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Aryabhata's Enduring Contributions to Astronomy in Ancient India: Unveiling the Cosmic Secrets

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Abstract:
Astronomy is one of the important scientific fields in the current scenario and this was also true in ancient times. Astronomy reached a gigantic peak between 400 and 700 AD. The most important contributor to astronomy during this period was Aryabhata. He produced many achievements in astronomy that are still useful today. He was also an ancient Indian mathematician during the Gupta period in 475 A.D, and many of his calculations are considered to be very close to modern calculations, and he is credited with various methods for observing celestial phenomena and celestial bodies. There are many hidden facts in the cosmic world that directly or indirectly affect our lives, such as astronomical changes, changes in the sun, changes in the positions of planets, and daily events. This study deals with the life of Aryabhatta and his contribution to our rich heritage of knowledge in astronomy. His astronomical calculation techniques were also very popular among various astronomers. These were often used to create Arabian astronomical tables called "Jijeh".

Keywords: Ancient Astronomy, Aryabhatta, Solar Systems, Planet, Mathematics.

1. Introduction

India has a rich history of indigenous scientific innovations, with Vedic technology being a prominent aspect of its traditional knowledge systems. Vedic technology encompasses a wide range of ancient scientific practices and principles that have been passed down through generations within the Indian subcontinent. These innovations cover various fields such as astronomy, mathematics, architecture, and medicine, showcasing the advanced understanding and application of science in ancient India. India's Vedic technology offers a rich tapestry of indigenous scientific advancements that have often been overlooked in mainstream discussions. Delving into these innovations not only sheds light on the remarkable scientific achievements of ancient India but also provides valuable insights for modern scientific research and development [1]. Through an exploration of Indigenous Scientific Innovations in India: Vedic Technology, we can uncover a wealth of knowledge that continues to hold relevance and significance in today's world.

Astronomy has always held a significant place in the realm of science, both in ancient times and in the

present day. During the period between 400 to 700 AD, astronomy experienced a momentous peak, with one of the key figures being Aryabhata. He made numerous groundbreaking achievements in astronomy that remain relevant to this day. His calculations were so advanced that they are often considered to be remarkably close to modern calculations, and he is also credited with developing various methods for observing celestial phenomena and bodies [2].

Aryabhatta, an Indian mathematician and astronomer, lived during the classical period of Indian mathematics and astronomy, thriving during the Gupta period. One of his notable works, the **Āryabhaṭīya,** mentions that he was 23 years old in 3600 Kali Yuga, which corresponds to 499 CE. He has great role in mathematics as well as in astronomical field, also he wrote many books on mathematics and astronomy. His remarkable invention made our country immense pride. The cosmic world is filled with hidden truths that have a direct or indirect impact on our lives. These truths include astronomical changes, shifts in the sun, movements of planets, and even daily occurrences. The study of Aryabhata's life and his contributions to the field of astronomy shed light on our cultural heritage and the vast knowledge he left behind. His techniques for astronomical calculations were highly esteemed by fellow astronomers and were widely used across various regions. In fact, these techniques were instrumental in the creation of Arabian astronomical tables known as "Jijeh." In present century a large amount of research has been done in subject of astronomy [3]. Astronomy is used to prepare calendars, to predict solar eclipse, lunar eclipse etc.

2. Methodology

This comprehensive research study seeks to delve into the enduring contributions of Aryabhata in the fields of Astronomy and Mathematics during the ancient times in India, particularly in uncovering the mysteries of the cosmos. The research for this study involves a thorough analysis of ancient Indian texts, scholarly articles on Aryabhatta and his work, particularly the influential text Aryabhatia, as well as epic literature. In addition, data from online journals and websites is also utilized to gather information for this study.

To ensure a comprehensive presentation and analysis, a methodical approach has been adopted in examining, verifying, and organizing the gathered material from various sources. This involved categorizing the information under appropriate headings to facilitate a structured and coherent discussion on Aryabhata's contributions in Astronomy and Mathematics.

3. Results and Discussion

Aryabhatta, an Indian mathematician and astronomer who lived between 476 and 550 CE, is considered a significant figure in both of these disciplines. While some of his works have been lost over time, subsequent Indian mathematicians often make references to his work. Aryabhata's accomplishments include calculating a very close approximation of pi, being the first person to solve Diophantine equations, explaining the shine of the moon and planets as a result of reflected sunlight, and making significant advancements in Trigonometry and Algebra. He is revered as one of the most influential mathematicians in history and a trailblazer in the classical era of Indian mathematics and astronomy. Explore his profound impact further by learning about his top achievements [4].

3.1 Major Contributions and Achievements

3.1.1 Aryabhatia: The Highly Influential Text

He authored the highly significant text known as the Aryabhatiya, which had a profound impact on the field of mathematics and astronomy.

Aryabhatiya is considered a groundbreaking work in the realm of Indian mathematics and science due to its innovative concepts and theories. This influential text revolutionized the way people understood the universe and made significant contributions to the development of mathematical and astronomical knowledge in ancient India. His work in Aryabhatiya paved the way for advancements in various branches of mathematics and astronomy that continue to influence scholars and researchers to this day. Through his writing in Aryabhatiya, he challenged existing beliefs and proposed new ideas that expanded the understanding of mathematical principles and the movement of celestial bodies. The Aryabhatiya is revered as a cornerstone in the history of Indian mathematics and played a crucial role in shaping the future directions of research in the field. It stands as a testament to his intellect and dedication to the pursuit of knowledge, inspiring generations of mathematicians and astronomers [5].

He works on complex calculation and made it in a simple format. These works divided into four chapters. In first chapter he reveals with Gitikapada which has 13 version, it deals with cosmology that is related to planetary motion. In second chapter he reveals with Ganitapada, means Sanskrit calculation, it has 33 versions.in Ganitapada, where he explained simple quadratic equation and indeterminate equation and geometric equations. In third chapter he defines kalakriyapada consisting of 25 versions, where he used various unit of time to calculate days, week and months. In fourth chapter it consists of 50 versions of Golapada, where he defined the causes of day and night, eclipse, celestial equations, shape of the earth and many more [6].

3.1.2 Solar System: Rotation of Earth

Despite not having precise astronomical instruments, Aryabhata was still able to determine that the Earth is round and rotates around its axis. He also linked this to the concept of day and night. Aryabhata's model of the solar system was geocentric, with the Sun and Moon moving on epicycles that orbit the Earth. Even though he used a geocentric model, Aryabhata correctly stated that moons and planets do not emit light on their own, but rather reflect sunlight. He also clarified the true causes of eclipses, refuting the idea that they are caused by the shadows of the Earth and Moon. Aryabhata's calculations were so precise that in the 18th century, Guillaume Le Gentil discovered that his prediction of the duration of a lunar eclipse in 1765 was only off by 41 seconds [7].

3.1.3 Movement of Celestial Bodies

Aryabhata provided a detailed explanation of how the Earth rotates on its axis, leading to the apparent movements of stars in the night sky. This challenged the prevailing belief at the time that the movement of stars was caused by the rotation of the sky itself. The concepts outlined by Aryabhata can be found in the initial chapter of the Aryabhatiya, where he delves into calculations regarding the Earth's rotations in a Yuga, one of the phases recognized in Hinduism. Aryabhata drew a comparison to a person on a boat observing a stationary object moving backward, likening it to an observer on the equator watching the seemingly motionless stars move consistently westward. He attributed the phenomenon of rising and setting to the collective westward movement of the stars and planets, propelled by what he described as the cosmic wind.

3.1.4 Length of the Day and the Year: Sidereal Periods

Aryabhata estimated the Earth's circumference to be 39,968 kilometers, slightly smaller than the actual

measurement of 40,075 kilometers by only 0.2%. He also made precise calculations on the Earth's sidereal rotation, calculating it as 23 hours, 56 minutes, and 4.1 seconds, which was very close to the modern-day value of 23 hours, 56 minutes, and 4.091 seconds, with an error of just 0.09 seconds. Similarly, Aryabhata determined the length of a sidereal year to be 365.25858 days, only off by 3 minutes and 20 seconds compared to the current calculation of 365.25636 days. These calculations by Aryabhata were considered some of the most accurate in the world at that time [8].

3.1.5 An Influential Text: Arya Siddhanta

Aryabhata also composed a significant work on astronomical calculations called the Arya-Siddhanta. Unfortunately, this invaluable text has been lost over time. The Arya-Siddhanta was brought to light largely through the contributions of astronomer Viharamitra, who lived during the same period as Aryabhata. Subsequently, the work was further studied by renowned mathematicians such as Brahmagupta and Bhaskara I. The Arya-Siddhanta is based on the ancient Surya-Siddhanta and utilizes the concept of midnight-day reckoning. It delves into various astronomical instruments prevalent during that era, encompassing tools like shadow instruments, angle measuring devices, semicircular and circular gadgets, an umbrella-shaped device, a cylindrical stick known as Yasti-yantra, and water clocks featuring bow-shaped and cylindrical designs. Moreover, Aryabhata is acknowledged for establishing an observatory at the Sun Temple in Taregana. This observatory served as a pivotal center for studying celestial phenomena and making astronomical observations. Aryabhata's contributions to astronomy and mathematics have left a lasting legacy, influencing scholars and scientists for generations to come. acknowledged for establishing an observatory at the Sun Temple in Taregana [9].

3.1.6 Contributions to Trigonometry and Algebra

Aryabhatiya offers straightforward solutions to intricate mathematical problems of its time, such as determining the sum of the first n integers, the squares of these integers, and even their cubes. Additionally, Aryabhatta was able to accurately calculate the areas of triangles and circles. In one of his works, Ganitapadam, he writes that for a triangle, the area can be found by taking the result of a perpendicular with the half-side. He also delves into trigonometry, providing a table of sines where he calculated approximate values at intervals of 3° 45′. He achieved this by utilizing a formula for sin (n + 1) x – sin nx in terms of sin nx and sin (n – 1) x. Moreover, Aryabhatta is credited with introducing the concept of the versine. (versin = 1 – cosine) into trigonometric calculations [10].

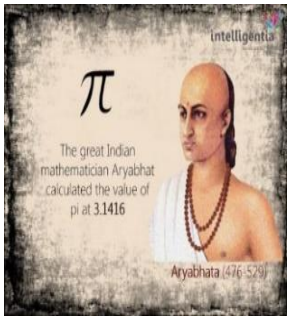
3.1.7 Understood the Concept of Zero

Aryabhatta, in his work Aryabhatiya, developed a numeral system using letters from the Indian alphabet to represent numbers. This system allowed for the representation of numbers up to 1018 using letters. While Aryabhatta never explicitly used the symbol for zero, French mathematician Georges Ifrah believes that the concept of zero was inherent in Aryabhatta's place-value system as a placeholder for powers of 10 with null coefficients. Ifrah argues that Aryabhatta's use of zero was vital for his alphabetical counting system and calculations involving square and cubic roots. This advancement in mathematics was groundbreaking for its time and demonstrated an early understanding of the concept of zero.

3.1.8 Calculated the Closest Approximate Value of Pi (π)

Aryabhatta's notable contribution includes providing an estimated value for Pi (π). This information can be found in the second section of Aryabhatiyam, where he details a formula to calculate the circumference of a circle with a diameter of 20,000. By following his instructions of adding four to 100, multiplying by eight, and then adding 62,000, This calculation gives the value of pi to be 62832/20000 = 3.1416. This calculation is accurate to 5 significant digits, whereas the modern value of π is 3.14159265, precise to 8

decimal places. Aryabhatta's approximation of Pi is considered to be one of the most accurate among ancient mathematicians, coming very close to the modern value. Moreover, Aryabhata is believed to have been aware of the fact that Pi is an irrational number, making this realization centuries before it was officially proven by Swiss mathematician Johann Heinrich Lambert in 1761 [11].



3.2 Aryabhatta: The Towering Figure in Astronomy and Mathematics

Aryabhatta, a prominent astronomer in ancient India, made significant contributions to the field of mathematics and astronomy. His groundbreaking achievements served as the foundation for future advancements in these areas by inspiring other scholars. Not only was Aryabhata's work admired in India, but it also left a lasting impact in the Islamic world during the Islamic Golden Age. His innovative methods for astronomical calculations and trigonometric tables were widely adopted in the Islamic world, leading to the creation of numerous Arabic astronomical tables (zijes). Despite being relatively unknown in the western world following his passing, Aryabhatta's work gained recognition when it was translated into Latin in the 1200s. This translation led to a surge in popularity for his ideas among European mathematicians and astronomers [12].

4. Conclusions

Aryabhata's contributions to astronomy and mathematics have had a profound and lasting impact on our understanding of the cosmos. His innovative calculations, theoretical explanations, and influential texts such as the Aryabhatiya and Arya-Siddhanta continue to inspire scholars and researchers in these fields. Aryabhata's pioneering work, which included precise calculations of Pi, understanding the concept of zero, and providing detailed explanations of the movement of celestial bodies, has left an indelible mark on the history of science. Furthermore, his ability to challenge existing beliefs and propose new ideas in astronomy and mathematics has shaped the trajectory of research in these areas [13], influencing generations of mathematicians and astronomers.

Aryabhata's legacy extends beyond his era, as his work was influential in the Islamic world during the Islamic Golden Age and gained recognition in the Western world through translations into Latin. His remarkable inventions and theories reflect his intellect and dedication to advancing human knowledge, and they continue to inspire and guide the pursuit of understanding the cosmic world. He was honoured by having the first Indian satellite named after him. In ancient India, he stood out as a skilled mathematician and astronomer. His ability to make accurate estimations and discoveries without modern tools was truly impressive. As Indians, we should be proud of his accomplishments.

Acknowledgement

This article acknowledges the substantial impact Aryabhata had on the advancement of Mathematics and Astronomy in ancient India, emphasizing his crucial contribution. His innovative breakthroughs have

paved the way for continued advancements in Mathematics, Astronomy, Science, and technology. Through the introduction of novel ideas and groundbreaking discoveries, he has established a lasting legacy that continues to influence these fields to this day.

Dedication: We dedicate this paper to Aryabhatta, the great Indian mathematician and astronomer, for his great achievements and accomplishments in the field of Mathematics, Astronomy, science and Technology.

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