Astronomical alignment of iron pillar and passageway at Udayagiri and date of Sanakanika inscription

K. Chandra Hari

Astronomical alignment of the passageway at Udayagiri is shown to be critically related to the date of the Sanakanika inscription which corresponds to the sunrise when the azimuth at equinox and solstices differed by the latitude 23°31′ of the place. The date of the Sanakanika inscription of cave 6 at Udayagiri is shown to be 29 May 402 CE. Astronomical alignment of the passageway corresponded to the direction of the rising sun on 29 May 402 CE, when the direction of the rising sun had a deviation equal to the latitude 23°31′ of the place. Original installation of the pillar in front of the passageway is shown to have represented the philosophy underlying Puruṣa sūkta of Ṛgveda by the proportions of the foundation : pillar and height of decorative bell capital : height of pillar. The date 29 May 402 CE as the date of the inscription and the reference date for the astronomical alignment explains well the shadow on the south wall observed at summer solstice and also brings out the extreme precision with which the passageway got constructed to mark the direction of the rising sun. Discussion has been provided as to how the illumination of the passageway may be further examined to understand the astronomical orientation of the same and the inner panels vis-à-vis motifs that may have existed on the rear wall.

The present work is a closer re-look at the astronomical alignment of the passageway at Udayagiri which is shown to mark the path of rays of the rising sun around the time of summer solstice by Balasubrahmaniam and Dass[1], and Sharan and Balasubrahmaniam[2]. Astronomical significance of the location, historical importance of the archaeological ruins[3] and the epigraphic record of cave 6 known as 'Sanakanika inscription' have been discussed in detail by Sharan and Balasubrahmaniam[2]. The Sanakanika inscription which reads as: 'Perfection has been attained! Samvatsare (in the year) 80 (and) 2, Āṣāḍhamāsa śukḷaikādaśyām (on the eleventh lunar day of the bright fortnight of the month Āṣāḍha) – this (is) the appropriate gift of the Sanakanika, etc.', is dated AD 26 June 402, close to the summer solstice of that year (22 June). Direction of the early morning sun at the site of Udayagiri has been calculated for the summer solstice day to be 25°56′, as against the latitude 23°31′ of the location.

A re-look at the date of the Sanakanika inscription

Given the luni-solar configuration of AD 402, it appears that the date AD 26 June 402 may correspond to the month of Śrāvaṇa than Āṣāḍhā proper, as may be understood from the sequence of new moon and full moon of the year given in Table 1.

It may be noted from Table 1 that: (i) Amānta-Caitra was over with the new moon of 18 April 402 CE. (ii) Amānta-Vaiśākha was over with the new moon of 18 May. (iii) Amānta-Āṣāḍhā began on 18/19 May and ended with the new moon of 16/17 June 402 CE. The sun was at the fag end of Mithuna rāśi and in no way it could have been Vaiśākha and there are no reasons to suppose that Āṣāḍhā may have been different in 402 CE.

With the above picture of Āṣāḍhā, the date of the inscription, i.e. Āṣāḍhā śukḷa ekādaśi, the 11th tithi of the light fortnight of Āṣāḍhā falls on 29 May 402 CE.

The date 26 June 402 CE, 06 : 00 LMT had sun λ = 93°59′ and moon 204° and the tithi would have been only Śrāvaṇa śukḷa daśamī instead of ekādaśī which falls on 27 June.

Table 2 furnishes the relevant data of sun and moon for the lunar month of Āṣāḍhā.

It becomes therefore evident that the date of the Sanakanika inscription is 29 May 402 CE. As the month was Āṣāḍhā proper instead of Śrāvaṇa, the tithi corresponded to Śāyana Ekādaśī, the beginning of Cāturmāsya, important for Viṣṇu, the lord of Udayagiri.

Evidence of the astronomical alignment of passageway at Udayagiri

The direction of the rising sun on the summer solstice day as given by Sharan and Balasubrahmaniam[2] is 25°56′ and does not match with the latitude of the place to have the sunrise exactly on the east. Even though Sharan and Balasubrahmaniam had remarked that the horizontal angle changes with time after sunrise to lower values, explanation was not attempted for the 2° higher value obtained on the summer solstice for the direction of sunrise, i.e. difference between azimuth at equinox and summer solstice. Table 3 explains the scenario and brings out the fact that 29 May 402 CE was the date when the sun rose exactly on the east at Udayagiri, so that the rays illuminated the passageway fully.

It is apparent from the contrast of the direction of the rising sun for 29 May and 26 June that the date 29 May was more significant to Udayagiri as the sun rose in the east and illuminated the passageway as well as the Ananthasayana panel that the passage had on its walls. This astronomical aspect supports the new dating given for the Sanakanika inscription, i.e. 29 May 402 CE.

The precision seen in the data is remarkable – for the zenith distance (z) of 90°, the direction angle had been 23.80 and for zenith distance 89.5°, the direction angle had been 23.56°, i.e. when we take into account the apparent radius of the sun and refraction (z = –91° for sun grazing the horizon), the direction of the rising sun illuminating the passage (z = –91° + 1.5° = 89.5°; note 1) had equalled the latitude precisely on 29 May 402 CE and the day of Śāyana ekādaśī of Āṣāḍha

Table 1. Configuration of new moons and full moons

Date and time – newmoon	Sun = Moon	Date and time – full moon	Moon λ	Full moon nakṣatra	Remarks
402/02/18 12 : 42	330.65	402/03/06 00:49	166.00	Hastha	Middle of Phālguni
402/03/20 03 : 06	359.84	402/04/04 10:00	194.72	Citrā and Svāti	Middle of Caitra
402/04/18 18 : 20	28.58	402/05/03 17:39	222.96	Viśākhā and Anurādha	Middle of Vaiśākha
402/05/18 09 : 58	56.98	402/06/02 00:42	250.91	Mūla	Middle of Āṣādhā
402/06/17 01 : 14	85.22	402/07/01 07:57	278.83	Uttarāṣāḍḥa	Middle of Śrāvaṇa

was chosen precisely after the astronomical alignment was finalized to have the worship of Viṣṇu there in the presence of Candragupta, Vikramāditya.

Shadow near the south wall of the passageway

Sharan and Balasubrahmaniam[2] have mentioned about the observation of Dass and Wills, which is noteworthy in the above context:

'Significantly it was noted that there was no shadow in the passage on the summer solstice day, because the sun was near the zenith at that time. They observed a shadow near the south wall but not north of the passageway. It would be interesting to understand the observation of Dass and Wills from a scientific perspective.'

Observation as above finds better explanation if we go by the date of the Sanakanika inscription as 29 May 402 CE and the fact that the passageway had been precisely aligned with respect to the rising sun at Udayagiri on 29 May 402 CE. Table 4 presents the precise declination data for the period from 28 May 402 CE to 1 July 402 CE.

It is apparent from Table 4 that the maximum declination of 23.645° at noon occurred for 22 June 402 CE, which is little more than the latitude of the place 23.517°. Technically speaking, there are two days on which the sun casts no shadow at noon, viz. 16 June and 28 June, and there will be a shadow towards the south during 16–28 June. When we look at the azimuth of the rising sun it becomes clear, as stated earlier, that the sun rose exactly on the east for 29 May 402 CE. As the sun progressed towards the summer solstice, it can be noted that the rising sun had moved further north. Thus on the summer solstice day and around, the rising sun had been casting a shadow on the south wall of the passageway.

Table 2. Tithi 1–11 of light half of Āṣāḍḥā

Date: ZT : 05 : 30	Sun λ_1	Moon λ_2	$(\lambda_2 - \lambda_1)/12°$	Tithi
402/05/19	57.76	66.578	0.73	1
402/05/20	58.71	78.4	1.64	2
402/05/21	59.67	90.298	2.55	3
402/05/22	60.62	102.32	3.47	4
402/05/23	61.58	114.51	4.41	5
402/05/24	62.53	126.92	5.37	6
402/05/25	63.48	139.62	6.34	7
402/05/26	64.43	152.65	7.35	8
402/05/27	65.39	166.06	8.39	9
402/05/28	66.34	179.88	9.46	10
402/05/29	67.29	194.12	10.57	11

Table 3. Direction of rising sun at Udayagiri on 29 May and 26 June 402 CE

29 May 402 CE	Sun azimuth	Altitude	Direction east	26 June 402 CE	Sun azimuth	Altitude	Direction east
05 : 00	64.77	–2.93	25.23	05 : 00	62.56	–3.13	27.44
05 : 10	65.80	–0.85	24.20	05 : 10	63.60	–1.09	26.40
05 : 20	66.79	1.25	23.21	05 : 20	64.60	0.97	25.40
05 : 30	67.75	3.37	22.25	05 : 30	65.56	3.05	24.44
05 : 40	68.68	5.49	21.32	05 : 40	66.49	5.15	23.51
05 : 50	69.59	7.64	20.41	05 : 50	67.39	7.26	22.61
06 : 00	70.46	9.79	19.54	06 : 00	68.26	9.38	21.74
06 : 10	71.32	11.96	18.68	06 : 10	69.11	11.51	20.89

Time shown as hh : mm and all other values in degrees.

It may be noted from the above that in the case of the passageway aligned for summer solstice, it is impossible for the sun to cast a shadow on the south wall of the passageway. Discussion as above brings out the fact that the passageway was designed for the rising sun on the east and the structure had its inauguration on 29 May 402, the date of the Sanakanika inscription.

Table 4 provides an illustration for the slow change in declination with the approach of the solstice. It may have been difficult for the astronomers to understand the limit of the sun's northward motion as happening precisely on a particular date. The passageway (Figure 1) helped the ancient astronomers to solve this problem as the lighting up of the passage provided an indirect observation of the sun[4]. Just as 29 May 402 CE marked the direction of the rising sun due east ($\delta = 21°43'$) before the solstice, 16 July 402 CE marked the swing back of the rising sun ($\delta = 21°39'$) to the same point. These dates are roughly 24 days on either side of the solstice. As nearly 48 days intervene, we get the declinational swing of the sun between Āṣāḍḥā śukḷa ekādaśī and Śrāvaṇa amāvāsya – the latter tithi too of great religious significance in Indian tradition. During this interval, the lighting of the passage by the sun may have been of observational significance to the astronomers at Viṣṇupadagiri, i.e. modern Udayagiri.

It is apparent from Figure 1 that when the rising sun rays had lighted up the

Table 4. Declination of sun and shadow for 12 units gnomon 28 May to 26 June 402 CE

Date (12 Noon)	Declination δ	Latitude ϕ	Altitude 90 – ϕ + δ	Azimuth of rising sun	Shadow for gnomon 12 Angulam	Shadow for gnomon 320 Angulam
402/05/28	21.59791	23.517	88.081	66.36	0.402	10.72
402/05/29	**21.75799**	**23.517**	**88.241**	**66.20**	**0.368**	**9.83**
402/05/30	21.91189	23.517	88.395	66.05	0.336	8.97
402/05/31	22.05955	23.517	88.543	65.90	0.305	8.14
402/06/01	22.20094	23.517	88.684	65.76	0.276	7.35
402/06/02	22.33601	23.517	88.819	65.63	0.247	6.59
402/06/03	22.46472	23.517	88.948	65.49	0.220	5.88
402/06/04	22.58701	23.517	89.070	65.37	0.195	5.19
402/06/05	22.70284	23.517	89.186	65.25	0.170	4.55
402/06/06	22.81216	23.517	89.295	65.13	0.148	3.93
402/06/07	22.91492	23.517	89.398	65.02	0.126	3.36
402/06/08	23.01109	23.517	89.494	64.92	0.106	2.82
402/06/09	23.10061	23.517	89.584	64.82	0.087	2.32
402/06/10	23.18344	23.517	89.667	64.72	0.070	1.86
402/06/11	23.25956	23.517	89.743	64.63	0.054	1.44
402/06/12	23.32892	23.517	89.812	64.55	0.039	1.05
402/06/13	23.3915	23.517	89.875	64.47	0.026	0.70
402/06/14	23.44726	23.517	89.931	64.40	0.015	0.39
402/06/15	23.49617	23.517	89.980	64.33	0.004	0.11
402/06/16	23.53822	23.517	90.022	64.27	–0.005	–0.12
402/06/17	23.57339	23.517	90.057	64.22	–0.012	–0.32
402/06/18	23.60165	23.517	90.085	64.17	–0.018	–0.47
402/06/19	23.62299	23.517	90.106	64.13	–0.022	–0.59
402/06/20	23.63739	23.517	90.121	64.09	–0.025	–0.67
402/06/21	23.64485	23.517	90.128	64.06	–0.027	–0.72
402/06/22	**23.64536**	**23.517**	**90.129**	**64.03**	**–0.027**	**–0.72**
402/06/23	23.63891	23.517	90.122	64.02	–0.026	–0.68
402/06/24	23.6255	23.517	90.109	64.00	–0.023	–0.61
402/06/25	23.60514	23.517	90.088	64.00	–0.019	–0.49
402/06/26	**23.57783**	**23.517**	**90.061**	**64.00**	**–0.013**	**–0.34**
402/06/27	23.54358	23.517	90.027	64.01	–0.01	–0.15
402/06/28	23.50242	23.517	89.986	64.02	0.00	0.08
402/06/29	23.45435	23.517	89.938	64.04	0.01	0.35
402/06/30	23.39941	23.517	89.883	64.07	0.02	0.65
402/07/01	23.33761	23.517	89.821	64.10	0.04	1.00

Anantaśāyin panel on the solstice day of extreme north declination, viz. 22 June 402 CE, the width of the passage must have allowed the rays to be admitted on 29 May 402 CE, when the direction of the rising sun (90° azimuth) equalled the local latitude.

Studies on the lighting up of the passageway

Lighting up of the passageway during 29 May–16 July is dependent upon factors like north-south movement of the rising sun (azimuth), declination or obliquity of the rising sun (not perpendicular to the horizon for non-zero latitudes), angular diameter of the sun and dimensions of the passageway. Declinational change during the above period of 48 days has the midpoint on summer solstice on

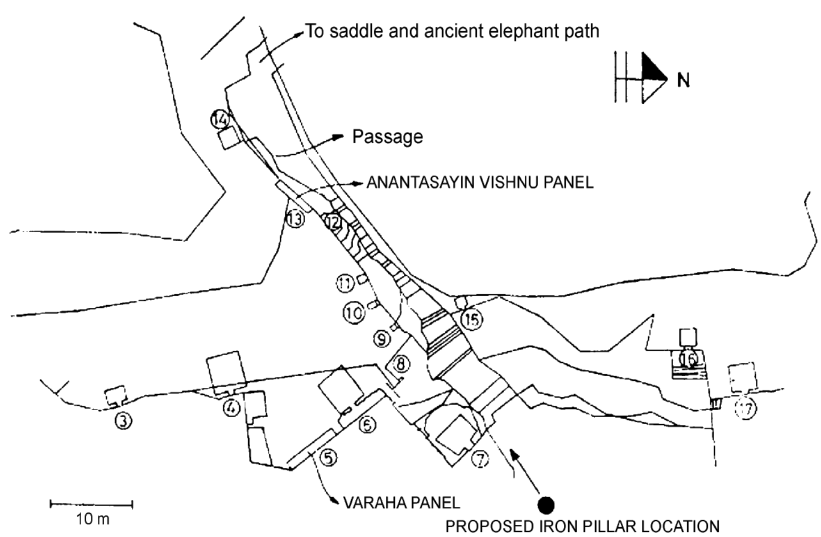

Figure 1. Layout of the passageway at Udayagiri[4].

either side of which declination varied by nearly 2°. Variation in the azimuth data of the sun shows that during the 24 days from 29 May to 22 June, azimuth changed by –2.18° (northward), and between 22 June and 16 July, the azimuth had a change of nearly +1.5° (southward). This change (average 1.75°) may have caused the light beam to have a width of nearly 36 in over a rear-end marker motif placed 100 ft inside the passage (note 2). At different inward distances and changes in azimuth, the width of the light beam will be as shown in Table 5.

In the same way, if the light strikes the rear motif at a height say 3–6 ft, it can move down 3 ft before grazing on the floor across an angle of 1.7°. This when added to the angular diameter of the sun, yields 2.2° as the ascent of the sun during the lighting up of the passageway. Table 6 presents the different scenarios (note 3).

Identified decorative capital which may have included the wheel of asterisms may have been of an angular radius related to the above variation in declination and azimuth and also on the angular diameter of the sun. Also it is possible that it may have been of critical significance in orienting the light beam to specific spots in the passageway with the help of windows or openings chosen for the purpose.

Subtle changes possible for the lighting up may be understood from data provided in Table 7.

Table 7 is illustrative of the significance of the date and precise time of the day in observing the lighting up of the passageway and understanding the astronomical alignment of the same. After sunrise, the azimuth changes swiftly and may alter the lighting significantly than at sunrise across even 5-day intervals. During the 45-day interval of 29 May to 13 July, the azimuth had little change for the rising sun compared to the change in azimuth due to diurnal movement of the sun. Lighting up of the passageway during the 48-day interval, therefore shall be dependent more upon the width and height of the tunnel and the profile of illumination of the north wall and the inward direction of the floor needs to be studied as a function of altitude of the sun.

Time interval of illumination and daily shift of the direction of light noted using

Table 5. Width of the light beam on rear motif possible at different distances

	Width of the light beam (in) for azimuth change across 24 days on either side of the solstice					
Rear motif distance (ft)	0.5°	1°	1.75°	2°	3°	4°
20	2	4	7	8	13	17
40	4	8	15	17	25	33
60	6	13	22	25	38	50
80	8	17	29	34	50	67
100	10	21	37	42	63	84

Table 6. Impact of diurnal motion on lighting up of passageway

	Altitude of sun and time of rise for vertical ascent of the rays in feet							
Rear motif distance (ft)	0.5 ft	Time (min)	1 ft	Time (min)	1.5 ft	Time (min)	2 ft	Time (min)
20	2.0°	9	3.4°	15	4.8°	22	6.3°	28
40	1.2°	6	2.0°	9	2.7°	12	3.4°	15
60	1.0°	5	1.5°	7	2.0°	9	2.4°	11
80	0.9°	4	1.2°	6	1.6°	7	2.0°	9
100	0.8°	4	1.1°	5	1.4°	6	1.7°	8

Time given in minutes, altitude given in degrees.

Table 7. Variation of azimuth after sunrise and across 5-day intervals

29/05/402 CE	Azimuth	Altitude	Declination	Date 05:10	Azimuth	Altitude	Declination
05 : 10	65.80	–0.85	21.713	402/05/29	65.80	–0.85	21.713
05 : 20	66.79	1.25	21.714	402/06/03	65.25	–0.35	22.429
05 : 30	67.75	3.37	21.715	402/06/08	64.82	0.04	22.984
05 : 40	68.68	5.49	21.716	402/06/13	64.52	0.32	23.374
05 : 50	69.59	7.64	21.717	402/06/18	64.37	0.51	23.594
06 : 00	70.46	9.79	21.719	402/06/23	64.36	0.62	23.641
06 : 10	71.32	11.96	21.720	402/06/28	64.52	0.65	23.515
06 : 20	72.15	14.13	21.721	402/07/03	64.83	0.61	23.216
06 : 30	72.95	16.32	21.722	402/07/08	65.31	0.53	22.747
06 : 40	73.75	18.52	21.723	402/07/13	65.95	0.40	22.112

appropriate markers during 29 May–16 July can render more precise understanding of the astronomical alignment of the passageway.

Iron pillar and astronomical interpretation of Puruṣa sūkta

Balasubrahmaniam[3] has discussed the dimensions of the Delhi Iron Pillar which probably served the purpose of a gnomon at the entrance of the passageway. Height above the ground level of 240 units of modern inch equalled 324 aňgulam. On the date of the inscription, i.e. 29 May 402 CE, the Iron Pillar had a noon shadow of 10 aňgulam, which may be computed as shown below: For a gnomon of height γ, the midday shadow ψ at a place of latitude ϕ is given by

$$\psi = \gamma * \tan(\phi - \delta),$$

where δ is the declination of the sun. Midday declination of the sun at Udayagiri on 29 May 402 CE was 21.76° and yielded the shadow for a gnomon of 324 aňgulam as $324 * \tan(23.5 - 21.76) = 9.84 \approx 10$ aňgulam.

Here we meet with an allusion to the Puruṣa sūkta of *Ṛgveda*, where the Virāṭpuruṣa is described in terms of the five circles and the shadow of 10 aňgulam.

सहस्रशीर्षा पुरुषः । सहस्राक्षस्सहस्रपात् ।
स भूमिं विश्वतो वृत्वा । अत्यतिष्ठद्दशाङ्गुलम् ॥ १ ॥

Sahasra śīrṣā puruṣaḥ |
sahasrākṣaḥ sahasrapāt |
Sa bhūmim viśvato vṛtvā |
atyatiṣṭad daśāňgulam |

Ṛgveda (10.7.90.1)

Traditional interpretation mentions[5]:

A thousand heads hath Purusa, a thousand eyes, a thousand feet. On every side pervading earth he fills a space ten fingers wide.

The verse may also be interpreted to yield the following meaning:

'Endowed with a thousand heads, thousand eyes and thousand feet, Puruṣa stands with his ten finger (angulam) long foot firmly established on Earth.'

The verse as above contains archaic words of Sanskrit, whose meaning is not clear. When the word Sahasra is taken to mean a great circle, we can see five circles described in the above verse, viz. (i) Śīrṣa vṛtta or the Meridian Circle, (ii) Akṣa-vṛtta or the Celestial Equator, (iii) Pāta-vṛtta or Prime Vertical, (iv) Bhūmi-vṛtta or Horizon and (v) Viśva-vṛtta or Ecliptic.

Sūkta may be interpreted as a symbolic description of the sun identified in terms of the ancient mode of fixing time with the help of a gnomon and on the tropic of Cancer when the sun rose exactly on the east, he had a foot 10 angulam long as the noon shadow.

As $27 \times 12 = 324$ and a gnomon of height 324 aňgulas gave a shadow of 10 aňgulam at Viṣṇupadagiri on 29 May 402 CE (note 4). The shadow obviously finds a symbolic interpretation as the feet of the sun or Viṣṇu and thus we reach an explanation for the name Viṣṇu-pada-giri in the above analysis. Is this is a coincidence or not? The answer lies in the Iron Pillar or Viṣṇudhvaja of Udayagiri.

Balasubrahmaniam[3] has discussed the geometry of the Delhi Iron Pillar vis-à-vis dimensions above and below the ground level as follows:

'If the start of the smooth surface section is taken as the original level to which it was buried, the rough surface occupies one-fourth (60 U) and smooth surface three-fourths (180 U) of the length of the main body of the pillar, excluding the decorative top. . . . The decorative bell capital is a symmetrical object as well . . . . The Cakra idol must have been 20 U in length, thereby making the total length of the decorative top 60 U. The length of the decorative capital (60 U) would now be exactly one-fourth of the total pillar exposed above the ground level (240 U). Therefore, it is concluded that the depth to which it was buried was equal to the height of the decorative capital, which is indicative of the excellent engineering design of the pillar'.

This description of the dimensions of Visnu-dhvaja which has come to be known as Delhi Iron Pillar, echos the description that we find of Purusa in the Purusa sukta *Ṛgveda* (10.7.90.3-4) as explained below:

एतावानस्य महिमा । अतो ज्यायागम्श्च पूरुषः ।
पादोऽस्य विश्वा भूतानि । त्रिपादस्यामृतं दिवि ॥ ३ ॥

etāvānasya mahimā |
ato jyāyāgamūśca puruṣaḥ |
pādo*f*sya viśvā bhūtāni |
tripādasyāmṛtam divi |

Ṛgveda (10.7.90.3)

'So mighty is his greatness; yea, greater than this is Purusa. All creatures are one-fourth of him, three-fourths eternal life in heaven.'

The verse receives the detailed interpretation that the earthly transient world is one-fourth of Purusa, while the eternal world is three-fourths and we the echo of this description of Purusa in the dimensions of Visnu-dhvaja, whose one-fourth stood buried in Earth. Three eternal parts are sat, cit, ananda – the highest one-fourth ananda may be depicted additionally as the decorative capital of 60 U.

त्रिपादूर्ध्व उदैत्पुरुषः । पादोऽस्येहाभवात्पुनः ।
ततो विष्वङ्व्यक्रामत् । साशनानशने अभि ॥ ४ ॥

tripādūrdhva udayat puruṣaḥ |
pādo*f*'syehābhavatpunaḥ |
tato viśvajnakrāmat |
sāṣanāna aṣane abhi |

Ṛgveda (10.7.90.4)

'When three-fourths Purusa went up: one-fourth of him again was here. Thence he strode out to every side over what eats not and what eats.'

The 1 : 3 ratio of heights of the pillar beneath and above the ground reminds us of the fourth verse as well. Three parts of the Purusa are above all earthly beings and of only one part is the cycle of creation again and again – all that eats and eats not comes forth from the one-fourth. It may be further noted that the Iron Pillar above the ground also exhibited the 1 : 3 ratio that we see in Purusa sukta between the decorative capital of one-fourth height and the three-fourths height of the Iron Pillar above ground.

It is apparent that the design of the Iron Pillar and its installation at Visnu-pada-giri was guided by Vaisnava darsana, the root of which is traceable to the Purusa sukta, which is commonly used in Vedic ceremonies and rituals. Even in modern times, the traditional importance is reflected in the use of Purusa sukta for the worship of Visnu or Narayana in temples. The fact that the sukta is the cornerstone of Vaisnava philosophy and the description of the Puruṣa resembling the Iron Pillar suggest that both philosophical and astronomical knowledge had gone into the design of the site.

Appendix 1 provides a discussion regarding the original location of the observation that formed the basis of the Puruṣa sūkta verse.

Appendix 1. Location of 10 aṅgulam shadow observed on solstice day

What kind of Vedic wisdom inspired the artisans and astronomers of the Gupta Age to incorporate the 10 aṅgulam shadow in the design and installation of the Candra Pillar or Viṣṇu-dhvajā at Udayagiri?

The only reason by which importance got attached to a 10 aṅgulam shadow is the knowledge of the rationale of the sūkta as referring to the great circles of heaven and the fact that the sun did cast a shadow of 10 aṅgulam at the place where the hymn had its origin on the summer solstice day. Table A1 illustrates variation of the shadow with latitudes on the solstice day.

Latitudes 1 and 2 represent solutions for places north to the tropic of Cancer and those which are at lower latitudes. It can be understood from Table A1 that a declination of 21.877 for the sun resulted in a shadow of 10 angulams at Udayagiri. The date of the Sanakanika inscription had been one such date when the Candra Iron Pillar of 324 aṅgulam had cast a shadow of 10 aṅgulams at noon and the day coincided with Śāyana ekādaśi on 29 May 402 CE, the date of the Sanakanika inscription.

Figure A1 presents the latitudes for which there will be a noon shadow of 10 aṅgulam with a gnomon of height 324 angulam.

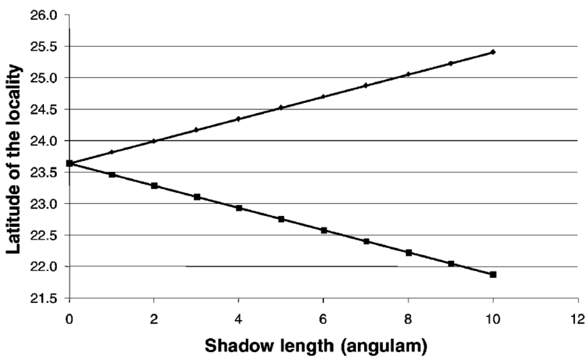

Figure 1A. Shadow of 10 angulam on summer solstice.

Table A1. Declination of sun and gnomon shadow

Sun δ	Shadow	Latitude 1	Latitude 2
23.645	0	23.645	23.645
23.645	1	23.822	23.469
23.645	2	23.999	23.292
23.645	3	24.176	23.115
23.645	4	24.353	22.938
23.645	5	24.530	22.761
23.645	6	24.706	22.584
23.645	7	24.883	22.408
23.645	8	25.060	22.231
23.645	9	25.236	22.054
23.645	10	25.413	21.877

It can be deduced from Table A1 that the Puruṣa sūkta probably had its origin at a place of latitude 25°N25′, where the sun had been casting a shadow of 10 aṅgulam on the summer solstice day. This latitude when we considered against the possible locations on the banks of erstwhile Sarasvatī, or say roughly in the same longitude as the Ujjayinī meridian, falls north of modern Kota on the eastern banks of River Chambal, the main tributary of the Yamuna. It is likely that the Ujjayini meridian of ancient Indian astronomy may have grown out of a remnant of the Vedic astronomical tradition that existed at 25°N25′, 75°E45′.

We have innumerable evidences in the *Vedas* and *Brahmanas* of the summer solstice observations in ancient days[1]. *Aitareya Brāhmaṇa* has recorded the observation that the sun remained stationary for a period of 21 days or more precisely during a period of seven days and the Vedic people could ascertain this by observing the noon shadow of a vertical pole. Sengupta* gives the following details:

'*If we assume that the observation was made at the latitude of Kurukṣetra (about 30°N) and when the obliquity of the ecliptic was about 24°15′, and the height of the pole was taken equal to, say, 6 ft then:*

(a) When the sun had a longitude of 80°, the length of the noon shadow = 7.44 in.
(b) When the sun had a longitude of 87°, the length of the noon shadow = 6.98 in.
(c) When the sun had a longitude of 90°, the length of the noon shadow = 6.93 in.

Now 7.44 – 6.98 = 0.46 in and 6.98 – 6.93 = 0.05 in. Hence by use of any sort of measuring rods, they could perhaps easily discern a change in the noon shadow of about half an inch, but a difference of 0.05 in was, of course, quite impossible of perception with them. They could thus infer that the sun remained stationary at the summer solstice for 7 days when they used any measuring rods and when they used rougher methods, they could conclude that the sun remained stationary for 21 days at the summer solstice . . . It should thus be clear that the Vedic Hindus knew how to determine the summer or the winter solstice day. When they found that the sun apparently remained stationary at the solstice for 21 days, the true solstice day was the 11th and when they found that the sun remained stationary for 7 days, they took the fourth day as the real solstice day.'

In a footnote Sengupta offers the following comments on the Varāhamihira's mention of the methods for fixing the solstice:

'*The solstice day may be determined by observing the coincidence of the sun at the time of rising or setting with a distant signpost or by the marks of entrance or exit of the tip of the shadow of a gnomon in a large horizontal circle (having for its centre the foot of the gnomon). Here two methods are described by Varāhamihira, in the first of which the sun's amplitude at sunrise or sunset is to be observed. If the Vedic Hindus followed this method, they could perhaps observe the sun to remain stationary, i.e. without any appreciable change of amplitude, for 21 days near the solstices. It does not appear probable that the second method was followed by the Vedic Hindus . . .*'.

The detailed records of solstice observations available in the *Brāhmaṇa* literature amply illustrate the social significance of the event and there cannot be any doubt that the Vedic people had sufficient intellectual caliber as to devise appropriate methods for observation. Vedic literature cannot be expected to contain exhaustive description of the astronomical methods and as such, the only recourse is to infer such details circumstantially from other known factors.

*Sengupta, P. C., *Ancient Indian Chronology*, University of Calcutta, 1947, pp. 90–92.

Viṣṇupadagiri on tropic of cancer

Symbolic engravings at Udayagiri eloquently bring out the fact that the site incorporated the Vedic symbolism of sun and Viṣṇu, as given in the expressions by the Ṛṣis in different hymns praising Viṣṇu. The original installation of the Candra Iron Pillar or the Viṣṇu-Dhvaja had been for astronomical purpose, and it also reflected the concept of the Cosmic Man or Puruṣa as we find described in the Puruṣa-sūkta. We can also find evidence for the fact that the title assumed by Candragupta II, viz. Vikramāditya too had explicit connection with the worship of Viṣṇu and the Vedic hymns in praise of Viṣṇu.

Pande[6] has traced the origin of the Vikrāmāditya legend to the mythic antiquity of the *Vedas* citing many verses: *Ṛgveda* I.154:1

विष्णोनु कं वीर्याणि पर वोचं यः
पार्थिवानि विममेरजांसि।
यो अस्कभायदुत्तरं सधस्य
विचक्रमाणस्त्रेधोरुगायः।।

'Let me tell forth the mighty deeds of Viṣṇu, He who has measured out the earthly regions. And has the upper gathering place established, Having strode out the wide-paced one, with three strides.'

This picture of Viṣṇu wherein his greatest exploit mentioned is the three strides or steps (krama) with which he measures or conquers the earthly regions, has led to the coining of the name Krmāditya, Vikramāditya, Vikramārka, Vikramānka, etc.

It may be noted here that the Nakṣatra Śrāvaṇa has Viṣṇu as the deity and had the name Trivikrama owing to the stars α, β and γ Aquilae, which symbolized the three footsteps of Viṣṇu. When we place the use of gnomon against the celebration of Indradhvaja, it becomes apparent that the raising of Dhvaja or Veṇuyaṣṭi (bamboo pole) is in fact a redundant form or a symbolic imitation of the original Vedic practice of determining the summer solstice.

Emulating Uparicara Vasu by installing the Viṣṇordhvajā

In *Mahābhārata* Ch. 63, Sloka 13-15 we find that Indra provides Uparicara Vasu with many gifts, including the bamboo pole and Vasu achieved prosperity by instituting the worship of Indra-Dhvaja or Indrotsava in Indra's honour.

We have evidence in many coins issued by Candragupta-II that the great King wanted to conquer the heavens like Uparicara Vasu:

On the Chhatra type of coins[6]:

क्षितिमवजित्य सुचरितैर् दिवं
जयति विक्रमादित्यः

'Vikramāditya, having conquered the world through his pious actions conquers the heavens.'

On the Lion-slayer type of coins:

नरेन्द्रचन्द्र प्रथितश्रिया दिवं
जयत्यजेयो भुवि सिंहविक्रमः

'Indra among men, (King Candra) of lion's valour who is invincible in the world, conquers the heavens.'

The *Ṛgveda* I.22.16 and 21 speaks of the three strides of Viṣṇu across the seven regions and his position on the zenith[5].

अतो देवा अवन्तु नो यतो विष्णुर्विचक्रमे ।
पृथिव्या स्सप्तधामभिः ॥

'The Gods be gracious unto us even from the place whence Viṣṇu strode through the seven regions of the earth.' (16)

इदं विष्णुर्विचक्रमे त्रेधा निदधे पदम् ।
समूढमस्य पागुं सुरे ॥

'Through all this world strode Viṣṇu; thrice his foot he planted, and the whole was gathered in his footstep's dust.' (17)

त्रीणि पदा विचक्रमे विष्णुर्गोपा अदाभ्यः ।
ततो धर्माणि धारयन् ॥

'Viṣṇu the Guardian, he whom none deceiveth, made three steps; thenceforth establishing his high decrees.' (18)

विष्णोः कर्माणि पश्यत यतो व्रतानि पस्पशे ।
इन्द्रस्य युज्यस्सखा ॥

'Look ye on Viṣṇu's works, whereby the friend of Indra, close-allied, hath let his holy ways be seen'. (19)

तद्विष्णोः परमं पदगुं सदा पश्यन्ति सूरयः ।
दिवीव चक्षुराततम् ॥

'The princes evermore behold that loftiest place where Viṣṇu is, laid as it were an eye in heaven'. (20)

तद्विप्रासो विपन्यवो जागृवागं सस्समिन्धते ।
विष्णोर्यत्परमं पदम् ॥

'This, Viṣṇu's station most sublime, the singers, ever vigilant, lovers of holy song, light up.' (21)

These verses of the *Ṛgveda* in later times formed the basis of the worship of Viṣṇu, who is known by the epithet Upendra or the second in command of the Devas. Balasubrahmaniam has discussed in detail the mythical background of Udayagiri, which in the Gupta age bore the name Viṣṇupadagiri, meaning the foot of Viṣṇu or sun. Looking at the portrayal of Viṣṇu as available in the *Vedas* and the later Purāṇic literature, one cannot miss the astronomical symbolism of Viṣṇu as the deity having the lordship of 12 Ādityas. This sovereignity that Viṣṇu has over the Ādityas suggests the possibility that Viṣṇu has a deeper significance as the ecliptic north pole (ENP).

Identification of the modern Udayagiri located on the tropic of Cancer as Viṣṇupadagiri stems from the identity or symbolism of Viṣṇu with the sun. Apparent path of the sun or the ecliptic has its north pole (ENP) permanently located in ζ (zeta) Draconis (β = 65.89 and λ = 102.74), which is circumpolar at the latitude of Udayagiri (23°31′). The pole of the equator or Dhṛuvam goes round the ENP, and therefore ENP and its location, viz. ζ-Draconis cannot go below the horizon on the day of summer solstice. This discovery of ENP on the northern horizon and on Draco had been the crux of Purāṇic myths that make Viṣṇu sleep on a serpent. Anantaśāyin panel[7] in the passageway symbolically depicts the ENP (18h00m, 66°33′38″) location on Draco. As ENP grazed the horizon during the times of solstice over the tropic of Cancer, Udayagiri was chosen for the worship of the sun or Viṣṇu and the mount was given the appellation Viṣṇupadagiri. For places north of Udayagiri, ENP was always above the horizon and at Udayagiri ENP touched the lowest altitude or horizon and hence the place became the foot of Viṣṇu.

Observation of Polaris (Dhruva) and the north pole and the associated ENP is obvious from the precise orientation of the passageway to the rising sun of 29 May 402 CE. Polaris and ζ-Draconis may have been firm observational references for the cardinal directions fixed using the gnomon.

Conclusion

It is apparent from the above discussion that:

(i) Astronomical alignment of the Udayagiri structure is shown to be based on the azimuth difference of the rising sun between the vernal equinox and 29 May 402 CE, the date of the Sanakanika inscription in cave 6.

(ii) The date of the Sanakanika inscription of cave 6 at Udayagiri is 29 May 402 CE, which corresponded to Asadha-sukla ekadasi of the year 82 of the Gupta-kala.

(iii) The date of inscription 29 May 402 CE corresponds to the astronomical alignment of the passageway of the Udayagiri archaeoastronomy structure and the date corresponded to the precise easterly rising of the sun.

(iv) The height of the Iron Pillar was designed to cast a noon shadow of 10 angulam on 29 May 402 CE and installation of the pillar with the ratio 1 : 3 of the parts beneath and above the ground level is shown to reflect the philosophy of Purusa sukta of the *Ṛgveda*.

(v) It becomes clear that both astronomical and philosophical wisdom were utilized to perfection in the construction of the passageway and the gnomon or Visnu-dhvaja in the form of the Iron Pillar.

(vi) Future studies on the illumination of the passageway are needed in order to have a better understanding of the astronomical orientation of the passageway and the motifs on the walls.

(vii) Appendix 1 suggests that the Puruṣa sūkta may be based on an observation of the midday shadow of the gnomon (Viṣṇu or Indra Dhvjā) on the solstice day at the place 25°N25′ on the meridian of Udayagiri (75°E45′) with a bamboo pole of height 324 aṅgulam.

(viii) Height of the Iron Pillar as 324 angulam strikes our attention as the year of the Saka Era corresponding to the year 82 of the Gupta Kala, i.e. Year 420 AD.

Notes

1.

Z	90 – Az	
89	23.32	$h = 0°$, Centre of Sun's disk touches a mathematical horizon.
89.5	23.56	$h = -0.25°$, Upper limb touches a mathematical horizon.
90	23.80	
90.25	23.92	$h = -0.583°$, Centre of the disk touches the horizon (refraction accounted).
90.583	24.07	
90.833	24.20	$h = -0.833°$, Upper limb touches the horizon (refraction accounted).
		Z = Zenith distance = 90 – altitude, Az, Azimuth.

2. With the rear motif at a distance d, the azimuth variation of α (since the rays had their first entry into the passageway on 29 May), width of the light beam w at distance d, $\sin\alpha = w/d$ and $w = d*\sin\alpha$ in units of d. Given d in ft, we obtain w in inches as $12*d*\sin\alpha$.
3. Given that the variation in altitude of the sun is α, vertical ascent of the rays h on a rear motif at distance d is obtained as $h = [\arcsin(\alpha/d) + 0.53°$ (angular diameter of the sun)]. Time taken by the rays for vertical ascent over a height h is obtained as $h/0.222$, in minutes.
4. Gnomon shadow $\psi = \gamma*\tan(\phi - \delta)$, gives $324*\tan(23.5 - 21.76) = 9.84 \approx 10$ aṅgulam.

1. Balasubramaniam, R. and Dass, M. I., *Curr. Sci.*, 2004, **86**, 1134–1142.
2. Sharan, M. A. and Balasubramaniam, R., *Curr. Sci.*, 2004, **87**, 1562–1566.
3. Balasubramaniam, R., *Delhi Iron Pillar: New Insights*, Indian Institute of Advanced Study, Shimla, 2002, pp. 6–18.
4. Dass, I. M. and Balasubrahmanyam, R., *Indian J. Hist. Sci.*, 2004, **39**, 59.
5. Griffith, R. T. H., *The Hymns of the Rigveda*, Motilal Banarsidass, New Delhi, 1973.
6. Pande, R., *Chandragupta-II Vikramāditya*, Chowkhmaba Amarabharati Prakasan, Varanasi, 1982.
7. Balasubrahmanyam, R., Dass, M. I. and Raven, E. M., *Indian J. Hist. Sci.*, 2004, **39**, 177–203.

K. Chandra Hari is in the Institute of Reservoir Studies, ONGC, Ahmedabad 380 005, India.
e-mail: chandra_hari18@yahoo.com

Edited and published by P. Balaram, Current Science Association, Bangalore 560 080.
Typeset by WINTECS Typesetters (Ph: 2332 7311), Bangalore 560 021 and Printed at Lotus Printers, Bangalore (Ph: 2320 9909)