were obviously different from what we get by modern computations. Therefore, an error of several hours in computing the soli-lunar days (*tithis*) is not unusual.

Throughout his article, Chandra Hari mentions the sun's rising exactly in the east on the day of summer solstice! Obviously, this is incorrect. The sun rises exactly in the east, for a non-equitorial place, only on the two equinoctial days and not on the solsticial days.

In conclusion, the date of the Sanakanika inscription must be 27 June 402 AD (Julian) and not in the month of May.

1. Chandra Hari, K., *Curr. Sci.*, 2008, **95**, 117–124.
2. Sharan, M. A. and Balasubramaniam, R., *Curr. Sci.*, 2004, **87**, 1562–1566.

S. BALACHANDRA RAO

Gandhi Centre of Science and Human Values,
Bharatiya Vidya Bhavan,
#43/1, Race Course Road,
Bangalore 560 001, India

Summer solstice and Udayagiri

Chandra Hari[1] has discussed the astronomical significance of the cave at Udayagiri in great detail. However, there seems to be some confusion about the direction of the rays of the rising sun on summer solstice. As has been shown in the context of the Vidyashankara temple in Sringeri[2], the direction of the rising sun may be calculated from the formula

$$\sin \delta = \sin \phi \sin a + \cos \phi \cos a \cos A, \quad (1)$$

where δ is the declination of the sun, a the altitude, ϕ the latitude of the place and A the azimuth. Using the fact that at the time of rise (and set) a is zero, the azimuth is calculated as the direction of the rising sun.

The direction has been observed by Sharan and Balasubramaniam[3] to be 25°56′. This fits exactly into eq. (1) for a latitude value of 23°31′ for the date of summer solstice. It should be noted that neither 29 May nor 22 June satisfies this requirement for CE 402. It is well known that owing to the precession of equinoxes, the date of solstices has been shifting gradually. In fact, this was responsible for the reformation of calendar 400 years ago. Thus an extrapolation from today naturally leads to some discrepancies, which can be accounted for. Hundreds of stone inscriptions with the dates of solstices have been identified all over India and their study corroborates with the gradual shift of solstice dates. Thus the date was around 25 June in the 11th century and therefore 26 June as the date for CE 402 is not unrealistic. Moreover, the type of small differences in the declination of the sun as depicted in table 4 of the paper can be observed only after compiling the data over several decades. Solstice is an event and not a day. Thus some margin should be allowed depending on whether the solstice occurred at noon or some other time of the day. For example, in the year 2008 the solstice occurred at 05:29 am IST and therefore, the noon shadow would not reflect the exact event. However, any such architectural plan will incorporate a finite margin so that about a week on either side of the solstice, the rays of the sun enter the cave, as in the case of the Gavi Gangadhareshwara Temple in Bangalore[4].

The paper mentions about the sun rising exactly at the east on the day of Sanakanika inscription, which cannot be true. As is well known the sunrise at the exact point east happens only on the days of equinoxes all over the globe. This can also be deduced from eq. (1) by putting $\delta = 0$. The paper mentions that on summer solstice the earth is nearest to the sun. The situation is the opposite – the aphelion passage occurs on 4 July every year.

The observation by Balasubramaniam and Dass[5] that the shadow near the south wall disappears on summer solstice at noon is a simple extension of the eq. (1). At meridian transit the value of A is 180°/0°. Then, eq. (1) simplifies to

$$\sin \delta = \sin \phi \sin a. \quad (2)$$

The disappearance of the shadow implies that $a = 90°$ or that $\delta = \phi$. This is true for CE 402 and any other year. In fact, observing the noon shadow on solstice was and is one of simplest methods of finding the latitude of a place.

In light of the above simple explanation, the lengthy discussion on the minute variation of declination and the discussion based on sunrise at 'exact' east point are uncalled for. Likewise, the second part of the paper and appendix throw no light on the Udayagiri architecture. The appendix completely ignores the fact that Manasara gives a rule to apply correction for the change in declination of the sun within a day. There was no assumption that the sun remains 'stationary' for 21 days.

1. Chandra Hari, K., *Curr. Sci.*, 2008, **95**, 117–124.
2. Shylaja, B. S., *Curr. Sci.*, 2007, **92**, 846–849.
3. Sharan, M. A. and Balasubramaniam, R., *Curr. Sci.*, 2004, **87**, 1562–1566.
4. Jayanth Vyasanakere, P., Sudeesh, K. and Shylaja, B. S., *Curr. Sci.*, 2008, **95**, 1632–1636.
5. Balasubramaniam, R. and Dass, M. I., *Curr. Sci.*, 2004, **86**, 1134–1142.

B. S. SHYLAJA

Jawaharlal Nehru Planetarium,
High Grounds,
Bangalore 560 001, India
e-mail: shylaja.jnp@gmail.com

Response to comments from S. Balachandra Rao

(i) 'The authors of the earlier historical note are right in their observation that the direction of the rising sun at the place of latitude 23°31′ on the day of summer solstice is 25°56′ . . .'.

Nobody will dispute the result of a basic equation like the one quoted by Sharan *et al.* and I have given reference to that:

$$\sin\delta = \sin\varphi \times \sin h + \cos\phi \times \cos h \times \cos A.$$

At a place of latitude 23°31′, can the direction of 25°56′ be due east, when the azimuth will be 64.06?

Azimuth has to be $90 - \phi$, i.e. 90-latitude and those who had the date of the Sanakanika inscription fixed had this knowledge and the observational skill to make out that the sun rose due east on āsāḍha śukḷa ekādaśī of the year 402 AD, which fell on 29 May 402 AD.

(ii) 26 June 402 AD in *Śravana*.