CHAPTER 5

CANDRAGRAHAṆĀDHIKĀRAḤ

(Lunar Eclipse)

Śloka 1 : This *śloka* explains the method of finding the true longitude of planets at a given time (*iṣṭakāla*). In this case we consider the bodies, Ravi, Candra and Rāhu.

(i) Multiply the motion of the planet which is expressed in *kalās* by *gata ghaṭī* or *eṣyaghaṭī* (as the case is) and divide by 60.

(ii) Correspondingly add (or subtract) the result of (i) to (or from) the mean longitude. This gives the mean longitude of the heavenly body.

Note : While finding the mean position of a body, if the given time (*iṣṭkāla*) is after the sunrise, then the *gata* (elapsed) time in *ghaṭīs* must be used in (i) above and added in (ii).

On the otherhand, if the given time is before the sunrise, then the *eṣyaghaṭī* (to be covered) must be subtracted in item (ii).

From the mean positions of the Sun and the Moon, applying the prescribed equations, the true positions are determined. From these the instant of true full-moon (*śukla parvānta*) is found out as follows :

Subtract the true longitude of the Moon from that of the Sun, divide the difference by the difference between the true daily motions of the Moon and the Sun and then multiply the quotient by 60 to get the *ghaṭīs* to be covered for the *śukla parvānta* from the *iṣṭakāla*. That is, if S and M are the true longitudes of the Sun and the Moon at time t_0 gh. (*iṣṭakāla*) and DS and DM are their true daily motions then the instant of the (*śukla*) *parvānta* is given by

$$\left[t_o + \frac{S + 6^R - M}{DM - DS} \times 60\right] \textit{ghaṭīs.}$$

At the instant of the *parvānta*, the true longitudes of the Sun, the Moon and the ascending node (*Rāhu*) of the Moon are determined.

Example : *Vikrama Samvat* 1677, *Śālivāhana Śaka* 1542 *Mārgaśira Śukla Pūrṇimā* Wednesday. *Cakra* = 9, *Ahargaṇa* = 636.

This corresponds to December 9, 1620 (G).

At the sunrise, we have

Mean Sun = $8^R\ 0°\ 8'\ 59''$

Mean Moon = $1^R\ 25°\ 19'\ 57''$

Mean Rāhu = $7^R\ 28°\ 25'\ 27''$

According to that year's *Pañcāṅga*, the end of *Pūrṇimā tithi* is at $38|11$ gh. (after the sunrise). The true postions of the heavenly bodies at that instant are

True Sun = $8^R\ 0°\ 9'\ 26'' = S$

True Moon = $1^R\ 29°\ 36'\ 06'' = M$

True daily motion of the Sun, $DS = 61'\ 11''$

True daily motion of the Moon, $DM = 824'\ 05''$

Therefore, the instant of *parvānta* t_p is given by

$$t_p = \left[t_o + \frac{S + 6^R - M}{DM - DS} \times 60\right] \text{gh.}$$

where $t_o = 38|11$ gh. (after the sunrise)

$$\therefore \qquad t_p = 38|11 + \frac{33'\,20''}{762'\,54''} \times 60 = 40|48 \text{ gh. (after sunrise).}$$

i.e. $2^{gh}\ 37^{vig}$ after the *iṣṭakāla*, $38|11$ gh.

Now, at the instant of *Parvānta*, we have true Sun = $8^R\ 0°\ 12'\ 06''$

true Moon = $2^R\ 0°\ 12'\ 01''$ and Rāhu = $7^R\ 28°\ 23'\ 18''$

Śloka 2 : This *śloka* explains the method of finding *śara* (latitude) of the Moon and the possibility of an eclipse.

(i) Find the true longitudes of the Sun, the Moon and Rāhu at the *Parvānta*.

(ii) Consider (Sun – Rāhu). This result is called *virāhvarka*. If this is less than $14°$ then there is a possibility of an eclipse. If this is greater than $14°$, then there is no chance of an eclipse.

(iii) Divide the above difference (*virāhvarka*) by 7 and multiply it by 11. The result obtained is known as *śara* (latitude) of the Moon which will be in *angulas*. The direction of *śara* is the same as that of *virāhvarka*. (i.e., if *virāhvarka* is less than $180°$, *śara* is the $+^{ve}$ and otherwise $-^{ve}$)

$$\text{i.e.,} \qquad \acute{S}ara = \frac{11}{7} \times (\text{Sun} - \text{Rāhu})$$

Remark : *GL* uses the approximation

$$120 \sin\theta \approx \frac{72}{35}\theta$$

Let S and R be the true longitudes of the Sun and Rāhu.

Then we know that latitude $\beta = 270' \sin (S - R)$

$$\approx \frac{270 \times 72}{120 \times 35}(S - R) \approx \frac{11}{7}(S - R)$$

Example : At the *parvānta*, we have

True Sun = $8^R\ 0°\ 12'\ 6''$ and Rāhu = $7^R\ 28°\ 23'\ 18''$

Virāhvarka = Sun – Rāhu = $0^R\ 1°\ 48'\ 48''$

Bhuja of virāhvarka = $1°\ 48'\ 48'' < 14°$.

Therefore there is a possibility of an eclipse.

Now, we have

$$\acute{S}ara = \frac{11}{7}\ (\text{Sun} - \text{Rāhu}) = \frac{11}{7}\ (1°\ 48'\ 48'') = 2|50\ \textit{aṅgulas}$$

Since *virāhvarka* is in the *uttaragola* (i.e., less than 180°), the *śara* is also in the *uttaragola* and hence positive.

Śloka 3 : This *śloka* gives the methods of finding *Sūryabimbam* (Sun's diameter), *Candrabimbam* (Moon's diameter) and *bhūchāyābimbam* (diameter of the earth's shadow).

(i) *Sun's* (angular) diameter,

$$\textit{Sūryabimbam} = \left[\frac{DS - 55}{5} + 10\right]\ \textit{aṅgulas}$$

where DS is the Sun's true daily motion in ***kalās***.

(ii) Moon's (angular) diameter,

$$Candrabimbam = \frac{DM}{74} \ \textit{aṅgulas}$$

where DM is the true daily motion of the moon in *kalās*.

(iii) The angular diameter of the earth's shadow cone,

Bhūchāyābimbam

$$= \left[\left(\frac{3}{11} \times \text{Moon's diameter}\right) + (3 \times \text{Moon's diameter}) - 8\right] \ \textit{aṅg.}$$

According to the commentator Viśvanātha, the expressions for the angular diameters of the Sun, the Moon and the earth's shadow cone are as follows :

(1) The Sun's diameter, $d_s = \dfrac{2\,DS}{11}$ *aṅgulas*

(2) The Moon's diameter, $d_m = \dfrac{DM}{74}$ *aṅgulas*

(3) Diameter of the earth's shadow cone

$$d_e = \left[\frac{DM - 716}{22} + 32 - \frac{DS}{7}\right] \ \textit{aṅgulas}$$

$$= \left[\frac{DM}{22} - \frac{DS}{7} - \frac{6}{11}\right] \ \textit{aṅgulas}$$

Example : $DS = 61'\,11''$, $\quad DM = 824'\,05''$

Therefore, we have the diameters of the Sun, the Moon and the earth's shadow given by

(1) $d_s = 11|7$ *aṅgulas*, (2) $d_m = 11|8$ *angulas* and (3) $d_e = 28|10$ *aṅgulas*.

Śloka 4 : This *śloka* explains *mānaikya khaṇḍa* and *grāsa*.

In the case of a lunar eclipse the earth's shadow is called *chādaka* (the eclipser) and the Moon is called *chādya* (the eclipsed).

We define

$$\textit{Mānaikya khaṇḍa} = \frac{1}{2}\,[\textit{Chādaka bimbam} + \textit{Chādya bimbam}]$$

$$= \frac{1}{2}\,[\text{shadow diameter} + \text{Moon's diameter}]$$

Also, *grāsa* (the covered portion) is given by *grāsa* = *Mānaikya khaṇḍa* – *Śara* and *khagrāsa* is given by *khagrāsa* = *grāsa* – Moon's diameter.

Note :

(i) If it is not possible to subtract *Śara* from *mānaikya khaṇḍa* (i.e., when *śara* > *mānaikyakhaṇḍa*), then there will be ***no eclipse.***

(ii) If the *grāsa* is greater than the *chādya bimbam* (ie Moon's diameter) then the ***eclipse is total.***

Example : Suppose the earth shadow's diameter

Chādaka bimbam = $28|10$ *aṅgulas* and

the moon's diameter, *Chādya bimbam* = $11|8$ *aṅgulas*. Then

(i) *Mānaikya khaṇḍa* = $\left(\dfrac{28|10 + 11|8}{2}\right) = 19|39$ *aṅgulas*

Śara = 2|50 *aṅgulas*

(ii) *Grāsa* = *Mānaikya khaṇḍa* – *śara*

= 19|39 – 2|50 = 16|49 *aṅgulas*

(iii) *Khagrāsa* = *grāsa* – Moon's diameter

= 16|49 – 11|7 = 5|42 *aṅgulas*

In this case, *grāsa* > Moon's diameter. Therefore the lunar eclipse is ***total.***

Śloka 5 : This *śloka* explains the method of finding *sthiti* (the half duration of the eclipse) and *marda* (the half duration of totality). It is as given below.

To find sthiti :

(i) Add *śara* to the *mānaikya khaṇḍa* and multiply the sum by 10.

(ii) Multiply the above result by *grāsa* and take the square-root of the product.

(iii) Subtract $\frac{1}{6}$th of the result obtained in step (ii) from itself.

(iv) Divide the above value by the diameter of the Moon. The result obtained is called *spaṣṭa sthiti* and it will be in *ghaṭīs.*

That is, if *grāsa* = *g*, *mānaikya khaṇḍa* = *m*, *śara* = *s* and the Moon's diameter = d_m, then

Spaṣṭa sthiti = half duration of the eclipse

$$= \frac{[(s+m)\,10 \times g]^{1/2} - \frac{[(s+m)\,10 \times g]^{1/2}}{6}}{d_m} = \frac{\frac{5}{6} \times [(s+m) \times 10 \times g]^{1/2}}{d_m} \text{ gh.}$$

To find *marda* :

(i) Consider half of the *difference* between the diameters of the earth's shadow and of the Moon.

(ii) Add *śara* to the above and multiply it by *khagrāsa*.

(iii) Multiply the result of step (ii) by 10 and take the square root.

(iv) Add $\frac{1}{6}^{th}$ of the result obtained above to itself.

(v) Divide the above result by the Moon's diameter. This gives *marda* in *ghaṭīs*.

That is, if the diameter of earth's shadow = d_e, *khagrāsa* = *kg*, *śara* = *s* and the Moon's diameter = d_m then

Marda = Half duration of totality

$$= \frac{\left[\left\{\left(\frac{d_e - d_m}{2}\right) + s\right\} \times 10 \times kg\right]^{1/2} - \frac{\left[\left\{\left(\frac{d_e - d_m}{2}\right) + s\right\} \times 10 \times kg\right]^{1/2}}{6}}{d_m}$$

$$= \frac{\frac{5}{6} \times \left[\left\{\left(\frac{d_e - d_m}{2}\right) + s\right\} \times 10 \times kg\right]^{1/2}}{d_m} \; ghaṭīs$$

Half-Durations of Eclipse and of Maximum Obscuration :

The next important step is to determine the instants of the beginning and the end of a lunar eclipse as also of the maximum obscuration. For this, we need to find the duration of the first half and the second half of the total duration of the eclipse. This is explained in Fig. 5.1.

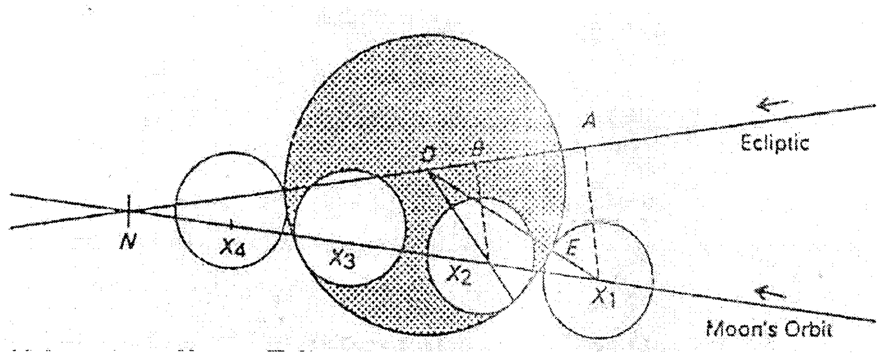

Fig 5.1: Half-duration of Lunar eclipse

A half-duration is the time taken by the Moon, relative to the Sun, so that the point A in the figure moves through OA. We have

$$OA^2 = OX_1^2 - AX_1^2 = (OE + EX_1)^2 - AX_1^2 = (d_1 + d_2)^2 - \beta_1^2$$

where

$OE = d_1$ = Semi-diameter of the shadow

$EX_1 = d_2$ = Semi-diameter of the Moon

$\beta_1 = AX_1$ = Latitude of the Moon (*vikṣepa* or *śara*)

When the Moon's centre is at X_1, we have

$$\text{Half-duration} = \frac{\sqrt{(d_1 + d_2)^2 - \beta_1^2}}{(\text{Moon' sdaily motion} - \text{Sun' s daily motion})}$$

Since the actual moment of the beginning of the eclipse, and hence the Moon's latitude then, are not known, the above formula is used iteratively.

By a similar analysis, the half-duration of maximum obscuration (or totality as the case may be) is given by

$$\text{Half-duration of max. obsn.} = \frac{\sqrt{(d_1 \sim d_2)^2 - \beta_1^2}}{(DM - DS)}$$

where DM and DS are the true daily motions of the Moon and the Sun, respectively.

The, thus obtained half-duration of the eclipse and the maximum obscuration are :

(1) subtracted from the instant of the opposition to get the first moments; and

(2) added to the instant of the opposition to obtain the last moments.

Finally, the magnitude (*pramāṇam*) of the eclipse is given by

$$\text{Magnitude} = \frac{\textit{Amount of obscuration(Grāsa)}}{\textit{Angular diameter of the Moon}}$$

Obviously, if the magnitude is greater than or equal to 1, then the eclipse is total; otherwise, it is partial.

It is also clear, from Fig. 5.1, that if the sum of the angular semi-diameters of the Moon and the shadow is less than the latitude of the Moon, there will be no eclipse.

Example : *Śara*, $s = 2|50$ *aṅgulas*

Manaikya khaṇḍam, $m = 19|38$ *aṅgulas*.

grāsa, $g = 16|48$ *aṅgulas.*

khagrāsa, $kg = 5|41$ *aṅgulas.*

Moon's diameter, $d_m = 11|7$ *aṅgulas*

Earth shadow's diameter, $d_e = 28|10$ *aṅgulas*

$$\therefore \; Sthiti = \frac{5}{6}\,\frac{[(s+m)\times 10\times g]^{1/2}}{d_m}\; ghaṭīs = \mathbf{4|36}\; \textbf{\textit{ghaṭīs}}$$

$$Marda = \frac{\frac{5}{6}\left[\left(\left(\frac{d_e - d_m}{2}\right)+s\right)\times 10\times kg\right]^{1/2}}{d_m}\; ghaṭīs = \mathbf{1|54}\; \textbf{\textit{ghaṭīs}}$$

Śloka 6 : The methods of finding *sparśa sthiti*, (first half duration of the eclipse), *mokṣa sthiti* (second half duration of the eclipse) and *sammīlana marda* (first half of totality) and *mokṣa marda* or *unmīlana* (second half of totality) are explained as follows.

(i) Find the *bhuja* of *vyagu* (true longitude of the Sun – true longitude of Rāhu). Multiply this bhuja of *vyagu* by 2. Express the product in *palas* (*vighaṭīs*).

Note : The word *vyagu* (*vi* + *agu*) means true Sun – Rāhu. Here, *agu* means Rāhu. If vyagu is in the even quadrant (II or IV i.e., $90^\circ < vyagu < 180^\circ$ or $270^\circ < vyagu < 360^\circ$) then the above product is respectively subtracted from and added to *sthiti* in *ghaṭīs* to get *sparśa sthiti* and *mokṣa sthiti.*

i.e., *sparśa sthiti* = *sthiti* – 2 × *bhuja of vyagu*

mokṣa sthiti = *sthiti* + 2 × *bhuja of vyagu*

Carry out the same operations by considering *marda* in the place of *sthiti*. This gives the *sammīlana marda* and the *mokṣa marda* or *unmīlana marda*.

i.e., *sammīlana marda* = *marda* – 2 × *bhuja of vyagu*

mokṣa marda = *marda* + 2 × *bhuja of vyagu*

If *vyagu* is in the odd quadrant (I or III i.e., $0 < vyagu < 90^\circ$ or $180^\circ < vyagu < 270^\circ$) then $2 \times bhuja$ is added to *sthiti* to get *sparśa sthiti* and it is subtracted from *sthiti* to get *mokṣa sthiti*.

The same rule holds in the case of *sammīlana* and *mokṣa marda* also considering *marda* instead of *stithi*.

Note : *Vyagu* is also called *virāhvarka*.

Example : *Sthiti* = $4|36$ *ghaṭīs*

Vyagu = $1^\circ\ 48'\ 48''$

bhuja of vyagu = $1^\circ\ 48'\ 48''$

$2 \times bhuja\ =\ 3|37|36 \approx 3$ *vighaṭīs*

marda = $1|54$ *ghaṭīs*

Since the *vyagu* is in first quadrant,

sparśa sthiti = First half-duration

$= sthiti + 2 \times bhuja$

$$= 4^{gh}\ 36^{vig} + 3^{vig} = \mathbf{4|39}\ \textit{\textbf{ghaṭīs}}$$

mokṣa sthiti = Second half-duration

$$= sthiti - 2 \times bhuja$$

$$= 4^{gh}\ 36^{vig} - 3^{vig} = \mathbf{4|33}\ \textit{\textbf{ghaṭīs}}$$

sammīlana marda = *marda* + 2 × *bhuja*

$$= 1^{gh}\ 54^{vig} + 3^{vig} = 1^{gh}\ 57^{vig}$$

mokṣa marda = *marda* − 2 × *bhuja*

$$= 1^{g}\ 54^{vig} - 3^{vig} = \mathbf{1|51}\ \textit{\textbf{ghaṭīs}}$$

Śloka 7 : This *śloka* explains about the *madhyakāla* (*parvānta* or middle of the eclipse), *sparśakāla* (beginning of the eclipse) and *mokṣakāla* (end of the eclipse) as follows.

(i) The *parvānta* is the middle of the eclipse or *madhyakāla*.

(ii) By subtracting sparśa sthiti from the *madhyakāla*, we get *sparśakāla*

i.e., *sparśakāla* = *madhyakāla* – *sparśa sthiti*

(iii) By adding the *mokṣa* sthiti to the *madhyakāla*, we get the *mokṣakāla*.

i.e., *mokṣakāla* = *madhyakāla* + *mokṣa sthiti*

(iv) Similarly, for a total elipse, we have

sammīlanakāla = *madhyakāla* – *sammīlana marda*

and *unmīlanakāla* = *madhyakāla* + *unmīlana marda*

Example : We have already obtained

Madhyakāla = 40|48 *ghaṭīs* (after sunrise)

Sparśa sthiti = 4|39 *ghaṭīs*

Mokṣa sthiti = 4|33 *ghaṭīs*

Sammīlana marda = 1|57 *ghaṭīs*

Unmīlana marda = 1|51 *ghaṭīs*

Now, therefore we get

Sparśakāla = 36|09 *ghaṭīs*

Mokṣakāla = 45|21 *ghaṭīs*

Sammīlanakāla = 38|51 *ghaṭīs*

and *Unmīlanakāla* = 42|39 *ghaṭīs*

Śloka 8 : This *śloka* explains the method of finding *grāsa* at a given time (*iṣṭaghaṭī*).

(i) Multiply *grāsa* by *iṣṭaghaṭī* and divide the product by *sparśa sthiti*.

(ii) Add 1|15 *aṅgula* to the above result. This gives *grāsa* at *iṣṭakāla*.

i.e., $$\textit{grāsa} \text{ at } \textit{iṣṭakāla} = \left[\frac{\textit{grāsa} \times \textit{iṣṭaghati}}{\textit{sparśa sthiti}}\right] + 1|15 \text{ in } \textit{aṅgulas}$$

This is the *grāsa* at *iṣṭakāla* after *sparśakāla* (before *madhyakāla*). If *mokṣa sthithi* is used in the place of *sparśa sthiti* then we get *grāsa* at *iṣṭakāla* before *mokṣakāla* (after *madhyakāla*).

Example :

Suppose the given time, *iṣṭaghaṭī* = 2 gh. after *sparśakāla*

grāsa = 16|48 *aṅgulas*

sparśa sthiti = $4|39$ *ghaṭīs*

grāsa at 2 gh. after *sparśakāla* $= \left(\dfrac{2 \times 16|48}{4|39}\right) + 1|15$ *aṅgulas*

$= 8|28$ *aṅgulas*

Śloka 9 : This *śloka* explains the method of finding *āyanavalanam.*

(i) In the case of a lunar eclipse, consider the true longitude of the Sun at the *parvānta*. Subtract 90° from it. This gives *tribhoṇa* Ravi.

In the case of a solar eclipse add 90° to the true position of the Sun at the *darśānta* (conjunction).

(ii) Add *ayanāṃśa* to (i) to get *sāyana tribhoṇa* Ravi. Find *bhuja* of this.

(iii) Considering 7, 5, 1 as *carakhaṇḍas*, find *gatakhaṇḍa*, *bhogyakhaṇḍa* and the remainder for the above result (as explained in *śloka* 5 of Chapter 2).

Then, *āyanavalanam* is given by

$$\bar{A}yanavalanam = \left[\frac{Bhogyakhaṇḍa \times \text{Remainder}}{30}\right] + gatakhaṇḍa$$

Example : (*Nirayaṇa*) Ravi at *parvānta* = $8^R\ 0^\circ\ 12'\ 16''$

Ayanāṃśa = $18^\circ\ 18'$

Sāyana tribhoṇa Ravi = $5^R\ 18^\circ\ 30'\ 16''$

Bhuja of *sāyana tribhoṇa* Ravi = $11^\circ\ 29'\ 44''$

Gatakhaṇḍa = 0, *bhogyakhaṇḍa* = 7

and remainder = $11^\circ\ 29'\ 44''$

$$\therefore\ \bar{A}yana\ valanam = \left[\frac{7 \times 11^\circ\ 29'\ 44''}{30^\circ}\right] + 0 \quad = 2|40\ \textit{aṅgulas}$$

Since *tribhoṇa* Ravi is in the *uttaragola* (i.e., less than 6 R) the *valanam* is also in the *uttaragola*.

Notes : In Fig. 5.2 γSA is the ecliptic and γMB is the celestial equator and ϵ is the obliquity of the ecliptic. The position of a celestial body is represented by S on the ecliptic.

Āyana valanam is the deflection of a point due to the obliquity of the ecliptic i.e., the angle subtended at the point by arc *KP* where *K* and *P*

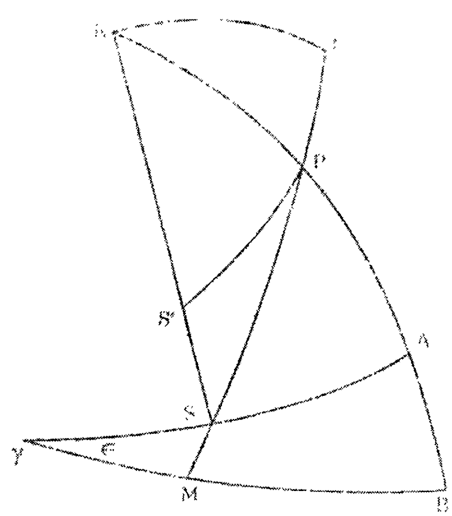

Fig. 5.2 *Āyanavalanam*

are respectively the poles of the ecliptic and the celestial equator.

In the figure, from spherical triangle *SKP*, we have

$$\frac{\sin v_1}{\sin \in} = \frac{\sin S\hat{K}P}{\sin SP}$$

But $S\hat{K}P = 90° - \lambda$ and $SP = 90° - \delta$ where λ and δ are respectivly the celestial longitude and declination of the body.

$$\therefore \qquad \sin v_1 = \frac{\sin\in \ \cos\lambda}{\cos\delta}$$

where v_1 is the *āyana valanam*.

Śloka 10 : Now, computation of the *akṣa valanam* is explained.

(i) Divide the mean *natakāla* by 5 to get the result in *rāśis* etc.

(ii) Taking the *bhuja* of (i) and using the *khaṇḍas* 7, 5, 1 (as explained in the previous *śloka*) find the *valanam*.

(iii) The *valanam*, obtained in (ii), is multiplied by the *palabhā* of the place and then divided by 5. This gives the (*spaṣṭa*) *akṣa valanam*.

This *akṣavalanam* is north or south according as the *nata* is eastern or western.

(iv) If the *āyana valanam* and the *akṣa valanam* are in the same direction, then take their sum (which will have the same direction). If these are in the opposite directions, then take their difference (whose direction will be that of the *valanam* with higher magnitude).

(v) Divide the above combined *valanam* by 6 which gives the *valanāṅghri*, in the above obtained direction, of the commencement of the eclipse.

Example : *Madhya nata* = $2|27$ (east). (i) Dividing by 5, we get $0^R\,14°\,42'\,0''$. (ii) *Bhuja* = $14°\,42'$. Using the *bhogya khaṇḍa* 7, we have $14°\,42' \times 7/30 = 3|25$. (iii) *palabhā* = $5|45$ aṅg. Multiplying $3|25$ by $5|45$ and dividing by 5, we get $3|56$. This is (*spaṣṭa*) *akṣa valanam*. This is in the north direction since the *nata* is in the east. (iv) The (previously obtained) *āyana valanam* = $2|40$ north. (iv) Since both *āyana* and *akṣa valanams* are in the north (the same direction), adding them, we get the combined (*samskṛta*) *valanam* = $3|56 + 2|40 = 6|36$, north (v) Dividing $6|36$ by 6, we get $1|06$ north. This is the *valanāṅghri* (or *valana caraṇa*).

Śloka 11 : Now, determination of *grāsāṅghri* and *khagrāsāṅghri* is explained.

(First half of *Śloka* 11) :

(i) Multiply *grāsamāna* by 60 and divide by *mānaikya khaṇḍà* (sum of the diameters of the *chādya* and the *chādaka*).

Take the square root of the above result. This gives the *grāsāṅghri* in *aṅg.*

(ii) Add $1|30$ *aṅg.* to the *khagrāsa* to get *khagrāsāṅghri.*

Example : *Grāsa* = $16|48$ *aṅgulas* and *Mānaikyakhaṇḍa* = $19|38$ *aṅgulas.*

(i) Therefore, *Grāsāṅghri* = $\sqrt{\dfrac{16|48 \times 60}{19|38}}$ *aṅg.*

$$= 7|9|55 \text{ aṅg.}$$

(ii) *Khagrāsa* = 5|41 *aṅgulas*

Adding 1|30 *aṅg*. to the *khagrāsa*, we get *khagrāsāṅghri* = 7|11 *aṅgulas*.

(Second half of *Śloka* 11) :

Draw a circle and mark the north, east, south and west directions. Divide this circle into 32 parts (through the centre). If the (combined) valana is south, then starting from the direction of the *śara* proceed in the clockwise direction and measure the amount of the *valanāṅghri*. This gives the middle of the eclipse.

On the otherhand, if the *valana* is north, then proceed in the anticlockwise direction and measure the amount of the *valanāṅghri*. Similarly, in the opposite direction the *khagrāsa* or *bimba śeṣa* takes place.

Śloka 12 : Now, the determination of the directions of the beginning and the end of an eclipse (and of the totality) is explained.

From the middle of the eclipse, in the eastern direction the amount of the *grāsāṅghri* is measured to obtain the direction of the *sparśa* (beginning) of the eclipse. The same in the western direction gives the direction of the end (*mokṣa*) of the eclipse in the case of a lunar eclipse. In the case of a solar eclipse the opposite of the said directions must be taken. The same is the case for a total eclipse (*khagrāsa*) to obtain its beginning (*sammīlana*) and the end (*unmīlanam*) starting with *khagrāsa* point.

CHAPTER 6

SŪRYAGRAHAṆĀDHIKĀRAḤ

(Computation of Solar Eclipse)

***Ślokas* 1 and 2** : These *ślokas* explain the method of finding *lambana*. It is as follows :

(i) Find the *sāyana lagna* at the *kṛṣṇa parvānta* (i.e. *darśānta*). Subtract 3 *rāśis* from it. The result is called *sāyana vitribha lagna* (or *tribhoṇa lagna*).

(ii) Find the *krānti* (declination) of the above *sāyana vitribha lagna*. Add *akṣāṃśa* to (or subtract from) the *krānti*. This result is called *natāṃśa*.

i.e., *natāṃśa* = *krānti* ± *akṣāṃśa*

or *natāṃśa* = $\delta - \phi$

where δ = declination and ϕ = latitude of the place.

(iii) Divide the *natāṃśa* by 22. Square the resulting quotient.

(iv) If the square obtained in step (iii) is less than 2, then add 12 to it. This result is called *hāra*.

(v) On the otherhand, if the result of step (iii) is greater than 2, then subtract 2 from it. Divide the difference by 2. Add this to the square obtained in step (iii) and add 12 to the result. This is called *hāra*.

i.e., $$\textit{hāra} = \left(\frac{\textit{natāṃśa}}{22}\right)^2 + \left[\frac{\left(\frac{\textit{natāṃśa}}{22}\right)^2 - 2}{2}\right] + 12$$

To find *lambana* (effect of parallax on the longitude] :

(i) Consider the difference between *sāyana vitribhalagna* and the Sun. Divide this difference by 10.

(ii) Multiply the difference between the above result and 14 by the result of step (i).

(iii) Divide the result of (ii) by *hāra*. The resulting quotient is called *lambana.*

i.e., if $$x = \left(\frac{\textit{vitribhalagna} - \textit{the Sun}}{10}\right)$$

then, $$\textit{lambana} = \frac{(14 - x)x}{\text{hāra}}$$

Note : (i) In x, its *bhuja* must be taken;

(ii) If *vitribha lagna* > the Sun, add *lambana* to *darśānta* to get *spaṣṭa darśānta* (corrected *darśānta*).

Remark : *Lambana* is the effect of parallax on the longitude and *nati* is that on the latitude of the Moon.

Example : *Vikrama samvat* 1677, *Śālivāhana śaka* 1532. *Mārgaśira kṛṣṇa amāvāsyā*, Wednesday, *Cakra* = 8, *Varṣagaṇa* = 90 and *Ahargaṇa* = 1005.

This corresponds to December 15, 1610 (G), Wednesday

At the mean sunrise, we have

$$\text{Mean Sun} = 8^R\, 5^\circ\, 39'\, 25'',\quad \text{Mean Moon} = 8^R\, 1^\circ\, 10'\, 33''$$

$$\text{Rāhu} = 2^R\, 11^\circ\, 41'\, 59'' \quad \text{and} \quad \textit{Candrocca} = 8^R\, 17^\circ\, 7'\, 21''$$

According to that year's *pañcāṅga* the end of *amāvāsya tithi* is at $12|36$ *ghaṭīs* (after the sunrise). At this instant the true positions of the heavenly bodies are as follows.

$$\text{True Sun} = 8^R\, 5^\circ\, 25'\, 57'' \equiv S,\quad \text{True Moon} = 8^R\, 5^\circ\, 20'\, 41'' \equiv M$$

$$\textit{Candrocca} = 8^R\, 17^\circ\, 8'\, 45'' \quad \text{and} \quad \text{Rāhu} = 2^R\, 11^\circ\, 41'\, 19''$$

True daily motion of the Sun, $DS = 61'15''$

True daily motion of the Moon, $DM = 726'\,30''$

Therefore, the instant of *parvānta*, t_p is given by

$$t_p = \left[t_o + \frac{S - M}{DM - DS} \times 60\right] gh.$$

where $t_o = 12|36$ *ghaṭīs* (after the sunrise)

$$\therefore \qquad t_p = \left[12|36 + \frac{5'16''}{726'\,30'' - 61'\,15''} \times 60\right] gh.$$

$$= 12|36 + 0|28 \text{ ghaṭīs} = \mathbf{13|4} \text{ ghaṭīs}$$

i.e., $0^{gh}\, 28^{vig}$ after the *iṣṭakāla*, $12|36$ *gh*. Now, at this instant of *parvānta* (or *darśānta*).

True Sun = $8^R\, 5^\circ\, 26'\, 25''$, True Moon = $8^R\, 5^\circ\, 26'\, 20''$

Rāhu = $2^R\, 11^\circ\, 41'\, 18''$ and

Virāhvarka = Sun – Rāhu = $5^R\, 23^\circ\, 45'\, 7''$

Now, *darśānta* = $13|4$ *ghaṭīs ; lagna* at *darśānta* = $11^R\, 2^\circ\, 46'\, 17''$

Vitribha lagna = *lagna* – 3 *rāśis*

$= 11^R\, 2^\circ\, 46'\, 17'' - 3^R = 8^R\, 2^\circ\, 46'\, 17''$

Krānti of *Vitribhalagna* $\delta = 23^\circ\, 38'\, 10''$ (south)

akṣāṃśa $\phi = 25^\circ\, 26'\, 42''$ (north) for *Kāśī*

$\therefore$ *natāṃśa* = *krānti* – *akṣāmśa* $\equiv \delta - \phi$

$$= -23^\circ\, 38'\, 10'' - 25^\circ\, 26'\, 42'' = -49^\circ\, 4'\, 52''$$

i.e., $49^\circ\, 4'\, 52''$ (south)

Now, $\left(\dfrac{nat\bar{a}\d{m}\acute{s}a}{22}\right)^2 = \left(\dfrac{49|4|52}{22}\right)^2 = (2|13|51)^2 = 4|58|37$

Since $\left(\dfrac{nat\bar{a}\d{m}\acute{s}a}{22}\right)^2 = 4|58|37 > 2$, subtracting 2 from the square and dividing this by 2, we get $\dfrac{4|58|37-2}{2} = 1|29|18$

$$h\bar{a}ra = \left(\frac{nat\bar{a}\dot{m}\acute{s}a}{22}\right)^2 + \frac{1}{2}\left[\left(\frac{nat\bar{a}\dot{m}\acute{s}a}{22}\right)^2 - 2\right] + 12$$

$$= (4|58|37 + 1|29|18 + 12)\ gh. \approx 6|27{+}12\ gha\d{t}\bar{\imath}s = 18|27\ gha\d{t}\bar{\imath}s$$

To find *lambana* :

Vitribha lagna = $8^R\ 2°\ 46'\ 17''$

The Sun - *vitribha lagna* = $2°\ 40'\ 8''$

Let $x = \dfrac{2°\ 40'\ 8''}{10} = 0|16$

Now, we have

$$lambana = \frac{(14 - x)x}{h\bar{a}ra} = \frac{(14 - 0|16)\,0|16}{18|27} = 0|11\ gha\d{t}\bar{\imath}s$$

Since *vitribha lagna* < the Sun, subtract *lambana* from *darśānta* to get the *spaṣṭa darśānta*.

i.e., *spaṣṭa darśānta* = $13^{gh.}\ 04^{vig} - 0^{gh.}\ 11^{vig} = \mathbf{12^{gh.}\ 53^{vig}}$

***Śloka* 3** : This *śloka* explains the method of finding the *lambana* corrected *vyagu* and the *lambana* corrected *natāmśa*. It is as follows.

(i) Multiply *lambana* by 13. The resulting product will be in *kalās*.

(ii) The above result is added to or subtracted from *vyagu* (Sun – *Rāhu*) depending on whether the *lambana* is additive or subtractive respectively.

(iii) Find *śara* of the above *lambana* corrected *vyagu*.

(iv) Multiply *lambana* by 6.

(v) If *lambana* is negative, subtract the result of step (iv) from *vitribha lagna*. If *lambana* is positive, add the result of step (iv) to *vitribha lagna*.

(vi) Find the *krānti* (declination) of the *lambana* corrected *lagna*.

(vii) Now, the *lambana* corrected *natāmśa* is obtained from the declination δ of the corrected *lagna* $\pm$ *akṣāmśa* i.e., $\delta - \phi$

where δ is the declination of the corrected *lagna* and ϕ is the latitude of the place.

Example : We have

vitribha lagna = $8^R\ 2^\circ\ 46'\ 17''$, *lambana* = $-0|11$ *ghaṭīs* and

vyagu = $5^R\ 23^\circ\ 45'\ 07''$

$\therefore$ (i) *lambana* corrected *vyagu* = *vyagu* $-\ 13 \times$ *lambana*

$$= 5^R\ 23^\circ\ 45'\ 07'' - (13 \times 0|11) = 5^R\ 23^\circ\ 45'\ 07'' - 2'\ 23''$$

$$= 5^R\ 23^\circ\ 42'\ 44''$$

(ii) *Śara* for the *lambana* corrected *vyagu*

$$= \frac{11}{7} \times (\textit{bhuja of corrected vyagu}) = \frac{11}{7} \times (6^\circ\ 17'\ 16'') = 9|53$$

aṅgulas

Since *vyagu* $< 180^\circ$, *śara* is positive.

Now, $6 \times$ *lambana* $= 6 \times 0|11 = 1^\circ\ 6'$

Since *lambana* is negative, subtract $6 \times lambana$ from *vitribha lagna* to get the corrected *vitribha lagna*.

i.e., corrected *vitribha lagna* = $vitribha\ lagna - 6 \times lambana$

$$= 8^R\ 2^\circ\ 46'\ 17'' - 1^\circ\ 06' = 8^R\ 1^\circ\ 40'\ 17''$$

The *krānti* of the corrected *lagna* = $23^\circ\ 34'\ 35''$ (south)

(obtained as explained in Chapter 4)

Akṣāmśa = $25^\circ\ 26'\ 42''$ (north) for Kāśī

$\therefore$ corrected *natāṃśa* = *krānti* of corrected *lagna* – *akṣāṃśa*

$$= -23^\circ\ 34'\ 35'' - 25^\circ\ 26'\ 42'' = 49^\circ\ 01'\ 17''\ \text{(south)}$$

***Śloka* 4** : The method of determining *nati* as well as the *sthiti* is explained in this *śloka* as follows :

(i) Divide the *lambana* corrected *natāṃśa* by 10.

(ii) Subtract the above result from 18.

(iii) Multiply the results of step (i) and step (ii). The product will be in *kalās*.

(iv) Subtract the result obtained in step (iii) from $6^\circ\ 18'$.

(v) Divide the result of step (iii) by that of step (iv). The result obtained is called *nati*. Thus if *lambana* corrected *natāṃśa* is denoted by *ln*, then

$$nati = \frac{\left(18 - \frac{ln}{10}\right)\frac{ln}{10}}{6^\circ\ 18' - \left[\left(18 - \frac{ln}{10}\right)\frac{ln}{10}\right]}$$

(vi) Using the above *nati*, we can get corrected *śara* (or *spaṣṭa śara*) by adding *śara* to (or subtracting from) *nati.*

i.e., *spaṣṭa śara = nati* ± *śara*

Note : Here the *śara* of the *lambana* corrected *vyagu* is to be considered.

Using the *spaṣṭa śara* find *mānaikyakhaṇḍa, grāsa* and *khagrāsa* or *khacchanna.*

Example : We have

lambana corrected *natāṃśa* $ln = 49^\circ\ 1'\ 17''$

$$nati = \frac{\left(18 - \frac{ln}{10}\right)\frac{ln}{10}}{6^\circ\ 18' - \left[\left(18 - \frac{ln}{10}\right)\frac{ln}{10}\right]} = -12\,|16$$

∴ *Spaṣṭa Śara* = $-12|16 + 9|53$ *aṅgulas* = $-2|23$ *aṅgulas.*

(**Note** : *nati* is –ve since *natāṃśa* is south).

To find *sthiti* :

The method of finding *sthiti* is the same as that explained in Chapter 5 (computation of lunar eclipse). We have

Spaṣṭa Śara, s = $2|23$ *aṅgulas* (south)

Sun's diamater, $d_s = 11|8$ *aṅgulas*

Moon's diameter, $d_m = 9|49$ *aṅgulas*

Mānaikyakhaṇḍam, $m = 10|28.5$ *aṅgulas*

grāsa, $g = 8|6$ *aṅgulas* (approximately)

$$\therefore\ sthiti = \frac{5}{6}\frac{[(s+m)\times 10\times g]^{1/2}}{d_m}\ ghaṭīs\ = 2|44\ \mathbf{ghaṭīs}$$

(*Śloka* 5 in Chapter 5).

***Śloka* 5** : This *śloka* explains the method of finding the *sparśa* and *mokṣa kālas* of the eclipse. It is as follows.

(i) Multiply *sthiti* by 6. The result will be in degrees, minutes, seconds.

(ii) Subtract the result of step (i) from the *parvānta tribhoṇa lagna* (*PTL*) to get the *sparśakāla tribhoṇa lagna* (*STL*) and adding the same result to the *tribhoṇa lagna* (*PTL*) we get the *mokṣakāla tribhoṇa lagna* (*MTL*).

(iii) Find *lambana* using the *sparśakāla tribhoṇa lagna* and the *mokṣa kāla tribhoṇa lagna*. These are called *sparśakāla lambana* and *mokṣakāla lambana* respectively.

(iv) The *sthiti* is added to and subtracted from the *sparśa lambana* and the *mokṣa lambana* to get the corrected *sparśa* and *mokṣa sthitis* respectively.

(v) Subtract the corrected *sparśa sthiti* from *darśānta*.This gives the *sparśa kāla* in *ghaṭīs*.

(vi) Add *mokṣa sthiti* to *darśānta*. This gives the *mokṣakāla* in *ghaṭīs*.

Example : We have the *sthiti* = $2|44$ *ghaṭīs*

(Śāyana) vitribha (or *tribhoṇa*) *lagna* = $8^R\ 2°\ 46'\ 17''$

Now, $6 \times$ *sthiti* = $6 \times (2|44) = 16°\ 24'$

(i) *Spraśakāla tribhoṇa lagna* $= 8^R\ 2°\ 46'\ 17'' - 16°\ 24'$

$= 7^R\ 16°\ 22'\ 17''$

(ii) *Mokṣa kāla tribhoṇa lagna* $= 8^R\ 2°\ 46'\ 17'' + 16°\ 24'$

$= 8^R\ 19°\ 10'\ 17''$

To find *sparśa lambana* :

Declination of the *sparśakāla tribhoṇa lagna,* $\delta = -21°\ 24'\ 39''$

Akṣāṃśa $\phi = 25°\ 26'\ 42''$

Natāṃśa = $\delta - \phi = 46°\ 51'\ 21''$ (south)

$$\text{Now, } H\bar{a}ra = \left(\frac{nat\bar{a}\,\dot{m}\,\acute{s}a}{22}\right)^2 + \frac{1}{2}\left[\left(\frac{nat\bar{a}\dot{m}\acute{s}a}{22}\right)^2 - 2\right] + 12$$

$$= \left(\frac{46|51|21}{22}\right)^2 + \frac{1}{2}\left[\left(\frac{46|51|21}{22}\right)^2 - 2\right] + 12 = 17|48$$

Ravi at *parvānta* = $8^R\ 5^\circ\ 26'\ 25''$

True motion of Ravi = $61'\ 15''$

Sthiti = $2^{gh}\ 44^{vg}$

Motion of Ravi in $2^{gh}\ 44^{vg} = 2'\ 47''$

$\therefore$ Ravi at *sparśa kāla* = $8^R\ 5^\circ\ 26'\ 25'' - 2'\ 47'' = 8^R\ 5^\circ\ 23'\ 38''$

Sparśakāla vitribha Lagna = $7^R\ 16^\circ\ 22'\ 17''$

Ravi – *Lagna* = $19^\circ\ 01'\ 21''$

Now,

$$\frac{1}{10}^{th} \text{ of } Bhuja \text{ of (Ravi} - Lagna) = 1^\circ\ 54' \text{ and } 14^\circ - 1^\circ\ 54' = 12^\circ\ 6'$$

Sparśa lambana (Numerical Value) $= \dfrac{12^\circ\ 6' \times 1^\circ\ 54''}{H\bar{a}ra} = \dfrac{22|49}{17|48} = 1^{gh.}\ 17^{vg.}$

i.e., *Sparśa lambana* = $-\ 1^{gh}\ 17^{vg}$

To find *mokṣa lambana* :

Mokṣakāla vitribha Lagna = $8^R\ 19^\circ\ 10'\ 17''$

Declination of the above (Numerical value) = $-\,23^\circ\ 42'\ 28'' \equiv \delta$

Akṣāṃśa = $+\ 25^\circ\ 26'\ 42'' \equiv \phi$

Natāṃśa = $\delta - \phi = -\ 49°\ 9'\ 10''$

Hāra = $18|28$ (obtained as explained earlier)

Ravi at *Mokṣakāla* = $8^R\ 5°\ 26'\ 25'' + 2'\ 47'' = 8^R\ 5°\ 29'\ 12''$

where $2'\ 47''$ is the motion of Ravi in $2^{gh}\ 44^{vg}$ *(sthiti).*

Now, Ravi – *lagna* = $0^R\ 13°\ 41'\ 5''$

$\frac{1}{10}^{th}$ of *Bhuja* of (Ravi – *lagna*) = $1|22$

and $14 - 1|22 = 12|38$

Now, $\dfrac{12|38 \times 1|22}{Hāra} = \dfrac{12|38 \times 1|22}{18|28} = 0^{gh}\ 56^{vig}$

i.e., *Mokṣa lambana* = $0^{gh}\ 56^{vig}$

To find *sparśa* and *mokṣa kālas* :

We have *darśānta* = $13^{gh}\ 04^{vg}$ and *sthiti* = $2^{gh}\ 44^{vig}$

$\therefore$ *darśānta – sthiti* = $13^{gh}\ 04^{vig} - 2^{gh}\ 44^{vig} = 10^{gh}\ 20^{vig}$

Sparśa lambana = $-1^{gh}\ 17^{vig}$

Now, *sparśakāla* = $10^{gh}\ 20^{vig} - 1^{gh}\ 17^{vig} = 9^{gh}\ 03^{vig}$

We have

darśānta + *sthiti* = $13^{gh}\ 04^{vig} + 2^{gh}\ 44^{vig} = 15^{gh}\ 48^{vig}$

Mokṣa lambana = $0^{gh}\ 56^{vig}$

$\therefore$ *Mokṣakāla* = $15^{gh}\ 48^{vig} + 0^{gh}\ 56^{vig} = 16^{gh}\ 44^{vig}$

Summary of the eclipse :

Beginning of the eclipse: $9^{gh}\ 03^{vig}$

Middle of the eclipse: $13^{gh}\ 04^{vig}$

End of the eclipse : $16^{gh}\ 44^{vig}$

***Śloka* 6** : This *śloka* explains the method of finding *sammīlanakāla* and *unmīlanakāla* (in the case of a total eclipse). The colour of the eclipse is also explained.

(i) To find *sammīlana* and *unmīlana kālas* :

Consider *marda* in the place of *sthiti* and proceed as explained previously to get *sammīlana kāla* and *unmīlana kāla.*

(ii) Colour of the eclipse :

If the *grāsa* of the lunar eclipse is small (*alpagrāsa,* less than $1/2$) then the colour of the eclipse is smoke colour (*dhūmra varṇa*). If the *grāsa* of the lunar eclipse is half (i.e., *ardhagrāsa*) then the colour of the eclipse is black (*kṛṣṇa varṇa*) and the colour of the eclipse will be brown (*piṅgalavarṇa*) if the *grāsa* is full (*sampūrṇa grāsa*).

In the case of a solar eclipse whether the *grāsa* is small or half or full the solar eclipse will be only of black colour. Further, if the *grāsa* of a total eclipse is less than one *aṅgula*, the eclipse should not be predicted since the small eclipsed portion cannot be recognised due to the powerful solar rays.

***Śloka* 7** : This *śloka* explains the method of finding *grāsa* at a given time (*iṣṭakāla*)

(1) Multiply the *iṣṭaghaṭī* (i.e., given time in *ghaṭīs*) by $2 \times$ *grāsa.*

(2) Divide the above product by the difference of *sparśa* and *mokṣa ghaṭīs.*

(3) Add $\frac{1}{2}$ *aṅgula* to the result obtained in step (2). This gives the *grāsa* at the *iṣṭakāla.*

Example : Let *iṣṭaghaṭī* = 1 *ghaṭī* and *grāsa* = $8|6$ *aṅgulas*

(1) Now, 2 × *grāsa* × *iṣṭaghatī* = $2 \times 1 \times 8|6 = 16|12$

(2) *Spaśakāla* = $9^{gh}\ 03^{vig}$ and *Mokṣakāla* = $16^{gh}\ 44^{vig}$

The difference = $7^{gh}\ 41^{vig}$ (i.e., duration of the eclipse)

(3) We have

Grāsa at the given the time

$$\frac{16|12}{7|41} + \frac{1}{2} = 2|6 + 0|30 \qquad [\because \tfrac{1}{2}\ \textit{aṅgula} = 0|30\ \textit{aṅgula}]$$

$$= 2|36\ \textit{aṅgulas} = 2^{ang}\ \ 36^{p.ang}$$

(Note : 1 *aṅgula* = 60 *pratyaṅgulas).*

To find *valanam* and *parilekhā* :

We have

lambana corrected *darśānta* = $12^{gh}\ 53^{vig}$

The Sun at *parvānta* = $8^{R}\ 5°\ 26'\ 14''$

Adding 3 *rāśis* we get $11^{R}\ 5°\ 26'\ 14''$

Adding *ayanāmśa* $18°\ 08'$ to the above, we get $11^{R}\ 23°\ 34'\ 14''$

Now, as explained in Ch. 5, *Ślokas* 9 and 10, we have

(i) *Ayana valanam* = $1|30$ (south) and *dinārdham* = $13^{gh}\ 3^{vig}$

nata = $0|10$, *akṣa valanam* = $0|14$ (north) and *palabhā* = $5|45$ *aṅgulas*

$\therefore$ *corrected akṣa valanam* = $\dfrac{5|45 \times 0|14}{5} = \dfrac{1|20}{5} = 0|16$ (north)

Resultant of the *two valanas* :

$1|30 - 0|16 = 1|14$ (south)

Now, *valanāṅghri* = $\dfrac{1|14}{6} = 0|12$ (south)

grāsa = $8|6$ *aṅgulas*

(ii) *Parilekhā* $= \left[\dfrac{gr\bar{a}sa \times 60}{m\bar{a}naikyakha\d{n}\d{d}a}\right]^{1/2}$

$$= \left[\frac{8|6 \times 60}{10|28}\right]^{1/2} = (46|26)^{1/2} = 6|49$$

(also called *channāṅghri*).

CHAPTER 7

MĀSAGAṆĀDHIKĀRAḤ

(Accumulated Lunar Months)

***Śloka* 1** : Now, computations of lunar and solar eclipses are presented, with *māsagaṇa* (heap of lunar months) by obtaining the true positions of the Sun, *vyagu, tithi, bimba* (diameters) and *grāsa* using simple and ingenuous techniques.

Śloka 2 : This *śloka* gives the *kṣepaka* of the Sun, *vyagu*, *vṛtta* (i.e., *candrakendra*) and *vārādika* of *tithi* as follows :

Sun	$0^R\ 4^\circ\ 21'$
Vyagu	$11^R\ 07^\circ\ 18'$
Candrakendra	$0^R\ 14^\circ\ 51'$
Tithi (vārādika)	$2^d\ 48^{gh}\ 45^{vig}$

The above values are the mean positions at the mean fullmoon following the epochal date [March 19, 1520 (J)] i.e. on April 2, 1520 (J), Monday at $48^{gh}\ 47^{vig}$.

Remark : In the chapter *Madhyamādhikāra* the epochal mean positions (*kṣepakas*) are as follows :

Mean Sun : $11^R\ 19^\circ\ 41'$, Mean Moon : $11^R\ 19^\circ\ 06'$

Moon's apogee (*Mandocca*) : $5^R\ 17^\circ\ 33'$ and Rāhu : $0^R\ 27^\circ\ 38'$

$\therefore$ *Vipāta* = Mean Sun – Rāhu = $10^R 22°06'$,

Candra kendra = Mean Moon – *Mandocca* = $6^R 1°33'$

Vārādika = 2^d at the mean sunrise at Ujjayinī.

These are the mean positions at the mean sunrise on *Śaka* 1442 *Caitra Pratipat* (March 19, 1520, Monday). Now, since the mean sunrise is not the time of the *darśānta* (*amāvāsyā*), we shall find out the mean instant of the conjunction of the Sun and the Moon.

The difference between the mean Sun and the mean Moon = $11^R 19° 41' - 11^R 19° 06' = 35' = 2100''$. The difference in the mean daily motions of the Moon and the Sun = $790' 35'' - 59' 08'' = 731' 27'' = 43887''$. Therefore, the time required (after sunrise) for the mean conjunction is

$$\frac{2100}{43887} \times 60 \approx 2\ gh.\ 52\ vig.$$

$\therefore$ *Vārādika* of Amāvāsyā = $2^d\ 2^{gh}\ 52^{vig}$

The motion of the Sun in $2\ gh.\ 52\ vig.$ is $\frac{2\ gh.\ 52\ vig.}{60} \times 59' 08'' \approx 3'$

Thus at the mean conjunction of the Moon and the Sun (i.e., at the instant of the New Moon) we have

the mean Sun = the mean Moon = $11^R 19° 44'$

the Moon's apogee (*mandocca*) = $5^R 17° 33'$

Vṛttam = Moon's *mandakendra*

= Mean Moon – Moon's *mandocca* = $6^R 02° 11'$.

Vipāta (Vyagu) = Mean Sun – Rāhu = $10^R 22° 09'$.

Pākṣika Cālanam **: (Motion of the Sun etc. in the course of a half lunar month) :**

The length of a mean lunar month = $29^d.53059$.

$\therefore$ Half lunar month (*pakṣa*) = $14^d.765295$

The mean motions of the bodies in a *pakṣa* are

(i) Sun : $0^R\ 14^\circ\ 33'$

(ii) Moon : $6^R\ 14^\circ\ 33'$

(iii) *Vṛtta* (*mandakendra*) : $6^R\ 12^\circ\ 54'$

(i.e., Moon's motion – *Mandocca*'s motion = $6^R\ 14^\circ\ 33' - 1^\circ\ 39'$

= $6^R\ 12^\circ\ 54'$)

(iv) *Vipāta's* (i.e., Sun – Rāhu) = $0^R\ 15^\circ\ 20'$ which can be obtained as follows:

Sun's mean daily motion : $59'\ 08''$

Rāhu's mean daily motion : $-3'\ 11''$

$\therefore$ *Vipāta*'s daily motion : $62'\ 19''$ $[= 59'\ 08' - (-3'\ 11'')]$

Hence *vipāta*'s *pākṣika gati*

$$= \frac{62'\ 19'' \times 14^d.765295}{60} \text{ degrees } = 0^R\ 15^\circ\ 20'$$

(v) *Vārādi pākṣika* for *tithi* :

We have *pakṣa* = 14.765295 days. Dividing the number of days by 7 and taking the remainder, we get $0^d\ 45^g\ 55^{vig}$.

Adding the *pākṣika* motions to the relevant *kṣepakas* (epochal positions) we get, at the succeeding full moon: Mean Sun = $0^R 4°21'$,

Vipāta (Vyagu) = $11^R 7°29'$, *Candra kendra* (≡ *Vṛttam*) = $0^R 14°51'$,

Vārādika of *tithi* = $2^d 48^{gh} 55^{vig}$ (with small differences!).

***Śloka* 3** : This *śloka* gives the *dhruvaka* of the mean Sun, *vyagu*, *candrakendra* and *vāra* etc. of *tithi* as follows.

Sun	$0^R\ 1°\ 40'$
Vyagu	$7^R\ 1°\ 12'$
Candrakendra	$9^R\ 1°\ 16'$
Tithi	$5^d\ 9^{gh}\ 36^{vig}$

Dhruvaka is the residual motion in a *cakra* after removing completed revolutions.

***Śloka* 4** : This *śloka* explains the method of finding positions of the Sun and the *vyagu* using *māsagaṇa*. It is as given below :

(i) Find the *māsagaṇa* for the given date.

(ii) Divide the *māsagaṇa* by 67 and multiply it by 2.

(iii) Subtract the result obtained in step (ii) from the *māsagaṇa*. This gives Ravi in *rāśis* etc.

(iv) Take the *māsagaṇa* as *rāśis* (for *Vyagu*). Divide the *māsagaṇa* by 3. Subtract this from the *māsagaṇa* to get the result in *aṃśas*.

(v) Divide the *māsagaṇa* by 4. The result will be in *kalās*.

(vi) The results of steps (iv) and (v) give the *amśas* and *kalās* of *vyagu*.

Example : *Samvat* = 1669, *Śaka* = 1534

Kārtika Śukla Paurṇimā, Thursday i.e. Nov.8, 1612(G).

For the given date, *Cakra* is 8 and *māsagaṇa* is 57.

The *māsagaṇa* is arrived at as follows :

(i) *Śālivāhana Śaka Varṣa* – 1442 = 1534 – 1442

i.e., elapsed years from the epochal year = 92

(ii) *Cakra* = Quotient of $92/11 = 8$

(iii) *Śeṣa* (remainder) = 4

(iv) *Śeṣa* $\times$ $12 = 48$ months

(v) Months elapsed till the beginning of the given month (i.e., *Kārtika*) = 7

(i.e., from *Caitra* to *Āśvayuja*)

(vi) Adding results of (iv) and (v), we get 48 + 7 = 55

(vii) *Adhikamāsas* = 2

(viii) Therefore the total elapsed

Māsagaṇa = 48 + 7 + 2 = 57

To find Ravi :

(i) *Māsagaṇa* $\times$ $2|67$ = $114|67$ *rāśis* etc. = $1^R\ 21^\circ\ 2'\ 41''$

(ii) Ravi = *Māsagaṇa* – item (i)

$$= 57^R - 1^R\ 21^\circ\ 2'\ 41'' = 55^R\ 8^\circ\ 57'\ 19''$$

Removing the multiples of 12 (i.e., 48), we get

Ravi = $7^R\ 8°\ 57'\ 19''$

To find *Vyagu* :

(i) *Māsagaṇa* = 57, ∴ *Rāśis* = 57 i.e. 9^R (removing 48^R)

(ii) Dividing the *māsagaṇa* by 3, quotient = 19

(iii) Dividing the *māsagaṇa* by 4, we get 14.25 *kalās* i.e., 14 *kalās* and 15 *vikalās*.

(iv) *Māsagaṇa* – item (ii) = $57° - 19° = 38°$ (in rāśis)

(v) *Vyagu* = item (i) + item (iv) + item (iii)

$$= 9^R 38° 14' 15'' = 10^R 8° 14' 15''$$

***Śloka* 5** : Now, the method of finding the *vṛtta* (i.e., moon's *mandakendra*, anomaly) and *vārādi* (weekday etc.) of the *tithi* is explained.

(i) Divide *māsagaṇa* by 14.

(ii) Removing the multiples of 14, consider the remainder and divide it by 7.

(iii) Subtract the result of (ii) from the *remainder*.

(iv) Add $\frac{1}{10}^{th}$ of the *māsagaṇa* (in degrees) to item (iii).

This gives the *vṛttam* (this is to be corrected as explained in the next *śloka*).

Example : *Māsagaṇa* = 57

(i) Dividing *māsagaṇa* by 14, the remainder is 1 considered as *rāśis*.

(ii) Remainder/7 = 1/7 *rāśi* = $0^R\ 4°\ 17'\ 08''$

(iii) Remainder – Remainder/7

$$= 1^R - 0^R\ 4°\ 17'\ 08'' = 0^R\ 25°\ 42'\ 52''$$

(iv) *Māsagaṇa*/10 + item (iii)

$$= 5°\ 42' + 0^R\ 25°\ 42'\ 52'' = 1^R\ 1°\ 24'\ 52''$$

Thus, *Vṛttam* = $1^R\ 1°\ 24'\ 52''$

(this has to be further corrected with *dhṛuva* and *kṣepaka*, explained in the next *śloka*).

To find the *vārādi* of *tithi* :

(i) Divide the *māsagaṇa* by 14 and consider the remainder.

(ii) Add $\frac{1}{2}$ of the remainder to itself.

(iii) Multiply the *māsagaṇa* by 10.

(iv) Divide the product by 327.

(v) Add the result of (iv) to (ii).

This gives the *vārādika* (weekday etc.) of the *tithi*.

Example : *Māsagaṇa* = 57

(i) *Māsagana* /14 : Quotient = 4, Remainder = 1.

(ii) Remainder + Remainder/2

$$= \left(1 + \tfrac{1}{2}\right)^d = 1^d\ 30^{gh}$$

(iii) *Māsagaṇa* $\times$ 10 = $57 \times 10 = 570$

(iv) Dividing (iii) by 327, we get $1^{d}\ 44^{gh.}\ 35^{vig.}$

(v) Adding (ii) and (iv), we get

$$1^{d}\,30^{gh.} + 1^{d}\,44^{gh.}\,35^{vig.} = 3^{d}\ 14^{g}\ 35^{vig.}$$

Thus, the *vārādik*a (weekday etc.) of the *tithi*

$$= 3^{d}\ 14^{gh}\ 35^{vig}$$

(This has to be further corrected with *dhruva* and *kṣepaka* as explained in the next *śloka*).

***Śloka* 6** : Here, corrections with *dhruvaka* and *kṣepaka* are explained.

(i) In the case of Ravi, subtract ($cakra \times dhruvaka$) from and add *kṣepaka* to the *māsagaṇa* derived Ravi (obtained from *Śloka* 4).

(ii) In the case of *vipāta* (or *vyagu*), *vṛtta* (Moon's *mandakendra*) and *vārādika* (weekday etc.) of the *tithi* add ($cakra \times dhruvaka$) and *kṣepaka* to the corresponding *māsagaṇa* derived results.

Example :Śaka 1534 Kārtika śukla paurṇimā, Thursday.

(i)	**Ravi** : *Māsagaṇa* derived Ravi	=	$7^{R}\ 8°\ 57'\ 19''$
	Subtract $Dhruvaka \times Cakra$:		$-\ 0^{R}\ 13°\ 20'$
	We get		$6^{R}\ 25°\ 37'\ 19''$
	Add *kṣepaka* :		$+\ 0^{R}\ 04°\ 21'$

	Corrected Mean Ravi :	**$6^R\,29°\,58'\,19''$**
(ii)	***Vyagu*** : *Māsagaṇa* derived *vyagu* =	$10^R\,08°14'15''$
	Add (*Cakra* × *Dhruvaka*) :	$+8^R\,09°\,36'$
	Add *kṣepaka* :	$+11^R\,07°18'$
	Corrected *vyagu* :	$5^R\,25°08'15''$
(iii)	***Vṛtta*** **(moon's *mandakendra*)** :	
	Māsagaṇa derived *vṛtta* =	$1^R\;01°\;24'\;52''$
	Add (*Cakra* × *Dhruvaka*) :	$+\;0^R\;08°\;48'$
	Add *kṣepaka* :	$+\;0^R\;14°\;51'$
	Corrected *vṛtta* :	$1^R\;25°\;03'\;52''$

(iv) ***Vārādika* of *tithi*** :

Māsagaṇa derived :	3^d	14^{gh}	35^{vig}
Add (*Cakra* × *Dhruvaka*) :	+6	16	48
Add *kṣepaka* :	+2	48	45
Adding the above results:	12^d	20^{gh}	08^{vig}

Removing the nearest multiple of 7^d we get

Vārādika of *tithi* : $5^d\ 20^{gh}\ 08^{vig}$ (5^d indicates Thursday)

Śloka 7 : This *śloka* gives the motions in a *pakṣa* of the Sun, *vipāta*, *vṛtta* and *vārādika* of *tithi*. It is as given below.

The motion of the Sun = $0^R\ 14°\ 33'\ 0''$

The motion of the *vipāta* = $0^R\ 15°\ 20'\ 0''$

The motion of the *vṛtta* = $6^R\ 12°\ 54'\ 10''$

The motion of the *vārādika* of *tithi* = $0^d\ 45^g 55^{vig}$

The derivations of the above are shown in our explanation of *Śloka* 2.

Śloka 8 : The motions of Ravi, *vipāta, vṛtta* and *vārādika* of *tithi* in six months are given as below :

The motion of Ravi = $5^R\ 24°\ 38'$

The motion of *vipāta* = $6^R 4° 01'$

The motion of *vṛtta* = $5^R\ 4°\ 53'$

The motion of *dinādi* (vārādi) of *tithi* = $2^d\ 11^{gh}\ 01^{vig}$

Śloka 9 : Now, for the given (*iṣṭa*) *tithi*, finding of *dinādi* (weekday etc.) of the *tithi*, Ravi and *vṛtta* (Moon's *mandakendra*) is explained.

(i) From the *tithi* (before or after *pūrṇimānta* i.e., in the *śukla* or *kṛṣṇa pakṣa*) $1/64^{th}$ of it is subtracted. This gives the motion of the *tithi* in *vārādika* (weekday etc.)

i.e., Motion of *tithi* = $Tithi - Tithi/64$

(ii) Ravi's motion = $Tithi - Tithi/34$

(iii) *Vṛttam* motion = $[Tithi - Tithi/93] \times 13$

Derivation of the above expressions

Duration of a lunar month = $29^{d}\ 31^{gh}\ 50^{vig}$

Therefore, we have

(i) Civil days of the given *tithi*

$$= \frac{Tithi}{30} \times \left(29^{d}\ 31^{gh}\ 50^{vig}\right)$$

$$\approx \frac{Tithi}{30} \times \left(\frac{106310}{3600}\right)$$

$$= \frac{Tithi \times 10631}{10800}$$

$$= \frac{Tithi\,(10800 - 169)}{10800}$$

$$= Tithi - (169/10800)\ Tithi$$

$$\approx Tithi - Tithi/64$$

(ii) Ravi : Mean daily motion = $59'\,08''$

Civil days of *Tithi* = $Tithi - Tithi/64 = [(63|64) \times Tithi]$

$\therefore$ Motion of Ravi for the given *Tithi*

$$= (63/64) \times Tithi \times 59'\,08''$$

$$= \frac{63}{64} \times Tithi \times \left(\frac{3548}{3600}\right)^{\circ} = \frac{63}{64} \times (Tithi) \times \left(\frac{887}{900}\right) = \frac{55881}{57600} \times Tithi$$

$$= \frac{57600 - 1719}{57600} \times Tithi = \left(1 - \frac{1719}{57600}\right) \times Tithi$$

$$= \left(1 - \frac{1}{33.51}\right) \times Tithi \approx \left(1 - \frac{1}{34}\right) \times Tithi$$

(iii) *Vṛttam*, Moon's *mandakendra* :

We have

Moon's daily motion – *Mandocca*'s daily motion

$$= 790'\,35'' - 6'\,41'' = 783'54''$$

i.e., *Vṛatta*'s daily motion $= 783'\,54''$

Now, therefore the motion of *vṛtta* for 1 (one) *tithi* is given by $\frac{63}{64} \times 783'\,54''$

$\therefore$ For the required *tithi* (*iṣṭatithi*), the motion of *vṛtta* is

$$Tithi \times \frac{63}{64} \times 783'\,54'' = Tithi \times \frac{63}{64} \times \left[\frac{47034}{3600}\right]^{\circ}$$

$$= Tithi \times (12.8609) = Tithi \frac{92}{93} \times 13$$

$$= Tithi \times \frac{93-1}{93} \times 13 = Tithi \times \left(1 - \frac{1}{93}\right) \times 13$$

$$= \left[Tithi - \frac{Tithi}{93}\right] \times 13$$

Śloka 10 : Now, for finding the true Sun and the true *tithi*, the *mandakendras* of the Sun and the Moon will be obtained.

The *khaṇḍas* to find *mandakendraphalam* are as follows :

17, 16, 14, 12, 9, 5 and 2.

(i) Divide the *bhujāṃśa* of *vṛtta* by 13.

The resulting quotient gives the total number of elapsed or *gata khaṇḍas*.

(ii) Multiply the remainder obtained in step (i) by *eṣyakhaṇḍa* (the *khaṇḍa* to be covered) and divide the product by 13.

(iii) Add the above result to the sum of the *gatakhaṇḍas*. The result gives *mandakendraphalam* of Candra.

(iv) In the case of Ravi, considering the *mandakendra* of Ravi,follow the procedure of (i) to (iii) above. Then divide the result of (iii) by 2. Subtract $\frac{1}{6}^{th}$ of this result from itself. This gives the *Raviphalam*.

Example : *Vṛtta* = $1^R\ 25°\ 3'\ 52''$ (see example under Śloka 6).

Its *Bhuja* = $55°\ 3'\ 52''$

(i) Now, $\dfrac{Bhuja}{13^\circ} = \dfrac{55^\circ\,3'\,52''}{13^\circ} = 4 + \dfrac{3^\circ\,3'\,52''}{13^\circ}$

This implies that the number of *gatakhaṇḍas* is 4. They are 17, 16, 14 and 12. Their sum = 17 + 16 + 14 + 12 = 59

Eṣyakhaṇḍa (or *Bhogyakhaṇḍa*) = 9

(ii) $\dfrac{Bhogyakhanda \times \text{Remainder}}{13} = \dfrac{3^\circ\,3'\,52'' \times 9}{13} = 2^\circ\,7'\,17''$

(iii) Sum of *gatakhaṇḍas* + item (ii)

$= 59^\circ + 2^\circ\,7'\,17'' = \mathbf{61^\circ\,7'\,17''}$

Candra's *mandakendraphalam* (*vṛttaphalam*) = $+\,\mathbf{61^\circ\,7'\,17''}$ (additive)

Note :

(i) If *vṛttam* is within 6 *rāśi*s from *Meṣa* (i.e., if $0^\circ <$ *vṛttam* $< 180^\circ$) then *mandakendraphalam* is additve.

If *vṛttam* is within 6 *rāśi*s from *Tulā*

i.e., if ($180^\circ <$ vṛttam $< 360^\circ$) then *mandakendraphalam* is negative.

(ii) The *mandakendraphalam* defined here is different from the *mandaphalam* (eqn. of centre) used in the *Śpaṣṭādhikāra*. However, the former is a multiple of the latter.

Now, Ravi = $6^R\,29^\circ\,58'\,19''$

Mandocca of *Ravi* = $2^R\,18^\circ = 78^\circ$ (from example under Śloka 6).

Ravikendra = *Mandocca* – Ravi

$= 78° - 6^R\ 29°\ 58'\ 19'' = 7^R\ 18°\ 1'\ 41''$ (adding 12^R)

$= 228°\ 1'\ 41''$

Bhuja of Ravikendra $= 228°\ 1'\ 41'' - 180° = 48°\ 1'\ 41''$

(i) $$\frac{Bhuja}{13°} = \frac{48°\ 1'\ 41''}{13°} = 3 + \frac{9°\ 1'\ 41''}{13°}$$

This implies that the number of *gatakhaṇḍas* = 3

They are 17, 16 and 14.

Their sum = 17 + 16 + 14 = 47

Remainder = $9°\ 1'\ 41''$

Eṣyakhaṇḍa = 12

(ii) Sum of the *gatakhaṇḍas* + $\dfrac{\textit{Eṣyakhaṇḍa} \times \text{Remainder}}{13}$

$$= 47 + \frac{12 \times 9°\ 1'\ 41''}{13} = 55°\ 20'\ 0''$$

(iii) Take half of item (ii) :

$$\frac{55°\ 20'\ 0''}{2} = 27°\ 40'\ 0''$$

(iv) Subtract $1/6^{th}$ of (iii) from (iii) :

$$27° \; 40' \; 0'' - \frac{27° \; 40' \; 0''}{6} = 23° \; 03' \; 20''$$

Since Ravi = $6^R \; 29° \; 58' \; 19'' > 180°$ the above result is subtractive.

Therefore,

Ravi's *mandakendraphalam* (*vṛttaphalam*) = $-23° \; 03' \; 20''$

Note : Here also, the *"mandakendraphalam"* of Ravi is different from the *mandaphalam* (equation of centre) explained in *Spaṣṭādhikāra*.

Now, *Candraphalam* + *Raviphalam*

$= 61° \; 07' \; 17'' + (-23° \; 03' \; 20'')$

$= 38° \; 03' \; 57''$

This is the combination of the two *phalams* (*phala-dvaya-samskṛti*).

***Śloka* 11** : This *śloka* gives the method for finding *hara* (for determining *tithi*).

(i) Find *bhogyakhaṇḍa* (or *eṣyakhaṇḍa*) of *vṛtta*. Divide it by 6 and the result is taken in degrees (*amśas*) etc.

(ii) Divide the *amśas* obtained in step (i) by 3 and add $30°$ to it.

(iii) Subtract the result of (i) from that of (ii). This gives *hara*.

i.e., $$Hara = \left(30° + \frac{amsas}{3}\right) - \frac{Bhogyakhaṇḍa}{6}$$

Example : *Vṛtta* = $1^R \; 25° \; 3' \; 52''$, *Bhogyakhaṇḍa* of *vṛtta* = 9 (obtained in the previous *śloka*)

(i) $\dfrac{\textit{Bhogyakhaṇḍa}}{6} = \dfrac{9}{6} = 1°\,30'$

(ii) $\dfrac{\textit{aṃśa obtained in(i)}}{3} + 30° = \dfrac{1°}{3} + 30° = 20' + 30° = 30°\,20'$

(iii) $\therefore$ *Hara* = step (ii) – step (i)

$$= 30°\,20' - 1°\,30' = 28°\;50'$$

Now, *Cara* must be obtained (as explained in *Ravicandra spaṣṭādhikāra, Ślokas* 5 and 6) from the true longitude of the Sun.

Example : We have, *Nirayana* Ravi : $6^R\ 29°\ 58'\,19''$

Ayanāṃśa : $18°\ 10'$ and hence

Sāyana Ravi : $7^R\ 18°\ 08'\,19''$ and *Cara* = + 84

***Śloka* 12** : The method of obtaining true (*spaṣṭa*) *tithi* is explained :

(i) Consider *phalasamskṛti* (i.e., *Raviphalam* + *Candraphalam*, obtained in *Śloka* 10). Multiply this by 10 and divide by *hara*. The result will be in *ghaṭīs*.

(ii) Find *cara*. If *cara* is positive, then consider it as negative. If *cara* is negative consider it as positive (i.e., take the opposite sign).

(iii) Consider the *deśāntara* distance in *yojanas*. Subtract $\frac{1}{4}$ of *deśāntara* distance from itself. The result is called *deśāntaraphalam*.

Cara is subtracted from the *deśāntaraphalam*, given by *deśāntara* in *yojanas* reduced by $\frac{1}{64}$ of it (taken positive or negative according as the place is to the east or west of the Ujjaiyinī meridian). This has to be added to or subtracted from (according as it is $+^{ve}$ or $-^{ve}$) the result obtained in item (i).

Example : We have, from the example under *Ślokas* 10 and 11

Phalasamskṛti = $+38° \; 3' \; 57''$

and *hara* = $28|50$

(i) $$\frac{Phalasamskṛti \times 10}{hara} = \frac{(38|3|57) \times 10}{28|50} = +13|12$$

(ii) We have *Cara* = + 84

(iii) *Deśāntara yojanam* = 64 *yojanas.*

Now, $64 - \frac{64}{4} = 48$

(iv) Taking the *opposite sign* for the *cara* (i.e., – 84), we have

– *Cara* + 48 = – 84 + 48 = – 36

Phalatraya samskṛti = 13′ 12″ – 0′ 36″ = 12′ 36″ (in *kalās*)

(v) *Tithi* = $5^d \; 20^{gh} \; 8^{vig}$ (mean *tithi vārādika* obtained under Śloka 6).

The *phalatraya sanskṛti* 12 | 36, considered as ghaṭīs, being additive, with the **mean** *vārādi* of *tithi* gives true ***vārādi*** of *tithi* as $5^d 32^{gh} 44^{vig}$.

(vi) We have obtained earlier (in example **under Śloka** 6):

Nirayaṇa Mean Ravi : $6^R \; 29° \; 58' \; 19''$

Phala-traya-saṃskāra : $+12' \; 36''$

Corrected Nirayaṇa Ravi: $7^R\ 0°\ 10'\ 55''$

(vii) *Vyagu* (obtained earlier): $5^R\ 25°\ 08'\ 15''$

(According *Viśvanātha*) :

Phala-traya-samskāra : $+12'\ 36''$

Corrected *vyagu:* $5^R\ 25°\ 20'\ 51''$

***Śloka* 13** : The method of obtaining true Sun and true *vyagu* is explained as follows.

(i) Multiply *Raviphalam* by 4. The result will be in *kalās*.

(ii) Divide the above result by 24.

(iii) Add the results of step (i) and step (ii).

(iv) The result of step (iii) is added to or subtracted from Ravi accordingly to get *spaṣṭa* Ravi. Similarly the same result of step (iii) is added to or subtracted from *vyagu* to get *spaṣṭa vyagu*.

(v) Add $\left(2 - \frac{1}{3}\right)$ to *hara*. Divide this by 3. The result gives the diameter of the Moon in *aṅgulas*. The moon's diameter

i.e., $$Candrabimbam = \frac{hara + \left(2 - \frac{1}{3}\right)}{3} \text{ aṅgulas.}$$

Example : We have *Raviphalam* = $23'\ 3''\ 20'''$

(i) $Raviphalam \times 4 = 92'\ 13''\ 20'''$

(ii) $\dfrac{Raviphalam \times 4}{24} = 3' \, 50'' \, 33''$

(iii) $92' \, 13'' \, 20''' + 3' \, 50'' \, 33''' = 96' \, 3'' \, 53''' = 1^\circ 36' 3'' 53'''$

(iv) Ravi (obtained earlier from *Śloka* 12) : $7^R \, 0^\circ \, 10' \, 55''$

Since (iii) is subtractive, we get

Spaṣṭa Ravi = $7^R \, 0^\circ \, 10' \, 55'' - (1^\circ \, 36' \, 3'' \, 53''')$

i.e. **True Ravi** = $6^R \, 28^\circ 34' 52''$ (neglecting $53'''$)

(iv) (Earlier obtained) *Vyagu* = $5^R \, 25^\circ \, 20' \, 51''$

Subtracting item (iii) : $-1^\circ \, 36' \, 3''$ (neglecting $53'''$)

True *Vyagu* : $5^R \, 23^\circ 44' 48''$

(v) Now, we have

$$Candrabimbam = \frac{hara \times \left(2 - \frac{1}{3}\right)}{3} \text{ } a\dot{n}gulas$$

$$= \frac{28|50 \times \left(2 - \frac{1}{3}\right)}{3} \text{ } a\dot{n}g. = \frac{30|30}{3} \text{ } a\dot{n}g. = 10|10 \text{ } a\dot{n}gulas$$

i.e., Diameter of the Moon = 10|10 *aṅgulas*

Śloka **14** : This *śloka* explains the method of finding the diameters of the Sun and earth's shadow.

For the *Ravibimbam* (Sun's diameter) :

(i) Consider $\left(11-\frac{1}{6}\right) = 10|50$ *aṅgulas*

(ii) Divide *bhogya* (*agrima*) *khaṇḍa* by 40.

(iii) According as the Ravi *(manda) kendra* is from $90°$ to $270°$ (II or III quadrant) or from $270°$ to $90°$ (IV or I quadrant) item (ii) must be *added to* or *subtracted from* item (i). This gives

$$Ravibimbam = (10|50) \pm \frac{Agrimakhaṇḍa}{40}$$

(iv) The diameter of the earth's shadow cone

$$Bhūbhābimbam = (Hara-5)+\frac{Hara-5}{15}\pm\frac{Agrimakhaṇḍa}{50}$$

where $+^{ve}$ sign or $-^{ve}$ sign is taken according as Ravi *(manda) kendra* is between $270°$ and $90°$ (i.e., IV or I quadrant) or between $90°$ and $270°$ (i.e., II or III quadrant).

Example : *Agrimakhaṇḍa* (i.e., the last of the elapsed *khaṇḍas*) of the Sun's *manda kendra* is 12 (obtained in *Śloka* 10). Therefore,

(1) *Ravibimbam* = $(10|50)-\frac{12}{40} = 10|32$ *aṅgulas*

Note that the Ravi *(manda) kendra* = $228°\ 1'\ 41''$ (lying in III quadrant).

(2) *Bhūbhābimbam* : Here, *hara* = $28|50$.

$\therefore$ Earth's shadow diameter

$$= (28|50 - 5) + \frac{28|50 - 5}{15} - \frac{12}{50} = (23|50) + \frac{23|50}{15} - \frac{12}{50}$$

$$= 23|50 + 1|35 - 0|14 = 25|11 \text{ } \textit{aṅgulas}.$$

***Śloka* 15** : Here the possibility (or otherwise) of an eclipse is explained.

As explained earlier, the *tithi* etc. (i.e., *tithi, śara, bimba* etc.) are used for determining an eclipse. After the occurrence of an eclipse, a fortnight earlier or later than six months hence (i.e., $5\frac{1}{2}$ or $6\frac{1}{2}$ months) or a fortnight hence, the possibility of an eclipse is to be found out. If the *bhujāṃśa* is less than $15°$ an eclipse is possible. Further, if the (southern) *bhujāṃśa* of the *vyagu* is less than $8°$, then the possibility of a solar eclipse has to be considered. If the duration of the day is greater than that of the *tithi* (new moon), then a solar eclipse can be considered. On the otherhand, if the *tithi* (full-moon) ends after the sunset, a lunar eclipse can be considered.

***Śloka* 16** : This *śloka* explains the method of finding *grāsa* (or *channam*) in the case of a lunar eclipse as follows.

(i) Subtract $3|20$ from *hara* and multiply the difference by 4.

(ii) Divide the above result by 9.

(iii) Subtract the *bhujāṃśa* of *vyagu* from the result of step (ii) and multiply the difference by 11.

(iv) Divide the result of step (iii) by 7. This gives *channam* or *grāsa* in *aṅgulas* in the case of a lunar eclipse.

i.e., *Grāsa* (or *Channam*) = $\left\{\frac{(hara - 3|20)\,4}{9} - \textit{bhuja} \text{ of } \textit{vyagu}\right\} \times \frac{11}{7}$

Note : If the *bhuja* of *vyagu* is greater than the result of step (ii) then there is *no eclipse.*

Example : We have, *hara* = $28|50$

(i) $(28|50 - 3|20) \times 4 = 102|0$

(ii) $\frac{102|0}{9} = 11|20$

(iii) *Vyagu bhujāṃśa* = $6|15|12$

Now, $11|20|0 - 6|15|12 = 5|4|48$

(iv) *grāsa* = $\frac{5|4|48 \times 11}{7} = \frac{55|52|48}{7} = 7|58$ *aṅgulas*

***Śloka* 17** : This *śloka* gives the method of finding *grāsa* (or *Channam*) in the case of a solar eclipse as follows.

(i) Find *darśānta* and *natam* at *darśānta.*

(ii) Divide *natam* by 4. The result will be in *rāśis.*

(iii) In the case of *pūrva* (i.e., eastern) *nata* subtract $\frac{1}{4} \times nata$ from the Sun, and in the case of *paścima* (i.e., western) *nata* add $\frac{1}{4} \times nata$ to the

Sun. This gives *the nata* corrected Sun.

(iv) Find the *krānti* (declination) of the *nata* corrected Sun.

(v) Now, *natāṃśa* = *krānti* ±*akṣāṃśa* $\equiv(\delta-\phi)$

(vi) Divide *natāṃśa* by 6.

(vii) Add the result of step (vi) to *vyagu bhujāmśa* if *natāmśa* and *vyagu* are in the same direction. Otherwise, subtract the result of step (vi) from *vyagu bhujāṃśa.*

(viii) Subtract the result of step (vii) from 7 and divide it by 2. Then

(ix) *Grāsa* = $(7 - step\ (vii)) + \left(\dfrac{7 - step\ (vii)}{2}\right)$

in *aṅgulas* in the case of a solar eclipse.

Note : If it is not possible to subtract the result of step (vii) from 7. (i.e., step (vii) > 7) then *there is no eclipse*

Example : *Smavat* 1669, *Śaka* 1534, *Vaiśākha kṛṣṇa* 30 (*amāvāsyā*), Wednesday, *Cakra* 8, *Māsagaṇa* = 51. End of the *amāvāsyā* i.e., *amānta* = 26|40 *gh.*

(i.e. May 30, 1612 (G) A.D., Wednesday).

We have

dinārdham = 16|48 gh.

(i) *nata* = 9|52 in the west (obtained as explained earlier)

(ii) $\dfrac{nata}{4} = \dfrac{9|52}{4} = 2^R|14^\circ$

(iii) *nata* corrected Ravi = $4^R\ 5^\circ\ 26'\ 34''$

(iv) *krānti* of the *nata* corrected Ravi = $13^\circ\ 52'\ 22''$ (north) $\equiv \delta$

(v) *akṣāṃśa* = $25^\circ\ 26'\ 42'' \equiv \phi$

$\therefore$ *natāṃśa* $(\delta - \phi) = 13^\circ\ 52'\ 22'' - 25^\circ\ 26'\ 42''$

$= -11^\circ\ 34'\ 20''$ *i.e.*, $11^\circ\ 34'\ 20''$ (south)

(vi) $\dfrac{natāṃśa}{6} = \dfrac{11^\circ\ 34'\ 20''}{6} = 1^\circ\ 55'\ 43''$ (south)

(vii) *vyagu bhujāṃśa* = $7^\circ\ 59'\ 36''$ (north)

Now $7^\circ\ 59'\ 36'' - 1^\circ\ 55'\ 43'' = 6^\circ\ 3'\ 53''$

(viii) $7^\circ - 6^\circ\ 3'\ 53'' = 0^\circ\ 56'\ 7''$

(ix) $\dfrac{0^\circ\ 56'\ 7''}{2} = 0^\circ\ 28'\ 3''$

$\therefore$ *Grāsa* = $0|56|7 + 0|28|3 = 1|24$ *aṅgulas*

***Śloka* 18** : This *śloka* explains the determination of the *parveśa* (Lord of the *parva*).

(i) Find the mean *vyagu* using the *māsagaṇa*. Divide the number in the *rāśi* position by 12. This result is called *vyagu madhya paryāya gaṇa*

(ii) Multiply the above result by 2.

(iii) If *vyagu* is greater than 180° add 1 to it.

(iv) Add *cakra* to the above result and then divide by 7. The remainder gives the *parveśa* as follows :

Remainder	*Parveśa*
1	*Brahmā*
2	*Candra*
3	*Indra*
4	*Kubera*
5	*Varuṇa*
6	*Agni*
7 or 0	*Yama*

Note : The remainder indicates *gataparveśa;* to get the present (*vartamāna*) *parveśa*, add 1 to it.

Śloka 19 : Now, the determination of the Moon's position from that of the Sun is explained.

(i) Multiply the *tithi* number by 12. The result will be in degrees.

(ii) Add the above result to the *spaṣṭa* Ravi.

(iii) Multiply *hara* by 24 and add 62 to the product. This gives *candragati* (i.e., daily motion of the Moon) in *kalās*. i.e., *Candragati* = $(hara \times 24) + 62$

(iv) *Sūrya gati* (daily motion of the Sun) = $59' 08''$

(v) Find the *tithikāla* using the Sun and the Moon obtained above.

(vi) Also find the *gata* (elapsed) and the *gamya* (balance) *ghaṭīs* of the *nakṣatra* and *yoga*.

Example : *Thithi* = 15, **Ravi** : $6^R\ 28^\circ\ 34'\ 52''$ and ***hara*** = $28|50$

(i) *Spaṣṭa* Candra = $(15 \times 12)^\circ + 6^R\ 28^\circ\ 34'\ 52'' = 0^R\ 28^\circ\ 34'\ 52''$

(removing 12 *rāśis)*

(ii) *Candragati* = $28|50 \times 24 + 62 = 754'$.

CHAPTER 8

GRAHAṆADVAYA SĀDHANĀDHIKĀRAḤ

(Eclipses from *Pañcāṅga* - Shortcut Method)

Śloka **1** : Now, the computations of the two eclipses (solar and lunar) by a shorter method based on the data from the *pañcāṅga* (almanac) viz., *parvānta* (end of the lunar fortnight), postions of the Sun, the Moon and Rāhu, *gata* (elapsed) and *eṣya* (balance) *ghaṭīs* of *tithi* and *nakṣatra*, duration of the day (from sunrise to sunset) are explained.

Example : We have the following data from *pañcāṅga* :

Samvat year = 1669, *Śaka* year = 1534

Vaiśākha Śukla Pūrṇimā, Monday [i.e. May 14-15, 1612 (G)]

The elapsed portion of *Pūrṇimā*

$$gataghaṭī = 2|23 \ gh.$$

The balance portion of *Pūrṇimā*

$$eṣyaghaṭī = 54|20 \ gh.$$

Sum of the *gata* and the *eṣya ghaṭīs,*

Tithiyoga ghaṭī = $2|23 + 54|20 = 56|43$ *gh.*

gataghaṭīs of the *Anurādhā nakṣatra* = $20|4$ *gh.*

eṣyaghaṭīs of *Anurādhā* = $38|35$ *gh.*

Sum of the *gata* and *eṣya ghaṭīs* of *Anurādhā nakṣatra*

= $20|4 + 38|35 = 58|39$ *gh.*

Dinamānam = $33|6$ *gh.*

Ravi at *parvānta* = $1^R\ 6°\ 34'\ 37''$

Rāhu at *parvānta* = $1^R\ 14°\ 18'\ 11''$

Virāhvarka = (Sun – Rāhu) = $11^R\ 22°\ 16'\ 26''$

***Śloka* 2** : This *śloka* explains the method of finding *channam* (*grāsa*) as follows :

(i) Subtract 7 from *tithiyoga ghaṭī* (i.e., the sum of the *gata* and *the eṣya ghaṭīs* of the *tithi*)

(ii) Divide 627 by the result of step (i). The result will be in *aṃśas.*

(iii) Subtract *bhujāṃśa* of *vyagu* from item (ii).

(iv) Add $\frac{1}{16}$ of item (iii) + and $\frac{1}{2}$ of item (iii) to item (iii) i.e., take the sum : item (iii) + $\frac{1}{16}$ item (iii) + $\frac{1}{2}$ item (iii).

This sum gives *grāsa* or *channam* in *aṅgulas.*

i.e., Let $x = \left[\dfrac{627}{tithiyoga - 7} - bhuj\bar{a}\dot{m}\acute{s}a\ \ of\ \ vyagu\right]$, Then, *grāsa* (*channam*) = $x + \frac{x}{16} + \frac{x}{2}$ *aṅgulas*

Example : *Tithiyoga* = $56|43$ *gh. and Vyagubhuja* = $7^\circ\ 43'\ 34''$

$$\text{Then } x = \left[\frac{627}{56|43 - 7|0} - 7^\circ\ 43'\ 34''\right] = 4|53|7$$

grāsa (*channam*) = $x + \frac{x}{16} + \frac{x}{2} = 7|37|59$ *aṅgulas*

Śloka **3** : This *śloka* gives the formula for finding diameters of the Moon and earth's shadow in the case of lunar eclipse as follows :

(1) **The diameter of the Moon,**

$$\textit{Candrabimbam} = \frac{695}{\textit{tithiyoga} + 6} \ \textit{aṅgulas}$$

(2) The diameter of the earth's shadow

$$\textit{Bhūbhābimbam} = \frac{1322}{\textit{tithiyoga} - 10} \ \textit{aṅgulas}$$

Example : *Tithiyoga ghaṭī* = $56|43$ *gh.*

(1) *Candrabimbam* = $\frac{695}{56|43 + 6} = 11|4$ *aṅgulas*

(2) *Bhubhābimbam* = $\frac{1322}{56|43 - 10} = 28|17$ *aṅgulas.*

Śloka **4** : This *śloka* gives the method of finding *grāsa* using *nakṣatra ghaṭī.*

It is as follows :

(i) Subtract 10 from *nakṣatrayoga ghaṭī* (sum of *gata* and *eṣya gaṭīs* of *nakṣatra*)

(ii) Divide 610 by item (i).

(iii) Subtract *bhujāṃśa* of *vyagu* from item (ii).

(iv) Multiply item (iii) by 11.

(v) Divide item (iv) by 7. This gives *grāsa* in *aṅgulas.*

i.e., $Grāsa = \left[\dfrac{610}{Nakṣatrayoga\ ghaṭī\text{ - }10} - Bhujāṃśa\,of\,vyagu\right] \times \dfrac{11}{7}$ *aṅg*

Example : *Nakṣatrayoga ghaṭī* = 58|36 *gh.*

Vyagu bhujāṃśa = 7° 43′ 34″

$$\therefore grāsa = \left[\frac{610}{58|36-10} - 7^\circ\ 43'\ 34''\right] \times \frac{11}{7} = 7|34 \text{ aṅgulas}$$

Remark : We had obtained earlier (from *śloka* 2) *grāsa* = 7|37|59 *aṅgulas* using *tithi yoga ghaṭīs.*

Viśvanātha in his commentary gives a correction (*samskāra*) to the ***bhūbhābimbam*** (diameter of the shadow cone) as follows :

Consider the following values in *pratyaṅgulas* for six *rāśis* : 11, 16, 20, 16, 11, 0. If Ravi is within 6 *rāśis* from *Meṣa* then *add* the corresponding value for that *rāśi* to the *bhūbhābimbam* (obtained earlier from *Śloka* 3). If Ravi is in a *rāśi* among the six *rāśis* from *Tulā* then *subtract* the corresponding values.

Example : The *bhūbhābimbam* obtained earlier : $28|17$ *aṅgulas.*

$$\text{Ravi} = 1^R\, 6^\circ\, 34'\, 37''$$

i.e., in the second *rāśi* from *Meṣa*. The corresponding value in *pratyaṅgulas* is 16. Therefore, corrected *bhūbhābimbam* = $28|17 + 0|16 = 28|33$ *aṅgulas.*

***Śloka* 5** : This *śloka* gives the method of finding the *candrabimbam* (diameter of the Moon) and the *bhūbhābimbam* (diameter of earth's shadow) using *nakṣatrayoga ghaṭī*. It is as follows :

$$(1)\ \textit{Candrabimbam} = \frac{649}{\textit{nakṣatrayoga ghaṭī}}\ \textit{aṅgulas}$$

$$(2)\ \textit{Bhūbhābimbam} = \frac{1255}{\textit{nakṣatrayoga ghaṭī} - 14}\ \textit{aṅgulas}$$

Example : *Nakṣatrayoga ghaṭī* = $58|36$

$$(1)\ \textit{Candrabimbam} = \frac{649}{58|36} = 11|4\ \textit{aṅgulas}$$

$$(2)\ \textit{Bhūbhābimbam} = \frac{1255}{58|36 - 14} = 28|8\ \textit{aṅgulas}$$

Viśvanātha's suggested correction (under *Śloka* 4) yields :

$$\textit{Bhūbhābimbam} = 28|8 + 0|16 = 28|24 \ \textit{aṅgulas}$$

Remark : Viśvanātha gives another method for obtaining *bhūbhābimbam* (and its correction) :

$$\textit{Bhūbhābimbam} = \frac{1200}{\textit{Nakṣatrayoga ghaṭī} - 16}$$

$$= \frac{1200}{58|36 - 16} = 28|10 \ \textit{aṅgulas}$$

$\therefore$ Corrected *bhūbhābimbam* $= 28|10 + 0|16 = 28|26$ *aṅgulas*

***Śloka* 6** : This *śloka* explains the method of finding *grāsa* (*channam*) of solar eclipse using *tithi ghaṭī*. It is as follows.

(i) Divide 170 by *tithighaṭī*.

(ii) Add 4 to item (i).

(iii) Subtract *vyagusphuṭa bhujāṃśa* from item (ii) [see note below].

(iv) Multiply item (iii) by 11, and divide the product by 7. This gives *grāsa* of Ravi in *aṅgulas*.

i.e., $$\textit{grāsa} = \left[\left[\left(\frac{170}{\textit{tithi ghaṭī}}\right)+4\right] - \textit{vyagu sphuṭa bhujāṃṣa}\right] \times \frac{11}{7}$$ *aṅgulas*

Example : On a solar eclipse day, *Tithighaṭī* $= 64|49$

$$\textit{Vyagusphuṭa bhujāṃśa} = 1^\circ\ 56'\ 45''$$

$$\textit{Grāsa} \text{ of Ravi} = \left[\left(\frac{170}{64|49} + 4\right) - 1^\circ\ 56'\ 45''\right] \times \frac{11}{7} = 7|20|58 \ \textit{aṅgulas}$$

Another Method for *grāsa* of Ravi :

Another method of finding *grāsa* of Ravi using *nakṣatraghaṭī* is as given below :

(i) Divide 233 by *nakṣatraghaṭī*. The result will be in *amśas.*

(ii) Add 3 to item (i).

(iii) Subtract *vyagu sphuṭa bhujāṃśa* from item (ii).

(iv) Multiply item (iii) by 11, and divide by 7. This gives *grāsa* of Ravi in *aṅgulas.*

i.e., *Grāsa* of Ravi

$$= \left[\left(\frac{233}{\textit{nakṣatraghaṭī}} + 3\right) - \textit{vyagu sphuṭa bhuja}\right] \times \frac{11}{7}$$

Example : On a solar eclipse day, *Nakṣatraghaṭī* = $65|56$

$$\therefore\ \textit{Grāsa} = \left[\left(\frac{233}{65|56} + 3\right) - 1^\circ\ 56'\ 45''\right] \times \frac{11}{7} = 7|12|35 \ \textit{aṅgulas}$$

We notice a small difference of only about 8 *pratyaṅgulas.*

Note : To find *vyagusphuṭa bhujāṃśa* used above :

For the given date : *Śaka* 1432, *Mārgaśira kṛṣṇa amāvāsyā* Wednesday,

we have the following :

gata tithi ghaṭī = $51|50$, *eṣya ghaṭī* = $12|59$

tithiyoga ghaṭī = $64|49$, *nakṣatrayoga ghaṭī* = $65|56$

[*gataghaṭī* = $13|54$ and *eṣyaghaṭī* = $52|2$]

dinamānam = $26|4$ *gh.*

Ravi at the end of the *tithi* = $8^R\ 5°\ 26'\ 20''$

Rāhu = $2^R\ 11°\ 41'\ 18''$, *vyagu* = $5^R\ 23°\ 45'\ 2''$, and *natam* = $1°30'$

Now, we have

nata corrected Ravi = $\text{Ravi} - \frac{1}{4} \times natam = 8^R\ 5°\ 3'\ 50''$

Krānti of the *nata* corrected Ravi, $\delta = -23°\ 43'\ 40''$, *Akṣāṃśa*

= $25°\ 26'\ 42'\ N$

Natāṃśa = $\delta - \phi = 49°\ 10'\ 22''$ (south)

Vyagu bhujāṃśa = $6°\ 14'\ 58''$

Sphuṭa vyagu bhujāṃśa = $\frac{1}{6} \times$ *natāṃśa* − *vyagubhuja*

$$= \frac{1}{6} \times 49°\ 10'\ 22'' - 6°\ 14'\ 58'' = 1°\ 56'\ 45''$$

***Śloka* 7** : This *śloka* gives the method of finding the *sūryabimbam* (diameter of the Sun) as follows :

(i) Add $12°$ to Ravi. Consider the *bhuja* of it.

(ii) Divide item (i) by 3. The result will be in *aṅgulas*, *pratyaṅgulas* etc. Consider the number in the *aṅgula* position.

(iii) Consider $11 - \frac{1}{6} = 10|50$ *aṅgulas (i.e. mean sūryabimbam)*

(iv) If Ravi is within 6 *rāśis* from *Meṣa* (i.e., $0^\circ < \text{Ravi} < 180^\circ$) subtract item (ii) from item (iii).

If Ravi is within 6 *rāśis* from *Tulā* (i.e., $180^\circ < \text{Ravi} < 360^\circ$) add item (ii) to item (iii). This gives *sūryabimbam* in *aṅgulas.*

Example : Ravi = $8^R\ 5^\circ\ 26'\ 20''$

(1) Adding 12° to Ravi, we get $8^R\ 5^\circ\ 26'\ 20'' + 12^\circ = 8^R\ 17^\circ\ 26'\ 20''$ and its

bhujāṃśa = $77^\circ\ 26'\ 20''$

(2) $\frac{bhuj\bar{a}\dot{m}\acute{s}a}{3} = \frac{77^\circ\ 26'\ 20''}{3} = 25|48|46$ *aṅgulas*

Now, the number in the *aṅgula* position = 25

(3) $11 - \frac{1}{6} = 10|50$ *aṅgulas*

(4) Since Ravi is within 6 *rāśis* from Tulā, we have

Ravibimbam = $10|50 + 0|25 = 11|15$ *aṅgulas.*

CHAPTER 9

UDAYĀSTĀDHIKĀRAḤ

(Rising and Setting of Planets)

In this chapter the rising and setting of the Sun, the Moon and the planets are discussed. On the first day (*pratipat*) of the bright fortnight whether the Moon is visible or not is determined.

Śloka 1: **To find *prathamaphalam* :**

(i) Find the Sun, the Moon, Rāhu and *virāhvarka* (*vyagu*) at the end of the *pratipat*. Add 12° to both, the true Sun and the *vyagu*.

(2) Find the *cara* of *virāhvarka* (i.e., of *vyagu*)

(3) Divide the *cara* by 56. This result is called *prathamaphalam*.

If the *vyagu* is in the *uttaragola*, the above result is positive and if the *vyagu* is in the *dakṣiṇagola* the result is negative.

i.e., $$prathamaphalam = \frac{cara\ of\ vyagu}{56}$$

Note : *Vyagu* is said to be in the *uttaragola* (northern hemisphere) if $0^\circ < vyagu < 180^\circ$ and in the *dakṣiṇagola* (southern hemisphere) if $180^\circ < vyagu < 360^\circ$.

Example : The given date is as follows :

Śaka 1532, *Māgha śukla pratipat,* Saturday i.e., Jan. 15, 1611 (G).

For the above date, *Cakra* = 8, *Ahargaṇa* = 1036

Śravaṇa nakṣatra ghaṭī = 28|25, *Siddhayoga ghaṭī* = 40|8

Mean Sun = $9^R\ 6°\ 12'\ 37''$, Mean Moon = $9^R\ 19°\ 38'\ 33''$

Candrocca = $8^R\ 20°\ 54'\ 28''$, Rāhu = $2^R\ 10°\ 3'\ 25''$

As given in the *pañcāṅga, Tithighaṭī* = 7 *gh.*

(i.e., the end of *pratipat* after sunrise)

At this instant we have

> Mean Sun = $9^R\ 6°\ 19'\ 31''$, Mean Moon = $9^R\ 21°\ 10'\ 47''$
>
> Rāhu = $2^R\ 10°\ 3'\ 3''$, *Cara* = $106'$
>
> True Sun = $9^R\ 7°\ 2'\ 44''$, True Moon = $9^R\ 18°\ 52'\ 12''$
>
> True daily motion of the Sun = $61'\ 10''$
>
> True motion of the Moon = $735'\ 01''$
>
> *Ayanāṃśa* = $18°\ 8'$, *Tithi* (*pratipat*) = 1

We shall find the instant of the ending of the *pratipat*. After the instant of new moon, for the end of *pratipat*, the moon has to cover $12°$ away from the Sun. Now, True Moon – True Sun = $11°\ 49'\ 28''$. To complete $12°$ the Moon has to cover, relative to the Sun, $12° - 11°\ 49'\ 28'' = 10'\ 32''$. The difference in the daily motions of the Moon and the Sun = $735'\ 01'' - 61'\ 10'' = 673'\ 51''$. Therefore, the balance of time taken till the end of *pratipat* is

$$\frac{10'\,32''}{673'\,51''} \times 60^{gh} \approx 56\,vig.$$

Adding this to the *pañcāṅga* given *tithi ghaṭī*, we get

$$\text{End of } pratipat = 7gh + 0|56gh = 7|56\,gh$$

To find *prathamaphalam* (the first result) :

At the end of *pratipat,* we have

$$\text{True Ravi } = 9^R\,7^\circ\,3'\,41''$$

$$\text{True Rāhu} = 2^R\,10^\circ\,3'\,1'', \; vyagu\,(virāhvarka) = 6^R\,27^\circ\,0'\,40''$$

Adding 12° to both true Ravi and *vyagu*, we get respectively $9^R\,19^\circ\,3'\,41''$ and $7^R\,9^\circ\,0'\,40''$. For this, *cara* = 70.

Note : In the text it is printed as 6^R in place of 9^R in the case of the Sun.

Now, we have

$$prathamaphalam = \frac{cara}{56} = \frac{70}{56} = 1|15|0$$

Since *vyagu* is in the *dakṣiṇagola*, the *prathamaphalam* is negative.

$$\text{i.e.,} \quad Prathamaphalam = -1|15|0$$

***Ślokas* 2 and 3** : These two *ślokas* explain the method of finding *dvitīyaphalam*, *tṛtīyaphalam* and *caturthaphalam* as follows.

(1) **To find *dvitīyaphalam* (the second result) :**

(i) Consider *satribha sāyana* Ravi.

(i.e., *Nirayaṇa* Ravi + 3^R + *Ayanāṃśa*)

Find the *cara* of the *satribha sāyana* Ravi.

(ii) Multiply the *cara* and the magnitude of *prathamaphalam*.

(iii) Multiply the *palabhā* by 2. Square the product.

(iv) Divide the result of step (ii) by that of step (iii). This result is called *dvitīyaphalam*.

i.e., $$Dvit\bar{\imath}yaphalam = \frac{|Prathamaphalam| \times Cara}{(2 \times palabha)^2}$$

It is positive if Ravi and the *Vyagu* are in different *golas*, and negative if they are in the same *gola*.

(2) To find *tṛtīyaphalam* (the third result) :

(i) Find the *udayamāna* of *saṣaḍbha sāyana* Ravi [i.e., *sāyana* Ravi + 6 *rāśis*].

(ii) Take the difference of 300 and *udayamāna* of *saṣaḍbha sāyana* Ravi.

(iii) Divide the above difference by 25. The result is positive if the *udayamāna* of *saṣaḍbha sāyana* Ravi is greater than 300 *vig.* and it is negative if the *udayamāna* of *saṣaḍbha sāyana* Ravi is less than 300 *vig.*

i.e., $$T\d{r}t\bar{\imath}yaphalam = \frac{Udayam\bar{a}na - 300}{25}$$

(3) To find *caturthaphalam* (the fourth result) :

(i) Consider the difference between the *dinamānam* and the end of the *tithi.*

(ii) Divide the above difference by 5. This gives *caturthaphalam.*

i.e., $$Caturthaphalam = \frac{dinam\bar{a}nam - end\, of\, the\, tithi}{5}$$

To find *Candrodaya* at *pratipat* :

Find *prathama, dvitīya, tṛtīya* and *caturthaphalas.* Add all the four. If the resulting sum is positive, then *Candra* (Moon) is visible. If the sum is negative, *Candra* is not visible.

Example :

Satribha sāyana Ravi = $1^R\ 7°\ 11'\ 41''$, *Cara* of the above = $68'$

Prathamaphalam = $-1|15|0$, *Palabhā* = $5|45$ *aṅgulas*

$$Dvit\bar{\imath}yaphalam = \frac{|prathamaphalam| \times cara}{(2 \times palabha)^2}$$

$$= \frac{(1|15|0) \times 68'}{(2 \times 5|45)^2} = +\,0|38|33$$

Since *vyagu* and Ravi are in different *golas*, *dvitīyaphalam* is positive.

Saṣaḍbha sāyana Ravi = $4^R\ 7°\ 11'\ 41''$

Udayamāna of the *rāśi* of the above = 345 *vig.*

[i.e., *udyamāna* of *Siṃha rāśi* for *Kāśi*]

$$Tṛtīyaphalam = \frac{Udayamāna - 300}{25}$$

$$= \frac{345-300}{25} = \frac{45}{25} = +1|48|0$$

Since *udayamāna* > 300, the *tṛtīyaphala* is positive.

$$Dinamānam = 26|28 \text{ } ghaṭīs$$

The end of the *pratipat* = 7|56 *ghaṭīs*

$$Caturthaphalam = \frac{dinamāna - \text{end of the } tithi}{5}$$

$$= \frac{26|28 - 7|56}{5} = +3|42|14$$

Since *dinamāna* > end of the *tithi*, the *caturthaphala* is positive.

To find *Candrodaya* on *śukla pratipat* :

Sum of the four *phalas* = $-1|15|0 + 0|38|33 + 1|48|0 + 3|42|14 = +4|53|47$

Since the sum of all the four *phalas* is positive, the Moon is *visible*.

(i.e., *Candrodaya* will have taken place before the end of the *pratipat*).

***Śloka* 4** : This *śloka* explains the method of finding the rising and setting of the planet Guru (Jupiter) by using *māsagaṇa*. It is as follows :

(i) Add *cakra* to *māsagaṇa*.

(ii) Divide *cakra* by 13.

(iii) Subtract item (ii) from item (i).

(iv) Multiply item (iii) by 2. Add 10 *māsas* and 11 days to the product.

(v) Divide item (iv) by 27. Consider the remainder.

(vi) Subtract the above remainder from 27.

(vii) Divide the above difference by 2. The result will be in *rāśis*, *amśas* etc.

(viii) Subtract 15° from item (vii).

(ix) Find the *bhuja* of item (viii).

(x) Divide item (ix) by 12. If the result is within 6 *rāśis* from *Tulā* (i.e., $>180^\circ$) it is negative. If the result is within 6 *rāśis* from *Meṣa* (i.e., $<180^\circ$) the result is positive.

(xi) The result of item (x) is added to or subtracted from item (vii) accordingly.

(xii) Consider the above result. Subtract 15 days from it. This gives the setting of Guru.

(xiii) Add 15 days to the result of (xi). This gives the rising of Guru.

Note : Here *māsas* are counted starting from *Caitra*.

Example : For the given date, *śaka* 1532, *cakra* = 8, *māsagaṇa* = 25.

Completed years from the epoch *(i.e., Śā. śā.* 1442*)* = 90.

(i) *Cakra* + *Māsagaṇa* = 8 + 25 = 33

(ii) $\dfrac{cakra}{13} = \dfrac{8}{13} = 0^m\ 18^d\ 27^{gh}\ 41^{vig}$

(iii) item (i) – item (ii) = $33^m - 0^m\ 18^d\ 27^{gh}\ 41^{vig}$.

$$= 32^m\ 11^d\ 32^{gh}\ 19^{vig}$$

(iv) $[item\ (iii) \times 2] + 10^m\ 11^d$

$$= [(32|11|32|19) \times 2] + 10^m\ 11^d = 75^m\ 04^d\ 04^{gh}\ 38^{vig}$$

(v) $$\frac{item\ (iv)}{27} = \frac{75|04|04|38}{27} = 2 + \frac{21|04|04|38}{27}$$

i.e., the remainder $= 21|04|04|38$

(vi) 27 – remainder $= 27 - 21|04|04|38 = 5|25|55|22$

(vii) Dividing item (vi) by 2, we get

$$\frac{5|25|55|22}{2} = 2^R\ 27°\ 57'\ 41''$$

(viii) item (vii) – 15° $= 2^R\ 27°\ 57'\ 41'' - 15° = 2^R\ 12°\ 57'\ 41''$

(ix) *Bhuja* of $2^R\ 12°\ 57'\ 41'' = 72°\ 57'\ 41''$

(x) $$\frac{Bhuja}{12} = \frac{72|57|41}{12} = 6°\ 4'\ 48''$$

(xi) Now, the sum of the results of items (vii) and (x) gives

$$2|27|57|41 + 6|4|48 = 3^m\ 4^d\ 2^{gh}\ 29^{vig}$$

(xii) item (xi) – 15 days $= 3^m\ 4^d\ 2^{gh}\ 29^{vig} - 15^d = 2^m\ 19^d\ 2^{gh}\ 29^{vig}$

Here *māsas* are elapsed counted from *Caitra*. Therefore the above result tells that Guru sets after $2^{m}\ 19^{d}\ 2^{gh}\ 29^{vig}$ from *Caitra* i.e., on *Jyeṣṭha kṛṣṇa pañcamī*.

(xiii) item (xi) + 15 days = $3^{m}\ 4^{d}\ 2^{gh}\ 29^{vig} + 15^{d} = 3^{m}\ 19^{d}\ 2^{gh}\ 29^{vig}$

This implies that Guru rises after $3^{m}\ 19^{d}\ 2^{gh}\ 29^{vig}$ from *Caitra*. (i.e., on *Āṣāḍha Kṛṣṇa Pañcamī*).

Note : Guru is also called *Bṛhaspati* and *Mantrī*.

***Śloka* 5, 6, 7** : These three *ślokas* explain the method of finding, *asta* (setting) and *udaya* (rising) of Śukra, as follows :

(a) To find the rising of Śukra in the west and setting in the east :

(1) Multiply *cakra* by 17.

(2) Divide $cakra \times 17$ by 45. Add the quotient which will be in *māsas* etc. to item (1).

(3) Add *māsagaṇa* to item (2).

(4) Add 64^{m} to the product $5 \times \text{item (3)}$.

(5) Divide item (4) by 99. Consider the remainder.

(6) Subtract item (5) from 99 months.

(7) Divide item (6) by 5. The result will be in *māsas* etc.

(8) Consider the result of item (7). Add 36 days to it. This gives the rising of Śukra in the west. (*paścimodaya* of Śukra).

(9) Subtract 36 days from result of item (7). This gives the setting of *Śukra* in the east (*pūrvāsta*).

Example : *Māsagaṇa* from *Caitra* = 25, *cakra* = 8

(1) $17 \times cakra = 17 \times 8 = 136$ months

(2) $\dfrac{17 \times cakra}{45} + (17 \times cakra) = \dfrac{136}{45} + 136 = 139^m\ 0^d\ 40^{gh}$

(3) *Māsagaṇa* + item (2) = $25^m + 139^m\ 0^d\ 40^{gh} = 164^m\ 0^d\ 40^{gh}$

(4) $64 + [5 \times \text{item (3)}] = 64^m + (5 \times 164^m\ 0^d\ 40^{gh}) = 884^m\ 3^d\ 20^{gh}$

(5) $\dfrac{884^m\ 3^d\ 20^{gh}}{99} = 8 + \dfrac{92^m\ 3^d\ 20^{gh}}{99}$

i.e., remainder = $92^m\ 3^d\ 20^{gh}$

(6) $99^m - \text{item (5)} = 99^m - 92^m\ 3^d\ 20^{gh} = 6^m\ 26^d\ 40^{gh}$

(7) $\dfrac{\text{item (6)}}{5} = \dfrac{6^m\ 26^d\ 40^{gh}}{5} = 1^m\ 11^d\ 20^{gh}$

(8) item (7) + 36 days = $1^m\ 11^d\ 20^{gh} + 36^d = 2^m\ 17^d\ 20^{gh}$

This implies that Śukra rises in the west after the lapse of $2^m\ 17^d\ 20^{gh}$ from *Caitra*. i.e., on *Jyeṣṭha kṛṣṇa tṛtīya*.

(9) item (7) – 36 days = $1^m\ 11^d\ 20^{gh} - 36^d = 0^m\ 5^d\ 20^{gh}$

This implies that Śukra sets in the east after $5^d\ 20^{gh}$ from the beginning of *Caitra*, i.e., on *Caitra Śukla ṣaṣṭī*.

To find the rising of Śukra in the east (*pūrvodaya* of Śukra) and the setting in the west (*paścimāsta* of Śukra)

(1) Consider the *māsas* etc. obtained previously in step (7).

(2) If the above is less than 9 months and 27 days, add $9^m\ 27^d$ to it. If it is greater than $9^m\ 27^d$, subtract $9^m\ 27^d$ from it.

(3) Consider item (2). Add 4 days to it. This gives rising of Śukra in the east.

(4) Subtract 4 days from item (2). This gives setting of Śukra in the west.

Example :

(1) *Māsās* etc. obtained previously in item (7) : $1^m\ 11^d\ 20^{gh}$.

(2) Since it is less than $9^m\ 27^d$, adding $9^m\ 27^d$ we get

$$1^m\ 11^d\ 20^{gh} + 9^m\ 27^d = 11^m\ 08^d\ 20^{gh}$$

(3) item (2) + 4 days = $11^m\ 08^d\ 20^{gh} + 4^d = 11^m\ 12^d\ 20^{gh}$

This implies that Śukra rises in the east after the lapse of $11^m\ 12^d\ 20^{gh}$ from *Caitra* i.e., on *Phālguṇa śuddha trayodaśī.*

(4) item (2) – 4 days = $11^m\ 8^d\ 20^{gh} - 4\ days = 11^m\ 04^d\ 20^{gh}$

This implies that Śukra sets in the west after the lapse of $11^m\ 04^d\ 20^{gh}$ from *Caitra*

i.e., on *Phālguṇa śuddha pañcamī.*

***Śloka* 8** : This *śloka* explains the method of finding *parivartana kāla* (recurrence time) of the rising (*udaya*) and setting (*asta*) of Guru and Śukra. That is, by knowing the *asta* and *udaya* to find the next *udaya* and *asta* of Guru and Śukra.

(1) In the case of Śukra, by adding 19 months and 24 days (*tithis*) to the rising and setting times we get again the next rising and setting of Śukra. Similarly by subtracting the same ($19^m 24^d$), the earlier rising and setting of Śukra are obtained.

(2) In the case of Guru, the period to be added or subtracted is $13^m\ 15^d$.

Remark :

(i) The interval between successive rising and setting or between two successive risings (or settings) of planets given above are only *mean* values. In reality these intervals vary from year to year based on true positions of the Sun and the planets.

For example, the setting (*asta*) of Guru in 1995 was on December 6. The next setting of the same planet was January 8, 1997. The interval (*parivartana*) between these two successive settings of Guru is given by (1997-1-8) – (1995-12-6) = $1^y\ 1^m\ 2^d = 13^m\ 2^d$. The interval given in the text is $13^m\ 15^d$. Similarly, the interval between successive risings is given by 1999-12-30 and 1997-2-2 is $1^y\ 1^m\ 2^d$ i.e., $13^m\ 2^d$.

(ii) The interval given in the text, $13^m\ 15^d$ is actually 13.5 *lunar* months which is equivalent to 13 months, 8 days of the civil calendar.

***Śloka* 9** : This *śloka* gives the method of finding *śara* of Candra as follows.

(1) Consider the *bhuja* of *vyagu*. If *bhuja* is in the first *raśi* i.e., less than

30°, add $\frac{1}{2} \times bhuja$ to *bhuja* of *vyagu*. This gives the *śara* in *aṅgulas*.

(2) If the *bhuja* of *vyagu* is in the second *rāśi* (i.e., $30^\circ \le bhuja \le 60^\circ$) add 47 to *bhuja* to get the *śara* in *aṅg.*

(3) If the *bhuja* is in the third *rāśi* (i.e., $60^\circ \le bhuja \le 90^\circ$) then add 77 to $\frac{1}{2} \times bhuja$ to get the *śara* in *aṅg.*

Example : Candra = $8^R\, 5^\circ\, 26'\, 20''$, Rāhu = $2^R\, 11^\circ\, 41'\, 18''$

Vyagu = $5^R\, 23^\circ\, 45'\, 02''$, *bhuja* of *vyagu* = $6^\circ\, 14'\, 58''$

Since the *bhuja* of *vyagu* is in the first *rāśi* we have

$$śara = bhuja + \frac{bhuja}{2}$$

$$= 6^\circ\, 14'\, 58'' + \frac{6^\circ\, 14'\, 58''}{2} = 9|22|27 \text{ } aṅgulas$$

Since *vyagu* is in the *uttaragola* (i.e., < 6 *rāśis*), the *śara* is also in the *uttaragola* (i.e., positive or nothern).

***Śloka* 10** : This *śloka* gives another method of finding the *śara* (of the Moon) using *khaṇḍas*. It is as below :

(1) The *śarakhaṇḍas* are

0, 16, 15, 14, 13, 11, 9, 7, 4, 1.

Using these *khaṇḍas* for (Moon – Rāhu) find *śara* by following the same procedure which is adopted to find the *krānti* using *khaṇḍas*.

Example : *Vyaguvidhu* i.e., (Moon – Rāhu) = $5^R\ 23°\ 45'\ 2''$

(**Note** : The moon is also called *Vidhu*.)

The *bhuja* of the *vyagu* = $6°\ 14'\ 58''$

(1) $\dfrac{6°\ 14'\ 58''}{10} = 0 + \dfrac{6°\ 14'\ 58''}{10}$, remainder = $6°\ 14'\ 58''$

This implies that the *gata* (elapsed) *khaṇḍa* = 0 and

eṣyakhaṇḍa = 16 (from Table 9.1 of *khaṇḍas*)

(2) $\dfrac{\textit{Eṣyakhaṇḍa} \times \text{remainder}}{10} = \dfrac{16 \times 6°\ 14'\ 58''}{10}$

$$= \frac{99°\ 59'\ 28''}{10} = 9|59 \ \textit{aṅgulas}$$

(3) *gatakhaṇḍa* + item (2) = $0 + 9|59$ *aṅgulas*

i.e., *śara* = $9|59$ *aṅgulas*

Explanation : The *khaṇḍas* for finding the *śara* of the Moon given in *GL* are as follows :

Table 9.1 : *Śara khaṇḍas* of the Moon

Vyagu bhuja	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Difference	16	15	14	13	11	9	7	4	1	
Śara(aṇg)	0	16	31	45	58	69	78	85	89	90

$$\text{For } Vyagu = \begin{cases} 30^\circ : \acute{s}ara = 0+16+15+14 = 45\ a\dot{n}gulas \\ 60^\circ : \acute{s}ara = 45+13+11+9 = 78\ a\dot{n}gulas \\ 90^\circ : \acute{s}ara = 78+7+4+1 = 90\ a\dot{n}gulas \end{cases}$$

Note : The actual formula for *śara* is

Śara = 90 sin (*Vyagu*) *aṅgulas*

(Note that 90 *aṅg.* = 270′).

For example for *Vyagu* = 30°, 60° and 90°, we get from the above formula *śara* = 45, 78 and 90 *aṅgulas.*

According to *GL*, the *śara* of the Moon is obtained as follows.

(i) For $0^\circ < bhuja < 30^\circ$, *śara* = 90 sin (*vyagu*)

$$\text{i.e., } \acute{s}ara \approx 90^\circ \times \left[\frac{72}{120 \times 35} \times vyagu\right] = \frac{54}{35} \times vyagu \approx \frac{3}{2}\ vyagu.$$

[Ref. *GL*, *Tripraśnādhikāra*, *Śl.* 22 :

$$120 \sin\theta \approx \frac{72}{35}\theta \ \therefore\ \sin\theta \approx \frac{72}{120 \times 35}\theta \text{ where } \theta \text{ is in radians].}$$

(ii) For $30^\circ < bhuja < 60^\circ$

Śara = [Accummulated *śara* upto *bhuja* 30°]

$$+ (78 - 45)\frac{bhuja}{30} \approx 45 + (1.1)\, bhuja$$

GL takes it as 47 + *bhuja* (approxly).

(iii) For $60^\circ < bhuja < 90^\circ$,

$$\acute{S}ara = [\text{Accumulated } \acute{s}ara \text{ for } bhuja \text{ upto } 60^\circ]$$

$$+(90-78)\times\frac{bhuja}{30} = 78+\frac{12}{30}\ bhuja$$

GL takes this as $77+\frac{1}{2}\times bhuja$.

Remark : The following table provides a comparison between the approximated values of *śara* as per *GL* and the actual values using the formula, $\acute{s}ara = 90^\circ \sin(vyagu)$ *aṅgulas.*

Table 9.2 Comparison of *GL śaras* with actuals

Vyagu	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
GL	0	16	31	45	58	69	78	85	89	90
Actual	0	15.63	30.78	45	57.85	68.94	77.94	84.57	88.63	90

***Śloka* 11** : This *śloka* gives the direction of *udaya* (rising) and *asta* (setting) of the planet.

(1) The planet, whose longitude and daily motion are less than those of the Sun, rises in the east.

(2) The planet having greater longitude and daily motion than those of the Sun, rises in the west.

(3) The planet whose longitude is greater than the longitude of the Sun, and whose daily motion is less than that of the Sun will set in the west.

(4) The planet whose daily motion is greater than that of the Sun and whose longitude is less than that of the Sun will set in the east.

***Śloka* 12** : This *śloka* gives the *kālāṃśa*s of planets.

Table 9.3 : *Kālāṃśas* of planets

Planets	Ca	Ku	Bu	Gu	Śu	Śa	*Va. Bu*	*Va.* Śu
Kālāṃśa	12°	17°	13°	11°	09°	15°	12°	08°

Note : If Budha and Śukra are in retrograde motion (*vakragati*), subtract 1 from their usual (direct motion) *kālāṃśas (as shown in Table 9.3).*

***Śloka* 13** : This *śloka* gives the *pātas* of the five planets (*tārāgrahas*) as below:

Table 9.4 : *Pātas* (Nodes) of Planets

Planets	Budha	Kuja	Guru	Śukra	Śani
Pātāmśa	20°	40°	80°	60°	100°

In the case of Budha and Śukra subtract *śighrakendra* (obtained using *ahargaṇa*) from *patāṃśa* to get the corrected *pātāṃśa*.

***Śloka* 14** : The method of finding *śīghrakarṇa* of planets is explained in this *śloka* as follows :

(1) The six *khaṇḍas* using which we can find *śīghrakarṇa* are:

1, 2, 3, 4, 4, 2.

(2) If the *śīghrakendra* of the planet is greater than 6 *rāśis*, subtract it from 12 *rāśis.*

(3) The number in the *rāśi* position gives the total number of elapsed *khaṇḍas.* Find the sum of all the *gata* (elapsed) *khaṇḍas.*

(4) Now, we have

$$\textit{Śīghrakendraphalam} = \underset{\textit{khaṇḍas}}{\textit{Sum of the elapsed}} + \frac{\textit{Eṣyakhaṇḍa} \times \text{Remainder}}{30}$$

(5) Divide the result of (4) by 1, 2, 4, 1, 7 and subtract the quotients from 18, 15, 13, 19 and 12 respectively. The result gives *śīghrakarṇa* of Kuja, Budha, Guru, Śukra and Śani respectively.

Example : Given date is *Śaka* 1534, *Vaiśākha Śukla Pūrṇimā* (refer to the example under *śloka* 10 in Chapter 3). For the five *tārā grahas* (star-planets) we have their *śīghrakendras* (anomaly of conjunction) as given in Table 9.5.

Table 9.5 *Śīghrakendras* of planets

Planet	*Śīghrakendra*
Kuja	$3^R\ 01°\ 04'\ 57''$
Budha	$1^R\ 16°\ 25'\ 17''$
Guru	$8^R\ 21°\ 20'\ 58''$
Śukra	$3^R\ 04°\ 59'\ 52''$
Śani	$2^R\ 02°\ 50'\ 00''$

The above values are the second *śīghrakendras* while finding the true positions of planets.

(1) To find the *śīghrakarṇa* of Kuja :

Śīghrakendra = $3^R\ 1°\ 4'\ 57''$

(i) In the *rāsi* position, we have 3. This implies that the first three *khaṇḍas* are over.

The elapsed *khaṇḍas* are 1, 2, 3.

(ii) Sum of the elapsed *khaṇḍas* = 6.

(iii) Remainder = $1°\ 4'\ 57''$, *Eṣyakhaṇḍa* = 4

(iv) Sum of the elapsed *khaṇḍas* + $\dfrac{\text{Remainder} \times \textit{Esyakhanda}}{30}$

$$= 6 + \frac{1^\circ\ 4'\ 57'' \times 4}{30} = 6|8|39$$

(v) Dividing by 1 (in the case of Kuja), subtracting the result from 18, we get the *śīghrakarṇa* of Kuja as

$$\textit{Śīghrakarṇa} = 18 - \frac{6|8|39}{1} = 18 - 6|8|39 = 11|51|21$$

(2) To find the *śīghrakarṇa* of Budha :

Śīghrakendra of Budha = $1^R\ 16^\circ\ 25'\ 17''$

Gatakhaṇḍa = 1, *Eṣyakhaṇḍa* = 2, and Remainder = $16^\circ\ 25'\ 17''$

Sum of the *gatakhaṇḍas* + $\dfrac{\textit{Esyakhanda} \times \text{remainder}}{30}$

$$= 1 + \frac{2 \times 16^\circ\ 25'\ 17''}{30} = 2|5|41$$

Dividing the above by 2 and subtracting the resulting quotient from 15 we get the *śīghrakarṇa* of Budha.

i.e., *Śīghrakarṇa* of Budha = $15 - \dfrac{2|5|41}{2} = 13|57|10$

(3) To find the *śīghrakarṇa* of Guru :

Guru's *śīghrakendra* = $8^R\ 21^\circ\ 20'\ 58''$

Śīghrakendra phalam = Sum of the *gatakhaṇḍas* +

$$\frac{\textit{Eṣyakhaṇḍa} \times \text{remainder}}{30} = 7|9|11$$

$$\textit{Śīghrakarṇa} \text{ of Guru} = 13 - \frac{7|9|11}{4} = 11|12|42$$

(4) **To find the *śīghrakarṇa* of Śukra :**

Śighrakendra = $3^R\ 4°\ 59'\ 52''$

Śīghrakendrāt phalam = $6|39|58$

$$\textit{Śīghrakarṇa} \text{ of Śukra} = 19 - \frac{6|39|58}{1} = 12|20|2$$

(5) **To find the *śīghrakarṇa* of Śani :**

Śīghrakendra = $2^R\ 2°\ 50'\ 0''$

Śīghrakendrāt phalam = $3|17|0$

$$\textit{Śīghrakarṇa} = 12 - \frac{3|17|0}{7} = 11|31|52$$

***Śloka* 15** : This *śloka* explain the method of finding the *śara* (latitude) of Kuja, Budha, Guru, Śukra and Śani. It is as follows.

(1) Consider the difference between the *manda* corrected planet and its *pāta*.

(2) Find the declination (*krānti*) of the above result. [Here the *nirayaṇa* planet from which the *pāta* is subtracted has to be considered].

(3) In the case of Budha and Śukra consider

[*Manda* corrected planet – (*Pāta* – *Śīghrakendra*)]

(4) Multiply the declination obtained in step (2) by 23.

(5) Divide the result of step (4) by *śīghrakarṇa*. This gives the *śara* of the planet in *aṅgulas*.

(6) In the case of Kuja, subtract $\frac{1}{4}$ of the *śara* from the *śara* to get the corrected *śara*.

(7) In the case of Guru, divide *śara* (from step 5) by 2 to get the corrected *śara*.

(8) Multiply the *śara* in *aṅgulas* by 3 to get the same in *kalās*. Divide *śara* in *kalās* by 60 to get it in *aṁśas*.

(9) The *śara* will be north or south according as the (*manda* corrected planet – *pāta*) is in the northern or southern hemisphere.

(10) The declinations of the above planets are to be corrected with their *śaras*.

(1) To find *śara* of Kuja :

Manda corrected Kuja = $10^R\ 3°\ 8'\ 45''$, *Pāta* of Kuja = $1^R\ 10°$

(i) *Manda* corrected Kuja – *Pāta* = $10^R\ 3°\ 8'\ 45'' - 1^R\ 10°$

$= 8^R\ 23°\ 8'\ 45''$

(ii) Declination of the above = $23°\ 43'\ 33''$ (south)

(obtained using *Krāntikhaṇḍas* as explained in Chapter 4).

(iii) *Śīghrakarṇa* of Kuja = $11|51|21$

(iv) $23 \times$ (declination) = $23 \times (23|43|33) = 545^\circ\ 41'\ 39''$

(v) $\acute{s}ara = \dfrac{545^\circ\ 41'\ 39''}{11|51|21} = 46|1|38$ *aṅgulas*

(vi) Corrected *śara* :

Śara obtained = $46|1|38$ *aṅgulas* [in step (v)]

Corrected *śara* of Kuja = $\acute{s}ara - \dfrac{sara}{4}$

$$= 46|1|38 - \frac{46|1|38}{4} = 34|31|14 \text{ } \textit{aṅgulas} \text{ (south)}$$

(2) To find *śara* of Budha :

(i) *Manda* corrected Budha = $1^R\ 5^\circ\ 3'\ 15''$, *Pāta* = $0^R\ 20^\circ$

Śīghrakendra of Budha obtained from *Ahargaṇa* : $1^R\ 17^\circ\ 14'\ 50''$

(ii) Budha – (*Pāta* – *Śīghrakendra*)

$$= 1^R\ 5^\circ\ 3'\ 15'' - (0^R\ 20^\circ - 1^R\ 17^\circ\ 14'\ 50'') = 2^R\ 2^\circ\ 18'\ 05''$$

(iii) Declination of the above = $21^\circ\ 0'\ 51''$

(iv) $23 \times$ declination = $21^\circ\ 0'\ 51'' \times 23 = 483|19|33$

(v) *Śīghrakarṇa* of Budha = 13|57|10 *aṅgulas*

(vi) *Śara* of Budha = $\dfrac{483|19|33}{13|57|10}$ = 34|38|24 *aṅgulas* (north)

(3) To find *śara* of Guru :

(i) *Manda* corrected Guru = $4^R\ 12°\ 12'\ 44''$, *Pāta* = $2^R\ 20°$

(ii) Guru – *Pāta* = $1^R\ 22°\ 12'\ 44''$

(iii) Declination of (Guru – *Pāta*) = $18°\ 49'\ 11''$ (north)

(iv) $23 \times 18°\ 49'\ 11''$ = 432|51|13

(v) *Śīghrakarṇa* of Guru = 11|12|42

(vi) *Śara* of Guru = $\dfrac{432|51|13}{11|12|42}$ = 38|36|26

(vii) Corrected *śara* of Guru = $\dfrac{38|36|26}{2}$ = 19|18|13 *aṅg.* (north)

(4) To find *śara* of Śukra :

Pāta of Śukra = $2^R\ 0°$

Śīghrakendra of Śukra = $3^R\ 5°\ 41'\ 35''$

Manda corrected Śukra = $1^R\ 5°\ 25'\ 25''$

(i) Śukra – (*Pāta* – *Śīghrakendra*)

$= 1^R\ 5°\ 25'\ 25'' - (2^R - 3^R\ 5°\ 41'\ 35'') = 2^R\ 11°\ 07'\ 0''$

(ii) Declination of the above = $22°\ 32'\ 2''$ (north)

(iii) $23 \times (22°\ 32'\ 2'') = 518|16|46$

(iv) *Śīghrakarṇa* of Śukra = $12|24|2$ *aṅgulas*

(v) *Śara* of Śukra = $\dfrac{518|16|46}{12|24|2} = 41|47|41$ *aṅgulas* (north)

(5) To find *śara* of Śani :

(i) *Manda* corrected Śani = $10^R\ 21°\ 23'\ 42''$

(ii) *Pāta* of Śani = $3^R\ 10°$

(iii) Śani – *Pāta* = $7^R\ 11°\ 23'\ 42''$

(iv) Declination of (Śani – *Pāta*) = $15°\ 31'\ 06''$ (south)

(v) $23 \times (15^\circ\ 31'\ 06'') = 356|55|18$

(vi) *Śīghrakarṇa* = 11|23|18 *aṅgulas*

$\therefore$ *Śara* of Śani = $\dfrac{356|55|18}{11|23|18}$ = 31|20|27 *aṅgulas* (south)

Table 9.6 gives the *śara* (latitude) of each planet in *aṅgulas* and in degrees (*amśa*), minutes (*kalās*) and seconds (*vikalās*) of arc for the given example.

Table 9.6 : *Śaras* of planets in *aṅgulas* and degrees

Planets	*Śara* (Latitude)				North / South
	Aṅgulas	Deg.	Min.	Sec.	
Kuja	34|31|14	1	43	33	South
Budha	34|38|24	1	43	55	North
Guru	19|18|13	0	57	54	North
Śukra	41|47|41	2	05	23	North
Śani	31|20|27	1	34	01	South

Note :

(1) The *śara* in *aṅgulas* is converted into *kalās* (minutes of arc) by multiplying by 3 and then into degrees on dividing by 60.

(2) The *śara* is north or south according as the (*manda* corrected planet – *pāta*) is less than or greater than 180°.

The true positions and the declinations of the five *tārāgrahas* are shown in Table 9.7.

Table 9.7 : True longitudes, *krāntis* and *śara spaṣṭa krāntis*

Planets	True longitudes	*Krānti* (N/S) (Declination)	*Śara* (Latitude)	*Śara spaṣṭa Krānti*
Kuja	11^R 05° 56′ 04″	2° 21′ 34″ S	1° 43′ 33″ S	4° 05′ 07″ S
Budha	1^R 17° 04′ 0″	21° 32′ 31″ N	1° 43′ 55″ N	23° 16′ 26″ N
Guru	4^R 02° 9′ 45″	14° 59′ 15″ N	0° 57′ 54″ N	15° 57′ 09″ N
Śukra	2^R 12° 15′ 46″	23° 58′ 58″ N	2° 05′ 23″ N	26° 04′ 21″ N
Śani	10^R 26° 42′ 30″	6° 03′ 00″ S	1° 34′ 01″ S	7° 37′ 01″ S

In the above table, to the right of the column headed by *krānti* (declination), we have the *śara* and the *śara* corrected declination, called (*śara*) *spaṣṭa krānti*, tabulated for all the five "star planets" in two columns. This is obtained for each planet by taking the algebraic sum of its latitude and declination. That is, (i) if the latitude (*śara*) and declination (*krānti*) are in the same direction, then the sum of their numerical values is taken and the direction is the same as their common direction; (ii) if the *śara* and *krānti* are in opposite directions, then the difference of their numerical values is taken and the direction is that of the higher numerical value.

***Śloka* 16** : Now obtaining, from the *pañcāṅga*, the *manda* corrected planets for the purpose of determing the *śara* (latitude) is explained.

On the day on which a planet retrogrades or rises or sets, according to the *pañcāṅga* (traditional ephemeris or almanac),the *śīghrakendra* of that planet can be known.

The *śīghrakendra* and the true longitude of the planet for the given time are determined using their respective rates of motion. By finding the *śīghraphalam*, from the *śīghrakendra*, and applying this to the true position in the reverse process, the *manda* corrected planet can be obtained, Then from this the *śara* is determined as explained earlier (in *śloka* 15).

***Śloka* 17** : This *śloka* gives the *natāṃśa* of planets, as follows :

(i) If the planet rises or sets in the east, subtact 3 *rāśis* from the true postion, of the planet and find its declination (*krānti*).

(ii) If the planet rises or sets in the west, add 3 *rāśis* to the true position and find the declination of the sum.

(iii) The *natāṃśa* = *krānti* $\pm$ *akṣāṃśa* $\equiv \delta - \phi$

where δ and ϕ are respectively the declination and the latitude of the planet.

Example :

True Śukra = $11^R\ 13^\circ\ 14'\ 29''$

Since Śukra sets in the east, subtract 3 *rāśis* from it.

i.e., $11^R\ 13^\circ\ 14'\ 29'' - 3^R = 8^R\ 13^\circ\ 14'\ 29''$.

The declination (*krānti*) of the above $\delta = 23^\circ\ 55'\ 42''$ South.

Natāṃśa = *krānti* $\pm$ *akṣāṃśa* = $\delta - \phi$ = $49^\circ\ 23'\ 24''$ South

Here, the latitude of the place $\phi = 25^\circ\ 27'\ 42''$ (N) i.e. of Kāśī.

***Śloka* 18** : This *śloka* explains the method of finding *dṛkkarma* correction using *khaṇḍas* as follows :

(i) The *dṛkkarma khaṇḍas* are 6, 7, 8, 9, 12 and 18.

(ii) Divide *natāmśa* by 10. The quotient gives the number of elapsed *khaṇḍas*.

(iii) Consider the product of remainder in (ii) and *eṣyakhaṇḍa* (*khaṇḍa* to be covered). Divide the product by 10.

(iv) Add the sum of elapsed *khaṇḍas* to the result of step (iii).

(v) Mutiply the above result by *śara* and divide the product by 12. The result will be in *kalās* and is called *dṛkkarma phala*.

(vi) The *dṛkkarma phala* is additive if *śara* and *natāmśa* are in the same direction and it is subtractive if *śara* and *natāmśa* are in different directions. This convention is followed in the case of *pūrvodayāsta* (i.e., setting and rising in the east). For *paścimodayāsta* (i.e., rising and setting in the west) consider the reverse operation.

Example :

(i) *Natāṃśa* = $49^\circ\ 23'\ 24''$ for Śukra (see example under *śloka* 17).

We have $\dfrac{Nat\bar{a}\dot{m}\acute{s}a}{10} = \dfrac{49^\circ\ 23'\ 24''}{10} = 4 + \dfrac{9^\circ\ 23'\ 24''}{10^\circ}$

Here, quotient = 4 and remainder = $9^\circ\ 23'\ 24''$

The number of *gata* (elapsed) *khaṇḍas* = 4

They are 6, 7, 8, 9.

Sum of these *khaṇḍas* = 6 + 7 + 8 + 9 = 30°

Eṣyakhaṇḍa = 12

(ii) Now, $\dfrac{E\d{s}yakha\d{n}\d{d}a \times \text{Remainder}}{10}$ + Sum of *gata khaṇḍas*

$$= \frac{12 \times 9^\circ\ 23'\ 24''}{10} + 30^\circ = 41^\circ\ 16'\ 14''$$

(iii) *Śara* = $30|12|15$ *aṅgulas* (South)

$$\therefore \text{\textit{Śara}} \times 41^\circ\, 16'\, 14'' = 30|12|15 \times 41|16|14 = 1246|20|29$$

$$\therefore \text{\textit{Dṛkkarma}} = \frac{1246|20|29}{12} = 103'\, 51'' = 1^\circ\, 43'\, 51''$$

Since *natāṃśa* and *śara* are in the same direction (south), the *dṛkkarma* is additive.

(iv) Now, therefore, the *dṛkkarma* corrected *Śukra* = True *Śukra* + *dṛkkarma*

$$= 11^R\, 13^\circ\, 14'\, 29'' + 1^\circ\, 43'\, 51'' = 11^R\, 14^\circ\, 58'\, 20''$$

***Śloka* 19** : This *śloka* explains about the time (*kālāṃśa*) of setting and rising of a planet.

(1) Consider Ravi and the *dṛkkarma* corrected planet. Between these two, the one having lesser longitude is to be treated as Ravi and the one with greater longitude as *Lagna*.

(2) Add *ayanāṃśa* to both Ravi and *lagna* (thus considered).

The time interval between these in *ghaṭikās* (from the *udayakālas* of the intervening *rāśis* and the elapsed portions of the *rāśis*) is determined. This on multiplying with 6 gives the *antarāṃśas* i.e., the difference in degrees. If the *antarāṃśa* is greater than the *kālāṃśa* mentioned earlier for the planet, the *setting* of the planet is yet to take place. On the other hand, if the *antarāṃśa* is less than the *kālāṃśa*, then the planet has already set.

Similarly, in the case of *rising* (*udaya*) of the planet, the reverse is the case.

Example : True Ravi = $11^R\, 23^\circ\, 32'\, 26''$

Dṛkkarma corrected *Śukra* = $11^R\, 14^\circ\, 58'\, 20''$

Ayanāṃśa = $18^\circ\ 08'$

Since, of the above two bodies, Śukra is less than Ravi, Śukra is to be treated as Ravi and (the actual) Ravi as Lagna. i.e., now, the changed

(*Sāyana*) Ravi = $0^R\ 3^\circ\ 6'\ 20''$ and (*Sāyana*) Lagna = $0^R\ 11^\circ\ 40'\ 26''$

The difference between them = $0^R\ 8^\circ\ 34'\ 06''$

Since both are in *Meṣa rāśi* and the *udayamāna* of *Meṣa* is 221 *vig.* for Kāśī, the time interval = $\dfrac{8^\circ\ 34'\ 06''}{30^\circ} \times 221\ \textit{vig.} = 1^{gh.}\ 03^{vig.}$

$\therefore$ *Antarāṃśas* = $1^{gh.}\ 03^{vig.} \times 6 = 6^\circ\ 18'$

Since the *antarāṃśa* of Śukra is less than its corrected *kālāṃśa* ($6^\circ\ 46'$) the planet has already set. *Antarāṃśa* is also referred to as *Iṣṭa kālāṃśa*.

***Śloka* 20** : This *śloka* explains the method of finding the day of the *udaya* (rising) and the *asta* (setting). It is as follows.

(i) Consider the difference between the *iṣṭa kālāṃśa* (obtained in the previous *śloka*) and the corrected *kālāṃśa*. Express the difference in *kalās*.

(ii) Multiply the above difference by 300.

(iii) Divide the result of step (ii) by *udayamāna* of the *rāśi* in which Ravi is present (Ravi *rāśi*).

(iv) Divide the above result by the difference between the daily motion of the Sun and that of the planet whose *udayāsta* is to be determined. This gives the day of *udayāsta*. This is in the case of *pūrvodayāsta*. (i.e., for planets rising and setting in the east).

(v) For the planets rising and setting in the west (i.e., *paścimodayāsta*), proceed upto step (ii) as explained above. Divide the result of step (ii) by the *udayamāna* of the 7th *rāśi* of *sāyana* Ravi (i.e., 180° from the *sāyana* Ravi).

(vi) If the planet is in retrograde motion, then consider the sum of the motion of the planet and that of he Sun in step (iv).

Example : Corrected *kālamṃśa* = $6^\circ\ 46'$ (explained later in *Śloka* 21).

Iṣṭa kālāṃśa = $6^\circ\ 18'$ (obtained from the previous *śloka*)

(i) The difference = $6^\circ 46' - 6^\circ 18' = 0^\circ\ 28' = 28'$

Here we consider Śukra which rises and sets in the *east.*

(ii) *Udayamāna* of Rāvi *raśi* = $221^{vig.}$ (i.e., of *Meṣa*)

(iii) Multiplying the result of (i) by 300 and dividing by that of (ii)

we have $\dfrac{28 \times 300}{221} = 38|0|32$

(iv) Difference between the motions of Śukra and the Sun = $15'\ 53''$

Now, $\dfrac{38|0|32}{15|53} = 2^{d}\ 23^{gh}\ 34^{vig}$

Therefore, $2^{d}\ 23^{gh}\ 34^{vig}$ before the given date viz. *Caitra Śukla Aṣṭamī* Śukra had set.

Śloka **21** : The correction for the *kālāṃśas* for the rising and setting of the Moon and Śukra is explained.

The difference between 300 and the *udayamāna* (in *vighaṭīs*) of the *rāśi* of the *sāyana* planet (the Moon or Śukra) divided by 27. The result will be in *aṃśas* (degrees) etc. and it is additive or subtractive according as the *udayamāna* is greater than or less than 300 *vig.* i.e., (*Udayamāna* $-$ 300) is positive or negative. The result is accordingly added to or subtracted from *dṛkkarma phalam* of the planet. If both are of the same sign then take the sum of their numerical values (and attach their common sign). If they are of opposite signs, the difference of their numerical values is taken (and the sign of the bigger number is attached). In other words, consider their algebraic sum.

Then $\frac{1}{5}$th of the above result is accordingly added to or subtracted from the prescribed *kālāṃśas* of the planet (viz., 12° and 9° respectively for the Moon and Śukra).

In the case of Śukra subtract 2° from the above result. This gives the corrected *kālāṃśa*.

Example : *Sāyana* Śukra = $0^R\, 3^\circ\, 06'\, 20''$

(i) *Dṛkkarma phala* = $+1^\circ\, 43'\, 51''$

Śukra is in *Meṣa rāśi* and its *udayamāna* is 221 *vig.* (for *Kāśī*)

(ii) Now, $\dfrac{221-300}{27} = -2^\circ\, 55'\, 33''$

iii) The algebraic sum of (i) and (iii) is $-1^\circ\, 11'\, 42''$.

iv) $\frac{1}{5}$th of the result of (iii) is $\frac{1}{5} \times (-1^\circ\, 11'\, 42'') \approx -0^\circ\, 14'$

v) The prescribed *kālāṃśa* of Śukra = 9°.

Combining the results of (iv) and (v) and subtracting 2° (for Śukra) we get

Corrected *kālāṃśa* $= (9^\circ - 0^\circ\, 14') - 2^\circ = 6^\circ\, 46'$.

***Śloka* 22** : Now, the rising and setting timings of the *Agastya* star (Canopus) are explained.

Multiply the *palabhā* by 8 and subtract from and add to 78° and 98° respectively. These values correspond respectively to the setting and rising of the *Agastya* star after those of the Sun.

Example : *Palabhā* = $5|45$ *aṅgulas* (for Kāśī)

We have

(i) $78^\circ - 8 \times$ *palabhā* $= 32^\circ \equiv 1^R\, 2^\circ$ i.e., *Vṛṣabha rāśi* 2°.

This corresponds to the *setting* of the *Agastya* star.

(ii) $98^\circ + 8 \times$ *palabhā* $= 144^\circ \equiv 4^R\, 24^\circ$

i.e., *Siṃha* 24° corresponding to the rising of the *Agastya* star. This means that the *Agastya* star sets when the Sun reaches *Vṛṣabha* 2° and rises when the Sun is at *Siṃha* 24°.

Remark : The commentator gives the following explanation for the constants used in the above method.

According to the procedure given by Bhāskara II, at a place whose *palabhā* (or *akṣabhā*) is 1 *aṅgula*, the *dṛkkarma* = 8°. Therefore, by the rule of three, if the *palabhā* of a place is x *aṅg.* then the *dṛkkarma* = $8x$ degrees.

The *āyana dṛkkarma* corrected *udaya dhruvaka* (longitude) of the *Agastya* star is 87° (i.e., for the rising). For this the *kālāṃśa* is 12° and the *kṣetrāṃśa* is 11°. The *asta dhruvaka* (i.e., for setting) after the *āyana dṛkkarma* correction is 89°. Therefore, adding and subtracting 11° respectively to the two *dhruvakas* we get 98° and 78° for the setting and rising of *Agastya*.

***Śloka* 23** : This *śloka* explains the daily setting and rising of a planet.

(1) Find the true longitude of the Sun and the planet at the time of the sunset.

(2) If the planet is greater than the *saṣaḍbha Sūrya* (i.e., true Sun + 6^R) or less than the true Sun, then it rises in the night.

(3) Otherwise, i.e., if the planet is less than *saṣaḍbha Sūrya* and greater than the Sun then it sets in the night.

(4) Obtain the *dṛkkarma* corrected planet to find the time or *lagna* of rising and setting. Find *pūrva dṛkkarma* for rising and *paścima dṛkkarma* for setting.

Example : *Śaka* = 1534, *Vaiśākha śukla* 15 (*Pūrṇimā*)

To find daily setting and rising of Guru we have the following :

True Sun = $1^R\ 5^\circ\ 42'\ 37''$, True daily motion of the Sun = $57'\ 36''$

True Guru = $4^R\ 2^\circ\ 9'\ 49''$, True daily motion of Guru = $5'\ 22''$

Dinamānam = 33|6 *ghaṭīs*

Sun at the sunset = $1^R\ 6^\circ\ 14'\ 13''$

True Guru at the sunset = $4^R\ 2°\ 12'\ 46''$

Now, the Sun + 6^R i.e., *saṣaḍbha Sūrya* = $7^R\ 5°\ 42'\ 37''$ is greater than Guru and Guru = $4^R\ 2°\ 12'\ 46''$ is greater than the Sun. Therefore Guru sets in the night [from condition (3) above].

To find *paścima dṛkkarma* :

Guru + 3^R = $7^R\ 2°\ 12'\ 46''$, *Krānti* = $18°\ 12'\ 41''$ (South)

Natāṃśa = $43°\ 38'\ 23''$ (South), *Dṛkkarma* = $55'\ 18''$

Dṛkkarma corrected Guru = $4^R\ 3°\ 08'\ 04''$

***Śloka* 24** : Now, the *rātri* (night) *ghaṭīs* of *udaya* (rising) and *asta* (setting) of a planet is explained.

For the rising and the setting of a planet, the corrected true longitude and the same *plus* 6 *rāśis* respectively are considered. Find the *bhukta kāla* (elapsed time) of the above. To this add the *bhogya kāla* (balance time) of 6 *rāśis* plus true Ravi. Add the *udayamānas* of the *rāśis* lying between the relevant value of the planet and (6^R + Ravi). Divide this by 60 to get the *rātri gata kāla*. This is corrected by considering the true positions (in degrees etc.).

Example : At the sunset we have

Dṛkkarma corrected Guru = $4^R\ 3°\ 08'\ 04''$.

6 *rāśis* + *nirayaṇa* Guru = $10^R\ 3°\ 08'\ 04''$

Bhuktakāla of the *sāyana* of the above = 179 *vighaṭīs*

6 *rāśis* + *nirayaṇa* Ravi = $7^R\ 6°\ 14'\ 23''$

Bhogyakāla of the *sāyana* of the above = 64 *vig.*

Intervening *rāśis* are *Dhanus* and *Makara*. Their *udayamānas* are 342 *vig.* and 304 *vig.*

Sum of these *kālas* (time intervals) = 179 + 64 + 342 + 304 = 889 *vig.*

Dividing this sum by 60, we get 889 *vig.*/60 = $14^{gh.}\ 49^{vig.}$

Thus, Guru sets at $14^{gh.}\ 49^{vig.}$ after the sunset.

To obtain the corrected (*spaṣṭīkṛta*) instant :

At $14^{gh.}\ 49^{vig.}$ (after sunset) Guru = $4^R\ 2°\ 14'\ 06''$

At that instant, Ravi = $1^R\ 6°\ 28'\ 46''$

Lagna *bhukta kāla* = 179 *vig.*, Ravi *bhogyakāla* = 61|36|06 *vig.*

Udayamānas of *Dhanu* and *Makara* are respectively 342 and 302 *vighaṭīs*. Adding these timings, we get 886 *vig.* Dividing by 60, we get $14^{gh.}\ 46^{vig.}$.

***Śloka* 25** : A special correction for the instants of the Moon's rising and setting is explained.

Respectively add to and subtract from the timings of *udaya* and *asta* of the Moon 9 *palas* (*vighaṭīs*). Then add (in both cases) 2 *palas* (*vig.*) for each *ghaṭī* thus obtained. These values give the corrected instants of the Moon's rising and setting. In this case there is no need of obtaining the true Moon at the particular instants.

CHAPTER 10

GRAHACCHĀYĀDHIKĀRAḤ

(Planetary Shadows)

The visibility or otherwise of a planet in the night and obtaining *dinagata kāla* and shadow of a planet are explained.

Śloka 1 : From this *śloka* we find the *dinagatakāla* of the planets and the Moon as follows.

(1) If the *dṛkkarma* corrected planet at sunrise is less than the *iṣṭakāla lagna* (i.e., *lagna* at a given time) and if it is greater than the *saptama lagna*, then the planet is visible at the *iṣṭakāla.*

(2) Adding the *bhuktakāla* of *lagna* and the *udayamānas* of the *madhyagata* (intervening) *rāśis* to the *bhogyakāla* of the planet, we get *dinagatakāla* of the planet.

(3) In the case of Moon, subtract 9 *palas* from its *dinagatakāla* to get the corrected *dinagatakāla* of the Moon.

Example : Given date is May 1, 1610 A.D. (*G*) :

Śaka 1532, *Vaiśākha Śukla navamī* (9), Saturday.

Cakra = 8 and *Ahargaṇa* = 777

Rātrighaṭīs = 10 *gh.* (*iṣṭakāla*)

Mean positions of the Sun, the Moon, Moon's *mandocca* and Rāhu for the given date, at the mean sunrise, are as follows :

Sun = $0^R\ 20°\ 56'\ 22''$, Moon = $3^R\ 26°\ 58'\ 3''$

Moon's *uccam* = $7^R\ 22°\ 04'\ 6''$, Rāhu = $2^R\ 23°\ 47'\ 3''$

Now, *Ayanāṃśa* = $18°\ 08'$, *Cara* = $-73''$

Manda corrected Ravi = $0^R\ 22°\ 46'\ 02''$

Cara corrected Ravi = $0^R\ 22°\ 44'\ 49''$

True daily motion of the Sun = $59'\ 58''$

Manda corrected true Moon = $4^R\ 1°\ 7'\ 13''$

True daily motion of the Moon = $719'\ 19''$

Dinamānam = $32^{gh}\ 26^{vig}$

Since the given time is *rātrighaṭīs* 10 *gh*. (*iṣṭakāla*),

the time from sunrise = $32^{gh}\ 26^{vig} + 10^{gh} = 42^{gh}\ 26^{vig}$.

At this instant, we have

True Sun = $23°\ 25'\ 48''$, True Moon = $4^R\ 10°\ 46'\ 39''$

Rāhu = $2^R 23° 44' 48''$

Now, Moon – Rāhu = $1^R 17° 01' 51''$ *Śara* = $65|44$ *aṅgulas*

Moon – 3 *rāśis* = (*tribha-varjita-Candra*)

$$= 4^R\ 10°\ 46'\ 39'' - 3^R = 1^R\ 10°\ 46'\ 39''$$

Declination of the above, $\delta = 20°\ 19'\ 39''$ (north)

Akṣāṃśa $\phi = 25°\ 26'\ 42''$ (north) for Kāśī

Natāṃśa = $(\delta - \phi) = -5°\ 7'\ 3''$

Dṛkkarma = $-16'\ 49''$

Dṛkkarma corrected Moon = $4^R\ 10°\ 29'\ 50''$

Rātrigata ghaṭīs = 10^{gh} (given time)

(*Nirayaṇa*) *Lagna* = $8^R\ 16°\ 24'\ 22''$

(*Nirayana*) *Asta Lagna* = $2^R\ 16°\ 24'\ 22''$ (by adding 6^R)

We note that the *sāyana dṛkkarma* corrected Moon is in the *Simha rāśi*, and the *sāyana lagna* is in the *Makara rāśi*.

Sum of the rising durations (*udayamānas*) of intervening *rāśis* from *Kanyā* to *Dhanus* = 1357 *vig.*

Remark : For the town of *Kāśī*, the rising durations (*udayamānas*) for *Siṃha, Kanyā, Tulā, Vṛṣcika, Dhanus* and *Makara* are respectively 345, 335, 335, 345, 342 and 304 *vighaṭīs*. However, considering the four *rāśis* in between *Siṃha* and *Makara* the sum of the *udayamānas* is 335 + 335 + 345 + 342 = 1357 *vighaṭīs* (i.e., of *Kanya, Tulā, Vṛścika* and *Dhanus*).

***Bhukta kāla* of *Sāyana lagna* :**

Nirayana lagna : $8^R\ 16°\ 24'\ 22''$, *Ayanāṃśa* = $18°\ 08'$

∴ *Sāyana lagna* : $9^R\ 4°\ 32'\ 22''$

i.e., *Bhuktāṃśas* = $4°\ 32'\ 22''$ in (*sāyana*) *Makara*

$$\therefore \quad Bhukta\ k\bar{a}la = \frac{4°\ 32'\ 22''}{30°} \times 304\ vig. = 46\ vig.$$

Bhogyāṃśas of *Sāyana dṛkkarma* corrected Moon = $5^R - (4^R\ 28°\ 37')$

= $1°\ 23'$ in *Sāyana Siṃha*

$$\therefore \quad Bhogyak\bar{a}la = \frac{1°\ 23'}{30°} \times 345\ vig. \approx 15.90\ vig. \approx 16\ vig.$$

Their sum = $46^{vig.} + 16^{vig.} = 62^{vig.}$

Now, the sum of the *udayamānas* and the above result

$$= (1357 + 62)^{vig.} = 1419\ vig.$$

Dividing this by 60, we get the *dinagatakāla* of the Moon (in *ghaṭīs*)

$$\text{i.e.,} \quad dinagatak\bar{a}la = \frac{1419}{60}\ gh. = 23^{gh.}\ 39^{vig.}$$

For the Moon, subtract 9 *palas* from the above result,

i.e., *dinagatakāla* of the Moon = $23|39\ gh. - 0|9\ gh. = 23|30\ gh.$

from the sunrise.

***Śloka* 2** : This *śloka* explains the method of finding *grahacchāyā* (planet shadow) as follows :

(1) Multiply *śara* (in *aṅgulas*) by the *palabhā* of the place.

(2) Divide the product by 24.

(3) The above result is added to or subtracted from the *cara* to get *spaṣṭa cara* (corrected *cara*)

i.e., Corrected *cara* = $cara \pm \left(\dfrac{śara \times palabhā}{24} \right)$

(4) Obtain the *dinamānam* (duration of the day) from the corrected *cara*.

(5) Obtain the *chāyā* of the planet from *dinagatakāla*.

Example : *Cara* obtained from *dṛkkarma* corrected Moon = $59''$ (northern).

Śara = $65|44$ *aṅgulas* ; *Palabhā* = $5|45$ *aṅg.*

$\therefore$ Corrected *Cara* = $Cara + \dfrac{śara \times palabhā}{24}$

$$= 59 + 15|44 = 74|44 \ vig. \ = 1^{gh}\ 14^{vig}\ 44^{pv.}$$

Dinamānam = $32^{gh}\ 28^{vig}$

Note : *Dinamānam* = 2 × [Mean *dinārdha* + Cor. *Cara*)

$$= 2 \times [15^{gh.} + 1^{gh.}\ 14^{vig.}\ 44^{pv.}] \ \approx 32^{gh}\ 29^{vig}$$

Dinagata kāla of the Moon = $23^{gh}\ 29^{vig}$ (obtained from *Śloka* 1).

Dinamānam – *Dinagata kāla* = $32^{gh}\ 29^{vig} - 23^{gh}\ 29^{vig} = 9^{gh}$

Paścima natam = $7^{gh}\ 15^{vig}$

Akṣakarṇa = $\sqrt{(\acute{s}a\dot{n}ku)^2 + (Palabh\bar{a})^2}$

$= \sqrt{(12)^2 + (5|45)^2} = 13|18$ *aṅgulas*

Hāra = 128|56, *Samākhya* = 30|01, *Abhimatahāra* = 7|25

Bhājya = 117|55, *Karṇa* = 15|53 *aṅgulas*

Iṣṭachhāyā = 10|24 *aṅgulas*

***Śloka* 3** : Finding the *chāyā* of a planet using *dhīyantra* is explained. The reflection of the planet is first seen in water. The *lamba* is measured from the (horizontal) ground level to the point of reflection. The distance between the foot of the *lamba* and the point of reflection is measured in *aṅgulas*. This will be the *bhuja*. This value is multiplied by 12 and divided by the elevation (height) of the reflected point. The result gives the *chāyā* of the planet in *aṅgulas*.

From the similar triangles *ABD* and *RMD*, in Fig. 10.1 we have

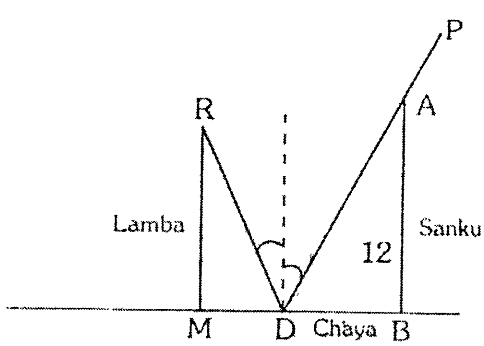

Fig. 10.1 *Grahacchāyā*

Chāyā $DB = \dfrac{MD}{MR} \times 12$ aṅgulas

***Śloka* 4** : Now, the obtaining of *dinagata kāḷa* from a planet's *chāyā* (shadow) is explained. Knowing the time in the night, find the then position of the planet and hence *cara*. Using the *cara* and *chāyā*, the *dinagata kāla* of the planet is determined just as in the case of the Sun as explained in *tripraśnādhikāra*. In the case of the Moon, 9 *palas* is added to the result.

Example : We have the given time (*iṣṭakāla*) :

Ratrigata ghaṭikā (time in the night) = 10 *gh.* (after sunset)

Cara = $74|44$,*Dinamānam* = $32|28$ *gh.* *Iṣṭacchāyā* = $10|24$ *aṅg.*

Karṇa = $15|53$, *Bhājya* = $117|55$, *Hāra* = $7|25$

Akṣakarṇa = $13|18$ *aṅg.* *Madhyahara* = $128|56$

Natam = $7|15$ (West), *Dinārdham* = $16|14$ *gh.*

Dinagatakāla of the planet = *Natam* + *Dinārdham*

= $(7|15 + 16|14)$ *gh.* = $23|29$ *gh.*

Dinagatakāla of the Moon = $(23|29 + 0|9)$ *gh.* = $23|38$ *gh.*

***Śloka* 5** : Between the *dṛkkarma* corrected planet and the Sun *plus* six *rāśis* whichever is less is treated as the Sun and the other as the *lagna*. The *antarāṃśa ghaṭī* is determined by the process explained earlier. According as the (*dṛkkarma*) corrected planet is less than or greater than the Sun *plus* six *rāśis*, the *antarāṃśa ghaṭī* will be *dina śeṣa ghaṭī* (the balance *ghaṭī* of the day time) or *rātrī gata ghatī* (the elapsed *ghaṭī* in the night i.e., after the sunset).

Example : *Dṛkkarma* corrected Candra = $4^R\ 10°\ 29'\ 50''$. Sun + 6 *rāśis* = $6^R\ 23°\ 25'\ 48''$ (*nirayaṇa*). Between these, Candra is less. Therefore Candra is to be considered as the Sun and the other value viz. $6^R\ 23°\ 25'\ 48''$ as of the *Lagna*.

We shall find the *antarāṃśa ghaṭīs*. We have *ayanāṃśa* = $18°\ 10'$. *Sāyana* Candra (to be considered as the Sun) = $4^R\ 10°\ 29'\ 50'' + 18°\ 10'$ = $4^R\ 28°\ 39'\ 50''$. *Sāyana* Sun + 6 *rāśis* = $6^R\ 23°\ 25'\ 48'' + 18°\ 10'$ = $7^R\ 11°\ 35'\ 48''$. Therefore,we have *Arkabhogya* = $30° - 28°\ 39'\ 50'' = 1°\ 20'\ 10''$ in *Siṃha rāśi* whose *udayamāna* = 345 *vig*. Therefore, we have

$$\textit{Arkabhogya ghaṭīis} = \frac{1°\ 20'\ 10''}{30°} \times 345\ \textit{vig.} \approx 15\ \textit{vig.}$$

Tanu bhukta bhāga (i.e., elapsed degrees in the *sāyana Lagna*) = $11°\ 35'\ 48''$ in *Vṛścika*. Therefore, we have

$$\textit{Tanu bhukta ghaṭī} = \frac{11°\ 35'\ 48''}{30°} \times 345\ \textit{vig.} \approx 133\ \textit{vig.}$$

(noting that the *udayamāna* of *Vṛścika* = 345 *vig.*)
In between these, the completed *rāśis* risen = *Kanyā* 335 *vig.* + *Tulā* 335 *vig.* = 670 *vig.* Therefore,

$$\textit{Antarāṃśa ghaṭīs} = \frac{(15 + 133 + 670)}{60}\ \textit{vig.} = \frac{818}{60}\ \textit{gh.} = 13^{gh.}\ 38^{vig.}.$$

Since *Candra* < (Sun + 6^R), *dina śeṣa kāla* = $13^{gh.}\ 38^{vig.}$.

***Śloka* 6** : By adding to or subtracting from the *dina gata kāla* of a planet the *dinaśeṣa* or *rātrigata kāla* respectively, we get the *rātri gata kāla* (i.e., time after the sunset). In the case of the Moon, if the obtained time is less than or greater than the guessed time (*anumita kāla*), then accordingly the difference multiplied by 2 in *palās* is added to or subtracted from the obtained time to get the correct time.

Example : *Dinagatakāla* of the Moon = $23^{gh.}\,38^{vig.}$ (see example under *Śloka* 4). *Dina śeṣa kāla* = $13^{gh.}\,38^{vig.}$ (obtained under *Śloka* 5). Subtracting the latter from the former, we get $23^{gh.}\,38^{vig.} - 13^{gh.}\,38^{vig.} = 10^{gh.}$. This is the *rātri ghaṭī* after the sunset (see example under *Śloka* 1).

CHAPTER 11

NAKṢATRA CHĀYĀ

(Shadow of Stars)

In this chapter the shadow of stars is discussed.

***Ślokas* 1 and 2** : The *āyana dṛkkarma* corrected *dhruvas* (polar longitudes) of the *nakṣatras* (junction stars or *yogatārās*) from *Aśvinī* onwards are (in degrees) respectively 8, 21, 38, 49, 62, 66, 94, 106, 107, 129, 148, 155, 160, 183, 198, 212, 224, 230, 242, 255, 261, 258, 275, 286, 320, 325, 337, 0. Dividing these by 30 we get them in *rāśi* etc. The 28 *yogatārās* include *Abhijit* and their *dhruvas* are shown in Table 11.1.

Multiply the *śara* (celestial latitude of the junction star given in the next *śloka*) by the *palabhā* (equinoctial shadow of the gnomon) and divide by 12. The result is added to or subtracted from the *dhruvas* given above (to get those for the given place). When the *śara* is south then the above result is added to or subtracted from the above given *dhruvas* according as those are eastern or western. If the *śara* is north then the addition and subtraction are reversed.

***Śloka* 3** : The *śaras* (cel. latitude) of the 13 *yogatārās* from *Aśvinī* to *Hasta* are 10, 12, 5, 5, 10, 11, 6, 0, 7, 0, 12, 13 and 11. Those of the next nine *nakṣatras* from *Citrā* to *Abhijit* are 2, 37, 1, 2, 3, 8, 5, 5, 62. The *śaras* of the remaining six *nakṣatras* from *Śravaṇa* to *Revatī* are 30, 6, 3, 0, 24, 0.

Among these *Citrā*, *Hasta*, *Āśleṣā* and 6 *nakṣatras* from *Viśākhā*, the 3 from *Rohiṇī* and *Śatabhiṣaj* have their *śara* (latitude) south. The remaining 15 *nakṣatras* have their *śara* north.

Table 11.1 *Nakṣatras* with their *Dhruvas* and *Śaras*

No.	*Nakṣatra Yogatāra*	*Dhruva* (Degrees)	*Śara* (Degrees)
1.	*Aśvinī*	8	10
2.	*Bharaṇī*	21	12
3.	*Kṛttikā*	38	5
4.	*Rohiṇī*	49	– 5
5.	*Mṛgaśira*	62	– 10
6.	*Ārdrā*	66	– 11
7.	*Punarvasu*	94	6
8.	*Puṣya*	106	0
9.	*Āśleṣā*	107	– 7
10.	*Makhā (or Maghā)*	129	0
11.	*Pubba (Pūrva Phālguni)*	148	12
12.	*Uttarā (Uttara Phālguni)*	155	13
13.	*Hasta*	160	– 11
14.	*Cittā (or Citrā)*	183	– 2
15.	*Svātī*	198	37
16.	*Viśākhā*	212	– 1
17.	*Anurādhā*	224	– 2
18.	*Jyeṣṭhā*	230	– 3
19.	*Mūlā*	242	– 8
20.	*Pūrvāṣādhā*	255	– 5
21.	*Uttarāṣādhā*	261	– 5
22.	*Abhijit*	258	62
23.	*Śravaṇa*	275	30
24.	*Dhaniṣṭhā*	286	6
25.	*Śatabhiṣaj*	320	– 3
26.	*Pūrvābhādrā*	325	0
27.	*Uttarābhādrā*	337	24
28.	*Revatī*	0	0
29.	*Prajāpati*	61	39
30.	*Brahmahṛdaya*	56	30
31.	*Agni*	53	8
32.	*Agastya*	88	– 76
33.	*Apāmvatsa*	183	3
34.	*Lubdhaka*	81	– 40

Ślokas **4 and 5** : The *dhruvāṃśas* of *Prajāpati, Brahmahṛdaya, Agni, Agastya, Apāmvatsa* and *Lubdhaka* are respectively 61, 56, 53, 88, 183, 81. The *śarāṃśa* of these are respectively 39, 30, 8, 76, 3, 40. Among these, *Agastya* and *Lubdhaka* have their *śara* south. The remaining are in the nothern hemisphere.

Table 11.1 lists the *nakṣatras* with their *dhruvas* and *śaras*. Table 11.2 gives the list of the 27 *nakṣatras*, in their natural order, and their angular extents. Each *nakṣatra* was named after the most prominently visible star (called *yogatārā* or junciton-star) contained within its range, given in Table 11.2. The *yogatārās* with modern equivalents and their co-ordinates are listed in Table 11.3 (reproduced from *Lahiri's Indian Ephemeris* for 1995).

Table 11.2 *Nakṣatras* and their range of *nirayaṇa* longitudes

No.	*Nakṣatra*	From	To
1.	*Aśvinī*	0°0′	13°20′
2.	*Bharaṇī*	13°20′	26°40′
3.	*Kṛttikā*	26°40′	40°00′
4.	*Rohiṇī*	40°00′	53°20′
5.	*Mṛgaśira*	53°20′	66°40′
6.	*Ārdrā*	66°40′	80°00′
7.	*Punarvasu*	80°00′	93°20′
8.	*Puṣya*	93°20′	106°40′
9.	*Āśleṣā*	106°40′	120°00′
10.	*Makhā* (or *Maghā*)	120°00′	133°20′
11.	*Pubba* (*Pūrva Phālguṇī*)	133°20′	146°40′
12.	*Uttarā (Uttara Phālguṇī)*	146°40′	160°00′

Table 11.2 (continued)

No.	*Nakṣatra*	From	To
13.	*Hasta*	160°00′	173°20′
14.	*Cittā (or Citrā)*	173°20′	186°40′
15.	*Svātī*	186°40′	200°00′
16.	*Viśākhā*	200°00′	213°20′
17.	*Anurādhā*	213°20′	226°40′
18.	*Jyeṣṭhā*	226°40′	240°00′
19.	*Mūlā*	240°00′	253°20′
20.	*Pūrvāṣādhā*	253°20′	266°40′
21.	*Uttarāṣādhā*	266°40′	280°20′
22.	*Śravaṇa*	280°20′	293°20′
23.	*Dhaniṣthā*	293°20′	306°40′
24.	*Śatabiṣaj*	306°40′	320°00′
25.	*Pūrvābhādrā*	320°00′	333°20′
26.	*Uttarābhādrā*	333°20′	346°40′
27.	*Revatī*	346°40′	360°00′

Table 11.3 *Mean places* of stars for 1995.0

(i.e., on Jan. 0.822 UT = Jan. 0.25h 14m IST)

Note : Tropical or *Sāyana* long. = *Nirayaṇa* long. + 23° 47′ 14″.1 *ayanāṃśa*

Star	Indian Name	Mag.	*Nirayaṇa* Longitude				Latitude			Right Ascension			Declination		
			s	°	′	″	°	′	″	h	m	s	°	′	″
β Arietis	*Aśvinī*	2.72	0	10	06	46	+8	29	14	1	54	21.8	+20	47	01
α Arietis	...	2.23	0	13	48	19	+9	57	54	2	06	53.4	+23	26	20
41 Arietis	*Bharaṇī*	3.68	0	24	20	48	+10	26	58	2	49	41.3	+27	14	24
Algol 1	...	2.7v	1	2	18	39	+22	25	41	3	07	50.5	+40	56	12
Alcyone 2	*Kṛttikā*	2.96	1	6	08	07	+4	03	02	3	47	11.2	+24	05	24
Aldebaran 3	*Rohiṇī*	1.06	1	15	55	56	-5	28	04	4	35	38.0	+16	29	58
Rigel 4	...	0.34	1	22	58	21	-31	07	24	5	14	17.8	-8	12	26
Bellatrix 5	...	1.70	1	27	05	22	-16	49	00	5	24	51.8	+6	20	44
Capella 6	*Brahmahṛday*	0.21	1	28	00	03	+22	51	51	5	16	19.1	+45	59	36
β Tauri	*Agni*	1.78	1	28	43	05	+5	23	05	5	25	58.5	+28	36	13
ε Orionis	...	1.75	1	29	36	24	-24	30	25	5	35	57.5	-1	12	17
λ Orionis	*Mṛgaśiras*	3.66	1	29	50	59	-13	22	12	5	34	51.7	+9	55	52
Polaris	*Dhruva*	2.1v	2	4	42	39	+66	06	03	2	26	21.9	+89	14	31

(continued)

Star	Indian Name	Mag.	*Nirayaṇa* Longitude				Latitude			Right Ascension			Declination		
			s	°	′	″	°	′	″	h	m	s	°	′	
Betelguese 7	*Ārdrā*	0.6v	2	4	53	51	-16	01	40	5	54	54.1	+7	24	23
Sirius 8	*Lubdhaka*	-1.58	2	20	13	32	-39	36	15	6	44	55.6	-16	42	32
Canopus 9	*Agastya*	-0.86	2	21	06	17	-75	49	28	6	23	50.6	-52	41	34
Castor 10	...	1.99	2	26	23	02	+10	05	44	7	34	16.9	+31	53	59
Pollux 11	*Punarvasu*	1.21	2	29	21	34	+6	41	02	7	45	00.6	+28	02	19
Procyon 12	...	0.48	3	1	55	46	-16	01	07	7	39	01.7	+5	14	17
δ Cancri	*Puṣya*	4.17	3	14	51	54	+0	04	37	8	44	24.1	+18	10	23
ε Hydrae	*Āśleṣā*	3.48	3	18	29	18	-11	06	15	8	46	30.7	+6	26	14
α Cancri	”	4.27	3	19	47	05	-5	04	51	8	58	12.8	+11	52	38
Dubhe 13	*Kratu*	1.95	3	21	20	25	+49	40	47	11	03	25.3	+61	46	41
Regulus 14	*Makhā*	1.34	4	5	58	21	+0	27	53	10	08	06.3	+11	59	30
δ Leonis	*Pūrva Phālguṇī*	2.58	4	17	27	33	+14	20	00	11	13	50.6	+20	33	04
Denebola 15	*Uttara Phālguṇī*	2.23	4	27	45	39	+12	16	02	11	48	48.3	+14	36	00
δ Corvi	*Hasta*	3.11	5	19	35	42	-12	11	45	12	29	36.3	-16	29	16
Spica 16	*Citrā*	1.21	5	29	59	03	-2	03	15	13	24	35.7	-11	08	07

(continued)

Star	Indian Name	Mag.	*Nirayaṇa* Longitude				Latitude			Right Ascension			Declination		
			s	°	′	″	°	′	″	h	m	s	°	′	″
Arcturus 17	*Svātī*	0.24	6	0	22	36	+30	44	23	14	15	26.0	+19	12	30
α Libra	*Viśākhā*	2.90	6	21	13	32	+0	20	01	14	50	36.1	-16	01	16
β Centauri	...	0.86	6	29	56	09	-44	08	13	14	03	28.0	-60	20	57
α Centauri	...	0.06	7	5	37	45	-42	35	39	14	39	15.3	-60	48	54
δ Scorpii	*Anurādhā*	2.54	7	8	42	50	-1	59	08	16	00	02.2	-22	36	28
Antares 18	*Jyeṣṭhā*	1.2v	7	15	54	19	-4	34	09	16	29	06.0	-26	25	16
λ Scorpii	*Mūlā*	1.71	8	0	43	43	-13	47	16	17	33	16.1	-37	06	02
δ Sagittarii	*Pūrvāsāḍhā*	2.84	8	10	43	26	-6	28	18	18	20	40.5	-29	49	52
ε Sagittarii	...	1.95	8	11	13	18	-11	03	04	18	23	50.4	-34	23	14
δ Sagittarii	*Uttarāṣāḍhā*	2.14	8	18	31	41	-3	26	56	18	54	57.3	-26	18	12
Vega 19	*Abhijit*	0.14	8	21	27	31	+61	43	59	18	36	46.1	+38	46	44
Altair 20	*Śravaṇa*	0.89	9	7	55	06	+29	18	13	19	50	32.4	+8	51	18
β Capricorni	...	3.25	9	10	11	25	+4	35	21	20	20	43.8	-14	47	51
β Delphini	*Dhaniṣṭhā*	3.72	9	22	29	04	+31	55	07	20	37	18.9	+14	34	39
α Delphini	...	3.86	9	23	31	25	+33	01	22	20	39	24.4	+15	53	39
Formalhaut 21	...	1.29	10	10	00	10	-21	08	06	22	57	22.5	-29	38	36

(continued)

Star	Indian Name	Mag.	*Nirayaṇa* Longitude				Latitude			Right Ascension			Declination		
			s	°	′	″	°	′	″	h	m	s	°	′	″
Deneb 22	...	1.33	10	11	28	23	+59	54	24	20	41	15.7	+45	15	44
λ Aquarii	*Śatabhiṣaj*	3.84	10	17	43	08	-0	23	11	22	52	21.2	-7	36	23
Achernar 23	...	0.60	10	21	27	12	-59	22	41	1	37	31.7	-57	15	43
Markab 24	Pūrvābhādrapada	2.57	10	29	37	43	+19	24	22	23	04	30.7	+15	10	42
β Pegasi	...	2.6v	11	5	31	02	+31	08	26	23	03	31.9	+28	03	20
γ Pegasi	*Uttarābhādhrapada*	2.87	11	15	17	57	+12	36	00	0	12	58.7	+15	09	21
α Andromeda	...	2.15	11	20	27	06	+25	40	50	0	08	07.7	+29	03	45
ζ Piscium	*Revatī*	5.57	11	26	01	13	-0	12	48	1	13	28.2	+7	32	56

1. β Persei	7. α Orionis	13. α Ursae Majoris	19. α Lyrae
2. η Tauri	8. α Canis Majoris	14. α Leonis	20. α Aquilae
3. α Tauri	9. α Carinae	15. β Leonis	21. α Piscis Austrini
4. β Orionis	10. β Germinorum	16. α Virginis	22. α Cygni
5. γ Orionis	11. α Germinorum	17. α Bootis	23. α Eridani
6. α Aurigae	12. α Canis Minoris	18. α Scorpii	24. α Pegasi

Table 11.4 Distribution of *Nakṣatra Pādas* into *Rāśis*

No.	*Nirayaṇa Rāśi*	*Nakṣatra*	*Pādas* included
1.	*Meṣa*	*Aśvini*	All
		Bharaṇī	All
		Kṛttikā	1
2.	*Vṛṣabha*	*Kṛttikā*	2, 3, 4
		Rohiṇī	All
		Mṛgaśira	1, 2
3.	*Mithuna*	*Mṛgaśira*	3, 4
		Ārdrā	All
		Punarvasu	1, 2, 3
4.	*Karkaṭaka*	*Punarvasu*	4
		Puṣya	All
		Āśleṣā	All
5.	*Simha*	*Makhā*	All
		*Pubba**	All
		*Uttarā***	1
6.	*Kanyā*	*Uttarā***	2, 3, 4
		Hasta	All
		Cittā (Citrā)	1, 2
7.	*Tulā*	*Cittā (Citrā)*	3, 4
		Svātī	All
		Viśākhā	1, 2, 3
8.	*Vṛścika*	*Viśākhā*	4
		Anurādhā	All
		Jyeṣṭhā	All
9.	*Dhanus*	*Mūlā*	All
		Pūrvāṣāḍhā	All
		Uttarāṣāḍhā	1
10.	*Makara*	*Uttarāṣāḍhā*	2, 3, 4
		Śravaṇa	All
		Dhaniṣṭhā	1, 2
11.	*Kumbha*	*Dhaniṣṭhā*	3, 4
		Śatabhiṣaj	All
		Pūrvābhādrā	1, 2, 3
12.	*Mīna*	*Pūrvābhādrā*	4
		Uttarābhādrā	All
		Revatī	All

* *Pūrva Phālguṇī* is referred to as *Pubba*.

** *Uttara Phālguṇī* is referred to as *Uttarā*.

Example : We shall find the *dhruva* of *Aśvinī* for *Kāśī* whose *palabhā* is $5|45$ *angulas*. The *śara* of *Aśvinī* is 10° (given in *Śloka* 3) and its *dhruva* is 8°. Multiplying the *śara* by *palabhā* we get $10 \times (5|45) = 57|30$. Dividing this by 12, we get $4^\circ\ 47'\ 30''$. Since *śara* is north, the result is subtracted from the *dhruva* of *Aśvinī* (eastern) to get the *udaya* (rising) *dhruva* of *Aśvinī* at *Kāśī*

i.e., *Udaya dhruva* of *Aśvinī* $= 8^\circ - 4^\circ\ 47'\ 30'' = 3^\circ\ 12'\ 30''$.

Similarly, performing the reverse operation we get the *asta* (setting) *dhruva* of *Aśvinī* viz., $8^\circ + 4^\circ\ 47'\ 30'' = 12^\circ\ 47'\ 30''$.

***Śloka* 6** : By considering the *dhruva* of a *nakṣatra* for the given place, similar to that of a planet, find the *cara* (from the *dhruva*) and hence the *dinamānam*, *unnata*, *nata*, *karṇa* and hence *yantrabhāga* (discussed in *tripraśnādhikāra*). The *chāyā*, *rātrigata kāla* (time elapsed during night) and the *yantrabhāga* are determined as in the case of a planet (discussed in the chapter *Grahacchāya*). Further, the conjunction of a star and a planet can be worked out as in the case of *grahayuti* (conjunction of planets).

Remark : Though Gaṇeśa Daivajña has not explained, in clear terms, the obtaining of conjunction of a planet and a star (*graha nakṣatra yuti*), his nephew (brother's son) Nṛsimha Daivajña has discussed the same in detail in his handbook.

Śloka* 7** : ***Rohiṇī śakaṭa bheda (breaking of *Rohiṇī* cart) is explained. If a planet is at 17° of *Vṛṣabha*, having its *śara* southern and greater than 50 *aṅgulas*, it is said to "break the *Rohiṇī* cart (wain)." (It is believed that) if any one of Kuja, Śani and Candra breaks the *Rohiṇī* cart then there will be a great calamity.

Śloka **8** : Determination of the *Rohiṇī sakaṭa bheda* of the Moon is explained.

As long as Rāhu is in the eight *nakṣatras* from *Punarvasu* to *Citrā* the Moon breaks the *Rohiṇī* cart.

In fact, for this configuration, actually, Rāhu must lie between about $80^\circ.75$ and $193^\circ.25$ i.e., just after the beginning of *Punarvasu* and before the end of the second *pāda* of *Svātī*.

Explanation : The *Rohiṇī* asterism is composed of five important stars (with southern latitudes) in the constellation of *Vṛṣabha* and is said to be in the shape of a cart (*śakaṭa*). The celestial longitudes vary from $45^\circ\ 46'$ to $49^\circ\ 45'$ i.e., around 17° of Taurus. The latitudes of these stars vary from $2^\circ\ 36'$ to $5^\circ\ 47'$ i.e., from $156'$ to $347'$ or 52 *aṅgulas* to about 116 *aṅgulas*. Therefore, to enter the 'cart' (wain) of *Rohiṇī* a planet must have more than 2.5° latitude (i.e., 50 *aṅgulas*). Thus, Gaṇeśa Daivajña prescribed 50 *aṅgulas* (negative) of *śara* for the *Rohiṇī śakaṭa bheda*.

Considering the well-known expression for the latitude (*śara*) of the Moon, we have

$$\beta = 270' \sin (R - M)$$

where β is the south latitude of the Moon (in minutes, *kalās*), R and M are respectively the longitudes of Rāhu and the Moon. Now, *GL* prescribes β to be above 50 *aṅgulas* i.e., $150'$ for the *Rohiṇī śakaṭa bheda*.

$$\therefore \qquad 270' \sin (R - M) > 150'$$

$$\text{i.e.,} \qquad \sin (R - M) > \frac{150'}{270'} = \frac{5}{9}$$

$$\text{i.e.,} \quad (R - M) > \begin{cases} \sin^{-1} \dfrac{5}{9} \approx 33^\circ.4 \\ 180^\circ - \sin^{-1} \dfrac{5}{9} \approx 146^\circ.6 \end{cases}$$

$$\text{or} \quad R > \begin{cases} 33^\circ.4 + 47^\circ = 80^\circ.4 \\ 146^\circ.6 + 47^\circ = 193^\circ.6 \end{cases}$$

i.e., Rāhu should lie between $80^\circ.4$ and $193^\circ.6$

***Śloka* 9** : Finding the *lagna* and the time by observing a star on the meridian in the night is explained.

By the *dhruva* of a star on the meridian of a place in the night, its *cara* is determined. From this the half-day duration (*dinārdha*) is found out. Treating the star as the Sun, and adding *ayanāmśa* to its *dhruva*, the *udaya lagna* for that instant at the given place is determined using the rising durations of the *rāśis* at the place. Now, adding six *rāśis* to the position of the Sun and taking the difference between that *rāśi* and the one of the current *lagna* (from the star on the meridian), the total rising durations of these *rāśis* give the time at the instant from the sunset.

Example : *Aśvinī dhruva* = $0^R\ 8^\circ$, *Ayanāmśa* = $18^\circ\ 10'$. Therefore *sāyana Aśvinī dhruva* = $0^R\ 26^\circ\ 10'$. From this, the *cara* = $+\,49^{vig}$. Therefore *dinārdham* (half-day duration) is $15^{gh}\ 49^{vig}$. The *bhogya kāla is* 28^{vig}. Since *iṣṭakāla* = $15^{gh}\ 49^{vig}$, by the method explained earlier, the *madhya lagna* is $3^R\ 13^\circ\ 44'\ 46''$.

***Śloka* 10** : The *udaya dhruva* of the *nakṣatra* at the rising (eastern) horizon for the given place is the first *lagna* of the given time (*iṣṭakāla*) and the *asta dhruva* of the *nakṣatra* at the setting (western) horizon, for the given place to which six *raśis* is added becomes the *asta lagna*. To the position of the Sun 6 *rāśis* when added and from the *asta lagna* of the *nakṣatra*, we can find the time elapsed since sunset at the place.

Example : *Aśvinī nakṣatra udaya dhruva* is $0^R\ 3°\ 12'\ 30''$ (obtained in the example under *Śloka* 3). This itself is the *udaya lagna*. The *asta dhruva* of *Aśvinī nakṣatra* is $0^R\ 12°\ 47'\ 30''$. Adding 6 *rāśis* to this we get $6^R\ 12°\ 47'\ 30''$. In this manner the *udaya* and *asta lagnas* of all bodies can be obtained.

***Śloka* 11** : In this manner, for a given place the rising (*udaya*), the meridian (*khamadhya*) and setting (*asta*) *sthira* (fixed) *lagnas* of *nakṣatras* can be determined.

Note : In Viśvanātha's commentary the *asta dhruvaka* of *Aśvinī* is given as $6^R\ 3°\ 47'\ 30''$.