a working paper. I have barely mentioned astrology and divination, which have in this period their own complex set of developments. The preceding notes do indicate, I think, the possibility of how to approach the study of Jyotiḥśāstra in the early modern period, as part of the larger intellectual history of Sanskrit knowledge systems in that era.

There is a plausible dating at the beginning of the 16th century, when a group of movements in different parts of South Asia began to establish new methods and make new arguments.

For Jyotiṣ these newnesses include: 1) a philosophizing tendency, which attempts to incorporate Jyotiṣ into philosophical practice specifically in its epistemological grounding; 2) the use in some cases of logical argumentation of the philosophers' sort, self-consciously so, or else the appeal to textual authority in distinctively philosophical ways: either in content – references to Kumārila and Udayana, for example, or else in a Mimamsist mode of reading the Purāṇas; and 3) a new way of using observation as foundation for "improvement" of the astronomy, which involves of course a new idea of what it is in which improvement consists. Other forms of the appeal to experience are more natural developments of the philosophers' account of loka-prasiddhi or demonstration from common experience.

On the other hand, there are still the peculiarities of this discipline: in the last case we considered a seeking to accommodate with the Purāṇas in cosmological issues to a greater extent than classically had been done; then also the beginnings of engagement with Arabic/Persian knowledges, the mlecchamata or yavanamata, even if it did not culminate in a merging of traditions. This was a form of curiosity in which the astronomers were not followed by the other knowledge systems, so far as I know. Thus we are confronted with a complex grouping of movements in several directions, but all of them varieties of a new interest in establishing foundations for astronomy.

As for the self-consciousness about newness, of the sort described in the previous essays by Bronner and McCrae, this is a more difficult question. Certainly what the Pārthapurians, Nīlakaṇṭha, and especially Gaṇeśa are doing amount to new things, and the authors indicate in their arguments that they are aware that what they are proposing is something different. But would they call it new (navya) and value it as such, rather than as improvement, or reconciliation, or correction? The evidence so far does not support that claim for Jyotiṣ.

NOTES

[1] A version of this paper was presented as part of a panel on "Sanskrit Knowledge Systems on the Eve of Colonialism" at the Association for Asian Studies in Washington, D.C., in April '02.

[2] For discussion of this list of disciplines and terms, see the NEH proposal written by Sheldon Pollock, and posted on the Sanskrit Knowledge Systems Website at the following URL address: http://dsal.uchicago.edu/sanskrit/proposal.html. The last category of dharmaśāstra has the closest overlap, since the timing of dharmic performances is in the later period determined according to calendrical systems developed by the Jyotiṣīs.

[3] See especially his *Census of the Exact Sciences in Sanskrit* (henceforth CESS) published in five volumes by the American Philosophical Society in Philadelphia, 1970–1994. My thanks to David Pingree and to Kim Plofker for reading a draft of this paper, though they are not at fault for any errors made. As will become evident, I have relied throughout on Pingree's findings, though I have organized them into a form that responds to the questions of the group project. Some sections are based on the results of my own research.

[4] Randall Collins, *The Sociology of Philosophies* (Cambridge: Harvard University Press, 1998), 543–556; partial in two different ways.

[5] Collins, op. cit. 551.

[6] In fact Collins makes his judgments based on Pingree, "History of mathematical astronomy in India," *Dictionary of Scientific Biography* 15 (New York, 1978), 533–633.

[7] Johannes Bronkhorst has already remarked on this point, "Pāṇini and Euclid: Reflections on Indian Geometry," JIP 29.1–2 (April 2001): 64.

[8] David Pingree, *Jyotiḥśāstra: Astral and mathematical Literature* (Wiesbaden: Otto Harrassowitz, 1981), 10, 12, etc.

[9] See for example D. Pingree, "The Greek Influence on Early Islamic Mathematical Astronomy," JAOS 93 (1973): 32–43.

[10] For the rationale of the periodization, see the proposal at the website as listed above in note 2.

[11] CESS III 75–76; IV 100; V 122–123. For a family tree see *Jyotiḥśāstra* 124. Pārthapura probably lay in the region of the Ahmadnagar kingdom.

[12] Jñānarāja and his son(s) made a similar resumption of mathematical literature, which had received its authoritative formulation in Bhāskara's Līlāvatī, though in that case there had been another important mathematician a century and a half earlier (Nārāyaṇa Paṇḍita).

[13] CESS II pp. 94–107; III 27–28; IV 72–75; V 69–74. Pingree *Jyotiḥśāstra* 126. Gaṇeśa gives the credit for his innovation to his astronomer father, Keśava, the date of whose Grahakautuka (1496) is closely contemporary with Jñānarāja's work, but Gaṇeśa would appear to be the greater innovator. S. B. Dikshit, *History of Indian Astronomy*, Translated by R. V. Vaidya. 2 vols. (Delhi: Director General of Observatories, 1969) 2: 128–130.

[14] Grahalāghava – "The Planets Made Easy." On karaṇas see Pingree, *Jyotiḥśāstra* 13–14.

[15] One reason for this would be that the Grahalāghava, as its name might suggest, does away with the need for Siddhāntic treatises with their full geometric models and calculations reckoned from the distant beginning of long ages. For this reason the Grahalāghava has an alternative name, the Siddhāntarahasya. Dikshit, *History of Indian Astronomy* 130–139.

[16] His approach, which features a boldly approximative stance, is unique enough that Pingree identifies his system as a pakṣa or school of thought in its own right. "History of mathematical astronomy in India," 624–625. Plofker [personal communication] suggests that it is in a way a recapitulation of the Babylonian, non-geometric method of positional astronomy by mathematical/arithmetical functions alone. It is not an easy matter to reconstruct how Ganesa evolved his systems; see now K. Plofker and S. Ikeyama, "The Tithicintāmaṇi of Gaṇeśa, a medieval Indian treatise on astronomical tables," SCIAMVS 2 (2001), 251–289.

[17] Pingree, *Jyotiḥśāstra* 120.

[18] CESS II 65–74; III 24; IV 64–66; V 56–59.

[19] Pingree, *Jyotiḥśāstra* 49.

[20] Pingree devotes a separate section to their treatment in *Jyotiḥśāstra* 47–50.

[21] See Pingree, "Nīlakaṇṭha's Planetary Models," 29.1–2 (April 2001): 192–193. A reconfiguration of the arrangement of the deferent circles and the epicycles of each planet. For sun and moon the manda epicycle is made concentric about the earth, and the center of the deferent is made to move on the manda. For other planets the center of the manda circle is in turn placed on the śīghra epicycle, which is made concentric with the earth at center. Pingree argues that though significantly new, pace Ramasubramaniam, etc., this is not a quasi-Tychonian reformation.

[22] See Bronkhorst on this text and the math/philosophy divide, "Pāṇini and Euclid," 61–64.

[23] Pingree, "Nīlakaṇṭha's Planetary Models," 187.

[24] Tantravārttika on JMS I.3.2.

[25] Pingree, *Jyotiḥśāstra* 51. K.V. Sarma, ed. *Jyotirmīmāṃsā: Investigations on Astronomical Theories* (Hoshiarpur: VVRI, 1977), xi–xiii, xix–xx.

[26] *Jyotirmīmāṃsā*, xv, and 1–2. In fact the extant manuscripts do not preserve the text's beginning.

[27] Pingree, *Jyotiḥśāstra* 49–51.

[28] Note that Pingree's most recent history of Indian astronomy, "Astronomy," forthcoming in the volume of the Enciclopedia Italiana on the History of Indian Science, approaches the descriptive problem by making regional variation of the organizing principle for describing historical developments from approximately the 12th to the 18th Centuries: South India, Kerala, West and Central India, Rājasthān, Kāśī, etc.

[29] S.B. Dikshit, *History of Indian Astronomy*, 2: 134–137.

[30] S.B. Dikshit, *History of Indian Astronomy*, 2: 129–130.

[31] See S.R. Sarma, "Astronomical Instruments in Brahmagupta's Brahmasphuṭasiddhānta," *Indian Historical Review* 13 (1986–1987): 68–69; Pingree, "History of Mathematical Astronomy," 629–630.

[32] Pingree, "Bīja-corrections in Indian Astronomy" JHA 27 (1996), 161–172. Bīja-corrections had been in use for a long time. The authority of observation was sometimes invoked in earlier bīja texts as the basis for making the corrections. In fact most early bīja tables were designed to approximate all of the parameters of one astronomical pakṣa to the parameters of another. There is little evidence that observation played anything but a secondary role until the work of Keśava, who is also at variance with the older bīja-correction tradition in his eclectic choice of parameters.

[33] At about the same time as Keśava, another astronomer, perhaps named Rāma,

appears to have been working independently in the same fashion, combining observation with bīja-corrections to adjust existing parameters. It is further possible that, relying on observations, Rāma, and another astronomer Rāmacandra (fl. 1599) "may well have introduced entirely new corrections unconnected with other pakṣas as well." Pingree, "Bīja-corrections," 168–171.

[34] That of the Saurapakṣa. Pingree, "Nīlakaṇṭha's Planetary Models," 189, 191, also n. 10 on p. 194.

[35] See Pingree, "Islamic Astronomy in Sanskrit," 315–316. On the typical contents of an ilm al hay'a text, see for example F.J. Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy (al-Tadhkira fi 'ilm al-hay'a)* 2 vols. (Springer Verlag, 1993). On the use of observations in relation to theory, see especially Book Two, chapter 11.

[36] Pingree – personal communication. The astrolabe had been introduced into India from Arabic/Persian sources. Various Sanskrit texts about their construction and use date from the mid-14th Century onward.

[37] Tājikapaddhati, also called Varṣaphalapaddhati. On this form of astrology and its explicitly Arabic/Persian terminology, see Pingree, "Tājika: Persian Astrology in Sanskrit," in *From Astral Omens to Astrology; From Babylon to Bikaner* (Roma: Istituto Italiano per L'Africa e L'Oriente, 1997), 79–90.

[38] S.R. Sarma, "Indian Astronomical and Time-measuring instruments," IJHS 29(4) (1994): 515–516. Its first description in Sanskrit occurs in Rāmacandra's Yantraprakāśa of 1428. Gaṇeśa is the author of three texts on instruments – the Cābukayantra, Pratodayantra, and Sudhīrañjanayantra. CESS references given above in note 13. 'Cābuka' is a Persian word meaning whip, i.e. 'pratoda' in Sanskrit. Though he might have been influenced in his interest in the use of instruments and the taking of observational measurements, Ganeśa's astronomical mathematical method is not discernibly influenced by the contents of Arabic/Persian astronomy.

[39] CESS III pp. 75–76; IV pp. 100; V pp. 122–123.

[40] For a family tree see Pingree, *Jyotiḥśāstra* 124.

[41] Some of the examples and arguments of this section are drawn from a more detailed discussion that appears in a separate article, "Competing Cosmologies in Early Modern Indian Astronomy," forthcoming.

[42] Siddhāntasundara (henceforth SSJ), II.1.30.

[43] SSJ II.1.22.

[44] Grahagaṇitacintāmaṇi (henceforth GGC) on SSJ II.1.22 f. 13v 11. 2–6.

[45] GGC on SSJ II.1.22 f. 14r 11. 4–7.

[46] A pala is a unit of time, a 60th of a 60th of a day, or 24 seconds.

[47] $\frac{C}{10} = \frac{3600}{7\frac{1}{5}}$. $C = \frac{10\cdot 3600}{\frac{36}{5}} = 5000$ yojanas. GGC on SSJ II.1.26, f. 16r 11. 8–10.

CintāmaṇI acknowledges, again via his imaginary interlocutor, that there is no sapakṣa for this inference, which should invalidate it as a proof, but does not do so because the hetu pervades the sādhya in places other than the pakṣa, and so on.

[48] GGC on SSJ II.1.26, f. 16r 11.2–4.

[49] GGC on SSJ II.1.32 f. 22r 11 6–7; and GGC on SSJ II.1.37, f. 23v 11 8–10. In the first case the experiment is done with slab of rock and an areca nut.

[50] GGC on SSJ 31 f. 21r 11. 1–4. The argument is about the inference of the existence of air because of the many small things that are seen to be supported by it, since non-falling implies support. The passage cited is found on p. 58 of the Gaekwad oriental Series edition, in the commentary on Praśastapāda 54.

[51] GGC on SSJ 31 f. 21r 11. 10–11. This discussion is found in Kusumāñjali 5.4. My thanks to Phyllis Granoff for this reference.

[52] For the most complete list of his works, see Sarma, "Siddhānta-saṃhitā-sāra-samuccaya." See also Dikshit, *History of Indian Astronomy* 144–145; Dvivedi *Gaṇakataraṅginī* 65–67.

[53] There is a commentary on the SŚB attributed to him, which unfortunately was not available to me at the time of this writing. Sūryadāsa is a figure worthy of a great deal more study, especially for the particular nature of his polymathia, which combined the fields of kāvya and astronomy.

[54] A reference in the last chapter appears to indicate a date of composition in 1583. The text is as yet unpublished; a copy of one flawed manuscript was made available to me (courtesy of David Pingree) (Jaipur Khasmohor 5026). My synopsis in the following is provisional, pending the creation of a proper edition.

[55] Pingree has written several articles outlining the history of the awareness of the Muslim astronomy among the Sanskrit jyotiṣīs, ("Islamic Astronomy in Sanskrit," *Journal for the History of Arabic Science* 2 (1978): 315–330; and "Indian Reception of Muslim Versions of Ptolemaic Astronomy," in eds. F.J. and S.P. Ragep, *Tradition, Transmission, Transformation* (Leiden: 1996), 471–485), but did not describe this chapter by Sūrya. I plan to provide a more detailed description of the chapter in a forthcoming study.

[56] Pingree "Islamic Astronomy in Sanskrit," 318.

[57] Pingree "Tājika: Persian Astrology in Sanskrit," note 37.

[58] Pingree, "Indian Reception of Muslim Versions of Ptolemaic Astronomy," 474–475.

[59] The Risalah Dar Hay'ah of 'Alī al-Qūshjī, composed ca. 1460. Pingree, "Islamic Astronomy in Sanskrit," 327–328; "Indian Reception of Muslim Versions of Ptolemaic Astronomy," 475–476. The Sanskrit translation was published as *Hayata*, ed. Vibhūtibhūṣan Bhaṭṭācārya, Sarasvatibhavana Granthamālā 96 (Vārāṇasī: 1967).

[60] Pingree, "The Sarvasiddhāntarāja of Nityānanda," forthcoming. Also "Islamic Astronomy in Sanskrit," pp. 323–326, and "Indian Reception of Muslim Versions of Ptolemaic Astronomy," 476–480.

[61] Pingree, "Amṛtalaharī of Nityānanda," SCIAMVS 1 (2000), 209–217.

[62] This debate has been described by Pingree in "Islamic Astronomy in Sanskrit," 320–323.

[63] See most recently D. Pingree, "An Astronomer's Progress," *Proceedings of the American Philosophical Society* 143 (1999), pp. 73–85. Subsequent encounters with European, Copernican astronomy are described in Richard F. Young, "Receding from Antiquity: Indian Responses to Science and Christianity on the Margins of Empire," Kokusaigaku-Kenkyu 16 (Meiji Gakuin Ronso 595), 1997 pp. 241–274; C. Minkowski, "The Paṇḍit as Public Intellectual: The Controversy over virodha or Inconsistency in the Astronomical Sciences," in ed. Axel Michaels, *The Pandit: Traditional Sanskrit Scholarship in India (Festschrift P. Aithal*). Heidelberg South Asian Studies XXXIX (New Delhi: Manohar Publications, 2001), pp. 83–102; Kim Plofker, "Derivation and revelation: the legitimacy of mathematical models in Indian cosmology," in ed. Teun Koetsier, *Mathematics and the Divine* (Amsterdam: forthcoming); and Michael Dodson, "Re-Presented for the Pandits: James Ballantyne, 'Useful Knowledge,' and Sanskrit Scholarship in Benares College during the Mid-Nineteenth Century," *Modern Asian Studies* 36.2 (2002): 257–298.

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