Correspondence

On an Alternative Interpretation for the Application of *Cara*

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This refers to the paper "Determination of Ascensional Difference in *Lagnaprakaraṇa*" by Aditya K, *et al*., published in *IJHS*, 53.3 (2018): 302–16.

The concept of *lagna* and the challenge of calculation of the same during day time are very well known. It is noteworthy that Mādhava devoted an entire book to address this problem of *lagna* determination. One of the interesting exercises involved here is to fix the coordinates of the point on ecliptic, which is on the horizon at any given instant. While a trained eye can easily fix it by actually looking at the horizon during the night, the day time poses a challenge. This is dependent on the time of the year, the time of the day and the latitude of the observer. The procedure requires the calculation of the quantity called *cara*, which is the excess or deficit duration of half day over the mean value of six hours. This is applicable to all celestial bodies and not only the sun. In short this is the duration by which the sun (or the celestial body) rises later or earlier than the mean value of 6'o clock; here it is assumed that the noon transit occurs exactly at 12:00 noon (or the time of noon transit of the celestial body).

The paper assumes that the *cara* calculation is applicable for the sun only. Therefore one has to replace the word sun as 'any celestial body' all through the paper. The Fig. 6 of the paper is reproduced here to explain the meaning of *cara*. In fact, we need to carefully look at the figure caption which says that this is for sunrise and sun
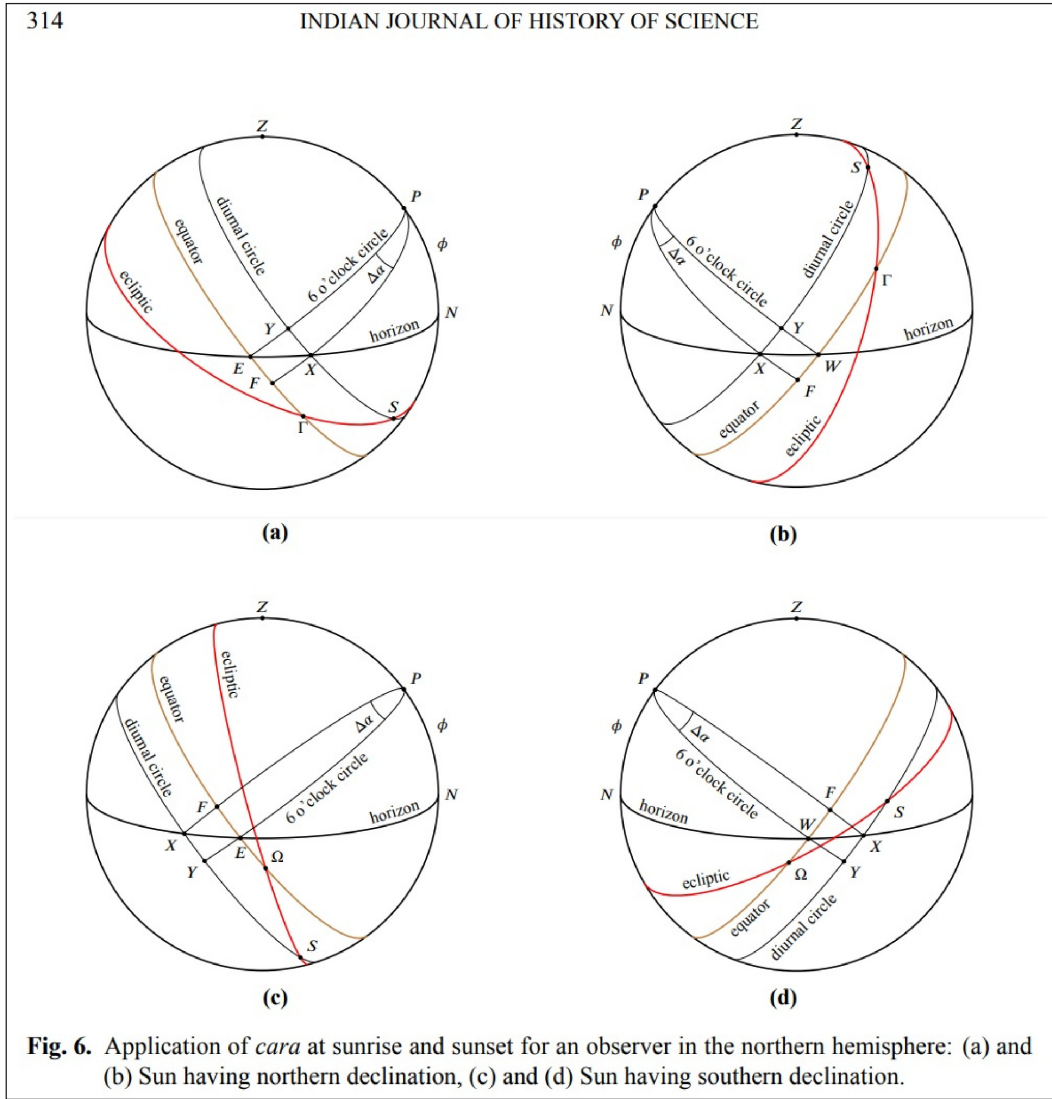
set. The explanation is true for any celestial object on the diurnal circle defined for the point S. For example the *cara* is same for S or X or Y. As can be clearly seen in (a) the object will rise earlier than its corresponding point on the celestial equator, E. Similarly (b) shows that it sets later than its corresponding point W. Therefore the time corresponding to XY is the excess defined as *cara*. In the figure (c), the objects S, X and Y are all to the South of equator. They rise later than the corresponding point E. [set early as in (d)]. Again, the difference in time corresponds to XY. Thus *cara* is negative or positive as decided by not only the declination of the object, but the latitude of the observer also.

It is very easy to understand this in the case of the sun. When the sun has northern declination, it rises earlier than 6' o clock, for an observer in northern hemisphere. When the sun has southern declination it rises later than 6' o clock for an observer in northern hemisphere. Thus it can be generalised as the excess or deficit in the duration of the half day (of the object).

This difference is given by the expression $-\tan(\phi)\tan(\delta)$, where ϕ is the latitude and δ the declination, which is also derived as equation (3) in the paper.

Therefore, the figure caption needs to be rewritten to explain the meaning in the two hemispheres (east and west) as we shall in the context of verse number 24.

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Fig. 6. Application of *cara* at sunrise and sunset for an observer in the northern hemisphere: (a) and (b) Sun having northern declination, (c) and (d) Sun having southern declination.

The paper describes various interesting ways of deriving the *cara*. The authors have analysed all the verses and provided very interesting results. They feel that the whole exercise has been addressed only as a theoretical problem with no practical application. On the contrary the constraints posed by practical observations necessitate different methods to be evolved to get solutions.

This idea is reflected very well in the interpretation of the verse number 24 given in page 302. The readers may refer to the paper for the original Sanskrit verse. The verse and the translation are reproduced here:

प्रातश्चरं वणिगजादिवशाद्धनर्णम्
अस्तेऽन्यथा न तदहर्निशयोस्तु मध्ये ।
कार्यं त्रिपञ्चमलवादिषु चानुपातात्
नैवानुपातविधिरस्य घटीप्रसारे ॥२४॥

prātaścaraṃ vaṇigajādivaśāddhanarṇam
aste'nyathā na tadaharniśayostu madhye |
kāryaṃ tripañcamalavādiṣu cānupātāt
naivānupātavidhirasya ghaṭīprasāre ||24||

At sunrise, the ascensional difference is positive or negative depending on [the Sun's position with regard to] Libra or Aries. While setting, it is otherwise. That should not be applied during midst of the day and night. And in case of third, fifth etc. portions [of the day, the *cara*] should be calculated [afresh] successively. The rule of proportion for this (*cara*) will not be applicable in [setting] the motion of the clock (*ghaṭīprasāra*).

In the following pages in Section 3.1, 3.2 and 3.3 of the paper, the meaning of the verse has been explained in greater detail. Although it is explained very clearly and satisfactorily in 3.1, as to why the term can have positive or negative values, it is not the intended meaning of the verse itself. A continuation of the explanation in the section 3.2, therefore, poses problems. It says that the *cara* 'should not be applied during noon and midnight'. Further, the authors say, this reiterates the point that the sun crosses the prime meridian at the same instant for all the observers on the same longitude.

The latter statement is true by the very definition of the prime meridian. Therefore Mādhava did not have to express that in this context. Moreover the term longitude does not enter into picture anywhere in the derivation and discussion and therefore, perhaps the statement does not refer to this. The former statement that *cara* is zero at noon and midnight demands explanation. As defined in the text in equation (3), *cara* is a function of latitude and the declination. It cannot be zero unless one of these terms is a zero.

In view of this, I am suggesting an alternate interpretation as follows:

The objective of the book is to calculate the longitude of the ascendant. This requires the knowledge of *cara*, the excess or deficit in the duration of the half day. Later its projection on to the ecliptic has to be calculated. As already explained *cara* is given by $-\tan(\phi)\tan(\delta)$, where ϕ is the latitude and δ, the declination.

I plan to apply this to the points on the ecliptic referred to as *vanigajaadi*. They are the two special points known as the First Point of Aries and the First Point of Libra. For the sun it is very easy to understand. On the day of equinoxes, the sun's position itself is on these points.

Let us analyse the situation of the day equinoxes. On the day of vernal equinox, March 22, the declination of the sun changes from negative value to positive. The zero value is achieved any time during the day or night. Therefore in early part of the day the declination is negative and therefore the *cara* is positive. Sometime later, after the instant of equinox, declination becomes positive therefore *cara* is negative. Therefore depending upon the time of instant of equinox the *cara* value can be (though very small) positive or negative. The instant can be anytime during the day. The opposite occurs at the autumnal equinox when the change of declination of the sun is from positive to negative.

Let us consider the variation *cara* on the day equinox for the sun. It should be zero ideally. But the transition across the equator demands that there is a flip over of the sign and this can be established only by monitoring it continuously. (Not interpolation). This also gives a hint that on other days an interpolation was the usual practice.

It should be noted that the noon transit is cited nowhere in the verse. It states '*aharniśayostu madhye*' – sometime between day and night, clarifying that it is an instant when $\delta = 0$ and can occur anytime (not necessarily at noon).

This gives a totally different meaning to the verse number 24. The intended meaning involves the First point of Aries and First Point of Libra; the translation now can be rewritten as

> For the First Points of Libra and Meśa the *cara* is positive or negative in the morning and the opposite in the evening. Sometime in between the day and night it is not to be applied [zero]. During the day at [small] intervals like one third or one fifths, interpolation [may] not be done. (fresh calculations are necessary).The interpolation is not to be extended like a clock work [all through the day]

Since this is a general relation for any point on the ecliptic, it can be applied to any object. However the position of the sun is relevant to fix the time during the day. It should be noted that the word sun is not used anywhere in the text. 'When applied to sun it becomes relevant for *lagna* determination.'

The verses provide methods to estimate the *cara* for ANY point on the ecliptic and not necessarily the sun, which can be only verified if there is any such statement in the introduction. Therefore, a relook is necessary for the statement in section 2 that these techniques are to be applied for the sun. As may be verified from the text cited in the paper, none of the methods state that they are referring to the sun. All derivations are valid taking S as any object on the ecliptic.

Let us say we are to apply *cara* for the moon when it is on one of these points. Depending upon the transit time (across the equator), the *cara* can be positive or negative when it is rising or setting. The *cara* is zero at the time of transit across the equator (not meridian). This is referred to as "*aharniśayostu madhye*" in between the day and night. During the day when it is above the horizon, the cara cannot be extrapolated but needs to be calculated often. It should be noted the words *uṣās, sandhyā* or sunset or sunrise are not used here. Depending on the time of the year and the month, the rise time (set time) of the moon can be anywhere during the 24 hours. Thus the verse is applicable to any solar system object.

In view of this the verse number 24 refers to the *cara* corresponding to these two unique points. Since there is a crossover of zero declination a routine calculation (interpolation) is not to be done.

I would therefore offer a translation as follows:

For [an object on] the First Points of Libra and Aries, the *cara* is positive or negative before the meridian transit and the opposite after the transit. Between the day and night [of the object] the *cara* is zero. The calculations for *cara* should be carried out at intervals of the day, like the third, fifth etc [during day of the object] and cannot be interpolated like a clockwork:

The meaning becomes very clear when applied to the sun as explained above.

Any other interpretation of the verse is welcome from the readers since this verse is explaining a very complicated concept expressed very concisely.