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On the chronology of Hindu astronomy

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Abstract. An estimate for the probable age of the Hindu astronomy is made here from a reference to the exact longitude of the so-called exaltation of Mars. If it is interpreted as the location of the perihelion of the orbit of Mars at the time of the formulation of the above convention, the epoch is found to be about 1160 BC.

Key words: History of astronomy—chronology—Hindu astronomy

1. Introduction

The oldest astronomical text in India is *Vedaanga Jyautisha* (literally, astronomy as a limb of the *Vedas*) compiled by one *Lagadha*. Nothing is known about *Lagadha* and it is not possible to date *Vedaanga Jyautisha* independently, but internal evidence places it about 1500 BC (see e.g. Sastry 1984).

An epoch of historical antiquity can be astronomically identified if there is a reference to the everchanging location of the vernal equinox. The vernal equinox precesses backwards, that is from east to west, with respect to the background stars, at a rate of about $50''.29 + 2''.22\ T$ per century, where T is the number of centuries measured from AD 2000. This corresponds to a retrograde motion of vernal equinox at a rate of about 1° of arc every 71.6 years.

We know that the Hindu *nirayana* system reckons its first point of Aries not from the moving vernal equinox, but from a point where the vernal equinox was in AD 285. This epoch is usually believed to be the time when the *Surya Siddhaanta* was formulated. Aryabhata I wrote his treatise on astronomy, *Aryabhatiya*, in AD 499, by which time the vernal equinox had receded by about 3° from the canonically accepted location of the first point of Aries. The angle by which the vernal equinox recedes from its position in AD 285 to any running epoch is technically known as the *ayanaamsha* (A). Using the reference data on the precession of the equinox given by Zhang *et al.* (1988), we can write

$$A = 23°51'25''.10 + 5029''.0966\ T + 1''.111971\ T^2 + 0''.00007732\ T^3 - 0''.00002353\ T^4, \quad \ldots(1)$$

where T is the number of Julian centuries from 12^h noon of AD 2000 January 1 to the epoch under consideration. The constant A is made to be consistent with the Saha committee's recommendation, namely $A = 23°15'$ on AD 1957 March 21.

The *Shatapatha Brahmana* states that the *Krittikaas* (Pleiades; central star η Tauri) rise in the east. This is taken to mean that η Tauri more or less coincided with the vernal equinox. Now, Pleiades (RA $03^h46^m.3$; Dec. 24°05′ N), is about 37°30′ away from the first point of Aries of the Hindu *nirayana* system (the projection measured along the ecliptic) so that it would have coincided with the vernal equinox about 2300 BC.

The term *nakshatra* (asterism) is used to refer to both, the star or star group itself as well as an arc of 13° 20′ so that 27 *nakshatras* span 360°. If *Krittikaa* is taken to mean the beginning of the asterism, (26° 40′), rather than the star group itself, the epoch of *Krittikaa* rising exactly in the east would be about 1500 BC. However, from the context in *Shatapatha Braahmana* and elsewhere, it is clear that the star group itself is meant rather than the asterism, in which case the date 2300 BC is the relevant one.

Since the Vedic texts are dated about 1000 years later, it must be that the memory of a bygone observation was retained and uncritically incorporated in the texts.

Here we present an entirely different datum which can independently fix the date of its introduction.

2. Points of exaltation (*Uchcha avasthaan*)

A quantity specified while giving planetary positions is *uchcha avasthaan* of the planets to be found in the works of *Varaahamihira*, for example. For the inner planets, its simplest meaning would be the highest possible altitude at sunset or sunrise when a planet's maximum solar elongation takes place at a specified point on the ecliptic.

However, for Mars, its interpretation could be even simpler. We know that during the oppositions Mars comes closest to the earth, and appears to be brightest in phase. But since the orbit of Mars is highly elliptical (eccentricity $e = 0.0934$) compared to the eccentricity of the earth's orbit ($e = 0.0167$), not in all oppositions can Mars come truly very close to the earth. Obviously, only in those oppositions, in which Mars stays also close to its perihelion, it would appear strikingly brightest. The worst oppositions take place when Mars stays as far out as about 0.67 AU, compared to the most favourable ones at a distance of only 0.37 AU from the earth. In terms of the apparent magnitudes, this effect amounts to a difference of about 1.7 magnitudes. As a result, Mars in its brightest ever oppositions assumes an apparent brightness of roughly three times brighter than that of the brightest star Sirius, while during the worst oppositions the maximum brightness of Mars is only about 60% of that of Sirius—a naked-eye effect quite noticeable to any serious observer who keeps a systematic record of observations over a period of 20 years or so.

It can also be shown that the brightest oppositions of Mars repeat systematically at an interval of alternately 15 and 17 years, that is, alternately every eight and ninth opposition. Now the interesting point to note is that the ancient astronomers have specified the location of exaltation of Mars at a longitude not very different from that of the perihelion of the orbit of Mars. The ancient specification of the *nirayana* longitude of the exaltation of Mars is 298 degrees of arc. Using the most accurate ephemerides produced by the Jet Propulsion Laboratory, USA, the longitude of the perihelion of Mars is calculated from the data given in Laskar (1986):

$$\Gamma_0 = 336°03'36''.8422 + 1598''.0459163\ T - 0''.623275\ T^2 - 0''.01085437\ T^3 + 0''.00000776\ T^4, \qquad \ldots(2)$$

measured with respect to the equinox and ecliptic of the Julian year epoch J2000.0.

Therefore, after applying the correction (1) for the epoch J2000.0 to the expression (2), the motion of the perihelion of Mars with respect to the first point of Aries of the *nirayana* system can be expressed as

$$\Gamma_0' = 312°\,12'11''.7 + 1598''.0459163\ T - 0''.623275\ T^2 - 0''.01085437\ T^3 + 0''.00000776\ 6T^4 \qquad \ldots(3)$$

So the rate of drifting of the perihelion of Mars in space is quite slow, about a degree of arc every 225 years. It is now easy to calculate when exactly the *nirayana* longitude of the perihelion of Mars (Γ_0') was 298 degrees of arc, which is found to be the year 1161 BC. An error of 0.5 degree of arc in the specification of Γ_0' would obviously imply an error of 112 years in the determination of the above epoch.

It should be noted here that the observational deduction of the above longitude for the exaltation or the brightest oppositions of Mars may not have anything to do with the knowledge of the orbital longitude of the perihelion of Mars. It can be a simple observation without knowing what it means in terms of the orbital configuration. In the geocentric models, one of course has to specify the longitude of apsidal line for the epicycle of Mars, which at the time of Brahmagupta (628 AD) attained an observational accuracy of about 1 degree of arc, but upto the time of Aryabhata I its accuracy was perhaps no better than about 10 degrees. The present work is based on the assumption that it was the simple observational fact that Mars appears brightest during the oppositions, and that among all the oppositions which take place in one's lifetime, the brightest of the oppositions take place when Mars is at some particular longitude at the time of the opposition.

3. Conclusion

From the exactly specified *nirayaṇa* longitude (298°) of the so-called exaltation of Mars, it is here calculated that the Mars used to have the brightest of its oppositions to the sun around that specified longitude at about 1160 BC. If this interpretation of 'exaltation' of Mars is correct, it may then mean that this particular convention in Hindu astronomy was introduced c.1160 BC.

References

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