Tracing the Celestial Legacy Through Mathematical and Astronomical Advancement During the Vijayanagar Empire

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ABSTRACT: During the late medieval Deccan, advancements in trigonometry, infinite series, and computational techniques strengthened indigenous mathematical practice and improved astronomical prediction. This study examines refined sine tables, early calculus-like series expansions, and iterative algorithms for numerical solutions, and observational methods that supported increasingly accurate planetary models. Drawing on manuscripts, inscriptions, and Sanskrit treatises, it highlights contributions of scholars associated with the Vijayanagar sphere—such as Madhava, Jyesthadeva, and Nilakantha Somayaji—whose innovations in trigonometric series and quasi-heliocentric modelling anticipated later scientific developments. By situating these achievements within systems of patronage, scholarly networks, and practical needs like calendrical computation, navigation, and ritual timing, the study demonstrates how courtly support fostered scientific activity. Comparative perspectives with contemporary Chinese and European traditions reveal parallel moves toward empirical measurement and analytic approximation while maintaining distinct conceptual frameworks.

Keywords: Astronomy, mathematical innovation, Quasi-Heliocentric model, mathematics, Indian Knowledge system, Vijayanagar empire, medieval science.

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1. Introduction

Significant developments in mathematics and astronomy emerged during the 14th–17th century rule of the Vijayanagar Empire, leaving an enduring impression on South Indian intellectual history. There happened many individuals who contributed to astronomical theories and mathematical methods. Nilakantha Somayaji belonged to Kerala school of astronomy from 15th century was one such prominent figure. His contribution in astronomy, especially the "Ardharatrika" theory developed by him, corrected previous models of planetary positions. His work show cases Vijayanagar Empire's dedication to the scientific temperament and the use of exacting mathematical methods to understand the movement of astronomical bodies. Further, this study will also dwell upon how this knowledge of astronomy was utilised in the practicality during the rule of Vijayanagar Empire. The way architecture of temples and drafted ceremonial calendars matched astronomical events demonstrated how this knowledge was incorporated into daily life. Another contemporary mathematician and astronomer of this age is Narhari, who was in the court of King Krishnadevaraya. He wrote multiple books on astronomy and mathematics. The period under study saw the development of new mathematical theories and the refinement of earlier ones, particularly in the field of algebra, geometry, trigonometry, and astronomy. Several key scholars from the Vijayanagar court, such as Parameshvara (Patronised by Devaraya II), Mahadeva, Narayana Pandita, and Bhaskara II, contributed towards these advancements.

1.1. Literature Review

Table 1. Recent work on the Current Topic

Author(s)/ Editor(s)	Year	Focus Area	Key Contribution
T.V. Venkateswaran	2020	Vijayanagar cosmology & astronomY	Links temple sightlines, rituals, and celestial symbolism in Hampi with historical texts.
Malville, Fritz et al.	2018–2024	Archeoastronomy of Hampi	GIS-based studies on temple orientations; show alignments within <1° accuracy to solstices/equinoxes.
Hemakuta Temple Study (MDPI)	2022	Temple spatiality & solar design	Analyzes Virupaksha/Hemakuta layouts, embedding astronomical principles in architecture.
ISROSET / Academic Review Authors	2024	Kerala School (Madhava → Jyesthadeva)	Reviews infinite series, proto-calculus, trigonometry; bibliographic updates.
ICTS – Madhava Lecture Series	2023–2025	Kerala school historiography	Modern expositions of Madhava, Nilakantha, Jyesthadeva; connects to global history of calculus.
Ramasubramanian & Sriram (Eds.)	2025 (rev. ed.)	Nilakantha's Tantrasamgraha	Updated critical edition & translation; adds commentary on trigonometry and quasi-heliocentric model.
Regional Scholars (ResearchGate/Theses)	2021–2024	Vijayanagar education & Kerala manuscripts	Studies on pathshalas, manuscript traditions, and transmission of Yuktibhāṣā.
Archaeological Site Reports (Hampi)	2019–2023	Temple alignments & observational practices	Show how architecture embedded astronomical timing for rituals/festivals.

1.2. Research Gap and Objectives

Existing scholarship often treats Indian astronomy as a uniform tradition or focuses primarily on the Kerala School, leaving limited insight into how astronomy functioned in diverse institutional settings such as courts, temples, and observatories. The scientific culture of the Vijayanagar Empire, including its networks of patronage, education, and ritual practice, remains comparatively understudied. Likewise, despite their significance in observational and teaching methods, instruments such as gnomons, armillary spheres, and temple-based yantras have not been sufficiently examined in relation to textual sources.

This study addresses these gaps through two key objectives: (a) to document and analyze astronomical practices within the Vijayanagar Empire, especially their roles in calendrical systems, ritual timing, and observational techniques; and (b) to assess mathematical innovations—particularly planetary modelling and trigonometric refinement—in comparison with developments in China, Europe, and the Islamic world.

2. Methodology

This study examines the advancements in mathematics and astronomy throughout the Vijayanagar Empire (1336–1646 CE) using a qualitative historical and comparative intellectual analysis. The three main pillars of the methodology are the analytical approach, comparison framework, and sources.

Sources Used. Numerous primary materials are used in the study, such as astronomical tables, temple inscriptions, surviving Sanskrit texts (such as Tantrasamgraha, Yuktibhāṣā, and Ganit Kaumudi), and architectural evidence (such as temple alignment and epigraphic references to astronomical techniques). Secondary analyses in intellectual and scientific history, such as contemporary research on the Kerala School, Hampi's archaeoastronomy, and comparative histories of mathematics, supplement these. The study guarantees philological and contextual richness by placing manuscripts and inscriptions in conversation with academic commentary.

Comparative Framework. The study clearly places Vijayanagar intellectual traditions in relation to current events in China, Europe, and the Islamic world. For example, the Kerala School's infinite series and trigonometric refinements are contrasted with European pre-calculus traditions; the Chinese Bureau of Astronomy's reforms are contrasted with Vijayanagar calendrical practices; and the Zij-i Sultani star catalogues of the Islamic world are contrasted with observational astronomy. Both domestic innovation and areas of global convergence are highlighted by this comparative viewpoint.

3. Astronomical, Astrology and Mathematical Texts and Scholarly Contributions

Astronomy in the Vijayanagar era was closely related to Hindu cosmology and temple rituals. There are several important pieces and researchers of the period that contributed in the advancements of astronomy:

3.1. The Panchangam

The Vijayanagar Empire used a calendar system that was highly developed by the results of astronomical observations and was similar to ancient Indian system, like Vedic calendar. The Panchangam had information regarding lunar and solar movements, favourable timings (muhurthas), eclipses, and planetary arrangements. This system was vital for planning religious and royal events.

3.2. Mahadeva

He was a famous mathematician and astronomer at the Vijayanagar court. Mahadeva contributed to the fields of algebra and astronomy on a large scale. His works, such as the Mahadeva Siddhanta, covered planetary movements as well as eclipses. His observations and calculations were used to refine previous astronomical models.

3.3. The Tolkāppiyam and Later works

The Tolkāppiyam, which predates the foundation of Vijayanagar Empire, had significant influence on the astronomical works of the period under study. Later works that were produced after the Tolkāppiyam, including Jyotish Sastras (astronomy treatises), were produced under royal patronage during the Vijayanagar Empire, providing understandings into how astronomers exhibited celestial events.

3.4. Ganit Kaumdi

Ganit Kaumudi meaning "Moonlight of Mathematics" is a mathematical work written in sanskrit by Narayan Pandit in the 14th century CE. The work is known for explaining mathematical principles in an understandable and creative manner. It covers a variety of mathematical operations like "Rule of Three", "permutations and combinations", "problems involving motion and time". Ganit Kaumudi uses riddles or story-like situations for explaining the problem-solving techniques. Its approach to understand the problems through verses and examples makes it an important educational tool and a reflection of the advanced state of mathematical thought in medieval India [1]. It contains the traditional paribhasa, parikarmas, and vyavaharas, followed by the pulverizer, "Pell's equation," factors, combinations, and magic squares. Before writing the Ganikaumudi, Narayana had written a work on algebra, the Bijaganitavatamsa.

3.5. Parameshvara

He is primarily known for his contributions to the Drigganita (observational astronomy) tradition. He resurrected and improved techniques for determining planetary locations based on real observations, rather than depending entirely on ancient Siddhantic procedures. Parameshvara was one of the few Indian astronomers who favoured direct observation [2]. He is credited for keeping records of more than 70 solar and lunar eclipses, as well as his personal observations, for about 55 years. There are three major works of Parameshvara – Grahanmanadana, Grahanastaka and Grahananyayadipika [3].

3.6. Nilkantha Somayyaji

Nilkantha Somayyaji: He used observations of Parameshvara in the formulation of his work, Tantrasangrah. He introduced more accurate computations of planetary positions, especially for the outer planets. Tantrasangrah contains detailed trigonometric computations and innovative methods for calculating the sine and cosine values. This work had a profound impact on later Indian astronomers and mathematicians like Jyesthadeva, elaborated on its concepts in works like Yuktibhasha [4].

3.7. Nilakantha Somayaji's Quasi-Heliocentric Model

Nilakantha Somayaji's Quasi-Heliocentric Model: The development of a quasi-heliocentric model of the solar system was one of Nilakantha Somayaji's most notable accomplishments, which are recorded in his Tantrasangraha (1501). According to this theory, the Sun orbited the Earth, while the planets Mercury and Venus orbited the Sun. Compared to previous geocentric theories, this arrangement provided a more precise explanation for the inner planets' retrograde motion. Although his concept of Earth being stationary was a significant departure from Copernicus' heliocentric theory, still it was a conceptual advancement in Indian astronomy. An empirical mentality may be seen in Nilakantha's model, as he refined planetary tables by drawing on decades of eclipse observations made by his predecessor, Parameshvara. By using trigonometric techniques to locate planetary positions, he was able to predict European events more than a century ago.
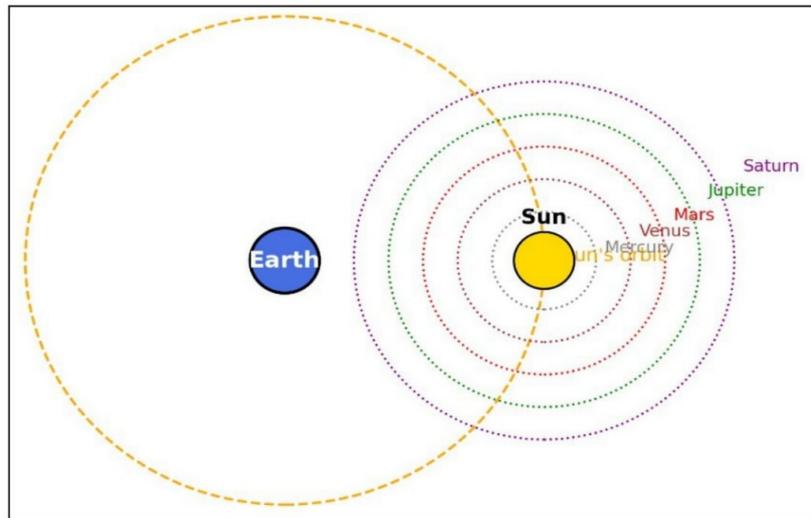

Figure 1: **Nilakantha Somayaji's Quasi-Heliocentric Model (ca.1500 CE)**
Reconstruction based on Tantrasamgraha

Source: K. Ramasubramanian, M. D. Srinivas, M. S. Sriram, The Traditional Indian Planetary Model and its Revision by Nilakantha Somayaji, esp. Fig. F.4b (pp. 12–15).

3.8. Jyesthadeva

Jyesthadeva is an Indian mathematician and astronomer from Kerala belonging to the sixteenth century. His most well-known work is Yuktibhāṣā, a revolutionary treatise on mathematics written in Malayalam in 1530 CE. Yuktibhāṣā is distinctive for its logical rigour and early application of calculus-like techniques. It is regarded as one of the first works to methodically convey the rationale (yukti) underlying mathematical and astronomical conclusions. In addition to offering thorough explanations and derivations for conclusions pertaining to trigonometry, infinite series, and astronomical computations, the text is a commentary on Nilakantha Somayaji's Tantrasamgraha. The early formulations of the infinite series for sine and cosine functions found in Yuktibhāṣā are noteworthy since they predate comparable advances in Europe by centuries (Joseph, 2011) [5]. Jyesthadeva's work has a sophisticated comprehension of convergence, iterative techniques, and mathematical proofs. Yuktibhāṣā, which was written in Malayalam rather than Sanskrit, simplified difficult mathematical concepts and demonstrated a regional and inclusive approach to scientific education (Raju, 2007) [6].

4. Mathematics and Astronomy

The mathematical developments under the Vijayanagar rulers were the outcome of their astronomical studies. Mathematics in India during this period saw considerable growth, with a focus on the refinement of trigonometric functions, sine tables, and planetary motion models. The more accurate location needed a more accurate sine and cosine tables. Thus, mathematicians of this time developed power series of sine and cosine. These series appear in written form in the Tantrasamgraha-vyakhya of about 1530, a commentary on a work by Nilakantha. Derivations appear in the Yuktibhasa, whose author credits these series to Madhava (1359–1425) [7].

4.1. Trigonometry and Sine Tables

Trigonometry and Sine Tables: The improvement of trigonometric functions was one of the most important advancements of this time period. Power series expansions and extremely precise sine tables were created by Indian mathematicians of the Kerala school, who were intimately linked to the Vijayanagar academic network. Madhava of Sangamagrama (c. 1350–1425), for instance, created infinite series expansions for sine, cosine, and arctangent functions, over three centuries before the concepts of calculus were developed [8]. Later, Jyesthadeva's Yuktibhāṣā and Nilakantha's Tantrasangraha expanded on these themes.

A practical example can be seen in Madhava's approximation for π using the arctangent series: π=4 (1-31+51-71+$\cdots$) This formula, centuries ahead of Europe, reflects the precision with which Indian mathematicians engaged infinite processes. Such calculations were not merely theoretical; they improved the accuracy of planetary models and predictions of eclipses, which were central to both ritual practice and royal legitimacy.

4.2. Planetary Models

Planetary Models: Advanced theories of planetary motion were passed down from older Indian astronomers such as Aryabhata and Bhaskara II to the Vijayanagar Empire. These concepts were improved by academics like Parameshvara and Nilakantha Somayaji, who produced what some historians refer to as a "proto-heliocentric" framework. According to Nilakantha's theory, the Sun and the other planets orbited the Earth, while Mercury and Venus orbited the Sun. Although this quasi-heliocentric method maintained the Earth's centrality in line with Indian cosmology, it bore a remarkable resemblance to elements of Copernicus' later paradigm (1543). These models' mathematical strength was their trigonometric accuracy, which made it possible to anticipate eclipses and make calendrical adjustments more precisely than those made in modern-day China or Europe [9].

4.3. Practical Application in Temple construction

Practical Application in Temple construction: The architecture of Vijayanagar was likewise infused with astronomy and mathematics. More than 150 temples, shrines, and palaces in Hampi and the surrounding areas have had their orientations assessed by recent archeoastronomy research (e.g., Malville et al.) [10]. In accordance with solar events like equinoxes and solstices, most of the great temples face east. Certain sanctuaries have alignment accuracy of less than one degree, indicating the application of sophisticated trigonometric computations and observational tools. For instance, the Virupaksha Temple in Hampi is positioned so that the sanctuary is directly illuminated by the rising sun's beams during specific solar occurrences.

4.4. Courtly Dimension on Indian Astronomy

Courtly Dimension on Indian Astronomy: Numerous inscriptions from the Vijayanagar era document the relationship between astronomical occurrences and royal power. A Sanskrit copper-plate inscription dated June 28, 1456 CE, during the reign of King Mallikarjuna of Vijayanagar, recalls the appearance of a comet ("dhūmaketu") and meteor shower. The inscription donates land to Vedic scholar Limgaṇarya with the specific intention "to mitigate the great calamity believed to arise due to the appearance of comet and meteor shower." This demonstrates that astronomical phenomena were regarded as having direct political or ceremonial importance, necessitating royal involvement via sponsorship.

Another epigraphic record from Kodigehalli (in the Bengaluru area) from the Vijayanagar Empire (1431 CE) records a solar eclipse and a land donation associated with a temple and its ceremonies [11]. The grant clearly mentions the eclipse and is granted during that event.

Such inscriptions demonstrate how kings exploited astronomical-ritual occasions (eclipses, comets) to strengthen ceremonial order and legitimacy by performing public acts (gifts) in reaction to cosmic phenomena. [1]

4.5. Mathematical Interpretation of Astronomical Data

Mathematical Interpretation of Astronomical Data The mathematical foundation of Vijayanagar–Kerala astronomical science relied heavily on trigonometric computation, iterative algorithms, and proto-calculus series expansions. These techniques allowed scholars to generate accurate values for planetary latitudes, eclipse timings, and angular separations. Two examples illustrate the mathematical sophistication: **(A) Infinite Series for Sine (Madhava's Formula)**
Jyesthadeva's Yuktibhāṣā (c. 1530) presents the earliest known infinite series for sine:

$$\sin(\theta) = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \frac{\theta^7}{7!} + \cdots$$

This series enabled error-controlled approximations of celestial longitudes.

For example, computing the sine of 30°:

$$\theta = \frac{\pi}{6} \qquad \Rightarrow \qquad \sin\left(\frac{\pi}{6}\right) \approx \frac{\pi}{6} - \frac{\pi^3}{6^3 \cdot 6} = 0.5000$$

This matches the modern value 0.5 with remarkable accuracy.

(B) Madhava's π Approximation (Arctangent Series)
To improve circle measurements essential for astronomical tables, Madhava used:

$$\pi = 4\left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \cdots\right)$$

After 50 terms, the result differs from modern π by less than 0.0004.

(C) Nilakantha's Planetary Equation for Mercury/Venus
For inner planets, Nilakantha proposed:
$$L = L_s + \Delta L$$

where L = true longitude of planet, L_s = solar longitude, and ΔL = correction term based on epicyclic geometry.

(D) Eclipse Computation (Parameshvara's Drigganita)
Parameshvara improved the calculation of eclipse magnitude using:

$$M = \frac{d - r_1 - r_2}{2r_1}$$

where d = observed distance between solar–lunar centers, and r_1, r_2 = angular radii.

Temple alignments in Hampi correspond to these measured angles.

5. Global Context of Vijayanagar Scientific Thoughts

Global Context of Vijayanagar Scientific Thoughts It is impossible to appreciate the intellectual legacy of the Vijayanagar Empire without placing it in the larger context of world scientific history. China, the Islamic world, and Europe all saw concurrent but different scientific advancements between thefourteenth and seventeenth centuries.

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[1] Several recent news reports say that the Halley's Comet copper-plate from Srisailam (Śaka 1378 / June 1456) is a new-discovery by ASI, not previously published. The ASI's Epigraphy Branch's report for the year ending 31 March 2025 mentions that "25 stone inscriptions and 1 copper plate copied from different places." This suggests that the copper plate (perhaps the Srisailam plate) is in the process of being transcribed or documented by ASI.

5.1. China

China Without putting the Vijayanagar Empire's intellectual legacy in the broader framework of global scientific history, it is impossible to fully comprehend it. Between the fourteenth and seventeenth centuries, China, the Islamic world, and Europe all experienced simultaneous but distinct scientific breakthroughs.

5.2. Islamic World

Islamic World Greek and Indian astronomy was transmitted to later European contexts through the Islamic world, which served as a knowledge bridge. A prime example of the accuracy of star catalogues created in observatories such as Samarkand was Ulugh Beg's Zij-i Sultani (1437 AD). The development of spherical trigonometry and sophisticated observational methods by Islamic academics paralleled Vijayanagar's interest in planetary precision and eclipse prediction. Institutional differences were evident, though, as South Indian temple-schools were not as well-supported by the state as Islamic observatories.

5.3. Europe

Europe The Ptolemaic system continued to rule Europe throughout the late medieval era, but a dramatic change was brought about by the Renaissance. Copernicus' De Revolutionibus (1543 AD) suggested heliocentrism, which conceptually changed the structure of the universe, despite his less sophisticated mathematical correctness than Nilakantha Somayaji's. Later, Tycho Brahe, Kepler, and Galileo launched the Scientific Revolution by fusing mathematics, instruments, and observation. Vijayanagar astronomers, on the other hand, improved geocentric and quasi-heliocentric models while retaining philosophical presumptions about the primacy of Earth.

5.4. Discussion: Limits of Vijayanagar Science

Discussion: Limits of Vijayanagar Science A major paradox in world history is highlighted by the scientific traditions of Vijayanagar and the Kerala School: Indian advancements did not spread globally in the same manner as European science, while developing mathematically complex and conceptually novel models. Several factors account for this divergence:

Table 2. Comparative Features of 14th–17th Century Scientific Traditions

Aspect	Vijayanagar–Kerala (India)	Islamic World	China (Yuan–Ming)	Europe (Renaissance)
Core Focus	Trigonometry, infinite series, planetary models	Precision observation, spherical trigonometry	Calendrical reform, algorithmic math	Cosmological reform, mathematical modelling
Institutional Base	Temple-schools, court patronage	State observatories	Imperial Astronomical Bureau	Universities, printing press
Key Strength	Proto-calculus, accurate trigonometric series	Highly accurate star catalogues	Efficient calendars	Integration of math + observation
Cosmology	Geocentric + quasi-heliocentric	Geocentric variants	Geocentric-mandate system	Heliocentric (post-Copernicus)
Knowledge Transmission	Manuscripts, oral teaching	Arabic scientific networks	State-sponsored records	Printed books, widespread translation

6. Comparison of Mathematical Development with Contemporary China

Comparison of Mathematical Development with Contemporary China During the same period, the Vijayanagar/Indian tradition developed highly theoretical concepts in infinite series and trigonometry, foreshadowing calculus [12]. Meanwhile, Chinese mathematics was more algebraic, algorithmic, and applied, with a focus on practical government and engineering.

Table 3. Comparison of Mathematical Development with China

Aspect	Vijayanagar Empire (India)	Medieval China (Yuan-Ming)
Core Influence	Hindu tradition, Aryabhata, Bhaskara, Kerala school	Nine Chapters, Song/Yuan mathematicians
Focus Areas	Trigonometry, infinite series, proto-calculus	Algebra, equations, calendrical and engineering
Innovation Level	High (infinite series, early calculus)	High in algebra (symbolic methods, elimination)
Language of Work	Sanskrit, Malayalam	Classical Chinese
Methodological Depth	Proofs and derivations (e.g., Yuktibhāṣā)	Algorithmic, rule-based, less emphasis on proof
Application	Astronomical and ritual use	Administrative, calendrical, engineering
Foreign Influence	Minimal; indigenous development	Later influenced by Jesuit (Western) mathematics
Institutional Setting	Individual scholars, temple schools	State officials, calendar bureaus, civil exams

7. Comparison of Mathematical Development with Contemporary Europe

Comparison of Mathematical Development with Contemporary Europe India (Vijayanagar era) retained and extended a long-standing mathematical tradition, reaching early calculus concepts ahead of Europe. Madhava, for example, created early forms of infinite series expansions for trigonometric functions, laying the groundwork for what can be considered proto-calculus centuries before Newton and Leibniz in Europe. In contrast, Europe in the late mediaeval and early Renaissance periods was uncovering and integrating ancient Greek and Arabic knowledge, with practical and commercial applications driving innovation [13]. Formal symbolic algebra and calculus would emerge in Europe in the 17th century, long after Indian scholars had hinted at similar concepts.

Table 4. Comparison of Mathematical Development with Europe Category Vijayanagar India (14th–16th c.) Europe (13th–16th c.)

Numeral System Fully developed decimal system, zero Adoption of Hindu-Arabic numerals in progress Algebra Developed algebra (Bhāskara II) Revival via translations, rudimentary symbolism Trigonometry Advanced, including infinite series (Madhava) Used primarily for astronomy; less developed Calculus Concepts Early ideas of limits, series, etc. Not until Newton & Leibniz (17th century) Astronomy/Math Link Strong, with planetary models, calendars Also strong, esp. in Copernican astronomy Practical Application Architecture, ritual, commerce Commerce, navigation, architecture Institutional Support Temples, courts, scholarly patronage Church, universities, royal courts

8. Comparison of Astronomical Development with Europe

Using texts like the Āryabhaṭīya, Brahmasphuṭasiddhānta, and Sūrya Siddhānta, astronomy during the Vijayanagar period was firmly based on India's classical Jyotiṣa tradition. These systems used trigonometric functions, deferents, and epicycles to forecast calendrical occurrences, eclipses, and planetary motion (Pingree, 1981).

8.1. Quasi-Heliocentrism and Copernican Parallels

Quasi-Heliocentrism and Copernican Parallels One of the most notable intellectual developments of the Vijayanagar era is Nilakantha's quasi-heliocentric paradigm, which was presented in the Tantrasamgraha (1501). According to this theory, Mercury and Venus orbited the Sun, while Earth stayed fixed and the Sun orbited it. Saturn, Jupiter, and Mars kept their orbits around Earth. This hybrid system provided a better mathematical explanation for the inner planets' retrograde motion while maintaining geocentric assumptions (Ramasubramanian and Sriram, 2025) [14]. Nilakantha's approach and Nicolaus Copernicus' De Revolutionibus (1543) exhibit a significant similarity in that both attempted to address discrepancies in planetary motion by altering inherited cosmological systems. Copernicus completely

moved Earth away from the center, but Nilakantha did not reach this metaphysical rupture. However, Nilakantha's improvements frequently beat early European heliocentric models in terms of computational accuracy (Joseph, 2011), demonstrating that the intellectual trend toward rethinking cosmic order was not exclusive to Europe.

8.2. Knowledge Transmission and Its Limits

Knowledge Transmission and Its Limits The Vijayanagar model, in spite of its sophistication, failed to gain worldwide traction. Its dissemination methods are more to blame than its scientific content. Oral instruction, temple schools (paṭhaśālās), and palm-leaf manuscripts were the main ways that Indian scholarship was disseminated (Raju, 2007). Knowledge was rarely shared across linguistic and cultural divides; instead, it was maintained, improved, and passed down locally. In contrast, Copernican books were widely disseminated thanks to the development of the printing press in Europe in the middle of the 15th century. Transregional intellectual exchange was promoted by universities and court-sponsored organizations (Westman, 2011) [15]. Despite having similar intellectual rigor, Vijayanagar's advancements were nevertheless constrained by limited pedagogical systems and manuscript culture (Pingree, 1981).

8.3. Historiographical Debate and Global Pluralism

Historiographical Debate and Global Pluralism Significant historical problems are brought up by the comparison between Vijayanagar and Europe. Indian, Chinese, and Islamic contributions have been marginalized as "precursors" rather as coequal traditions in traditional narratives of the "Scientific Revolution," which frequently privilege Europe as the exclusive location of modern science's development (Shapin, 1996) [16]. This Eurocentric framework is contested by recent scholarship, which promotes a global plurality of scientific modernities (Joseph, 2011; Ramasubramanian & Sriram, 2025). According to this viewpoint, Nilakantha's quasi-heliocentric model was a component of a larger intellectual experiment with planetary order rather than a failed premonition of Copernicus. It shows how various cultures followed different paths to comprehend the universe, but their regional embedding does not lessen its originality.

9. Global Timeline: Mathematical & Astronomical Progress (1336–1646 CE)

Table 1: Table 5. Global Timeline of Mathematical and Astronomical Progress

Period / Date	Vijayanagar Empire & Kerala School	Islamic World	Europe (Renaissance & Early Modern)	China (Yuan & Ming Dynasties)
c. 1360–1400	Compilation and refinement of astronomical tables based on Aryabhata and Bhaskara II's works.	Ulugh Beg's observatory in Samarkand planned (later built 1420s).	Early translations of Ptolemaic works from Arabic to Latin continue.	Yuan dynasty's Shoushi calendar still in use; astronomy influenced by Islamic techniques.
c. 1380–1420	Observational refinements in planetary positions; emphasis on eclipse prediction.	Ulugh Beg trains astronomers, compiles Zij-i Sultani.	Early use of mechanical clocks for astronomical purposes in Italy.	Ming dynasty establishes Imperial Astronomical Bureau.
c. 1420–1460	Parameshvara develops improved planetary models; works on the Drigganita and eclipse calculation methods.	Completion of Zij-i Sultani (1437) with highly accurate star charts.	Gutenberg's printing press (1440s) accelerates spread of astronomical texts.	Ming court exchanges astronomical knowledge with Islamic scholars.
c. 1460–1500	Parameshvara's disciples (like Damodara) and Nilakantha Somayaji advance trigonometric series, prefiguring calculus ideas.	Islamic astronomy begins to influence Ottoman navigational charts.	Regiomontanus publishes Ephemerides (1474) improving European navigation.	Ming dynasty refines water-powered astronomical clocks.
c. 1500–1540	Nilakantha Somayaji's Tantrasamgraha proposes a quasi-heliocentric planetary model (1501) anticipating later European models.	Ottoman astronomers refine planetary theories; Arabic texts translated to Turkish.	Copernicus publishes De Revolutionibus (1543).	Chinese astronomers adopt and adapt Islamic spherical trigonometry.
c. 1540–1580	Sankara Varman and others continue eclipse prediction and trigonometric refinements.	Taqi al-Din builds Istanbul Observatory (1577), creates precise astronomical instruments.	Tycho Brahe builds Uraniborg Observatory (1576); detailed planetary observations.	Ming dynasty reforms lunar calendar.
c. 1580–1646	Kerala school scholars like Jyesthadeva explain infinite series expansions (Yuktibhasa).	Decline of large-scale observatories but legacy continues through manuscripts.	Galileo uses telescope for celestial observations (1609); Kepler's laws published (1609–1619).	Jesuit missionaries introduce European astronomy to China (late Ming period).

Ulugh Beg in Samarkand directed the production of the Zij-i Sultani (1437), one of the most precise star catalogues prior to modern times [17], while Parameshvara in South India documented decades of eclipses to enhance planetary forecasts. Although direct observation was valued in both traditions, they functioned in distinct institutional contexts—state-funded observatories in the Islamic world versus temple schools and royal courts in Vijayanagar.

Through the Royal Astronomical Bureau, the Ming dynasty in China, on the other hand, placed a strong emphasis on the bureaucratic use of astronomy. Its lunar calendar modifications show that it prioritises ceremonial order and control over theoretical innovation. On the other hand, the printing press's introduction in Europe sped up the spread of astronomical concepts, guaranteeing that Copernicus, Kepler, and Galileo changed the intellectual landscapes much beyond their local settings.

When seen together, these achievements show a startling convergence of innovation: Vijayanagar's infinite series, the Islamic world's star catalogues, China's calendar reforms, and Europe's heliocentric revolution. However, their paths diverged due to different institutional, linguistic, and political systems. Whereas European science expanded globally through colonialism and printing, Indian and Chinese advancements remained regionally rooted, conveyed mostly through manuscripts and oral traditions. The contrast emphasises that the so-called "Scientific Revolution" was not a unique European occurrence, but rather part of a wider, multifaceted worldwide history of knowledge [18].

10. Recommendations and Conclusion

Recommendations and Conclusion The scientific legacy of the Vijayanagar period reveals a sophisticated intellectual culture that combined traditional cosmology with mathematical innovation. Astronomy and mathematics were not peripheral pursuits but formed an essential part of ritual governance, temple architecture, and scholarly activity. Royal courts and temple-schools supported scholars such as Parameshvara, Nilakantha Somayaji, and Narayana Pandita, enabling advances in planetary models, trigonometry, and eclipse prediction.

Despite this intellectual richness, the wider transmission of these ideas was limited. Knowledge remained embedded in manuscript culture, temple pedagogy, and regional scholarly networks. In contrast, Europe's printing press, universities, and cross-cultural circulation allowed astronomical ideas—from Copernicus to Galileo—to spread rapidly and reshape global scientific thought. The limited diffusion of Indian work reflects institutional constraints rather than conceptual limitations.

A balanced historiography must therefore recognize the Vijayanagar–Kerala tradition as an independent center of scientific innovation. Rather than viewing non-European traditions as precursors to European breakthroughs, it is necessary to acknowledge multiple, parallel scientific trajectories. The Vijayanagar case affirms that scientific modernity was not the outcome of a single region but a cumulative, multicultural process shaped by diverse intellectual environments.

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