

The Golden Age of Indian Astronomy

Spin Genius

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Photographs - Radhika Nargolkar

Stellar tracks near the Anglo - Australian telescope

The era from the fifth to the twelfth century A.D. is sometimes referred to as the Golden Age of Indian astronomy. This period produced a number of astronomers starting with Aryabhata and ending with Bhaskara II, whose work displays a high level of technical expertise as well as intuitive ability when judged against the overall background of time.

Aryabhata was born in the year 476 A.D. in Kusumapura, which is identified with Patna of today. Very little is known about his life, since there are no documented records relating to him. It is fortunate that we are able to work out the year of his birth because in one of the *shlokas* of his book 'Aryabhateeya', he explicitly states it: "When sixty times sixty years and three quarter *yugas* (eras) had elapsed (of the current Kaliyuga), twenty three years had then passed since my birth." The Christian year began in the Kaliyuga year 3101, thus making 60 times 60, that is 3600 as the year 499 A.D. Taking off 23 from this we get the year of birth as 476 A.D.

Although Aryabhata was a respected figure of his time and his book carrying detailed calculations of positions of stars and planets in the sky using trigonometry, was considered the last word on the subject, his one conclusion brought embarrassment to his admirers and detractors alike - he believed that the stars in the sky form a frame fixed in space and it is the Earth that spins round its polar axis.

This belief was contrary to the widely held conviction that the Earth is fixed in space and it is the stars that go round the sky in circles. We can appreciate why people thought so. If we look at the daytime sky, we see the Sun move in a circular trajectory, rising in the East and setting in the West. At night we see stars doing the same. A spectacular way of demonstrating it is to take a photograph of the night sky wherein the shutter is kept open for several hours. One then sees circular trajectories in the sky as shown in the photograph by David Malin from the Anglo-Australian Observatory. The circular star trajectories are shown very clearly. Had there been a pole star in the South, we would have seen it as a fixed point at the centre of all these circles.

Looking at such a photograph, we get the first impression that the Earth is fixed in space and the celestial bodies move around it in circular trajectories. This was

the impression prevalent in the days of Aryabhateeya; prevalent not only in India but in Arabia, Europe, etc. It required a great deal of courage to take a stand differing from this view.

But this is exactly what Aryabhata did. In his volume Aryabhateeya there is a verse that translates thus:

Just as a person going in a boat (in a river) sees fixed things (on the banks) going in the opposite direction, so do the shining objects in the sky, though fixed (in space) seem to be going towards the West.

In short, Aryabhata is saying that the stars are fixed and it is the Earth which spins around its polar axis from the West to the East; and that this relative motion makes us see the stars moving from the East to the West.

How did Aryabhata's contemporaries and followers react to this statement? We have ample written evidence that a millennium later Copernicus had



Aryabhata

to face considerable opposition to his theory that the Earth is not fixed but goes round the Sun. Later Galileo had to face the inquisition for defending Copernicus and he ended by recanting. Both Copernicus and Galileo were in trouble because the establishment was motivated by religious dogma. To say that the Earth is not fixed at the centre of the universe was considered anti-religious.

In India there was no religious factor in this situation. Aryabhata was, however, a victim of social dogma. It may have been because of the Greek influence that the geocentric theory had gained adherence in India. It was believed that the earth was fixed in space and did not spin about an axis. Rather the firmament of stars, the Sun and the Moon rotated around the Earth. Aryabhata was alone in raising the counter-issue that the stars are fixed in space and the Earth spins about an axis.

Whatever literature we have on astronomical developments in India during the Golden Age shows that Aryabhata was criticised, derided or ignored where this fundamental issue was concerned. Obviously influential in scholastic circles for his erudite working of positions of stars on the celestial sphere, Aryabhata in general commanded respect. It was therefore embarrassing for his followers when he came out with the above statement. It is interesting to see how they reacted to it.

Bhaskara I who followed him as the principal disciple, writes in his commentary of Aryabhateeya that the normal meaning of the verse above was as given: but that cannot be right! If the Earth moved, that is, if it was spinning about an axis, the oceans would be disturbed and would cause havoc. So, he concludes that what the learned Aryabhata must have meant was that the stars actually move and if one observed the Earth from a moving star we would find it spinning in the opposite direction! Sanskrit being a very flexible language one can 'extract' convoluted meaning from any sentence.

It is believed that Bhaskara I had carried out this whitewashing exercise because leading astronomers of his time like Varahamihira came down very heavily against his mentor Aryabhata for his above statement and some damage control was clearly necessary. It is interesting that around 1540 when Copernicus' book was published, its preface was apparently changed. His claim for a heliocentric theory was watered down by calling it a 'hypothesis'.

And so, later astronomers refused to accept Aryabhata's statement that the Earth spins. The seventh century astronomer Brahmagupta was very scornful of Aryabhata. He said: "Since Aryabhata knows nothing of mathematics, celestial sphere or time, I have not separately mentioned his demerits."

This criticism is unfair, considering what Aryabhata achieved in his lifetime. Here are a few examples.

He gave a good approximation to the ratio of the circumference to the diameter of a circle, which we write as the symbol π . In school texts the approximation is given as 22/7. Aryabhata gave a better approximation as 3.1416, quoting a value for it as 62832/20000. This value is a better approximation than the value 3.141666 given by Ptolemy. It is also significant that Aryabhata called the ratio above as "approximate" value. Today mathematicians call a 'transcendental irrational' thus recognizing that it cannot be represented by a ratio of whole numbers exactly.

Aryabhata did not stop at stating that the Earth spins about its axis...he went on to determine its rate of rotation. He came up with a time of one rotation as 23 hours, 56 minutes and 4.1 seconds, a value remarkably close to the modern value of 23 hours 56 minutes and 4.091 seconds. He seems to have been the first astronomer and mathematician to have given trigonometric tables for different angles. Western scholars have compared the Indian tables with Greek ones and have found that the former, though based on pragmatic interpolation rather than elaborate geometric constructions, are more accurate.

The old Indian system of expressing numbers in terms of letters which is found in many old sources for mathematical results was modified by Aryabhata and made much more effective.

Brahmagupta, as stated before, started off as a critic of Aryabhata. However, he too realized the merits of Aryabhata's works and based several of his results on it. His book simplifying Aryabhata's techniques was named by him Khanda-Khadyaka, that is, "Food prepared with sugar candy". It became very popular, but had the unfortunate effect that the original work of Aryabhata on which it was based was lost.

Though the Golden Age of Indian Astronomy has passed, its significance has not and the far-reaching impact of the thought and vision of those times is very much part of the bedrock of our scientific tradition.

Photo Courtesy : IUCAA
(Inter University Centre for Astronomy and Astrophysics)

