

AL-BIRUNI'S WORKS AS SOURCES FOR THE STUDY OF EMPIRICAL KNOWLEDGE IN MEDIEVAL SCIENCE

Sharof Rashidov Samarkand State University

Doctoral Student of the Department of "History of Uzbekistan",

Acting Associate Professor at Oriental University, PhD

Turdaliyev Jahongir Rustam ogli

Tel.: +99894 280-03-70; E-mail: jahongirturdaliyev1991@gmail.com

ORCID: <https://orcid.org/0009-0002-2186-7765>

***Annotatsiya.** Maqolada Abu Rayhon Beruniy asarlari o'rta asr ilmi-fanida empirik bilimlarni o'rganish uchun muhim manba sifatida tahlil qilinadi. Empirik bilim kuzatuv, tajriba, o'lchov, qiyoslash, hisob-kitob, dalilni tekshirish va manbalarni solishtirish tizimi sifatida talqin etiladi. Beruniyning astronomik, geografik, mineralogik, farmakologik, tarixiy va etnografik asarlari o'rta asr ilmiy tafakkurida dalilga asoslangan bilish shakllarini tiklash imkonini beradi. Tadqiqot natijalari Beruniy asarlarining qiymati faqat ulardagi ma'lumotlarda emas, balki ma'lumotni yig'ish, tekshirish va tizimlashtirish usulida ham ekanini ko'rsatadi.*

***Kalit so'zlar:** Beruniy, empirik bilim, o'rta asr fani, manbashunoslik, kuzatuv, o'lchov, verifikatsiya, geodeziya, mineralogiya, qiyosiy tahlil*

***Аннотация.** В статье труды Абу Райхана Бируни рассматриваются как важные источники для изучения эмпирического знания в средневековой науке. Эмпирическое знание понимается как система наблюдения, опыта, измерения, сравнения, вычисления, проверки доказательств и сопоставления источников. Астрономические, географические, минералогические, фармакологические, исторические и этнографические труды*

Бируни позволяют реконструировать формы доказательного знания в средневековой научной мысли. Результаты исследования показывают, что ценность трудов Бируни заключается не только в содержащейся в них информации, но и в способах сбора, проверки и систематизации данных.

Ключевые слова: *Бируни, эмпирическое знание, средневековая наука, источниковедение, наблюдение, измерение, проверка, геодезия, минералогия, сравнительный анализ*

Abstract. *This article analyzes Al-Biruni's works as important sources for the study of empirical knowledge in medieval science. Empirical knowledge is interpreted not only as experiment in the modern laboratory sense, but also as observation, measurement, comparison, calculation, verification, and critical treatment of sources. Al-Biruni's astronomical, geographical, mineralogical, pharmacological, historical, and ethnographic writings make it possible to reconstruct evidence-based forms of medieval scientific reasoning. The study argues that the source value of his works lies not only in the information they preserve, but also in the methods by which information was collected, compared, tested, measured, and organized.*

Keywords: *Al-Biruni, empirical knowledge, medieval science, source criticism, observation, measurement, verification, geodesy, mineralogy, comparative analysis*

INTRODUCTION. Al-Biruni's works occupy a special place in the history of medieval science because they preserve not only scientific information, but also the intellectual procedures through which information was obtained, tested, corrected, and systematized. In his writings, knowledge is rarely presented as a passive repetition of inherited authority. It is usually mediated by observation, mathematical

calculation, comparison of reports, linguistic clarification, and critical evaluation of earlier views. For this reason, his works are important not only for the history of astronomy, geography, mineralogy, chronology, pharmacology, and Indology, but also for the reconstruction of empirical knowledge as a historical form of scientific reasoning.

The term “empirical knowledge” in the context of medieval science should not be reduced to modern laboratory experimentation. In Al-Biruni’s intellectual world, empirical knowledge included direct observation of natural phenomena, measuring distances and coordinates, determining the physical properties of minerals, comparing calendars, examining historical reports, studying foreign languages to access primary texts, and verifying the reliability of information through comparison. The sources used in this study indicate that such practices were especially visible in Al-Biruni’s treatment of geography, geodesy, astronomy, mineralogy, pharmacology, and Indian culture.

Al-Biruni’s intellectual formation was historically situated. The political and cultural environment of Central Asia before and after the Arab conquest shaped the conditions in which scientific centers, translation traditions, and multilingual scholarship developed. Ungalov’s study of pre-conquest Movarounnahr notes that the Western Turkish Khanate, despite its vast territory, lacked a truly centralized political structure; this fragmented background helps explain why later Islamic scholarly networks and courtly patronage became important mechanisms for intellectual integration [Ungalov, 2020, p. 670]. The Khwarazmian milieu, the Ma’munid scholarly environment, the Ghaznavid court, and Al-Biruni’s direct contact with India created a historically specific setting in which observation and comparison became central to knowledge.

The research problem may therefore be formulated as follows: in what sense can Al-Biruni's works be used as sources for reconstructing the formation, structure, and historical meaning of empirical knowledge in medieval science? The aim of the article is to analyze his works as source-critical materials that reveal the medieval practices of observation, measurement, verification, comparison, and organization of knowledge.

METHODS. The study is based on historical-analytical, comparative, source-critical, contextual, and conceptual methods. The historical-analytical method is used to interpret Al-Biruni's works within the conditions of medieval Central Asian and Islamic science rather than through anachronistic categories of modern laboratory research. The comparative method makes it possible to distinguish different forms of empirical knowledge in his writings: astronomical observation, geodetic measurement, mineralogical testing, pharmacological classification, chronological calculation, and ethnographic description.

The source-critical method is central to the article because Al-Biruni's works are treated not merely as collections of facts, but as materials that disclose how facts were selected, verified, and arranged. The conceptual method is used to define the analytical categories of "empirical knowledge", "scientific observation", "measurement", "verification", "source criticism", "comparative evidence", "instrumental accuracy", "cross-cultural knowledge", and "medieval scientific method". These categories are applied cautiously, with attention to the historical distance between medieval scientific practice and modern experimental science.

For analytical purposes, Al-Biruni's works are grouped into several source categories: astronomical and mathematical sources; geographical

and geodetic sources; historical and chronological sources; ethnographic and comparative-religious sources; mineralogical and natural-philosophical sources; and methodological or source-critical materials. The sources and scholarly literature were selected according to three criteria: direct relevance to Al-Biruni's empirical procedures, availability of exact page references, and bibliographic clarity. Sources without reliable page data were not used as the basis for precise factual claims.

RESULTS. The analyzed literature shows that Al-Biruni's works preserve empirical knowledge in several interrelated forms. The first form is astronomical observation. Even in his youth, Al-Biruni was engaged in the determination of geographical and astronomical data. Karimboyev and co-authors note that in his "Geodesy" Al-Biruni recorded that he determined the latitude of Kath in 990, which indicates an early use of astronomical observation for geographical purposes [Karimboyev et al., 2023, p. 54]. This fact is important from a source-critical perspective because it shows that his geographical knowledge was not simply inherited from earlier authorities, but was connected with personal observation and calculation.

A second form is geodetic measurement. Al-Biruni's geographical works function as sources for understanding how medieval scholars connected mathematical astronomy with the physical measurement of the Earth. King shows that Al-Biruni discussed the length of one degree of the meridian and referred to the value of $18 \frac{1}{3}$ farsakhs, or 55 miles, for one degree [King, 2000, p. 213]. At the same time, he did not accept earlier measurements uncritically. He examined data on the distance between Mecca and Baghdad and assessed Mansur ibn Talha's value for the latitude of Mecca as $21;40^\circ$, close to the rounded value of $21;42^\circ$ [King, 2000, p. 221]. He also questioned the value of $56 \frac{2}{3}$ miles derived from

the Ma'munid expedition, considering it problematic [King, 2000, p. 229]. These examples show that Al-Biruni's works are valuable because they preserve not only numerical results, but also the practice of evaluating earlier data.

The geodetic dimension of Al-Biruni's empiricism is further illustrated by the measurement of the Earth's radius. Sparavigna notes that, when the Arabic mile is converted into English miles, Al-Biruni's calculation of the Earth's radius differs from modern values by a relatively small margin [Sparavigna, 2013, p. 3]. Rizvi gives a more detailed reconstruction of the Nandna measurement and reports that Al-Biruni calculated the angle of the dip of the horizon as 34 minutes from the Nandna height [Rizvi, 1973, p. 10]. Rizvi also compares Al-Biruni's result for the Earth's mean radius with a later reference ellipsoid and finds a small numerical difference [Rizvi, 1973, p. 12]. These data should not be used to portray Al-Biruni as a modern geophysicist, but they clearly demonstrate that medieval empirical knowledge could combine field observation, trigonometry, and numerical correction.

A third form is synchronized astronomical observation. Bakhromzod's analysis of the longitude difference between Baghdad and Khwarazm shows that Al-Biruni and Abu al-Wafa al-Buzjani used the simultaneous observation of a lunar eclipse to determine the difference in longitude between the two regions [Bakhromzod, 2024, p. 1]. The same study notes that Al-Biruni refined astronomical instruments such as the astrolabe and sextant and used a large wall-mounted quadrant for accurate observation [Bakhromzod, 2024, p. 2]. This episode is important because it represents empirical knowledge as a coordinated procedure: the same celestial event could serve as a common reference point for observers located in different cities.

A fourth form is mineralogical and mechanical measurement. Al-Biruni's works on metals and precious stones preserve empirical knowledge about weight, volume, density, and material classification. Kuranbaeva states that the treatise "*Maqāla fī al-nisab allatī bayna al-filizzāt wa al-jawāhir fī al-ḥajm wa al-wazn*" was written between 1010 and 1017 and dealt with the relation between volume and weight in metals and precious stones [Kuranbaeva, 2025, p. 33]. Hassaan describes Al-Biruni's use of an equal-arm balance and an instrument measuring displaced water for determining the specific gravity of solids [Hassaan, 2015, p. 29526]. The reported accuracy of his specific-gravity values, with differences of less than one percent from modern values in some cases, indicates the high level of instrumental care in his work [Hassaan, 2015, p. 29528]. Such data make "*Kitāb al-Jamāhir*" and related treatises important sources for the history of measurement and material science.

A fifth form is pharmacological and terminological empiricism. Roohnavaz, Tekiner, Shams Ardakani, and Zargaran report that Al-Biruni's "*Saydana*" included 1116 monographs, covering plants, animals, and minerals, and recorded more than 4500 drug names in different languages [Roohnavaz et al., 2022, p. 359–360]. The same study shows that Al-Biruni divided the study of pharmacy into stages: gathering information on drugs, studying natural sciences and logic, and finally engaging in practice and experience [Roohnavaz et al., 2022, p. 359]. This demonstrates that empirical knowledge in Al-Biruni's works was not restricted to astronomy or geodesy; it also included classification, multilingual terminology, and practical medical knowledge.

A sixth form is ethnographic and comparative source criticism. Al-Biruni's study of India is one of the clearest examples of empirical knowledge in the humanities. Xoldarov notes that Al-Biruni learned

Sanskrit in order to access Indian texts directly and translate important Hindu works into Arabic [Xoldarov, 2024, p. 237]. He also compared Indian and Greek astronomical systems, showing that different cultures could approach similar intellectual problems through different methods [Xoldarov, 2024, p. 240]. In addition, Al-Biruni carefully examined the reliability of reports, distinguished myth from fact, and compared information to ensure accuracy [Xoldarov, 2024, p. 237]. These features make “Kitāb al-Hind” not only a source about Indian society, but also a source about medieval methods of cross-cultural verification.

The same ethnographic dimension appears in his attention to social practice. Xoldarov points out that Al-Biruni compared food laws in different cultures and analyzed the influence of environment, religion, and tradition on human behavior [Xoldarov, 2024, p. 240]. This shows that his empirical approach extended beyond celestial and material phenomena to social customs and cultural systems. Al-Biruni’s works therefore preserve a broad form of empirical knowledge in which observation, language, comparison, and interpretation interact.

A seventh form is the treatment of error. Sheynin’s study of Al-Biruni’s mathematical treatment of observations states that he introduced into mathematical practice the distinction between stochastic and deterministic components of error long before it became common in later European science [Sheynin, 1992, p. 299]. More cautiously formulated, this means that Al-Biruni was unusually attentive to the fact that observations could be distorted by human, instrumental, and environmental factors. Sheynin also notes that in “Taḥdīd” Al-Biruni analyzed how errors connected with the observer, instruments, and external conditions affected astronomical and geodetic calculations

[Sheynin, 1992, p. 306]. This is one of the strongest reasons to treat his works as sources for the history of empirical method.

DISCUSSION. Al-Biruni's works are especially important for the history of empirical knowledge because they show that medieval science was not a simple repetition of textual authority. His writings demonstrate a layered method: observation provided data; measurement gave numerical form to data; mathematical calculation made comparison possible; source criticism filtered unreliable reports; and linguistic awareness allowed access to foreign intellectual traditions. This structure appears across different fields. In geography, it appears as coordinates and distance; in astronomy, as observation of celestial events; in mineralogy, as density and specific weight; in pharmacology, as classification and terminology; in Indology, as direct engagement with language, texts, customs, and beliefs.

The difference between medieval empirical knowledge and modern experimental science must remain clear. Al-Biruni did not work within modern laboratories, statistical institutions, or contemporary protocols of experimental replication. His work belonged to a manuscript culture, to courtly and scholarly networks, and to an intellectual world where astronomy, mathematics, medicine, theology, philology, and philosophy were deeply interconnected. Nevertheless, the available evidence shows that he repeatedly sought to test inherited knowledge against observation, numerical calculation, and comparison. This historical form of empiricism should be recognized on its own terms.

Al-Biruni's empirical method was historically situated. The needs of religious practice encouraged the precise determination of qibla and prayer times; state administration and travel required geographical coordinates and distances; trade and craft practices made the

identification of stones and metals important; medical practice required drug classification; and intercultural contact with India created the need for linguistic competence and comparative interpretation. In this sense, empirical knowledge in Al-Biruni's works emerged from concrete social and intellectual needs, not from abstract theory alone.

From a source-critical perspective, his works are valuable for several fields. For the history of medieval science, they reveal how mathematical and observational procedures were connected. For the study of Central Asian intellectual culture, they show the role of Khwarazmian and Islamic scholarly traditions in the formation of evidence-based reasoning. For the study of Islamic scientific methodology, they demonstrate that observation and calculation could operate inside a religiously shaped intellectual world without being reduced to theology. For historical geography and geodesy, they preserve data on coordinates, distances, meridian measurements, and Earth-size calculations. For ethnography and comparative religion, they show how another culture could be studied through language, texts, social practice, and critical comparison.

The limitations of Al-Biruni's works must also be considered. Manuscript transmission, incomplete copies, later editorial interventions, and translation problems can affect the way his data are read today. Kuranbaeva notes that one surviving photocopy of the Beirut manuscript of the specific-gravity treatise consists of only 17 folios, while the original work contained 30 folios [Kuranbaeva, 2025, p. 36]. Such evidence reminds us that the modern researcher often works not with the full original text, but with transmitted, copied, abridged, or damaged forms of it. Therefore, Al-Biruni's works should be used with attention to codicology, textual history, and the difference between original observation and later preservation.

A second limitation is the danger of modernization. It is tempting to describe Al-Biruni as a modern scientist before modernity. Such a description may sound attractive, but it risks obscuring the historical specificity of his method. His empirical knowledge was not identical with modern experimental science; rather, it was a medieval form of disciplined inquiry that combined observation, calculation, comparison, and critical judgment. Its importance lies precisely in this historical structure: it shows how empirical reasoning could develop within the intellectual, linguistic, religious, and political conditions of medieval science.

CONCLUSION. Al-Biruni's works serve as key sources for reconstructing the formation of empirical knowledge in medieval science, for they preserve not merely information but also the very methods by which that information was observed, measured, compared, and verified. Their empirical value lies in the way direct observation, mathematical calculation, instrumental accuracy, source criticism, and cross-cultural interpretation are brought together – a combination that recurs across astronomy, geography, geodesy, mineralogy, pharmacology, chronology, and ethnography. His geographical and astronomical writings, in particular, reveal that medieval empirical knowledge could involve coordinated observation, numerical correction, careful attention to error, and mathematical modelling; his treatment of latitude, longitude, qibla, the measurement of the Earth, and lunar-eclipse observation is especially significant for the history of measurement. At the same time, the "Kitāb al-Hind" and related ethnographic materials show that empirical inquiry in his work was not confined to natural science but extended to the direct study of languages, texts, customs, beliefs, and social practices. Such study, however, demands caution: manuscript

transmission, translation, terminology, damaged copies, and later editorial interventions must all be weighed before broad historical conclusions are drawn. Accordingly, future research should concentrate on the comparison of manuscripts, the digital mapping of his geographical data, the detailed analysis of his mineralogical tables, and a wider comparison between his empirical practices and those of other medieval scientific traditions.

REFERENCES

1. Bakhromzod R. Determination of the Longitude Difference between Baghdad and Khwarezm Using a Lunar Eclipse // arXiv. – 2024. – P. 1–13.
2. Hassaan G. A. Innovation of Mechanical Machinery in Medieval Centuries, Part V: Balances and Astrolabes // Elixir Mechanical Engineering. – 2015. – Vol. 78. – P. 29526–29534.
3. Karimboyev Sh. D. et al. Studying the Scientific and Cultural Heritage of Abu Rayhan Beruni // Journal of Academic Research and Trends in Educational Sciences. – 2023. – Vol. 2, Issue 1. – P. 53–55.
4. King D. A. Too Many Cooks... A New Account of the Earliest Muslim Geodetic Measurements // Suhayl. – 2000. – Vol. 1. – P. 208–241.
5. Kuranbaeva U. S. On Abu Rayhan Al-Biruni's Treatise "Maqāla fī al-nisab allātī bayna al-filizzāt wa al-jawāhir fī al-ḥajm wa al-wazn" // Science and Innovation. – 2025. – Vol. 4, Issue 9. – P. 33–37.
6. Rizvi S. S. H. A Newly Discovered Book of al-Biruni "Ghurrah-uz-Zijāt" and al-Biruni's Measurements of Earth's Dimensions // Al-Biruni International Congress. – 1973. – P. 1–12.
7. Roohnavaz M., Tekiner H., Shams Ardakani M., Zargarani A. Abu Rayhan Biruni (973–1048 CE): The Pioneer in Clarifying the Role of

- Pharmacy in Medical Practice // Traditional and Integrative Medicine. – 2022. – Vol. 7, № 3. – P. 357–360.
8. Sheynin O. Al-Bīrūnī and the Mathematical Treatment of Observations // Arabic Sciences and Philosophy. – Cambridge University Press, 1992. – Vol. 2, Issue 2. – P. 299–306.
 9. Sparavigna A. C. The Science of al-Biruni // International Journal of Sciences. – 2013. – Vol. 2, Issue 2. – P. 52–60.
 10. Ungalov A. The Political Situation in Movarounnahr on the Eve of the Invasion of the Arab Caliphate // JournalNX – A Multidisciplinary Peer Reviewed Journal. – 2020. – P. 670.
 11. Хуснутдинова, К., & Муслимова, Ю. (2020). Поиск кратных и рассеянных звездных скоплений на близких расстояниях. Молодой исследователь: вызовы и перспективы. Москва, 31(178), 26.
 12. Муслимова, Ю. Ч., & им Низами, Т. Г. П. У. (2022). Формирование экологической культуры при обучении астрономии в непрерывном образовании.“. Парадигма современной науки в условиях модернизации и инновационного развития научной мысли: теория и практика”-2022-с, 705-708.
 13. Абраева, М., Халилова, Р. У., & Муслимова, Ю. Ч. (2020). Анализ двойных рассеянных звездных скоплений из разных каталогов вероятно двойных РЗС. In Colloquium-journal (No. 22 (74), pp. 17-19). Голопристанський міськрайонний центр зайнятості.
 14. Muminov, M. M., Nuritdninov, S. N., Latyov, A. A., & Muslimova, Y. (2000). Search for double and multiple open star clusters. Astronomical and Astrophysical Transactions, 18(4), 645-647.
 15. Xoldarov S. R. Al-Biruni’s Anthropological Views (Historical Analysis) // American Journal of Social Sciences and Humanity Research. – 2024. – Vol. 04, Issue 12. – P. 235–241.