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Indian Council for Cultural Relations

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New York

INDIA
INTERNATIONAL
CENTRE
IIC

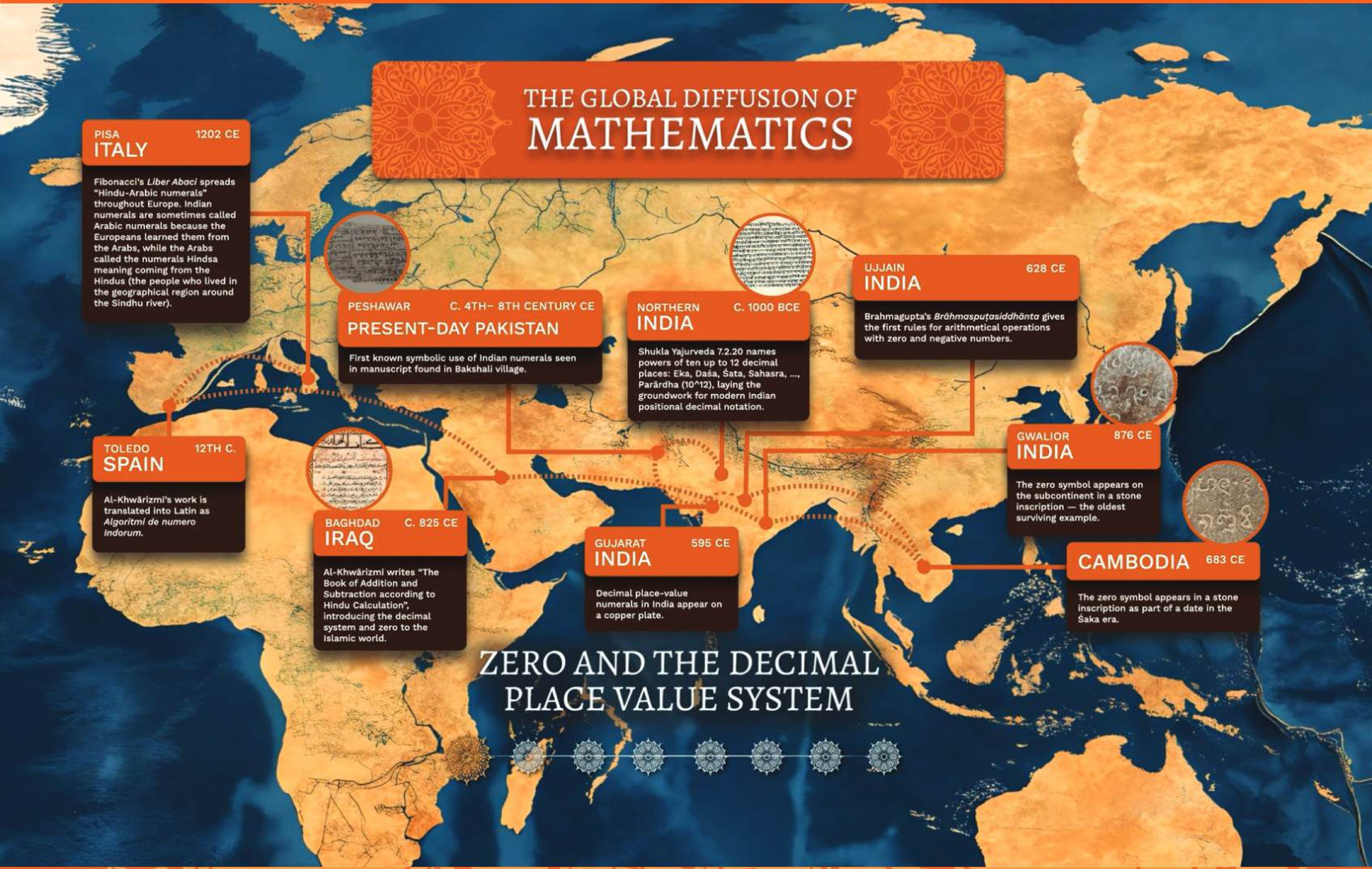
from shunya to ananta

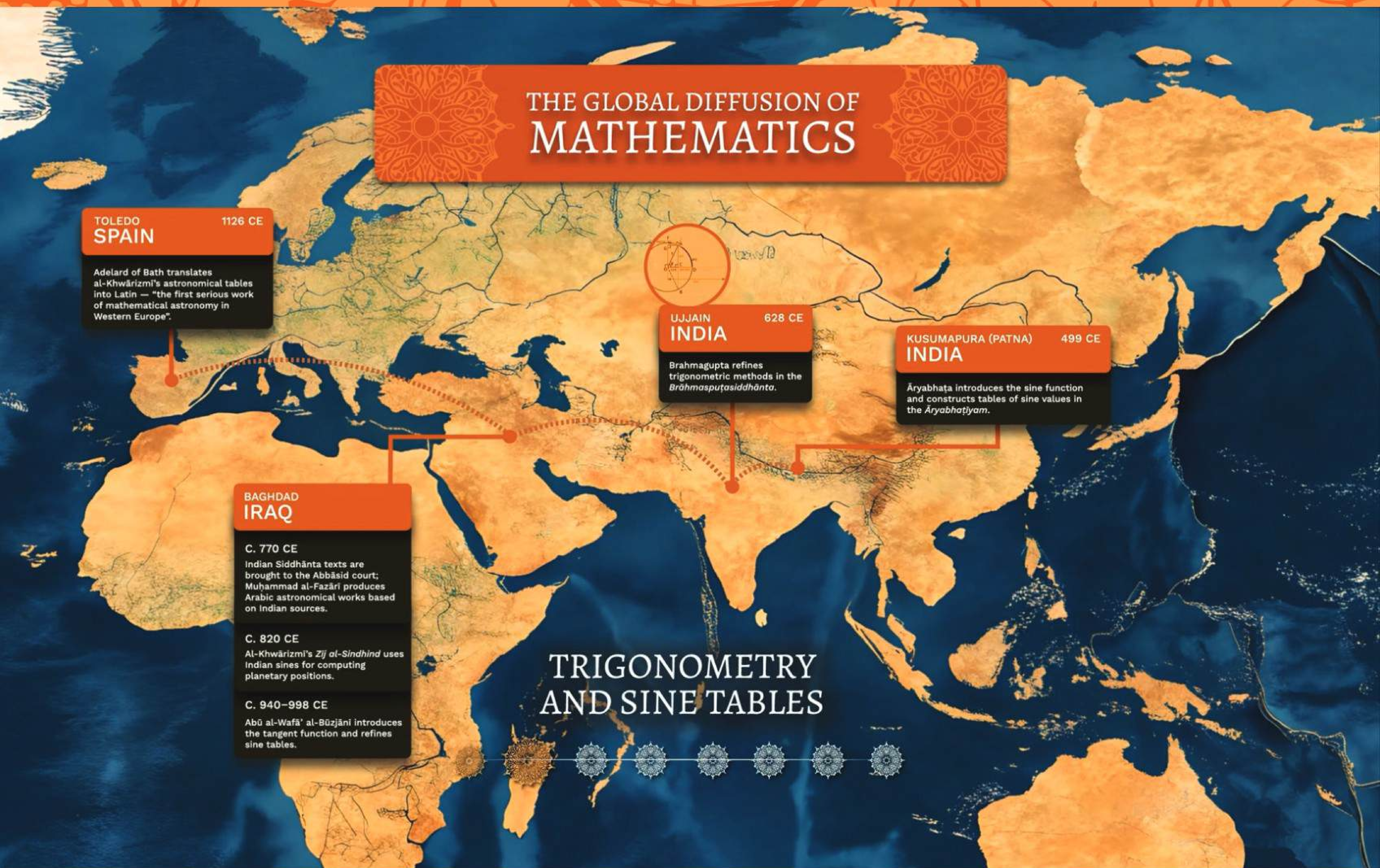
ZERO TO INFINITY

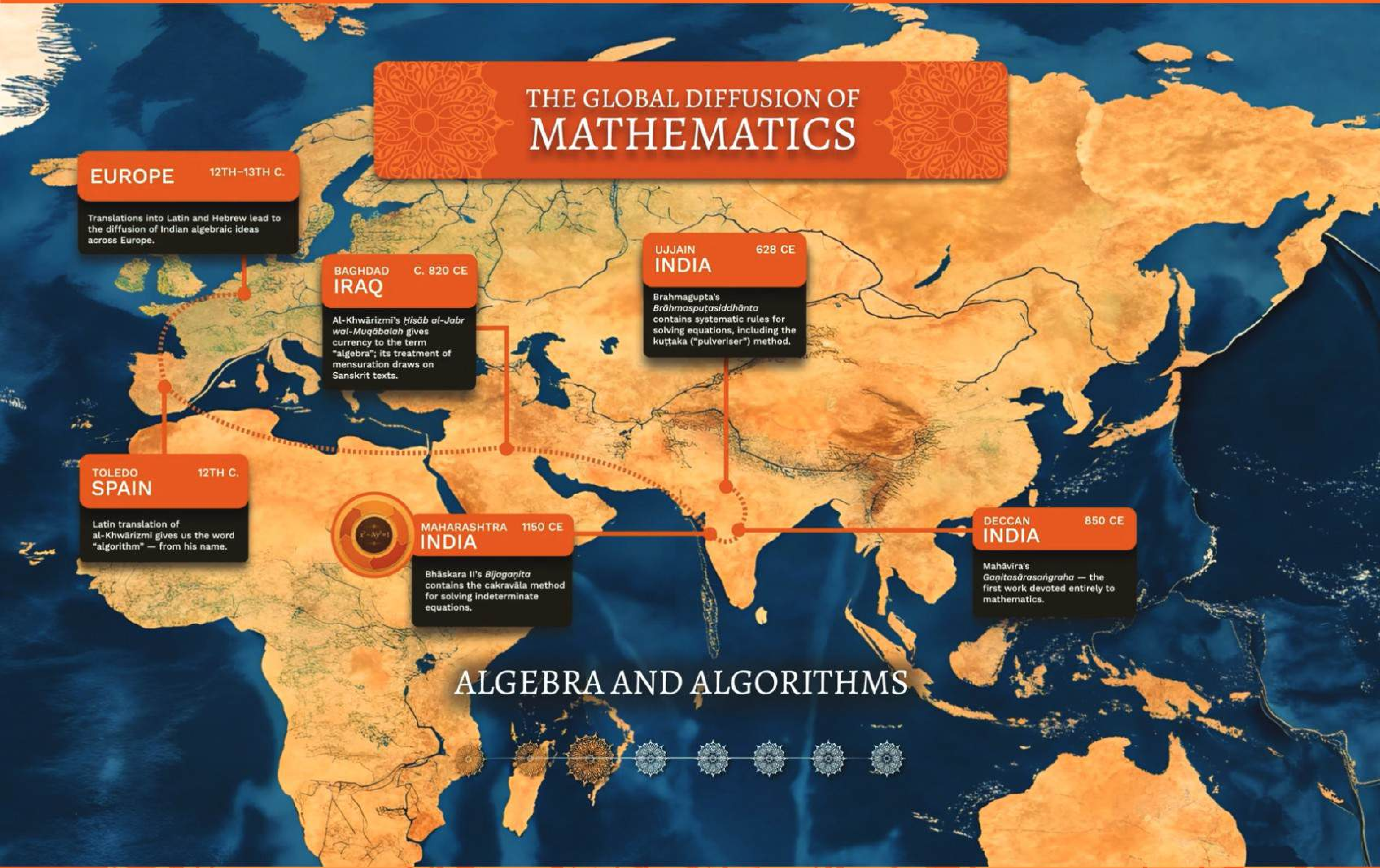
THE INDIAN CIVILISATION'S CONTRIBUTION TO MATHEMATICS

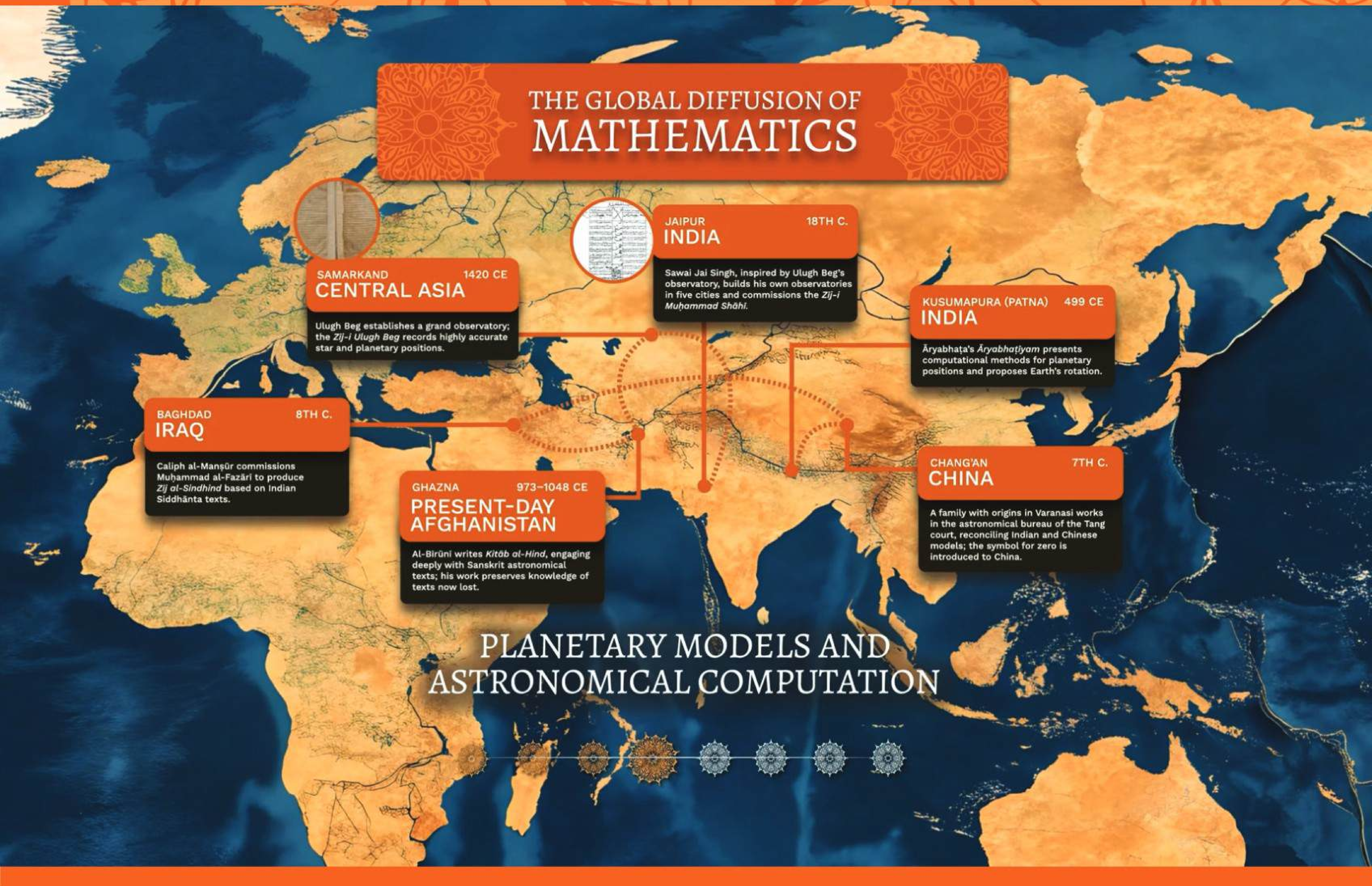
Journey across millennia to witness how mathematical discoveries from the Indian civilisation traveled across the world and continue to shape our modern lives.

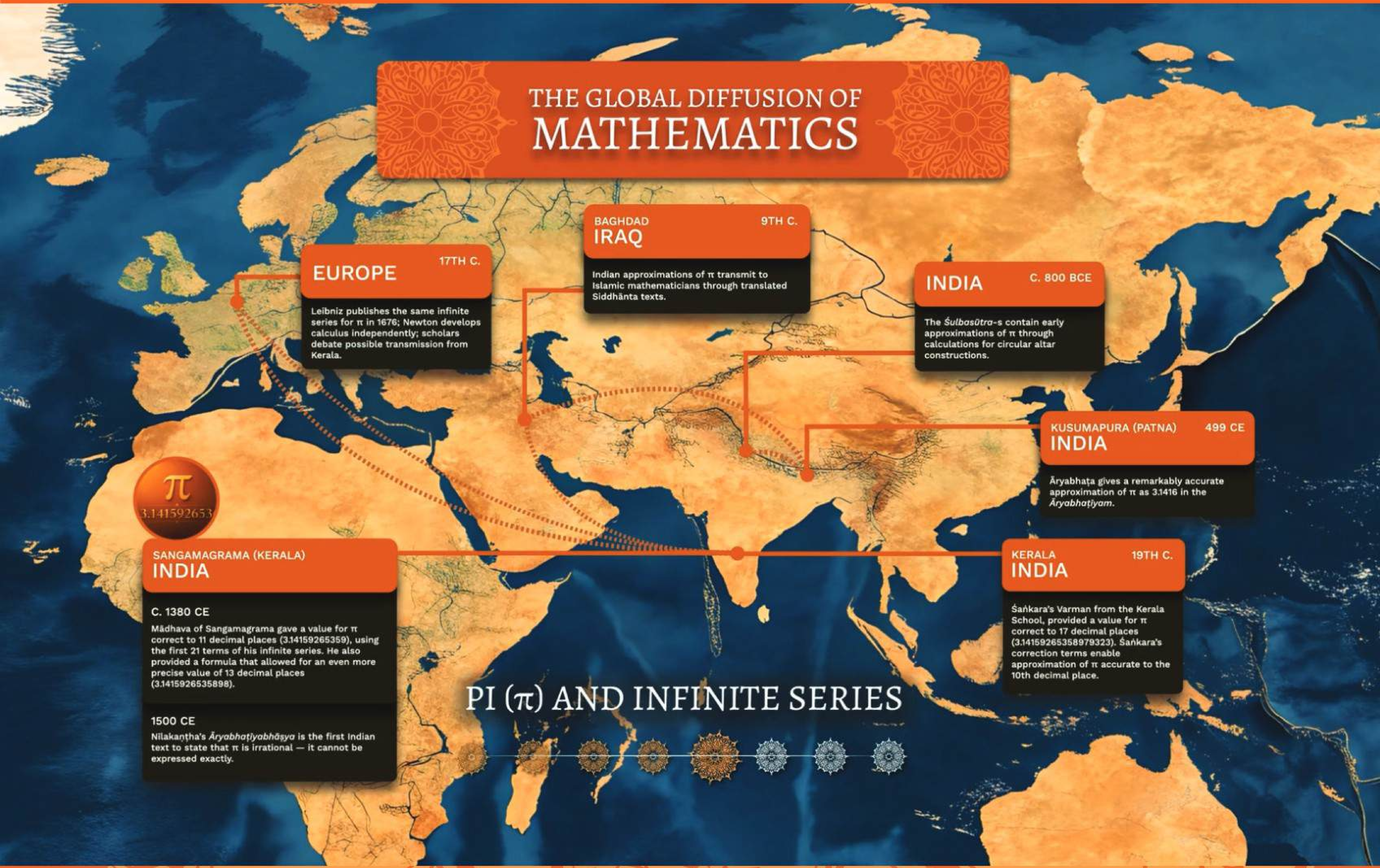
Global Diffusion of Mathematics

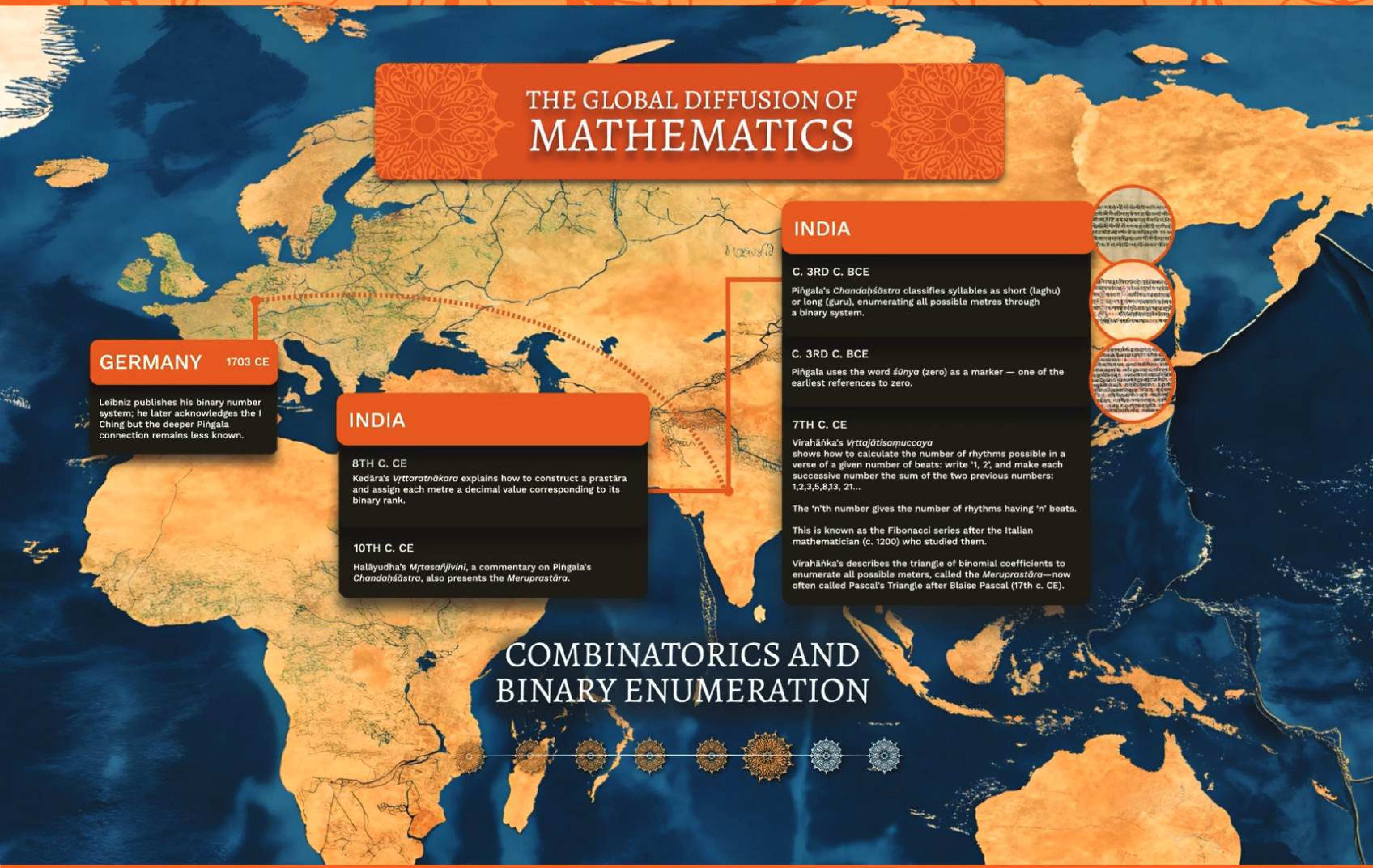

THE GLOBAL DIFFUSION OF
MATHEMATICS
PISA 1202 CE
ITALY
Fibonacci's *Liber Abaci* spreads "Hindu-Arabic numerals" throughout Europe. Indian numerals are sometimes called Arabic numerals because the Europeans learned them from the Arabs, while the Arabs called the numerals Hindsa meaning coming from the Hindus (the people who lived in the geographical region around the Sindhu river).
PESHAWAR C. 4TH– 8TH CENTURY CE
PRESENT-DAY PAKISTAN
First known symbolic use of Indian numerals seen in manuscript found in Bakshali village.
NORTHERN C. 1000 BCE
INDIA
Shukla Yajurveda 7.2.20 names powers of ten up to 12 decimal places: Eka, Daśa, Śata, Sahasra, ..., Parārdha (10^12), laying the groundwork for modern Indian positional decimal notation.
UJJAIN 628 CE
INDIA
Brahmagupta's *Brāhmasputasiddhānta* gives the first rules for arithmetical operations with zero and negative numbers.
TOLEDO 12TH C.
SPAIN
Al-Khwārizmi's work is translated into Latin as *Algoritmi de numero Indorum.*
GWALIOR 876 CE
INDIA
The zero symbol appears on the subcontinent in a stone inscription — the oldest surviving example.
BAGHDAD C. 825 CE
IRAQ
Al-Khwārizmi writes "The Book of Addition and Subtraction according to Hindu Calculation", introducing the decimal system and zero to the Islamic world.
GUJARAT 595 CE
INDIA
Decimal place-value numerals in India appear on a copper plate.
CAMBODIA 683 CE
The zero symbol appears in a stone inscription as part of a date in the Śaka era.
ZERO AND THE DECIMAL
PLACE VALUE SYSTEM

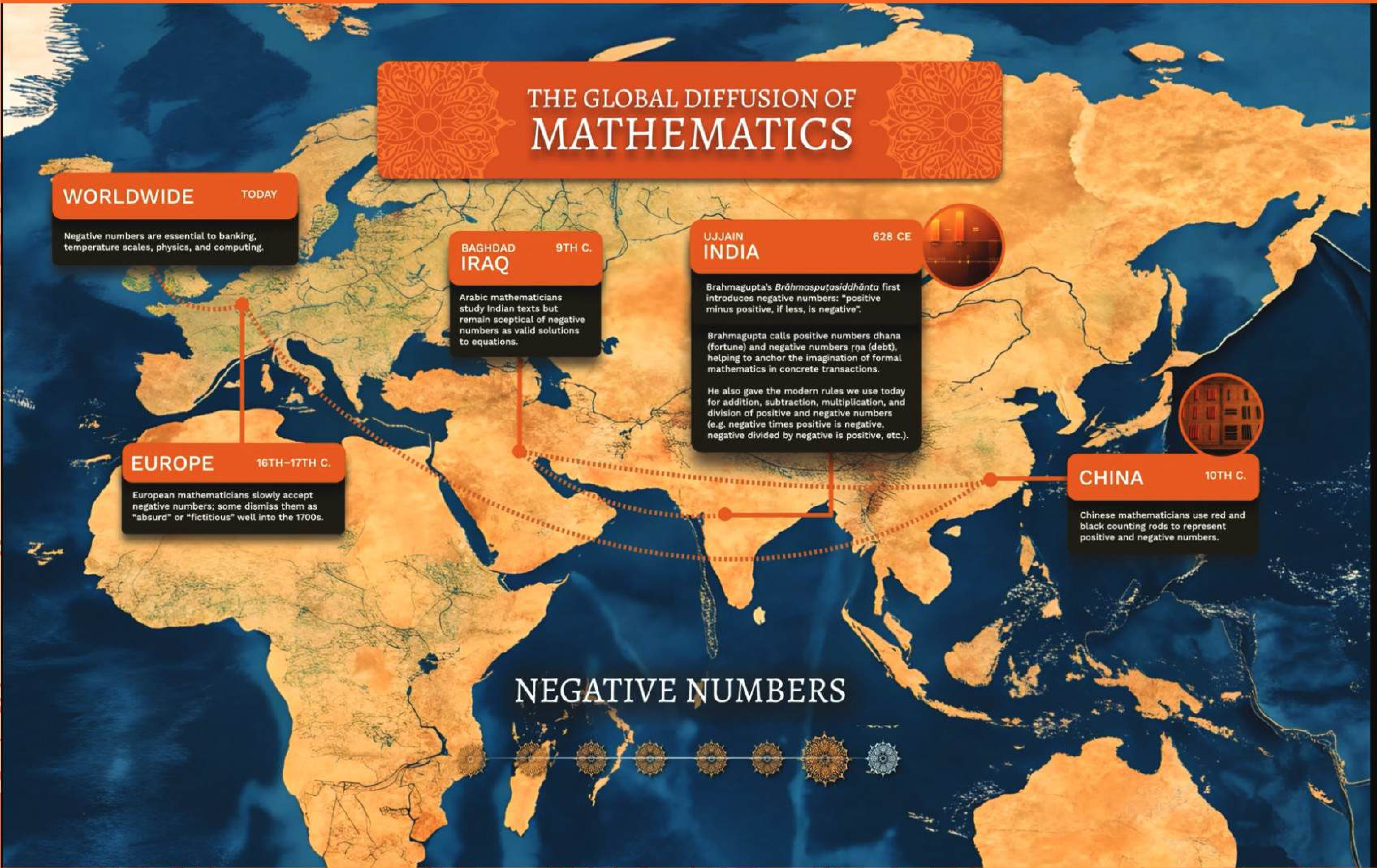

THE GLOBAL DIFFUSION OF
MATHEMATICS
TOLEDO 1126 CE
SPAIN
Adelard of Bath translates al-Khwārizmī's astronomical tables into Latin — "the first serious work of mathematical astronomy in Western Europe".
UJJAIN 628 CE
INDIA
Brahmagupta refines trigonometric methods in the *Brāhmasputasiddhānta.*
KUSUMAPURA (PATNA) 499 CE
INDIA
Āryabhaṭa introduces the sine function and constructs tables of sine values in the *Āryabhaṭiyam.*
BAGHDAD
IRAQ
C. 770 CE
Indian Siddhānta texts are brought to the Abbāsid court; Muḥammad al-Fazārī produces Arabic astronomical works based on Indian sources.
C. 820 CE
Al-Khwārizmī's *Zīj al-Sindhind* uses Indian sines for computing planetary positions.
C. 940–998 CE
Abū al-Wafā' al-Būzjānī introduces the tangent function and refines sine tables.
TRIGONOMETRY
AND SINE TABLES

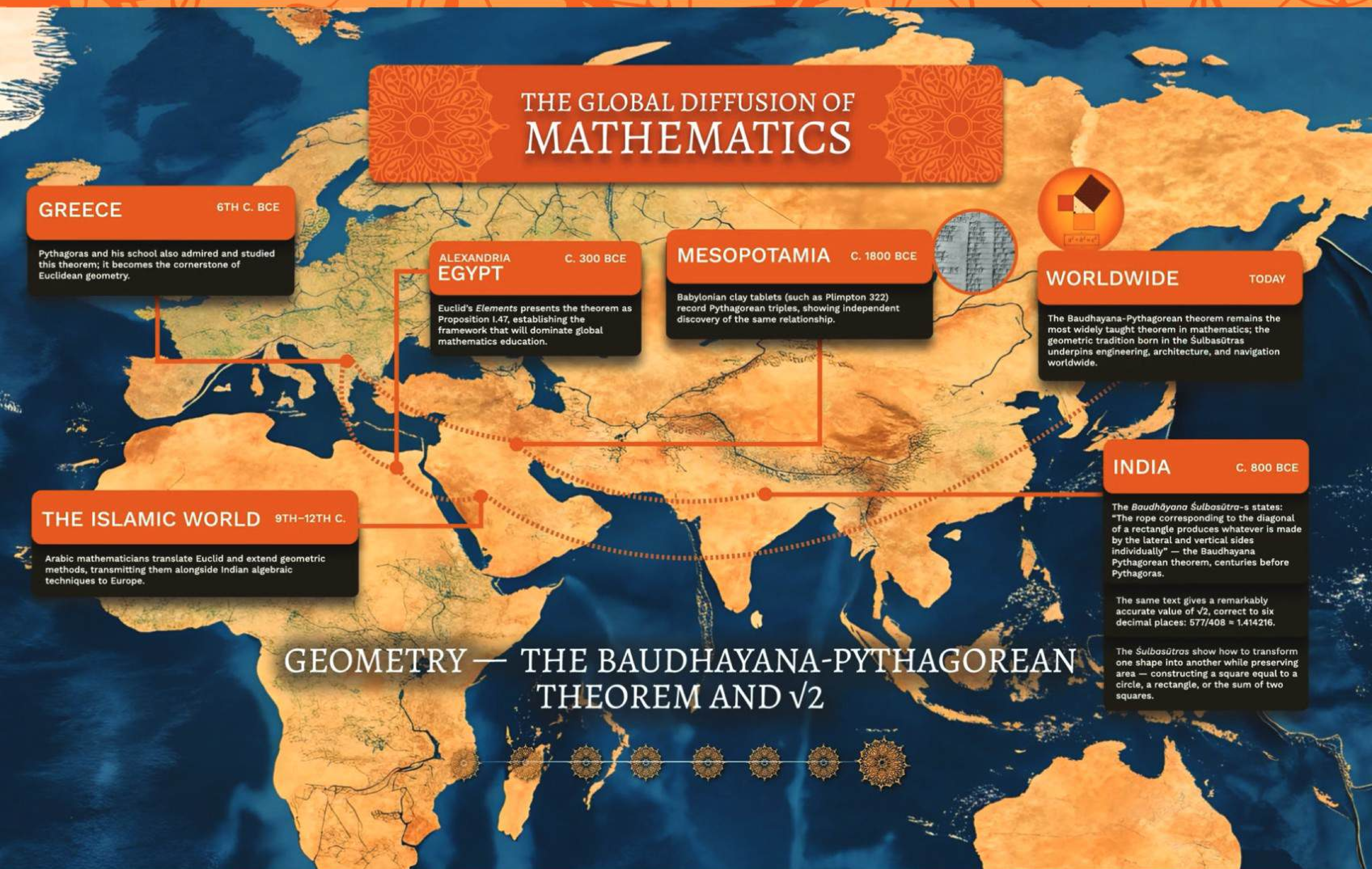

THE GLOBAL DIFFUSION OF
MATHEMATICS
EUROPE 12TH–13TH C.
Translations into Latin and Hebrew lead to the diffusion of Indian algebraic ideas across Europe.
BAGHDAD C. 820 CE
IRAQ
Al-Khwārizmī's *Ḥisāb al-Jabr wal-Muqābalah* gives currency to the term "algebra"; its treatment of mensuration draws on Sanskrit texts.
UJJAIN 628 CE
INDIA
Brahmagupta's *Brāhmasphuṭasiddhānta* contains systematic rules for solving equations, including the kuṭṭaka ("pulveriser") method.
TOLEDO 12TH C.
SPAIN
Latin translation of al-Khwārizmī gives us the word "algorithm" — from his name.
MAHARASHTRA 1150 CE
INDIA
Bhāskara II's *Bījagaṇita* contains the cakravāla method for solving indeterminate equations.
DECCAN 850 CE
INDIA
Mahāvīra's *Gaṇitasārasaṅgraha* — the first work devoted entirely to mathematics.
ALGEBRA AND ALGORITHMS


THE GLOBAL DIFFUSION OF
MATHEMATICS
SAMARKAND 1420 CE
CENTRAL ASIA
Ulugh Beg establishes a grand observatory; the *Zij-i Ulugh Beg* records highly accurate star and planetary positions.
JAIPUR 18TH C.
INDIA
Sawai Jai Singh, inspired by Ulugh Beg's observatory, builds his own observatories in five cities and commissions the *Zij-i Muḥammad Shāhī*.
KUSUMAPURA (PATNA) 499 CE
INDIA
Āryabhaṭa's *Āryabhaṭīyam* presents computational methods for planetary positions and proposes Earth's rotation.
BAGHDAD 8TH C.
IRAQ
Caliph al-Manṣūr commissions Muḥammad al-Fazārī to produce *Zīj al-Sindhind* based on Indian Siddhānta texts.
GHAZNA 973–1048 CE
PRESENT-DAY AFGHANISTAN
Al-Bīrūnī writes *Kitāb al-Hind*, engaging deeply with Sanskrit astronomical texts; his work preserves knowledge of texts now lost.
CHANG'AN 7TH C.
CHINA
A family with origins in Varanasi works in the astronomical bureau of the Tang court, reconciling Indian and Chinese models; the symbol for zero is introduced to China.
PLANETARY MODELS AND
ASTRONOMICAL COMPUTATION


THE GLOBAL DIFFUSION OF
MATHEMATICS
EUROPE 17TH C.
Leibniz publishes the same infinite series for π in 1676; Newton develops calculus independently; scholars debate possible transmission from Kerala.
BAGHDAD 9TH C.
IRAQ
Indian approximations of π transmit to Islamic mathematicians through translated Siddhānta texts.
INDIA C. 800 BCE
The Śulbasūtra-s contain early approximations of π through calculations for circular altar constructions.
KUSUMAPURA (PATNA) 499 CE
INDIA
Āryabhaṭa gives a remarkably accurate approximation of π as 3.1416 in the Āryabhaṭīyam.
π
3.141592653
SANGAMAGRAMA (KERALA)
INDIA
C. 1380 CE
Mādhava of Sangamagrama gave a value for π correct to 11 decimal places (3.14159265359), using the first 21 terms of his infinite series. He also provided a formula that allowed for an even more precise value of 13 decimal places (3.1415926535898).
1500 CE
Nīlakaṇṭha's Āryabhaṭīyabhāṣya is the first Indian text to state that π is irrational — it cannot be expressed exactly.
KERALA 19TH C.
INDIA
Śaṅkara's Varman from the Kerala School, provided a value for π correct to 17 decimal places (3.14159265358979323). Śaṅkara's correction terms enable approximation of π accurate to the 10th decimal place.
PI (π) AND INFINITE SERIES


THE GLOBAL DIFFUSION OF
MATHEMATICS
GERMANY 1703 CE
Leibniz publishes his binary number system; he later acknowledges the I Ching but the deeper Piṅgala connection remains less known.
INDIA
8TH C. CE
Kedāra's Vṛttaratnākara explains how to construct a prastāra and assign each metre a decimal value corresponding to its binary rank.
10TH C. CE
Halāyudha's Mṛtasañjīvinī, a commentary on Piṅgala's Chandaḥśāstra, also presents the Meruprastāra.
INDIA
C. 3RD C. BCE
Piṅgala's Chandaḥśāstra classifies syllables as short (laghu) or long (guru), enumerating all possible metres through a binary system.
C. 3RD C. BCE
Piṅgala uses the word śūnya (zero) as a marker — one of the earliest references to zero.
7TH C. CE
Virahāṅka's Vṛttajātisamuccaya shows how to calculate the number of rhythms possible in a verse of a given number of beats: write '1, 2', and make each successive number the sum of the two previous numbers: 1,2,3,5,8,13, 21...
The 'n'th number gives the number of rhythms having 'n' beats.
This is known as the Fibonacci series after the Italian mathematician (c. 1200) who studied them.
Virahāṅka's describes the triangle of binomial coefficients to enumerate all possible meters, called the Meruprastāra—now often called Pascal's Triangle after Blaise Pascal (17th c. CE).
COMBINATORICS AND
BINARY ENUMERATION


THE GLOBAL DIFFUSION OF
MATHEMATICS
WORLDWIDE TODAY
Negative numbers are essential to banking, temperature scales, physics, and computing.
BAGHDAD IRAQ 9TH C.
Arabic mathematicians study Indian texts but remain sceptical of negative numbers as valid solutions to equations.
UJJAIN INDIA 628 CE
Brahmagupta's *Brāhmasphuṭasiddhānta* first introduces negative numbers: "positive minus positive, if less, is negative".
Brahmagupta calls positive numbers dhana (fortune) and negative numbers ṛṇa (debt), helping to anchor the imagination of formal mathematics in concrete transactions.
He also gave the modern rules we use today for addition, subtraction, multiplication, and division of positive and negative numbers (e.g. negative times positive is negative, negative divided by negative is positive, etc.).
EUROPE 16TH–17TH C.
European mathematicians slowly accept negative numbers; some dismiss them as "absurd" or "fictitious" well into the 1700s.
CHINA 10TH C.
Chinese mathematicians use red and black counting rods to represent positive and negative numbers.
NEGATIVE NUMBERS


THE GLOBAL DIFFUSION OF
MATHEMATICS
GREECE 6TH C. BCE
Pythagoras and his school also admired and studied this theorem; it becomes the cornerstone of Euclidean geometry.
ALEXANDRIA EGYPT C. 300 BCE
Euclid's *Elements* presents the theorem as Proposition I.47, establishing the framework that will dominate global mathematics education.
MESOPOTAMIA C. 1800 BCE
Babylonian clay tablets (such as Plimpton 322) record Pythagorean triples, showing independent discovery of the same relationship.
WORLDWIDE TODAY
The Baudhayana-Pythagorean theorem remains the most widely taught theorem in mathematics; the geometric tradition born in the Śulbasūtras underpins engineering, architecture, and navigation worldwide.
THE ISLAMIC WORLD 9TH–12TH C.
Arabic mathematicians translate Euclid and extend geometric methods, transmitting them alongside Indian algebraic techniques to Europe.
INDIA C. 800 BCE
The *Baudhāyana Śulbasūtra*-s states: "The rope corresponding to the diagonal of a rectangle produces whatever is made by the lateral and vertical sides individually" — the Baudhayana Pythagorean theorem, centuries before Pythagoras.
The same text gives a remarkably accurate value of √2, correct to six decimal places: 577/408 ≈ 1.414216.
The *Śulbasūtras* show how to transform one shape into another while preserving area — constructing a square equal to a circle, a rectangle, or the sum of two squares.
GEOMETRY — THE BAUDHAYANA-PYTHAGOREAN THEOREM AND √2

SECTION III

The Language of Logic

How ancient India’s analysis of poetry created the logical foundations for the digital age

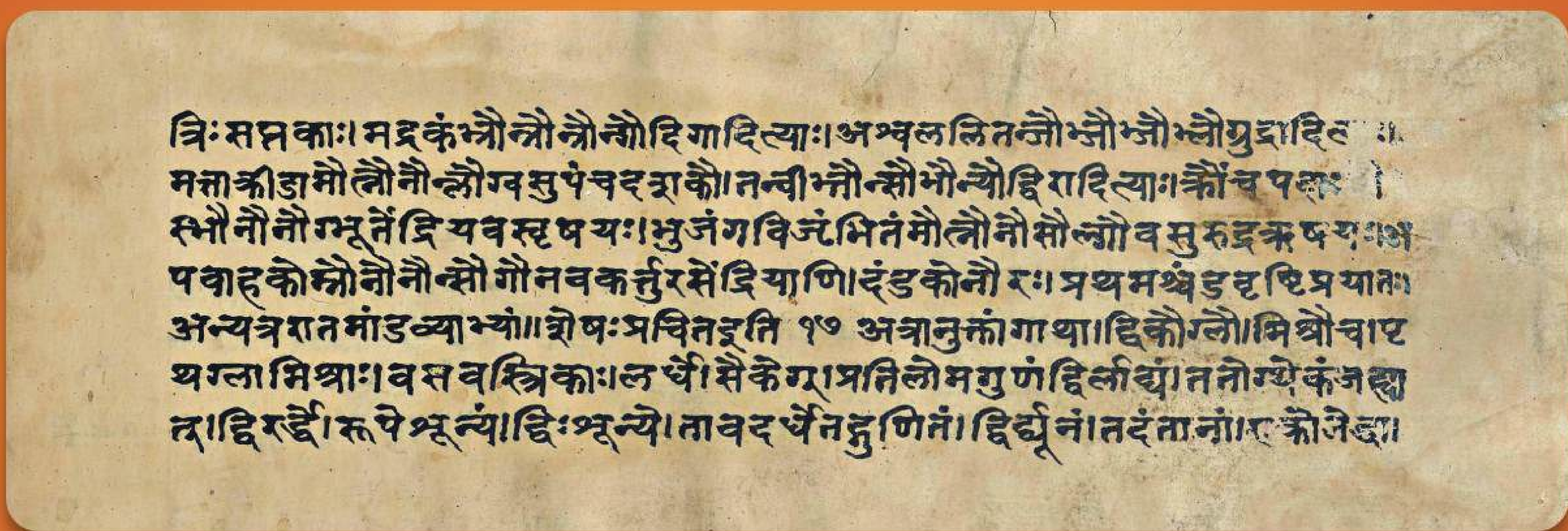
The Language of Logic

PART ONE

How Sanskrit Poetry Pioneered Mathematics

Over two thousand years ago, Piṅgala, an ancient Indian scholar analysing Vedic hymns, discovered a revolutionary mathematical concept that continues to power modern computing — binary enumeration.

Around the 3rd century BCE, Piṅgala set out to catalogue every possible rhythmic pattern in Sanskrit poetry. His treatise, the ‘Chandaḥśāstra’, contained an insight foundational for mathematics. His system classified each syllable as either laghu (short) or guru (long)—a binary distinction that would resonate through millennia.



Chandaḥśāstra by Piṅgala (c. 3rd century BCE) —
Sanskrit manuscript on the science of prosody

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The Earliest Reference to Śhūnya (Zero)

रूपे शून्यम्॥

"WHEN UNITY [IS SUBTRACTED, RECORD] ZERO"
— CHANDAḤŚĀSTRA, VERSE 8.29

Tucked within Piṅgala's verses on poetic metre lies this remarkable line—one of the earliest known references to śhunya, the Sanskrit word for "void" or "zero," used here as a placeholder in his notation system.

Śhūnya — The Void: The concept of zero as a number and placeholder, born from the analysis of Sanskrit poetry, would revolutionise mathematics worldwide.

An empty place still holds a position in the pattern.

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The Birth of Binary

The Birth of Binary

Piṅgala's great insight was deceptively simple. In Sanskrit poetry, each syllable is classified as either laghu (short) or guru (long). Since every syllable must be one or the other, he realised he could represent any rhythmic pattern using just two symbols.

S	I
Guru Long Syllable	**Laghu** Short Syllable

Piṅgala worked out a system for ordering sequences of long and short syllables for a verse. The steps are below.

A verse of one syllable has two possibilities, short or long (S I).

For a verse of two syllables, take the pattern above, and successively add long and short syllables to arrive at four permutations:

S I	+S +S	S S I S	S S I S
S I	+I +I	S I I I	S I I I

For a verse of three syllables, take the four sequences for two-syllable verses, and add long and short syllables to get eight permutations

S S I S S I I I	+S	S S S I S S S I S I I S

S S I S S I I I	+I	S S I I S I S I I I I I

If we turn the list upside down, and represent S by 1 and I by 0, we get the binary notation for 0 to 7

S	I	I	S	S	I
↓	↓	↓	↓	↓	↓
1	0	0	1	1	0

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Try It Yourself

Tap the syllables to toggle between guru and laghu

G

G G

G G G

G G G G

Guru (long) = 1   Laghu (short) = 0

1

1 1

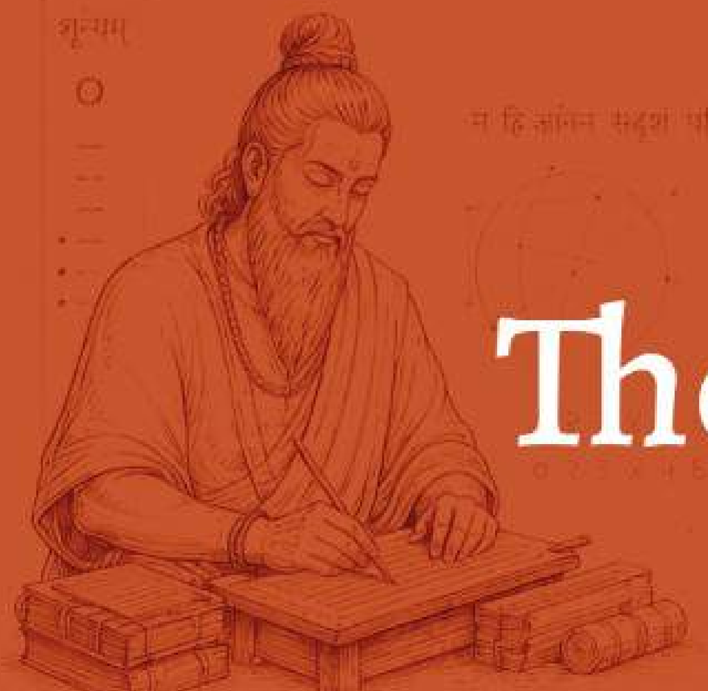
1 1 1

1 1 1 1

ANCIENT INNOVATIONS, MODERN APPLICATIONS:

This is precisely how a modern computer stores and processes information—as sequences of 1s and 0s. Piṅgala discovered binary notation more than two thousand years before the first electronic computer.

The Prastāra Algorithm



PART THREE

The Prastāra Algorithm

Piṅgala's method for exhaustively enumerating metrical patterns was elaborated by Kedāra (c. 8th century CE). Long and short syllables are set out in rows in a matrix called prastāra ("to spread out" in Sanskrit).

To work out all permutations for a three-syllable verse, follow the steps below:

Write a row with all three syllables set to long.	SSS
Start another row, and write a short syllable below the first long syllable in the row above. Leave the rest unchanged.	ISS
Start a third row of long syllables. Again, switch the syllable below the first long syllable above. Leave the rest unchanged.	SIS
Start another row, switching the syllable below the first long syllable above. Copy the rest unchanged.	IIS
Start a new row of long syllables, and switch the syllable below the first long syllable above to short.	SSI

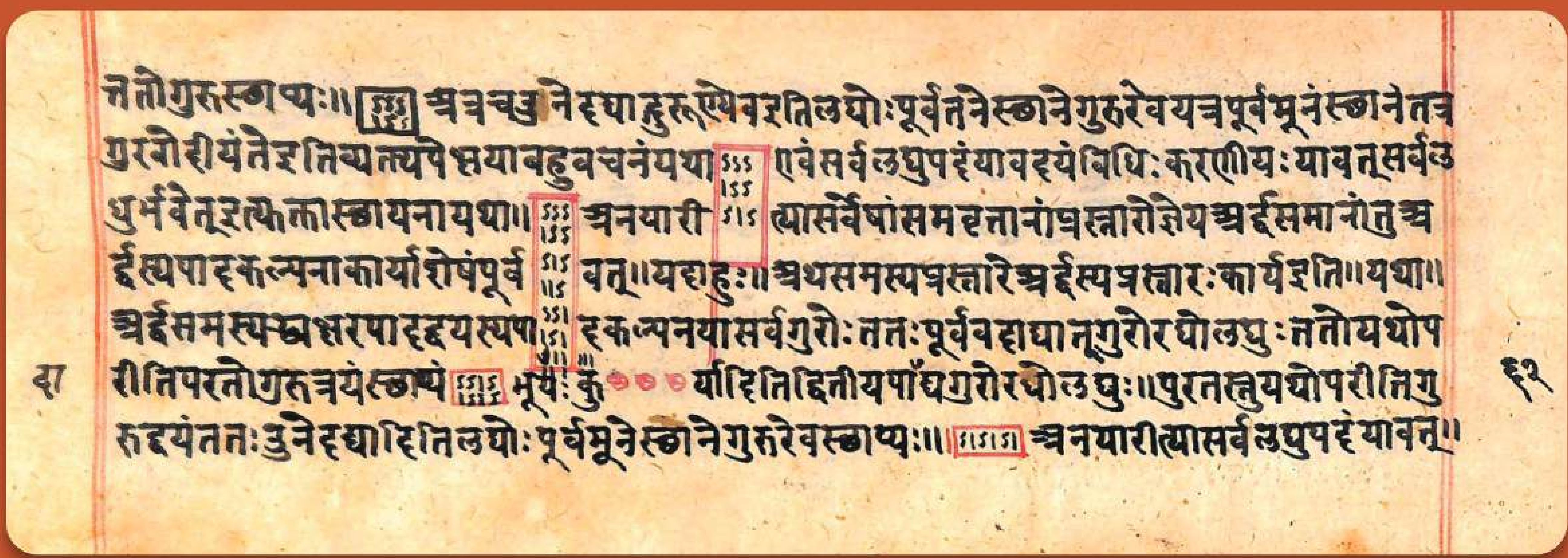
Start a new row, and switch the syllable below the first long syllable in the previous row to short. Copy the rest unchanged.	ISI
Start another row of long syllables, and switch the syllable below the first long syllable in the row above to short.	SII
Repeat, so that you get a row where all syllables are short. This brings the process to a close.	III

If we turn the list upside down, and represent S by 1 and I by 0, we get the binary notation for 0 to 7

III	000	0
IIS	001	1
ISI	010	2
ISS	011	3
SII	100	4
SIS	101	5
SSI	110	6
SSS	111	7

This binary system—encoding information using only two states—was not merely convenient notation. It was a conceptual breakthrough that would prove essential to the digital age. Today, binary code is at the core of all software.

It was the world's first known algorithm for binary enumeration, the same logic that, two millennia later, enables computers to count, search, and store information in the form of zeros and ones.



Vṛttaratnākara by Kedāra (8th century CE) — This manuscript elaborates Piṅgala’s prastāra algorithm

For a three-syllable verse, this procedure generates exactly eight patterns—which is 2×2×2, or 2^3. This is binary counting in action:

G G G - 111	L G G - 011
G L G - 101	L L G - 001
G G L - 110	L G L - 010
G L L - 100	L L L - 000

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All Possible Patterns

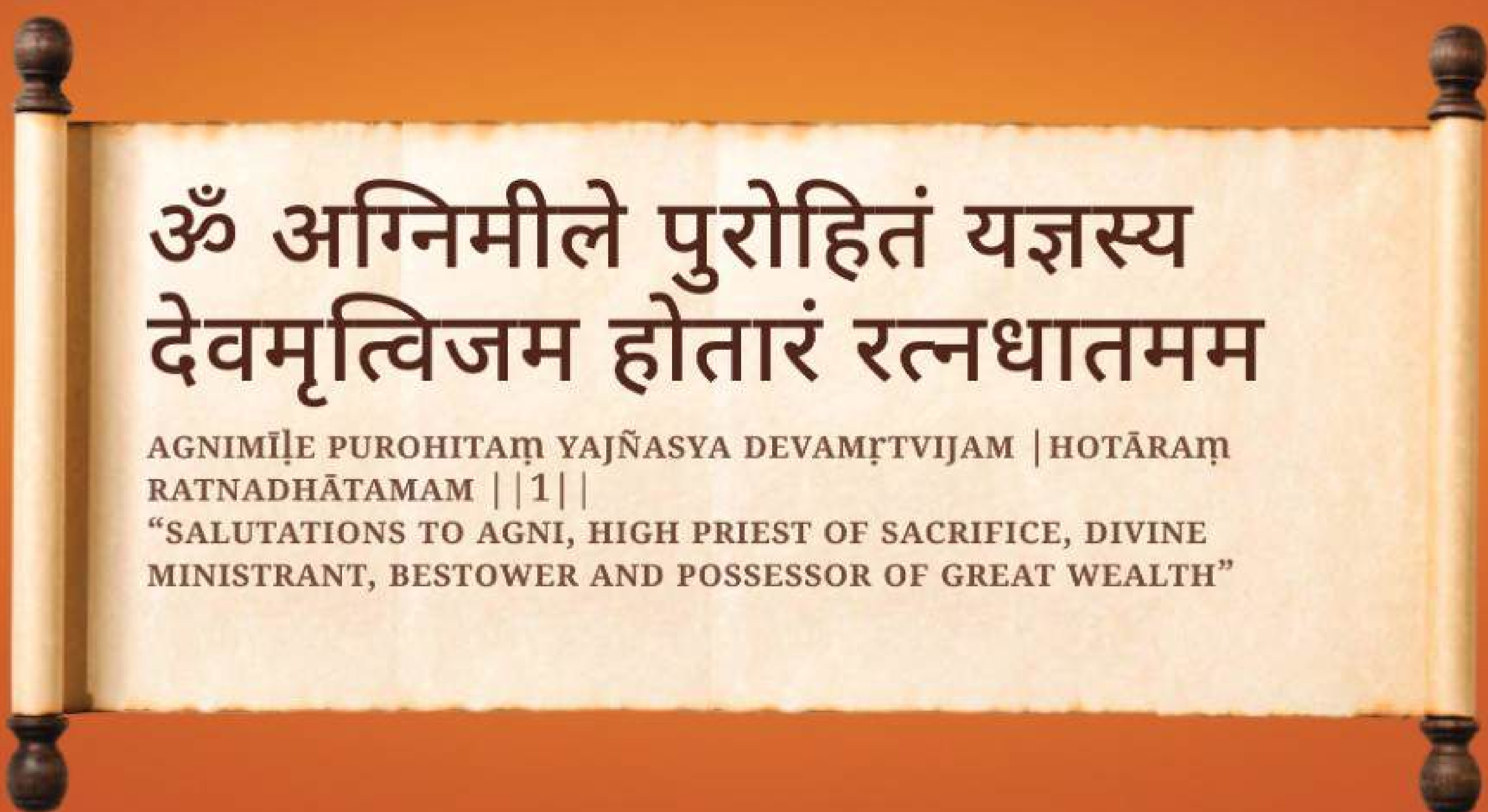
Halāyudha's Classification: In the 10th century, scholar Halāyudha wrote the book Mṛtasañjīvinī, a commentary on Piṅgala's Chandaḥśāstra, in which he arranged metrical in an array that captures arithmetic and geometric progressions.

Classification of metres based on Halāyudha's commentary on Piṅgala's Chandaḥśāstra

The first row of the array above lists the seven metres, starting with Gāyatrī. Each metre can take seven forms, according to the class it is in. The eight classes are listed in the first column.

Each cell gives the syllable-count of a metre of a given class. E.g., in the first row showing metres in the Ārṣī class, Gāyatrī has 24 syllables. Ārṣī is the sum of the three classes below it, where Gāyatrī has 1, 15, and 8 syllables respectively.

Ārṣī Gāyatrī is the metre for the first verse of the Vedas, the Agnisuktam, which invokes the deity of fire.



The mathematics of metre did not just structure poetry, it generated myths.

Kakubh has three feet with 8 + 12 + 8 = 28 syllables; Usnih has 8 + 8 + 12 = 28 syllables.

The Tandya Mahabrahmana (VIII.5.2.) describes Indra hurling his thunderbolt at Vrtra.

At Kakubh chanda he took a stride onwards; at Usnih he hurled the weapon.

We see that in Kakubh metre, the middle foot has the most syllables, like Indra's foot lifting in his stride. In Usnih, the last foot has the most syllables, as Indra casts the thunderbolt with all his power.

Q: How many rhythms are possible given a metre of n syllables?
A: 2n, because each syllable is either laghu or guru

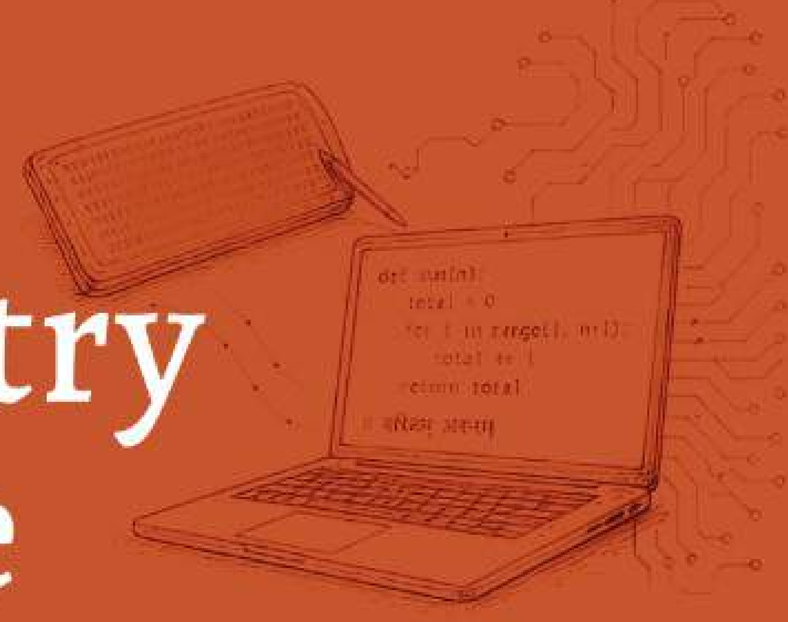
$2^0 =$	1	0-syllable metre
$2^1 =$	1 (S) 1 (I)	1-syllable metre
$2^2 =$	1 (SS) 2 (SI) 1 (II)	2-syllable metre
$2^3 =$	1 (SSS) 3 (SSI) 3 (SII) 1 (III)	3-syllable metre
$2^4 =$	1 (SSSS) 4 (SSSI) 6 (SSII) 4 (SIII) 1 (IIII)	4-syllable metre

This is termed the meru-prastāra ('mountain arrangement'). It was first formulated by Virahāṅka (c. 600 CE), in Vṛttajātisamuccaya, a work in Prakrit. He explains how to generate a series where each successive number is the sum of the two immediately preceding it or, if S_n is the number of metrical patterns possible in a verse of n syllables, $S_n = S_{n-1} + S_{n-2}$

This pyramid was later formulated by French mathematician Blaise Pascal in 1664, and known in the West as Pascal's Triangle.

Today many people know this as the system of binomial coefficients, or of picking a sub-set of 'y' elements from a total set of 'x' elements.

From Ancient Poetry to Modern Code



PART FOUR

From Ancient Poetry to Modern Code

The journey of binary thinking from Sanskrit prosody to silicon chips spans centuries and continents:

c. 300 BCE

Piṅgala develops binary enumeration for Sanskrit prosody

1703

Leibniz publishes his binary number system in Europe

1854

George Boole creates Boolean algebra—the logic of true/false

1936

Alan Turing describes his theoretical computing machine, laying the foundation for modern software

Today

Every smartphone, satellite, and AI runs on binary logic

	श्री	छंदप्रस्तारो लिख्यते ॥					
गायत्र्यादि	गा॰	उष्णि॰	अ॰	बृह॰	पंक्ति	त्रि॰	ज॰
आर्षी	२४	२८	३२	३६	४०	४४	४८
दैवी	१	२	३	४	५	६	७
आसु॰	१५	१४	१३	१२	११	१०	९
प्राजाप॰	८	१२	१६	२०	२४	२८	३२
याजुषी॰	६	७	८	९	१०	११	१२
साम्ना॰	१२	१४	१६	१८	२०	२२	२४
आर्ची॰	१८	२१	२४	२७	३०	३३	३६
ब्राह्मी॰	३६	४२	४८	५४	६०	६६	७२

Mṛtasañjīvinī classification showing the organisation of metres, demonstrating how these ideas were systematised over centuries

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PART FOUR

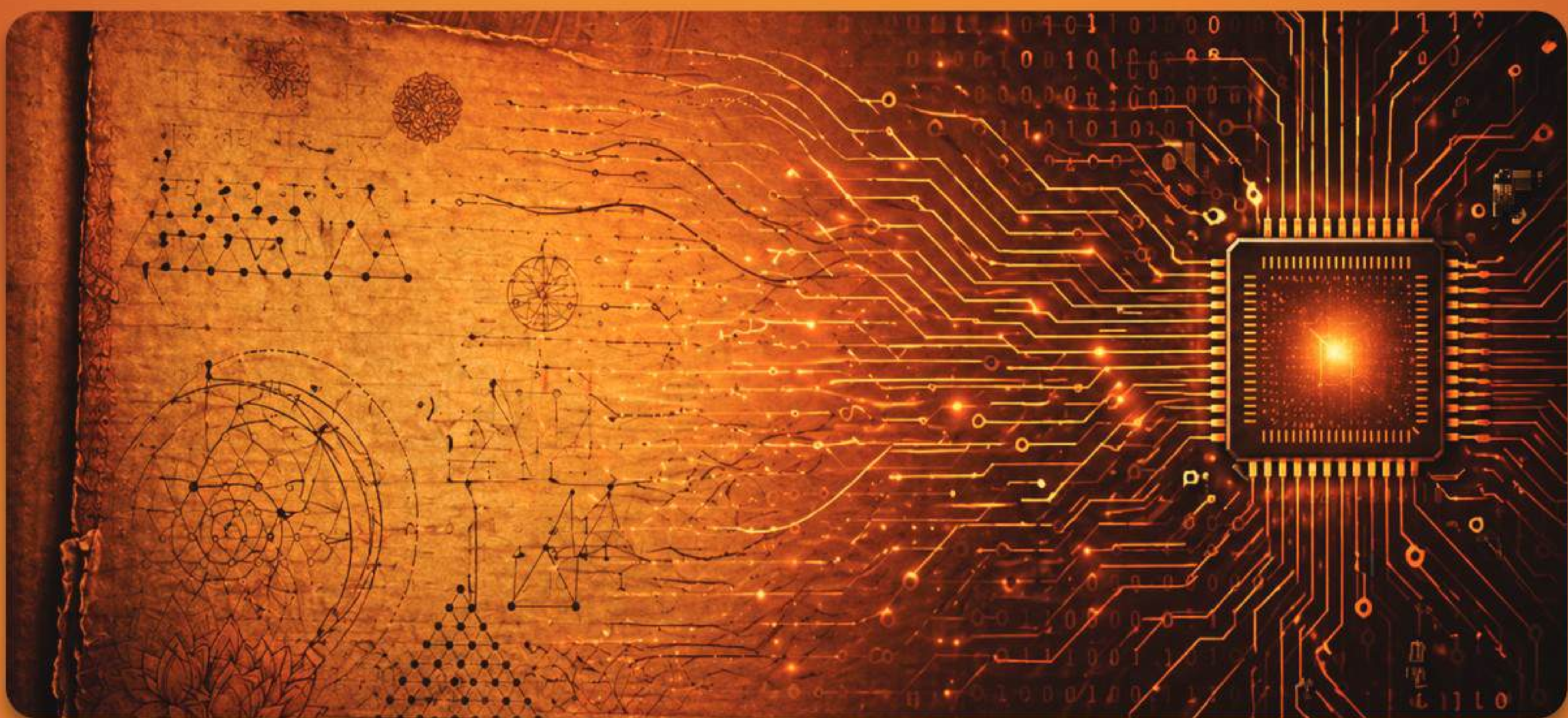
The Poetry of Computation

When you send a message, stream a video, or ask an AI a question, the underlying principle is the same one Piṅgala used to analyse Vedic hymns: information reduced to two states, processed systematically, step by step.

In modern technology, ancient wisdom is echoed.

FULL CIRCLE:

From the rhythms of Sanskrit verse to the rhythms of digital computation, the legacy of Piṅgala's Chandaḥśāstra continues to shape our world.



From Piṅgala to the digital age—a juxtaposition of an ancient manuscript with a modern circuit board

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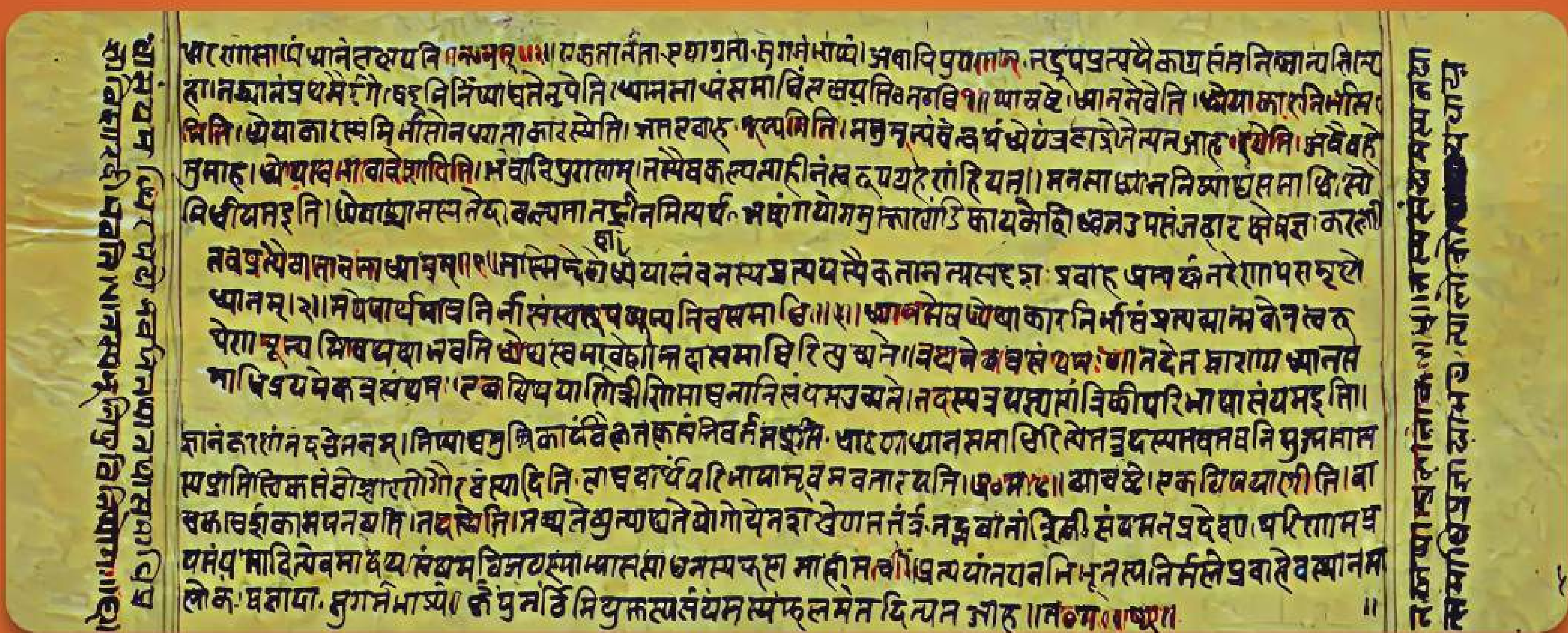
PART FOUR

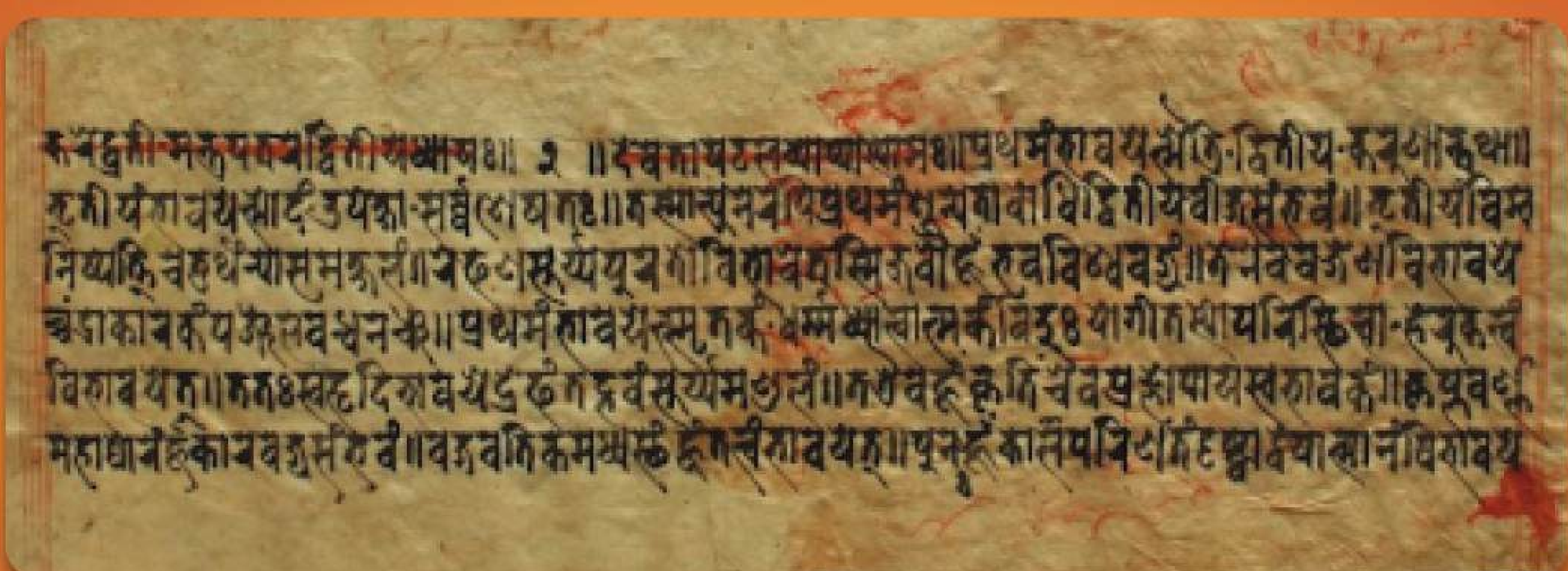
Philosophies Around the Void

In literature and philosophy from the late first millennium BCE, the concept of Shūnyatā (emptiness or nothingness) had profound meanings. The word Shūnya means zero, and the word shūnyatā (zeroness) was used to describe the state that one tries to reach during meditation—that of emptying one's mind of all vṛttis (fluctuations) to achieve perfect stillness and tranquility. This is described in the Yogasutras of Patanjali (c. 3rd century BCE). Likewise, for the Jainas, shūnya-dhyāna leads to liberation. The Maitreyī Upanishad (2.27) says shunya is the goal of ascetic contemplation, and an aspect of the Ultimate Being, who transcends dualities (3.5). For Buddhists, their belief that a stable "self" is an illusion led them to evolve the doctrine of shunyata, which recognises the limits of our mind's conceptual categories.



Yogasastra Samkhyapravacana with Tattvavaisaradi Sanskrit manuscript from Nepal digitised by British Library Endangered Archives Programme

In yoga, the mind's attention is directed to a place or object, so it shines with the light of what is contemplated, and becomes devoid of self (svarupa shunya).



Hevajratantra Sanskrit manuscript from Nepal housed at the University of Tokyo

The Hevajratantra describes how visualising the Deity starts with realising shunyata ("prathamam shunyabodhim").

SECTION IV

The Scholars and their Innovations

A journey through two millennia of mathematical discovery in the Indian subcontinent

Inceptions

Numbers, Geometry, and Shunya

The Vedic texts reveal a civilisation deeply fascinated by the power of numbers. Invocations in the Yajurveda name powers of ten from hundreds to trillions, while references to the infinitesimally small hint at an imagination that reached far beyond the demands of daily life.

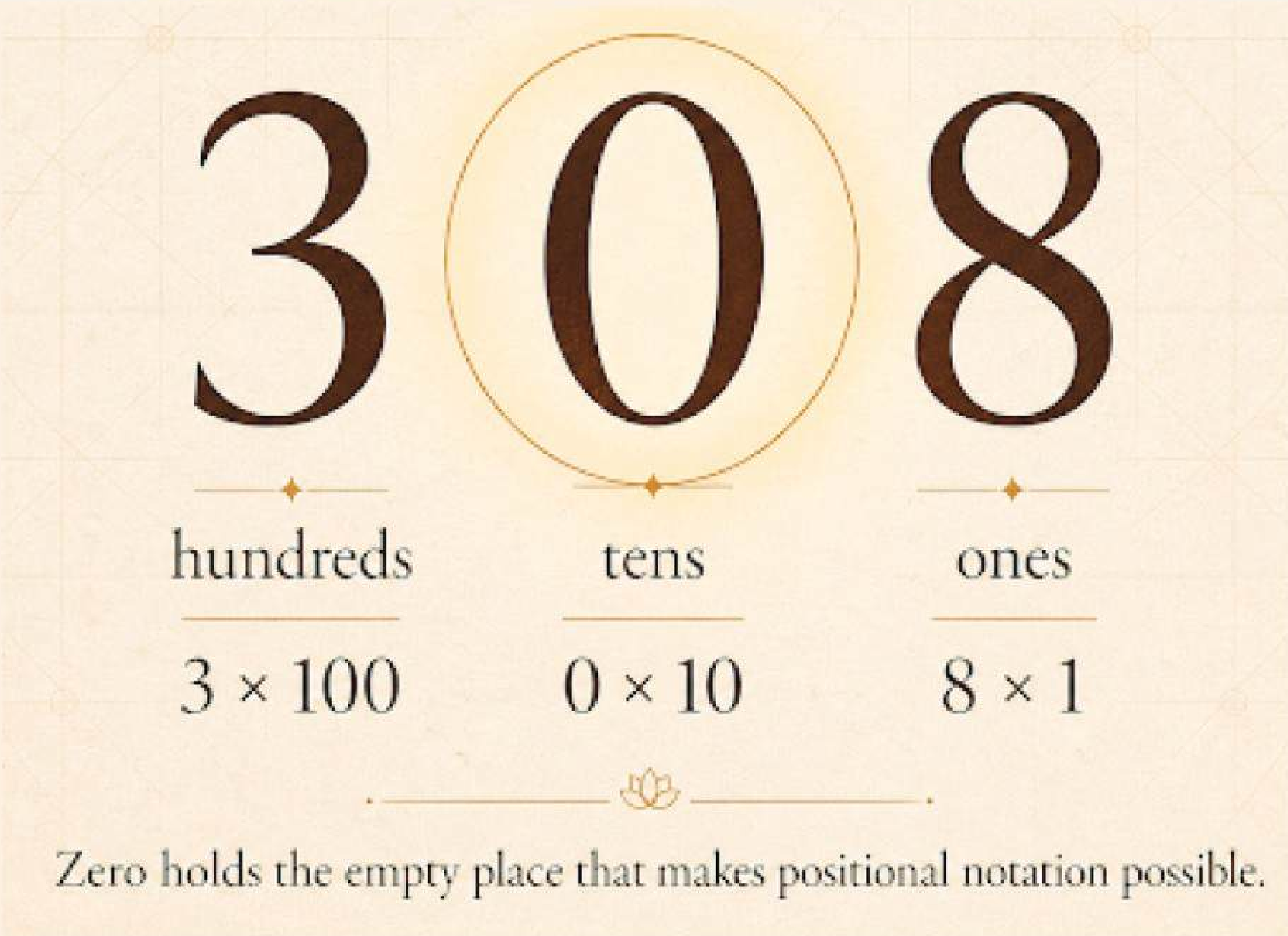
> शतायस्वाहा सहस्राय स्वाहा
> अयुतायस्वाहा नियुतायस्वाहा...
>
> **"HAIL TO A HUNDRED, HAIL TO A THOUSAND, HAIL TO TEN THOUSAND, HAIL TO A HUNDRED THOUSAND..."**
> **— YAJURVEDA, 7.2.20**

This is a formulation of the theorem which at one time was ascribed to Pythagoras (c. 570–495 BCE), though we find it recorded here centuries before the Greek tradition.

The decimal system was in use at least by the time of the Ṛigveda (1500-1200 BCE), with names for each of the nine numerals and for ascending powers of ten. Rigvedic names were formed by applying rules of multiplicative and additive composition (shashtim sahasra navatimnava for 60,099).

We may discern here the genesis of the place-value system, which has been described as a set of rules that allow us to represent all numbers larger than the base through a recursive arithmetical procedure.

The decimal place-value system has the advantage of making it possible to write any number, however large, using only ten symbols.



The notion of zero was essential to making the place-value system work. In the number 308, the digit 3 occupies the hundreds place (3 × 100), 0 holds the tens place (0 × 10), and 8 sits in the ones place. Without zero as a placeholder, positional notation collapses.

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Constructing Forms

The Śulbasūtras (“Rules of the Chords”) is a genre of texts that show how to construct different shapes using a cord to mark off lengths, and how to transform one shape into another while preserving its area.

दीर्घचतुरश्रस्य अक्ष्णयारज्जुः,
पार्श्वमानी तिर्यङ्मानी च यत्
पृथग्भूते कृतः तदुभयं करोति

“THE ROPE CORRESPONDING TO THE DIAGONAL OF A RECTANGLE PRODUCES WHATEVER IS MADE BY THE LATERAL AND VERTICAL SIDES INDIVIDUALLY.”
— BAUDHĀYANA ŚULBASŪTRA, C. 800 BCE VERSE 2.5

This is a formulation of the theorem which later came to be ascribed to Baudhyan–Pythagoras (c. 570–495 BCE)—recorded here centuries before the Greek tradition. The same text gives a remarkably accurate value of √2, correct to six decimal places.

प्रमाणं तृतीयेन वर्धयेत् तच्च
चतुर्थेन आत्मचतुस्त्रिशोनेन सविषेषः

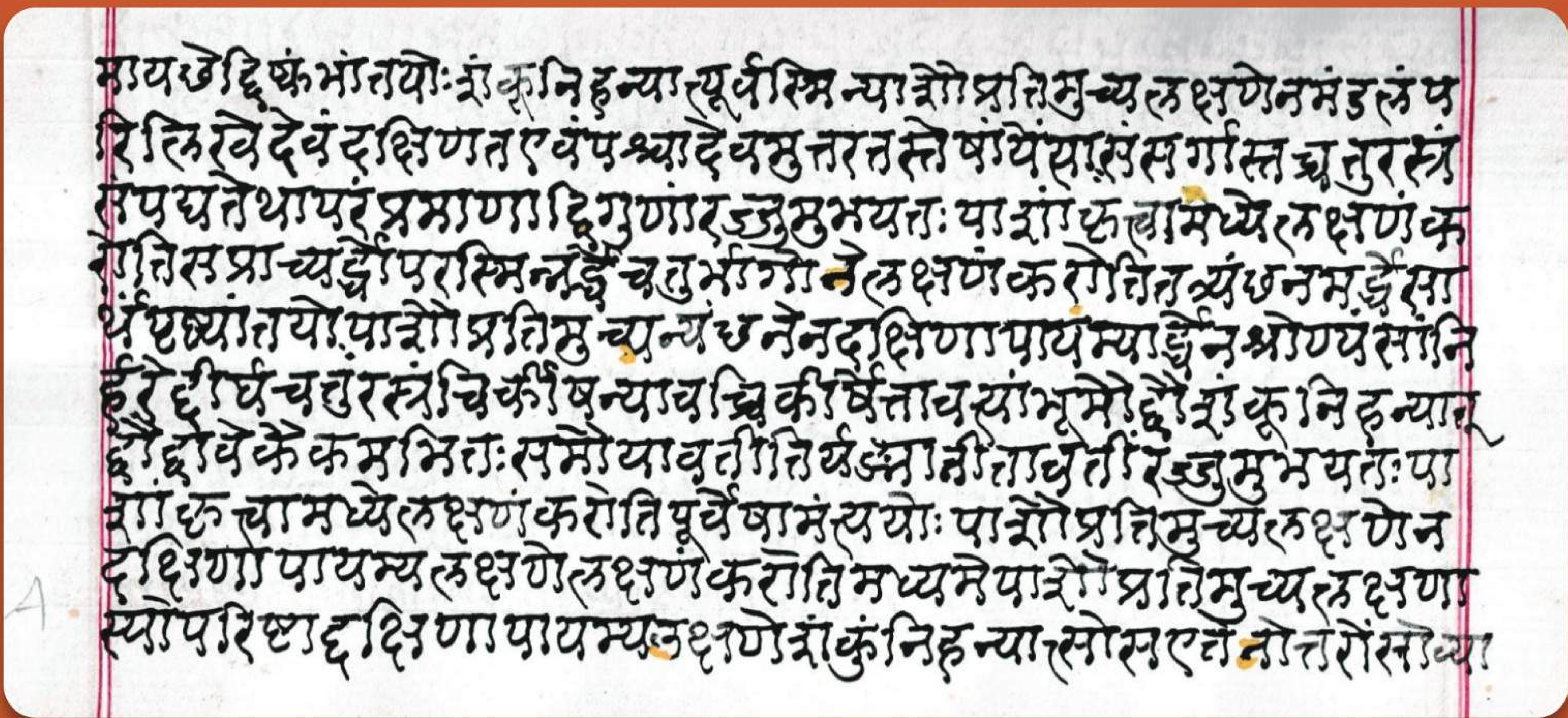
PRAMĀṆAM TṚITĪYENA VARDHAYET TATCA
CATURTHENĀTMACATUSTṂŚŚONENA SAVIŚIṢAḤ

“INCREASE THE MEASURE OF THE STANDARD UNIT BY ONE THIRD, AND AGAIN BY ONE FOURTH (OF THIS THIRD), LESS BY A THIRTY-FOURTH OF ITSELF. THIS WOULD BE THE DIAGONAL.”

BAUDHĀYANA'S APPROXIMATION

$$\sqrt{2} \approx 1 + \frac{1}{3} + \frac{1}{3 \cdot 4} - \frac{1}{3 \cdot 4 \cdot 34} = 577/408 \approx 1.414216\ldots$$

(true value: 1.414213...)



Baudhāyana Śulbasūtra- - manuscript from Bhandarkar Oriental Research Institute - showing how to construct fire altars by measuring off lengths with rope

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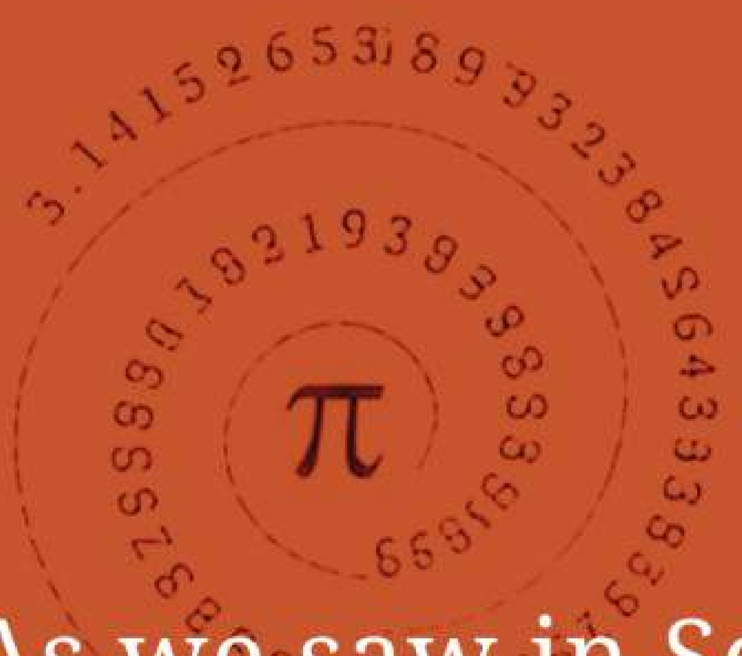


The Evolution

As we saw in Section III, Piṅgala's Chandaḥśāstra first named the concept of ZERO (shunya). But how did this idea become a number the whole world could use?

458 CE

The Lokavibhāga, a Jaina cosmological text completed in 458 CE, is an early source for the verbal decimal place-value system: the diameter of an island is given as a number in which zero takes the first position (śūnyaṃ navaikaṃ catvāri pañca trīṇi trikaṃ dvikam).

c. 3rd–7th century CE

The oldest surviving manuscript using zero for mathematical calculations is the Bakhshali Manuscript.

595 CE

Decimal place-value numerals are used in a copper plate in Gujarat.

683 CE

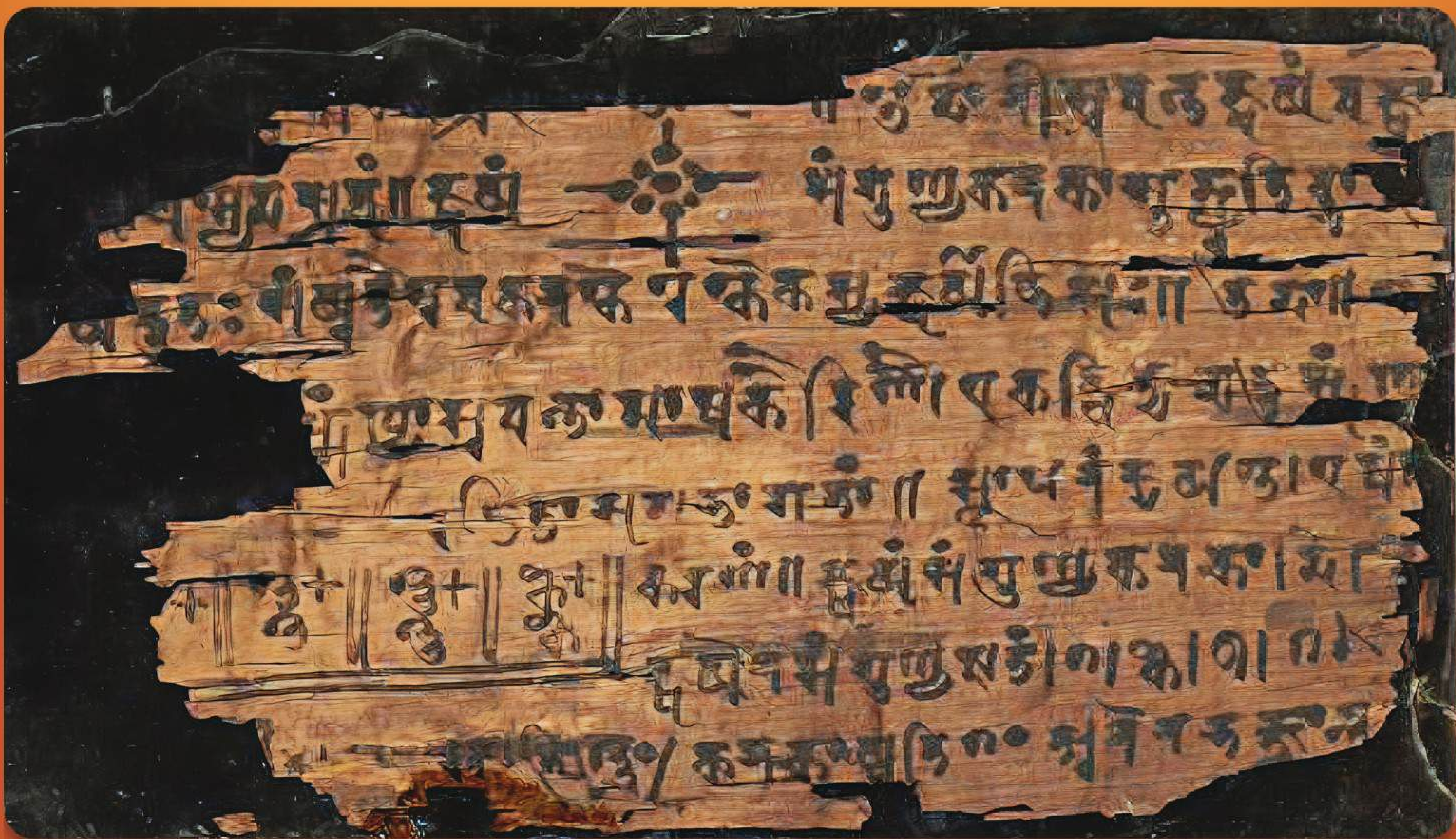
The zero symbol appears in an inscription in Cambodia

876 CE

The zero symbol appears in a stone inscription at Gwalior, India

How did Indians come to conceptualise the decimal system? Perhaps their capacity to imagine numbers beyond what can be counted led them to devise an efficient means of representing these. Stories about the Buddha's previous lives describe his ability to perform calculations with numbers going up to the 50th decimal place.

Bakshali Manuscript, 3rd-7th century CE
Image courtesy - Wikimedia Commons



Bakshali Manuscript, 8th–12th century CE.
Image courtesy - Wikimedia Commons

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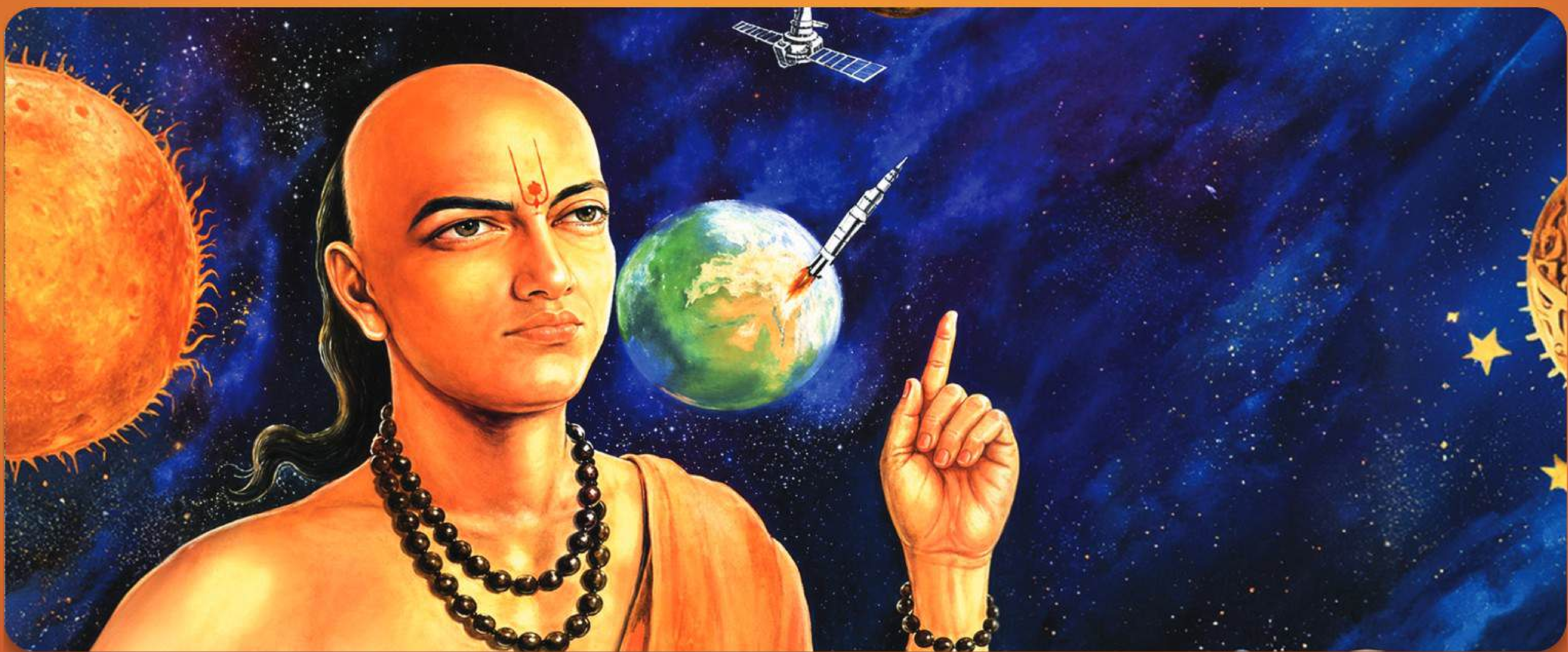
Breakthroughs

The Classical Tradition

From the middle of the first millennium CE, advances in Indian mathematics proved pivotal not just for the subcontinent, but for the entire world. Successive generations of scholars built on, argued with, and refined one another's work, accelerating insights in trigonometry, algebra, and the solution of equations.

5th – 12th century CE — Treatises composed across ancient India: Pataliputra, Malwa, Ujjain, the Deccan, Maharashtra, and beyond.



476 CE

Āryabhaṭa I

Āryabhaṭīyam

Sine tables, recursive relations, the Kuṭṭaka algorithm

598 CE

Brahmagupta

Brāhmasputasiddhānta

Rules for zero and negative numbers, the Bhāvanā principle

850 CE

Mahāvīrācārya

Gaṇitasārasaṅgraha

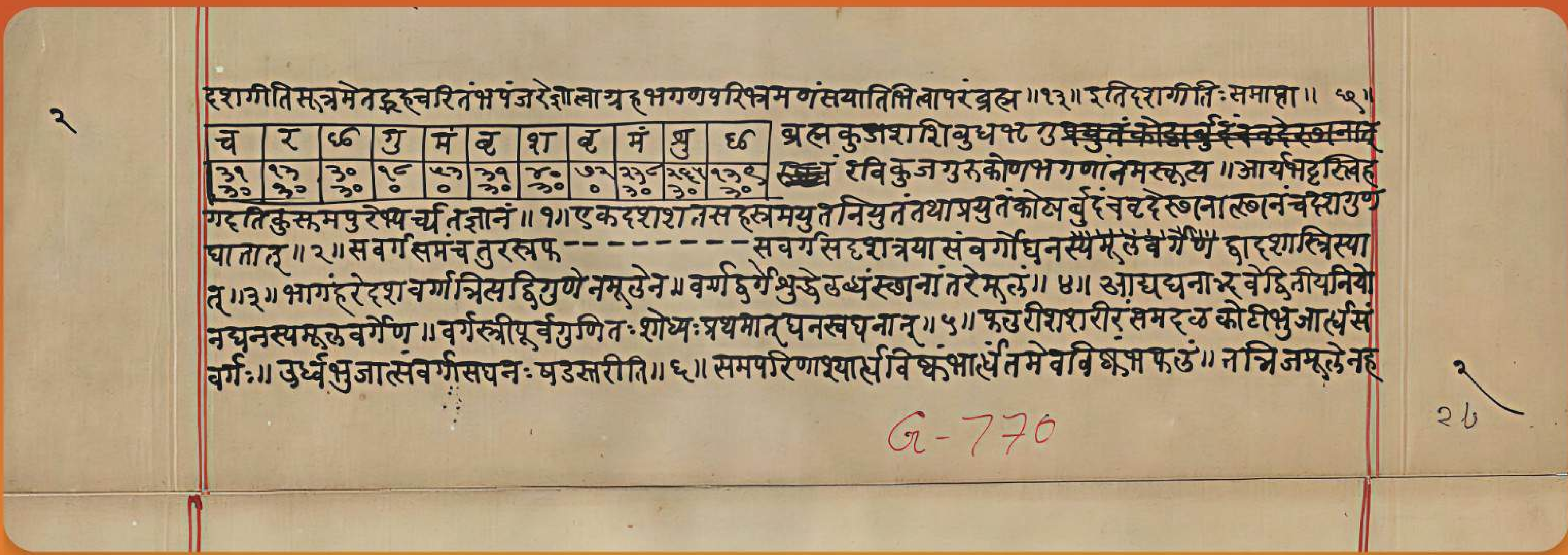
Comprehensive treatment of arithmetic, fractions, and series

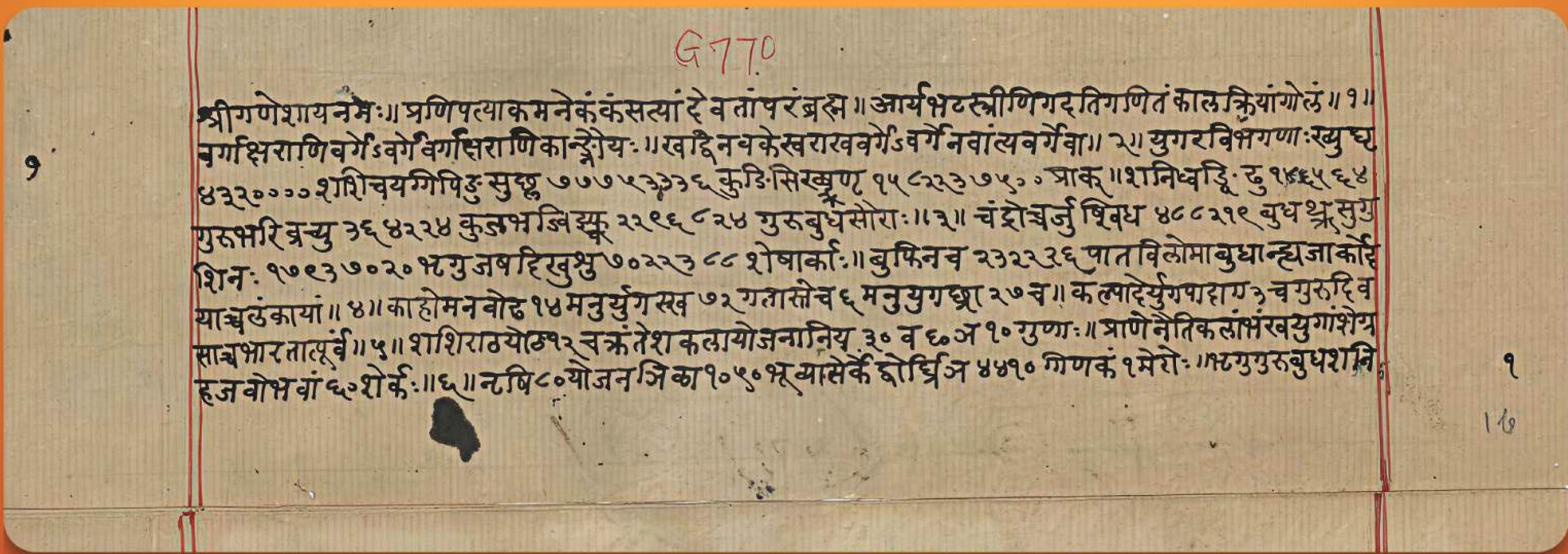
1114 CE

Bhāskara II

Līlāvatī, Bījagaṇita

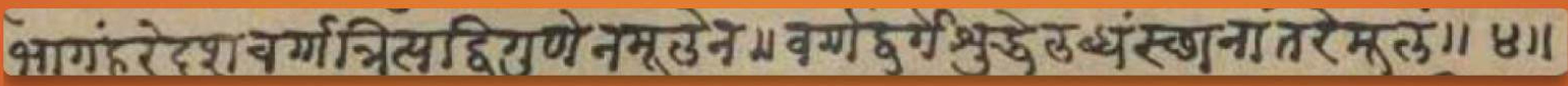
Elegant exposition, the Cakravāla method for indeterminate equations





Āryabhaṭīyam manuscript, 499 CE — Asiatic Society, Kolkata. A foundational text of Indian mathematical astronomy, introducing sine tables and the kuṭṭaka algorithm.

Āryabhaṭa's Procedure for Extracting Square Roots



Verse 1.4 of the Āryabhaṭiyam: "One should divide, constantly, the non-square [place] by twice the square root. When the square has been subtracted from the square [place], the quotient is the root in a different place."

1	Set it out, underscoring digits in places that are even powers of 10.	1 2 2 5
2	From the square place (12), subtract the largest square (here, 3 x 3 = 9). We get 3.	-9 =3
3	The next number in the "non-square" place is 2. Bring it down so we have 32. Divide 32 by twice the previous root (2 x 3 = 6). The quotient is 5. Subtract 30 (6 x 5) from 32. Remainder is 2.	32-30 =2

4	Bring down the last digit (5). Subtract the largest square (5 x 5) We get 0.	25 -25

Final square root: 35

The procedure follows the principle $(a + b)^2 = a^2 + b^2 + 2ab$

Here 35 = 30 + 5

Therefore 30 = 900 (The "Square" place)

2 x 30 x 5 = 300 (The "Double the root" step)

5 = 25 (The final "Square" subtraction)

Total: 1,225

Following Āryabhaṭa’s procedure above, we have successively removed the components:

900 (Square of 30)

300 (Twice the root x next digit)

25 (Square of 5)

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Brahmagupta and the Arithmetic of Śūnya (Zero)

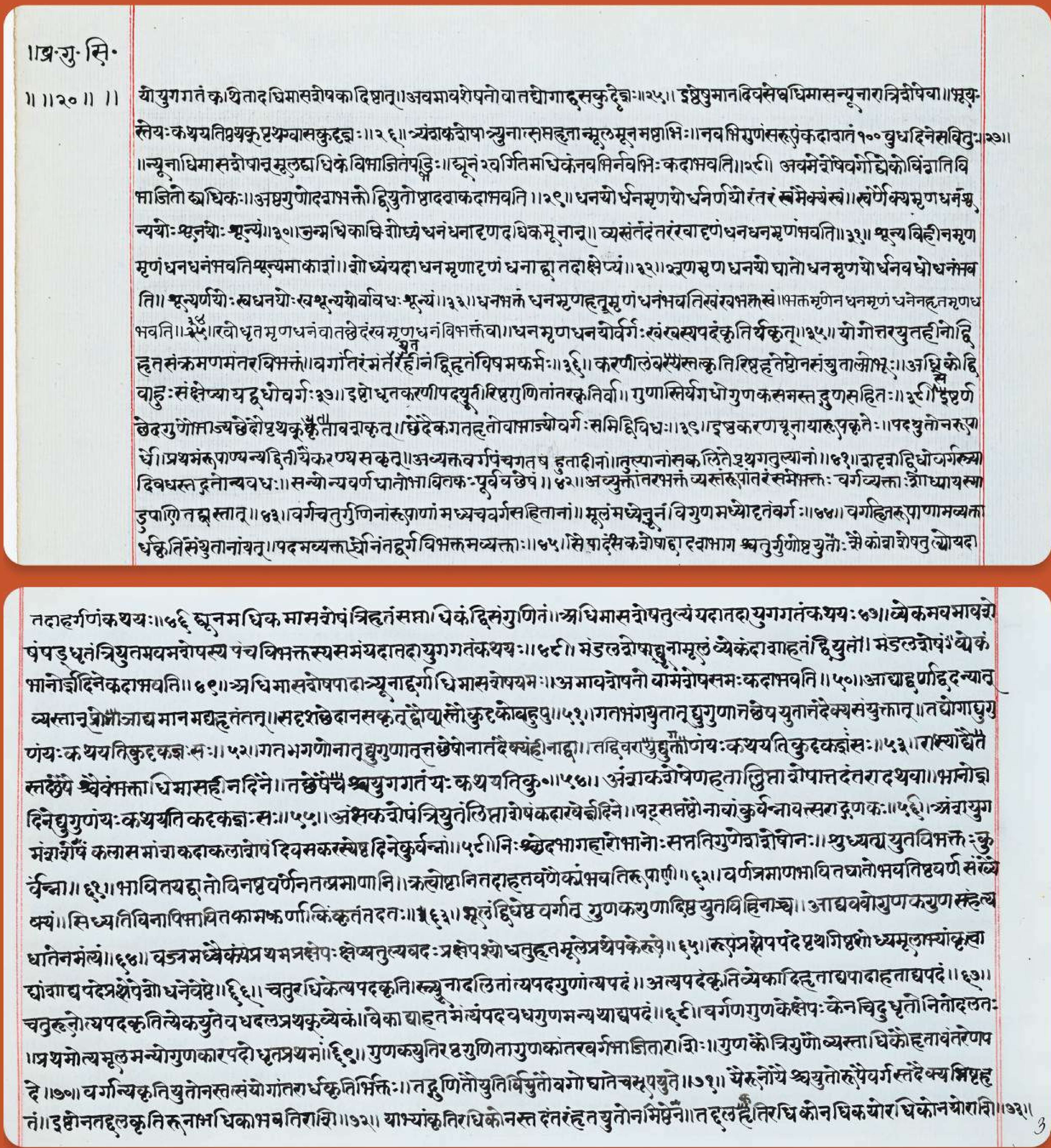
The Brāhmasputasiddhānta (628 CE) contains the first surviving explanation of the arithmetic of positive and negative numbers and zero, nearly all identical to their modern counterparts.

- positive + negative = the difference of the two numbers
- positive - negative = the addition of the two numbers
- positive or negative x zero = zero
- nonzero ÷ zero = “zero-divided” (an open question)

धनयोर्धनमृणमृणयोः
धनर्णयोरन्तरं समैक्यं खम्

“THE SUM OF TWO POSITIVES IS POSITIVE, OF TWO NEGATIVES IS NEGATIVE; OF A POSITIVE AND A NEGATIVE IT IS THEIR DIFFERENCE; IF THEY ARE EQUAL, IT IS ZERO.”
— BRĀHMASPUṬASIDDHĀNTA, 18.30

Brahmagupta also introduced the bhāvanā principle for solving second-order indeterminate equations of the form $x^2 - Dy^2 = K$. If two solutions are known, infinitely many more can be generated—Samāsa, a principle of mathematical composition that was centuries ahead of its time.



Brāhmasphuṭasiddhānta manuscript, 628 CE. Courtesy Bibliothèque Nationale de France. Folio showing rules for addition and subtraction of positive and negative numbers and zero (Chapter 18, verses 30–34).

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