Date of Sanakanika inscription and its astronomical significance for archaeological structures at Udayagiri

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The historical importance of the original location of the Delhi Iron Pillar, namely Udayagiri, has been briefly introduced. The specific date mentioned in the Sanakanika inscription of cave 6 has been analysed and its date determined according to modern calendar. This day was 26 June 402 AD, close to the summer solstice of that year (22 June). The angle of cut of the most important passageway at Udayagiri was specially designed based on astronomical calculations. There is no shadow along the passageway at noon only in the period around summer solstice. The early morning sunlight falls along the passageway, only in the time period around the summer solstice. This study proves the advanced state of astronomical knowledge that existed during the time of Chandragupta II Vikramaditya (AD 375–414).

A six-line three-stanza Brahmi–Sanskrit inscription on the Delhi Iron Pillar, the oldest and largest of all the inscriptions on the pillar, mentions that it was set up as a standard of Vishnu (*Vishnuordhvaja*) at *Vishnupadagiri* by *Chandra*[1]. The Delhi Iron Pillar is currently located in the courtyard of the Quwwat-ul-Islam mosque in New Delhi. However, this is not the original erection site of the pillar. The iron pillar inscription has been analysed in great detail elsewhere[1,2] and Chandra has been identified with Chandragupta II Vikramaditya (AD 375–414) based on a detailed analysis of the archer-type gold coin of the imperial Guptas (AD 320–600). The original location of the pillar, Vishnupadagiri, has been identified as modern Udayagiri[1–3], in the close vicinity of Vidisha and Sanchi. These towns are located about 50 km east of Bhopal, central India, and the region is called Malwa. The astronomical significance of the Delhi Iron Pillar has been recently addressed[4], with respect to its original erection site at Udayagiri[5] and the original image that was probably atop the capital of the pillar[6].

The location of Udayagiri near the Tropic of Cancer is itself an important observation to be noted. The Tropic of Cancer has been mentioned as the ideal latitude for establishment of astronomical observatories in ancient India[7]. There are several significant days in the year as regards the position of the sun with respect to the earth. These are the summer and winter solstices and the equinoxes. It is important to understand which event among these was the most important during the Gupta period. In this regard, there is specific mention of a particular day, in addition to the mention of the name Chandragupta, in an important Gupta-period inscription in Udayagiri in cave 6. In the present article, this particular date will be deciphered. The motion of the sun around summer solstice and its relation to the important archaeological structures would be understood in order to shed further light on the importance of annual solar events at Udayagiri, i.e. ancient Vishnupadagiri.

Historical background

The developments at Udayagiri are not apparent until it is realized that Udayagiri may not have been the original name of the hill. The word 'Udayagiri' literally translates as 'sunrise mountain'. Udayagiri is not mentioned in inscriptions of the Gupta period or before. The earliest record that mentions Udayagiri comes from Bhilsa (i.e. Vidisha)[8] and belongs to eleventh century AD.

The importance of Udayagiri is its association with two important Gupta monarchs, Chandragupta II Vikramaditya and his son, Kumaragupta I. The caves at Udayagiri are dated AD 401/2 on the basis of an epigraph at cave 6 that mentions the consecration of the cave by a Sanakanika king who 'meditates on the feet of Chandragupta'. Another inscription in cave 20 was inscribed in AD 426 during the reign of Kumaragupta I. The Udayagiri site has a rare distinction of being the only one where a Gupta monarch, Chandragupta II Vikramaditya, is known to have been personally involved[3]. It is also the only known site where the king is depicted in the carvings (in caves 5 and 13). The inscription in cave 6 is significant because a precise date has been mentioned in it.

Calendar date of cave 6 inscription

The Gupta-period epigraph by a local king that is inscribed to the north of the entrance to cave 6 is academically referred to as the 'Sanakanika inscription' because of its patron[9]. The two-line inscription translates 'Perfection has been

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attained! *Samvatsare* (in the year) 80 (and) 2, *Ashadha-masa Shukle(ai)kadasyam* (on the eleventh lunar day of the bright fortnight of the month Asadha), – this (is) the appropriate religious gift of the Sanakanika, the maharaja . . . dhala (?), – the son's son of the maharaja Chhagalaga; (and) the son of the Maharaja Visnudasa, – who meditates on the feet of the paramabhattaraka and maharajadhiraja, the glorious Chandragupta (II)'.

The Sanakanika inscription specifically mentions the above particular day in the year when the event mentioned in the inscription took place. Therefore, this inscription proves that Chandragupta II Vikramaditya was present at Udayagiri on this particular day. In order to understand the possible significance of this date, we shall estimate the exact date of this particular day based on modern (Western) calendar. As Udayagiri was an astronomically important site during the Gupta period[5], the possible astronomical significance of the time period near this date will also be explored.

As the motions of the planets are well known, it is possible to retract in time and determine the positions of the planets. It is obvious that such a mathematical task involves vast amount of computations, which can be advantageously performed using modern digital computers. The names of the months in the ancient Indian astronomical system are based on the Purnima of a particular asterism (nakshatra)[10,11]. Nakshatras are 27 star groups identified by Indians along the path of the sun and the moon, i.e. the ecliptic just like the 12 zodiacal constellations (Indian rashis) known in the West. As both of them cover 360°, approximately 2¼ nakshatras make one rashi. For example Ashwini, Bharani and quarter of Krittika make up Mesha rashi, and so on. Table 1 shows the span in degrees of zodiac constellations (Indian rashis), and nakshatras over the ecliptic. The range per constellation is 30°. The ranges is shown in column 3. Columns 4 and 5 shows another system (i.e. asterisms of the Hindu system) of dividing the ecliptic into 27 equal segments, where each segment has a span of 13.333°. The total number of days in 12 lunar months is less than 365.25, which is the time period of the earth. To reconcile this difference, an extra month, called the Adhik-masa, is added in the ancient Indian calendar.

There are two different types of period for the rotation of the moon around the earth. The sidereal month is the time taken by the moon to complete one full orbit of the earth, measured with respect to the distant stars[12]. The major assumption in determining sidereal month is that the distant stars are fixed relative to earth, and for most part they are stationary. The sidereal month is the moon's true orbital period and is equal to 27.3 days, i.e. it takes the moon 27.3 days to be in the same position relative to the distant stars. On the other hand, synodic month is the

Table 1. Spans of Nirayan longitudes of Indian rashis and nakshatras. (*Rashis are fixed stellar zodiacal constellations like Aries, etc. They differ from zodiacal signs like Aries, etc. which move backward among stars due to the phenomenon of precession. At present, the difference between them is about 24°. The sun enters Mesha rashi on 14 April, while it enters Aries sign on 21 March.)

Indian Rashi	Western * Name	λ_n (Rashi)	λ_n (Nakshatra)	Nakshatra	
Mesha	Aries	0 - 30	00.00 - 13.33	1. Ashwini	0
			13.33 - 26.67	2. Bharani	
Vrishaba	Taurus	30 - 60	26.67 - 40.00	3. Krittika	
			40.00 - 53.33	4. Rohini	40
Mithuna	Gemini	60 - 90	53.33 - 66.67	5. Mrigashira	
			66.67 - 80.00	6. Ardra	
			80.00 - 93.33	7. Punarvasu	80
Karkataka	Cancer	90 - 120	93.33 - 106.67	8. Pushya	
			106.67 - 120.00	9. Ashlesha	
Simha	Leo	120 - 150	120.00 - 133.33	10. Magha	120
			133.33 - 146.67	11. Poorva Phalguni	
Kanya	Virgo	150 - 180	146.67 - 160.00	12. Uttara Phalguni	
			160.00 - 173.33	13. Hasta	160
Tula	Libra	180 - 210	173.33 - 186.67	14. Chitra	
			186.97 - 200.00	15. Swati	
			200.00 - 213.33	16. Visakha	200
Vrishchika	Scorpio	210 - 240	213.33 - 226.67	17. Anuradha	
			226.67 - 240.00	18. Jyeshtha	
Dhanus	Sagittarius	240 - 270	240.00 - 253.33	19. Moola	240
			253.33 - 266.67	20. Poovashadha	
Makara	Capricorn	270 - 300	266.67 - 280.00	21. Uttarashadha	
			280.00 - 293.33	22. Shravana	280
Kumbha	Aquarius	300 - 330	293.33 - 306.67	23. Dhanishtha	
			306.67 - 320.00	24. Shatabhisaj	
			320.00 - 333.33	25. Poorva Bhadrapada	320
Meena	Pisces	330 - 360	333.33 - 346.67	26. Uttara Bhadrapada	
			346.67 - 360.00	27. Revathi	360

time taken for the moon to complete one cycle of phases, i.e. the time between successive new moons. Therefore, the synodic month is measured with respect to the sun and is approximately 29.5 days[12]. A tithi is the 30th part of the synodic month and it is less than a day. Similarly, a nakshatra lasts more than a day because the moon has to cover 27 nakshatras in 27.3 days. Tithi and nakshatra of a day are taken to be those prevailing at sunrise. A tithi can be scientifically defined as the time during which the difference between the position angle of the moon and the sun (celestial longitude l) increases by 12°. This period is dependent upon the orbital speed of the earth around the sun and also of the moon around the earth. Therefore, a tithi does not have the length equal to that of the day. It can be more than a day or less also, depending upon the positions of the earth and the moon. By definition, for Shukla Pratipada {ë(moon) – ë(sun)} = 0 to 12°; for Shukla Ekadashi, the difference is between 120 and 132°, and so on. Similarly, on Purnima it is between 168 and 180°. This definition of Purnima will be used to identify the Purnima of the month of Ashadha later on. Ashadha itself is defined as the amanta (new moon ending) month which contains Karkasankranti at l_n (sun) = 90°.

The celestial longitudes ë are measured on the ecliptic from the vernal equinox. The Nirayan longitudes $\ddot{e}_n$ of the sun and moon are measured from a fixed point on the ecliptic. The limits of rashis and nakshatras are fixed with respect to this point. Ayanansha is the difference between that fixed point (reference point when the vernal equinox was taken as zero) and the vernal equinox at any particular time. It increases at the rate of 50″ per year on account of the backward movement of the vernal equinox due to precession of the earth's axis, so $\ddot{e}_n = \ddot{e}$ – Ayanansha. Here, the Ayanansha was referenced with respect to a value of 23°27′ for the year 1954 as given in Devi[10]. For any other year, it can be calculated based on the linear variation rate with a period of 26,000 years, which is 360° in 26,000 years. This was of sufficient accuracy because we were looking for a tithi (ekadashi), where the span of the angle of the moon for a given tithi is sufficiently large. The result obtained was also checked with another software called ASTROLOG[13].

Here, the numerical computations were performed using a software written in FORTRAN in double precision. Details about the software are provided elsewhere[14,15]. The input variables were the calendar date, latitude, and longitude of the place, while the outputs were planetary positions, including nodes of the moon and the Ayanansha. Table 2 shows the results of the calculations. The longitudes of the sun and the moon are provided in columns 6 and 7 respectively. The longitudes in the Nirayana system are shown in columns 9 and 10 respectively. The value of Ayanansha is provided in column 5. The Ayanansha would have been zero approximately in the year AD 260, which is close to AD 285 recommended by Saha and Lahiri[16].

The Guptas rose to power during the first half of the 4th century AD. The first Gupta monarch to declare his sovereignty and call himself a Maharajadhiraja (i.e. Great King of Kings) was Chandragupta I. The Gupta era commences with the date of his coronation as Maharajadhiraja in AD 319–320. As the Sanakanika inscription refers to the 82nd year of the Gupta era, calculations were performed for the years AD 401 and AD 402 to determine in which year the particular date mentioned in the inscription was close to a major annual astronomical event. It was initially determined that in the year AD 402, the ekadashi (i.e. eleventh tithi) of the bright or waxing phase (Shukla paksha) of the Ashadha month was closest to the summer solstice. Therefore, further calculations were performed for the year AD 402.

Tithi and nakshatra of a day are taken to be those prevailing at sunrise. Table 2 gives the data for O^h UT, i.e. 5 : 30 IST, which is close to sunrise in India. Therefore, from Table 2 it is noted that Purnima occurred on 30 June and Shukla ekadashi occurred on 26 June. As Karkasankranti, $\ddot{e}_n$ (sun) = 90°, took place on 23 June (shukla ashtami) during this amanta lunar month, which is the main criterion for Ashadha month, and the moon's nakshatra on Purnima (30 June) was Uttarashadha, the month was Ashadha (Table 2). Closeness to summer solstice and auspiciousness of ekadashi could have been the main points for the choice of the day. Interestingly, this is the time period around which monsoon arrives annually in the Udayagiri region. It may be noted that Ashadha shukla ekadashi is known as Devasayana ekadashi or Sayana ekadashi, which starts the 'chaturmasya' period during which Vishnu is asleep, as depicted in the Anantasayin Vishnu panel in cave 13 at Udayagiri.

Illumination of passageway at noon

Dass and Willis[17] have described in detail the walls of a specially-cut passageway at Udayagiri (the layout of the Udayagiri site and the passageway are shown in Figure 1 of Dass and Balasubramaniam[5]. Udayagiri is one of the most important Gupta-period sites and contains a large number of Gupta-period sculptures. Therefore, the importance of Udayagiri needs to be emphasized. The southern sidewall possesses carved images, cave-shrines and a host of shell inscriptions. On the other hand, the northern wall is practically untouched except for the presence of one small figure, possibly that of Ganga. Dass[3] has also uncovered the ancient Gupta-period water passageways of Udayagiri and based on a detailed survey of the site, has proposed that the water from a storage lake situated above the passage way was collected above the northern wall and allowed to overflow, such that the entire northern wall had water gushing down the side. This was collected and led through a series of shrines, in front of cave 6, to a lake that was situated in front of the Varaha panel in cave 5.

Some interesting observations were recorded at Udayagiri on summer solstice by Dass and Willis[17]. They visited

Table 2. Ephemeresis of the sun and the moon for June 402 AD

Year	Month	Date	Declination	Ayananshа	*l* (Sun)	*l* (Moon)	*l* (moon) – *l* (sun)	*l* (Sun) (Nirayana)	*l* (Moon) (Nirayana)
402	6	1	21°56′	1.955	71.1	251.7	180.7	69.1	249.8
402	6	2	22°04′	1.955	72	264.6	192.6	70.1	262.7
402	6	3	22°12′	1.955	73	277.6	204.6	71	275.6
402	6	4	22°20′	1.955	73.9	290.7	216.8	72	288.7
402	6	5	22°27′	1.955	74.9	303.9	229.1	72.9	302
402	6	6	22°33′	1.955	75.8	317.3	241.5	73.9	315.4
402	6	7	22°40′	1.955	76.8	330.8	254	74.8	328.9
402	6	8	22°45′	1.955	77.7	344.4	266.6	75.8	342.4
402	6	9	22°51′	1.955	78.7	357.9	279.2	76.7	356
402	6	10	22°56′	1.955	79.6	11.4	291.8	77.7	9.4
402	6	11	23°00′	1.955	80.6	24.8	304.2	78.6	22.8
402	6	12	23°05′	1.955	81.5	38	316.4	79.6	36
402	6	13	23°09′	1.955	82.5	51	328.5	80.5	49
402	6	14	23°12′	1.955	83.4	63.9	340.5	81.5	61.9
402	6	15	23°15′	1.955	84.4	76.7	352.3	82.4	74.7
402	6	16	23°18′	1.955	85.3	89.4	4.1	83.4	87.5
402	6	17	23°20′	1.955	86.3	102.2	15.9	84.3	100.3
402	6	18	23°22′	1.955	87.2	115	27.8	85.3	113.1
402	6	19	23°23′	1.955	88.2	128	39.8	86.2	126.1
402	6	20	23°24′	1.955	89.2	141.1	52	87.2	139.2
402	6	21	23°24′	1.955	90.1	154.4	64.3	88.2	152.5
402	6	22	23°24′	1.955	91.1	167.8	76.8	89.1	165.9
402	6	23	23°24′	1.955	92	181.4	89.3	90.1	179.4
402	6	24	23°23′	1.956	93	194.9	101.9	91	192.9
402	6	25	23°22′	1.956	93.9	208.4	114.5	92	206.4
402	6	26	23°21′	1.956	94.9	221.8	126.9	92.9	219.8
402	6	27	23°19′	1.956	95.8	235	139.2	93.9	233.1
402	6	28	23°17′	1.956	96.8	248.1	151.3	94.8	246.2
402	6	29	23°14′	1.956	97.7	261.1	163.4	95.8	259.1
402	6	30	23°11′	1.956	98.7	274	175.3	96.7	272

the site during different seasons and on equinox and solstice days. The summer solstice day was found to be significant because the sun rose in direct alignment with the passage. Significantly, it was noted that there was virtually no shadow in the passage on the summer solstice day, because the sun was near the zenith at that time[17]. They observed a shadow near the south wall, but not north of the passageway.

It would be interesting to understand the observations of Dass and Willis from a scientific perspective. We shall understand the illumination of the specially-cut passageway by estimating the midday altitude of the sun in the period around summer solstice in AD 402.

The declination of the sun is given in column 4 of Table 2. If *ä* is the declination of the sun and *f* the latitude of the place, the midday attitude of the sun will be *â* = 90°–|*ä*–*f*|. The sun will be north of the zenith if *ä* > *f*, and it will be south of the zenith if *ä* < *f*. The latitude of Udayagiri is *f* (Udayagiri) = 23°31′. It is noted from Table 2 that the maximum declination of the sun around summer solstice was 23°24′. Actually, it should have been 23°39′ in AD 402 (according to Dass and Willis[17]). So, our calculations do not have the required accuracy for this quantity. However, it does not affect the dating of the inscription. Therefore, at that time, the sun would be 8′ north of the zenith and a faint penumbra near the north wall. But during our times *ä* (sun) = 23°26′ on 22 June. Therefore, the sun would be south of the zenith by 5′ and the observations noted by Dass and Willis[17] can be reasonably explained. It should also be noted that the diameter of the sun's disc is 16′. As the value 8′ or 5′ is a fraction of the same, the passageway will be practically fully illuminated at noon on several days around summer solstice. This must have been the intended effect of the architects of Udayagiri, who have blended astronomical knowledge in the creation of this ancient site.

Early morning sunrise

In order to understand the possible significance of the early morning sun, the direction of the early morning sun on summer solstice will be estimated. The speciality of the passageway will also be understood by the conditions prevailing at sunrise. The morning sun is considered auspicious in Indic religions. The modern name of Vishnupadagiri, namely Udayagiri, itself suggests the importance of the early morning sun at this particular site. The name Udayagiri may have been related to the special aspects of early morning sun at this location.

The direction of sunrise on any particular day can be estimated using the following spherical astronomical relationship:

$$\sin d = \sin j \cos z + \cos j \sin z \cos A, \tag{1}$$

where d is the declination of the sun, j is the latitude of the place, z is the zenith distance and A is the azimuth measured from the north. Putting $d = 23°39'$, $j = 23°31'$ and $z = 90°$, we obtain A as 64°04′. Therefore, the angular distance from east or west will be 25°56′. It must also be noted that the horizontal angle changes towards lower values with time after sunrise.

At all other periods in the time of the year, d will be less than its value on summer solstice and therefore, the maximum angle of early morning sunrise (measured east-west) is obtained only in the period around summer solstice. Therefore, the rays from the morning sun would fall along the passageway, in which several important bas-reliefs are carved, only around summer solstice period and not at other times of the year. On properly placing the iron pillar, it will cast its shadow at the entrance of the passageway at sunrise during this period. This further validates the utilization of Siddhantic astronomical knowledge in the design of the Udayagiri site, which predates the seminal works of Aryabhata (AD 499) and Varahamihira (AD 505) by about 100 years.

Conclusion

The historical importance of Udayagiri (ancient Vishnupadagiri) has been reviewed. The specific date mentioned in the Sanakanika inscription of cave 6 has been analysed to determine the date according to modern calendar. Astronomical calculations indicated the day to be 26 June, AD 402, which was close to the summer solstice of that year (22 June). The motion of the sun on summer solstice and its relation to archaeological structures have also been highlighted. A specially-cut passageway at Udayagiri was completely illuminated by the sun at noon only in the period around summer solstice. The angle of cut of the passageway at Udayagiri was specially designed such that the early morning sunlight fell along the passage way, only in the time period around summer solstice. This study proves the advanced state of astronomical knowledge that existed during the time of Chandragupta II Vikramaditya (AD 375–414).

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