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History of Ancient Astronomy through Contribution of "Aryabhata and Bramhgupta" (Two greatest astronomers of India)

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Abstract

Astronomy is one of the key part of science in present scenario and same was also true in ancient times. Astronomy has reached tremendous height from 400CE to 700CE.The main contributors to astronomy in that period were Aryabhata and Bramhgupta. They provided numerous results in astronomy which are of use today also. Many of their calculations are considered very near to our modern days calculations and had invented various instruments to observe celestial phenomenon and astronomical objects. There are many hidden facts which are to be discovered which affects our life directly or indirectly like astronomical changes, changes in Sun, changes in positions planets and day to day happenings in the world of universe**.** Scientists are researching to find possibility of life on Mars and moon. Hence present paper studies the astronomical results in context of Aryabhata and Bramhgupta.

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Introduction

The branch of Science/ Mathematics in which we study planets, stars, comets and other objects moving in the universe is called Astronomy or spherical sciences. In present century a large amount of research has been done in subject of astronomy. Mathematicians / Scientist are very keenly interested in knowing possibility of life on Mars and Moon. Astronomers/ Scientist are spending sleepless night to study the various changes in celestial objects like changes in Sun, changes in planets, and also study day to day happenings in the world of universe. Astronomy is used to prepare calendars, to predict solar eclipse, lunar eclipse. Astronomy plays a vital role to locate positions of planets and changes occurring in the atmosphere of earth due to various astronomical phenomenon. Yet there are many hidden facts which are to be discovered, which directly or indirectly effects our earth and ourselves. Astronomy has been a subject of concern from ancient times. In the period of 400C.E to 700C.E many astronomical facts were discovered and findings of Aryabhata and Bramhagupta are crucial to study of astronomy at this point of time also. The present study/ research deals with the life and contribution of both Aryabhata and Bramhgupta to our rich heritage of knowledge in astronomy. We shall present in short the life and contribution of both ancient astrologers/ mathematicians "Aryabhata and Bramhagupta" to stress on the fact that we have great history in astronomy.

Birth of Aryabhata and Bramhagupta

The famous astronomer and mathematician Aryabhata of India was born in 476 A.D. and wrote the manuscript bearing title Āryabhaṭiya in 499 A.D that contains amazing contents on Astronomy and Mathematics. His birth year and age (23years) was supported by following verse of Āryabhaṭiya

षष्ट्यब्दानां षष्टिर्यदा व्यतीतास्त्रयश्च युगपादाः ।
त्र्यधिका विंशतिरब्दास्तदेह मम जन्मनो ऽतीताः ॥

(Kern, 1874)

In which he meant that "when three yugapadas and 3600 years had elapsed (From beginning of Yuga), then 23 years of my life had elapsed". Aryabhata was a native of Kusumapura or Pataliputra which is present day Patna, Bihar. 'University of Nalanda' was in Pataliputra and Aryabhata went to Kusumapura (Pataliputra) for higher studies at the astronomical observatory at Kusumapura (Walter, 1930); Bhau Daji, 1865).

Bramhagupta was born in 589AD (520śaka) in reign of king vyāghramukha, belonging to Cāpa family and his Father was Jishnugupta as explained by Bramhagupta in his verse:

श्री चापवंशतिलके श्री व्याघ्रमुखे नृपे शकनृपालात् ,
पञ्चाशत्संयुक्तै र्वर्षशतैः पञ्चभिरतीतैः ।
ब्राह्मस्फुटसिद्धान्तः सज्जनगणितज्ञगोलवित्प्रीत्यै,
त्रिंशद्वर्षेण कृतो जिष्णुसुतब्रह्मगुप्तेन ॥

He lived in Bhillamāla, Gurjaradesa today modern Bhinmal in Rajasthan, India. He spent a lot of time at Bhillamala and worked there for a long time in his life. 'Prithudaka Svamin'(a renowned commentator), called him *Bhillamalacharya*, which means 'Teacher from Bhillamala'. At an early age of 30 *i.e.* in the year 628 AD he composed the 'Brāhmasphuṭasiddhānt' which is the improved version of treatise of Brahma and considered to be a revised version of *siddhanta* of the Brahmapaksha School where he studied. Various Scholars considered he incorporated a great deal of originality to his revision, adding a large amount of new material (Bhau Daji, 1865). The new book consists of 24 chapters with 1008 verses. George Sarton (The Historian of science) called him "one of the Greatest Scientists of his race and the greatest of his time" (Gupta, 2008).

Contribution of Aryabhata in ancient astronomy

He wrote the manuscript "Āryabhaṭiya" in 499 A.D. which have fascinating contents on Astronomy and Mathematics. Āryabhaṭiya contains a large number of original concepts and phenomenon on astronomy as well as Mathematics. Āryabhaṭiya is divided into four chapters written in very concise form: 1) Daśagitika 2) Gaṇita 3) Kālakriya 4) Gola.

The three centuries extending from 400 to 700 C.E saw tremendous development and immense depth and complexity in the

Astronomy. In 1874 Kern published at Leiden a text called the Āryabhaṭiya which claims to be the original work of Aryabhata. The Āryabhaṭiya of Aryabhata contains about 123 stanzas. The Āryabhaṭiya is classified in four chapters as Padas:

(1) **Gitikapada**: It consists of 13 verses and this chapter consist of large units of time known as kalpa, manvantra, and yuga—which present a cosmology different from earlier texts such as Lagadha's Vedanga Jyotisha (in 1st century BCE). Sines (jya) table was also provided by him which is given in a single verse. According to the first verse of Āryabhaṭiya

युगरविभगणाः ख्युघृ शशि चयगियिङुशुछ्लृ कु ङिशिबुण्लृष्खृ प्राक् ।
शनि ढुङ्विघ्व गुरु ख्रिच्युभ कुज भद्लिझ्नुखृ भृगुबुध सौराः

(Kern, 1874)

"In a yuga the revolutions of Sun are 4,320,000, of the moon 57,753,336, of the Earth eastward 1,582,237,500, of Saturn 146,564, of Jupiter 364,224, of Mars 22,296,824, of Mercury and Venus the same as that of Sun".

(2) **Ganitapada** : It consists of 33 verses and this chapter covers mathematics which consist of kṣetra vyāvahāra, shanku chhya and kuttaka i.e. mensuration, AP and GP, shadows, simple, quadratic, simultaneous, and indeterminate equations respectively.

(3) **Kalakriyapada:** It consist of 25 verses and this chapter consist of different units of time and a method for calculating the planets positions for a given day. It also contains calculations dealing with the intercalary month (adhikamAsa, kshaya-tithis) and week containing names for the week days (seven-days).

(4) Golapada: It consists of 50 verses and this chapter contains the Geometric/ trigonometric aspects of the celestial sphere. It also contains information about the ecliptic, celestial equator, node and shape of the earth. Various other celestial phenomenon like Cause of day and night, rising of zodiacal signs on horizon etc. were too studied.

Also we find that ten verses of Aryabhata from the chapter named Dasagitika or the Ten Giti stanzas give a very condensed form of the most important numerical elements of Aryabhata system of Astronomy. Because if use ordinary language or numerical words it would have occupied at least four to five times space. Aryabhata system of astronomy was called the "audAyaka system", in which days are reckoned from uday (rise), dawn at lanka ("equator"). Aryabhata also described the apparent motions of the heavens relative to earth rotation and believed that the planet's orbits are elliptical rather circular. Now the major contribution to astronomy are:

Study of Motions of the solar system: At point origin of Aryabhata it was considered that sky rotates but he corrected this anomaly by stating that earth rotates about its axis daily and relative motion of stars is due this motion of earth about its axis. He explained it in its treatise Āryabhaṭiya in first chapter which explained about Yuga and detailed literature was provided in chapter Golapada (Pingree, 1996; Translation from K. S. Shukla, 1976). He explained through an example that if in boat someone moving forward sees an unmoving an object going backward, so likewise someone on the equator sees the unmoving stars going uniformly westward.

He explained that this to be the cause of rising and setting the sphere of the stars together with the planets.

Aryabhata has described solar system in the form of a geocentric model, where Sun and Moon are each carried by the two epicycles a smaller manda (slow) and a larger śīghra (fast) and in turn, they revolve around the Earth (also described in Paitāmahasiddhānta (c. CE 425)) (5). The order of the planets in terms of distance from earth taken by him was: (i) the Moon, (ii) Mercury, (iii) Venus, (iv)the Sun, (v) Mars,(vi) Jupiter, (vii)Saturn, and (viii)the asterisms (Ansari, 1977)". According to him "The positions and periods of the planets was taken relative to a uniformly moving point and was calculated in same way. For example, for Mercury and Venus, he assumed that they move around the Earth at the same mean speed as for the Sun and for Mars, Jupiter, and Saturn, he told they move around the Earth at specific speeds, representing each planet's motion through the zodiac (Otto, 1956).

Study and results about Eclipses: Prevailing cosmogony in his period of superstition that eclipses were caused by Rahu and Ketu which were identified by him as the pseudo-planetary lunar nodes. He explained in verse 37 of golapada that eclipses were in terms of shadows cast by and falling on Earth so the lunar eclipse occurs when the Moon enters into the Earth's shadow. Thus Solar and lunar eclipses were explained scientifically by Aryabhata. He explained that the Moon and planets shine by reflected sunlight. Aryabhata discusses in verse 38 of golapada in detail the size and extent of the Earth's shadow and then provided the computation and the size of the eclipsed part during an eclipse.

Aryabhata's methods provided the core though there was improvement in calculation by various other Indian astronomers. His results were so accurate that in 18th-century scientist Guillaume Le Gentil, in his visit to Pondicherry, India, found computations of the time of the lunar eclipse of '30 August 1765' to be less by 41 seconds, whereas charts by him (by Tobias Mayer, 1752) were greater by 68 seconds (Ansari 1977).

Calculation of earth's circumference and Sidereal periods: Aryabhata's computation of Earth's circumference was 24,835 miles, which is very near to the actual value of 24,902 miles (only 0.2% smaller) and is believed that his approximation might be improved computation of Greek mathematician Eratosthenes (c.200 BC)

If we consider modern units of time (English system) then Aryabhata found that the sidereal rotation time i.e. the rotation time of the earth with reference to some fixed stars as 23 h, 56 min, and 4.1 sec (Gupta, 1977). The accuracy can be seen by the fact that modern exact value is 23 hour 56 minutes and 4.091seconds. Similarly, he calculated the length of the sidereal year and find that it is 365 days, 6 hours, 12 minutes, and 30 seconds *i.e.* 365.25858 days) (Aryabhatiya, 2009). Here we find that the error is of just 3 minutes and 20 seconds over the length of a year as per today day calculations (365.25636 days) (Aryabhatiya, 2009). Though the concept of 'sidereal time' was known in astronomical systems of his time, but his computation was likely the most accurate in the period.

Heliocentric model: Aryabhata found in an astronomical model that Earth turns on its own axis and model also gave corrections called the śīgra anomaly for the speeds of the various planets calculated in terms of the average speed of the Sun. So it is advocated that his calculations were on basis of heliocentric model, where the planets orbit the Sun (Waerden, 1987). Though this claim is generally considered as not true (Noel, 1973).

Contribution of Bramhgupta in ancient astronomy

Bramhgupta original contributions to Mathematics and Astronomy were embodied in the highly acclaimed treatises known as 1.) Brāhmasphuṭa - siddhānta and 2.) Khanḍa-khādyaka. The Brāhmasphuṭa - siddhānta was written in year 628 C.E., when he was 30-year-old under the patronage of King Vyaghramukh, and the Khanḍa-khādyaka in 665 C.E., at the age of 67. The title of "Ganak Chakra Chudamoni" which means gem of the circle of mathematicians was bestowed to him by Bhaskara II as a mark of his talent and contributions in Mathematics and Astronomy. The Brahmasphuta-siddhānta and Khanḍ-khādyaka were composed in Sanskrit verse, as was the custom of the day. The Brāhmasphuṭa-siddhānta consists of more than 24 chapters. In one of the verses Bramhgupta states that he has composed the treatise containing 1008 verses, historian Sudhakar Dvivedi has given the total as 1021, whereas he says, this number according to Bramhagupta should be 1020.If one deducts the concluding 12 verses of the sañjñanādhyāya, the number should be 1008.The major portion of the treatise deals with astronomy, arithmetic, geometry, while kuttaka, or algebra, is discussed in the remaining chapters.

In astronomy, Bramhagupta discussed the average and real motions of the planets, the problems of place-time-distance concerning the earth, sun, and planets, planetary conjunctions, and the rising and setting of celestial objects. He too correctly described the phenomena of solar and lunar eclipses as being caused by the moon and earth casting shadows, on which he based his calculations. Bramhagupta rejected the Jaina belief that there are two Suns, two moons and fifty-four stars (XI. 3). Al-Biruni (Al-Biruni, 1030).

Some of the other important contributions made by Bramhagupta in astronomy are:

Calculation of the position of heavenly bodies over time (ephemerides), their rising and setting and conjunctions: Bramhgupta in **'Brāhmasphuṭa-siddhānta**' chapter seven "Lunar Crescent" rejected the prevailing theory (an idea which was maintained in scriptures) that that the Moon was farther from the Earth than the Sun. "Bramhagupta discussed in detail the lighting of the moon by the sun. He explained that "because if the moon is closer than the portion of the illumination of the moon depends on the relative positions of the moon and the sun, which is calculated from the size of the angular separation α between them" (Hockey, 2007). This was also against the prevailing ideas which were maintained in scriptures of that time.

Description and use of various astronomical instruments: Many of the astronomical instruments were used by Bramhagupta and in twenty second chapter of Brāhmasphuṭa-siddhānta, there is description of 17 types of time-reckoning instruments (Kāla-yantra)

सप्तदश कालयन्त्राण्यतो धनुस्तुर्यं गोलकं चक्रम् ।
यष्टिः शंकुर्घटिका कपालकं कर्त्तरी पीठम् ।।
सलिलं भ्रमोऽवलम्बः कर्णश्छाया दिनार्धमर्कोऽक्षः ।
नतकालज्ञानार्थं तेषां संसाधनान्यष्टौ ।।

(Gupta, 2008)

1. **Dhanuryantra** - Bow instrument.
2. **Turyagolaka yantra** - Quadrant (one-fourth sphere)
3. **Cakra yantra** - wheel or circle
4. **Yaṣṭi yantra**- apole or staff instrument.
5. **Śaṅku yantra**- Gnomon
6. **Ghaṭikā yantra** - a clock or pot instrument.
7. **Kapāla yantra**- Bowl or pot shed instrument.
8. **Karttarī yantra** - scissor or knife; cutter.
9. **Pīṭha yantra** - Pedestal or seat instrument.
10. **Salila yantra** -Water-leveler.
11. **Brahma or Śāṅa yantra** - for describing circles.
12. **Avalamba Sūtra** –Threads with Plumbs (Plumb lines).
13. **Karṇa or chayā-karṇa** – A set of squares for diagonals.
14. **Chāyā or śaṅku**- Chāyā-sundial
15. **Dinardha yantra** –Midday measure instrument.
16. **Arkya yantra** – Sun instrument.
17. **Akṣa or Palāṅśa yantra** –Small degree measure arc Instrument.

Every instrument had its unique use in the field of Astronomy as told by him.

Shape of earth, rotation of earth and Law of Gravitation: Bramhagupta rejected the prevailing view of that time which was "Earth was flat and hollow". His observation was Earth and heaven were spherical and that the Earth is rotating. Commentator Al-Biruni, explained this in his commentary that Bramhagupta responded to old view with his argument on Gravitation. He explained that "On the contrary, if that were the case, the earth would not vie in keeping an even and uniform pace with the minutes of heaven, the pranas of the times". Bramhgupta explained that all heavy things are attracted towards the center of the earth and the earth on all its sides is the same; all people on earth stand upright, and all heavy things fall down to the earth by a law of nature. He told that "it is the nature of the earth to attract and to keep things, as it is the nature of water to flow, that of fire to burn, and that of wind to set in motion". The earth always attract thing, and seeds always return to it, in whatever direction you may throw them away, and never rise upwards from the earth."(Al-Biruni, 1030).

Study and results about Eclipses: Bramhagupta refined the previous calculations on solar and lunar eclipses and correctly predicted the time and duration of ellipses.

Conclusion

In our above paper we have discussed about birth and contribution of two greatest ancient astronomers "Aryabhata and Bramhgupta". The work these two is so vast that one cannot explain it in so concise form but we done it so to explain the legacy these two mathematicians and astronomers. This work was carried out to provide fellow researcher and readers about the golden history of Indian mathematics and astronomy. The work of both Aryabhata and Bramhgupta were of great influence in astronomical traditions and were received well by all around the world at period of time. Several concepts developed by them were new to the world at time and not only astronomy but there were several new finding in mathematics as well. The influence of Aryabhata was so much that India's first satellite and lunar crater was named after him. Also Bramhgupta influence was so much that it is mentioned by historians that use of zero was properly done and explained by him and his knowledge was propagated all around the world especially Islamic world at that period of time so we should work on our legacy and explain to the whole world about rich traditions in mathematics and astronomy. The literature provided by our ancestors is so rich that we should study it and develop the new concepts from them for our future generations.

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