

The Impact of Al-Biruni's Astronomical Works on Modern Astronomy

Mohammad Monjur-Ul-Haider

Assistant Professor, Department of Anthropology
Shahjalal University of Science & Technology, Sylhet.

Md. Mokhlesur Rahman

Associate Professor, Department of Anthropology,
Shahjalal University of Science & Technology, Sylhet.

ABSTRACT

Al-Biruni's foremost effort on astronomy is mainly a blend of observational diagram and mathematical context. In his astronomical work, the *Qanun-i Masoodi* (al-Qanun al-Masudi, fi al-Hai'a wa al-Nujum), he uses his observational facts to challenge Ptolemy's steady solar 'apogee'. Al-Biruni's eclipse facts were used by Dunthorne to support control the 'acceleration of the moon' and his observational facts have entered the more astronomical accounts and is still used today. The present paper aims to explore the major contributions of Al-Biruni to geophysics and astronomy as well as to identify the impacts of his works on the modern astronomy. Major findings indicate that Al-Biruni's key concern in astronomy was for calculations. He paid devotion to theoretical problems that had and have still been contributing to the development and critical analysis of both applied (in the procedure of solving problems), and theoretical (in the process of thought formulations) astronomy. This paper concludes that Al-Biruni's contributions must be seen in the comprehensiveness of his work, and in his continual attempts to formulate astronomical thoughts.

Keywords: Al-Biruni, Astronomy, planetary motions, rotation of the earth, solar and lunar system, trigonometry.

INTRODUCTION

The Muslim astronomers honestly approved their obligation to Greek writers. Indeed, they were the leading astronomers of the world. The first major Muslim work of astronomy was *Zij al-Sindh* by al-Khwarizmi in 830 (Dallal 1999). The work covers tables for the motions of the sun, the moon and the five planets known at the time. The work is noteworthy as it introduced Ptolemaic concepts into Islamic sciences. In 850, Al-Farghani wrote *Kitab fi Jawani* (meaning "A compendium of the science of the stars"). The book primarily gave a summary of Ptolemaic cosmography (Dallal 2010). They accepted the fundamental features of the Ptolemaic system of the universe with some modifications made by Persian scholar Al-Biruni (September 973 - December 1048).

Abu Raihan Muhammad Al-Biruni was an outstanding astronomer and brilliant mathematician in the contemporary world. During his illustrious profession, it is projected that the total amount of books that Al-Biruni composed comes up to 146; some sources round up the number to 180, and above an impressive number of 13,000 'folios' (A folio is a handwritten document which is usually one to two pages long). These estimations are precise to a great level. In his manuscript *Fi Fihrist Kitab Muhammad Ibn Zakariya Al Razi*, Al-Biruni himself indexes 114 of his identifiable books (Li, 2005). About 65% of the books composed by Al-Biruni were keen to astronomy, mathematics and allied focuses like mathematics and geography (Kennedy, 1970). He considered Arabic, Islamic Law, and several outlets of knowledge. Far ahead, he educated himself Greek, Syriac and Sanskrit.

His understanding of some languages facilitated him in considerate the existing work on philosophy, mathematics, geography and religion, and takes together a different and innovative style in his work. Agreeing to Max Meyerhoff, Al-Biruni is possibly the most noticeable character in the formation of those universally educated Muslim academics who portray the Golden Age (8th–15th centuries) of Islamic Science (Sarton, 1935).

OBJECTIVES AND METHODOLOGY

The main purpose of this paper is to explore and understand the major contributions of Al-Biruni to astronomy as well as to assess the impacts of Al-Biruni's astronomical computations on the development of modern astronomy. This study has been completed grounded on secondary documents hauled out from the books and articles already written by Al-Biruni's astronomical computations. The historical analysis method has been applied to understanding the works and dimensions of his pragmatic contributions to the growth and development of modern astronomy. An exclusion criterion of the systematic review method has been used to select secondary literature from library and internet sources. Uses of document and content analysis method have been used to extract significant data from the secondary sources.

Few key words: Al-Biruni's astronomy and planetary motions, rotation of the earth, solar and lunar system, and trigonometry have been used as to examining significant information from websites, records, articles, study reports, and print media. The processes of content analysis such as a selection of suitable materials, documents of sources, coding, unit of analysis, and strong point of content strength have been adopted to interpret the applicable findings from the materials. Archival records, figures and composed scripts of article study are also used to assemble data from the selected literatures which have been mentioned in the references.

MAJOR CONTRIBUTIONS OF AL-BIRUNI TO ASTRONOMY

In fact, the astronomy as a field of knowledge was significant to the Muslims for their religious conviction. Muslim religious practices generated three specific challenges, first: the complexity of which often went beyond the tangible needs of the society. Briefly, it can be said that they wanted to identify the start of the month of Ramadan (the sacred month of fasting), the hours of five times prayers (sunset, nightfall, daybreak, midday, and afternoon), and the direction of *the Kaaba* (the sacred shrine of Mecca). By observing position of the sun and moon, the Muslims could know the direction of Mecca. As Islam expanded into a wide empire rapidly, astronomers could help them know these things.

In accordance to David King, after the escalation of Islam, the spiritual commitment to regulate the *Qibla* and prayer times enthused more development in astronomy for centuries (King, 2004). Evidence attests that the scientific and intellectual accomplishments of Muslims amazed the then people in the past. The prominent scholars like al-Khwarizmi, al-Farghani, Abd Al-Rahman Al-Sufi, Ibn al-Haytham, Al-Biruni, Al-Zarqali (known as Arzachel in Europe), Al-Bitruji (known as Alpetragius in Europe), Al-Farabi and Nasir al-Din al-Tusi encouraged the thinking of great thinkers of Islamic astronomy.

Al-Biruni continued an outstanding career and was familiar in astronomy, astrology, comparative religion, chronology, ecology, geology, geography, history, linguistics, mathematics, medication, philosophy, and physics. His abundant contributions to many various fields gave him the name *al-Ustadh* (the master of knowledge). A number of historians named the time of his action as 'The Age of Al-Biruni'. However, Al-Biruni used scientific methods and predicted coming advances, including Darwin's theory of natural selection, the astronomic theory of Ptolemy, Newton's Second Law, the immutability of the elements, the characteristics of the Milky Way, and modern astronomy. He studied Indian literatures, and translated books related to Indian astronomy and mathematics from Sanskrit to Persian and Arabic, and at the same time Arabic to Sanskrit.

Doing research in the fields of geophysics and astronomy, Al-Biruni raised some basic queries:

- How does the earth spin on its axis?
- How do lunar eclipses take place by phases?
- What would be the recording system of latitude and longitude of thousands of towns that would allow people to define the direction to Mecca from those cities?
- What would be the probable approaches for separating scientific astronomy from superstitious astrology?
- How could the visual feature of shadows be used, mainly their usage for the defining of prayer times precisely?

However, Al-Biruni contributed original works to astronomy for better understanding regarding the above mentioned issues. For many centuries, Al-Biruni's proposition had been discussing that the earth takes turns on its axis. In the *Qanun-i Masoodi*, he wrote, the earth is in the middle of the universe and it has no mobility of its own, as it is described in the Ptolemaic system. However, in the above-mentioned book, he took the matter with this system on some points. For example, he said, the Sun's zenith is not static, and while his explanation admits the geocentric theory, it showed, the astronomical evidences could also be described by supposing the earth rotated around the sun (Boilot, 1974). Then, enduring his assumption on the mobility of the earth, Al-Biruni could neither prove nor disprove it, then remarked it favorable (Sparavigna, 2013).

It seemed that he had written in an observation on Indian astronomy that he has resolute the problem of the Earth's mobility in a book on astronomy that is not present indeed. He exposed seven altered means of finding the way of the north and south, and revealed mathematical methods to exactly define the beginning of the seasons. He also analyzed about the movement and eclipse of the sun. Besides, he proposed some astronomical instruments that helps to proceed further. He made an accurate calculation of the longitudes and latitudes, and determining methods to their relative positions from one place to another. These findings are included in his book *Al-Athar Al-Baqia*. He

analyses a discourse on timekeeping in the year of 1000 C.E. Al-Biruni wrote his understanding about the *Suryagrohon* (solar eclipse) on April 8, 1019 and the *Chondrogrohon* (lunar eclipse) on September 17, 1019. On the *Suryagrohon* that he had observed at Lamghan (A valley surrounded by mountains between the towns of Qandahar and Kabul, in Afghanistan.), he opined that at sunrise we saw approximately one-third of the sun was eclipsed, and that the eclipse was fading. He observed the lunar eclipse at Ghazna (a city in Afghanistan) and propose a precise of the exact altitude of different well-known stars at the moment of first interaction. Al-Biruni's work '*Al-Tafhimli-Awail Sina'at al-Tanjim*' translated by Ramsay Wright in 1934 was a summarization of his works on mathematics and astronomy.

Al-Biruni composed his well-known volume *Al-Qanun Al-Masudi Fi Al-Hai'a Wa Al-Nujum*, in 1030. This book was written after his most successful visiting in India. The book discusses several theorems of astronomy, trigonometry, lunar, solar, and planetary motions, and covers an anthology of twenty-three interpretations of equinoxes. Al-Biruni could establish trigonometry as a distinct branch of mathematics in his discussion. He used the *sin* principle in both astronomy and in the measurement of longitudes and latitudes of many towns. He studied broadly the prediction a hemisphere onto the plane. He wrote on the radius of the Earth, the astrolabe and mechanical calendar as well.

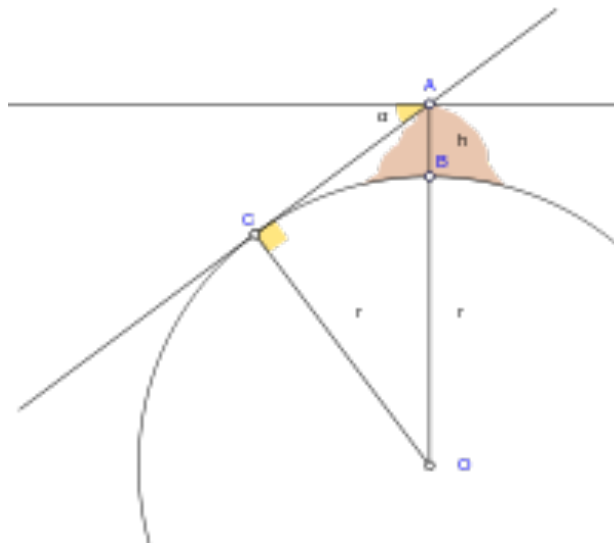


Figure-1: Diagram illustrating a method proposed and used by Al-Biruni to estimate the radius and circumference of the Earth. He also made use of algebra in his calculation. A = Highest point of mountain B = Lowest point of mountain h = Height of the mountain C = Lowest point of true horizon visible from point A O = Centre of Earth α = Dip angle r = Earth's radius Solution: The angle AOC = α . AO = (r+h) is the hypotenuse in triangle AOC. $r = (r+h) \cdot \cos(\alpha)$ Then the right side can be simplified to find r. $r = h \cdot \cos(\alpha) / (1 - \cos(\alpha))$.

Source: https://en.wikipedia.org/wiki/History_of_geodesy#/media/File:Abu_Reyhan_BiruniEarth_Circumference.svg

Al-Biruni established a different technique by using trigonometric designs to calculate the earth's radius and limits based on the position among the horizontal mark and accurate horizon from a mountain upper with identified altitude. He measured the altitude of the mountain by going for two points at sea level with a recognized space separately and then calculating the position among the plain and the upper of the mountain for both points. His approximation of 6,339.9 km for the Earth

radius had an error of 0.0026 and was 16.8 km less than the existing rate of 6,356.7 km. The clue came to him when he was on upper of a tall mountain near Nandana. He calculated the slope position by using an astrolabe and have applied to the law of sines method. Greek astronomer Ptolemy encouraged Al-Biruni for the formation of the circular form of the earth and its topographical mechanisms. In his book al-Qanun al-Masudi, Al-Biruni have addressed the theory of Ptolemy about the earth and boosted the argument of the dissemination of land and sea with different acquaintance and understanding.

He presented methods to calculate the earth and remoteness based on triangulation (see figure-1). He demanded that the radius of the earth was 6339.6 km, by observing the top of a mountain in India. By applying an Arabic mile equivalent to 1.225947 English miles, Al-Biruni's rate of the radius was equivalent to 3928.77 English miles that compares satisfactorily being dissimilar of 2%, with the mean radius of curving of the position ellipsoid at the latitude of calculation. This mean radius was of 3847.80 miles (Raju, 2007).

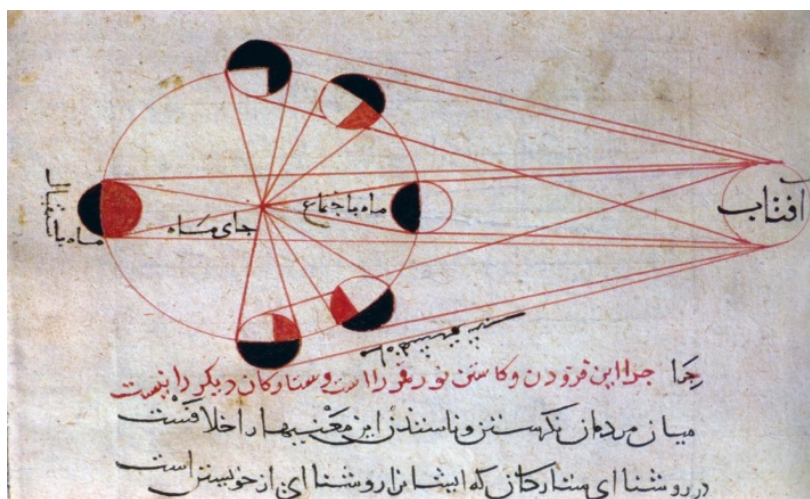


Fig-2: The above image made by Al-Biruni showing the phases of the moon.

Source: This image is from uploads/2011/08/Lunar_eclipse_al-Biruni.jpg. The original source of the eclipse diagram is the Parliament Library in Teheran.

Al-Biruni's view point what he said about an astronomical instrument was called the *Zuraqi*, (perhaps a mechanical astrolabe). He wrote that Abu Sa'id Sijzi, invented the mechanical astrolabe called *Zuraqi* based on the knowledge that the earth moves curved (Nasr, 1993). He liked it very much and praised Abu Sa'id Sijzi, as it was based on the knowledge and used by few effects that the mobility observed due to the movement of the earth and not to that of the skies. Throughout his life, it was a challenging work of the solution. Thus, it is similar whether someone takes the idea that the earth is on move or the sky (see figure-2); it does not affect the astronomical science in both cases (Nasr, 1993 & 1974).

It is an interesting topic of Islamic technology is the convention of astronomical gears defined in Arabic writings. A remarkable illustration is the geared astronomical mechanism described by Al-Biruni and titled by him *huqq al-qamar* that means box of the moon (see figure-3). From Al-Biruni's point of view, we can easily understand that these tools and techniques are recognized in the then Islamic astronomy. Another illustration is the geared almanac dated 1221-'2 that is actually part of the assemblage of the history of astronomical science at Oxford University (Al-Rodhan, 2012).



Figure-3: Al-Biruni's *huqq al-qamar*

Source: <http://www.islamic-study.org/astronomy.htm>

IMPACTS OF AL-BIRUNI'S ASTRONOMICAL COMPUTATIONS ON MODERN ASTRONOMY

When religious fanaticism spread out over medieval Europe, Al-Biruni was distant in the progress of the scientific understanding as a forerunner of the Renaissance. George Sarton (The founder of the History of Science discipline.) (1927-1956), identified Al-Biruni as one of the greatest scientists of Islam, and one of the greatest scholars of all times. Bobojan Gafurov (1974), a Tajik historian and academician, in his article pointed out that Al-Biruni was far ahead of his period by his brilliant discoveries, and contributions; he seemed incomprehensible to maximum of the scientists of his time.

Al-Biruni was the first scholar conducted elaborate experiments related to astronomy in the study of celestial objects and phenomena. 600 years before Galileo, he has stated that the earth moves on its axis daily and rotates around the sun yearly. He prepared a scientific description for the first time of why the sun never sets in the North or South Pole. He stated that the speed of light is massive as matched to the speed of sound as well. In his writings, he described the Milky Way as a collection of immeasurable fragments of the nature of nebulous stars.

Al-Biruni argued that the 'Earth' is a center sphere of the universe (it is first described by Ptolemy). It is supported by the then widely held view that the earth is the center of a system which goes around the planets and the sun. However, Al-Biruni regarded the earth as a domain and calculated its radius that is very close to modern values.

Al-Biruni's foremost involvement in astronomy is *Qanun-i Masoodi* (masudic canon of astronomy), covers the identical ground as Ptolemy's *Almagest* (Star catalogue from ancient times belongs to Ptolemy of Alexandria, who grouped 1022 stars into 48 constellations during the 2nd century A.D.) but introduces a new substantial. Ptolemy's *Almagest* does not comprise the constellations (catalogues of stars) that may only be observed from the southern hemisphere, it formulates the source for the later list of 88 constellations officially labelled by the International Astronomical Union (IAU) (IAU was established in 1919. Its mission is to promote and safeguard the science of astronomy in all its

aspects through international cooperation. Its individual members are professional astronomers from all over the world, at the Ph.D. level and beyond, and active in professional research and education in astronomy. The IAU has 12445 Individual Members in 96 countries worldwide. In addition, the IAU collaborates with various scientific organizations all over the world.).

Most of his creative theoretical ideas, were described in this work. Similar to the *Almagest*, the *Qanun* contains theoretical origins of astronomical limits as well as tabular meanings to enable the calculation of planetary positions. Thus it differs from the workings of most of Al-Biruni's forerunners and contemporaries who worried only with making astronomical tables for calculation of planetary positions generally deprived of any conversation of the origin of the limits upon which the tables were based.

Al-Biruni was one of the early scientists to be revived by Soviet science historians during the mid-twentieth century. This determination is an attempt to increase the name of *Soviet Science* or unjustly claims importance for substantial innovations (Ahmad, 2010). According to the Great Soviet Encyclopedia (1973):

Al-Biruni's exceptional erudition was combined with views that were very progressive for his time. He had an ironic attitude toward religious superstitions and spoke out against the enmity between peoples.

Faul and Faul pointed a more accurate assessment of Al-Biruni's historical significance.

'It is worthwhile for Biruni to become better known to western science ... his accomplishments were not insignificant and he did have considerable influence with contemporary Muslim scientists.' (1983:20)

Al-Biruni's eclipse documents was secondhand by Dunthorne (a Welsh novelist, poet and journalist) to support regulating the 'acceleration of the moon' and his observational documents has entered the greater astronomical record and isare worthy until today.

CONCLUSION

At ending, it can be said that Al-Biruni was one of the greatest scholars of his period in the world. He was also one of the Muslim scientists who promoted from both Islamic direction and scientific research. He said, the experiences he received from the astronomy, geometry and investigations in physics reveal that there must be a formation mind of limitless thought. His findings in astronomy show that there are imaginary workings in the universe that shows that there is a original organization and a careful control that could not be described through complete physical and material causes (Kamiar, 2009).

The astronomical portions of Al-Biruni's works are devoted to both applied (in the process of solving problems), and theoretical (in the process of thought formulations). Although his main concern in astronomy was for computations, he also paid attention to theoretical problems. Thus, the main contribution must be seen in the comprehensiveness of his work, and in his continual attempts to formulate astronomical thoughts.

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