

***Graha Chakra Jasti* and Traditional Indian Astronomical Model of Solar System**

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Abstract: *Mahamohopadhyaya Samanta Chandra Sekhar Harichandan Mohapatra* used a number of instruments and made terrestrial as well as astronomical measurements. These includes instruments like *Ek Kakshya Yantra*, *Dwi Kakshya Yantra*, *Kakshya Gola Yantra*, *Golardha Yantra*, *Mapa Yantra*, *Jasta Yantra*, *Swayamvaha Yantra*, *Graha Chakra Jasti*. In this communication we have discussed on the *Graha Chakra Jasti*. It describes the traditional Indian Astronomical model. Sun is at the center and *graha* (planets) like Mercury, Venus, Mars, Jupiter, Saturn revolve around Sun in specific orbits in this model. The position and motion of Earth is somehow different in this model of Solar System. This is known as Geo-Helio centric model of Solar system. The perimeter of the orbits of the five planets described above were calculated by *Samanta* and it is reflected in the model *Graha Chakra Jasti*. We have compared these results with the measurements made using modern telescopes by different astronomers in this communication. For the comparison, the perimeters of the 5 planets are normalized to a base value (perimeter of Mercury) and the results exhibits striking agreement with about 5 % error between traditional Indian measurements and modern observations.

Key words; Planets, Geo-Helio centric model, Solar system

1. INTRODUCTION

Indian Astronomy, from time immemorial, considered both experimental measurements, observations and theoretical deductions as important tools for understanding the Universe. In eighteenth century, *Siddhanta Darpan* was written and published. It is the last classic work in Siddhanta tradition. *Mahamohopadhyaya Samanta Chandra Sekhar Harichandan Mohapatra* made corrections in some of the measurements by his predecessors in this

tradition and authored this classic text [1-2]. In *Siddhanta Darpan* the design of a number of instruments were described and *Samanta* used these instruments for naked eye observation, both terrestrial and astronomical [2-3]. Instruments like *Ek Kakshya Yantra*, *Dwi Kakshya Yantra*, *Kakshya Gola Yantra*, *Golardha Yantra*, *Mapa Yantra*, *Jasta Yantra*, *Swayamvaha Yantra*, *Graha Chakra Jasti* are simple yet excellent tools for observations and measurements [2, 4]. For example, *Graha Chakra Jasti* is an effective tool to deduce a conclusion on the model of Solar system perceived by *Samanta*. His model is based on Geo-Heleo centric model of Solar System which is distinct from the modern Heleo centric model of Solar system. As per the model, Sun is at the center and *graha* (planets) like Mercury, Venus, Mars, Jupiter, Saturn revolves around Sun in specific orbits with earth having a different position and motion. *Samanta* used his tools and measured the perimeters of the orbits of these five planets as mentioned in the *Siddhanta*, the greatest naked eye astronomer of all time. The accuracy in his measurements could be seen in his description of *Graha Chakra Jasti* [2]. Moreover, the measurements could be validated against modern Astronomical observations made by expensive Telescopes and western scientific theory. In this communication, we have compared the perimeter of the orbits of the five planets measured by *Samanta* and the modern observations to demonstrate the striking resemblance between them with a high degree of precision.

2. MATERIALS AND METHODS

Samanta used raw materials available on and around him and designed all the instruments [2]. *Graha Chakra Jasti* was made up of wood. Sun is fixed at one end that is narrowed down from another end. Sun being at the center, the first orbit is that of Mercury and it is elliptical in nature. The second, third, fourth and fifth orbits are that of Venus, Mars, Jupiter, Saturn, respectively. These orbits are named as *Vimandal*. Each orbital distance is expressed in a unit of width of finger (*āṅgula*). The language of the text was Sanskrit, the calculations were mathematical and the concepts were that of the physics. Therefore, a scholar well versed in these three can only decode the texts and express in a tangible way.

3. RESULTS AND DISCUSSION

Samanta described *Graha Chakra Jasti* in *Vinsha Prakash* (20th Chapter) of *Siddhanta Darpan*. In verse 57 and 58, the perimeters of five planets under discussion was described and finger unit (*āngula*) was used for that.

Madhyarka Samvestana Kruj Jna Kakshyadhrutya 18 ngualasyachchipitatmaprustha I

Tadvat Sitasya arthaguna 35 ngula Syadyadrangula 72-Mangala Kakshikaiva II 57 II

Gurorasambhodhibhuja 264 ngulatha Rupavdhiveda 441 nguala Kah Arkashunawh I

Vimandalakshya Itikheta Kakshyah Purvokta Kineswasmesu Jojyah II 58 II

Mercury is the deity of knowledge and is known as *Jna* in Indian Mythology. The perimeter of Mercury needs to be kept at 18 fingers (*āngula*) in *Graha Chakra Jasti*. Venus is also called *Sita* and its orbit shall be 35 fingers (*āngula*). The orbit of *Mangala* (Mars) will be 72 fingers (*āngula*) and that of *Guru* (Jupiter) will be 264 fingers (*āngula*). *Arkasutah* or son of Sun, Saturn shall be placed in the far end of Sun and its orbital distance shall be 441 fingers (*āngula*). Modern values of perimeters of these five planets are shown in Table 1 along with these values. In order to compare the perimeters, the perimeter values are normalized to that of Mercury.

Modern astronomy data bases [5, 6] were referred to calculate the perimeter of the orbits and shown in Table 2. The database provides the values of semi major and eccentricity of the elliptical orbits. The following Equations (Eq. 1 and Eq. 2) were used to calculate the perimeter for modern astronomy data. The values used for the perimeter calculations are given in Table 1 as per the reference.

$$b = a\sqrt{1 - e^2} \quad (1)$$

Where, *b* is the semi minor axis, *a* is the semi major axis and *e* is the eccentricity of the ellipse.

Perimeter as per Ramanujan's approximation

$$P = \pi \left[3(a + b) - \sqrt{(3a + b)(a + 3b)} \right] \quad (2)$$

Table 1: Values of semi major axis and eccentricity of planetary orbits
[5, 6]

Sl No.	Name of Planets	Semi major axis (a) (10^{11} m)	Eccentricity (e)
1.	Mercury	0.005791	0.20564
2.	Venus	0.010821	0.00678
3.	Mars	0.022794	0.09339
4.	Jupiter	0.077834	0.0484
5.	Saturn	0.142671	0.0539

Table 2: Orbital distance of planets

Sl No.	Name of Planets	Perimeters of planets (Siddhanta Darpan) (fingers)	Perimeters of planets (Modern Value) (10^{11} m)
1.	Mercury	18	3.59983
2.	Venus	35	6.79833
3.	Mars	72	14.288099
4.	Jupiter	264	48.885343
5.	Saturn	441	90.028928

Unit conversion from Ancient Indian Astronomy to Modern Astronomy is 1 fingers (*āṅgula*) = $0.194E11$ m.

Indian astronomical calculations made by *Samanta Chandra Sekhar* and the modern astronomical calculation by several astronomers are shown in fig 1 after normalizing the values to the base value of Mercury in both the cases. Therefore, the perimeter ratio for Mercury is 1 according to both the observations. The error bars for *Samanta's* normalized perimeter are calculated with respect to the modern astronomy values, which is surprisingly low with the maximum error of 8 % for Jupiter.

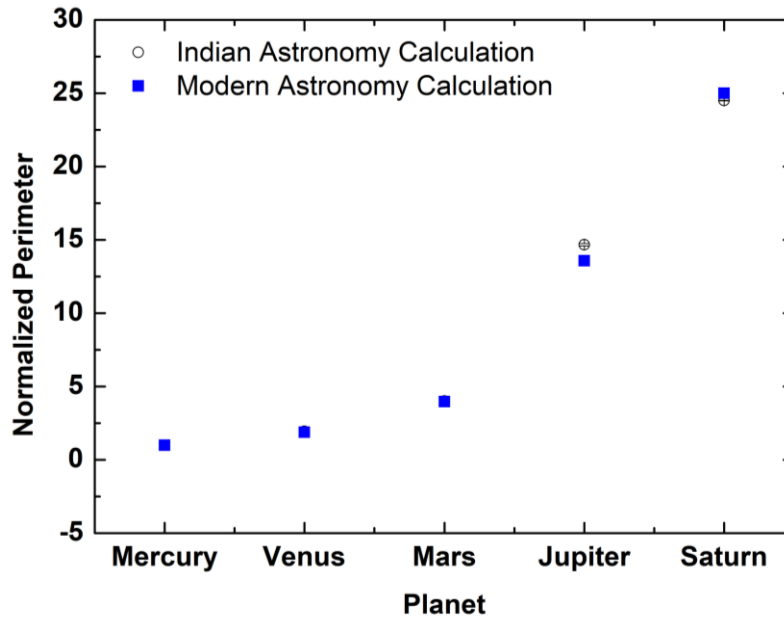


Fig 1: Normalized value of perimeters of planets in solar system

From fig 1 it is observed that naked eye measurements of *Samanta Chandra Sekhar* were excellent and *Graha Chakra Jasti* description confirms this [1]. This exact calculation in regard to planetary orbits needs concrete idea of physical laws. Without the knowledge of gravitational force between planets and Sun it is very much difficult to estimate velocity of planets and nature of their orbits. The knowledge of centripetal and centrifugal force is also necessary for accurate calculation of perimeters of planets in solar system. This can be a motivation to search for description and mathematical explanation of gravitational force and other physical concepts in *Siddhanta* tradition from *Aryabhatta* to *Samanta*.

4. CONCLUSION

Indian astronomical observations, so far as planetary position and motion concerned are not far behind modern calculations and model. The normalized value of perimeters of planets in solar system from Mercury to Saturn is compared with those of modern astronomical calculations and are very much accurate. These results shall be very much helpful in

designing *Graha Chakra Jasti*. Designing the instruments used in *Siddhanta* tradition can only accelerate the naked eye astronomical research with precision and accuracy comparable to that of modern astronomy [7-8].

References

- [1] J. C. Ray, *Nature*, **59**, 1532, (1899).
- [2] Mahamahopadhyaya Shri. Chandrasekhar Singh Harichandan Mohapatra Samanta , *Siddhanta Darpan*, Dharmagrantha Store Publication, Cuttack (1975).
- [3] G. Sahoo, *Orissa Journal of Physics*, **27**, 1 (2020).
- [4] Mahamahopdhaya Samant Chandra Sekhar Singha Harichandan Mohapatra, *Siddhanta Darpan*, Girish Bidyaratna Press, Calcutta, (1899).
- [5] A. J. Willman, *Sol Planetary System Data* (2021)
http://www.princeton.edu/~willman/planetary_system/Sol
- [6] Planetary data sheet, the NSSDCA (NASA),
www.nssdc.gsfc.nasa.gov/planetary/factsheet
- [7] P. C. Naik and L. Satpathy, *Current Science*, **69**, 8 (1995).
- [8] P. C. Naik, *Current Science*, **89**, 1 (2005).