SCIAMVS 1 (2000), 209–217

Amṛtalaharī of Nityānanda

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Dedicated to my students who made it possible for me to study this manuscript in Tokyo.

One of the first siddhāntic astronomers in India to attempt to present Islamic astronomy in Sanskrit during the Mughal period was Nityānanda, the son of Devadatta and a resident of Indrapurī or Delhi.[1] He was employed by Āsaf Khān, the wazīr of Shāh Jahān, to translate into Sanskrit the gigantic *Zīj-i Shāh Jahānī* that had been compiled in Persian by Farīd al-Dīn Mas'ūd ibn Ibrāhīm al-Dihlawī and presented to the Emperor in October of 1629.[2]

Nityānanda entitled his translation the *Siddhāntasindhu*; it is a vast collection of elaborate tables filling, in complete copies, nearly 450 folia of enormous size. Though extremely difficult to use, it was popular with Jayasiṃha, the founder of Jayapura and the builder of observatories who carried forward Nityānanda's efforts to promote Muslim astronomy in Sanskrit in the 1720's and 1730's.[3] Jayasiṃha owned four of the five surviving complete copies, one of which bears the seal of Shāh Jahān himself.[4] But, not surprisingly, no other siddhāntic astronomer seems to have been impressed by Nityānanda's heroic effort.

It may have been the less than enthusiastic reception accorded to the *Siddhāntasindhu* that induced Nityānanda to publish, in 1639, his slightly less gigantic *Sarvasiddhāntarāja*, in which he presented various arguments intended to persuade dedicated followers of the *Sūryasiddhānta* and of Brahmagupta's *Brāhmasphuṭasiddhānta* that the models, parameters, and observational techniques of the Muslims were worth emulating.[5] One argument that he used was the somewhat fraudulent claim

[1]Concerning Nityānanda see D. Pingree, *Census of the Exact Sciences in Sanskrit*, 5 vols., Philadelphia 1970–1994, A3, 173b–174a; A4, 141a–141b; and A5, 184a.

[2]On Farīd al-Dīn see the article by D. Pingree which is to appear in the *Encyclopedia Iranica*.

[3]See D. Pingree, "An Astronomer's Progress," *Proceedings of the American Philosophical Society* 143, 1999, 73–85.

[4]Manuscripts 266 to 269 in the forthcoming *Catalogue of the Astronomical Manuscripts in Sanskrit Preserved in the Palace Library, Jaipur*, by D. Pingree et al.; manuscript 266 bears the seal of Shāh Jahān.

[5]See D. Pingree, "Indian Reception of Muslim Versions of Ptolemaic Astronomy," in *Tradition, Transmission, Transformation*, ed. F. J. and S. P. Ragep, Leiden 1996, pp. 471–485, esp. 476–480.

that the results of computing planetary positions in accordance with the methods of Indian siddhāntas are not radically different from those arrived at by computing with Ulgh Beg's adaptations of Ptolemaic models.[6]

It was, then, with considerable delight that I observed on examining a manuscript — Sanskrit 19 — in the collections of the University of Tokyo the remains of the last three pādas of a verse preserved on the badly torn top of the verso of the first folium:

> yā paṃḍitair iṃdrapurī virājate |
> śrīdevadattasya suto dvijānugas
> tasyāṃ vasan kheṭakṛtiṃ vikīrṣati ||1||

For a son of Devadatta residing in Indrapurī and writing on astronomy could only be Nityānanda.

The manuscript, which I describe more fully in the appendix, consists of 51 folia written in Nepālī script. It is undated, but was brought to Tokyo from Nepal by Professor Junjirō Takakusu in 1913. It seems to be complete, though one might have expected more of an explanation of the meanings of the tables than the brief headings and notes provide, especially in view of the extraordinary novelties that the astronomical tables of which it chiefly consists contain. And, though in the verse cited above Nityānanda entitles this work *Kheṭakṛti*, in the torn left margin of the verse of the first folium another scribe has written <*A*>*mṛtalaharī* (the initial *a* is lost in the tear). Though there is no proof that Nityānanda used this title (it might have appeared at the top of this folium in the section that contained the first part of the verse and that is now torn off), I retain it since it was used in the catalogue of the Sanskrit manuscripts in the Library of the University of Tokyo.[7]

The tables provide material for computing the purely Indian calendrical elements basic to pañcāṅgas — tithis, nakṣatras, and yogas — as well as the right and oblique ascensions of the zodiacal signs and the longitudes of the Sun, the Moon, and the five star-planets. At several places the brief notes mention the *Sūryasiddhānta*,[8] and at one the *Makaranda*, a set of astronomical tables belonging to the Saurapakṣa that was composed by Makaranda in 1478.[9] Indeed, the tables of the equations of the planets use the parameters of the *Sūryasiddhānta*, while the mean motion tables are

[6]See D. Pingree, "The *Sarvasiddhāntarāja* of Nityānanda", to appear in the proceedings of the conference on *New Perspectives on Science in Medieval Islam* held at the Dibner Institute at MIT in November 1998.

[7]See S. Matsunami, *A Catalogue of the Sanskrit Manuscripts in the Tokyo University Library*, Tokyo 1965, pp. 8–9.

[8]E.g., on f. 51: atha bhaumādīnāṃ sūryasiddhāṃtoktaśīghrakendre ...

[9]On f. 2: tadā makarāṃdagraṃthasya tithighaṭipalāni samā syuḥ.

based on the *Sūryasiddhānta*'s sidereal parameters truncated so drastically as to be indistinguishable from tropical parameters even though the tabulated longitudes are intended to be sidereal; clearly these tabulated mean motions slowly diverge from true sidereal mean longitudes. The calendar employed in the mean motion tables, however, is not Indian; it is Nityānanda's own surprising invention.

Before discussing the calendar, however, let us first glean some information about the text from its other tables. The epoch of the tithi tables is the year 1669 of an unspecified era, and the cycle for tithis is 43 years. But the epoch of both the nakṣatra tables with a cycle of 38 years and the yoga tables with a cycle of 47 years is 1583. Since 1583 is just 86 years (two cycles of 43 years) before 1669, the latter year marks the beginning of the third cycle of tithis, and the original common epoch of all three tables was 1583 in an as yet unidentified era.

Each of these three sets of tables includes corrections for the terrestrial latitudes of their users. These latitudes, as is normal in Indian astronomy, are expressed by the lengths in digits of the shadows cast by a twelve-digit gnomon at noon of a day on which the Sun is at the equator.[10] Thus we are given corrections related to the lengths of the noon equinoctial shadows associated with Kāśī, Kurukṣetra, Kāśmīra, Kābula, Burahānapura, and Ahammadābāda. All of these cities were under Mughal control during Shāh Jahān's reign, when Nityānanda is known to have been active. Their noon equinoctial shadows, according to him, range between 4 1/2 and 8 1/2 digits. After the tables of planetary equations in the *Amṛtalaharī* are tables of the oblique ascensions at places whose latitudes are indicated by noon equinoctial shadows whose lengths have differences of half a digit and which lie between the same extrema. These are clearly modelled on the tables of oblique ascensions for the seven climata familiar in Greek and Islamic astronomy. In India such tables were included in the *Kheṭataraṅgiṇī* of Goparāja, whose epoch is 1608.

The epoch of all the mean motion tables is not 1583, but 1592, again with no era specified. A possible reason for this shift in epochs becomes apparent only after one investigates the calendar that Nityānanda uses. Though he gives the lunar months Sanskrit names — Caitra, Vaiśākha, Jyaiṣṭha, and so on — and though the parameters remain those of the *Sūryasiddhānta*, in truncated form, his is not a normal Indian calendar. Rather it is based on a luni-solar cycle equivalent to three Metonic cycles or 57 solar years. The apparent Western influence is further manifested in the fact that years of twelve synodic months may be 353, 354, or 355 days long, those of thirteen synodic months 383, 384, or 385 days long; these are precisely the six possibilities for year-lengths in the Jewish calendar. Such elements of the Jewish calendar were explained in many Muslim zījes, and evidently answered Nityānanda's desire to construct a new luni-solar calendar more regular than that in common use

[10]See D. Pingree, "Sanskrit Geographical Tables," *Indian Journal of History of Science* 31, 1996, 173–220.

in Indian pañcāṅgas. Moreover, the intercalary months, simply called adhimāsas, unlike the normal Indian usage, occur only after Phālguna, whereas in Indian astronomy their location depends on the occurrence of two successive conjunctions of the Sun and the Moon within the same zodiacal sign. Since Nityānanda's Caitra corresponds to the Jewish month Nīsān in that the vernal equinox occurs in it, his Phālguna corresponds to Adhār, which is the month to be intercalated also in the Jewish calendar. The intercalations occur in years 1, 4, 6 (7 in the second and third Metonic cycles of a 57-year period), 9, 12, 15, and 17; if we move the years ahead by two we get the normal Jewish pattern of intercalation: 3, 6, 8, 11, 14, 17, and 19.

The total number of days in a cycle of 57 years is 20,819, which is identical with the normal number of days in three Metonic cycles according to the Jewish calendar. This means that a solar year contains a little less than 365 1/4 days — i.e., it is a tropical year. But the Indian solar year is sidereal and contains a bit more than 365 1/4 days — in the *Sūryasiddhānta*, to be precise, a year contains 6,5;15,31,31,24 days. Therefore, 57 years according to the *Sūryasiddhānta* contain about two thirds of a day beyond 20,819; but, according to Nityānanda's tables, the mean motion of the Sun for 57 years is precisely for 20,819 integer days, and the difference seems never to have been made up.

Moreover, the solar mean motion in every odd month beginning with the first, which is Caitra, and including the adhimāsa is 29;34,5°, and that in every even month is 28;34,57°. These mean motions correspond precisely to months alternately of 30 and of 29 integer days if the mean daily motion of the Sun is 0;59,8,10°; this value is truncated from the *Sūryasiddhānta*'s 0;59,8,10,10,24,12,—° per day. And Nityānanda's choice of alternating 30 and 29 day months, whose use is confirmed by his lunar tables, seems to be based on the practice of the Muslim astronomical calendar, in which also the odd months are 30 days long, the even ones 29. But the intercalary day is added by the Muslims to the twelfth month, Dhū al-ḥijja, which then becomes 30 days long, while Nityānanda adds it to the year as a whole.

We can now turn to the question of the era in which the year-numbers 1583 and 1592 are given. In order to determine the answer to this question I use the mean longitudes of the Sun, the Moon, the Moon's ascending node (Rāhu), Mars, Mercury's anomaly, Jupiter, Venus' anomaly, and Saturn given in the tables for the year 1592 since these form a datable horoscope. Surprisingly, the date indicated by that horoscope is midnight of 20/21 February Julian in A.D. 1593, which is the day of the mean conjunction of Phālguna in Vikrama Saṃvat 1649.

Planets	*Amṛtalaharī* Sidereal	Computed Tropical	Differences
Saturn	88;12,53°	110°	−22°
Jupiter	290; 7, 0°	285°	+5°
Mars	235;49,35°	272°	−36°
Sun	330;30,16°	343°	−12°
Venus's anomaly	50;31,51°	18°	
Mercury's anomaly	348;33,24°	317°	
Moon	322;22,56°	345°	−23°
Rāhu	98;34,52°	74°	+25°

It is immediately apparent that 1592 and the other years mentioned by Nityānanda are lapsed years of the Christian era, but these years numbered as lapsed Christian years begin with the mean conjunctions that precede the vernal equinox.

Further evidence of the correctness of this date is provided by the number 4 written below the mean solar longitude for "1592" in the table. This refers to Wednesday, the weekday on which 21 February Julian fell in 1593. The choice of this year as the epoch of the *Amṛtalaharī* must have been dictated by the fact that its composition lay within the 57-year period beginning in that year and ending in 1649/50; this agrees well with Nityānanda's known dates in the 1630's. Further, the choice of a cycle of 57 years was probably influenced by the fact that it is the number of years between the epochs of the Vikrama and Christian eras, though 1593 is not an integer multiple of 57; the choice of 1593 depends on its position at the beginning of a carefully regulated cycle.

A few other observations may be made with regard to the *Amṛtalaharī*'s lunar and planetary tables. Normally Indian astronomical tables give the mean motions of the lunar apogee and of the śīghras of the two inferior planets; following Ptolemy and the Muslim tradition Nityānanda tabulates the mean motions of the anomalies of the Moon, Venus, and Mercury.

And, while his tables of the equations of the planets are computed with the parameters of the *Sūryasidddhānta* and so ignore the second and third equations of the Moon and the effect of the equant on planetary longitudes which are characteristic of Ptolemaic astronomy, following many medieval Muslim precedents these equation tables are normed so that all the equations are positive.

The *Amṛtalaharī*, therefore, is a bold but flawed experiment in melding together Indian, Jewish, Islamic, and Christian calendaric and astronomical elements. It remains unclear why Nityānanda wrote it; indeed, it is indeed astonishing that even one copy of this unusual attempt to reform siddhāntic astronomy has survived. It is a curiosity, but perhaps it played some role in history by suggesting to Jayasiṃha's astronomers how they might express de La Hire's Latin tables, which use the Julian and Gregorian calendars, in the form of an adjusted Indian calendar.

Appendix: Description of the tables of the *Amṛtalaharī*

These tables fall into six general groups.

I. Tithi, nakṣatra, and yoga tables. Ff. 1v–18.

A. Tithis. Ff. 1v–6v.

For years 1669, 1712, 1755, 1798, 1841, and 1884; and 1 to 42. F. 1v.
For months 1 to 13 with two columns each for Kāśī, Kurukṣetra, Kāśmīra, Burahānapura, and Ahammādāvā. F. 2.
Tables for days 0, 28, 56, 84, 112, 140, 168, 196, 224, 252, 280, 308, 336, and 364 at Kāśī (palabhā 5|45), at Kurukṣetra (palabhā 7|0), at Kāśmīra and Kāvula (palabhā 8|30), and at Burahānapura and Ahammadāvāta (palabhā 4|30). F. 2v.
Table of corrections to tithis for 0 to 28 horizontal and 0, 12, 24, 36, and 48 vertical. Ff. 3–3v.
Tables of corrections to tithis for 0 to 28 horizontal and 0 to 59 vertical. Ff. 3v–6v.

B. Nakṣatras. Ff. 7–11v.

For years 1583, 1622, 1661, 1700, 1739, and 1778; and 1 to 38. F. 7.
Tables for days 0, 27, 55, 82, 109, 136, 163, 191, 218, 245, 272, 300, 327, and 354 at localities whose palabhās are 5|45; 7|0; 8|30; and 4|30. F. 7v.
Tables of corrections to nakṣatras for 0 to 27 horizontal and 0 to 59 vertical. Ff. 8–11v.

C. Yogas. Ff. 11v–17v.

For years 1583, 1620, 1677, 1724, and 1771. F. 11v.
For years 1 to 46. Ff. 11v–12.
Tables for days 0, 29, 58, 87, 117, 146, 175, 204, 234, 263, 292, 322, 351, and 380 at Kāśī; at Kurukṣetra (palabhā 7|0); at Kāśmīra and Kāvula; and at Burahānapura and Ahammadāvāda (palabhā 4|30). Ff. 12–12v.
Table of corrections to yogas for 0 to 29 horizontal and 0, 12, 24, 36, and 48 vertical. Ff. 12v–13.
Table of corrections to yogas for 0 to 29 horizontal and 0 to 59 vertical. Ff. 13v–16 and 17 (f. 16v blank).
Yogacakra for 1 to 13 years and for years 1612, 1642, 1672, 1702, 1732, and 1762. F. 17v.

II. Saṅkrāntis. Ff. 17v–18.

Table of abdapas (truncated to two sexagesimal places) for 1 to 30 years. The yearly parameter is 1;15,31,31,17. This is the parameter of the Brāhmapakṣa. F. 17v.
The weekday of the Sun's entry into each of the 27 nakṣatras at Kāśī. F. 17v.
The weekday of the Sun's entry into each of the 12 zodiacal signs. F. 18.
A correction for each of the 24 half zodiacal signs. F. 18.

III. Mean motions. Ff. 18v–27.

A. The Sun. Ff. 18v–19.

For years 1592, 1649, 1706, and 1763; and 1 to 56. F. 18v.
For each of the 13 months. F. 18v.
For 353, 354, 355, 383, 384, and 385 dyas. F. 18v.
For 1 to 32 days. F. 19.
For 1 to 60 ghaṭikās. F. 19

B. The Moon. Ff. 19v–20.

For years 1592, 1649, 1706, and 1763; and 1 to 56. F. 19v.
For each of the 13 months. F. 19v.
For 384, 385, 354, and 355 days. F. 19v.
For 1 to 30 days. F. 20.
For 1 to 60 ghaṭikās. F. 20

The remaining planetary mean motion tables are set up in the same way, except that the third item, for 6 or 4 different year lengths, is omitted for each.

C. Lunar anomaly. Ff. 20v–21.
D. Lunar node. Ff. 21v–22.
E. Mars. Ff. 22v–23.
F. Mercury's anomaly. Ff. 23v–24.
G. Jupiter. Ff. 24v–25.
H. Venus's anomaly. Ff. 25v–26.
I. Saturn. Ff. 26v–27.

IV. Planetary equations. Ff. 27v–44.

For the Sun and the Moon there are just manda equations; for the other five planets three equations each: 1. śīghra (positive to mean longitude); 2. manda (negative to anomaly); and 3. śīghra (positive to mandasphuṭa, which is the mean longitude increased by the manda equation).

A. Sun's manda (5;27,32° at 11^s 14°, 1;6,28° at 5^s14°. The maximum equation is half of the difference: 2;10,32°). Ff. 27v–28.

B. Moon's manda (11;2,48° at 3^s 0°, 0;57,12° at 9^s0°. The maximum equation is half of the difference: 5;2,48°). Ff. 28v–29.

C. Mars. Ff. 29v–32.

1. First śīghra (0^s20;5° at 6^s2°–6°, 11^s9;49° at 9^s16°–14°. The maximum equation is the difference: 40;16°). Ff. 29v–30.
2. Manda (23;32° at 11^s9°–14°, 0;28° at 5^s20°–25°. The maximum equation is half of the difference: 11;32°). Ff. 30v–31.
3. Second śīghra (2^s21;16° at 5^s21°–23°, 0^s0;44° at 8^s29°–9^s1°. The maximum equation is half of the difference: 40;16°). Ff. 31v–32.

D. Mercury. Ff. 32v–35.

1. First śīghra (0^s10;18° at 4^s16°–20°, 11^s18;46° at 9^s4°–8°. The maximum equation is the difference: 21;32°). Ff. 32v–33.
2. Manda (9;28° at 3^s10°–11°, 0;32° at 9^s15°–16°. The maximum equation is half of the difference: 4;28°). Ff. 33v–34.
3. Second śīghra (1^s13;31° at 4^s11°–15°, 0^s0;29° at 8^s29°–9^s3°. The maximum equation is half of the difference: 21;32°). Ff. 34v–35.

E. Jupiter. Ff. 35v–38.

1. First śīghra (0^s5;25° at 3^s28°–4^s0°, 11^s23;53° at 9^s6°–8°. The maximum equation is the difference: 11;32°). Ff. 35v–36.
2. Manda (11;6° at 1^s28°–2^s2°, 0;54° at 8^s4°–7°. The maximum equation is half of the difference: 5;6°). Ff. 36v–37.
3. Second śīghra (0^s23;31° at 3^s21°–23°, 0;29° at 9^s0°–2°. The maximum equation is half of the difference: 11;32°). Ff. 37v–38.

F. Venus. Ff. 38v–41.

1. First śīghra (0^s22;20° at 6^s4°-8°, 11^s5;56° at 9^s0°-4°. The maximum equation is the difference: 46;24°). Ff. 38v–39.
2. Manda (3;45° at 9^s20°–10^s5°, 0;15° at 3^s25°–4^s8°. The maximum equation is half of the difference: 1;45°). Ff. 39v–40.

3. Second śīghra ($3^s3;24°$ at $6^s3°–5°$, $0^s0;36°$ at $8^s29°–9^s1°$. The maximum equation is half of the difference: 46;24°). Ff. 40v–41.

G. Saturn. Ff. 41v–44.

1. First śīghra ($0^s2;33°$ at $3^s17°$-26^s, $11^s26;11°$ at $9^s4°$-$13°$. The maximum equation is the difference: 6;22°). Ff. 41v–42.
2. Manda (15;40° at $4^s6°–9°$, 0;20° at $10^s12°–17°$. The maximum equation is half of the difference: 7;40°). Ff. 42v–43.
3. Second śīghra ($0^s13;22°$ at $3^s11°–16°$, $0^s0;38°$ at $8^s28°$-$9^s3°$. The maximum equation is half of the difference: 6;22°). Ff. 43v–44.

V. Rising-times of the zodiacal signs. Ff. 44v–49.

A. Right ascension of each degree, beginning from Capricorn 0° and giving the cusps of midheaven as in the Greek and Islamic traditions. Akṣabhā = 0. F. 44v.
B. Oblique ascension of each degree. Akṣabhā = 4;30. F. 45.
C. Oblique ascension of each degree. Akṣabhā = 5;0. F. 45v.
D. Oblique ascension of each degree. Akṣabhā = 5;30. F. 46.
E. Oblique ascension of each degree. Akṣabhā = 6;0. F. 46v.
F. Oblique ascension of each degree. Akṣabhā = 6;30. F. 47.
G. Oblique ascension of each degree. Akṣabhā = 7;0. F. 47v.
H. Oblique ascension of each degree. Akṣabhā = 7;30. F. 48.
I. Oblique ascension of each degree. Akṣabhā = 8;0. F. 48v.
J. Oblique ascension of each degree. Akṣabhā = 8;30. F. 49.

VI. Other tables. Ff. 49v–51.

A. Table of Sines ($R = 60$); declinations ($\epsilon = 24°$); shadows of 60-digit, 12-digit, and 7-digit gnomons; and lunar latitude ($\beta = 4;30°$) for 1° to 90° of argument. Ff. 49v–50v.
B. Tables of adjustments for the five star-planets. F. 51.

(Received: August 3, 1999)