Cosmic Echoes in the Art and Architecture of the Islamic Golden Age

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Abstract. This paper explores the embodiment of astronomy in the art and architecture of the Islamic Golden Age (eighth to fourteenth centuries CE), highlighting the contributions of scholars like al-Khwārizmī, al-Farghānī, al-Sufi, and Ibn al-Haytham. It examines how these figures advanced and transformed Graeco-Roman scientific legacies, illustrating the interconnectedness of global scientific development. Through an analysis of artefacts, texts, and monumental structures, the study reveals how Islamic societies conceptualized and depicted the cosmos, integrating astronomy with religious and cultural practices. Employing a decolonial framework, this study challenges Eurocentric narratives and advocates for an inclusive understanding of the history of human interaction with the cosmos, celebrating the intellectual traditions of the Islamic Golden Age.

Charting the Skies: The Role of Islamic Astronomy in a Global Heritage

The Islamic Golden Age, spanning roughly from the eighth to the fourteenth century CE, stands as one of the most transformative eras in human history. It was a period not only of remarkable scientific ingenuity but also of profound cultural exchange and intellectual collaboration. During this time, the Islamic world became a nexus of knowledge, fostering advancements in fields as diverse as mathematics, astronomy, medicine, architecture, and philosophy.[1] This era was defined by a synthesis of ideas, where Greek, Indian, Persian, and pre-Islamic Arab traditions were preserved, expanded, and transmitted to subsequent generations.[2]

At the heart of this intellectual flourishing lay the translation movement, initiated under the Abbasid Caliphate and epitomized by institutions such

[1] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp.1–3.
[2] John Freely, *Aladdin's Lamp: How Greek Science Came to Europe Through the Islamic World* (New York: Knopf, 2009), pp.15–18.

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as the *Bayt al-Hikmah* (House of Wisdom) in Baghdad.[3] This movement was more than the mere preservation of ancient knowledge; it was a transformative process through which Islamic scholars developed new frameworks for understanding the natural world. Figures like al-Khwarizmi, the father of algebra, and Ibn al-Haytham, the pioneer of optics, exemplify the innovative spirit of this era.[4] They were not isolated geniuses but part of an intricate tapestry of cross-cultural intellectual exchange, demonstrating that scientific progress is rarely linear or confined to a single tradition. Astronomy emerged as a cornerstone of Islamic science, deeply embedded in the fabric of religious, cultural, and practical life.[5] Far from being a purely academic pursuit, astronomy had profound applications—from determining prayer times and the direction of Mecca to inspiring architectural and artistic endeavours. For example, the geometric patterns that adorn Islamic architecture often symbolize the infinite nature of the cosmos, reflecting an advanced engagement with celestial principles.[6]

As part of a broader decolonization effort, I am engaging with this project to disrupt entrenched Eurocentric historical perspectives and acknowledge the diverse and multifaceted contributions made by civilizations globally to our understanding of the cosmos. By revisiting the Islamic Golden Age, I seek to challenge the presumption of Western exceptionalism in intellectual history and dismantle the notion that modernity has a monopoly on scientific advancement. Furthermore, this project questions the delusions of presumed self-importance, our arrogant posturing, and the belief that modern society is inherently more intelligent than those who came before us. Despite the technological advancements that distinguish our era, the fundamental essence of human curiosity and ingenuity remains unchanged. It serves as a reminder that we fundamentally share many similarities with the early astronomers who first charted the stars.

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[3] Dimitri Gutas, *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early Abbasid Society* (London: Routledge, 2001), pp.23–25.

[4] Roshdi Rashed, *Encyclopedia of the History of Arabic Science*, vol. 1, *Astronomy, Theoretical and Applied* (London: Routledge, 1996), pp.194–98.

[5] David A. King, *Astronomy in the Service of Islam* (Aldershot: Variorum, 1993), pp.45–50.

[6] Sheila S. Blair and Jonathan M. Bloom, *Islamic Art and Architecture 650–1250* (New Haven: Yale University Press, 1994), pp.190–92.

This paper explores the profound contributions of the Islamic Golden Age to astronomy and related disciplines, situating these advancements within their broader cultural and historical contexts. The story of the Islamic Golden Age is not merely one of historical interest; it offers enduring lessons on the power of knowledge, inclusivity, and collective human achievement. As we confront modern crises—ranging from climate change to technological inequality—the legacy of this era inspires us to rethink the boundaries of science and the possibilities of global intellectual cooperation.

Integrating a Decolonial Framework into Islamic Astronomy

Decolonial thought, pioneered by Aníbal Quijano and Walter Mignolo, provides a framework for interrogating the relationship between knowledge, power, and history. Quijano's concept of the coloniality of power emphasizes that modern Western dominance was inseparable from a global matrix of political, economic, and epistemic control that persisted long after the formal end of colonialism. His claim that 'there is no modernity without coloniality' reframed Western science and historiography as not universal achievements but as products of a system that actively marginalized other ways of knowing.[7] Mignolo expands this insight by describing coloniality as the 'darker side" of Western modernity, noting that the rhetoric of progress and civilization was always accompanied by the suppression of non-European peoples and knowledges.[8] In response, decolonial scholars call for epistemic delinking, a conscious disengagement from Eurocentric grand narratives and a restoration of knowledge from the perspectives of colonized peoples. Such an approach reveals that what Western thought has labelled as objective or universal is in fact rooted geopolitical and historical contexts that systematically silenced other epistemologies.

Linda Tuhiwai Smith's *Decolonizing Methodologies* deepens this critique by examining the complicity of research and historiography in the imperial project. She contends that scholarship has been 'inextricably linked to European imperialism and colonialism', such that the very word 'research' often carries traumatic associations for Indigenous

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[7] Aníbal Quijano, 'Coloniality and Modernity/Rationality', *Cultural Studies* 21, no. 2–3 (2007): pp.168–78.

[8] Walter D. Mignolo, *The Darker Side of Western Modernity: Global Futures, Decolonial Options* (Durham, NC: Duke University Press, 2011), pp.xv–xviii.

communities.[9] Academic knowledge production, she argues, has frequently reduced Indigenous and non-Western peoples to objects of study, denying them agency in defining their own past. A decolonial framework instead centres subaltern perspectives, treating Indigenous, African, Asian, and Islamic intellectual traditions as epistemologies rather than as filtered through a Western gaze. Māori and other Indigenous methodologies, for instance, emphasize community, holistic knowledge, and accountability, challenging the supposedly universal norms of modern research.[10] In historical studies, Dipesh Chakrabarty's call to 'provincialize Europe' similarly seeks to displace the assumption that modernity and rationality first appeared in Europe and then diffused outward, thereby restoring the legitimacy of multiple coexisting histories.[11] Boaventura de Sousa Santos adds to this by describing colonial expansion as a process of epistemicide, in which entire systems of knowledge—from pre-colonial sciences to non-Western philosophies—were erased or delegitimized.[12] Decolonial thinkers therefore advocate for what Mignolo calls pluriversality: a vision of many epistemic centres rather than a single, universalized West.[13] Taken together, these approaches expose the power relations embedded in what has been presented as 'knowledge' and open space for recovering suppressed intellectual traditions.

When applied to the historiography of Islamic science and art, a decolonial framework reveals how profoundly Eurocentric narratives have distorted the past. Standard accounts often reduced the Islamic Golden Age to a marginal footnote, casting Muslim scholars as passive custodians of Greek knowledge until the European Renaissance supposedly awakened civilization from a 'Dark Age'. This erasure is not incidental but reflects what decolonial scholars describe as the colonization of time—the institutionalization of European temporality as the universal measure of

[9] Linda Tuhiwai Smith, *Decolonizing Methodologies: Research and Indigenous Peoples*, 2nd edn (London: Zed Books, 2012), p.1.
[10] Linda Tuhiwai Smith, *Decolonizing Methodologies*, pp.125–140
[11] Dipesh Chakrabarty, *Provincializing Europe: Postcolonial Thought and Historical Difference*, 2nd edn (Princeton, NJ: Princeton University Press, 2008), pp.3–6
[12] Boaventura de Sousa Santos, *Epistemologies of the South: Justice against Epistemicide* (Boulder, CO: Paradigm Publishers, 2014), p.92
[13] Walter D. Mignolo, 'Delinking: The Rhetoric of Modernity, the Logic of Coloniality and the Grammar of Decoloniality', *Cultural Studies* 21, no. 2–3 (2007): pp.449.

history, which cast non-Europeans as perpetually behind.[14] The very labelling of the 'Middle Ages', for instance, positioned the centuries of Islamic scientific flourishing as a void between classical antiquity and Europe's own modern rebirth. Nineteenth-century European historiography went further, 'manufacturing the history of [European] superiority' by asserting that only Europeans had created history, while other civilizations merely existed without dynamism.[15] Such distortions downplayed the profound intellectual transformations of the eleventh and twelfth centuries—many catalyzed by contact with Islamic centres in Spain, Sicily, and the Levant—and effectively erased fifteen centuries of scientific activity in the Middle East.[16] A decolonial reading challenges these distortions by recognizing the Islamic Golden Age as a vibrant epoch of innovation and knowledge-making that unfolded concurrently with medieval Europe, not in its shadow. By decentring Europe as the measure of progress, concepts of advancement and backwardness are revealed as constructed categories designed to privilege the West. In this reframing, the Islamic Golden Age becomes an instance of polycentric modernity, where Baghdad, Cairo, and Samarkand stood as intellectual hubs equal to any European city of the time.

This reframing carries significant implications for how Islamic contributions to astronomy and art are understood. Figures such as al-Khwārizmī, al-Farghānī, al-Sūfī, and Ibn al-Haytham emerge not as derivative transmitters of Greek knowledge but as transformative thinkers who expanded the frontiers of science. George Saliba has shown, for example, that the astronomical models developed at the Maragha Observatory in the thirteenth century introduced the 'Tusi couple', a mathematical innovation later adopted by Nicolaus Copernicus in his heliocentric theory.[17] Similarly, the Jalali calendar reform of 1079 CE achieved a solar accuracy rivalling that of the Gregorian calendar introduced in Europe centuries later. Such evidence reveals that

[14] Walter D. Mignolo, *Local Histories/Global Designs: Coloniality, Subaltern Knowledges, and Border Thinking* (Princeton, NJ: Princeton University Press, 2000), pp.7–10.

[15] Dipesh Chakrabarty, *Provincializing Europe: Postcolonial Thought and Historical Difference*, 2nd edn (Princeton, NJ: Princeton University Press, 2008), p.27.

[16] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp.12–15

[17] George Saliba, *Islamic Science and the Making of the European Renaissance*, pp.189–193.

Renaissance Europe was not a self-contained miracle of rebirth but was fertilized by Islamic intellectual traditions. In the domain of art and architecture, a decolonial perspective encourages us to read intricate mosque geometries and astrolabe designs not as exotic ornament but as visual languages of scientific and cosmological inquiry. These cultural products embody a rigorous engagement with astronomy and metaphysics, demonstrating how science, art, and faith were deeply interwoven in the Islamic world. To 'relink' these works to their intellectual contexts, in Mignolo's sense, is to see them as parallel to, and in some respects more advanced than, contemporaneous European artistic-scientific practices. A decolonial framework, thus, allows us to reposition the Islamic Golden Age not as marginal or derivative but as integral to the collective history of science. It dismantles the hierarchy that elevates Europe as the sole protagonist of modernity and instead foregrounds a multiplicity of epistemic traditions that interacted across history.

Foundations of a Scientific Revolution: Translation, Collaboration, and the Abbasid Era

The foundations of Islamic science, and astronomy in particular, were laid during a transformative period in Islamic history that began approximately two centuries after the Prophet Muhammad's emigration from Mecca to Medina in 622 CE.[18] This event, known as the Hegira, marks the beginning of the Islamic calendar and represents a turning point not only in Islamic religious life but also in the eventual development of a vibrant scientific culture.[19] The first centuries of Islam were characterized by rapid territorial expansion, political upheaval, and the consolidation of a unified religious identity.[20] These conditions delayed the emergence of a stable intellectual environment. It was not until the late second century and early third century of the Hegira that a sufficiently cosmopolitan and politically stable atmosphere allowed the sciences to flourish.[21]

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[18] Seyyed Hossein Nasr, *Science and Civilization in Islam* (Cambridge, MA: Harvard University Press, 1968), p.23.

[19] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp.14–16.

[20] Hugh Kennedy, *The Prophet and the Age of the Caliphates: The Islamic Near East from the Sixth to the Eleventh Century*, 3rd edn (London: Routledge, 2016), pp.120–23.

[21] Dimitri Gutas, *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early Abbasid Society* (London: Routledge, 2001), pp.37–40.

The rise of the Abbasid dynasty in 750 CE marked the beginning of a golden age for scientific inquiry. With the establishment of Baghdad as the Abbasid capital in 762 CE, the city became a cosmopolitan centre of trade, culture, and knowledge.[22] The Abbasid caliphs, understanding the importance of intellectual engagement, launched an ambitious translation movement to preserve and enhance the scientific legacy of past civilizations. This translation movement should not be framed as a passive transfer of Greek knowledge to a stagnant culture, but as a dynamic process of knowledge production in its own right. By highlighting the agency of Islamic translators and scholars in adapting and elaborating upon received texts, a decolonial perspective challenges Eurocentric narratives that downplay the originality and global impact of this enterprise. Within a few decades, the major scientific works of antiquity—including those of Galen, Aristotle, Euclid, Ptolemy, Archimedes, and Apollonius—had been translated into Arabic.[23] Muslim scholars were not alone in this monumental effort; Christian, Jewish, and even pagan scholars played significant roles in the translation process, reflecting the inclusive and collaborative spirit of the era.

The House of Wisdom (*Bayt al-Hikmah*), founded under the patronage of Caliph al-Ma'mun (r. 813–833 CE), epitomized the intellectual ambition of the Abbasid dynasty. This institution became a hub for scholars from diverse religious and cultural backgrounds, facilitating not only the translation of texts but also the synthesis and expansion of knowledge. Al-Ma'mun appointed Hunayn ibn Ishaq, a Nestorian Christian with a profound command of Greek, to lead the translation efforts.[24] Hunayn's Arabic versions of works by Plato, Aristotle, Hippocrates, and Galen became foundational texts for both Islamic and European scholars.[25]

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[22] Hugh Kennedy, *When Baghdad Ruled the Muslim World: The Rise and Fall of Islam's Greatest Dynasty* (Cambridge, MA: Da Capo Press, 2004), pp.78–82.

[23] A. I. Sabra, 'The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement', *History of Science* 25 (1987), pp.223–43 (p. 228).

[24] Roshdi Rashed, *Encyclopedia of the History of Arabic Science*, vol. 1, *Astronomy, Theoretical and Applied* (London: Routledge, 1996), pp.234–37.

[25] Dimitri Gutas, *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early Abbasid Society* (London: Routledge, 2001), pp.58–60.

Fig 1. A manuscript illustration by Yahya ibn Vaseti, featured in the *Maqamat* of al-Hariri, housed at the Bibliothèque Nationale de France. The image portrays a library scene with students gathered within. Image courtesy of Wikimedia Commons.

Mathematical and astronomical advancements were among the most significant outcomes of this intellectual activity. Thabit ibn Qurra, a Sabian polymath, was one of the leading figures of this period.[26] He produced over one hundred scientific treatises, including a commentary on Ptolemy's Almagest, and played a crucial role in refining Greek astronomical theories.[27]

Similarly, al-Khwarizmi, whose name gave rise to the term 'algorithm,' revolutionized mathematics and astronomy.[28] His treatise *Al-Jabr wa'l-*

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[26] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp.88–91.

[27] Edward S. Kennedy, *Studies in the Islamic Exact Sciences* (Beirut: American University of Beirut Press, 1983), pp.165–70.

[28] Muhammad ibn Musa al-Khwarizmi, *Kitab al-Mukhtasar fi Hisab al-Jabr wal-Muqabala*, trans. Frederic Rosen (*The Algebra of Mohammed Ben Musa*) (London: The Oriental Translation Fund, 1831), pp.3–8.

Muqabala (The Compendious Book on Calculation by Completion and Balancing) laid the foundations of algebra, offering systematic solutions for linear and quadratic equations.[29] Al-Khwarizmi's writings on arithmetic, which incorporated Hindu numerals and the concept of zero, were later translated into Latin by Robert of Chester in 1145.[30] These translations introduced Arabic numerals to Europe, profoundly influencing medieval and modern mathematics.[31]

Another prominent figure of the Abbasid period was Ahmad al-Farghani, a mathematical astronomer whose textbook, *A Compendium of the Science of the Stars* (Kitab al-Harakat al-Samawiyya wa Jawami Ilm al-Nujum), became one of the most influential works on celestial mechanics. Written between 833 and 857 CE, it was translated into Latin in Toledo by John of Seville and Gerard of Cremona in the twelfth century, making al-Farghani's ideas accessible to European scholars.[32] Gerard's translation later informed Dante Alighieri's understanding of Ptolemaic astronomy and became a critical text for medieval European universities.[33]

The translation movement and the scholarly efforts it catalyzed were instrumental in transforming Baghdad into a beacon of intellectual activity. By adapting and building upon the works of Greek, Persian, and Indian scholars, the Islamic world did not merely preserve ancient knowledge but actively transformed it. The emergence of innovative concepts in fields such as trigonometry, algebra, and spherical geometry exemplifies the creative dynamism of the period.

This period also highlights the cosmopolitan and collaborative nature of Islamic science. The participation of scholars from diverse cultural and religious backgrounds—such as Thabit ibn Qurra, Hunayn ibn Ishaq, and al-Khwarizmi—reflects the Abbasid dynasty's commitment to fostering an environment where knowledge transcended sectarian and cultural

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[29] Roshdi Rashed, *The Development of Arabic Mathematics: Between Arithmetic and Algebra* (Dordrecht: Springer, 1994), pp.141–44.

[30] Robert of Chester, *Liber algebrae et almucabala*, trans. Louis Charles Karpinski (*The Algebra of al-Khwarizmi*) (Ann Arbor, MI: University of Michigan Press, 1915), pp.3–5.

[31] John Freely, *Aladdin's Lamp: How Greek Science Came to Europe Through the Islamic World* (New York: Knopf, 2009), pp.77–80.

[32] Paul Kunitzsch, *The Arabs and the Stars: Texts and Traditions on the Fixed Stars and Their Influence in Medieval Europe* (Northampton: Variorum, 1989), pp.78–83.

[33] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp.98–100.

boundaries. This ethos of inclusivity and intellectual curiosity set the stage for the profound advancements that characterized the Islamic Golden Age. By laying these intellectual foundations, Islamic scholars not only advanced their own scientific traditions but also laid the groundwork for the European Renaissance. Their contributions underscore the interconnectedness of global scientific traditions, challenging the narrative that intellectual progress is confined to a single culture or era. The achievements of the Abbasid scholars remind us that the pursuit of knowledge is a shared human endeavour, driven by curiosity, collaboration, and the desire to understand the cosmos.

The Celestial Mandate: Religious Observances and the Evolution of Islamic Astronomy

A major impetus for the flourishing of astronomy in the Islamic world stemmed from the practical and theological demands of religious observance. These requirements presented unique challenges in mathematical astronomy, particularly in spherical geometry, and motivated the development of sophisticated astronomical techniques. Far from being an abstract intellectual exercise, astronomy was deeply intertwined with religious life, serving as a critical tool for the fulfilment of Islamic rituals and practices.

At the time of the Prophet Muhammad, lunar calendars were already integral to religious observances among Jewish and Christian communities. Holy days like Passover and Easter were determined by the phases of the moon, requiring these communities to reconcile the 29.5-day lunar month with the 365-day solar year.[34] The solution lay in the 19-year Metonic cycle, devised by the Meton of Athens in 430 BCE, which synchronized lunar and solar calendars by inserting an extra month in seven out of every 19 years.[35] In contrast, the Islamic calendar, as decreed in the Qur'an (Chapter 9, Verse 36), adheres strictly to a lunar system:

> The number of months in the sight of God is twelve [in a year]—so ordained by Him the day He created the heavens and the earth; of them four are sacred: that is the straight usage.[36]

[34] Edward S. Kennedy, *Astronomy* and *Astrology in the Medieval Islamic World* (Aldershot: Variorum, 1998), pp.54–55.

[35] Seyyed Hossein Nasr, *Science and Civilization in Islam* (Cambridge, MA: Harvard University Press, 1968), pp.12–15.

[36] Qur'an, Chapter 9, Verse 36, trans. M. A. S. Abdel Haleem, *The Qur'an: A New Translation* (Oxford: Oxford University Press, 2005), p.119.

Caliph ʿUmar I (r. 634–644 CE) interpreted this decree as forbidding intercalation, resulting in a purely lunar calendar that remains in use today in most Islamic countries. Because the lunar year is about eleven days shorter than the solar year, Islamic holidays like Ramadan, the month of fasting, slowly cycle through all seasons over a 33-year period.[37]

The determination of the beginning of Islamic months, particularly Ramadan, posed a unique challenge. Unlike the astronomical definition of the new moon, which occurs when the moon and sun share the same celestial longitude and the moon is invisible, Islamic months begin when the thin crescent moon is first sighted in the western evening sky. Predicting this visibility required precise calculations and advanced models of lunar motion. Islamic astronomers, working with Ptolemaic models, adapted them to focus on the moon's motion relative to the horizon rather than the ecliptic, introducing a new level of sophistication in spherical geometry.[38]

The religious impetus for astronomy extended beyond the calendar. Muslims are required to pray five times a day, facing Mecca, a direction known as the *qibla*. Determining the qibla from different locations required advanced geometrical methods to calculate the direction of Mecca on the curved surface of the Earth.[39] Additionally, the five daily prayers are tied to specific celestial events—sunrise, midday, afternoon, sunset, and evening—necessitating the calculation of precise prayer times based on the positions of celestial bodies.

To solve such problems, Islamic astronomers refined spherical trigonometry, moving beyond the cumbersome methods inherited from Ptolemy, which relied on the Menelaus theorem and required repeated calculations involving intersecting right triangles.[40] By the ninth century CE, Islamic scholars had identified all six modern trigonometric

[37] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp.91–93.
[38] David A. King, *In Synchrony with the Heavens: Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization*, vol. 1 (Leiden: Brill, 2004), pp.235–38.
[39] David A. King, *World-Maps for Finding the Direction and Distance to Mecca: Innovation and Tradition in Islamic Science* (Leiden: Brill, 1999), pp.102–07.
[40] Roshdi Rashed, *Encyclopedia of the History of Arabic Science*, vol. 2, *Mathematics and the Physical Sciences* (London: Routledge, 1996), pp.449–52.

functions—sine, cosine, tangent, cotangent, secant, and cosecant.[41] While the sine function originated in Indian astronomy, the remaining functions were developed and refined within the Islamic tradition.[42] The discovery of trigonometric identities, such as the law of sines, revolutionized spherical geometry, enabling more efficient calculations.

The etymology of the word 'sine' reflects the cross-cultural exchange that underpinned Islamic science. Derived from the Sanskrit word *ardhajya* (half chord), it was transliterated into Arabic as *jyb*.[43] In the absence of vowels, *jyb* was later misread as *jayb*, meaning pocket or gulf, and subsequently translated into Latin as sinus.[44] This linguistic journey highlights the interconnectedness of Islamic, Indian, and European intellectual traditions.

Women also contributed to Islamic astronomy, exemplifying the inclusivity of this intellectual culture. Mariam al-ʿIjliyyah, a tenth-century CE astrolabe maker active in Aleppo, gained renown for her craftsmanship.[45] Similarly, Fatima of Madrid, the daughter of the Andalusian astronomer Maslama al-Majriti, collaborated with her father to produce star and planetary tables, advancing the precision of celestial data.[46] These contributions highlight the diversity of voices shaping the development of Islamic science.

Mapping the Heavens: Stellar Catalogues and the Astrolabe in Islamic Science

As religious needs spurred advancements in astronomy, the resulting knowledge led to innovations in tools and techniques. Two such monumental contributions—the refinement of stellar catalogues and the

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41 E. S. Kennedy, *The Planetary Equatorium of Jamshid Ghiyath al-Din al-Kashi* (Princeton, NJ: Princeton University Press, 1960), pp.52–56.

42 David Pingree, *The History of Mathematical Astronomy in India* (Leiden: Brill, 1981), pp.140–42.

43 Paul Kunitzsch, *The Arabs and the Stars: Texts and Traditions on the Fixed Stars and Their Influence in Medieval Europe* (Northampton: Variorum, 1989), pp.66–68.

44 Noel Swerdlow, *The Babylonian Theory of the Planets* (Princeton, NJ: Princeton University Press, 1998), pp.74–76.

45 Emilie Savage-Smith and Andrea P. A. Belloli, *Islamicate Celestial Globes: Their History, Construction, and Use* (London: Oxford University Press, 1985), pp.45–50.

46 Savage Smith and Belloli, *Islamicate Celestial Globes: Their History, Construction, and Use*, pp.45–50.

development of the astrolabe—epitomize the Islamic Golden Age's impact on global science. These tools, central to the study of the heavens, bridged cultural and scientific traditions, connecting the ancient Greek and Indian worlds to medieval Europe.

Ptolemy's Almagest, written in the second century CE, provided a foundational star catalogue that listed over 1,000 stars along with their magnitudes and positions.[47] Islamic astronomers inherited this work, but rather than passively preserving it, they subjected it to critical revision. One of the most significant contributions came from tenth-century Persian astronomer ʿAbd al-Raḥmān al-Ṣūfī. His *Kitāb suwar al-kawākib al-thābitah* (Book of Fixed Stars) retained Ptolemy's star list but introduced numerous corrections to star magnitudes, descriptions, and positions.[48] Al-Ṣūfī's meticulous observations included stars that were not previously recorded by Ptolemy, such as the Andromeda Galaxy, which he described as a 'small cloud.'[49]

Al-Ṣūfī's *Book of Fixed Stars* also included vivid illustrations of constellations that bridged scientific observation and artistic representation. These illustrations differed from Ptolemy's descriptions, often incorporating Arabic star names that are still in use today, such as Betelgeuse (from *Yad al-Jauza*, meaning 'The Hand of the Giant').[50] The integration of Arabic nomenclature into medieval Latin translations ensured that these terms entered the lexicon of European astronomers, influencing star charts and celestial atlases for centuries.

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[47] Ptolemy, *The Almagest*, trans. G. J. Toomer (Princeton, NJ: Princeton University Press, 1998), pp.325–28.

[48]Abd al-Raḥmān al-Ṣūfī, *Ṣuwar al-kawākib* (*Book of the Images of the Fixed Stars*), manuscript, c. 1730, Library of Congress, Washington, DC, https://www.loc.gov/item/2008401028/ [accessed 7 May 2024].

[49] Ihsan Hafez, *Abd al-Rahman al-Sufi and his Book of the Fixed Stars: A Journey of Re-Discovery*, PhD thesis, James Cook University, 2010, p.311.

[50] Paul Kunitzsch, *The Arabs and the Stars: Texts and Traditions on the Fixed Stars and Their Influence in Medieval Europe* (Northampton: Variorum, 1989), pp.78–83.

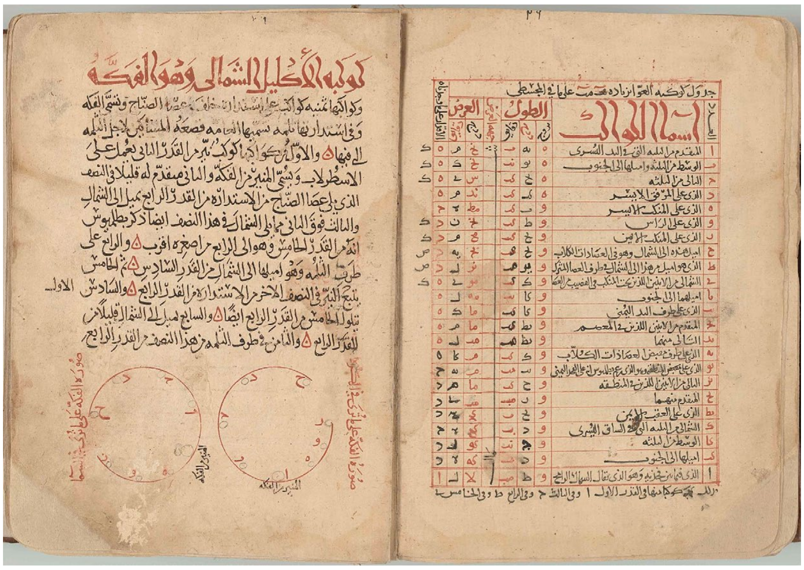

Fig 2. Two pages from a twelfth-century CE Iraqi illustrated manuscript of Abd al-Rahman al-Sufi's *Book of Fixed Stars*, now part of the Museum of Islamic Art collection in Doha. The left page describes Corona Borealis (The Northern Crown), while the right page provides a star table for the preceding constellation, Boötes (The Herdsman). Image courtesy of Google Art Project.

The influence of Islamic stellar catalogues extended to medieval Europe through translations of Arabic texts. For example, Gerard of Cremona's twelfth-century Latin translation of the Almagest, supplemented by Arabic refinements, introduced European scholars to advanced celestial models.[51] This integration of Islamic knowledge into European astronomy underscores the collaborative and transcontinental nature of scientific progress.

The astrolabe, a highly versatile instrument that epitomized Islamic scientific ingenuity, became one of the most emblematic tools of medieval astronomy.[52] Originally developed in ancient Greece, the astrolabe underwent significant refinements in the Islamic world, where it was

[51] Charles Burnett, *Arabic into Latin in the Middle Ages: The Translators and Their Intellectual and Social Context* (London: Ashgate, 2009), pp.101–04.
[52] David A. King, *Islamic Mathematical Astronomy* (London: Variorum Reprints, 1986), pp.150–53.

transformed into a highly accurate and multifunctional device.[53] A typical astrolabe consists of a brass or bronze disk, or *umm* (mother), upon which celestial coordinates are engraved. Superimposed on the disk is a rotating lattice, or *rete* (net), that marks the positions of prominent stars.[54]

The Islamic refinement of the astrolabe allowed it to serve a wide variety of purposes. These included determining the altitude of celestial bodies, calculating prayer times, finding the direction of Mecca, and solving complex mathematical problems.[55] In addition, astrolabes were used for navigation, particularly in the Indian Ocean, where the trading routes of the Islamic world demanded precise maritime calculations.[56]

Theoretical advancements also accompanied these practical innovations. In the ninth century CE, ʿAlī ibn ʿĪsā wrote one of the earliest comprehensive treatises on the astrolabe, which detailed its construction and applications. His work laid the foundation for subsequent advancements by figures such as al-Battani and Ibn Yunus, who expanded the astrolabe's capabilities to include intricate astronomical calculations.[57]

The astrolabe became a cultural symbol of Islamic scientific achievement, with its intricate designs and functional precision embodying the confluence of science and art. These instruments were often engraved with ornate geometric patterns and inscriptions, reflecting the broader aesthetic values of Islamic culture. Beyond their practical uses, astrolabes were viewed as objects of intellectual and spiritual significance, symbolizing humanity's effort to understand the cosmos and its divine order.

The dissemination of the astrolabe to Europe in the twelfth and thirteenth centuries, facilitated by Latin translations of Arabic treatises, significantly influenced the development of Western astronomy.[58] For example, Geoffrey Chaucer's *Treatise on the Astrolabe* (1391 CE), written

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[53] L. A. Mayer, *Islamic Astrolabists and Their Works* (Geneva: Albert Kundig, 1956), pp.3–8.

[54] Roshdi Rashed, *The Development of Arabic Mathematics: Between Arithmetic and Algebra* (Dordrecht: Springer, 1994), pp.222–25.

[55] George Saliba, *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam* (New York: NYU Press, 1994), pp.107–10.

[56] Toby E. Huff, *The Rise of Early Modern Science: Islam, China, and the West*, 2nd edn (Cambridge: Cambridge University Press, 2003), pp.125–28.

[57] Emilie Savage-Smith, *Islamic Science and Engineering* (Edinburgh: Edinburgh University Press, 1996), pp.56–58.

[58] David A. King, *In Synchrony with the Heavens: Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization* (Leiden: Brill, 2004), vol. 1, pp.203–210.

for his son, was based on Islamic sources and highlights the instrument's enduring importance in medieval Europe. The astrolabe also influenced the design of later instruments, such as the sextant, which became central to the Age of Discovery.[59]

Fig 3. Astrolabe by Nastulus, dated 101 AH (719 CE), housed in the al-Sabah Collection, Kuwait. This is the earliest known Islamic astrolabe with a definitive date, as earlier surviving Abbasid instruments are undated. Image courtesy of al-Sabah Collection, Kuwait.

The legacy of Islamic astronomy, particularly through stellar catalogues and the astrolabe, extends far beyond its immediate historical context. These contributions represent a paradigm shift in how humanity understands and navigates the cosmos, both literally and metaphorically.

- *Scientific Legacy* The innovations of Islamic astronomers formed the bedrock of modern astronomical practices. Their refinements to Ptolemaic models and their integration of observational precision with mathematical rigour laid the groundwork for future advancements in celestial mechanics. For example, the astrolabe's ability to measure the positions of celestial bodies influenced the development of instruments

[59] Geoffrey Chaucer, *A Treatise on the Astrolabe*, ed. Sigmund Eisner (Norman: University of Oklahoma Press, 2002), pp.15–18.

such as the telescope and the sextant. Even today, the Arabic origins of terms like ‘zenith’ and ‘azimuth’ remind us of the enduring influence of Islamic science.[60]

- *Global Knowledge Exchange:* The stellar catalogues and astrolabes of the Islamic world highlight the interconnectedness of global scientific traditions. By synthesizing knowledge from Greek, Indian, and Persian sources, and transmitting it to Europe, Islamic scholars acted as vital conduits in the global history of science. This collaborative exchange challenges the myth of scientific progress as a linear, Western-centric phenomenon, emphasizing instead the collective nature of intellectual advancement.
- *Cultural and Artistic Resonance*: Beyond their practical applications, these tools symbolize the fusion of functionality and beauty that defined Islamic scientific culture. The geometric and artistic embellishments of astrolabes reflect the philosophical and spiritual dimensions of Islamic cosmology, where the study of the heavens was seen to understand the divine. This holistic approach to science, art, and faith provides a valuable model for integrating multiple dimensions of human experience in contemporary scholarship.
- *Modern Relevance:* The legacy of Islamic astronomy carries profound lessons for the modern world. At a time when global collaboration is essential to addressing challenges such as climate change and technological inequality, the Islamic Golden Age serves as a reminder of the power of inclusive, transcultural scientific communities.

While Islamic astronomers did not always prioritize transient celestial phenomena—such as the supernova of 1054 CE, which was extensively documented in China—their emphasis on precision, systemic refinement, and the creation of enduring tools like the astrolabe demonstrates a profound commitment to the long-term advancement of science.[61] Yet

[60] David A. King, *Astronomical Instruments Between East and West* (Aldershot: Variorum, 1987), pp.75–78.

[61] The 1054 CE supernova was noted by Ibn Butlan, a Baghdad-based physician residing in Constantinople. His account, while not a formal astronomical record, provides evidence that scholars within the Islamic world were aware of and recorded unusual celestial occurrences. However, the event does not appear in major Islamic astronomical treatises, suggesting that while such phenomena were observed, they did not always integrate into the broader theoretical frameworks of Islamic astronomy in the same way as planetary motion, lunar cycles, or fixed star catalogues.

even the most precise instruments required dedicated spaces for observation, collaboration, and refinement. The pursuit of knowledge extended beyond individual scholars into purpose-built institutions—observatories that served as hubs for intellectual exchange, experimentation, and innovation. These centres not only advanced astronomical calculations but also institutionalized the study of the cosmos, laying the groundwork for future scientific revolutions.

Architectures of Knowledge: The Rise and Legacy of Islamic Observatories

The intellectual vitality of the Abbasid era was not limited to the translation and synthesis of knowledge. This spirit of innovation extended to the establishment of observatories, which institutionalized astronomy and catalyzed advancements that bridged theoretical research and practical applications. These observatories were not merely observational sites; they were centres of innovation, collaboration, and technological advancement that profoundly influenced both Islamic and global scientific traditions.

The Isfahan Observatory, also known as the MalikShah Observatory, holds the distinction of being the earliest known Islamic observatory. Constructed during the reign of Sultan Malik Shah I (r. 1072–1092 CE) and supervised by the renowned mathematician and astronomer Omar Khayyam, the observatory opened in 1074 CE.[62] Its most notable achievement was the development of the Jalali Calendar, a solar calendar introduced as a reform to the Islamic calendar. The Jalali Calendar, with its precise calculations of the solar year, was so accurate that it rivalled the Gregorian calendar later adopted in Europe.[63]

Unfortunately, little is known about the broader scope of the observatory's activities. Following Khayyam's death in 1092 CE, the observatory ceased operations, and no comprehensive records of its work survive.[64] This lack of documentation has left modern historians with only fragmentary glimpses into the institution's potential contributions to astronomy and other sciences. Nevertheless, the establishment of the Isfahan Observatory set a precedent for state-sponsored astronomical research in the Islamic world.

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[62] David A. King, *Astronomical Instruments Between East and West* (Aldershot: Variorum, 1987), pp.125–28.
[63] George Saliba, *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam* (New York: NYU Press, 1994), pp.175–78.
[64] Seyyed Hossein Nasr, *Science and Civilization in Islam* (Cambridge, MA: Harvard University Press, 1968), pp.98–100.

The Maragha Observatory, established in the thirteenth century CE under the patronage of Hulagu Khan, represents one of the most influential observatories in the history of astronomy. Situated in present-day Iran, the facility was designed and supervised by the polymath Nasir al-Din al-Tusi.[65] The observatory was a monumental undertaking that included living quarters for scholars, a library containing thousands of manuscripts, and a mosque, creating an environment conducive to interdisciplinary scholarship.[66]

The Maragha Observatory attracted leading astronomers from across the Islamic world and beyond, including scholars from as far as China.[67] Over a period of fifty years, the observatory's researchers made significant modifications to the Ptolemaic model of planetary motion, challenging its geocentric framework and laying the groundwork for later heliocentric theories. Among the most notable contributions was the 'Tusi couple,' a geometric model introduced by Nasir al-Din al-Tusi in 1247 CE.[68] This ingenious mechanism, which converted linear motion into circular motion, resolved several inconsistencies in Ptolemaic astronomy and was later adopted by Nicolaus Copernicus in his *De revolutionibus orbium coelestium*.[69]

The Maragha Observatory was more than just a site of observation; it was a hub of collaborative innovation. By integrating astronomical observations with mathematical rigour, the scholars at Maragha refined the understanding of celestial mechanics, trigonometry, and instrumentation. Their work not only advanced Islamic astronomy but also influenced the European Renaissance, underscoring the interconnectedness of global scientific traditions.

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[65] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp.148–52.

[66] E. S. Kennedy, *Studies in the Islamic Exact Sciences* (Beirut: American University of Beirut Press, 1983), pp. 289–92.

[67] Aydin Sayili, *The Observatory in Islam and Its Place in the General History of the Observatory* (Ankara: Türk Tarih Kurumu, 1960), pp.175–80.

[68] F. Jamil Ragep, *Nasir al-Din al-Tusi's Memoir on Astronomy (al-Tadhkira fi 'ilm al-hay'a)* (New York: Springer, 1993), pp.34–37.

[69] Noel Swerdlow, 'The Derivation and First Draft of Copernicus's Planetary Theory', *Proceedings of the American Philosophical Society*, 117.6 (1973), pp.423–32.

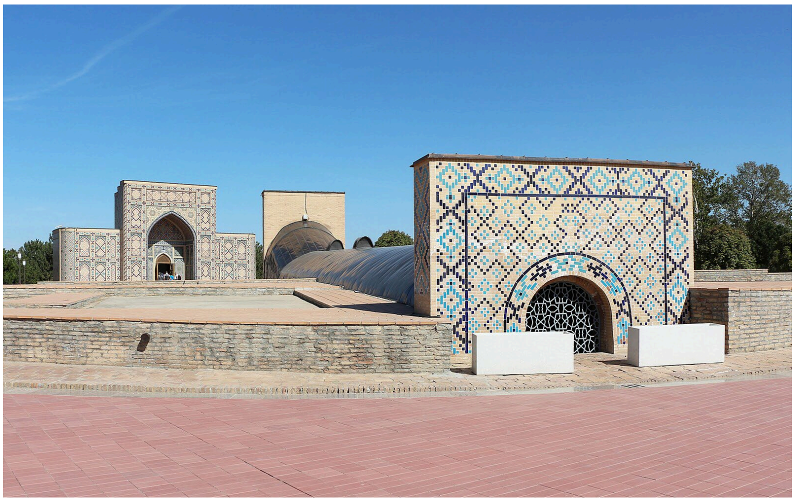

Fig 4. Ulugh Beg Observatory, Samarkand, Uzbekistan. Image courtesy of Wikimedia Commons.

Completed in 1429 CE under the direction of Ulugh Beg, a Timurid prince and astronomer, the Samarkand Observatory stands as a landmark in Islamic astronomy and a testament to his passion for celestial study.[70] The facility housed sophisticated instruments, including a massive meridian arc with a forty-meter radius that could measure celestial positions with unparalleled accuracy to within a few arcseconds. Other instruments included an armillary sphere and an azimuthal quadrant for measuring the horizontal angles of stars.[71]

The observatory's most enduring contribution was the *Zīj-i-Sultānī* (Sultan's Astronomical Tables), a comprehensive star catalogue compiled under Ulugh Beg's supervision. This work included precise measurements of over one thousand stars and remained one of the most accurate astronomical references of its time.[72] Ulugh Beg's observatory exemplified the synthesis of observational precision and mathematical sophistication, but it was tragically short-lived. Following Ulugh Beg's assassination in

[70] Robert Hillenbrand, *Islamic Architecture: Form, Function, and Meaning* (Edinburgh: Edinburgh University Press, 1994), pp.342–45.
[71] David A. King, *In Synchrony with the Heavens: The Call of the Muezzin and the Muslim Calendar*, vol. 2 (Leiden: Brill, 2005), pp 345–50.
[72] Paul Kunitzsch, *The Arabs and the Stars: Texts and Traditions on the Fixed Stars and Their Influence in Medieval Europe* (Northampton: Variorum, 1989), pp 83–86.

1449 CE, the observatory was dismantled, and much of its intellectual legacy was dispersed.[73]

In the late sixteenth century, the Ottoman Empire established its most ambitious astronomical institution: the Istanbul Observatory. Founded in 1577 CE by Taqi al-Din Muhammad ibn Ma'ruf, the observatory rivalled the scale and sophistication of Maragha and Samarkand.[74] Equipped with cutting-edge instruments, including a mechanical clock for precise timekeeping, the observatory was designed to advance both astronomy and astrology.[75]

Taqi al-Din is known to have used the Galata Tower as part of his astronomical observations. Built in 1348 CE during the Genoese period, the tower was repurposed by Taqi al-Din as an auxiliary observation site due to its height and strategic location overlooking Istanbul.[76] From this vantage point, he conducted detailed observations of celestial bodies, which complemented the work being carried out at the primary observatory.[77] The Galata Tower thus played a critical role in enhancing the accuracy of Taqi al-Din's astronomical data.

Despite its scientific promise, the Istanbul Observatory faced significant opposition from religious authorities, who viewed its focus on astrology with suspicion. While Islamic scholars and clergy generally embraced astronomy for its practical applications in navigation, timekeeping, and religious observance, they saw astrology as encroaching upon theological principles.[78] This tension culminated in the destruction of the observatory in 1580 CE, marking a setback for Ottoman science. The brief existence of the Istanbul Observatory and the involvement of the Galata Tower underscore the delicate balance between scientific inquiry and sociopolitical forces in the Islamic world.[79]

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[73] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp.192–94.

[74] Aydin Sayili, *The Observatory in Islam and Its Place in the General History of the Observatory* (Ankara: Türk Tarih Kurumu, 1960), pp.211–16.

[75] Sayili, *The Observatory in Islam and Its Place in the General History of the Observatory*, pp.242–45.

[76] Ekmeleddin İhsanoğlu, *History of Ottoman Astronomy and Astrology* (Istanbul: IRCICA, 1997), pp.112–15.

[77] Helaine Selin, ed., *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures* (Dordrecht: Springer, 1997), pp.1232–34.

[78] Sayili, *The Observatory in Islam and Its Place in the General History of the Observatory*, pp.175–78.

[79] İhsanoğlu, *Science, Technology, and Learning in the Ottoman Empire*, pp.98–101.

Islamic observatories were more than just centres for stargazing; they embodied the confluence of science, art, and culture. Sultan Murad III (r. 1574–1595 CE) commissioned a painting from the *Şehinşename* (History of the King of Kings), which vividly depicts Taqi al-Din's Istanbul Observatory [Fig 5]. The artwork shows astronomers using instruments such as astrolabes and quadrants, alongside shelves of books and a terrestrial globe. This visual representation highlights the sophisticated tools and collaborative spirit that defined Islamic observatories.

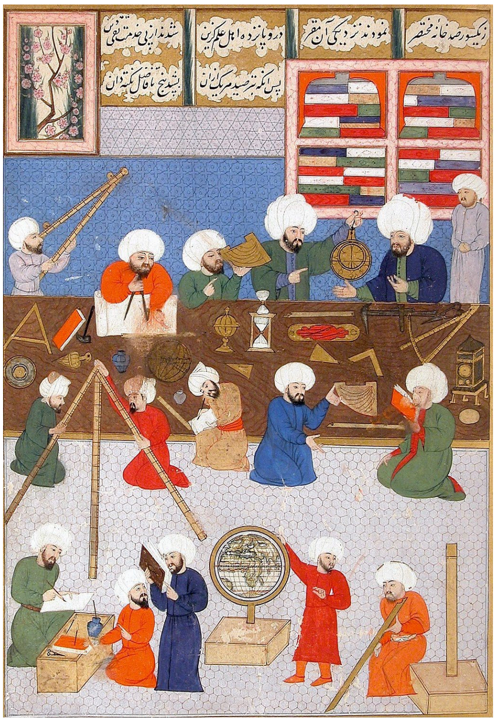

Fig 5. Depiction of work in the observatory of Taqi ad-Din, illustrated by Ala ad-Din Mansur Shirazi. From the *Şehinşename* (Book of the King of Kings), Istanbul University Library, F 1404, fol. 57a. Image courtesy of Wikimedia Commons.

The observatories of the Islamic Golden Age symbolize the institutionalization of scientific inquiry, where state patronage, intellectual curiosity, and technological innovation converged. Despite the eventual decline of many of these institutions, their contributions laid the groundwork for modern astronomy. The models, instruments, and mathematical theories developed within these observatories influenced scholars across the Islamic world and Europe, bridging ancient and modern scientific traditions. They remind us of the power of collaboration and the enduring value of intellectual curiosity in advancing human understanding of the cosmos.

From the Stars to the Present: The Enduring Legacy of the Islamic Golden Age

The journey through the Islamic Golden Age reveals a period of unparalleled scientific and cultural dynamism, where the pursuit of knowledge was not only an intellectual endeavour but also a collective human aspiration. From the meticulous revisions of Ptolemaic stellar catalogues to the transformative refinements of the astrolabe, Islamic scholars did not merely preserve ancient knowledge—they expanded and innovated, creating a legacy that transcends time and geography.[80] Their achievements remind us that curiosity has never belonged to one people or one place but has always been the shared inheritance of humanity, carried like starlight across generations.

The legacies of this time, whether in the form of mathematical innovations like algebra or the celestial catalogues that continue to guide astronomers, remain embedded in our contemporary scientific practices.[81] The development of sophisticated instruments, such as the astrolabe, and the pioneering work in trigonometry, spherical geometry, and celestial mechanics illustrate how deeply rooted modern scientific methodologies are in the contributions of Islamic scholars. These were not isolated flashes of brilliance, but sustained traditions of learning and collaboration that bound together communities from Cordoba to Samarkand in a pursuit that was at once practical, spiritual, and profoundly creative.

This exploration invites us to reimagine how we perceive the history of science. Too often, narratives of progress are confined to Eurocentric frameworks that overlook the critical role of other civilizations in shaping our shared intellectual heritage. The Islamic Golden Age dismantles the myth of the 'lone genius' by demonstrating that scientific advancement is a collaborative and interconnected process. It is a story of translations and transformations, of Greek, Indian, Persian, and Islamic traditions braided together into new constellations of thought. By acknowledging these contributions, we loosen the grip of narrow historical perspectives and

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[80] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), pp 92–95.

[81] George Saliba, *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam* (New York: NYU Press, 1994), pp.223–26.

allow a fuller sky of intellectual heritage to come into view, one where no single star dominates but where brilliance emerges through relation.

The cultural and philosophical dimensions of this era also offer profound lessons for the present. The integration of art, science, and spirituality in Islamic astronomy demonstrates a holistic approach to knowledge that contrasts sharply with the compartmentalization often seen in contemporary academia.[82] The mosque dome that mirrors the heavens, the astrolabe that embodies both precision and beauty, the geometric arabesque that enfolds infinity within its pattern, these testify to a vision of knowledge in which the functional and the aesthetic, the practical and the philosophical, were never sundered. This is not nostalgia but an invitation: to imagine scholarship that once again honours multiplicity and synthesis, that sees in wonder as much value as in measurement.

As we confront global challenges today—ranging from climate change and technological inequality to political and cultural polarization—the Islamic Golden Age speaks with renewed urgency. Its example compels us to cultivate a scientific community that is inclusive, collaborative, and accountable, one that resists the hierarchies of power that still govern whose knowledge is valued and whose is dismissed. Here the decolonial framework becomes most vital. By exposing how Eurocentric historiographies confined Islamic science to the margins, it allows us to restore this age to its rightful place: as a central actor in the global story of human inquiry. It shows us that modern science is not the exclusive property of Europe, but the outcome of many epistemic traditions converging across centuries and geographies.

Knowledge, like the stars themselves, cannot be contained within the borders of a single civilization. It is a shared inheritance—one that arcs outward, connecting distant points in space and time. Just as the night sky was once mapped by Islamic scholars seeking order in the cosmos, we too must rechart our understanding of history, ensuring that the constellations of intellectual heritage remain whole. To see through a decolonial lens is to look up at that sky anew, not with the arrogance of possession but with the humility of participation. The lessons of the Islamic Golden Age challenge us to recognize that the answers we seek—whether in art, science, or philosophy—may already be written in the stars, or in the pages of history, waiting patiently to be seen again.

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[82] Sheila S. Blair, and Jonathan M. Bloom, *The Art and Architecture of Islam: 1250–1800* (New Haven, CT: Yale University Press, 1994), pp.123–125.