The Speed of Light and Purāṇic Cosmology

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April 18, 1998 Corrected Dec 30, 2000

Abstract

We survey early Indian ideas on the speed of light and the size of the universe. A context is provided for Sāyaṇa's statement (14th century) that the speed is 2,202 yojanas per half nimeṣa (186,000 miles per second!). It is shown how this statement may have emerged from early Purāṇic notions regarding the size of the universe. Although this value can only be considered to be an amazing coincidence, the Purāṇic cosmology at the basis of this assertion illuminates many ancient ideas of space and time.

Keywords: Speed of light, Ancient Indian astronomy, Purāṇic cosmology

Indian texts consider light to be like a wind. Was any thought given to its speed? Given the nature of the analogy, one would expect that this speed was considered finite. The Purāṇas speak of the moving *jyotiścakra*, "the circle of light." This analogy or that of the swift arrow let loose from the bow in these accounts leaves ambiguous whether the circle of light is the Sun or its speeding rays.

We get a specific number that could refer to the speed of light in a medieval text by Sāyaṇa (c. 1315-1387), prime minister in the court of Emperors Bukka I and his successors of the Vijayanagar Empire and Vedic scholar. In

his commentary on the fourth verse of the hymn 1.50 of the Ṛgveda on the Sun, he says[1]

> *tathā ca smaryate yojanānāṃ sahasre dve dve śate dve ca yojane ekena nimiṣārdhena kramamāṇa*
>
> Thus it is remembered: [O Sun] you who traverse 2,202 *yojanas* in half a *nimeṣa*.

The same statement occurs in the commentary on the Taittirīya Brāhmaṇa by Bhaṭṭa Bhāskara (10th century?), where it is said to be an old Purāṇic tradition.

The figure could refer to the actual motion of the Sun but, as we will see shortly, that is impossible. Is it an old tradition related to the speed of [sun]light that Sāyaṇa appears to suggest? We would like to know if that supposition is true by examining parallels in the Purāṇic literature.

The units of *yojana* and *nimeṣa* are well known. The usual meaning of yojana is about 9 miles as in the *Arthaśāstra* where it is defined as being equal to 8,000 *dhanu* or "bow," where each dhanu is taken to be about 6 feet. Āryabhaṭa, Brahmagupta and other astronomers used smaller yojanas but such exceptional usage was confined to the astronomers; we will show that the Purāṇas also use a non-standard measure of yojana. As a scholar of the Vedas and a non-astronomer, Sāyaṇa would be expected to use the "standard" Arthaśāstra units.

The measures of time are thus defined in the Purāṇas:

15 nimeṣa = 1 kāṣṭhā

30 kāṣṭhā = 1 kalā

30 kalā = 1 muhūrta

30 muhūrta = 1 day-and-night

A nimeṣa is therefore equal to $\frac{16}{75}$ seconds.

De and Vartak have in recent books[2] argued that this statement refers to the speed of light. Converted into modern units, it does come very close to the correct figure of 186,000 miles per second!

Such an early knowledge of this number doesn't sound credible because the speed of light was determined only in 1675 by Roemer who looked at the difference in the times that light from Io, one of the moons of Jupiter, takes to reach Earth based on whether it is on the near side of Jupiter or the far side. Until then light was taken to travel with infinite velocity. There is no record of any optical experiments that could have been performed in India before the modern period to measure the speed of light.

Maybe Sāyaṇa's figure refers to the speed of the Sun in its supposed orbit around the Earth. But that places the orbit of the Sun at a distance of over 2,550 million miles. The correct value is only 93 million miles and until the time of Roemer the distance to the Sun used to be taken to be less than 4 million miles. This interpretation takes us nowhere. The Indian astronomical texts place the Sun only about half a million yojanas from the Earth.

What about the possibility of fraud? Sāyaṇa's statement was printed in 1890 in the famous edition of Ṛgveda edited by Max Müller, the German Sanskritist. He claimed to have used several three or four hundred year old manuscripts of Sāyaṇa's commentary, written much before the time of Roemer.

Is it possible that Müller was duped by an Indian correspondent who slipped in the line about the speed? Unlikely, because Sāyaṇa's commentary is so well known that an interpolation would have been long discovered. And soon after Müller's "Rigveda" was published, someone would have claimed that it contained this particular "secret" knowledge. Besides, a copy of Sāyaṇa's commentary, dated 1395, is preserved in the Central Library, Vadodara.[3]

One can dismiss Sāyaṇa's number as a meaningless coincidence. But that would be a mistake if there exists a framework of ideas—an old physics—in which this number makes sense. We explore the prehistory of this number by considering early textual references. We will show that these references in the Purāṇas and other texts indicate that Sāyaṇa's speed is connected, numerically, to very ancient ideas. This helps us understand the framework of ideas regarding the universe that led to this figure.

Physical ideas in the Indian literature

The Vedas take the universe to be infinite in size. The universe was visualized in the image of the cosmic egg, *Brahmāṇḍa*. Beyond our own universe lie other universes.

The Pañcaviṃśa Brāhmaṇa 16.8.6 states that the heavens are 1000 earth diameters away from the Earth. The Sun was taken to be halfway to the heavens, so this suggests a distance to the Sun to be about 500 earth diameters from the Earth, which is about 0.4375 million yojanas.

Yajurveda, in the mystic hymn 17, dealing with the nature of the universe, counts numbers in powers of ten upto 10^{12}. It has been suggested that this is an estimate of the size of the universe in yojanas.

The philosophical schools of Sāṃkhya and Vaiśeṣika tell us about the old ideas on light.[4] According to Sāṃkhya, light is one of the five fundamental "subtle" elements (*tanmātra*) out of which emerge the gross elements. The atomicity of these elements is not specifically mentioned and it appears that they were actually taken to be continuous.

On the other hand, Vaiśeṣika is an atomic theory of the physical world on the nonatomic ground of ether, space and time. The basic atoms are those of earth (*pṛthivī*), water (*āpas*), fire (*tejas*), and air (*vāyu*), that should not be confused with the ordinary meaning of these terms. These atoms are taken to form binary molecules that combine further to form larger molecules.[5] Motion is defined in terms of the movement of the physical atoms and it appears that it is taken to be non-instantaneous.

Light rays are taken to be a stream of high velocity of tejas atoms. The particles of light can exhibit different characteristics depending on the speed and the arrangements of the tejas atoms.

Although there existed several traditions of astronomy in India,[6] only the mathematical astronomy of the Siddhāntas has been properly examined. Some of the information of the non-Siddhāntic astronomical systems is preserved in the Purāṇas.

The Purāṇic astronomy is cryptic, and since the Purāṇas are encyclopaedic texts, with several layers of writing, presumably by different authors, there are inconsistencies in the material. Sometimes, speculative and the empirical ideas are so intertwined that without care the material can appear meaningless. The Purāṇic geography is quite fanciful and this finds parallels in its astronomy as well.

We can begin the process of understanding Purāṇic astronomy by considering its main features, such as the size of the solar system and the motion of the Sun. But before we do so, we will speak briefly of the notions in the Siddhāntas.

Size of the universe in the Āryabhaṭīya

Āryabhaṭa in his *Āryabhaṭīya (AA)* deals with the question of the size of the universe. He defines a *yojana* to be 8,000 *nṛ*, where a *nṛ* is the height of a man; this makes his yojana (y_a) approximately 7.5 miles.[7] Or $y_s \approx \frac{6}{5} y_a$, where y_s is the standard Arthaśāstra yojana. AA 1.6 states that the orbit of the Sun is 2,887,666.8 *yojanas* and that of the sky is 12,474,720,576,000 *yojanas*.

Commenting on this, Bhāskara I (c. 629) says:

> *yāvantamākāśapradeśam ravermayūkhāḥ samantāt dyotayanti tāvān pradeśaḥ khagolasya paridhiḥ khakakṣyā. anyathā hyaparimitatvāt ākāśasya parimāṇākhyānam nopapadyate.*

> That much of the sky as the Sun's rays illumine on all sides is called the orbit of the sky. Otherwise, the sky is beyond limit; it is impossible to state its measure.[8]

This implies that while the universe is infinite, the solar system extends as far as the rays of the Sun can reach.

There is no mention by Āryabhaṭa of a speed of light. But the range of light particles is taken to be finite, so it must have been assumed that the particles in the "observational universe" do not penetrate to the regions beyond the "orbit of the sky." This must have been seen in the analogy of the gravitational pull of the matter just as other particles fall back on Earth after reaching a certain height.

The orbit of the sky is 4.32×10^6 greater than the orbit of the Sun. It is clear that this enlargement was inspired by cosmological ideas.

The diameters of the Earth, the Sun, and the Moon are taken to be 1,050, 4,410 and 315 yojanas, respectively. Furthermore, *AA* 1.6 implies the distance to the Sun, R_s, to be 459,585 yojanas, and that to the Moon, R_m,

as 34,377 yojanas. These distances are in the correct proportion related to their assumed sizes given that the distances are approximately 108 times the corresponding diameters.[9]

Converted to the standard *Arthaśāstra* units, the diameters of the Earth and the Sun are about 875 and 3,675 yojanas, and the distance to the Sun is around 0.383 million yojanas.

Āryabhaṭa considers the orbits, with respect to the Earth, in the correct order Moon, Mercury, Venus, Sun, Mars, Jupiter, and Saturn, based on their periods.

Purāṇic cosmology

The Purāṇas provide material which is believed to be closer to the knowledge of the Vedic times.[10] Here we specifically consider Vāyu Purāṇa (VaP), Viṣṇu Purāṇa (ViP), and Matsya Purāṇa (MP). VaP and ViP are generally believed to be amongst the earliest Purāṇas and at least 1,500 years old. Their astronomy is prior to the Siddhāntic astronomy of Āryabhaṭa and his successors.

The Purāṇas instruct through myth and this mythmaking can be seen in their approach to astronomy also. For example, they speak of seven underground worlds below the orbital plane of the planets and of seven "continents" encircling the Earth. One has to take care to separate this imagery, that parallels the conception of the seven centres of the human's psychosomatic body, from the underlying cosmology of the Purāṇas that is their primary concern in their *jyotiṣa* chapters.

It should be noted that the idea of seven regions of the universe is present in the Ṛgveda 1.22.16-21 where the Sun's stride is described as *saptadhāman*, or taking place in seven regions.

The different Purāṇas appear to reproduce the same cosmological material. There are some minor differences in figures that may be a result of wrong copying by scribes who did not understand the material. In this paper, we mainly follow ViP.

ViP 2.8 describes the Sun to be 9,000 yojanas in length and to be connected by an axle that is 15.7×10^6 yojanas long to the Mānasa mountain and another axle 45,500 yojanas long connected to the pole star. The distance of 15.7 million yojanas between the Earth and the Sun is much greater than the

distance of 0.38 or 0.4375 million yojanas that we find in the Siddhāntas and other early books. This greater distance is stated without a corresponding change in the diameter of the Sun. It is interesting that this distance is less than one and a half times the correct value; the value of the Siddhāntas is one-thirtieth the correct value.

Elsewhere, in VaP 50, it is stated that the Sun covers 3.15 million yojanas in a muhūrta. This means that the distance covered in a day are 94.5 million yojanas. MP 124 gives the same figure. This is in agreement with the view that the Sun is 15.7 million yojanas away from the Earth. The specific speed given here, translates to 116.67 yojanas per half-nimeṣa.

The size of the universe is described in two different ways, through the "island-continents" and through heavenly bodies.

The geography of the Purāṇas describes a central continent, Jambu, surrounded by alternating bands of ocean and land. The seven island-continents of Jambu, Plakṣa, Śālmala, Kuśa, Kraunca, Śāka, and Puṣkara are encompassed, successively, by seven oceans; and each ocean and continent is, respectively, of twice the extent of that which precedes it. The universe is seen as a sphere of size 500 million yojanas.

It is important to realize that the continents are imaginary regions and they should not be confused with the continents on the Earth. Only certain part of the innermost planet, Jambu, that deal with India have parallels with real geography.

The inner continent is taken to be 16,000 yojanas as the base of the world axis. In opposition to the interpretation by earlier commentators, who took the increase in dimension by a factor of two is only across the seven "continents," we take it to apply to the "oceans" as well. We have done this because it harmonizes many numbers and so it appears to have been a plausible model that led to the development of the system. In itself, it has no bearing on the question of the speed of light that we will discuss later.

At the end of the seven island-continents is a region that is twice the preceding region. Further on, is the Lokāloka mountain, 10,000 yojanas in breadth, that marks the end of our universe.

Assume that the size of the Jambu is J yojana, then the size of the universe is:

$$U = J(1+2+2^2+2^3+2^4+2^5+2^6+2^7+2^8+2^9+2^{10}+2^{11}+2^{12}+2^{13}+2^{14})+20,000 \quad (1)$$

Or,

$$U = 32,767J + 20,000\ yojanas \quad (2)$$

If U is 500 million yojanas, then J should be about 15,260 yojanas. The round figure of 16,000 is mentioned as the width of the base of the Meru, the world axis, at the surface of the Earth. This appears to support our interpretation. This calculation assumes that around the Meru of size 16,000 yojanas is the rest of the Jambu continent which circles another 16,000 yojanas. In other words, it takes the diameter of Jambu to be about 48,000 yojanas.

Note that the whole description of the Purāṇic cosmology had been thought to be inconsistent because an erroneous interpretation of the increase in the sizes of the "continents" had been used.

When considered in juxtaposition with the preceding numbers, the geography of concentric continents is a representation of the plane of the Earth's rotation, with each new continent as the orbit of the next "planet".[11]

The planetary model in the Purāṇas is different from that in the Siddhāntas. Here the Moon as well as the planets are in orbits higher than the Sun. Originally, this supposition for the Moon may have represented the fact that it goes higher than the Sun in its orbit. Given that the Moon's inclination is 5° to the ecliptic, its declination can be 28.5° compared to the Sun's maximum declination of ±23.5°. This "higher" position must have been, at some stage, represented literally by a higher orbit. To make sense with the observational reality, it became necessary for the Moon is taken to be twice as large as the Sun.

The distances of the planetary orbits beyond the Sun are as follows:

Table 1: From Earth to Pole-star

Interval I	yojanas
Earth to Sun	15,700,000
Sun to Moon	100,000
Moon to Asterisms	100,000
Asterisms to Mercury	200,000
Mercury to Venus	200,000
Venus to Mars	200,000
Mars to Jupiter	200,000
Jupiter to Saturn	200,000
Saturn to Ursa Major	100,000
Ursa Major to Pole-star	100,000
Sub-total	17,100,000

Further spheres are postulated beyond the pole-star. These are the Maharloka, the Janaloka, the Tapoloka, and the Satyaloka. Their distances are as follows:

Table 2: From Pole-star to Satyaloka

Interval II	yojanas
Pole-star to Maharloka	10,000,000
Maharloka to Janaloka	20,000,000
Janaloka to Tapoloka	40,000,000
Tapoloka to Satyaloka	120,000,000
Grand Total	207,100,000

Since the last figure is the distance from the Earth, the total diameter of the universe is 414.2 million yojanas, not including the dimensions of the various heavenly bodies and *lokas*. The inclusion of these may be expected to bring this calculation in line with the figure of 500 million yojanas mentioned earlier.

Beyond the universe lies the limitless *Pradhāna*, that has within it countless other universes.

Purāṇic cosmology views the universe as going through cycles of creation and destruction of 8.64 billion years. The consideration of a universe of

enormous size must have been inspired by a supposition of enormous age.

Reconciling Purāṇic and Standard Yojanas

It is clear that the Purāṇic yojana (y_p) are different from the Arthaśāstra yojana (y_p). To find the conversion factor, we equate the distances to the Sun.

$$0.4375 \times 10^6 \; y_s = 15.7 \times 10^6 \; y_p \tag{3}$$

In other words,

$$1 \; y_s \approx 36 \; y_p \tag{4}$$

The diameter of the Earth should now be about $875 \times 36 \approx 31,500 \; y_p$. Perhaps, this was taken to be 32,000 y_p, twice the size of Meru. This understanding is confirmed by the statements in the Purāṇas. For example, MP 126 says that the size of Bhāratavarṣa (India) is 9,000 y_p, which is roughly correct.

We conclude that the kernel of the Purāṇic system is consistent with the Siddhāntas. The misunderstanding of it arose because attention was not paid to their different units of distance.

Speed of the Sun

Now that we have a Purāṇic context, Sāyaṇa's statement on the speed of 2,202 yojanas per half-nimeṣa can be examined.

We cannot be absolutely certain what yojanas did he have in mind: standard, or Purāṇic. But either way it is clear from the summary of Purāṇic cosmology that this speed could not be the speed of the Sun. At the distance of 15.7 million yojanas, Sun's speed is only 121.78 yojanas (y_p) per half-nimeṣa. Or if we use the the figure from VaP, it is 116.67. Converted into the standard yojanas, this number is only 3.24 y_s per half-nimeṣa.

Sāyaṇa's speed is about 18 times greater than the supposed speed of the Sun in y_p and 2×18^2 greater than the speed in y_s. So either way, a larger number with a definite relationship to the actual speed of the Sun was chosen for the speed of light.

The Purāṇic size of the universe is 13 to 16 times greater than the orbit of the Sun, not counting the actual sizes of the various heavenly bodies. Perhaps, the size was taken to be 18 times greater than the Sun's orbit. It seems reasonable to assume, then, that if the radius of the universe was taken to be about 282 million yojanas, a speed was postulated for light so that it could circle the farthest path in the universe within one day. This was the physical principle at the basis of the Purāṇic cosmology.

Concluding Remarks

We have seen that the astronomical numbers in the Purāṇas are much more consistent amongst themselves, and with the generally accepted sizes of the solar orbit, than has been hitherto assumed. The Purāṇic geography must not be taken literally.

We have also shown that the Sāyaṇa's figure of 2,202 yojanas per half-nimeṣa is consistent with Purāṇic cosmology where the size of "our universe" is a function of the speed of light. This size represents the space that can be spanned by light in one day.

It is quite certain that the figure for speed was obtained either by this argument or it was obtained by taking the postulated speed of the Sun in the Purāṇas and multiplying that by 18, or by multiplying the speed in standard yojanas by 2×18^2. We do know that 18 is a sacred number in the Purāṇas, and the fact that multiplication with this special number gave a figure that was in accord with the spanning of light in the universe in one day must have given it a special significance.

Is it possible that the number 2,202 arose because of a mistake of multiplication by 18 rather than a corresponding division (by 36) to reduce the Sun speed to standard yojanas? The answer to that must be "no" because such a mistake is too egregious. Furthermore, Sāyaṇa's own brother Mādhava was a distinguished astronomer and the incorrectness of this figure for the accepted speed of the Sun would have been obvious to him.

If Sāyaṇa's figure was derived from a postulated size of the universe, how was that huge size, so central to all Indian thought, arrived at? A possible explanation is that the physical size of the universe was taken to parallel the estimates of its age. These age-estimates were made larger and larger to postulate a time when the periods of all the heavenly bodies were

synchronized.[12]

The great numbers of the Purāṇas suggest that the concepts of mahāyuga and kalpa, sometimes credit to the astronomers of the Siddhāntic period, must have had an old pedigree. This is in consonance with the new understanding that considerable astronomy was in place in the second and the third millennia BC.[13]

We have provided a context in which Sāyaṇa's speed can be understood. In this understanding, the speed of light was taken to be 2×18^2 greater than the speed of the Sun in standard yojanas so that light can travel the entire postulated size of the universe in one day. It is a lucky chance that the final number turned out to be exactly equal to the true speed. Sāyaṇa's value as speed of light must be considered the most astonishing "blind hit" in the history of science!

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