

Al-Biruni and geodesy

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Core question

How did geometry, astronomy and field measurement become a system for locating places and estimating the dimensions of Earth?

Historical and evolutionary context

Abu Rayhan al-Biruni (973–c.1048) worked across astronomy, mathematics, geography, chronology and comparative scholarship. In geodesy he used trigonometric measurement and astronomical observations to connect local measurements with global dimensions. A famous method estimated Earth's radius from the dip of the horizon observed from a mountain whose height had first been determined geometrically.

The importance of al-Biruni is not a modern-looking numerical answer alone. His work joined instruments, geometry, repeated observation and explicit error-sensitive procedure. He also compiled coordinates for places while distinguishing direct measurements from inherited data.

What could communities know before this transition?

Eratosthenes and later geographers had already estimated Earth's size; Ptolemaic geography offered coordinate frameworks. The persistent limitation was how to derive global quantities from measurements made at particular sites with imperfect instruments and uncertain inherited coordinates.

What changed?

Al-Biruni made geodesy a **chain of transformations from local measurable quantities to global spatial inference**. Triangles, angular measurements and astronomical reference points could connect inaccessible distances.

Why could this capability emerge?

Islamic astronomy required accurate directions, times and coordinates. Mathematical traditions in trigonometry and access to Greek and Indian astronomy provided tools, while travel and political geography created practical incentives.

What later forms of knowledge did it enable?

The same epistemic pattern—measure locally, model geometrically, infer globally—became central to surveying, cartography and later geodesy. It also illustrates how a scientific result can depend on calibration and propagation of measurement uncertainty.

New limits and risks

Historical reconstructions sometimes report al-Biruni's radius estimate with spurious modern precision. The length of the historical mile and details of observational conditions matter. Accuracy should therefore be discussed with assumptions exposed.

What changed in the architecture of human knowledge?

Geometry became a bridge from **accessible observations to inaccessible dimensions**.

Loss, exclusion and uncertainty

Not all coordinates attributed to al-Biruni were personally measured, and many values circulated through earlier tables. His achievement lies partly in critical comparison of data, not merely in individual measurement.

Dependency map

- DIRECT ← PIO-032 Translation, commentary and original science in the Islamic world
- RETROSPECTIVE ← PIO-026 Eratosthenes and the size of Earth
- INDIRECT ← PIO-027 Hipparchus and quantitative astronomy
- INDIRECT ← PIO-031 Indian zero, positional notation and astronomy
- INDIRECT → PIO-042 Maps, coordinates and the representation of space

References

1. al-Biruni. *The Determination of the Coordinates of Positions for the Correction of Distances Between Cities*, trans. J. Ali. American University of Beirut (1967).
2. Kennedy, E. S. A survey of Islamic astronomical tables. *Transactions of the American Philosophical Society* 46(2), 123-177 (1956). <https://doi.org/10.2307/1005726>
3. O'Connor, J. J. & Robertson, E. F. Al-Biruni. MacTutor History of Mathematics, University of St Andrews.