The *Pañcasiddhāntikā* of Varāhamihira (1) *

The *Pañcasiddhāntikā* of Varāhamihira is one of the most important sources for the history of Hindu astronomy before the time of Āryabhaṭa I (b. 476 AD). Two editions of this work (both furnished with English translation and commentary) have appeared, one in 1889 under the editorship of G. Thibaut and S. Dvivedi, and the other in two parts in 1970 and 1971 under the editorship of O. Neugebauer and D. Pingree. But even now the contents of the work are at places not correctly understood. The object of the proposed series of papers is to deal with certain passages of the work which have not been properly understood so far. In the present paper, which is the first of the series, I propose to deal with four topics, viz. (i) criticism of Viṣṇucandra and Romaka by Pauliśa, (ii) the declination table of Varāhamihira, (iii) the fifth correction for Mercury and Venus in the old *Sūryasiddhānta*, and (iv) a traditional correction of the Pauliśa school for the longitude of the Moon's ascending node.

1 Viṣṇucandra and Romaka criticised by Pauliśa

The following seven verses (**ed.** see Table 1) occurring in the end of the third chapter of the *Pañcasiddhāntikā*, which contains the teachings of the *Pauliśa-siddhānta*, were not clear to G. Thibaut and S. Dvivedi and so these verses were left uninterpreted by them in their edition of the *Pañcasiddhāntikā*.

D. Pingree, whose edition of the *Pañcasiddhāntikā* appeared in 1970, has translated the above verses as follows:

> 32. If the beginning (*pratipatti*) occurs when there is separation of *tithi* and *nakṣatra*, then it is good. But it is not so in a *bhadrā tithi* and Viṣṇu's *nakṣatra* (Śravaṇa): for thus does the world disappear.
>
> 33. There is not simultaneously everywhere a rising of the Sun or its setting. In what place is its setting? From that basis they know what has passed of the day.

* K. S. Shukla, *Indian Journal of History of Science*, Vol. 9, No. 1 (1974), pp. 62–76. (Updated version of the paper originally published in *Gaṇita*, Vol. 24, No. 1 (June 1973), pp. 59–73. This paper was read at the seminar organised by the Indian National Science Academy, New Delhi, on the occasion of the 500th Birth Anniversary of Nicolaus Copernicus on February 19–20, 1973.)

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Table 1

Manuscript Text	Emended Text
तिथिनक्षत्रच्छेदा- प्रतिपत्तिर्यदि तथा ततः साधुः । न तथा च भद्रविष्णो- स्तथा विनिवर्तते लोकः ॥३२॥	तिथिनक्षत्रच्छेद- प्रतिपत्तिर्यदि तथा ततः साधुः । न तथा च भद्रविष्णो- स्तथापि विनिवर्तते लोकः ॥३२॥
न युगपदुदयो भानु- रस्तमयो वापि भवति सर्वत्र । कस्मिन् देशेस्तमये पादादित्ये न भक्तिमिंदुः ॥३३॥	न युगपदुदयो भानो- रस्तमयो वापि भवति सर्वत्र । कस्मिन् देशेऽस्तमयः पादाद्दिनेन भुक्तं विदुः ॥३३॥[1]
मार्गादुपेतमेतत् काले लघुता न तावदतिदूरे । षविषयभूताष्टरसै- रब्दैः पश्यास्य विनिपातम् ॥३४॥	मार्गादुपेतमेतत् काले लघुता न तावदतिदूरे । खविषयभूताष्टरसै- रब्दैः पश्यास्य विनिपातम् ॥३४॥
रोमकमहर्गणं पा- दमर्कमिंदुं च गणयतां तां ग्राह्य । चैत्रस्य पौर्णमास्यां नवमी नक्षत्रमादित्यम् ॥३५॥	रोमकहर्गणं पा- दमर्कमिंदुं च गणयतां ग्राह्य । चैत्रस्य पौर्णमास्यां नवमी नक्षत्रमादित्यम् ॥३५॥
कालापेक्षा विधय- श्रौताः स्मार्ताश्च तदपचारेण । प्रायश्चित्ती भवति द्विजो यतोतोधिगम्येदम् ॥३६॥	कालापेक्षा विधयः श्रौताः स्मार्ताश्च तदपचारेण । प्रायश्चित्ती भवति द्विजो यतोऽतोऽधिगम्येदम् ॥३६॥
कुकरणविदो द्विजो ये कथयंत्यस्फुट सत्यं ... । कुकरणकारसहि- ते क्षणं नरके कृतवासाः ॥३७॥	कुकरणविदो द्विजो ये कथयन्त्यस्फुट(म)सत्यं (च गणितम्) । कुकरणकारसहि(ताश्च) ते क्षणं नरके कृतवासाः ॥३७॥[1]
स्फुटगणितविदिह लब्ध्वा धर्मार्थयशांसि दिनकरादीनां ॥३८॥	स्फुटगणितविदिह लब्ध्वा धर्मार्थयशांसि दिनकरादीनाम् ॥३८॥

[1] Emended by D. Pingree

34. This is arrived at from a method; there is no quickness in so very long a time. Look at its (the world's) destruction in 68550 years.
35. Taking the Romaka *ahargaṇa* as the basis, let one calculate (the longitudes of) the Sun and the Moon on the full moon (*tithi*) of Caitra; on the ninth (*tithi*) the *nakṣatra* is Āditya (Punarvasu).
36. The *śrauta* and *smārta* regulations depend on time; because a twice-born through offending them is a *prāyaścittī* (i.e., he has to perform propitiatory rites), therefore he studies this (i.e., time).
37. Whatever twice-born men, knowing a bad *karaṇa*, say that (astronomical) calculations are inaccurate and false, they, together with the makers of bad *karaṇas*, instantly make their homes in hell.
38. (But) one who knows accurate calculations of the Sun, and so on, obtains *dharma*, wealth, and praise in this world.

O. Neugebauer and D. Pingree have supplemented the above translation by the following commentary:

> These verses are evidently based on some obscure speculation in *Romakasiddhānta* about the duration of creation.
>
> The separation of *tithi* and *nakṣatra* presumably means that at the first *tithi* of the month the Moon is not in the first *nakṣatra*, Aśvinī; this separation is supposed to be an auspicious *muhūrta* for the *pratipatti*, i.e. the beginning of any action (or the beginning of creation?). However, if on a *bhadrā tithi* (the 2nd, 7th, or 12th in any *pakṣa*) the Moon is in Śravaṇa (Sagittarius 10° to 23° 20′), the *muhūrta* is inauspicious. The inauspiciousness arises from the fact that the creation ceases at such a *yuga*, i.e. when the conjunction of the Sun and Moon (the first *tithi*) occurs in Uttarāṣāḍha, i.e. at the winter solstice. This is reminiscent of Hellenistic speculations regarding a "world-year".
>
> The 68550 years in verse 34 is derived from the *Romakasiddhānta*; it is equal to $24 \times 19 \times 150 + 150$, where $19 \times 150 = 2850$ years is the Romaka's *yuga* (*cf.* ch. 1, vs. 15). The significance of this computation is obscure.
>
> The meaning of verse 35 also defies comprehension. Dikshit has indeed demonstrated that, by the elements of Varāhamihira's *Sūryasiddhānta*, the Caitra whose *pratipad* is used as epoch in this

karaṇa is *pūrṇimānta*; but there is no reason to compute the longitudes of the Sun and Moon for the *pūrṇima* of that month. Moreover, at *Caitrapūrṇimā* the Moon must be close to Libra 0° so that the Moon on the ninth *tithi* is far from Punarvasu (Gemini 20° to Cancer 3°20′). The reference to Punarvasu rather suggests an ecpyrosis at the summer solstice as we had a cataclysm at the winter solstice (vs. 32), but the text as it stands does not allow us to arrive at this interpretation.

The above translation and commentary clearly shows that Neugebauer and Pingree have not understood the real import of the text and are guided by conjectures only. They are indeed off the track. The verses in question, in fact, constitute a criticism of Viṣṇucandra and Romaka whose *tithis* and *nakṣatra*s were showing a wide divergence from the actual ones. The following modified translation would make the contents quite clear:

32. If the end (*cheda*) or commencement (*pratipatti*) of *tithi* and *nakṣatra* is as it should be, then it is good. But that of Śrī Viṣṇu(candra)[1] is not so; even then people (instead of discarding him) revert to him.

33. There is not simultaneously everywhere (on the same meridian) a rising of the Sun or its setting. In what meridian (lit. place) is its setting? From that basis they say what has passed of the day.[2]

34. From the tradition (of the *śāstras*) it is learnt that there is no decrease in time even after a lapse of enormous time. (But) look at its (the world's) destruction in 68550 years (advocated by Romaka).

35. For those who calculate (the longitudes of) the Sun and Moon on the full moon day of Caitra, taking the Romaka *ahargaṇa* as the basis, it is the ninth (*tithi*) and the Punarvasu *nakṣatra* (and not the full moon *tithi* and the Citrā *nakṣatra* as it should be).

36. The *śrauta* and *smārta* regulations depend on time; because a twice-born through offending them is a *prāyaścittī* (i.e. he has to perform propitiatory rites), therefore he studies this (time-ascertaining science of astronomy).

37. Those twice-born who, having studied bad *karaṇas*, declare inaccurate and false calculations, they, together with the authors of bad *karaṇas*, instantly make their homes in hell.

[1] Bhadraviṣṇu = Bhadra (=Śrī) + Viṣṇu (=Viṣṇucandra).

[2] This is a criticism of the rule which seeks to tell the time of a place on one meridian from the time of a place on another meridian by using the difference of longitudes of the two places only. In fact, correction due to difference in latitudes of the two places has also to be made.

38. (But) one who knows accurate calculations of the Sun, etc., obtains *dharma*, wealth, and praise in the world.

This translation is self-explanatory and on the basis of it one can easily draw the following conclusions:

1. In the time of Pauliśa, Viṣṇucandra's edition of the *Vasiṣṭhasiddhānta* was not yielding correct *tithis* and *nakṣatras*. But Viṣṇucandra was a popular astronomer and had a great following.

2. Calculations based on the *Romakasiddhānta* were showing an error of six *tithis* and seven *nakṣatras*.

3. Pauliśa, like Āryabhaṭa I, believed that time had no beginning or end, but Romaka held the contrary view.

Criticism of Viṣṇucandra and Romaka in the *Pauliśasiddhānta* further shows that *Pauliśasiddhānta* was written subsequent to the *siddhāntas* of Viṣṇucandra and Romaka. The statement of Varāhamihira, viz.

रोमकसिद्धान्तेऽयं नातिचिरे पौलिशेऽप्येवम्।

in ch. 1, vs. 10 is thus significant and should be understood to mean:

> This is according to the *Romakasiddhānta*; so it is also according to the *Pauliśasiddhānta* which is not much old.

This is the natural and straightforward meaning of the above hemistich.

Occurrence of criticism of Viṣṇucandra, Romaka, Vijayanandī and Pradyumna in the writing of a person like Varāhamihira shows that Brahmagupta's critical remarks against them are not totally baseless and unjustified. Sarcastic remarks against the Romakas are also found in the writings of Bhāskara I who was a contemporary of Brahmagupta. It is significant that Pauliśa has not been criticised by Brahmagupta or others.

2 The declination table of Varāhamihira

We now turn to verses 16–18(i) of ch. IV of the *Pañcasiddhāntikā*. Thibaut and Dvivedi were unable to interpret these verses and the credit of interpreting them for the first time is again due to D. Pingree. Pingree supposed that these verses contained the declination-differences for every $7°30'$ of the ecliptic (beginning with the first point of Aries) corresponding to the obliquity of the ecliptic equal to $23°40'$. So he emended the text as follows:

Manuscript Text	As emended by D. Pingree
जीवाध्यार्द्धशतांशाः सैकाः षष्टिदिनेशकाष्ठांतः । चंद्रस्य सविक्षेप- स्तदपक्रमराशिपादेन्यः ॥१६॥	जीवा व्यश्व्यर्धशतांशाः साङ्कलिप्ता दिनेशकाष्ठातः । चंद्रस्य स विक्षेप- स्तदपक्रमो राशिपादेभ्यः ॥१६॥
लिप्ताशतमासीत- दशत्रिषयुक्तमिंद्रियमनूनां । गविसेमनुभवमुनि- रूपैश्चगुणैः संयुतं च शतं ॥१७॥	लिप्ताशतमशीतिं दशत्रिसंयुक्तामिन्द्रियमनूनाम् । गवि मनुभवमुनिरूपै- श्च (त्रि)गुणैः संयुतं च शतम् ॥१७॥
नवतिस्त्रियुता षष्टि- श्चत्वारिंशछिवाश्च मिथुनान्तरे ।	नवतिस्त्रियुता षष्टि- श्चत्वारिंशच्छिवाश्च मिथुनान्ते ।

And his translation runs as follows:

16. The Sine of the maximum declination (*kāṣṭhā*) of the Sun is 50 minus 2 (= 48) parts and 9 minutes. (As) there is a latitude of the Moon, (so) is there a declination (of the Sun; it is) for fourths of a sign:

17. 180 minutes, plus 10 (= 190), plus 3 (= 183), minus 5 (= 175), and minus 14 (= 166); in Taurus 100 plus 14 times 3 (= 142), plus 11 times three (= 133), plus 7 times 3 (= 121), and plus 1 times 3 (= 103);

18. 90, 60 plus 3 (= 63), 40 plus 3 (= 43), and 11 at the end of Gemini.

The declination-differences given above are exhibited in Table 2 which also gives the corresponding modern values when the obliquity of the ecliptic $\epsilon = 23^\circ 40'$. The value $48'9''$ of the Sine of the Sun's maximum declination given above corresponds to the obliquity of the ecliptic equal to $23^\circ 40'$.

Comparison of the textual values with the modern ones in Table 2 clearly shows that there is a significant difference between the two. We cannot expect such a wrong table from Varāhamihira. Evidently Pingree has missed the target and has not been able to interpret the text correctly. Had he checked the accuracy of his values by comparing them with the modern ones he must have saved himself from committing the error. He has also missed to see that according to Varāhamihira, $\mathrm{Sin}(23^\circ 40') = 48'9''$, and not 48 parts and 9 minutes as stated by him.

In fact, there is no need of changing the text to that extent. The following minor emendation of the text would be sufficient to rectify it:

Manuscript Text	Emended Text
जीवाध्यर्द्धशतांशाः सैकाः षष्टिदिनेशकाष्ठांतः । चंद्रस्य सविक्षेप- स्तदपक्रमराशिपादेन्यः ॥१६॥	जीवाऽध्यर्धशतांशाः सैका षष्टिर्दिनेशकाष्ठाऽतः । चंद्रस्य सविक्षेप- स्तदपक्रमो राशिपादेभ्यः ॥१६॥
लिप्ताशतमासीत- दशस्त्रिषयुक्तमिंद्रियमनूनां । गविसेमनुभवमुनि- रूपैश्चगुणैः संयुतं च शतं ॥१७॥	लिप्ता साशीतिशतं मेषे त्रिखयुक्तमिंद्रियमनूनम् । गवि मनुभवमुनिरूपै- श्च(तु)र्गुणैः संयुतं च शतम् ॥१७॥
नवतिस्त्रियुता षष्टि- श्चत्वारिंशछिवाश्च मिथुनांतरे ।	नवतिस्त्रियुता षष्टि- श्चत्वारिंशच्छिवाश्च मिथुनान्ते ।

This emendation does not interfere with the numerical parameters given in the text and is intended simply to rectify the grammatical error in the first half of verse 17 (Pingree has overlooked it) and to supply the missing word *meṣe* (meaning "in Aries") in view of the presence of the words *gavi* (meaning "in Taurus") and *mithunānte* (meaning "at the end of Gemini"). Thus we have interchanged the words *māsīta* (corrected as *sāśīti*) and *śata* (corrected as *śataṃ*) and replaced the unnecessary word *daśa* by *meṣe*. We have also inserted the missing letter *tu* in the last quarter of verse 17; Pingree had inserted *tri*. The unnecessary letter *se* has been removed from the third quarter of verse 17, as was also done by Pingree.

With the above emendation the text may be translated as follows:

16. The Sine (= 120′ × sine) of the Sun's maximum declination is $\frac{61}{75}$ of a degree or 48′48″ (*saikā ṣaṣṭiḥ* = 60 + 1; *adhyardhaśatāṃśāḥ* = *adhi* + *ardhaśatāṃśāḥ* = *adhyardha*+*ardhaśatāṃśāḥ* = one and a half times 50). With the help of it one may calculate the Sun's declination (for the desired time). That (declination) plus the Moon's latitude is the Moon's declination. The declinations arising from the successive quarters of the zodiacal signs are the following:

17. In Aries, 180 plus 3 (= 183), plus 0 (= 180), minus 5 (= 175), and minus 14 (= 166) minutes; in Taurus, 100 plus 4 times 14 (= 156), plus 4 times 11 (= 144), plus 4 times 7 (= 128), and plus 4 times 1 (= 104) minutes;

18. (then) 90, 60 plus 3 (= 63), 40, and 11 (minutes) at the end of Gemini.

Since $\frac{61}{75}$ of a degree is equal to 48′48″ which is the Sine of 24° according to Varāhamihira (vide ch. IV, vs. 24), it follows that the declination-differences given in the above verses correspond to the obliquity of the ecliptic equal to

Table 2: Declination-differences for every $7°30'$ of the Sun's longitude (λ) when $\epsilon = 23°40'$.

λ	$\Delta\delta$ (modern) (correct to half a minute)	$\Delta\delta$ (textual)	Difference
$7°30'$	$3°0'$	$180' + 10' = 3°10'$	$+ 10'$
$15°$	$2°57'30''$	$180' + 3' = 3°\ 3'$	$+ 5'30''$
$22°30'$	$2°52'30''$	$180' - 5' = 2°55'$	$+ 2'30''$
$30°$	$2°44'30''$	$180' - 14' = 2°46'$	$+ 1'30''$
$37°30'$	$2°34'$	$100' + 42' = 2°22'$	$- 12'$
$45°$	$2°20'30''$	$100' + 33' = 2°13'$	$- 6'30''$
$52°30'$	$2°5'$	$100' + 21' = 2°\ 1'$	$- 4'$
$60°$	$1°46'30''$	$100' + 3' = 1°43'$	$- 2'30''$
$67°30'$	$1°25'30''$	$90' = 1°30'$	$+ 4'30''$
$75°$	$1°2'30''$	$63' = 1°\ 3'$	$+ 0'30''$
$82°30'$	$0°38'30''$	$43' = 0°43'$	$+ 4'30''$
$90°$	$0°13'$	$11' = 0°11'$	$-2'$
Total	$23°40'$	$23°40'$	0

24°. We give below in Table 3 the declination-differences stated in the above verses along with the corresponding modern values, taking the obliquity of the ecliptic (ϵ) to be equal to 24°. The differences between the two are also noted.

Table 3 shows that the values given in the text are generally in agreement with the modern ones. This proves that our interpretation of the text is correct. The value of the Sine of the Sun's maximum declination according to our interpretation is exactly the same as that given by Varāhamihira in the same chapter (in vs. 24).

3 The fifth correction for Mercury and Venus in the old *Sūryasiddhānta*

In the old *Sūryasiddhānta* school, the true longitudes of the superior planets (Mars, Jupiter and Saturn) were obtained by applying the following four corrections:

Table 3: Declination-differences for every $7°30'$ of the Sun's longitude (λ) when $\epsilon = 24°$.

λ	$\Delta\delta$ (modern) (correct to half a minute)	$\Delta\delta$ (textual)	Difference
$7°30'$	$3°2'30''$	$180' + 3' = 3°3'$	$+0'30''$
$15°$	$3°$	$180' + 0' = 3°$	
$22°30'$	$2°54'30''$	$180' - 5' = 2°55'$	$+0'30''$
$30°$	$2°47'$	$180' - 14' = 2°46'$	$-1'$
$37°30'$	$2°36'$	$100' + 56' = 2°36'$	
$45°$	$2°23'$	$100' + 44' = 2°24'$	$+1'$
$52°30'$	$2°6'30''$	$100' + 28' = 2°8'$	$+1'30''$
$60°$	$1°48'$	$100' + 4' = 1°44'$	$-4'$
$67°30'$	$1°27'$	$90' = 1°30'$	$+3'$
$75°$	$1°3'30''$	$60' + 3' = 1°3'$	$-0'30''$
$82°30'$	$0°39'$	$40' = 0°40'$	$+1'$
$90°$	$0°13'$	$11' = 0°11'$	$-2'$
Total	$24°00'$	$24°00'$	0

For obtaining the true longitude of the planet's apogee:

1. Half *śīghraphala* to the longitude of the planet's apogee (reversely).
2. Half *mandaphala* to the corrected longitude of the planet's apogee (reversely).

For obtaining the true longitude of the planet:

3. Entire *mandaphala* (calculated with the help of the true longitude of the planet's apogee) to the mean longitude of the planet.
4. Entire *śīghraphala* to the corrected mean longitude (called true-mean longitude) of the planet.

In the case of the inferior planets (Mercury and Venus) a fifth correction (called *pañcama saṃskāra*) was applied in addition to the above mentioned four corrections. In the case of Mercury this correction was calculated and applied in accordance with the following rule:

Subtract the longitude of the Sun's apogee from the longitude of Mercury's *śīghrocca*; multiply the Rsine of the resulting difference by the Sun's epicycle and divide by 360; the quotient gives the fifth correction for Mercury. Apply it to the longitude of Mercury (as corrected for the above mentioned four corrections) like the *mandaphala* of the Sun, i.e., subtract it when Mercury's *śīghrocca* minus Sun's apogee is less than 180° and add it when otherwise.

This correction has been stated in verse 21, chap. XVI (Pingree's edition) of the *Pañcasiddhāntikā*, the correct text of which runs as follows:

सर्वे स्फुटाः स्युरेवं ज्ञस्य तु शीघ्राद्विहाय रविमन्दम् ।
रविपरिधिनतं बाहुं बुधेऽर्कवत् क्षयधनं कुर्यात् ॥२१॥

In Thibaut and Dvivedi's edition of the *Pañcasiddhāntikā* the reading is *budhaphalavat* in place of *budhe'rkavat*, so their interpretation of the text has become erroneous. This rule, however, has been mentioned by Lalla in his *Śiṣyadhīvṛddhida* (I, ii. 37 (ii)) and is stated correctly there.

Pingree supposed that the above correction was applicable not only to Mercury but to Venus as well, so he has emended the text as follows:

सर्वे स्फुटाः स्युरेवं ज्ञेऽन्येषु शीघ्राद्विहाय रविमन्दम् ।
रविपरिधिनतं बाहुं बुधे कवौ क्षयधनं कुर्यात् ॥२१॥

In doing so Pingree was probably guided by the consideration that in the school of Āryabhaṭa I in the matter of planetary correction Mercury and Venus go together. But from the writings of astronomer Sumati, who belongs to the school of the old *Sūryasiddhānta*, we now know definitely that the above correction was meant for Mercury and Mercury alone. Sumati writes:[3]

अर्कोच्चं बुधशीघ्रोच्चे शोध्य ज्याघ्नं शराश्विभिः ।
भक्तं रूपाब्धिकोषैस्तु क्षयक्षेपबुधस्फुटम् ॥

बुधस्य पंचमं कर्म सूर्यवत्संस्फुटीकृतम् ॥

Having subtracted the longitude of the Sun's apogee from the longitude of Mercury's *śīghrocca*, multiply the Rsine thereof by 25 and divide by 641;[4] application of this (quotient) as a negative or positive correction (to the longitude of Mercury as corrected for the four corrections) gives the true longitude of Mercury.

The fifth correction for Mercury should be applied like the correction for the Sun.

In the case of Venus, the fifth correction is always subtractive. Its value is found to be stated in three different forms:

[3] *Sumati-mahātantra* (MS., British Museum).
[4] $\frac{\text{Sun's epicycle}}{360} = \frac{14}{360} = \frac{25}{641}$.

1. Half the Sun's *mandaphala*.
2. $10 \times \frac{\text{radius}}{514}$ minutes, where radius $= 3438'$.
3. 67 minutes.

It can be easily verified that all the three forms yield the same value, viz. 67 minutes of arc. Form (3) is found in the *Pañcasiddhāntikā*; form (1) is mentioned in the *Śiṣyadhīvṛddhida* of Lalla. Sumati gives all the three forms. Writes he:

> व्यासार्धं दशभिर्निघ्नं शक्रबाणैर्विभाजयेत् ।
> भानोर्भूप्रतिचक्रार्धं स्फुटशुक्रे विशोधयेत् ॥
>
> शुक्रस्य पञ्चमं कर्म सप्तषष्टिकलैः क्षयम् ।
>
> The radius multiplied by 10 and divided by 514, or half the distance between (the centres of) the Earth and the Sun's eccentric should be subtracted from the true longitude of Venus (i.e., from the longitude of Venus as corrected for the four corrections).
>
> The fifth correction for Venus is the subtraction of 67 minutes of arc.

When Āryabhaṭa I wrote his *Āryabhaṭa-siddhānta* based on the old *Sūrya-siddhānta*, he dropped the fifth correction. And later on when Brahmagupta wrote his *Khaṇḍakhādyaka* based on the *Āryabhaṭa-siddhānta*, he followed Āryabhaṭa I and did not use the fifth correction. From Lalla's statement in his *Śiṣyadhīvṛddhida* we learn that it was in regular use in his time. Mallikārjuna Sūri (1178 AD), who has written a commentary on the *Śiṣyadhīvṛddhida*, does not seem to be aware of the school to which the correction belonged. He has ascribed it to the followers of Āryabhaṭa I.

When the old *Sūryasiddhānta* was revised and given the present form, the fifth correction was considered superfluous and was discarded.

4 A traditional correction of the Pauliśa school for the longitude of the Moon's ascending node

In Chapter VI of the *Pañcasiddhāntikā* where Varāhamihira deals with the calculation of a lunar eclipse according to the *Pauliśasiddhānta*, there occurs the following verse having reference to a correction to be applied to the longitude of the Moon's ascending node:

> राहोः सषड्भृतिकलं हित्वांशं तच्छशांकविवरांशैः ।
> ग्रहणं त्रयोदशान्तः पञ्चदशान्तस्तमस्तस्य ॥२॥

The same verse with some alteration reappears in Chapter VII, which deals with the calculation of a solar eclipse according to the same *Pauliśasiddhānta*:

राहोः सषड्भृतिकलं हित्वांशं तच्छशांकविवरांशैः ।
ग्रहणं त्रयोदशान्तः शशिनो भानोस्तथाष्टान्तः ॥५॥

These verses have been translated by Thibaut and Pingree as follows.

Thibaut's translation:

> 2. Deduct from the longitude of Rāhu twenty-six minutes, and thereupon take the degrees intervening between Rāhu and the Moon. If these degrees are within thirteen, there is an eclipse; if within fifteen, there is the shadow of an eclipse.
>
> 5. Deduct twenty-six minutes from the longitude of Rāhu, and take the degrees intervening between Rāhu and the Moon. If they are within thirteen, there takes place an eclipse of the Moon; and an eclipse of the Sun, if they are within eight.

Pingree's translation:

> 2. Put down the degrees of the ascending node increased by 36 (or 26?) minutes. (Operate) with the degrees of the difference between this and (the longitude of) the Moon; if they are within 13°, there is an eclipse, and if within 15°, a darkening of it (the Moon).
>
> 5. Put down the degrees of the ascending node increased by 36 (or 26?) minutes. (Operate) with the degrees of the difference between this and (the longitude of) the Moon; if they are within 13°, there is an eclipse of the Moon, and if within 8°, an eclipse of the Sun.

A close scrutiny reveals that the translation of the first line of each of the above two verses as given by both Thibaut and Pingree is not correct, because

राहोः सषड्भृतिकलं अंशं हित्वा

actually means "having subtracted one degree together with thirty six minutes". The above two verses should therefore be translated as follows:

> 2. One degree and thirty-six minutes having been subtracted from (the longitude of) the Moon's ascending node, if the degrees arising from the difference of that (corrected longitude of Moon's ascending node) and (the longitude of) the Moon are within thirteen, there is an eclipse (of the Moon), and if within fifteen, there is a darkening of that (Moon).

5. One degree and thirty-six minutes having been subtracted from (the longitude of) the Moon's ascending node, if the degrees arising from the difference of that (corrected longitude of the Moon's ascending node) and (the longitude of) the Moon are within thirteen, there is an eclipse of the Moon, and if within eight, there is an eclipse of the Sun.

The correctness of this translation is confirmed by the fact that the correction of 1°36′ to the longitude of the Moon's ascending node was in regular use amongst the followers of the *Khaṇḍakhādyaka* of Brahmagupta (b. 598 AD). Although this correction was not mentioned in the *Khaṇḍakhādyaka*, the followers of the *Khaṇḍakhādyaka* made use of it as a traditional correction. The following verse occurring in a manuscript[5] of the *Khaṇḍakhādyaka* in the collection of the Akhila Bharatiya Sanskrit Parishad, Lucknow, throws light on this tradition:

पातस्य सम्प्रदायाद् विशोधयेदेकमंशकं लिप्ताः ।
षड्त्रिंशत्स्फुटपातस्स भवति सर्वत्र साधने योग्यः ॥[6]

From (the longitude of) the Moon's ascending node one should, following the tradition, subtract one degree and thirty six minutes. Then is obtained the true (longitude of the) Moon's ascending node, which is fit for use in all calculations.

This verse is also mentioned in Bina Chatterjee's edition of the *Khaṇḍakhādyaka* (Vol. II, p. 8, footnote, lines 10–11), where it runs as:

पातस्य सम्प्रदायाद्विशोधयेदेकमंशकं लिप्ताः ।
षड्त्रिंशतिः स्फुटपातः स भवति सर्वत्र साधने योग्यः ॥

The reading **षड्त्रिंशतिः** given here is undoubtedly wrong, firstly because in the same edition elsewhere[7] the correction in question has been expressly stated as "ninety six minutes" (**षण्णवतिः कलाः**) and secondly because the reading **षड्त्रिंशतिः** does not fit in in the metre of the verse. With this reading the third quarter of the verse contains 13 syllabic instants (*mātrās*), whereas in fact there should be 12 syllabic instants only.

It is noteworthy that the commentators of the *Khaṇḍakhādyaka* have prescribed the use of the above correction if the longitude of the Moon's ascending node was calculated according to the rule given in the *Pūrva Khaṇḍakhādyaka* and have forbidden its use if the longitude of the Moon's ascending node was calculated according to the rule given in the *Uttara Khaṇḍakhādyaka*. Thus writes the commentator Pṛthūdaka (864 AD):

[5] Accession No. 1662; script: Śāradā.

[6] This verse occurs in the manuscript after verse 14 of chapter I of *PKK* (= *Pūrva Khaṇḍakhādyaka*).

[7] See comm. on *PKK*, p. 104, line 23 and p. 120, line 4. Also see comm. on *UKK* (= *Uttara Khaṇḍakhādyaka*), ch. 1, vs. 3, p. 177, line 14.

तस्मात् षण्णवतिः कलाः संशोध्याः सम्प्रदायावच्छेदाः। पारम्पर्येणैवं कृते कर्मयोग्यश्चन्द्रपातो भवति।[8]
उत्तरकृताच्चन्द्रपातात् षण्णवतिः कला न शोध्या इति।[9]

From that (i.e. the longitude of the Moon's ascending node calculated according to *Pūrva Khaṇḍakhādyaka*) one should subtract the traditional correction of 96 minutes. This correction having been applied in accordance with the tradition, the longitude of the Moon's ascending node becomes fit for use in calculations.

From the longitude of the Moon's ascending node calculated from (the rule given in) the *Uttara Khaṇḍakhādyaka*, 96 minutes should not be subtracted.

So also writes the commentator Bhaṭṭotpala (968 AD):

अंशः सषड्भृतिकलः शोध्यः पातस्य पूर्वस्य।[10]

अनेन प्रकारेण कृतस्य चन्द्रपातस्य षण्णवतिः कला न शोध्याः।[11]

One degree together with thirty-six minutes should be subtracted from (the longitude of) the Moon's ascending node calculated according to *Pūrva* (*Khaṇḍakhādyaka*).

Ninety-six minutes should not be subtracted from the longitude of the Moon's ascending node if it is calculated by this method (of the *Uttara Khaṇḍakhādyaka*).

Note that the language used by Bhaṭṭotpala in his first statement is exactly similar to that used by Varāhamihira.

One may ask the question: How is it that the correction prescribed for application to the longitude of the Moon's ascending node by the *Pauliśasiddhānta* of Varāhamihira was regarded as traditional by the followers of the *Pūrva Khaṇḍakhādyaka*? The reason seems to be that at a certain stage the followers of the *Pauliśasiddhānta* fell in line with the followers of the *Āryabhaṭa-siddhānta*. They revised the old *Pauliśasiddhānta* in the light of the teachings of the *Āryabhaṭa-siddhānta* and adopted the *Pūrva Khaṇḍakhādyaka* (which was based on the *Āryabhaṭa-siddhānta*) as a work of their own school. Quotations from the *Pauliśasiddhānta* which are found to occur in the writings of Pṛthūdaka (864 AD), Bhaṭṭotpala (968 AD), Āmarāja (c. 1200 AD) and the Persian scholar Al-Bīrūnī (b. 973 AD) leave no room to doubt that the revised

[8] See *Khaṇḍakhādyaka* (P. C. Sengupta's edition), ch. 1, vs. 14 (comm.), p. 13, lines 16–18. Also see p. 13, lines 26–27, and ch. IV, vs. I (i) (comm.), p. 91, lines 13–14.
[9] *Ibid*, *Khaṇḍakhādyakottaram*, vs. 2 (comm.), p. 150, lines 25–26.
[10] See *Khaṇḍakhādyaka* (Bina Chatterjee's edition), Vol. I, p. 163, line 6. Also see Vol. II, p. 104, lines 23–24 and p. 120, line 4.
[11] *Ibid*, Vol. II, *tithinakṣatrottarādhyāyaḥ*, vs. 3 (comm.), p. 177, lines 13–14.

Pauliśasiddhānta was in conformity with the teachings of Āryabhaṭa I under the midnight day-reckoning. It is noteworthy that the commentators of the *Khaṇḍakhādyaka* have shown special preference to *Pauliśasiddhānta* in their citations from the ancient *siddhāntas*.

The followers of the *Uttara Khaṇḍakhādyaka* did not apply the above correction because the *Uttara Khaṇḍakhādyaka* conformed to the teachings of the *Brāhmasphuṭasiddhānta* of Brahmagupta and such a correction was not prescribed there.

Note

The correction of $-96'$ for the Moon's ascending node shows its appearance in the school of Āryabhaṭa I under the sunrise day-reckoning also. For example, the *bīja* correction prescribed for the Moon's ascending node in the verses

शाके नखाब्धिरहिते शशिनोऽक्षदस्रैः
तत्तुङ्गतः कृतशिवैस्तमसः षडङ्कैः ।
शैलाब्धिभिः सुरगुणोर्गुणिते सितोच्चा-
च्छोध्यं त्रिपञ्चकुहतेऽभ्रशराक्षिभक्ते ॥
स्तम्बेरमाम्बुधिहते क्षितिनन्दनस्य
सूर्यात्मजस्य गुणितेऽम्बरलोचनैश्च ।
व्योमाग्निवेदनिहते विदधीत लब्धं
शीतांशुसूनुचलतुङ्गकलासु वृद्धिम् ॥

ascribed to astronomer Lalla is based in the assumption that in the year 420 *Śaka* (= 498 AD) the *bīja* correction for the Moon's ascending node was zero and that in the year 670 *Śaka* (= 748 AD) it decreased to $-96'$. Similarly, the *bīja* correction prescribed for the Moon's ascending node in the verses

चन्द्रे बाणकरा बीजाश्चन्द्रोच्चे मनुभूमयः ।
कुजे शून्यशरा ज्ञेयाः खाग्निवेदा बुधस्य तु ॥
गुरोः खपञ्च विज्ञेयाः शुक्रे खाक्षनिशाकराः ।
शनेः शशिकराः प्रोक्ता राहोः षण्णवतिः स्मृताः ।
भवभानूनिते शाके बीजघ्ने शबरोद्धृते ।
फलं लिप्ता विलिप्ताश्च ज्ञारार्कीणां धनं भवेत् ।
राहुचन्द्रोच्चजीवानामृणं कार्यं भृगोरपि ॥

mentioned in Haridatta's *Grahacāranibandhanasaṃgraha* (vv. 19–22(i)) and quoted by Sūryadeva in his commentary on the *Laghumānasa* (*dhruvakanibandha*, 1–2) and by Nīlakaṇṭha in his commentary on the *Āryabhaṭīya* (iv. 48) is based on the assumption that in the year 444 *Śaka* (= 522 AD) the *bīja* correction for the Moon's ascending node was zero and that in the year 679 *Śaka* (= 757 AD) it decreased to $-96'$. Assumption of $-96'$ as the *bīja* correction for the Moon's ascending node in the years 748 and 757 AD seems to

have been due to the influence of the followers of the *Pūrva Khaṇḍakhādyaka*. It must however be noted that whereas the followers of the *Pūrva Khaṇḍakhādyaka* used it as a fixed *bīja*, the followers of the *Āryabhaṭīya* used it as a variable *bīja* taking its value to be $\frac{-96}{250}$ or $\frac{-96}{235}$ minutes of arc per annum.