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Śrīpati's Rule for the True Daily Motion of the Planets

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In the *Siddhāntaśekhara* (hereafter SSS) Ⅲ, 42-43, Śrīpati (*ca.* A.D. 1050) gives a rule for computing the true daily motion of the planets. This rule is quite complicated and seems to be inaccurate. This paper is to explain how this rule is derived, with some approximations, from the epicycle model, and to show how it is related with the method called *karṇabhukti*. I also suggest a possibility of corruption in the process of the transmission of the *Brāhmasphuṭasiddhānta* (hereafter BSS) Ⅱ, 43-44* where the same method as SSS is found.

The text of SSS Ⅲ, 42-43 runs:

cañcalakendragatiḥ phalabhogyajyāguṇitādyaguṇena vibhaktā/
vyāsadalaghnaphalaṃ śrutibhaktaṃ tadrahitāśugatiḥ sphuṭabhuktiḥ//
syād avanītanayādikhagānāṃ śīghragateḥ phalam adhyadhikaṃ cet/
tāṃ phalato'pi viśodhaya śeṣaṃ vakragatir bhavati dyucarāṇām//

which I propose to translate as:

Multiply the [mean] daily motion of *śīghrakendra* ($\Delta\bar{\theta}$) by [the differrence of] the *R*sine [of the position of a planet where] the correction [is made] (J) and divide by the first *R*sine (=223). Mutiply the result by the Radius (R) and divide by the hypotenuse (H). The result subtracted from the [mean] daily motion of *śīghra* (Δs) is the true daily motion of Mars and so on ($\Delta\lambda$). When the result is greater [than the mean daily motion of *śīghra*], it is subtracted from the result. The remainder is the daily motion of the retrogression of the planets.

The formula prescribed here can be expressed as:

$$\Delta\lambda=\Delta s-\Delta\bar{\theta}\cdot\frac{J}{223}\cdot\frac{R}{H}. \tag{1}$$

The rule called *karṇabhukti* is more frequently found in this context:

$$\Delta\theta = \Delta\bar{\theta} \cdot \frac{R}{H}. \quad (2)$$

Let us explain how these two rules are derived (Figure 1). Let θ and $\bar{\theta}$ be the true and the mean anomaly of a planet respectively. We can easily get the following proportion:

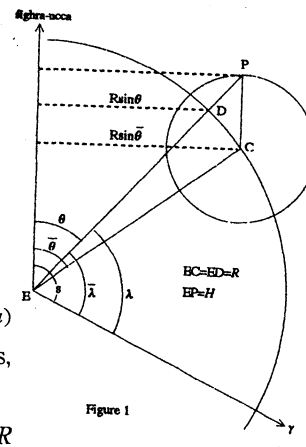

Figure 1

$$R : H = R\sin\theta : R\sin\bar{\theta},$$

$$R\sin\theta = R\sin\bar{\theta} \cdot \frac{R}{H}.$$

Assuming that the hypothenuse (H, *karṇa*) does not change in the consecutive two days, we get a similar formula for the next day:

$$R\sin\theta' = R\sin\bar{\theta}' \cdot \frac{R}{H}$$

where θ' and $\bar{\theta}'$ are the true and the mean anomaly of the planet in the next day. Taking the difference in two days, we get:

$$R\sin\theta' - R\sin\theta = (R\sin\bar{\theta}' - R\sin\bar{\theta}) \cdot \frac{R}{H}. \quad (3)$$

It is here that an approximaiton is used: the interval in minutes for the tabulated Rsines (225) is to the difference of the Rsines (J) as the difference of the true or mean anomalies of a planet ($\theta'-\theta$ or $\bar{\theta}'-\bar{\theta}$) is to the difference of the Rsines of the anomalies ($R\sin\theta' - R\sin\theta$ or $R\sin\bar{\theta}' - R\sin\bar{\theta}$), that is:

$$225 : J = (\theta' - \theta) : (R\sin\theta' - R\sin\theta),$$

$$225 : J = (\bar{\theta}' - \bar{\theta}) : (R\sin\bar{\theta}' - R\sin\bar{\theta}),$$

which are rewriten as:

$$(R\sin\theta' - R\sin\theta) = (\theta' - \theta) \cdot \frac{J}{225}, \quad (4)$$

$$(R\sin\bar{\theta}' - R\sin\bar{\theta}) = (\bar{\theta}' - \bar{\theta}) \cdot \frac{J}{225}. \quad (5)$$

From (3), (4), (5),

$$(\theta' - \theta) \cdot \frac{J}{225} = (\bar{\theta}' - \bar{\theta}) \cdot \frac{J}{225} \cdot \frac{R}{H}.$$

Thus,

$$\theta' - \theta = (\bar{\theta}' - \bar{\theta}) \cdot \frac{R}{H},$$

where $\theta' - \theta$ and $\bar{\theta}' - \bar{\theta}$ correspond to $\Delta\theta$ and $\Delta\bar{\theta}$ respectively in formula (2). Therefore we finally get:

$$\Delta\theta = \Delta\bar{\theta} \cdot \frac{R}{H}.$$

This is what is called *karṇabhukti.*

Śrīpati's rule was derived essentially on the same line, but he used one more approximation:

$$225 : 223 = (\theta' - \theta) : (R \sin\theta' - R \sin\theta),$$

$$(R \sin\theta' - R \sin\theta) = (\theta' - \theta) \cdot \frac{223}{225}, \tag{6}$$

and he substituted it for (4). From (3), (5), (6), he got:

$$(\theta' - \theta) \cdot \frac{223}{225} = (\bar{\theta}' - \bar{\theta}) \cdot \frac{J}{225} \cdot \frac{R}{H},$$

$$\theta' - \theta = (\bar{\theta}' - \bar{\theta}) \cdot \frac{J}{223} \cdot \frac{R}{H},$$

$$\Delta\theta = \Delta\bar{\theta} \cdot \frac{223}{J} \cdot \frac{R}{H}.$$

Because $\Delta\theta = \Delta s - \Delta\lambda$, this formula is rewriten as:

$$\Delta\lambda = \Delta s - \Delta\bar{\theta} \cdot \frac{J}{223} \cdot \frac{R}{H}.$$

The rule in BSS Ⅱ, 43-44 seems to mean:

$$\Delta\lambda = \Delta s - \textit{śīghraphala} \cdot \frac{J}{223} \cdot \frac{R}{H}$$

which, however, is inexplicable. Comparing the rule of BSS with that of SSS, it is clear that they are versified in a similar style. Thus it is reasonable to suppose that Śrīpati either had another recension or tried to restore the verse of BSS.

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* *śīghraphalaṃ bhogyajyāsaṅguṇitaṃ tv ādyajīvayā bhajet/*
phalaguṇitaṃ vyāsārdhaṃ vibhājayet śīghrakarṇena//
labdhonā śīghragatiḥ sphuṭabhuktir bhavati labdham adhikaṃ cet/
śīghragateḥ śīghragatiṃ labdhāt saṃśodhya vakragatiḥ//

〈Key Words〉 Śrīpati, Siddhāntaśekhara, Astronomy, True daily motion

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