Astronomy in India

From pre-history to advent of telescope

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Origins of Astronomy

- As human being gathered capacity to wonder at, and indulge in certain amount of speculation ……
- The regularity of appearance and disappearance of these objects should have impressed them.
  - the sequence of day and night, and the obvious connection of the sun
  - the periodic waxing and waning of the moon
  - the unchanging character of the stellar vault

- No wonder that all ancient civilisations possess proto-astronomy in one form or other.

Origins..

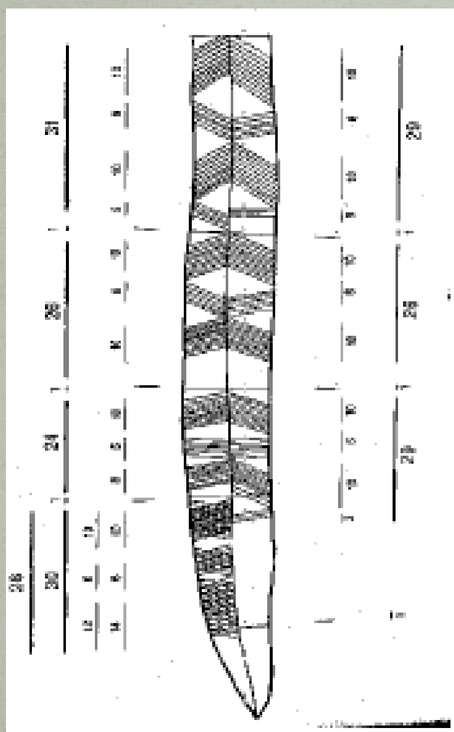
Primitive societies noticed that the hunting seasons changed along with the periodic change in the night sky. Animals and birds migrated with seasons…

Soon primitive agriculture settlements emerged

In agricultural societies sowing and other operations depended on climatic changes or the seasons.
The seasons arrived with appearance of certain groups of stars and changed with the arrival of others.

Proto astronomy in india

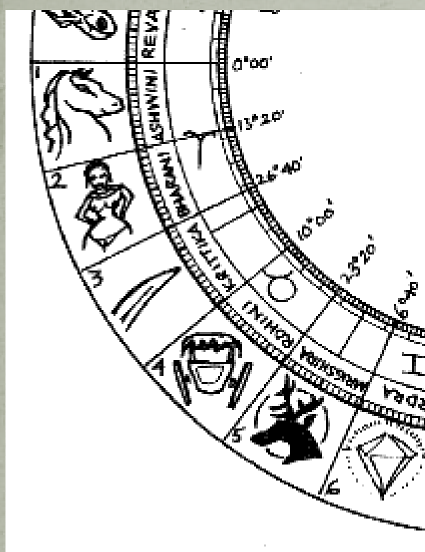
Just as any civilization, in India too proto-astronomy is seen even at the time of dawn of civilization



lunar calendar sticks from Nicobar Islands. waxing and waning of moon is recorded. The stick belongs to upper Paleolithic period. (11000 to 8000 years BP)

In addition we have engraved Ostrich egg shell in an open campsite, upper paleolithic layer near Patna and bone engraved with cross hatching in an upper paleolithic layer and another in a mesolithic layer at Bhimbhetka

Astronomy in folk tradtion…



in Andhra, the Orion is called as `prongs of a plough' (gorakoaiahlu or gorthi koaiahlu in Telugu) not by the traditionally known name of Mrigsirsha,

the Pleiades is called a `hen with chicks' (pillalakodi), and not as Krittikas. In Tamil this group of star is called ‘Addupu’ meaning ‘three stone stove’.

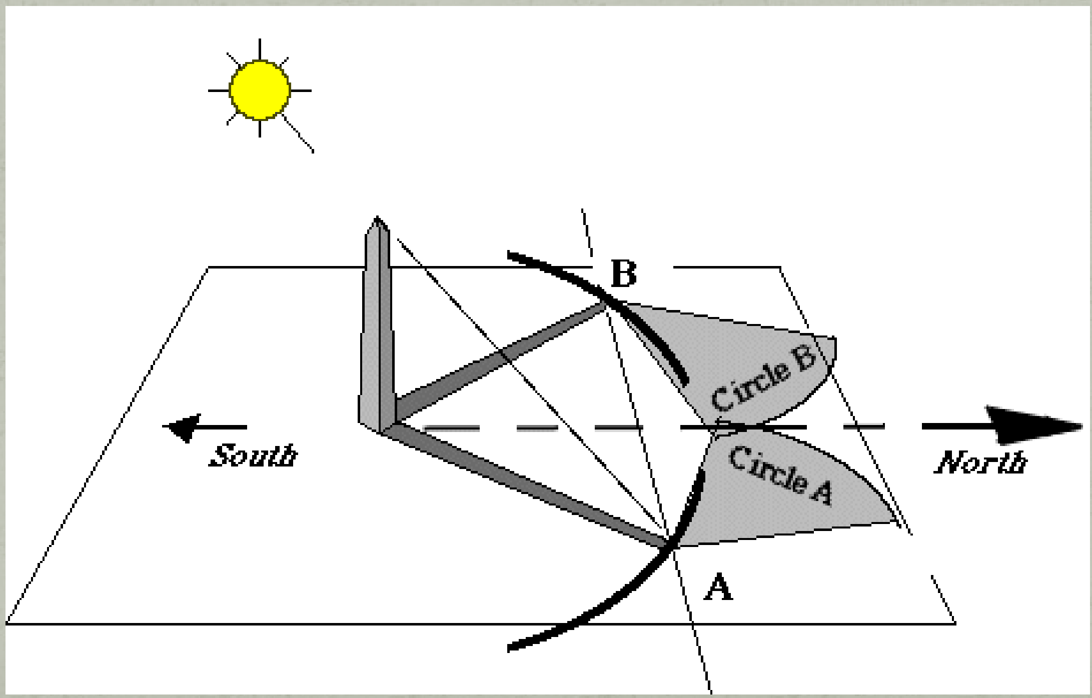
Megalith astronomy

Just as stones were used for making tools during megalithic period. Various stone arrangements are found scattered around the country having astronomical significance.

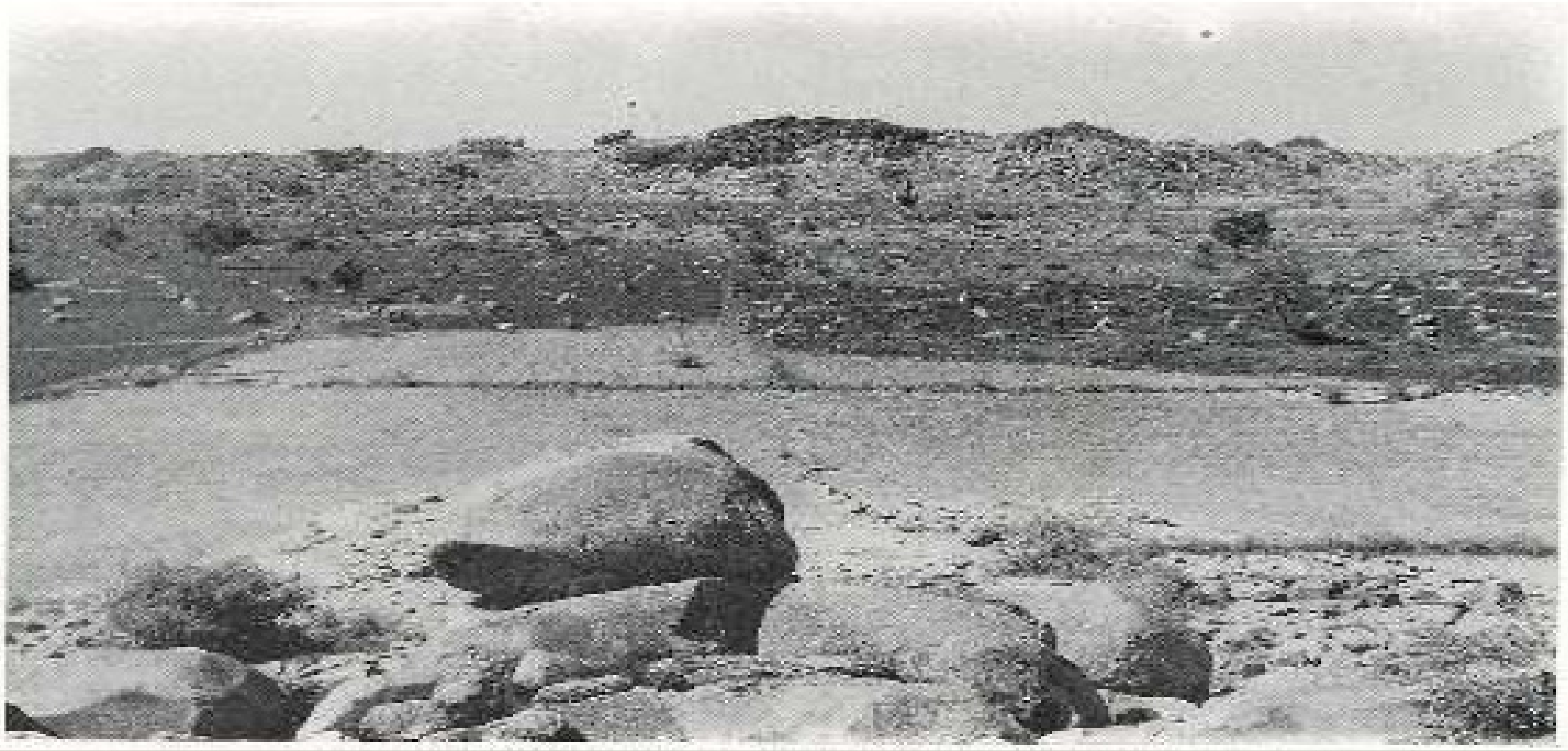
Alignment of three megaliths to the North South in Birbir in Hazaribag.

How do you find the north-south line

Install a vertical rod. Draw a circle with the rod as the center. Let A and B be the two points when the shadow of the pole touching the circle in the forenoon and afternoon. Now AB is exact East-West line. Perpendicular to it is North-South Line., which we can obtain by bisecting AB and drawing a perpendicular to the Pole.



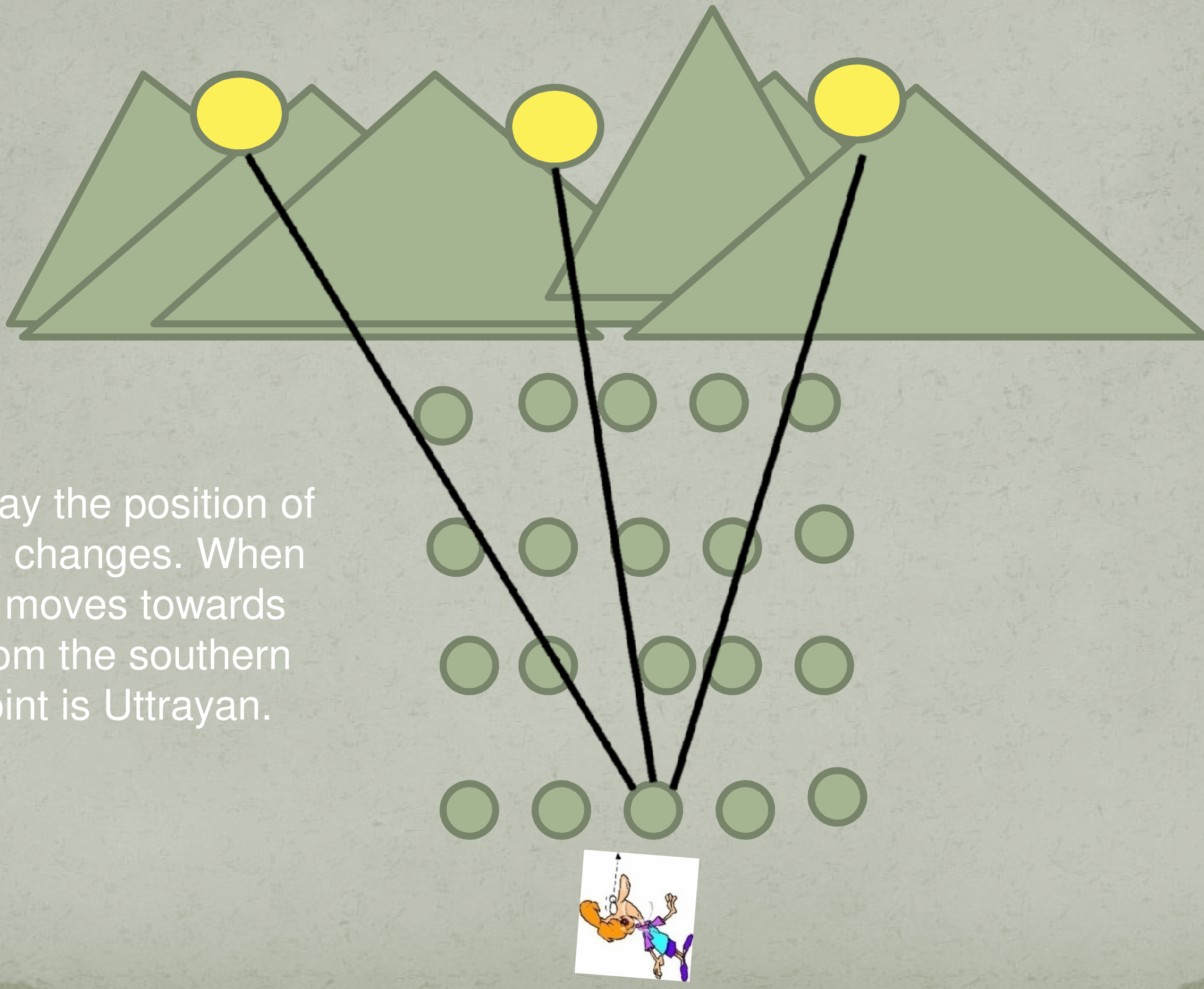
Stone alignment at Hanamsagar



Hanamsagar near Belgaum, is a site believed to be as old as 1000 BC. This megalith site has 2400 stones kept 12 meter apart in a weird arrangement.

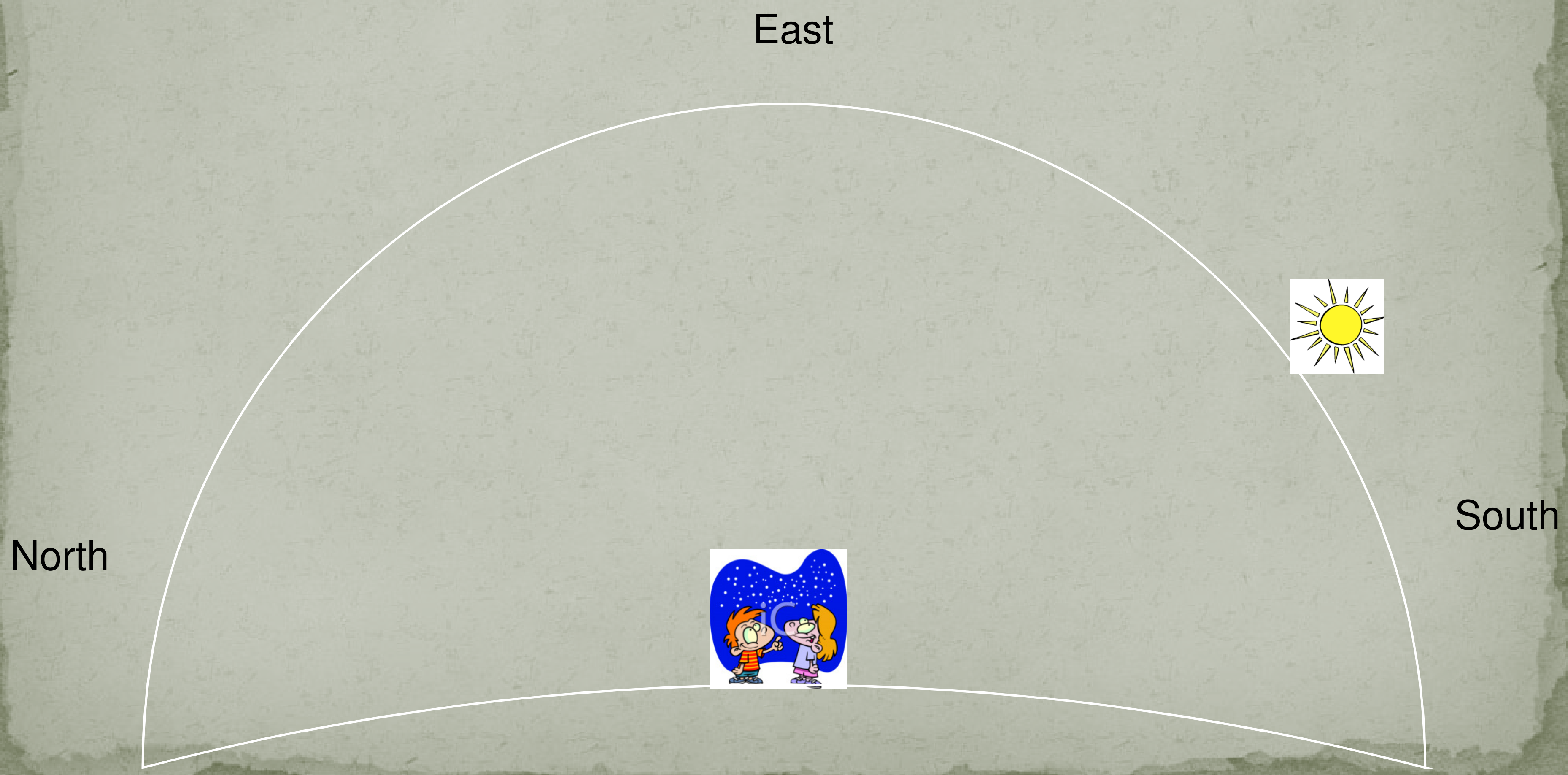
There are 50 rows each having 50 blocks (about 2500 stones) and are separated by 12 m from each other. The lines are oriented in cardinal directions. There is a squarish central structure known as chakri katti.

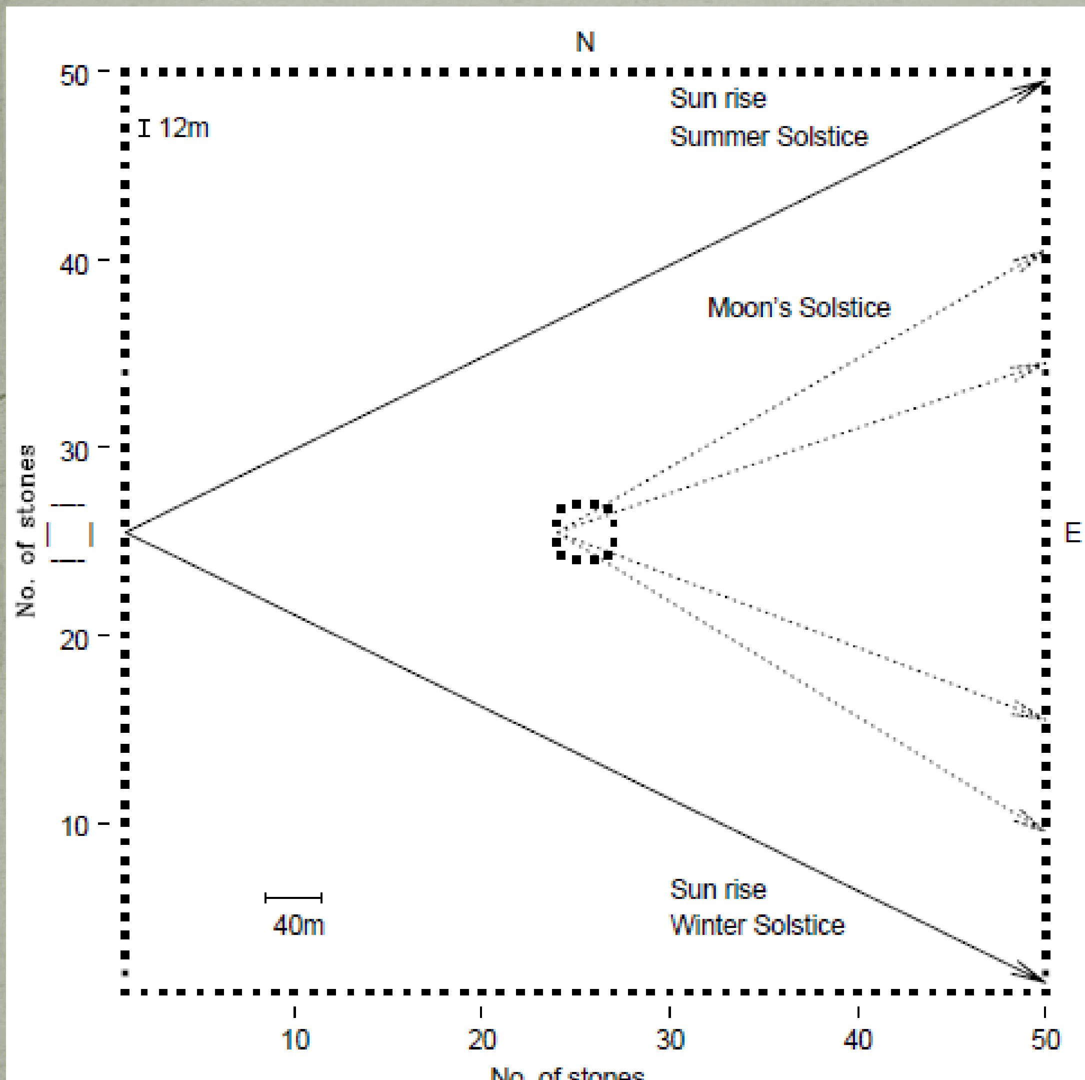
Watching the sunrise everyday…



Every day the position of sun rise changes. When the sun moves towards north from the southern most point is Uttrayan.

sun will appear to move from north to south and again to north..

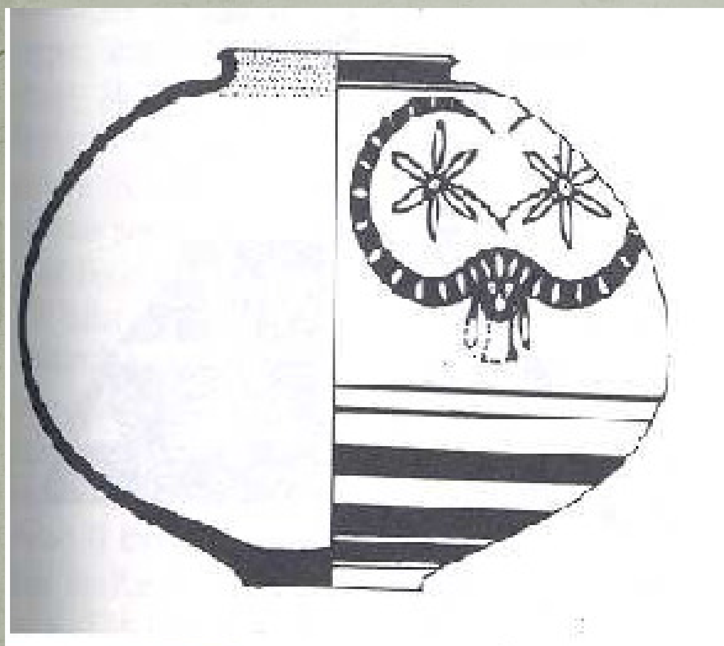




The stones are aligned in cardinal directions to form a square, the stones show summer and winter solstice.

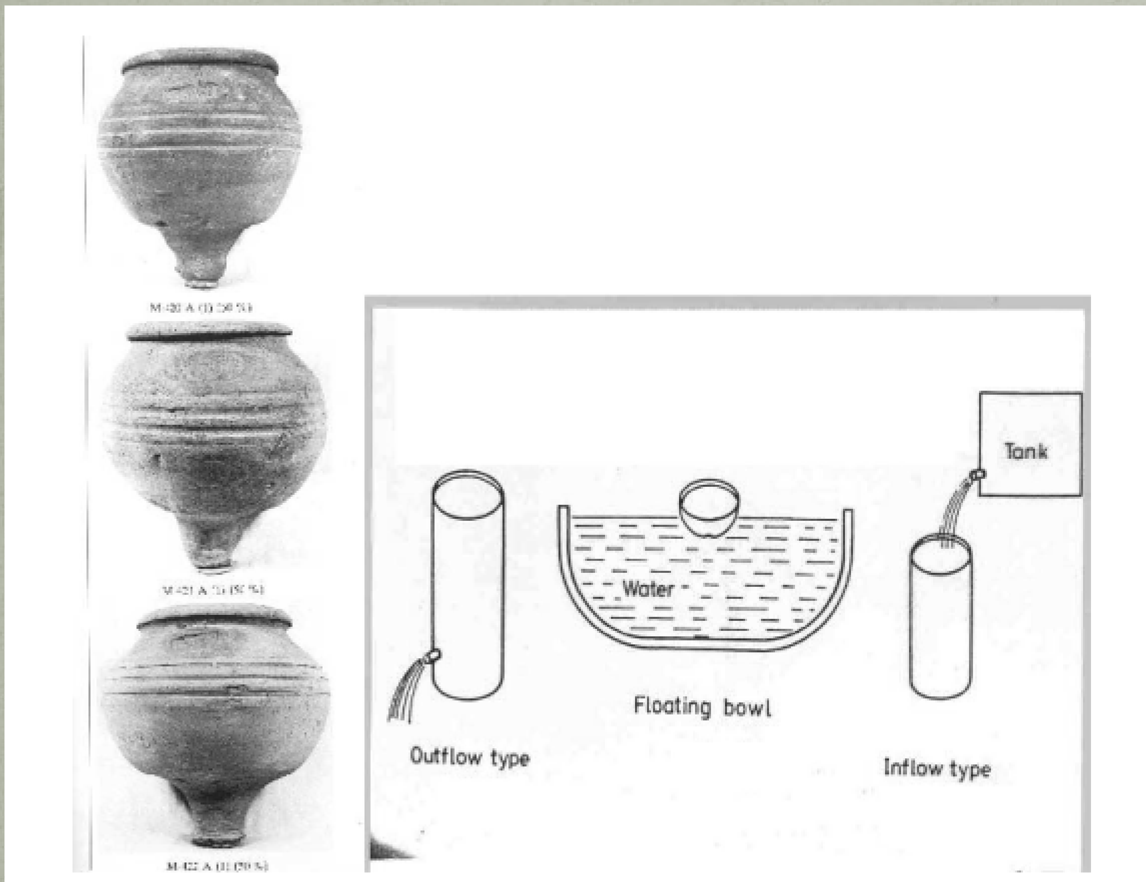
It could have been used for prediction of monsoon duration, season for agricultural purposes.

Pre Harappan archeological evidences



A pot depicting what looks like horned human excavated at the pre-Harappan site of Kot Dijian is dated back to 2600 BC E. Interestingly the horns show the paint marks corresponding to the lunar count - from new Moon to full Moon at the centre and back to new Moon. It contains 15 paint marks up to the middle of the forehead during which the size of the marks gets larger and
another 15 (or 14) marks to the other end of the horn during which the size decreases as though they are denoting the phases of the Moon from new Moon to full Moon at the centre and back to new Moon to complete the cycle.

Harrapan site

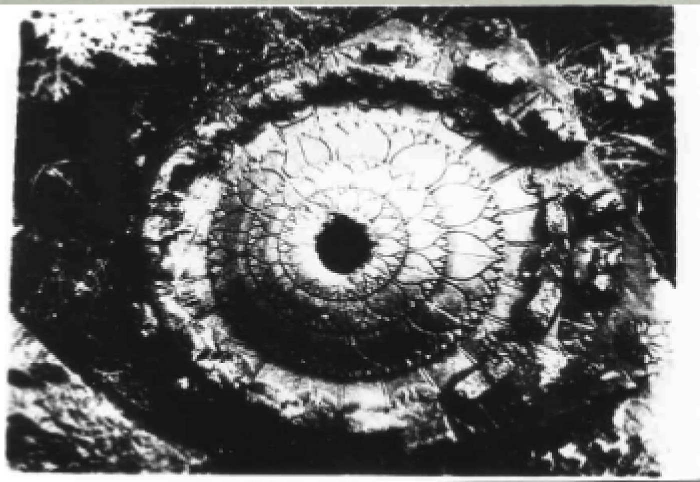


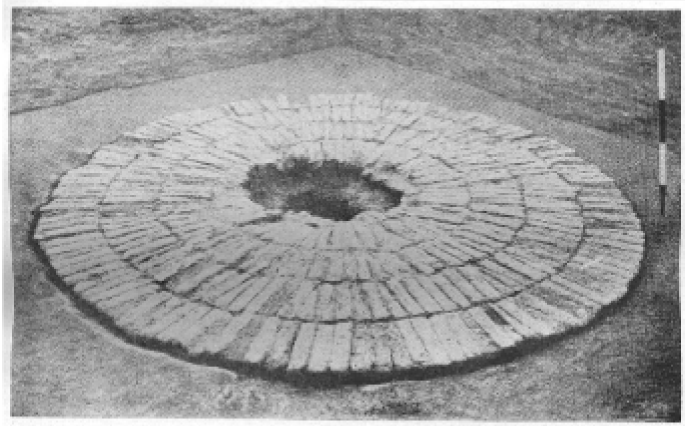
Pots from Harrapan site.

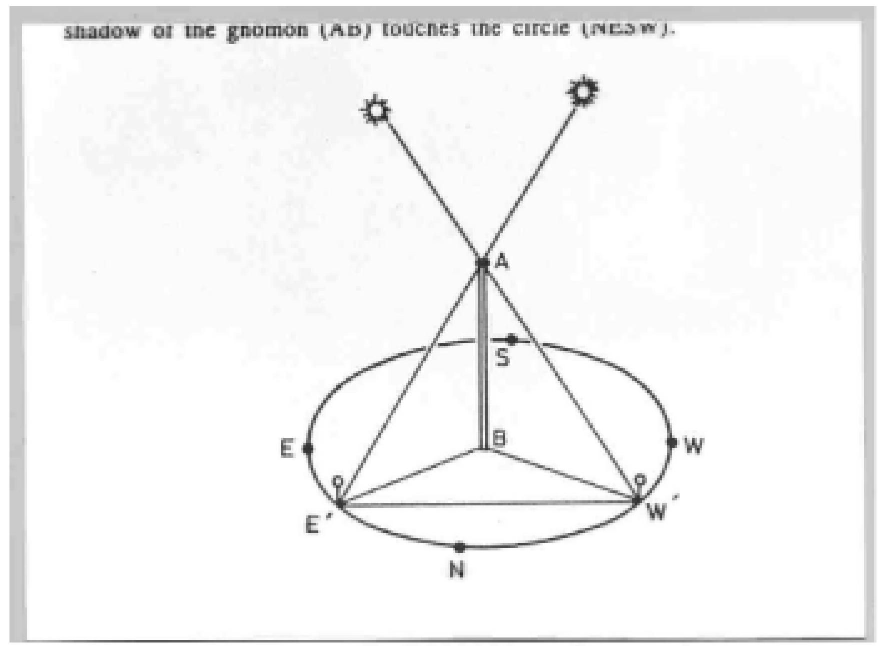
Perhaps water clock- Clepsydra?

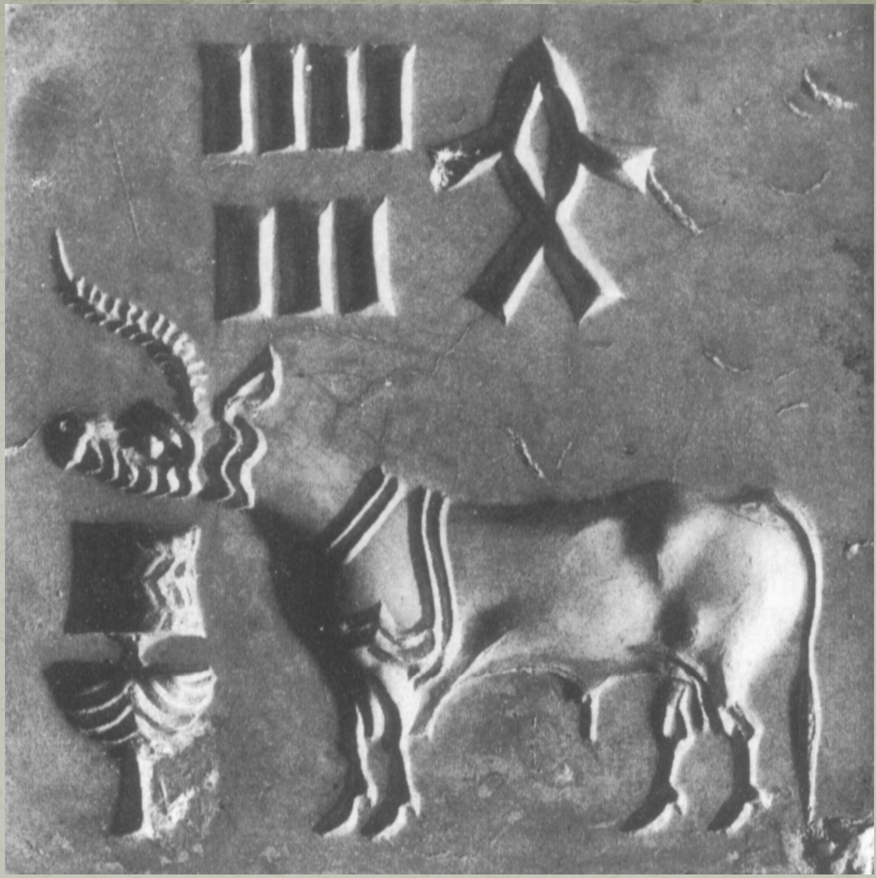
Instuments for proto-astronomy

Gnomon (Sanku) – Sun dial









Indus civilisation (c 2000 BCE) is said have had rudimentary astronomical thoughts. Many illustrations found in Indus seals have been interpreted as perhaps having astronomical significance. This seal is said to represent – seven stars – Ezhu meen (Tamil) – Saptha Rishi/ Ursa major.

Vedic period ~ 2000 BC

- In fact it is interesting to note that Vedic literature is largely devoid of astrology as we know today.
- There is no reference to Rasi which is most essential feature of astrology.

The ancient Indian Astronomy used concepts like Nakshatra, Tithi and so on but not Rasi chakra.
Even the 'Vedanga Jyothisha' of Lagadha, of around ~10th C. BC, does not give any such indication.

Vedic corpus

References to planets, nakstras, motion of Sun and moon are found in Rig Veda.

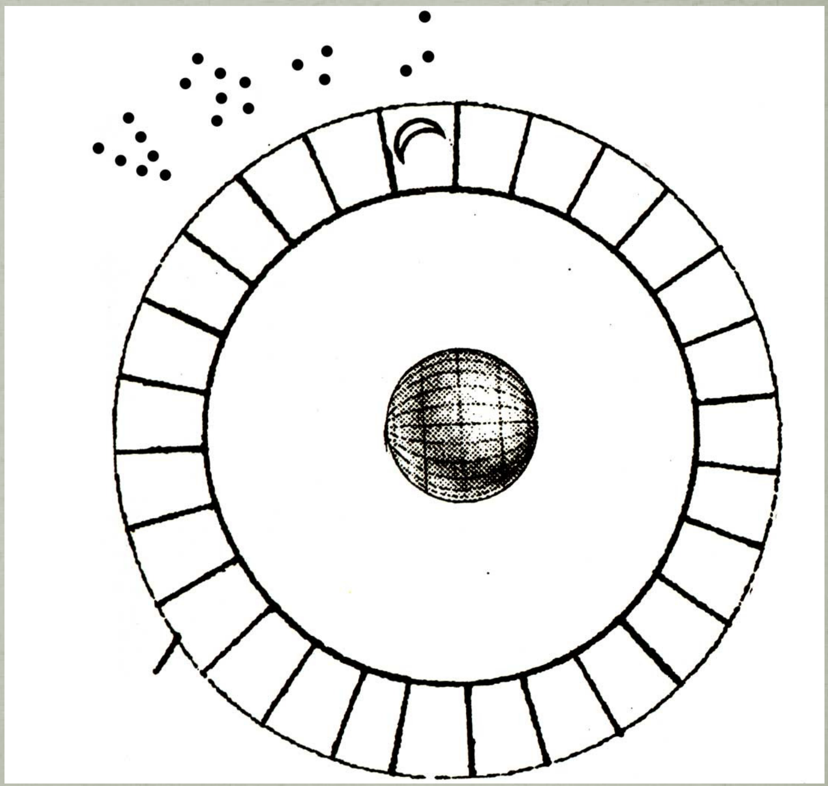
The details of darsapurnamasa, i.e. the new- and full- moon sacrifices, the caturmasya or four-monthly sacrifices, seasons, months and month names, are stated specifically in Yajurveda.

The importance of the winter solstice is emphasized through the mahavrata rites .

The Atharvaveda also contain stray passages of astronomical consequence, such as the solar eclipse, the mention of Rahu for the first time, intercalation with a thirteenth month and a list of 28 naksatras including Abhijit.

Nakshatra system

Indian astronomy followed unique naksatra traced to the Rgveda. Derived from nakta-tra, it means 'guardian of night' also meant lunar mansions. The whole series, numbering 27 or 28 and headed by Krttikas, turns up for the first time in the Yajurveda. Later on, naksatra meant one of the 27 equal parts, that is a space of 13 º 20' of the ecliptic.

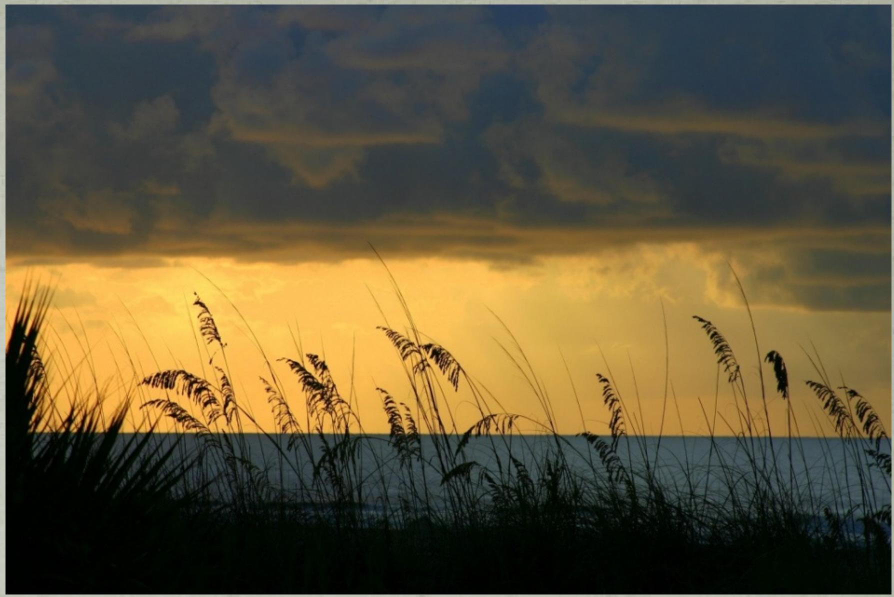


Planets

There is no mention of planets in Vedanga Jyotisa . However, names of planets like Jupiter and Venus finds a place in Rig Veda. In the Maitrayani Upanisad, planets (graha) are mentioned.

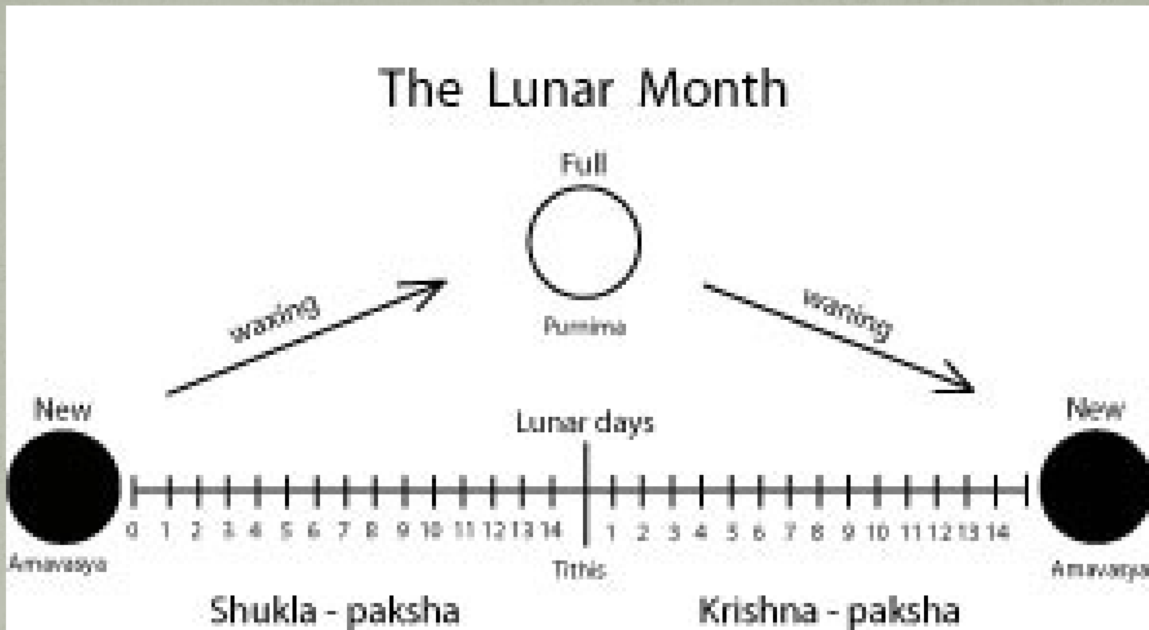
To the seven planets, including the sun and the moon, the Indians added Rahu and Ketu, to formulate their Rahu-ketu theories of eclipses. The word Rahu, in the sense of a planet, appears in the Atharvaveda and the Chandogyopanisad apparently with no astronomical meaning, but in the Yajnavalkyasmrti it does so in the astronomical sense (as ascending node). The word ketu also appears in the Atharvaveda in the sense of any unusual or striking phenomenon such as comet, meteor or a falling star. Astronomical samhitas, however, do not mention ketu as a cause of eclipse.

Day and night



Day, that is the bright half, was divided, according to the Atharvaveda and the Taittiriya Brahmana, into five parts, e.g udyan suryah (rising sun), samgava (gathering of cows),madhyam-dina (midday), aparahan (afternoon) and astam-yan (sunset). Further division of the day into muhurtas and still smaller units has been traced to the Brahmana period. According to the Satapatha Brahmana, 'there are ten thousand and eight hundred muhurtas in the year (1 day = 30 muhurtas), and fifteen times as many Kisprus as there are muhurtas ; and fifteen times as many idani as there are etarhi; and fifteen times as many breathing as there are idani'.

Month



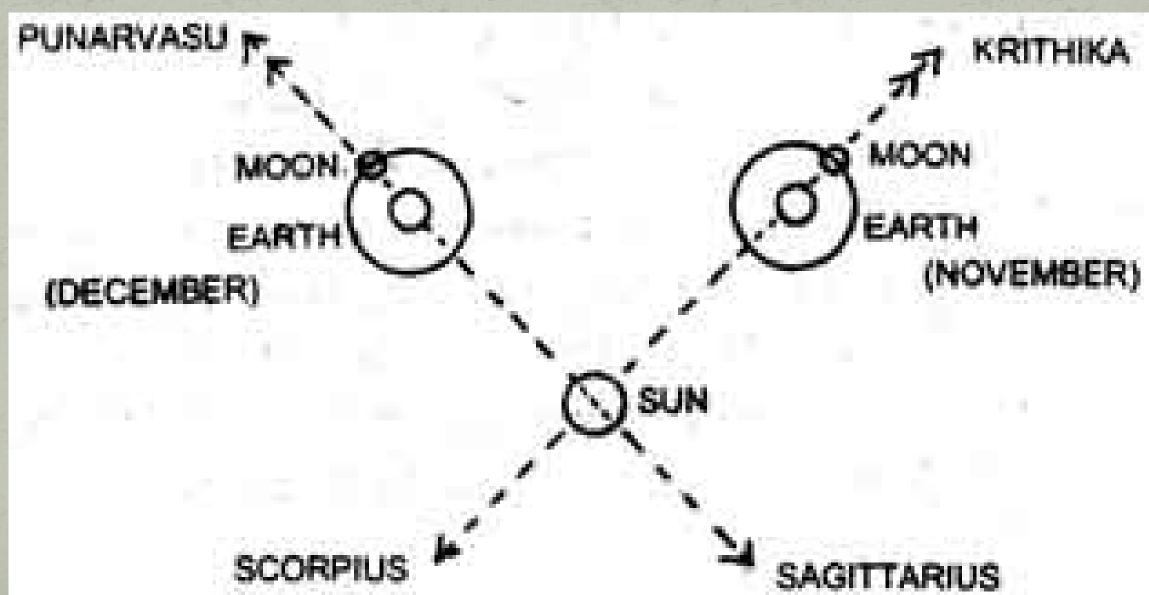
Rig Veda says 'Candrah Masakrt'- moon the maker of the month. In the vedic literature the month was again divided into two natural halves *paksa*, the light half (sukla) from new to full moon and the dark half (krsna) from full to the new moon; each *paksa* having 15 *tithis*, and ingenious devise, which is characteristically Indian.

Thithi was in the beginning 'lunar days'- one way of keeping track of the flow of time.

Tithi	Phase	Rising Time	Setting Time
Amavasya	New	Sunrise	Sunset
S.Chaturthi	Waxing	3 hrs after Sunrise	3 hrs.after Sunset
S.Ashtami	Waxing	Noon	Midnight
Ekadasi	Waxing	3 hrs after noon	3 hrs after Sunrise
Poornima	Full	Sunset	Sunrise
K.Chaturthi	Waning	3 hrs after Sunset	3 hrs after Sunrise
K.Ashtami	Waning	Midnight	Noon
K.Ekadasi	Waning	3 hrs after Sunrise	3 hrs after noon
Amavasya	New	Sunrise	Sunset

Lunar months

- The names of the lunar months were derived from the naksatras in which the full moon (or new moon) occurred, e.g. Phalguna, Caitra, Vaisakha, Jyaistha and so on from the naksatras Phalguni, Citra, Visakha, Jyestha respectively.

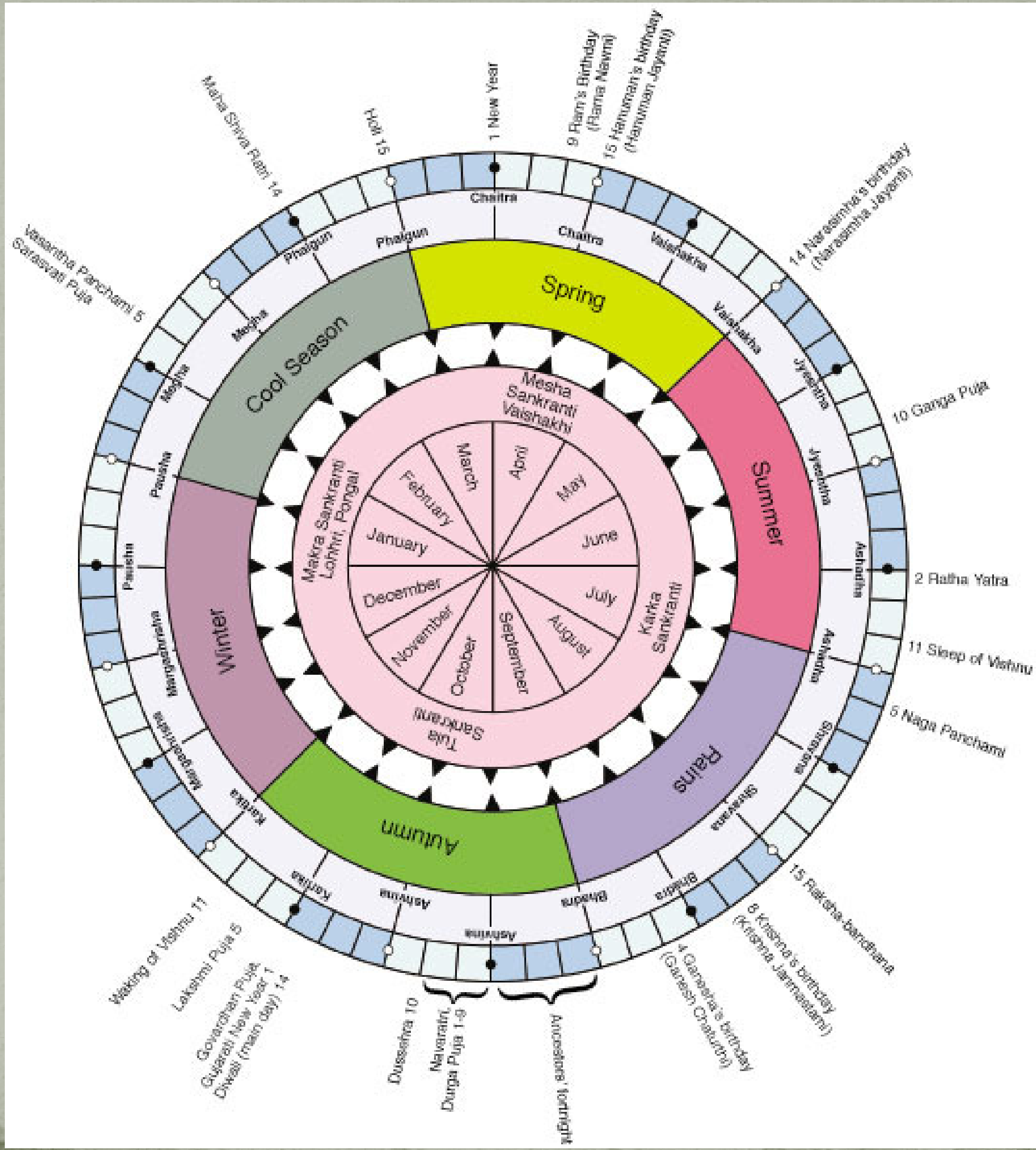


Year

It is only in the subsequent period, when the solar movement, in particular seasons became important for agriculture that year became aliened with Sun, even while month was according to moon resulting in Luni-solar calendar.

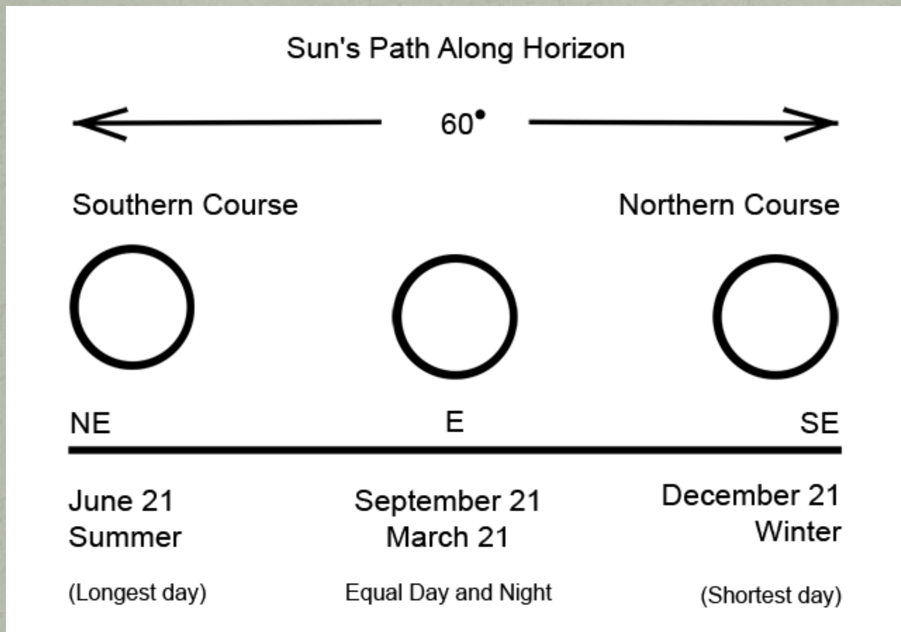
From Brahmanas, it is possible to infer that the Vedic Hindus recognized a lunar year of 354 days (12 X 29½), which was adjusted to the tropical solar year of 366 days (Vedanga Jyotisa) either by adding 12 days each year or a thirteenth month of 30 days every 2½ years.

The *Vedanga-jyotisa* conceived of a cycle of five years, a luni-solar cycle called the *yuga*, at the beginning of which the Sun and the Moon would lie at the starting point of the *naksatra Dhanistha*. During this period, there would be 5 revolutions of the Sun, 67 Moon's sidereal and 62 synodic months; 1830 *savana* or civil days; 1835 sidereal days, 1800 solar days and 1860 lunar days or *tithis*.



1 New Year
9 Ram's Birthday (Rama Navmi)
15 Hanuman's birthday (Hanuman Jayanti)
14 Narasimha's birthday (Narasimha Jayanti)
10 Ganga Puja
2 Ratha Yatra
11 Sleep of Vishnu
5 Naga Panchami
15 Raksha-bandhana
8 Krishna's birthday (Krishna Janmastami)
4 Ganesha's birthday (Ganesh Chaturthi)
Ancestors' fortnight
Navaratri, Durga Puja 1-9
Dussehra 10
Govardhan Puja, Gujarati New Year 1, Diwali (main day) 14
Lakshmi Puja 5
Waking of Vishnu 11
Vasantha Panchami 5 Sarasvati Puja
Maha Shiva Ratri 14
Holi 15
Chaitra
Vaishakha
Jyeshtha
Ashadha
Shravana
Bhadra
Ashvina
Kartika
Margashirsha
Pausha
Magha
Phalgun
Spring
Summer
Rains
Autumn
Winter
Cool Season
Mesha Sankranti Vaishakhi
Karka Sankranti
Tula Sankranti
Makra Sankranti Lohri, Pongal
January
February
March
April
May
June
July
August
September
October
November
December

solstice



Brahmanas point to knowledge of solstices. Vedanga Jyotisa- prapadyete sravisthadau suryacandramasavudak- (The sun and the moon turn north at the beginning of the naksatra Dhanistha).

.The increase of day-length from winter solstice to summer solstice are recorded in the Jyotisa.

A day was regarded as consisting of 30 *muhurtas*, (the longest at the summer solstice being 18 and the shortest at the winter solstice 12 *muhurtas*).

Astronomical tradition in Jaina tradition

MS 5297
Suryaprajnapti Sutra; astronomy. India, ca. 1500

The four branches of their canonical texts include ganitanuyoga (principles of mathematics), samkhyana (arithmetic) and iyotisa (astronomy). Like the Brahmanas, the Jainas, too, demanded of their priests great proficiency in astronomy for the proper observance of their religious ceremonies.

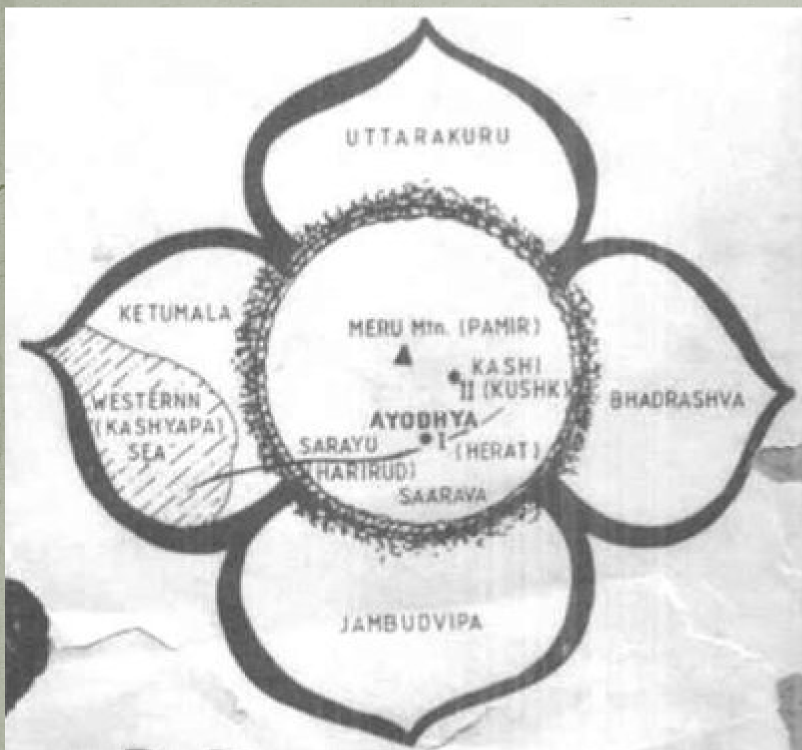
Major Jaina works

MS 4465

Sricandra: Sankhitta sangheyani; the concise compendium of cosmography. West India, 17th c.

Suryaprajnapti, free from Greek influence, the work was probably written a 1 or 2 C BCE, authorship attributed to Mahavira and Bhadrabahu (d. 298 B.C.) a prominent personage in the history of Jaina religion are basis of Jaina astronomy.

Peculiar Jain astronomy



The peculiarity of the Jaina astronomy consists in its conception of two suns, two moons and two sets of 27 naksatras. Earth is regarded as a series of flat concentric rings of land masses separated by concentric ocean rings. The central circle Jambudvipa, is divided into four quarters, of which the southernmost part is Bharatavarsa (India).

Post vedic developments

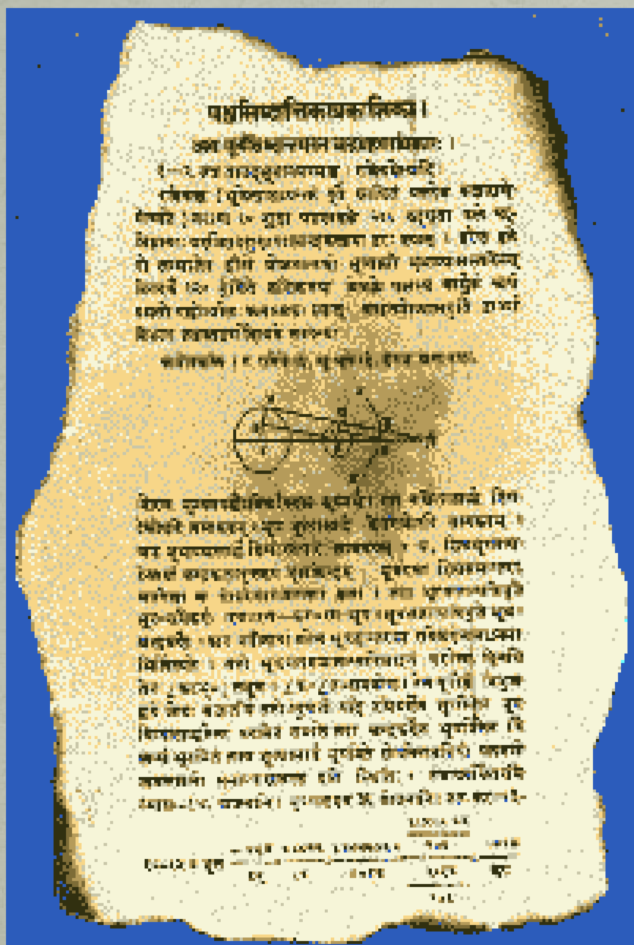
- Brhat-samhita, Bhadrabahu Samhita and other samhita texts indicate post vedic developments.
- Attempt on studies of planetary velocities, retrograde motions, their heliacal rising and setting or conjunctions with stars etc are seen.
- 12 years cycle of Jupiter is noted and on combining this period with Five Year Yuga, a 60-year cycle was designed.
- These consecutive 60 years are given different names and have much importance in Hindu religious calendar.

Katyayana Sulb Sutra, Buddist Pali literarure like Sardulakarnavadan, and other texts indicate that during the post vedanga period astronomy advanced to find :-

- Day time lapsed or remaining in any instant
- Seasons with midday shadows

Gnomon used to standardize unit of time on the basis of length during equinoxes days

Siddantha tradtion of Indian astronomy



Tradition says that there were 18 original siddhantas.

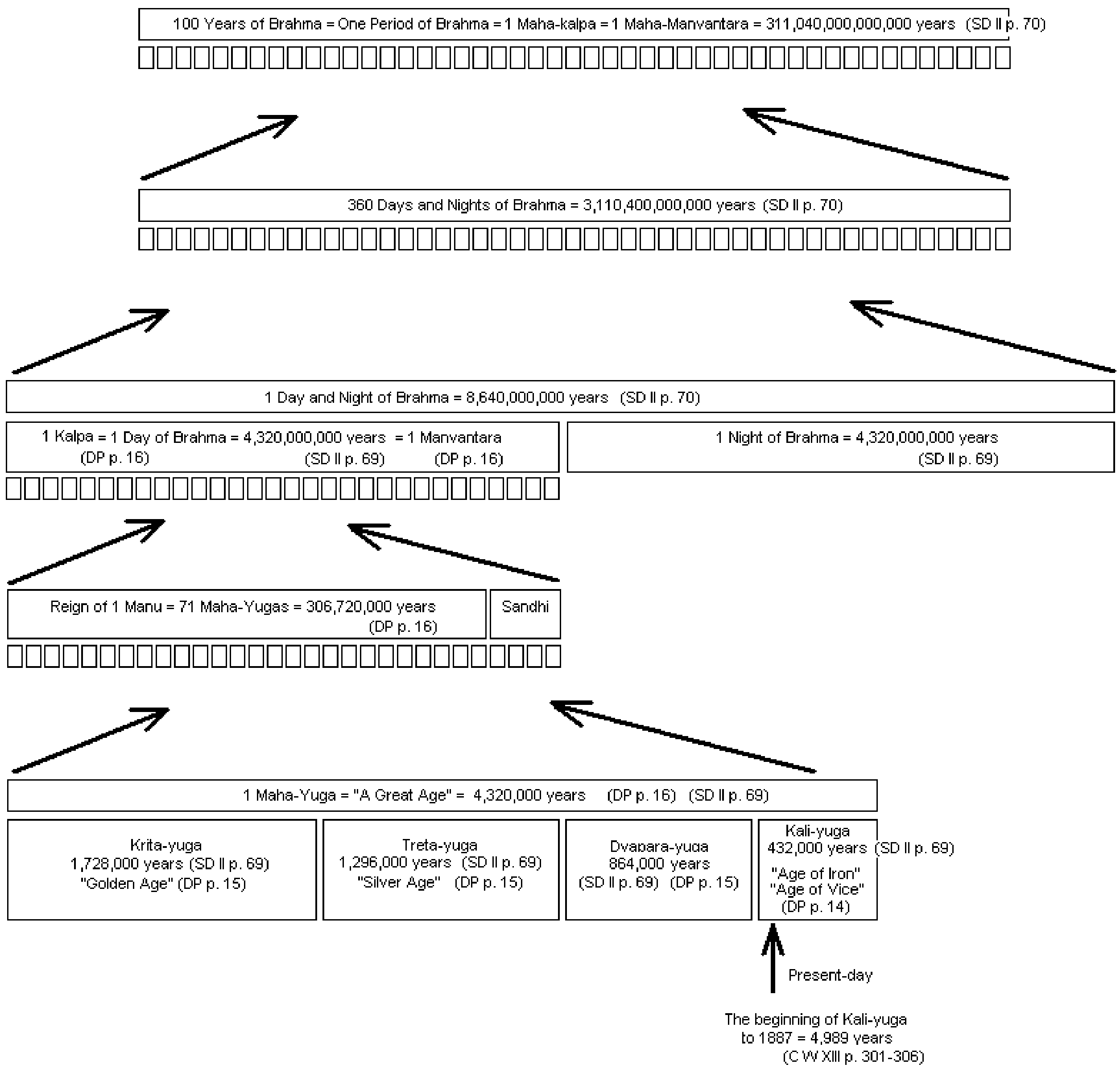
Most of them are lost and several of them invoked the name of some ancient sage. Varathamihira in his Pancasiddhantika consists inluding his own, the Paitamaha, the Vasistha, the Paulisa and the Romaka siddhantas.

Yuga concept

The concept of mahayuga is the central feature of the Indian astronomical siddhantas. It is a period at the beginning of which all planetary bodies are in conjunction, during which they all perform integral numbers of revolutions, and at the end of which, therefore, they are again in conjunction The mahayuga of 4,320,000 years is such a period. According to Aryabhata I, a mahayuga (simply called a yuga) is divided into four equal parts or yugapadas, each consisting of 1,080,000 years.

In Vedanga Jothisa Yuga of 5 year duration is discussed.

Yugas, Maha-Yugas, and Days of Brahma



Three major Siddnathas

- Aryabhata-siddhanta (due to Aryabhata), Brahma-siddhanta (due to Brahmagupta), Surya-siddhanta (the latest version attributed to Asura Maya).

These schools prevailed over centuries and are surviving even now in Pancanga making (in preparation of religious Hindu calendars) in the country. These were called 'siddhantas' (theoretical treatises) while the texts giving only the simple algorithms (without proofs) for computing planetary positions, eclipses, cusps of the Moon, heliacal rising and setting and other astronomical phenomena were called karanas (means of practical work out of ephemeredes and calendars).

Aryabhatta

- Aryabhata, tallest personality in ancient Indian astronomy (~ 450 AD) has no reference to Astrology in his work. He seeks no supernatural powers to explain natural (celestial) events like Eclipse.

In his work he explains how Solar eclipse occur due to obstruction by moon. He does not even refer to the Puranic myth of Ragu and Ketu.

Aryabhatiya C 499 AD

- His work Aryabhatiya, completed in 421 Saka or 499 A.D., when he was just 23
- It included, among others: (1) advocacy of the diurnal motion of the earth (rather than the apparent rotation of the sun around it), (2) a corresponding theory of gravity to explain why objects are not thrown out as the earth churns, (3) recognition of the parametric variability of the concept of ``up'' and ``down'' depending on where one is located on the globe, and (4) explanation of lunar and solar eclipses in terms respectively of the earth's shadow on the moon and the moon's obscuring of the sun.

Instruments in Aryabhatiya…

- The most significant aspect of Aryabhata's Siddhanta, is that he described there in sufficient details several astronomical instruments: Gnomon (sankuyantra), perfect circular shadow instrument (chaya-yantra), semi circle (dhanur-yantra) and circle (chakra-yantra), yasti-yantra (resembling a cylindrical stick), chatra-yantra (resembling an umbrella) and water clocks (cylindrical and bow shape).

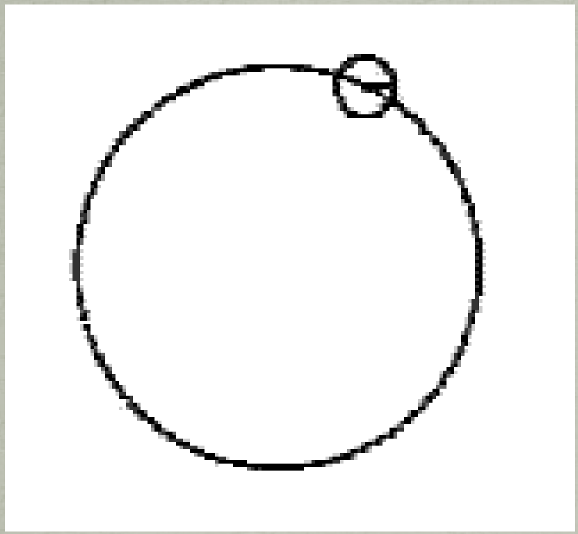
- The astronomical system of Aryabhata consists of the following: (i) Recognition of the terrestrial rotation, (ii) optical explanation of lunar and solar eclipses instead of the demonic Rahu-ketu mythology, (iii) a new yuga system and (iv) epicyclic-eccentric model of planetary motion
- In the verse IV-9 of Aryabhatiya, Aryabhata clearly identifies the apparent motion of fixed stars (asterisms) with that of stationary objects for an observer in a moving boat. In another verse (I-4) he gives even the angular velocity of the earth as 1 minute of arc per prana, i.e. in 4 seconds.

Scientific theory of eclipse, different from Puran

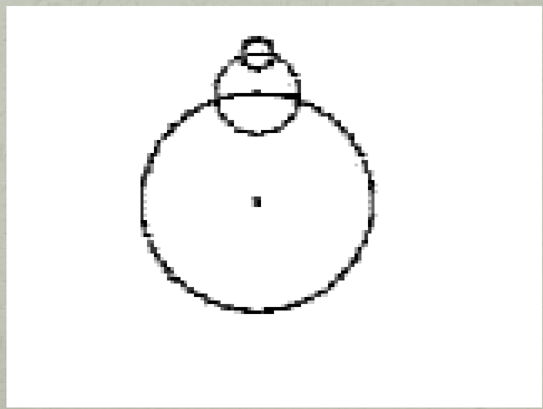
- In pre-siddhantic astronomy Rahu and Ketu, were supposed to cause solar and lunar eclipses. Aryabhata replaced this mythological explanation by a scientific one. In the first few verses of the fourth chapter of the Aryabhatiya he introduces the idea of shadows, cast by and falling on earth, moon and planets, and in verse IV-37 he states that the lunar eclipse is caused by the entering of the moon into the earth-shodow. In the following verses (38-48) he gives then formuals for the length and diameter of the earth shadow, the timing and duration of the eclipses and or the size of the eclipsed part of sun or moon.

Epicycle theory

Aryabhat assumes Earth is at the center and planets (including sun moon) go around it in epicycle- called mandaphala.



However some of the planets are assumed to go in mandaphala and sighraphala



Varahamihira(c. A.D. 505),

- author of the Pancasiddhantika- complied all the pre – siddnathic astronomical knowledge.
- more well known as an astrologer
- wrote compendious astrological treatises such as Brhatsamhita, Brhajjataka, Laghujataka and Yogayatra.
- The Romaka Siddantha ("Doctrine of the Romans") and the Paulisa Siddhantha ("Doctrine of Paul") were two works of Greek origin which influenced Varahamihira's thought.
- His astrology and horasastra (horoscopes) were of Greek origin, and it is therefore not surprising that his works abound in Greek technical terms.

Bhaskara I (c. A.D. 600- 680)

- was the greatest exponent of Aryabhata's system of astronomy,
- contemporary of another noted astronomer Brahmagupta.
- He wrote three works, e.g. the Mahabhaskariya, the Laghubhaskariya and a bhasya on the Aryabhatiya.
- The Laghubhaskariya, as the name implies, is an abridged version of the author's fuller work. Intended for the beginner, its treatment is more systematic.

Brahmagupta (A.D. 598-670)

- Important work is Brahma-sphuta-siddhanta
- The text deals with mean and true positions of planets, problems of direction, time and space, lunar and solar eclipses, heliacal rising and setting of planets, cusps of Moon, shadow of Moon, conjunctions of planets and stars, criticisms of other tantras (siddhantas), arithmetic problems on mean and true positions, indeterminate equations, algebraic equations, gnomonics, permutation and combination in meters, celestial sphere, instruments and some algorithms for fast computations

India goes west…

- It was through the *Brahmasphutasiddhanta* that the Arabs learned of Indian astronomy.
- The famous Abbasid caliph Al-Mansur (712–775) founded Baghdad, and made it a center of learning.
- The caliph invited a scholar of Ujjain by the name of Kankah in 770 A.D. Kankah used the *Brahmasphutasiddhanta* to explain the Hindu system of arithmetic astronomy.
- Muhammad al-Fazari translated Brahmugupta's work into Arabic upon the request of the caliph.

Surya Siddnatha

- The third important school is attributed to Mayasura.
- Scholars say that it may not be a work of one single author but a compilation updated from time to time.
- This SuryaSiddhantha is much different from the Surya-siddhanta of Panca-siddhantika.
- Based upon epicyclic theory
- The year-length adopted is 365 days 15 ghatis 31 palas and 30 vipalas. The text has reference to ayanamsa (angle of precession) while Arya-siddhanta and Brahma-siddhanta did not use this at all.

Aryabhat's time

- Gupta period in which Aryabhata and his followers lived was one that saw the building of not only Hindu temples but also Buddhist monuments such as Sanchi and universities such as Nalanda and Nagarjundakhonda.
- It was a period of openness to global ideas, that it was characterised by magnificent achievements in religious-philosophical debates among Jains, Buddhists and Hindus

Emergence of Hindu orthodoxy

- Soon many parts of India came under the influence of Hindu orthodoxy- esp Manu Smrithi- which had strict injunction against heretical thinking.
- Caste rules, rules of high and low, rules of untouchability and inequality all were made more and more strict. All knowledge and science was made more secret, secluded, hidden and concealed, and every new thought and invention was opposed. Even Auyrveda Vaidyas were considered 'polluted' and down graded

Astronomy and science attacked

- Scientists like Aryabhatta became the subject of attacks. For example, Aryabhatta's work was attacked by Brahmagupta, Bhaskaracharya and Varahmihira.
- Astronomers, or so-called 'jyotirvids' were denounced ; were declared 'polluted'. Manu Smrithi condemned and prohibited from being called to yadnyas, mahadanas and shraadhas.
- Further, the Brahmins changed the meaning of the word jyotirvidya, which now meant those who study the 'effects' of stars on human beings contrary to the original meaning of study of stars, and themselves became 'daivaidnyas', -- the knower of fate

Puranic myths were upheld

- Brahmasiddhanta says "Some people think that the eclipse is not caused by the Head. This, however, is a foolish idea, for it is he in fact who eclipses, and the generality of the inhabitants of the world say that it is the Head that eclipses. The Veda, which is the word of God from the mouth of Brahman, says that the Head eclipses… On the contrary. Varahamihira, Shrishena, Aryabhata and Vishnuchandra maintain that the eclipse is not caused by the Head, but by the moon and the shadow of the earth, in direct opposition to all (to the generality of men), and from the enmity against the just-mentioned dogma"

Post Sidnathic period

- Nevertheless, several astronomers flourished between the time of Brahmagupta and Bhaskara II (twelfth century), Vatesvara, Manjulacarya (also called Munjala), Aryabhata II, Sripati and Satananda.
- Lalla (720 - 790) mentions 6 degree angle of precession (ayanamsa).
- Vatesvar's importance lies mainly in his criticism of Brahmagupta. A follower of Aryabhata's system, he attacked Brahmagupta in the same manner as the latter had attacked his master about 250 years before.
- In Laghumanasa Manjulacarya introduced the corrections due to the precession of the equinoxes.
- Aryabhata II was a compiler and Sripati, son of Nagadeva, is well known for his Dhikoti, a karana work based on the Aryabhatiya.

Kerala School of Mathematics

Meanwhile in Southern part of India, Kerala a school of mathematicians- astronomers flourished- usually called as Kerala school of mathematics. Founded by Madhava of Sangamagrama in Kerala, the Kerala School included among its members, Parameshvara, Neelakanta Somayaji, Jyeshtadeva, Achyuta Pisharati, Melpathur Narayana Bhattathiri and Achyuta Panikkar. The school flourished between the 14th and 16th centuries and the original discoveries of the school seems to have ended with Narayana Bhattathiri (1559-1632).

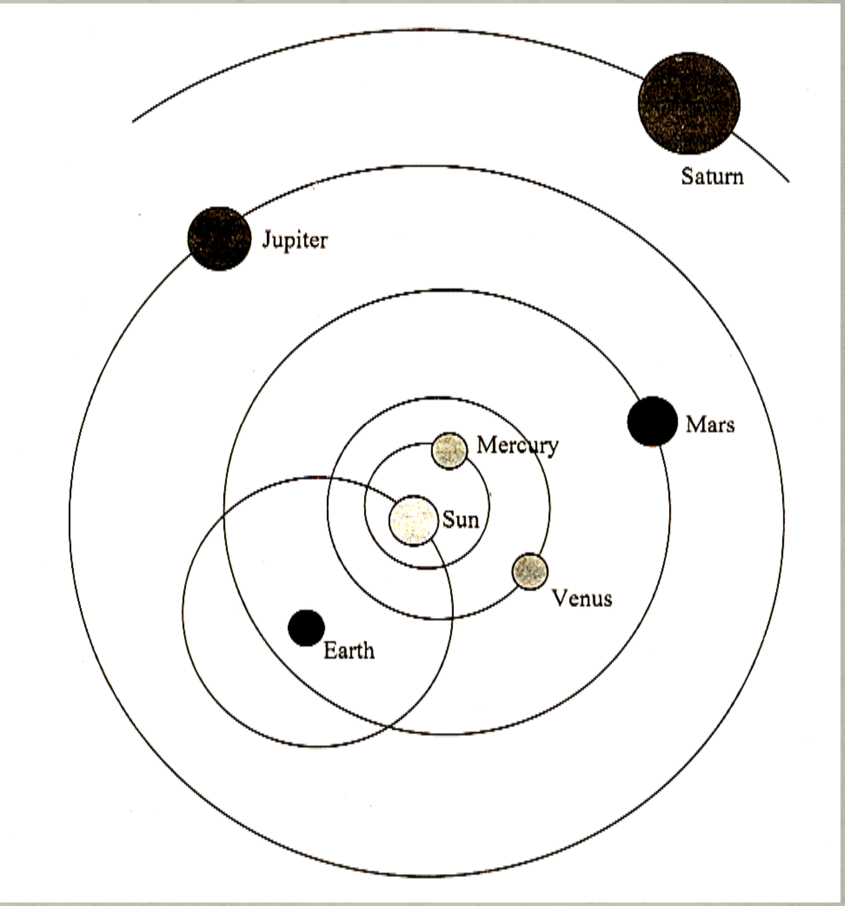
In attempting to solve astronomical problems, the Kerala school independently created a number of important mathematics concepts, such as Series.

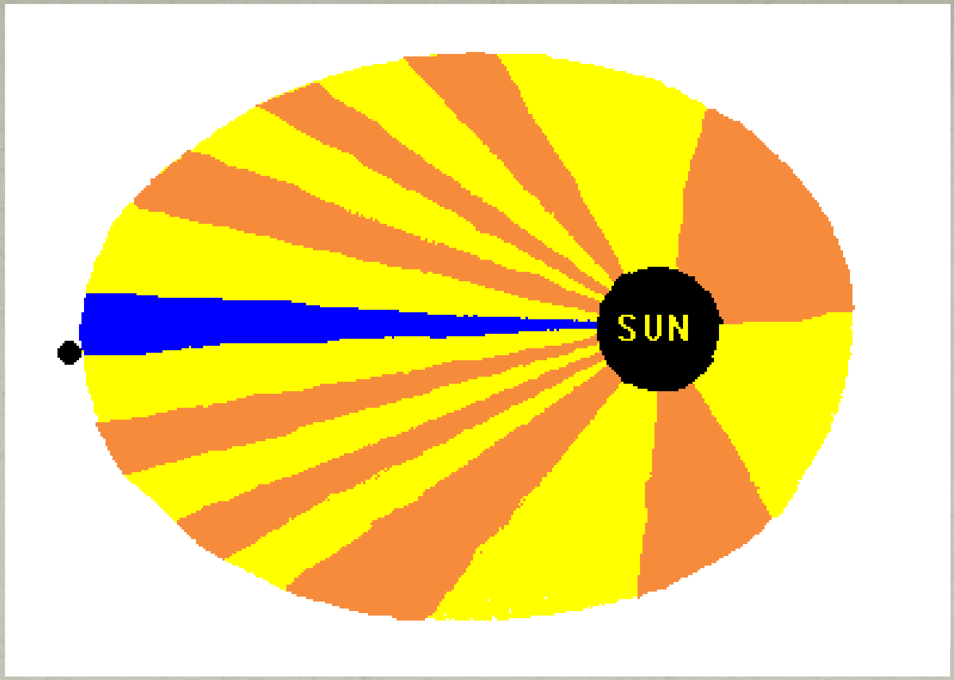
Madhava discovered a procedure to determine the positions of the Moon every 36 minutes, and methods to estimate the motions of the planets. Late Kerala school astronomers gave a formulation for the equation of the center of the planets, and a partial heliocentric model of the solar system.

Parameshvara (1370-1460), was the founder of the Drigganita system of Astronomy. He was a prolific author of several important works. He is stated to have made direct astronomical observations for fifty-five years before writing his famous work, Drigganita.

In 1500, Nilakanthan Somayaji (1444-1544) in his Tantrasangraha, revised Aryabhata's model for the planets Mercury and Venus. His equation of the centre for these planets remained the most accurate until the time of Johannes Kepler in the 17th century.

As a bridge between Ptolemy's geocentric epicycle cosmos to Copernicus's heliocentric theory, Kerala mathematician and astronomer, Neelakanta Somayaji (1444-1550) proposed a partial heliocentric theory. Inner planets like Mercury and Venus go around Sun. While other planets and Sun along with inner planets go around Earth.

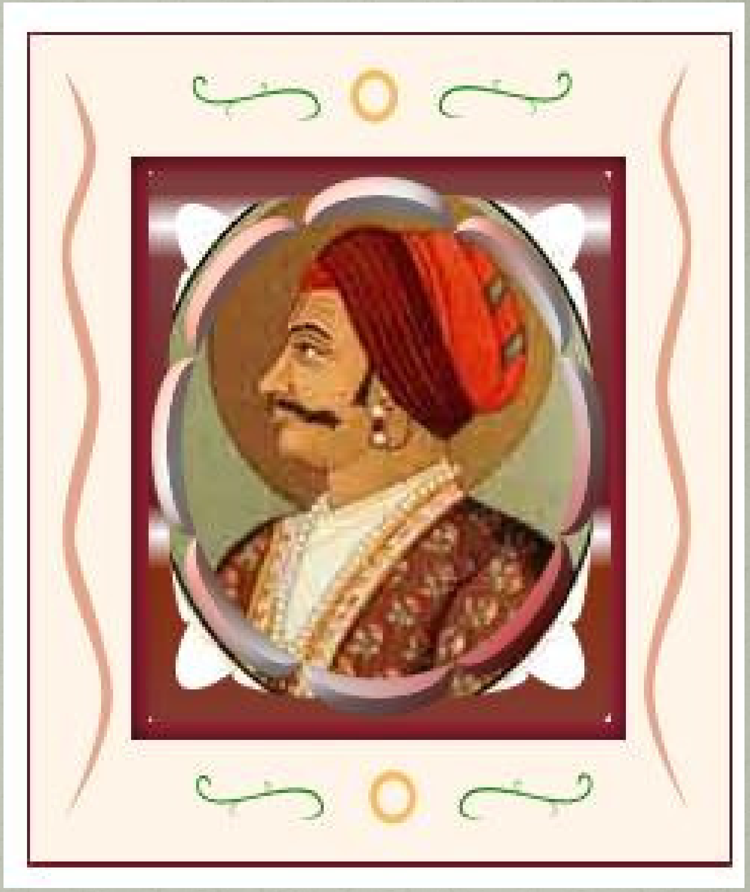




Anticipating Kepler, the Kollam calendar made by the Kerala mathematicians around 825 AD, devised a calendar wherein the time spend by Sun in each Rasi is not fixed uniform time, but varies. In the Rasis like Vrichika, Danush and Maragam Sun was spend about 29 days but Sun will stay for 32 days in Rishabam, Mitunam and Karkadagam. That is when Earth is far away in its elliptical path, (~ July) it's angular movement is slow. Whereas when it is nearer to sun (~ January) it will appear to move faster. This was taken into account by the Kerala mathematicians.

Middival period

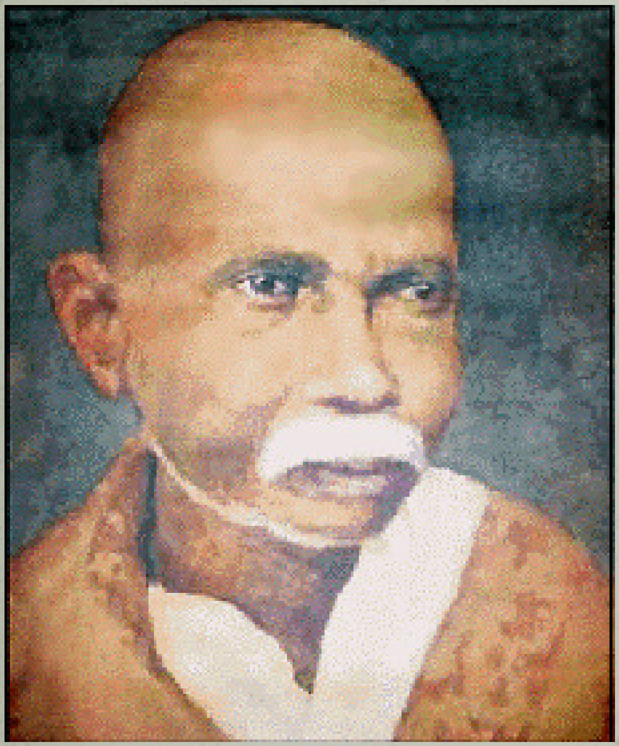
In the beginning of the eighteenth century a new interest in astronomy was created by the efforts of Maharaja Sawai Jai Sing II of Jaipur, a skilled astronomer and patron of learning. He developed an interest in astronomy at an early age and assiduously studied the Hindu, the Arabic and the European systems of astronomy.



He set up in Jaipur, Delhi, Ujjain, Banaras and Muttra astronomical observatories called Jantar Mantar.

Giant masonry instruments such as the Samrat Yantra (huge dials), Jai Prakas (hemispherical dial), Daksinovrtti Yantra (meridian circle), Sastyamsa Yantra (sextant), Rasi Yantra (Zodiac dial), etc were made to make accurate observations.

Enduring Siddanthic tradtion
Pathani Samanta Chandrasekhar (1835-1904)



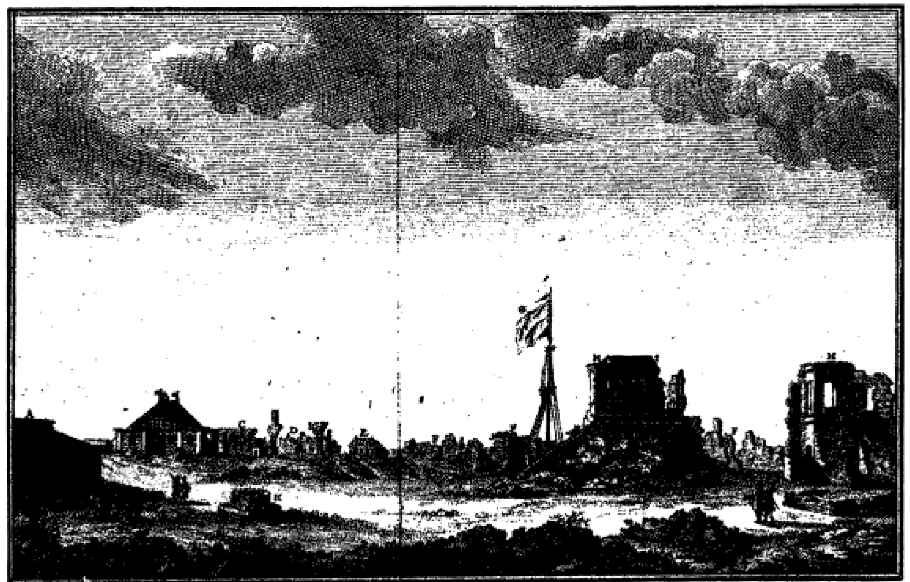
conferred the title 'Mahamahoadhyaya' by the British government in 1893, in recognition to his contribution in the field of astronomy.

He achieved great expertise in traditional Indian astronomy.

He constructed many instruments using the local available materials like wooden sticks and bamboo pieces.

His findings are recorded in his book titled 'Siddhanta Darpana', written in Sanskrit. Pathani Samanta Chandrasekhar's calculations are referred in the preparation of almanacs in Orissa.

19th century:infusion of modern astronomy



VUE D'UNE PARTIE DES RUINES DE PONDICHERY.
en 1769.

Le Gentil's Observatory is the building (HI) at the right of the flagpole.

With the advent of telescope and modern astronomy, it was soon clear that number of assumption and calculations made by traditional methods were wrong or inaccurate. Indian scholars attempted to improve and modernize Indian astronomy.

Indians have a taste of modern astronomy

Owing to the efforts of K. D. Naegamvala, an observatory was established in Pune around 1882 It was a premier spectroscopic observatory in India. Naegamvala made spectroscopic observations of the solar chromosphere and corona during the solar eclipse of 1898. He also made spectroscopic studies of the Orion nebula and sunspot groups.

In other observatories too, Indians begin to have a foothold. They are schooled in modern astronomy and use of instruments such as telescopes.

Establishment of Madras observatory

The old Madras Observatory was established by the East India Company in 1792.

The observing program included stars, the Moon, and eclipses of Jupiter's satellites. Measurements of stellar positions and brightnesses were made. At the end of the nineteenth century the Kodaikanal observatory was constructed and the madras observatory was shifted out.

Orthodoxy attacks..

Most of the tradtional panchang computers followed what is called Vakya tradtion- that is following the 'words'. They blindly followed the rules of computation prepared by Aryabhatta or another astronomer. Due to passage of time the results were not accurate. Yet they refused to change.

On the other hand, Driganitha tradtion, which formed part of the Kerala school, preferred observation (drig) to Vakya (word). However such improvements were criticized as 'westernization' and not accepted by the orthodeoxy.

Driganita is accepted

Reformation of the traditional panchang was undertaken by people like Mehanad Saha, Ragoonathachari and others. They noticed that the equinoxes were off by many days, the time of eclipse, moon rise were inaccurate and so on. Using the modern astronomy, calendar reform was undertaken. Driganita tradition is upheld by these reformers.