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A Comparative Study of the Moon at Perigee and Apogee

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Abstract:

The moon, natural satellite of the earth, moves around the earth in an elliptical orbit. In its movement crosses perigee (closest point of the earth) and apogee (most distant point from the earth). The moon at perigee and apogee is calculated using the number of revolutions and civil days of a long period *Mahayuga*. Indian classical astronomy texts discuss a number of revolutions, civil days and anomalistic period of the moon is calculated based on the motion of the moon.

In the present paper, we have discussed the actual working procedures, based on different Indian classical astronomical texts of perigee and apogee of the moon. The results are compared with those of modern astronomical procedures.

Key words: Perigee, Apogee, Anomalistic period, Ahargana, Super moon.

1. Introduction:

The rotation of the moon around the earth is an interesting one, in its rotation one particular day the moon comes nearer to the earth and it appears bigger. This event occurs when the moon is simultaneously full and at its **perigee**, the nearest point of the earth. In its rotation the opposite point of perigee is known to be apogee.

In this paper we have analyzed the periodicities of the full moon as well as its arrival at the perigee and apogee by using a anomalistic cycle of the moon. Since the moon moves in an elliptical orbit around the earth at its focus, the extremal points on the major axis of the orbit corresponds to the moon's **apogee** and the perigee, i.e., the farthest and the nearest point of the earth. Even though the moon moves along the orbits its apogee also moves and hence, we have to consider the moon's motion relative to its apogee.

The anomalistic period of the moon is defined as the interval between the two successive passages of the moon through its apogee and it is considered as 27.5545 days.

The interval between two successive full moon is defined as a lunar month, which has a mean value of 29.53089 days. Therefore, from these two cycles we get the periodicity of the Super moon as 411.7174 days i.e., 1 year 46 days.

We are investigating, in this paper, the actual occurrence of the moon's passage through its apogee according to Indian classical texts and also modern astronomy and comparing the two of them.

2. Indian Astronomy:

In Indian astronomy the mean motion of a heavenly body is given in terms of revolutions (each of 360^0 extent) made by the heavenly body in the course of a *Mahayuga* of 432×10^4 years. The advantage of choosing such a long period of time is that the motions of heavenly bodies could be expressed in an integral number of revolutions completed, avoiding inconvenient fraction.

The following table 2.1 gives the necessary details to determine the mean anomalistic cycle of the moon according to different Indian classical texts. i.e., revolutions of the sun, the moon, the moon's apogee and number of civil days in a *Mahayuga*.

Table 2.1: Revolutions of the sun, the moon and the moon's apogee in a *Mahayuga*.

Texts	Revolutions			Civil days
	Sun	Moon	Moon's Apogee	
Aryabhatiya	432×10^4	57753336	488219	1577917500
Khanda khadyaka	432×10^4	57753337	488219	1577917800
Surya siddhanta	432×10^4	57753336	488203	1577917828
Siddhanta shiromani	432×10^4	57753300	488206	1577916450

Note: 1 civil day is equal to 24 hours.

From the above table 2.1 we notice that the revolutions of the sun in a *Mahayuga* of all different texts are the same whereas the revolutions of the moon and its apogee are different. Further, the numbers of civil days in a *Mahayuga* are slightly different. These differences have resulted from the corrections made periodically based on observation and give rise to slightly different mean daily motions.

The mean daily motions are given in table 2.2 according to different texts.

Table 2.2: Daily mean motion of the sun and the moon in degree, minute and second.

Texts	Sun	Moon	Moon's Apogee
Khanda khadyaka	59'08"	$13^0 10'31''$	6'40"
Surya siddhanta	$59'08''10'''09^{iv}$	$13^0 10'34''52'''\ 02^{iv}$	6'40"
Siddhanta shiromani	$59'08''10'''21^{iv}$	$13^0 10'34''53'''$	$6'40''53'''56^{iv}$
Modern astronomy	$59'08''.2$	$13^0 10'34''.9$	$6'\ 40''.92$

These mean motions are calculated by using the following formula.

Daily mean motion = $\frac{No.of\ revolutions\ in\ a\ Mahayuga}{No.of\ civil\ days\ in\ a\ Manhayuga} \times 360^0$

According to different Indian classical texts the moon's mean anomalistic period is calculated as follows.

Suryasiddhanta:

Anomalistic Revolutions in a *Mahayuga*

= The moon's revolution – The moon's apogee revolution

$= 57753336 - 488203 = 57265133.$

The moon's anomalistic period (passage of the moon from apogee to apogee or perigee to perigee)

$= \frac{Number\ of\ civil\ days\ in\ a\ Mahayuga}{Number\ of\ anomalistic\ revolutions\ in\ a\ Mahayuga}$

$= \frac{1577917828}{57265133} = 27.5545999\ days$

Siddhantashiromani:

Anomalistic Revolutions in a *Mahayuga*

= The moon's revolution – The moon's apogee revolution

$= 57753300 - 488206 = 57265094.$

The moon's anomalistic period $= \frac{Number\ of\ civil\ days\ in\ a\ Mahayuga}{Number\ of\ anomalistic\ revolutions\ in\ a\ Mahayuga}$

$= \frac{1577916450}{57265094} = 27.5545946\ days$

In modern astronomy the moon's anomalistic period is given as 27.554550 days.

Comparing this modern anomalistic period with the Indian texts, they are equal upto the fourth decimal place. It is truly remarkable.

3. The moon at Apogee and Perigee:

According to *Suryasiddhanta* text the epoch is taken as the mean midnight between 17/18 of February 3102 B.CE. at Ujjain. For this time the mean position of the moon is considered as $0^0\ 0'\ 0''$ and its *mandocca* (apogee) as 90^0. Based on the daily motions of the moon and its apogee, the time taken for the moon at apogee for this epoch is 6.888933 days.

Using the *Ahargana* (the number of civil days elapsed since the chosen fixed epoch), apogee at epoch and an anomalistic period, we can find when the moon comes at apogee or perigee for a given date of the month. According to the *Surya Siddhanta* (astronomical text) procedure, we have computed the date and time of the mean moon at apogee and perigee for all the months of the year 2022 and listed in table 3.1. The following example explains the method to calculate apogee of the moon of the month April 2022.

Example: The mean moon at apogee for the month April, 2022.

At the midnight of April 1, 2022, the elapsed *ahargana* is 1871205, relative motions of moon's apogee is 6.8889333. So, we have

Ahargana for the first moon at apogee $= 1871205 - 6.888933 = 1871198.111$

No. of anomalistic periods completed $= \frac{1871198.111}{27.5545999} = 67908.738209$

$$= 0.738209 \times 27.5545999$$

Days after the last moon at apogee $= 20.3410578$

The moon at apogee = (27.5545999 – 20.3410578) $-\ (392/360)$

$$= 6.124652$$

$$= 6^d\ 2^h\ 59^m .$$

This means that in April 2022 the moon comes at apogee on 6^{th} at $2^h\ 59^m$ (I.S.T)

Table 3.1 : Mean moon at perigee and apogee, 2022 (in I.S.T)

Moon at Perigee			Moon at Apogee		
Month	Date	Time	Month	Date	Time
January	01	20^h 39^m	January	15	11^h 03^m
January	29	09^h 58^m	February	13	00^h 22^m
February	26	13^h 18^m	March	09	13^h 40^m
March	23	12^h 56^m	April	**06**	**02^h 59^m**
April	20	01^h 53^m	May	03	16^h 18^m
May	17	15^h 12^m	June	01	05^h 36^m
June	14	04^h 31^m	June	28	18^h 55^m
July	11	17^h 49^m	July	25	08^h 13^m
August	08	07^h 08^m	August	21	21^h 32^m
September	04	20^h 27^m	September	18	10^h 51^m
October	02	09^h 45^m	October	14	22^h 01^m
October	30	11^h 53^m	November	11	09^h 11^m
November	27	03^h 19^m	December	09	20^h 11^m
December	23	18^h 44^m	-------	-----	-------

4. Modern Astronomy:

In modern astronomy texts, the epoch is considered in Julian days from January 1st, 4712 B.CE. at Greenwich mean noon. The moon at apogee and perigee is calculated by the formula

$$JDE = 2451534.6698 + 27.55454989\ k - 0.0006691\ T^2 - 0.000001098\ T^3 + 0.0000000052\ T^4$$

where JDE =Julian Ephemeris days, k = (year – 1999.97) × 13.2555, $T = \frac{k}{1325.55}$

2451534.6698 corresponds to Christian date December 22, 1999 and 27.55454989 is the mean anomalistic period, 13.2555 = number of anomalistic revolutions in a tropical year (the interval between two successive passages of the sun through the vernal equinox). T – represents the time in Julian centuries since the epoch 2000.0. In 'k' "year" should be taken with decimals. For instance, 2022.33 represents the end of April 2022. To find the moon at perigee the value of 'k' in the above formula must be taken as an integer and to find the moon at apogee an integer is increased by 0.5.

Using the modern procedure, the perigee and apogee of the moon have been calculated and listed in table 4.1 for the year 2022. The following example explained the method of computation of the mean moon at apogee on April 2022.

Example: The mean moon at apogee for the month April, 2022.

we have k = 296.5, T = 0.223681

$$JDE = 2451534.6698 + 27.55454989\ k - 0.0006691\ T^2 - 0.000001098\ T^3 + 0.0000000052\ T^4 = 2459704.593809$$

It corresponds to Christian date: May 5th at 07^h 45^m (I.S.T)

Table 4.1: Mean moon at perigee and apogee, 2022 (in I.S.T)

Moon at Perigee			Moon at Apogee		
Month	Date	Time	Month	Date	Time
January	01	07^h 51^m	January	15	02^h 30^m
January	28	21^h 10^m	February	11	15^h 49^m
February	25	10^h 28^m	March	11	05^h 07^m
March	24	23^h 47^m	April	07	18^h 27^m
April	21	13^h 05^m	May	05	07^h 45^m
May	19	02^h 24^m	June	01	21^h 03^m
June	15	15^h 42^m	June	29	10^h 22^m
July	13	05^h 01^m	July	26	23^h 40^m
August	09	18^h 20^m	August	23	12^h 59^m
September	06	07^h 38^m	September	20	02^h 17^m
October	03	20^h 57^m	October	17	15^h 36^m
October	31	10^h 15^m	November	14	04^h 54^m
November	27	23^h 24^m	December	11	08^h 13^m
December	25	12^h 52^m			

We find that the occurrence of the passage of the moon through its perigee and apogee tallies with according to *Surya siddhanta* compares well with the corresponding results by modern procedures with a small difference.

To calculate the true moon at perigee or apogee, the moon's periodic terms of the time, in the days and parallax, in arc seconds is considered. Based on the modern astronomy, including periodic terms, table 4.2 gives the true moon at perigee and apogee for the year 2022. If we compare these values with the NASA values, they will vary by a few minutes.

Table 4.2: True moon at perigee and apogee, 2022 (in I.S.T)

Moon at Perigee			Moon at Apogee		
Month	Date	Time	Month	Date	Time
January	02	06^h 43^m	January	14	14^h 49^m
January	29	21^h 48^m	February	11	08^h 05^m
February	26	09^h 09^m	March	11	04^h 50^m
March	24	11^h 56^m	April	08	00^h 21^m
April	20	15^h 09^m	May	05	18^h 35^m
May	17	23^h 21^m	June	02	06^h 35^m
June	14	23^h 43^m	June	29	11^h 36^m
July	13	17^h 18^m	July	26	16^h 07^m
August	10	20^h 29^m	August	23	03^h 03^m
September	07	05^h 06^m	September	19	20^h 34^m
October	04	11^h 11^m	October	17	15^h 40^m
October	30	11^h 03^m	November	14	12^h 09^m
November	26	22^h 07^m	December	12	06^h 13^m
December	24	11^h 20^m			

The anomalistic period has the periodicity of 1460.611 days. This is calculated and compared on the number of revolutions of anomalistic period and the length of the mean tropical year (365.2422 days) for four years.

i.e., $27.5545 \times 53 = 1460.3885$ days

$365.2422 \times 4 = 1460.968$

This means once in four years the moon's perigee and apogee fall on the same calendar date, with a little variation in time.

5. Conclusion:

In the preceding sections we have discussed, the procedures of an anomalistic period of the moon and its passage through perigee and apogee. We have illustrated the phenomenon with an example and compared results. The values obtained by Indian classical procedures are compared with those of modern astronomy are comparable.

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