

# Al-Bīrūnī: Outstanding ‘Modern’ Scientist of the Golden Age of Islamic Civilisation

*Daud Abdul-Fattah Batchelor*

The great polymath Muslim scholar, Abū al-Rayhān Muhammad ibn Ahmad al-Bīrūnī (973-1048 CE), generally known as Al-Biruni, was one of the first Muslim scholars who demonstrated a modern scientific outlook. He lived a full life of 75 years and undertook ground-breaking research in almost all of the natural science fields then known. George Sarton described him as “one of the greatest scientists in Islam, and, all considered, one of the greatest of all times”<sup>1</sup>. Al-Biruni was an early exponent of the experimental scientific method<sup>2</sup> and also a pioneer of comparative sociology<sup>3</sup>. Arthur Pope in giving his highest accolade, wrote “Alberuni must rank high in any list of the world’s great scholars. No history of mathematics, astronomy, geography, anthropology, or history of religion is complete without acknowledgment of his immense contribution. One of the outstanding minds of all time, distinguished to a remarkable degree by the essential qualities which have made possible both science and social studies, Alberuni is the demonstration of the universality and timelessness of a great mind. One could compile a long series of quotations from Alberuni written a thousand years ago that anticipate supposedly modern intellectual attitudes and methods”.<sup>4</sup>

## ***His Life***

He was born in 973/362 in Kath (now called Biruni), the then capital of the Khwarazmian Empire<sup>5</sup>. The word *Biruni* means “from the outer district” in Persian; this became his *nisba*. This region lying on the southern shores of the Aral Sea is now located in Uzbekistan. Once this was in the easternmost Persian province but in Biruni’s time it was part of the Samanid Empire ruled from Bukhara. He was from a modest family of Tajik origin. He spent most of his life in central Asia and in India, and followed in the footsteps of other famous scientists from Central Asia, such as Ahmad al-Farghani. He learned the scholarly languages of Arabic and Persian, and the regional language of Khwarizmian. His studies began at an early age under the famous astronomer-mathematician, Abu Nasr Mansur, a prince of the ruling Banu Iraq. At the age of 17 he already had demonstrated his aptitude by calculating the latitude of Kath through observing the maximum altitude of the sun. From his own observation he knew that the earth was round. He was beginning to collect similar coordinates for other localities. By the age of 22 he exhibited considerable skill in publishing his *Cartography* – a work on map projections<sup>6</sup>. He apparently did not marry and was seemingly a man

---

<sup>1</sup> G. Sarton, *Introduction to the History of Science*, Vol. 1 (Baltimore: Williams and Wilkins, 1931), p. 707.

<sup>2</sup> J.J. O’Connor and E.F. Robertson, “Abu Arrayhan Muhammad Ibn Ahmad al-Biruni”, MacTutor History of Mathematics archive, University of St Andrews. <http://www-history.mcs.st-and.ac.uk/Biographies/Al-Biruni.html> Accessed 3 August 2015.

<sup>3</sup> Ziauddin Sardar, “Science in Islamic philosophy”, In *Islamic Philosophy*, Routledge Encyclopedia of Philosophy (London: Routledge, 1998). <https://www.rep.routledge.com/articles/science-in-islamic-philosophy>

<sup>4</sup> Arthur Upham Pope, “Al-Biruni as a thinker” in *Al-Biruni Commemoration Volume* (Calcutta: Iran Society, 1951), p. 281.

<sup>5</sup> *Khwarazm* is similar to the Persian word *Khorasem*, which literally means “where the sun rises”.

<sup>6</sup> J.J. O’Connor and E.F. Robertson, *Al-Biruni biography*, MacTutor (Scotland: St Andrews University, 1999) <http://www-history.mcs.st-and.ac.uk/Biographies/Al-Biruni.html> Accessed 5 August 2015.

fully devoted to science.<sup>7</sup> He consistently demonstrated throughout his education and adult life that he was “an indefatigable seeker of knowledge with no love for sensuous pursuits.”<sup>8</sup> His early peaceful life abruptly ended with the overthrow of the Banu Iraq in a coup around 995.

He fled from Khwarizm apparently moving to Rayy (near modern Tehran) and lived there from about 995-997 in poverty without a patron.<sup>9</sup> There he met the astronomer, al-Khujandi who had built a large instrument to observe meridian transits of the sun near the solstices. Al-Khujandi observed the summer and winter solstices in 994. From these he calculated the obliquity of the elliptic and the latitude of Rayy, which proved not very accurate. Al-Biruni mentioned later in his *Tahdid*<sup>10</sup> that the likely reason for error in Khujandi’s measurement was due to gravity settlement of the instrument occurring during his measurements.<sup>11</sup> He returned to Kath by May 997 as he observed there then an eclipse of the moon. He also found peace around 998 while settled in the northern Persian town of Jurjan (modern Gurgan, near the Caspian Sea) working for the local ruler, Shams al-Ma’ali Qabus. Here around 1000 he wrote the extensive work, *Al-Athar al-baqiya an al-qurun al-khaliya*<sup>12</sup>, dedicated to Qabus. This book, beautifully titled as “The Remaining Signs of Past Centuries”, is a comparative study of the calendar systems of different civilisations, together with historical, astronomical, ethnological and religious information of their peoples. By 1004 he had returned to his homeland and remained in the court of Ali ibn Ma’mum who then ruled Khwarizm, and subsequently with his brother Abu’l Abbas when he assumed rulership. Both were generous patrons of science and Abu’l Abbas especially sponsored al-Biruni, supporting him to construct an astronomical instrument to observe solar meridian transits, which he conducted in 1016.

However, the famous warrior-Sultan Mahmud Subuktakin ruling from Ghazni in eastern Afghanistan had high ambitions and he attacked Kath, deposed the Ma’mums, and annexed Kath in 1017. Al-Biruni and Mansur accompanied the victorious army to Ghazni, probably under duress, as it seems al-Biruni suffered considerable hardship at this time. He conducted astronomical observations in Ghazni and the Kabul area, and joined Mahmud and his conquering armies on their excursions into India during 1017-1030. By 1022 Mahmud controlled the northern parts of India (now Pakistan). Al-Biruni conducted extensive observations and determined the latitudes of towns in the Punjab and Kashmiri border regions. To distance himself from Mahmud, Al-Biruni removed to Lahore where he wrote “the world’s first book on comparative religion, focusing on Hinduism and Islam”. He then moved to Nandana, near modern Islamabad, and devised a new highly accurate technique to measure the earth’s circumference using spherical trigonometry and by applying the law of sines.<sup>13</sup>

On Sultan Mahmud’s death in 1030, his eldest son Mas’ud took power and treated al-Biruni much more kindly until his death in 1040. By 1030 al-Biruni had returned to live until he died in 1048 in

---

<sup>7</sup> Zia Shah, “Al Biruni: One of the Greatest Pioneers of Science”, *The Muslim Times*, 1 January 2012.

<http://www.themuslimtimes.org/2012/01/science-and-technology/al-biruni-the-great-pioneer-of-science>  
Accessed 5 August 2015.

<sup>8</sup> Hakim Mohammed Said and Ansar Zahid Khan, 1981. *Al-Biruni: His Times, Life and Works*. Paksitan: Hamdard Academy.

<sup>9</sup> O’Connor and Robertson.

<sup>10</sup> *Tahdid nihayat al-amakin li-tashih masafat al-masakin* (Demarcation of the Coordinates of Cities)

<sup>11</sup> O’Connor and Robertson.

<sup>12</sup> E. Sachau, *The Chronology of Ancient Nations*. An English translation of Al-Biruni’s Arabic text of “*Al-Athar al-baqiya ...*”, or “*Vestiges of the Past*” (London: 1879).

<sup>13</sup> S. Frederick Starr, “So, Who Did Discover America?” *History Today*, Vol. 63, Issue 12, Dec. 2013.

<http://www.historytoday.com/s-frederick-starr/so-who-did-discover-america> Accessed 5 August, 2015.

Ghazni where he is buried. Al-Biruni continued his prodigious scientific output right up until his death. He lived at a time of great political disturbance in his region but still managed to rise above this instability to conduct state-of-the-art research with findings of great benefit for humanity. He was believed to have been a devout Muslim and displayed no prejudice against different religious sects or races.<sup>14</sup>

### ***His Works***

Al Biruni writing mostly in Arabic produced more than 146 titles in a multitude of disciplines of which only 22 works are extant. These are known to have covered astronomy (35), astrolabes (4), astrology (23), chronology (5), time measurement (2), geography (9), geodesy and mapping theory (10), mathematics – arithmetic, geometry and trigonometry (15), mechanics (2), medicine and pharmacology (2), meteorology (1), mineralogy and gems (2), history (2), India (2), religion and philosophy (3), literary works (16), magic (2), and nine unclassified books. Only 13 of these have been published in modern times.<sup>15</sup> A comprehensive listing of Al-Biruni's known works is provided by Jan Hogendijk<sup>16</sup>.

### ***His Scientific Outlook Contrasted with Philosophical Approaches***

Al-Biruni – a pioneer of the scientific method – was clearly attracted to studying observable phenomena in nature and man and applied himself not only to (qualitatively) describe phenomena but to quantify his observations wherever possible using mathematics.<sup>17</sup> His was a surprisingly modern outlook of the dispassionate researcher beyond his age, as evidenced by his following insight:

*[I]n an absolute sense, science is good in itself, apart from its knowledge [content]; its lure is everlasting and unbroken ... [The servant of science] should praise the assiduous [ones] whenever their efforts [arise from] delight [in science itself] rather than from [hope of achieving] victory in argument.*<sup>18</sup>

One may validly suggest that it was enlightenment gained from Islamic teachings that allowed him to transcend in his spirit of scientific enquiry beyond his time and “the depths of the irrational and superstitious medieval world.”<sup>19</sup> William Durant described al-Biruni as “an objective scholar, assiduous in research, critical in scrutiny of traditions and texts (including the Gospels), precise and conscientious in statement, frequently admitting his ignorance, and promising to pursue his inquiries till the truth should emerge.”<sup>20</sup> Al-Biruni was a great linguist who was able to read first hand an enormous number of contemporary and ancient works. This is an essential element for any comprehensive research to first determine the state of existing knowledge prior to seeking advance to ascertain new knowledge.

---

<sup>14</sup> O'Connor and Robertson.

<sup>15</sup> E.S. Kennedy, “Biruni, Abu Rayhan al-“, *Dictionary of Scientific Biography, II* (New York: Charles Scribner's Sons, 1970-1980), p. 152.

<sup>16</sup> <http://www.jphogendijk.nl/biruni.html>

<sup>17</sup> Kennedy.

<sup>18</sup> Starr.

<sup>19</sup> Starr.

<sup>20</sup> W. Durant, *The Age of Faith* (New York: Simon and Shuster, 1950), p. 243.

In his *Al-Arthar* Al-Biruni wrote, “We must clear our minds ... from all causes that blind people to the truth – old custom, party spirit, personal rivalry or passion, the desire for influence.”<sup>21</sup> In developing his approach to historical analysis, he stuck “by the principle, that it is crucial to obtain information from a primary source rather than secondary sources. A prerequisite for a scholar was that he ought to be free from all bias and prejudices, selfish interests, ideas of profiteering and from the complexes of a conqueror. A historian should free himself from all such associations and drawbacks which inhibit him from observing the truth.”<sup>22</sup>

Zia Shah<sup>23</sup> contributed his assessment of Al-Biruni’s great diligence in achieving accuracy: “Biruni’s scientific method was similar to the modern scientific method in many ways, particularly his emphasis on repeated experimentation. Biruni was concerned with how to conceptualize and prevent both systematic and random errors, such as ‘errors caused by the use of small instruments and errors made by human observers.’<sup>24</sup> He argued that if instruments produce random errors because of their imperfections or idiosyncratic qualities, then multiple observations must be taken, analyzed qualitatively, and on this basis, arrive at a ‘common-sense single value for the constant sought’, whether an arithmetic mean or a ‘reliable estimate’.<sup>25</sup>” O’Connor and Robertson considered Al-Biruni had a better feel for errors than did Ptolemy. They believed he “treats errors more scientifically and when he does chose some to be more reliable than others, he also gives the discarded observations. He was very conscious of rounding errors in calculations, and always attempted to observe quantities which required minimal manipulation to produce answers.”<sup>26</sup>

Al-Biruni held an admirable approach to developing ideas worked out in discussions and arguments with other scholars. He had a long-standing collaboration with his teacher Abu Nasr Mansur, each asking the other to undertake specific pieces of work to support their own. He corresponded in a challenging manner with Ibn Sina (Avicenna); and also with al-Sijzi about the sine theorem, advances on which, Al-Biruni especially credited his teacher, Mansur.<sup>27</sup>

It is worthwhile reviewing the single exchange of letters that occurred between Al-Biruni and Ibn Sina – two towering intellectuals of their age. This debate was mentioned in his *Al-Arthar* and detailed in his book titled *al-As’ila wal-Ajwiba (Questions and Answers)*. Al-Biruni began by asking Ibn Sina eighteen questions; ten were criticisms of Aristotle’s *On the Heavens*. Some of the questions posed by Al-Biruni were:

- Aristotle has no sound reason for his supposition that the heavens are neither heavy nor light.
- Aristotle’s method of seeking support for his theories in the opinions of former thinkers (in respect of the idea that the universe had no beginning) is improper.
- Aristotle’s reasons for rejecting the atomic theory are not sound and his own theory of the infinite divisibility of matter is no less open to objection.

---

<sup>21</sup> Durant, p. 243.

<sup>22</sup> H.M. Said and A.Z. Khan, *Al-Biruni: His Times, Life and Works*, (Karachi: Hamdard Foundation, 1981), p. 181.

<sup>23</sup> Zia Shah.

<sup>24</sup> T.F. Glick, S.J. Livesey and F. Wallis. *Medieval Science, Technology, and Medicine: An Encyclopedia* (London: Routledge, 2005), p. 89.

<sup>25</sup> Glick, Livesey and Wallis, pp. 89-90.

<sup>26</sup> O’Connor and Robertson.

<sup>27</sup> O’Connor and Robertson.

- Aristotle is not justified in denying the possibility of the existence of other universes besides our own.
- Aristotle is not justified in saying that the Heavens move from the east, as the east is the right side. Right and left are merely relative terms.
- How is heat imparted from the rays of the sun and are the rays themselves material, or indicate a condition of something else?
- What is the nature of vision? How do we see below the water?
- Why is only one quarter of the earth supposed to be inhabitable, while the other three quarters are equally capable of being so?
- Why do vessels break by the solidification of water?
- Why does ice float on water?<sup>28</sup>

Biruni was dissatisfied with some of Ibn Sina's answers. After Al-Biruni wrote back commenting on them, Ibn Sina's student Ahmad ibn 'Ali al-Ma'sumi replied on Ibn Sina's behalf.<sup>29</sup> Ziauddin Sardar nicely compared the two different approaches used by Ibn Sina and al-Biruni: "Unlike his contemporary Avicenna's [deductive] scientific method where "general and universal questions came first and led to experimental work", Biruni developed [inductive] scientific methods where 'universals came out of practical experimental work' and 'theories are formulated after discoveries.'<sup>30</sup> American scholar Ahmad Dallal found that Biruni in his debate with Ibn Sina "made the first real distinction between a scientist and a philosopher, referring to Avicenna as a philosopher and considering himself to be a mathematical scientist."<sup>31</sup>

Al-Biruni criticised Aristotle's followers in his own time for their blind adherence to Aristotelian physics and natural philosophy, "*The trouble with most people is their extravagance in respect of Aristotle's opinions; they believe that there is no possibility of mistakes in his views, though they know that he was only theorizing to the best of his capacity.*" In contrast to the philosophers, al-Biruni only accepted as reliable, evidence that was either mathematical or empirical.<sup>32</sup>

### ***Sciences and Discoveries by Al-Biruni***

#### ***Astronomy, Astrology and Geodesy***

Important contributions to astronomy, geodesy and geography were made by al-Biruni. By age 30 he had applied the most advanced science to calculate the earth's radius to be 6339.6 km, an accuracy not exceeded in the West until 500 year later.<sup>33</sup>

The *Al-Qanun al-Mas'udi*, Al-Biruni's vast astronomical encyclopaedia, almost 1,500 pages, has been described as the "greatest work on astronomy from the period between late antiquity and the

<sup>28</sup> H.M. Said and A.Z. Khan, *Al-Biruni: His Times, Life and Works* (Karachi: Hamdard Foundation, 1981), pp. 105-106.

<sup>29</sup> Rafik Berjak and Muzaffar Iqbal, "Ibn Sina - Al Biruni correspondence", *Islam & Science*, June 2003.

<sup>30</sup> Ziauddin Sardar.

<sup>31</sup> Ahmad Dallal, "The Interplay of Science and Theology in the Fourteenth-century Kalam", *In Sawyer Seminar - From Medieval to Modern in the Islamic World* (Chicago: University of Chicago, 2001-2002).

<sup>32</sup> See Abdus Salam, H.R. Dalafi, and Mohamed Hassan, *Renaissance of Sciences in Islamic Countries*, (World Scientific, 1994), p. 96.

<sup>33</sup> O'Connor and Robertson. NASA provides figures of the earth's equatorial radius: 6378.0km and polar radius: 6356.8km.

modern era”.<sup>34</sup> In it he summarised all contemporary knowledge on astronomy and allied subjects. It contains a Table providing coordinates for 600 localities. George Saliba described it as having “the general outline of a *zij* (astronomical handbook) but it is much more detailed and analytical in its approach to observations and numerical tables.” Further he commiserated, “It is unfortunate that this text has not yet been translated and studied by modern scholars, for it not only promises to be of great importance to historians of Islamic history but also may change our accepted ideas about the general history of mathematics.”<sup>35</sup>

The *Muslim Heritage* authors wrote on the contents of the *Qanun*: “In it he determines the motion of the solar apogee, corrects Ptolemy’s findings, and is able to state for the first time that the motion is not identical to that of the precession, but comes very close to it. In this book, too, al-Biruni employs mathematical techniques unknown to his predecessors that involve analysis of instantaneous motion and acceleration, described in terminology that can best be understood if we assume that he had ‘mathematical functions’ in mind.”<sup>36</sup>

Frederick Starr in praising al-Biruni as a Muslim discoverer of the Americas called him “the greatest explorer between the ancient world and the great age of European exploration” resulting from his “constant urge to quantify whatever he observed, combined with his enquiring mind”. Starr believed al-Biruni’s role was all the more impressive given that “he achieved what he did through systematic and rigorous application of reason and logic, unconstrained by religious or secular dogmas, folklore or anecdotes”, and secondly, that “he carried out his breathtaking intellectual exploration while living far from the sea in a landlocked region ... which, in most respects put Columbus, Cabot and the Vikings in the shade”.<sup>37</sup> Starr provided well-thought arguments to support his views:

*In his Codex, Biruni also hypothesized about the existence of [the Americas]. Biruni began by presenting the research on the earth’s circumference that he had carried out at Nandana. He then set about fixing all known geographical locations onto his new, more accurate map of the globe. ... When Biruni transposed these data onto his map of the earth he noticed at once that the entire breadth of Eurasia ... spanned only about two fifths of the globe. This left three fifths of the Earth’s surface unaccounted for.*<sup>38</sup>

Based on logic, Biruni rejected the possibility that the missing area was all ocean and asked “why would the forces that had given rise to land on two fifths of the earth’s belt not also had a similar effect on the other three fifths as well?” He concluded that within the vast expanse of ocean between Europe and Asia unknown land masses must be present. He further developed the view that these lands between the Atlantic and Pacific Oceans would be inhabitable as, in fact, they were.

*[I]f ‘discovery’ includes the unreflective processes of Norse seafaring, then the prize must go to the Vikings. Yet Biruni is at least deserving of the title of North America’s discoverer as any Norseman. Moreover, the intellectual process by which he reached his conclusions is no less*

---

<sup>34</sup> Starr.

<sup>35</sup> G. Saliba, “Al-Biruni”, Dictionary of Middle Ages, 13 vols., edited by Joseph Strayer, New York: Charles Scribner’s Sons, vol.2 (1982), p.249; see Al-Biruni, Muslim Heritage.

<sup>36</sup> Al-Biruni, Muslim Heritage.

<sup>37</sup> Starr.

<sup>38</sup> Starr.

*stunning than the conclusions themselves. His tools were not the hit-or-miss methods of Venetian seamen or Norse sailors but an adroit combination of carefully controlled observation, meticulously assembled quantitative data and rigorous logic. Only after a further half-millennium did anyone else apply such rigorous analysis to global exploration. ... Biruni devised completely new methods and technologies to generate his voluminous and precise data and processed it with the latest tools of mathematics, trigonometry and spherical geometry as well as the austere methods of Aristotelian logic. He was careful to present his conclusions in the form of hypotheses, on the understanding that other researchers would want to test and refine his findings. This did not happen for another five centuries. In the end the European explorers confirmed his hypothesis and vindicated his bold proposals* [emphasis added].<sup>39</sup>

The most comprehensive work by Al-Biruni on astrology is his *Elements of Astrology* (*Kitab al-tahfīm li-awa'il sina'at al-tanjīm*)<sup>40</sup>, which was written at the request of Rayhana, daughter of al-Hasan of Khwarizm. The contents suggest that "Al-Biruni's heart was not in astrological doctrines. At several points in this text, he warns his reader against excessive belief in astrology. Later he wrote a refutation of astrology, *Warning Against the Craft of Deceit*, but this was apparently lost during his lifetime. He refuted astrology since the methods used by astrologers were conjectural rather than empirical, and also because the views of astrologers conflicted with orthodox Islam."<sup>41</sup>

Al-Biruni invented a number of astronomical instruments, wrote treatises on the astrolabe, the planisphere, and the armillary sphere, and noted the attraction of all objects towards the centre of the earth.<sup>42</sup> In a pioneering effort not matched until the Renaissance he constructed a globe 5.8m high showing the earth's terrestrial features.<sup>43</sup> He also discovered that the distance between the earth and the Sun is larger than Ptolemy's estimate.<sup>44</sup> By using the astrolabe and the presence of a mountain near a sea or flat plain, he calculated the earth's circumference by using trigonometry to solve a highly complex geodesic equation<sup>45</sup>.

The astrolabe was the most valuable instrument of medieval astronomers-astrologers. Al-Biruni provided in his astrolabe treatise the most comprehensive treatment on the history and construction principles of the various types of contemporary astrolabes.<sup>46</sup> In it he noted that the astrolabe of Abu Sa'id al-Sijzi (d. c.1024) was constructed employing the principle that, rather than the heavens moving, it was the earth that moved, presaging an important development of Muslim astronomers towards elucidating a heliocentric concept of the solar system that could only be confirmed 600 years later by Galileo following invention of the telescope.

<sup>39</sup> Starr.

<sup>40</sup> Al-Biruni, *Kitab al-tahfīm li-awa'il sina'at al-tanjīm. Book of the Instruction in the Elements in the Science of Astrology*, edited by R.R. Wright (London: Luzac, 1938).

<sup>41</sup> George Saliba, *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam* (New York University Press, 1994), pp. 60, 67-69.

<sup>42</sup> W. Durant, *The Age of Faith* (New York: Simon and Schuster, 1950), p. 244.

<sup>43</sup> S. Frederick Starr, "So Who Did Discover America?" *History Today*, Vol. 63(12), December 2013.

<http://www.historytoday.com/s-frederick-starr/so-who-did-discover-america>

<sup>44</sup> G. Saliba, vol.2 (1982), p.249.

<sup>45</sup> W. Durant, *The Age of Faith*, Simon and Shuster, New York, 1950, p. 244.

<sup>46</sup> G. Saliba, vol.2, p.250; see Al-Biruni, Muslim Heritage.

*I have seen the astrolabe called Zuraqi invented by Abu Sa'id al-Sijzi. I liked it very much and praised him a great deal, as it is based on the idea entertained by some<sup>47</sup> to the effect that the motion we see is due to the Earth's movement and not to that of the sky. By my life, it is a problem difficult of solution and refutation. ... For it is the same whether you take it that the Earth is in motion or [it is] the sky. For, in both cases, it does not affect the Astronomical Science.<sup>48</sup>*

According to Will Durant, Al-Biruni remarked that astronomic data can be explained as well by supposing that the earth turns annually around the sun, as by the reverse hypothesis.<sup>49</sup>

Al-Biruni wrote the first treatise on the sextant.<sup>50</sup> He also invented an early odometer<sup>51</sup>, and the first mechanical lunisolar calendar computer, which employed a gear train and eight gear wheels.<sup>52</sup> These were early examples of fixed-wired knowledge processing machines.<sup>53</sup>

Zia Shah highlighted further geodetic accomplishments of al-Biruni<sup>54</sup>: "In mathematical geography, Biruni, around 1025, was the first to describe a polar equi-azimuthal equidistant projection of the celestial sphere.<sup>55</sup> He was also regarded as the most skilled in ... measuring the distance between cities, which he did for many cities in the Middle East and western Indian subcontinent. He often combined astronomical readings and mathematical equation, in order to develop methods of pinpointing locations by recording degrees of latitude and longitude. He also developed similar techniques when it came to measuring the heights of mountains, depths of valleys, and expanse of the horizon, in *The Chronology of Ancient Nations*.<sup>56</sup>" Al-Biruni's ability to determine accurately the distances between cities was a use of great political and economic value.<sup>57</sup>

George Saliba noted that al-Biruni also conducted research in support of Muslims' Islamic obligation to pray in the direction (*qibla*) towards the city of Mecca. His *Tahdid Nihayat al-amakin li-tashih masafat al-masakin* was written to enable determination of the *qibla*. One has to first know with some precision the longitude and latitude of Mecca. The values are then applied to a spherical

<sup>47</sup> In his *Tahqiq* dated 1030, al-Biruni mentioned heliocentric theories held by some ancient Indian thinkers. See George Saliba, *Whose Science is Arabic Science in Renaissance Europe?* (Columbia University, 1999). <http://www.columbia.edu/~gas1/project/visions/case1/sci.1.html> Accessed 7 August 2015.

<sup>48</sup> See Seyyed Hossein Nasr, *An Introduction to Islamic Cosmological Doctrines* (New York: State University of New York, 1993), pp. 135-136.

<sup>49</sup> W. Durant, *The Story of Civilization, IV: The Age of Faith* (New York: Simon and Shuster, 1950), pp. 239-245.

<sup>50</sup> Jean Claude Pecker. *Understanding the Heavens: Thirty Centuries of Astronomical Ideas from Ancient Thinking to Modern Cosmology* (Springer, 2001), p. 311. British writers have claimed invention of the sextant themselves but this was the navigator's sextant, discovered 700 years after al-Khujandi's first sextant. See <http://www.oceannavigator.com/January-February-2003/Who-really-invented-the-sextant/> Accessed 7 August 2015.

<sup>51</sup> D. De S. Price (1984). "A History of Calculating Machines", *IEEE Micro* 4(1), pp. 22-52.

<sup>52</sup> Donald Routledge Hill (1985). "Al-Biruni's mechanical calendar", *Annals of Science* 42, pp. 139-163.

<sup>53</sup> Tuncer Oren (2001). "Advances in Computer and Information Sciences: From Abacus to Holonic Agents", *Turk J Elec Engin* 9(1), pp. 63-70; see Zia Shah.

<sup>54</sup> Zia Shah.

<sup>55</sup> David A. King, "Astronomy and Islamic Society: Qibla, gnomics and timekeeping", in Roshdi Rashed (ed.), *Encyclopedia of the History of Arabic Science*, Vol.1, pp. 128-184. (London and New York: Routledge, 1996).

<sup>56</sup> W. Scheppeler, "Al-Biruni: Master Astronomer and Influential Muslim Scholar of Eleventh-century Persia", In *Great Muslim Philosophers and Scientists of the Middle Ages* (New York: The Rosen Publishing Group, 2006).

<sup>57</sup> G. Saliba, vol.2, p.249; see Al-Biruni, Muslim Heritage.



triangle, and the angle from the local meridian to the required direction of Mecca can be determined.<sup>58</sup>

Al-Biruni also contributed an important new method for astronomical observations called the “three points observation”. The 16<sup>th</sup> century Muslim polymath, Taqi al-Din, described the three points as “two of them being in opposition in the elliptic and the third in any desired place.” Al-Biruni’s method was still used six centuries later by Taqi al-Din, Tycho Brahe and Copernicus to calculate eccentricity of the Sun’s orbit and the annual motion of the apogee.<sup>59</sup>

### *Mathematics and Physics*

Some of al-Biruni’s important mathematical contributions were listed by Rozenfel’d *et al.* (1973): theoretical and practical arithmetic, summation of series, combinatorial analysis, irrational numbers, ratio theory, algebraic definitions, method of solving algebraic equations, geometry, conic sections, stereometry, stereographic projections, trigonometry, the sine theorem in the plane, and solving spherical triangles.<sup>60</sup>

Al-Biruni’s important work, *Shadows (Ifrad al-maqal fi ‘amr al-zilal)*, written around 1021, is another of his studies linking Science and Islam and contains valuable innovative ideas, such as that acceleration is connected with non-uniform motion, using three rectangular coordinates to define a point in 3-dimensional space, and ideas that anticipate the use of polar coordinates.<sup>61</sup> He addressed the problem of determining the time of day from shadows, and connects this discipline with the time of the muslim daily prayers that are astronomically defined.<sup>62</sup> Al-Biruni was also the first to discover that the speed of light is much faster than the speed of sound.<sup>63</sup>

### *Geology, Mineralogy and Hydrogeology*

Following analysis of the geospatial distribution of sediment grain size variability, Al-Biruni hypothesised that India was once a sea, and that it became land through sedimentation:

*[I]f you consider the rounded stones found in the earth however deeply you dig, stones that are huge near the mountains and where the rivers have a violent current; stones that are of smaller size at a greater distance from the mountains and where the streams flow more slowly; stones that appear pulverized in the shape of sand where the streams begin to stagnate near their mouths and near the sea – if you consider all this you can scarcely help*

---

<sup>58</sup> G. Saliba, vol.2, p.249; see Al-Biruni, Muslim Heritage.

<sup>59</sup> Sevim Tekeli, “Taqi al-Din”, in Helaine Selin (1997), *Encyclopaedia of the History of Science, Technology and Medicine in Non-Western Cultures*, Kluwer Academic Publishers; see Zia Shah.

<sup>60</sup> B.A. Rozenfel’d, M.M. Rozhanskaya and Z.K. Skolovskaya, *Abu’l Rayhan al-Biruni (973-1048)*. (Russian), Moscow, 1973.

<sup>61</sup> O’Connor and Robertson.

<sup>62</sup> G. Saliba, vol.2, p.249-250; see Al-Biruni, Muslim Heritage

<sup>63</sup> George Sarton, “The Time of Al-Biruni” in *Introduction to the History of Science*.

[http://www.usc.edu/schools/college/crcc/private/cmje/heritage/History\\_of\\_Islamic\\_Science.pdf](http://www.usc.edu/schools/college/crcc/private/cmje/heritage/History_of_Islamic_Science.pdf) Accessed 7 August 2015.

*thinking that India was once a sea, which by degrees has been filled up by the alluvium of streams.*<sup>64</sup>

Al-Biruni pioneered contributions in the science of palaeontology in his *Book of Coordinates*, where he proposed that the presence of fossil shells similar to those found in modern seas proved that present mountains and dry lands were once beneath the sea. From such discoveries, he realised that the earth is constantly evolving and is a living entity. This was in agreement with his Islamic belief that nothing is eternal but is opposed to the ancient Greek belief that the universe is eternal. Al-Biruni also contributed towards elucidating the hydrological cycle by explaining the water level of natural springs and artesian wells using the hydrostatic principle that water finds its own level through subterranean interconnected channels.<sup>65</sup>

Together with al-Kindi and Ibn Sina, Biruni was one of the first scientists to reject the theory of the transmutation of metals as supported by some alchemists.<sup>66</sup> Al-Biruni introduced the scientific method into mineralogy where he was “the most exact of experimental scientists”.<sup>67</sup> Through numerous experiments Al-Biruni originated and applied the concept of specific gravity in his *Ayin-Akbari*<sup>68</sup> and made very accurate measurements providing the ratios between the densities of gold, mercury, lead silver, bronze, copper, brass, iron and tin. He determined the specific gravity of eighteen precious stones, and laid down the principle that the specific gravity of an object corresponds to the volume of water it displaces per unit weight.<sup>69</sup> His measurements correspond almost exactly to those we have today.<sup>70</sup> At the age of 80, Al-Biruni published his advanced scientific understanding of minerals and other substances as *Kitab al-Jamahir fi ma’rifat al-jawahir* (*The Comprehensive Book on Understanding Precious Stones*)<sup>71</sup>, the most extensive mineralogy book of its time.

### *Pharmacology and Psychology*

Abu Rayhan Al-Biruni published a comprehensive treatise from the results of his life-long study on pharmacology, the medicinal uses of plants, titled *Kitab al-Ṣaydana*. It mentioned and described the botanical aspects of 1,197 drugs and their applications, each with their equivalent name in at least four languages.

Al-Biruni was also a pioneer of experimental psychology as evidenced from the following comment based on empirical observation and experimentation in his discovery of the concept of reaction time:

---

<sup>64</sup> A. Salam (1984), “Islam and Science”. In C.H. Lai (1987), *Ideals and Realities: Selected Essays of Abdus Salam*, 2<sup>nd</sup> ed., World Scientific, Singapore, pp. 179-213.

<sup>65</sup> Durant, pp. 243-244.

<sup>66</sup> Michael E. Marmura (1965). “An Introduction to Islamic Cosmological Doctrines, Conceptions of Nature and Methods Used for Its Study by the Ikhwan Al-Safa, Biruni, and Ibn Sina, by Seyyed Hossein Nasr”, *Speculum* 40(4), pp. 744-746.

<sup>67</sup> Sardar Ziauddin.

<sup>68</sup> Max Jammer, “Concepts of Mass in Classical and Modern Physics”, In *Classical and Modern Physics*, (Courier Dover Publications, 1997), pp. 28-29.

<sup>69</sup> Durant, p. 244.

<sup>70</sup> Schepppler, pp. 42-43.

<sup>71</sup> Translated by Hakim Mohammad Said. Islamabad.

*Not only is every sensation attended by a corresponding change localized in the sense-organ, which demands a certain time, but also, between the stimulation of the organ and consciousness of the perception, an interval of time must elapse, corresponding to the transmission of stimulus for some distance along the nerves.*<sup>72</sup>

#### *Social Science - Anthropology, History and Comparative Religion*

Al-Biruni displayed his expansive interests and strong scholarly capabilities in crossing from the realm of the natural sciences to embrace the human sciences; but through application of the scientific method and seeking the truth in all matters, he contributed new insights to the extent that he has been called “the first anthropologist”<sup>73</sup>.

Al-Biruni used the golden opportunity as an early Muslim scientist accompanying Mahmud of Ghazni on his military expeditions to explore Indian Hindu-Buddhist civilization, to study their scientific knowledge, especially mathematics, medicine, weights and measures, astronomy, astrology and their calendar, as well as their language, religion, philosophy, geography, culture, and customs – its caste system and marriage customs. This was the substance of his massive and most famous encyclopaedic work called *On Research Verification in India (Fi tahqiq ma li-l-Hind)* – “the most authoritative account of medieval India”<sup>74</sup>, published around 1030. Al-Biruni had already learned Sanskrit and he translated several Sanskrit texts into Arabic.

As Zia Shah highlighted, until the 10<sup>th</sup> century that history most often meant political and military history. However, in his *Tahqiq*, al-Biruni did not record such history in any detail, but wrote instead on India’s cultural, scientific, social and religious history.<sup>75</sup> At the outset al-Biruni in assessing the authenticity of historical accounts, sharply distinguished between hearsay and eyewitness reports, and classified the varieties of ‘liars’ who have written history.<sup>76</sup>

Zia Shah has provided an excellent overview of al-Biruni’s contributions in anthropology and comparative religion, including the following excerpt<sup>77</sup>:

*Like modern anthropologists, he engaged in extensive participant observation with a given group of people, learnt their language and studied their primary texts, and presented his findings with objectivity and neutrality using cross-cultural comparisons.*<sup>78</sup> He wrote detailed comparative studies on the anthropology of peoples, religions and cultures in the Middle East, Mediterranean and South Asia. Biruni’s anthropology of religion was only possible for a scholar deeply immersed in the lore of other nations.<sup>79</sup> ...

*Al-Biruni spent time in India researching culture, religion and language from 1017 until 1031, resulting in the [Tahqiq, also known as al-Hind]. ... Al-Biruni used his interdisciplinary interests from an anthropological perspective before anthropology existed as a discipline. ...*

<sup>72</sup> Muhammad Iqbal, “The Spirit of Muslim Culture”, *The Reconstruction of Religious Thought in Islam*.

<sup>73</sup> <http://blogs.nature.com/houseofwisdom/2012/09/remembering-al-biruni-the-first-anthropologist.html>

<sup>74</sup> Saliba 1982, p. 248.

<sup>75</sup> Zia Shah.

<sup>76</sup> Durant, p. 243.

<sup>77</sup> Zia Shah.

<sup>78</sup> Akbar S. Ahmed, “Al-Beruni: The First Anthropologist”, *RAIN* 60 (1984), pp. 9-10.

<sup>79</sup> J.T. Walbridge, “Explaining Away the Greek Gods in Islam”, *Journal of the History of Ideas* 59(3), pp. 389-403.

*Through this modern practice, al-Biruni used the concepts of cross cultural comparison, inter-cultural dialogue and phenomenological observation which have become commonplace within anthropology today.<sup>80</sup> Within al-Hind, Al-Biruni does not pass judgment on the Indian culture or the Hindu faith, but rather speaks through them. Not only did Al-Biruni conduct what has been recognized as the first ethnographic fieldwork, he was also the first Muslim to study the Hindu tradition, developing an interest in religious coexistence. ...*

*Referring back to Al-Biruni's literary work, al-Hind ... one scholar suggests that "he (Al-Biruni) was probably Islamic civilization's first cultural anthropologist."<sup>81</sup> ... This recognition of Al-Biruni's work seems to equate with modern anthropology's ethnographic fieldwork. It is astounding the early practices and methods Al-Biruni contributed to such an array of disciplines centuries ago.*

It is evident from Al-Biruni's writings that he believed there is "a common human element that makes all cultures distant relatives".<sup>82</sup>

Al-Biruni was a pioneer of comparative religion. He endeavoured to attain a comprehensive understanding of foreign societies to identify "a social pattern of similarities across cultural and religious lines through his studies"<sup>83</sup> as a "staunch believer in the truth."<sup>84</sup> Arthur Jeffrey believed, "It is rare until modern times to find so fair and unprejudiced a statement of the views of other religions, so earnest an attempt to study them in the best sources, and such care to find a method which for this branch of study would be both rigorous and just."<sup>85</sup> Jeffrey believed that "in this field of the sciences of the spirit, al-Biruni's contribution to learning was possibly greater than in the field of the more exact senses". Al-Biruni stated in his introduction to the *Tahqiq* that his intention was to facilitate dialogue between Islam and the Indian religions:

*Abu Sahl at-Tiflisi incited me to write down what I know about the Hindus as a help to those who want to discuss religious questions with them, and a repertory of information to those who want to associate with them. We think now that what we have related in this book will be sufficient for anyone who wants to converse with the Hindus, and to discuss with them questions of religion, science or literature, on the very basis of their own civilization.<sup>86</sup>*

Montgomery Watt believed on the basis of al-Biruni's insistence on applying "a strict scientific method" that it could be claimed he "had gone beyond the Comparative Religion of the late nineteenth century". He further elaborated that he "is admirably objective and unprejudiced in his presentation of facts" but "selects facts in such a way that he makes a strong case for holding that there is a certain unity in the religious experience of the people he considers". In his *Tahqiq*, Al-

<sup>80</sup> Kemal Ataman, *Re-Reading al-Biruni's India: a Case for Intercultural Understanding: Islam and Christian-Muslim Relations* (London: Routledge, 2005).

<sup>81</sup> James W. Morris, *Imaging Islam: Intellect and Imagination in Islamic Philosophy, Poetry, and Painting, Religion and the Arts* (Leiden: Brill, 2008).

<sup>82</sup> Ataman.

<sup>83</sup> Zia Shah.

<sup>84</sup> Hakim Mohammed Said and Ansar Zahid Khan, *Al-Biruni: His Times, Life and Works* (Karachi: Hamdard Academy, 1981).

<sup>85</sup> William Montgomery Watt, *BIRUNI and the study of non-Islamic Religions* (14 April 2004)

<http://www.fravahr.org/spip.php?article31> Accessed 12 August 2015.

<sup>86</sup> Watt.

Biruni argued that Hinduism was a monotheistic faith like Islam, and justified this assertion by quoting Hindu texts. He argued that the worship of idols is exclusively a characteristic of the common people, with which the educated have nothing to do”<sup>87</sup>:

*The educated among the Hindus abhor anthromorphisms of this kind, but the crowd and the members of the single sects use them most extensively. ... The [true] Hindus believe [that] God is one eternal, without beginning and end, acting by free-will, almighty, all-wise, living, giving life, ruling, preserving; one who in his sovereignty is unique, beyond all likeness and unlikeness, and that he does not resemble anything nor does anything resemble him.*<sup>88</sup>

### *Islam and Science*

Al-Biruni like modern Muslim scientists, believed that no Qur’anic statements contradict knowledge about the natural world acquired through the senses and scientific investigation. In “On the Configuration of the Heavens and Earth According to Astrologers” section of the *Tahqiq* he contrasted the Qur’an in this respect with certain Indian religious scriptures:

*[The views of Indian astrologers] have developed in a way which is different from those of our [Muslim] fellows; this is because unlike the scriptures revealed before it, the Qur’an does not articulate on this subject [of astronomy], or any other [field of] necessary [knowledge] any assertion that would require erratic interpretations in order to harmonize it with that which is known by necessity.*

Zia Shah<sup>89</sup> citing Scheppler identified further aspects of al-Biruni’s outlook on the role of humankind. Al-Biruni agreed that the possession of intellect makes humans superior to animals.” He also considered hearing and sight to be the two most important senses, as they allow humans to “observe the signs of God’s divine wisdom in his creations” and “receive the word of God and his command.”<sup>90</sup>

### **Conclusions**

This gifted scholar, Al-Biruni, exemplified the great advances possible in human knowledge and understanding of the universe and the world, in its natural as well as human dimensions, from an enlightened Islamic understanding of its reality. This contrasted with those without a firm grounding on divine guidance who were eluded from the truth due to misguidance, superstition, or limited vision. Al-Biruni’s outlook is a proof that Islam can inspire advances in scientific knowledge of the natural and human sciences. Many of his extant books have not yet been (fully) translated and studied but already current studies demonstrate the huge debt humanity owes to the scholarly efforts of Al-Biruni, together with contemporary scholars with whom he collaborated.

---

<sup>87</sup> Watt.

<sup>88</sup> Watt

<sup>89</sup> Zia Shah.

<sup>90</sup> Scheppler.