History : Does it present the Truth ?

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1 Introduction

The civilizational genius of India, right from the Vedic times, seem to have maintained a clear demarcation between the practice of science and religion. That one did not eclipse the other, is quite evident from the fact that the major contributions to the foundations of calculus and mathematical analysis, came from the highly religious and orthodox section of the society.[1] While, this is the situation in the Indian scenario, it is a well known fact that in the west, at least from the end of Ptolemy's period (2nd cent. AD) till Keplerian times (later part of 16th cent) free thinking in scientist, to a large extent, was eclipsed by the imposed faith on certain established order.

While this being the true picture, it is unfortunate that the projected picture in the pages of history – besides being incomplete – is often misleading. There could be many reasons for this. But, one of the primary causes that can be attributed – is clearly the lack of founding of scholarship on the soil in which these studies got emerged. It is also partly because of the lack of thorough analysis of texts along with the commentaries, by the authors of the works on history that keeps emerging from time to time. Particularly, the premise that Indian astronomers and mathematicians were only concerned with the results and never worried about the logical reasoning, etc., is solely founded on misconception[2] and emanates from the incomplete history that is presented to us.

In offering scientific explanations for an observed phenomenon whether the Indian scientists were concerned about logical reasoning or not, is the primary issue that would be discussed in this paper. We take-up this by considering a concrete example, namely – 'the diurnal motion of celestial objects'.

2 What causes the diurnal motion of the celestial objects?

All of us observe the periodical rising and setting of the stellar objects including the Sun, the Moon and all the planets.[3] Curiosity demands an explanation and we ask the

[1] See for instance, the book by K.V. Sarma *A History of Kerala School of Hindu Astronomy*.

[2] See the article by M.D. Srinivas in *Contributions to the History of Indian Mathematics*.

[3] In our discussion, the term planets refers to five objects, namely Mercury, Venus, Mars, Jupiter and Saturn.

question – Why is this happening ? At once, there are two possible explanations:

1. The Earth spins around its axis once a day (and thereby causes an apparent motion), or,

2. The entire celestial sphere, with all the objects in it rotates once a day.

Since there was no empirical evidence, to prove either of them, both the explanations put forth have to be necessarily based on some belief or theoretical insight.

2.1 Beliefs held in the Greek and the Indian tradition

Plato (b. 427 BC), who continues to be held as one of the most influential philosopher of the ancient Greek tradition, was the student of Socrates, teacher of Aristotle, a profound thinker and founder of The Academy in Athens. The development of the physical picture of the world and the universe at large seems to have been greatly influenced by his views. They have been modified by Aristotle and further refined and polished by Ptolemy. By the time of Ptolemy (85-165 BC), the views had acquired fairly sophisticated mathematical foundation and they found a solid ground, which sustained them for about 1400 years, till the famous 'Copernican Revolution' took place in 1643 AD. The key role played by Plato and his successor Eudoxus in developing a belief system, among the Greeks and later the Europeans, are succinctly summarised as follows:[4]

> Although not really interested in astronomy, the philosopher Plato had a great influence on the course of its early history. Because he perceived the heavens to be more perfect than the Earth, Plato urged astronomers to describe celestial motions in terms of the most perfect of geometrical shapes, the circle. In fact, for Plato, the most perfect motion would be uniform circular motion, motion in a circle at a constant rate of speed.
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> One of Plato's pupils, Eudoxus of Cnidus (409–356 BC) was the first astronomer to follow Plato's recommendation. Blending careful observation with sophisticated mathematical constructs, Eudoxus sought to describe the motions of the heavens in terms of a series of concentric spherical shells, with the Earth geometrically at the centre of those shells. His model consisted of twenty-seven spheres, three each for the Sun and the Moon and four for each of the five known planets; Mercury, Venus, Mars, Jupiter, and Saturn. The final sphere carried all the "fixed" stars and presumably contained the whole universe.

But for some technical details and mathematical sophistication the overall picture in the Ptolemaic scheme remained the same till the time of Copernicus.

[4] *The tests of time*, Ed. Lisa M.Dolling *et al*, p.3-4.

It would be worthwhile to juxtapose this scenario in the Greek tradition with that in India. The earliest Indian text, exclusively devoted to astronomy, extant is the *Vedāṅga-jyotiṣa* of Lagadha.[5] In this, it is conceived that the cause of sidereal day[6] is the rotation of the celestial sphere, called *khagola*, once from the east to the west. The Hindu astronomers attributed this phenomenon to a wind called *Pravaha*, flowing in the upper regions of the sky, which was continuously and uniformly driving all the stellar objects. This obviously explains the observed phenomena of rising and setting of all the celestial objects, and this has been the view held by the astronomers of the Kerala school as late as 16th century.[7]

2.2 The Āryabhaṭan view

As far as we know, for the first time in the history of Indian astronomy, Āryabhaṭa proposes altogether a new hypothesis to explain the diurnal motion of the celestial objects.[8]

अनुलोमगतिर्नौस्थः पश्यत्यचलं विलोमगं यद्वत् ।
अचलानि भानि तद्वत् समपश्चिमगानि लङ्कायाम् ॥

> Just as a person in the boat moving in the forward direction (along with it) observes the stationary objects (trees etc., on the bank) to be moving in the opposite direction, so also the stationary stars seem to move directly westward for an observer in Laṇka.[9]

Unambiguously the verse describes the rotation of the Earth. Āryabhaṭa has employed an apt simile to explain the relative motion which leads us to conclude that he explains the observed phenomenon of diurnal motion of the celestial objects, as being due to the spinning of the Earth around its axis. In other words, as per the picture conveyed by this verse, the rotation of the Earth is 'real', whereas the motion of the celestial objects is only 'apparent' (illusory).

The very next verse in the text goes as:[10]

उदयास्तमयनिमित्तं नित्यं प्रवहेण वायुना क्षिप्तः ।
लङ्कासमपश्चिमगः भपञ्जरः सग्रहो भ्रमति ॥

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[5]Though scholars differ in their opinions regarding the precise time period of composition of the work, the generally accepted version is 1400 BC.

[6]The time interval between two successive star rises, which is less than the duration of the day by approximately 4 minutes.

[7]See for instance, *Tantrasaṅgraha*, chapter 1, verse 2.

[8]*Āryabhaṭīya*, *Golapāda*, verse 9.

[9]A 'ficticous' place to be supposedly on the equator.

[10]*Āryabhaṭīya*, *Golapāda*, verse 10.

> For the sake of rising and setting (of all the celestial objects), being blown by the *Pravaha* wind, the stellar sphere along with the planets moves westward at a uniform rate.

Here, Āryabhaṭa seems to have provided the picture of rotation of the stellar sphere and not the Earth. It is very clearly mentioned that the stellar sphere, along with the planets[11] (*bha-pañjaraḥ*[12]) is set into motion by the *Pravaha* wind and that this causes the rising and setting of the celestial objects.

From a critic's view point, the question that arises is – Is Āryabhaṭa justified in merely presenting two views without even mentioning as to which is his view point and much less as to which of the two is the correct one? Presenting both the views seems to be completely misleading and confuses the readers. Is it not against the norms of the ethics to be followed by a scientist?

2.3 Is Āryabhaṭa justified?

The question raised cannot be answered hurriedly or in isolation, before placing the problem in a larger context and a proper perspective. Here the attempt is to address the issue of a 'correct picture' which in turn involves the concept of 'reality'. In other words, we are asking the question – Is not the author obliged to state that – 'this is what is *real*' and 'this is mere *appearance*', at least, as conceived by him?

Before proceeding further, one needs to recall that all that Āryabhaṭa has done is to offer an 'explanation' to an observed phenomenon. In other words, he has provided an answer to the question – 'Why do the celestial objects periodically rise in the east and set in the west?'. As answer he presents two view-points as explanations. Now, arises the second question – Since these two view points are in direct contradiction to each other,[13] one of them must be 'real' and the other must be 'mere appearance'; Which, really, is the case; the Earth rotates or the stellar sphere?

If one of the propositions is proved[14] to be real, naturally the other turns out to be illusory. In fact, a clear or rather scientific distinction between *reality* and *appearance* can be drawn and understood only in conjunction with an *explanation*. The connection between them is so complex, that in the absence of any explanation it makes little sense to call a phenomenon *real* or *apparent*.

However, it is not to be forgotten that an explanation can be offered only on the basis of the data arrived through an experiment. In the present case of deciding whether the stellar sphere is rotating or the Earth is rotating around its axis, at least during the time of Āryabhaṭa, there were no devices available at one's disposal, by which a meaningful experiment could be carried out and the results interpreted. On the contrary, there

[11] which themselves have their own eastward motion

[12] The term *bhaṃ* is star and *pañjara* refers to cage, a place of residence. Hence, *bha-pañjaraḥ* means stellar sphere.

[13] Of course, the assumption, and reality happens to be that both are not rotating.

[14] Here by proof we simply mean offering a 'scientific' explanation and not mathematical derivation.

were arguments against Earth's rotation and favouring rotation of the stellar sphere. These arguments as it were may sound ridiculous (today!), but in the absence of other empirical evidences in those days, it would have been next to impossible to prove them to be based upon misconceptions.

In this scenario, where there were no clear empirical evidences other than theoretical insight or intuition, to give more weightage to one explanation than the other would be unjustified. Hence, it would only be fair to present both the hypotheses and leave the reader to choose whichever appeals to his logic. This is what Āryabhaṭa has done and in doing so he seems to be perfectly justified. One more related question, that arises in this context is – What made Āryabhaṭa propose a new hypothesis when already there existed one for explaining the phenomenon? This is answered in the next section.

2.4 Simplicity and elegance

It is known to the scientists and particularly the historians of science that search for simplicity and elegance plays a central role in the advancement of science. This has been well acknowledged both by the scientists as well as historians.[15] In fact, P.A.M. Dirac (1902–84 AD) a renowned theoretical physicist and one of the founding fathers of quantum theory, who contributed a great deal for its deeper understanding, seems to have claimed:[16]

> It is more important to have beauty in one's equation than to have them fit experiment.

This is quite a powerful and emphatic statement. One of the remarkable things about this statement is that it has been made in the recent past, when advancement in science and technology has reached great heights. Incidentally it reflects that scientists are actually craving for those theoretical entities that have exemplary beauty along with simplicity, of course, with a capacity to explain the observed phenomenon. So much so, Āryabhaṭa being an outstanding scientist, of his own class, might have sought for a much simpler and elegant model than the prevailing one. Being convinced by the fact that all the observed phenomena including different types of planetary motion can be well explained (in fact, more gracefully) with this simpler model he could have proposed the theory of rotation of Earth as an alternative hypothesis.

2.5 Defence in favour of the rotating Earth

Heraclides (388–15 BC) of Pontus seems to have proposed a theory of the rotation of Earth, as early as 350 BC, for the first time in the history of astronomy. Later Aristarchus of Samos (310–250 BC), had proposed a complete heliocentric theory with Sun at the centre of the celestial sphere. In the model of Aristarchus the rotating

[15] See for instance, *Six easy pieces*, Richard Feynmann.
[16] *The tests of time*, Ed. Lisa M.Dolling *et al*, p.472.

Earth itself was considered a planet and hence he is also described as the 'Copernicus of antiquity'. But then, there were critical problems, both theoretical and practical – which beset the heliocentric theory as soon as it was proposed – some of them being charges of failure to explain the variation in stellar brightness and angular separation of stars.[17] Further, due to fierce competition among the groups, the idea of a rotating Earth also fizzled out and met its natural end very soon.

Even assuming that some concepts in the Greek tradition might have permeated into the Indian tradition, for the reasons mentioned above, it would be very hard to speculate that Āryabhaṭa would have borrowed the idea from the Greeks. Thus it may be safely concluded that Āryabhaṭa came up with the theory of rotating earth independently for the first time in the history of 'Indian' astronomy. Given that he was the first to propose, if someone had approached Āryabhaṭa and asked him to defend his hypothesis in a 'scientific' way, I believe, Āryabhaṭa as a scientist would have simply said – 'I do not attempt to', for it is simply not possible.

In the scientific arena, questions regarding the 'correctness' of a model are generally decided by looking upon (a) Which of the models leads to more reliable results/predictions? and (b) If the power of prediction is equivalent, then which of them is simpler or more consistent with the other bodies of the knowledge systems.

As far as (a) is concerned, since the issue of the relative motion, and the planetary calculations are kinematical[18] in nature; one model scoring higher than the other with reference to 'reliable prediction' does not arise. Thus, both the models are predictively equivalent. As regards (b) we note that Āryabhaṭan model scores more in simplicity and elegance. However, as mentioned earlier, there have been stock arguments against the theory of rotation of Earth such as impossibility of the birds to return to their nests (see section 5.1). In fact, convincing replies to such questions could not be given, till the Newtonian mechanics got firmly established. Hence, the loss was more than the score gained by Āryabhaṭa.

In such a situation, it would only be fair to take both views as equivalent models explaining the phenomenon. Declaration such as – 'this is *real*' and 'that is *illusory*', etc., does not make much sense. This however does not mean that no investigation needs to be carried further, even when there are conflicting hypothesis, as long as the predictions are fine. The point that is being made here is that Āryabhaṭa was *not only just, but perfectly correct* in presenting both the hypothesis on equal footing. Given the tools available in those days, it would not have been possible for Āryabhaṭa to give more weightage for one model than the other without unwarranted and unjustifiable assumptions. That he did not do so, is itself an evidence to the fact that he has stood with the principles of ethics in the practise of science.

[17] *The tests of time*, Ed. Lisa M.Dolling *et al*, p.6.

[18] Without involving the concept of 'Force' as it is done today in the Newtonian framework.

3 Criticism founded on logical reasoning

The theory of rotation of Earth putforth by Āryabhaṭa was not acceptable to many of the astronomers of later period. Brilliant mathematicians and astronomers like Brahmagupta (b. 598 AD), Lalla (c. 768 AD) and Bhāskara II (b. 1114 AD), were quite sceptical about the theory and have strongly refuted it in their own works. However, it is very important to note that, such refutations were objective and solely based on sound logical reasoning[19] and not on the belief or faith on some established order or due to fear of the violation of authority.

3.1 The effects of rotating Earth

Brahmagupta, in his monumental treatise *Brahmasphuṭa-siddhānta* has devoted a chapter called *Tantra-parīkṣā* exclusively to examine the correctness of different schools of astronomy prevailing during his times. Most of the verses in this chapter are noted to be pointing towards Āryabhaṭan school. This is quite understandable recalling the fact that, the most popular school around that period (7th cent.) was that of Āryabhaṭa. After pointing out the inaccuracies in some of the parameters and the theoretical entities employed in Āryabhaṭan system, Brahmagupta refutes the theory of rotating Earth. Describing the effects of Earth's rotation he observes:[20]

प्राणेनैति कलां भूर्यदि तत्क्व कुतो व्रजेत् किमध्वानम् ।
आवर्तनमुर्व्याश्चेत् तत् पतन्ति समुच्छ्रयाः कस्मात् ॥

> If the Earth were to be spinning at the rate of one minute (*kalā*) in four seconds (*prāṇa*[21]) then what, where and why would they (birds) leave? Further, in a rotating Earth, how would the arrows shot up fall in the same place?

In the first half of the verse Brahmagupta raises the question – if the Earth was rotating at a tremendous speed,[22] then how would the birds, which having left their nest or trees, be able to reach back their own homes? This is one of the standard objections raised by the astronomers in the other traditions too. No satisfactory answer was available for these objections till the time of Newton. Though Copernicus tried to answer these objections the following way[23] –

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[19] The reasoning supplied by them may not stand the scrutiny today, but nevertheless we have no reason to deride them. Considering the knowledge of physics available then, they are perfectly valid.

[20] *Brahmasphuṭa-siddhānta*, chapter 11, verse 17.

[21] This is approximately the time taken for a healthy man to inhale and exhale, and is taken to be one of the standard units of time in the Indian tradition. Sixty *prāṇas* constitute a *nāḍikā* ($\sim$ 24 minutes) and sixty *nāḍikās* a day.

[22] Assuming the radius of the Earth to be approximately 6,400 kilometers (km), the surface of the Earth would sweep about 28 km/minute.

[23] *The Astronomical Revolution*, by Alexandre Koyre, p.57.

> ... these bodies being 'terrestrial' and consequently sharing the nature of the Earth, share also its 'natural' motion of rotation which co-exists in them together with their own proper motion'.

– it can be easily seen that the above explanation is based on 'revised' or slightly modified set of beliefs.

Coming back to the Indian scenario, Śripati (c.999 AD) in his *Siddhānta-śekhara* gives a more graphic description of the events and mis-happenings that may take place if the Earth were to rotate at tremendous speeds amidst the winds.

> यद्येवमम्बरचरा विहगाः स्वनीडं आसादयन्ति न खलु भ्रमणे धरित्र्याः ।
> किञ्चाम्बुदा अपि न भूरिपयोमुचः स्युः देशस्य पूर्वगमनेन चिराय हन्त ॥
> भूगोलवेगजनितेन समीरणेन केत्वादयोप्यपरदिग्गतयः सदा स्युः ।
> प्रासादभूधरशिरांस्यपि सम्पतन्ति तस्माद्भ्रमत्युडुगणस्वचलाऽचलैव ॥

> If it were so, (i.e., the Earth were rotating) the birds, which fly into the sky, may not be able to return to their nests on account of the rotation of the Earth. Moreover, Alas! the clouds may not be able to incessantly pour (at a particular location on the Earth) as that location over which they (the clouds) were residing would have long back shifted towards the east. Also, the flags that are hoisted should always be pointing towards the west, because of the *relative* speed picked up by the air due to the rotation of the Earth. And lastly, the peaks of the mountains and the top floors of the palaces may have to [collapse and] fall down for the same reason (the terrible speed generated in the winds due to relative motion). Therefore, it is the bunch of celestial objects (stellar sphere) that rotates and the Earth remains stationary.

The reason for giving such an extensive quotation is to stress the fact that any criticism of the theory of the rotation of Earth is purely based upon logical reasoning and not some 'obfuscate' faith. Another astronomer Lalla (c.768 AD) in his famous work, interestingly titled *Śiṣyadhīvṛddhida-tantraṃ*,[24] besides giving more or less the above reasons further observes:

> Notwithstanding the above contradictions, if you still wish to support the theory of rotating Earth, by stating that the Earth rotates very slowly (and hence, the speed of the wind is negligible) and therefore you do not see any of these events happenings, then you will land into more serious contradiction; 'the rotation will not get completed in one day'.

A person with a good understanding of the fundamentals of physics, may be tempted to deride the arguments presented above and declare them totally baseless. However, one

[24] The title means - 'text for enhancing the knowledge of the students'.

cannot deny the fact that they are based upon close examination of certain phenomena and application of induction and deduction, with whatever knowledge-base available to them.

3.2 Misunderstanding that prevails

While this being the true picture, derived from the source works on Indian astronomy regarding the refutation of the theory of rotating Earth, the modern scholarship is unfortunately of the opinion that Brahmagupta played up to the religious orthodoxy by criticising Āryabhaṭa.[25] This is a completely misconceived notion. Perhaps the misconception and reproachful language[26] used to refer to Brahmagupta are based upon misjudgement, which in turn is can be ultimately traced to Alberuni's works.[27] It is also possible that facts presented are misunderstood due to mis-readings and lack of scholarship in the original texts which are written in technical Sanskrit language.

While Brahmagupta deserves to be praised for his courage and uprightness in expressing his views soundly and clearly in a separate chapter, based on his own convictions, against fairly well-established Āryabhaṭan school, he seems to have been abused. Again, I would like to highlight the point that Brahmagupta challenged Āryabhaṭa's views purely on the basis of his own experimental and observational results along with perfect logical reasoning, which he has imbibed as a great mathematician, and not based upon religious scriptures and orthodoxy.[28] This is quite evident from his own statement towards the end of the chapter titled *Tantra-parīkṣādhyāya*.[29]

> श्रीषेणविष्णुचन्द्रप्रद्युम्नार्यभटलाटसिंहानाम् ।
> ग्रहणादिविसंवादात् प्रतिदिवसं सिद्धमक्रत्वम् ॥
> युक्त्या आर्यभटोक्तानि प्रत्येकं दूषणानि योज्यानि[30] ॥
>
> Since the eclipses, etc., are not being predicted properly by following the methods of Śrīṣaṇa, Viṣṇucandra, Pradyumna, Āryabhaṭa and Lāṭasimha, it is evident that their systems would be faulty in the daily predictions too. Hence, the errors that have been pointed out (by me), using logic or schematic analysis (*yuktyā*), in the Āryabhaṭan system should be understood to be applicable to the other systems (mentioned above) as well.

Here again, we have a clear evidence to show that, particularly while refuting other schools of thought, jointly or individually, Brahmagupta does not seem to have swerved

[25] See for instance, *The Argumentative Indian* by the renowned scholar and Nobel winner Prof. Amartya Sen, p.29.

[26] *ibid.,* '. . . spinelessly kowtowing to orthodoxy through bad-mouthing Āryabhaṭa'.

[27] *Alberuni's India*, Tr. E.C. Sachau, p.111 – quoted by Prof. Amartya Sen.

[28] As alleged by Alberuni, which seems to be completely baseless, and consequently over-read and misinterpreted by Prof. Amartya Sen.

[29] *Brahmasphuṭa-siddhānta*, chapter 11, verse 46-7.

[30] This line has to be understood in consonance with the other previous lines as – मया युक्त्या आर्यभटसिद्धान्ते उक्तानि दूषणानि प्रत्येकं श्रीषेण-विष्णुचन्द्र-प्रद्युम्न-लाटसिंहसिद्धान्तेषु योज्यानि ।

even an inch from pure reasoning. The explicit use of the term *yuktyā*, which means resort to 'logical reasoning' must be noted. Notwithstanding Brahmagupta's own explicit statement, and the fact that he has nowhere in this chapter made any reference to theories built upon religion or orthodoxy, it is surprising to note the remarks made by well-known scholar Prof. Amartya Sen.[31]

Not only Brahmagupta, but all other Indian astronomers of later period have been completely scientific in their approach while disagreeing with other schools of thought. It may be hard to find instances, to see the astronomers crossing the borders of ethical boundaries employed in the practise of science, either in the process of supporting or in the process of refuting one theory in favour of the other.

4 Summary and Conclusion

Notwithstanding the fact that India has been generally deemed religious, superstitious, etc., it is noteworthy that the practise of religion did not intrude into the practise of science or vice versa. Even renowned scientists such as Prof. Amartya Sen, seem to have failed to recognize this fact – which is quite evident from one of his recent books 'Argumentative Indian' (refer section 3.2) – perhaps being misled by earlier historians.

In order to have a fuller understanding and appreciation of the fact that Indian clearly demarcated practice of science and religion, we need to make a thorough study of the history and philosophy of Indian Science. While some of the elementary texts on astronomy, mathematics, logic, grammar, and medicine have been studied in depth and analyzed by modern scholarship from different aspects, many of them are yet to be explored. Much of the evidence for discovering how India's ancient philosophers, logicians and scientists developed their theories lies buried in the commentaries and the polemical texts, many of which have not been looked into and even if so, have not been studied in *to to*. For instance, some of the very important texts such as *Brahma-sphuṭa-siddhānta*, of Brahmagupta, or *Āryabhaṭīya-bhāṣya* and *Jyotirmīmāṃsa* of Nīlakaṇṭha, which have been frequently referred to in the present article, have not at all been studied by scholars.[32] Sadly, even good editions of these seminal works are not available for us to study. It is high time to take initiative to preserve these seminal texts and also launch research programmes to study history and philosophy of Indian Science.

[31] I quote - 'Brahmagupta played up to the religious orthodoxy by criticising Āryabhaṭa for apostasy in rejecting the established theological astrology, even though Brahmagupta himself continued to use Āryabhaṭa's scientific methods and procedures.' – *The Argumentative Indian*, cited above, p.29.

[32] The burden of this error, of not studying and yet commenting, has been pointed out by the author in the course of discussion through the article.