"Ancient Astronamy & Advance Science"

Engineering

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Prof M.Sajid Iqbal Kalsekar Collage of Engineering , New Mumbai.

Prof M.Aquil Saboo Sidek College of Engineering Bycuula Mumbai

ABSTRACT

Archaeoastronomy is the study of astronomical ideas and their evolution over time. India has one of the richest heritage of ancient monuments and documents that detail how human perspective has changed over the millennia. Looking at these ancient remains it is possible to decipher the relative evolution of ideas and cross cultural influences. Here we present some of these patterns that are discernible. However, absolute dating of ancient monuments that are more than 2 or 3 millennia old is not easy. We therefore suggest that there is a need for scientific instruments to carbon date these monuments in order to understand the chronology of evolution of scientific ideas.

Introduction

Humans took a long time to the third dimension of space, namely sky. But once the sky was noticed, it quickly became a focus of human interest and study. Right from the earliest periods, humans have built complex structures to keep track of the movement of the Sun and the Moon (Menon and Vahia, 2014) and also tried to keep track of constellations (Bhujle and Vahia, 2000). Our calendars are based on the movement of the Sun and the Moon and the division of year into 12 months or 24 fortnights and division of a day into 24 hours all come from astronomy. The Moon completes 12 cycles from full moon to full moon or new moon to new moon by the time the Sun returns to the same constellations, same point of sunrise in the horizon and the seasons return to their base (Vahia et al.,2015).

Many Indian tribes also use astronomy a variety of ways to tell stories, convey moral principles or to predict the monsoon (Vahia, 2015). Astronomy has impacted our architecture, our mythology, our travels, our timekeeping and all aspect of our lives. Understanding the growth astronomy therefore is crucial to our understanding of our past.

Stages of growth

We can identify four major phases of transition in the evolution of astronomy (Vahia and Yadav, 2008). These are:

- Initial phase: Marking of sunrise and seasons.
- Settlement phase: Marking of stars and constellations.
- Civilisation phase: Development of astrology and cosmogony.
- Technology based phase: Modem astronomy with all its trappings.
- We discuss them below, with examples from the Indian civilisation.

Initial phase

The initial phase consists of understanding and appreciating the fact that the Sun is related to warmth and life and the point of sunrise decides the level of warmth. The typical points of importance at this stage are given in figure 1.

At this stage, a human group or a culture can identify the following aspects of nature:

- Sun as the source of warmth and light.
- Realise that Sun and rains are crucial life givers and that sky rejuvenates the Earth.
- The sky becomes the abode for the gods.
- Astronomical observations get recorded on stones in the form of rock art.
- This phase brings in first generation astronomy - to the lev-

el of defining seasons and their relation to Sunrise points.

In figure 2, illustrates a rock art image from Chillas in Kashmir, which is a common form of expression of personal and social experiences at this stage of evolution (see e.g. Lewis- Williams, 2002 for a more extensive

Figure 2: A rock art from Chillas, Kashmir showing the Sun god with the disk of the Sun just behind him. The division of the disk into 4 quadrants is probably indicative of the 4 seasons.

(discussion on the Neolithic mind).

These images can often be very complex, making it difficult toin-terpret them; but they are likely to be important in understanding astronomical observations by ancient people.

In figure 3, we reproduce a stone etching found in Burzaham near Srinagar. While it has been variously

Figure 3: A stone etching from Burzaham, Kashmir. Picture from the collection of Indira Gandhi National Centre for the Arts, New Delhi

interpreted, Joglekar et al., (2011) have argued that since it is not possible to have two Suns in the sky and nor is it possible to have Sun and Moon so close to each other with comparable brightness, one of them * must be a transient object.

They suggest that the depiction could be that of a supernova a comet (see e.g. Strom, 2002). They found only one supernova that satisfied all these criteria and it was dated to around 5000 BC which also fitted the rest of the image of hunter at Orion and the stag at Taurus. This may be the first recorded supernova image (Joglekar et al.,2008).

Settlement phase

Once a population settles down in an area, it lives either by hunting or by farming (see e.g. Jain, 2006; p57). With fanning, they become more sensitive to the environment and its changes. Apart from observing that the Sun does not rise exactly in the east and does not set exactly in the west, they begin to find it necessary to keep track of the exact stage of the movement of Sun, Moon and stars in the sky. They evolve the following astronomical understanding:

- Large structures are created to keep track of the sunrise and sunset patterns. Megaliths are used as gnomons for calendrical purposes.
- Various aspects of Moon and probably planets get studied.
- In the Indian case, Nakshatra are defined while other cultures that are Solar centric define zodiacs.
- Eclipses are noticed and attempts are made to determine their periodicity.
- Transient objects such as comets are recorded.
- Myths are created to explain these observations.

One of the most conspicuous aspects of Megalithic period is the Megalithic structures that are marked by huge stones arranged in specific manner. While these may well be for ritualistic reasons, there is a fair case to be made that their primary purpose was to keep track of astronomical movements (see e.g. Baity, 1981).In India, the Lunar Mansions, called Nakshatras are found from the earliest period (see e.g. Abhyankar, 1999 p 241).

Vedic Astronomy

The oldest of Indian literature is the Rig Veda which forms the basis of Hindu Religion. Rig Veda is a document of a settled community with elaborate discussions of rituals and philosophy. Vedanga Jyotisa or the astronomical Treatise of the Vedas that insists that "Just like the combs of peacocks and the crest jewels of serpents, so does Jyotisa (astronomy) stand at the head of the auxiliaries of the Veda" (RV - VG 35, see Subbarayappa and Sarma, 1985, p1). From this, it is clear that the authors of Rig Veda were aware of the discrepancies between the duration of Lunar year and Solar year and the need to add intercalary month for synchronising the two (Sarma, 1985). The Concept of Yuga was introduced as a more sophisticated attempt to synchronise the Solar and Lunar calendars. The 5 Yugas were, Samvatsara, Parivatsara, Idavatsara, nuvatsara, and Idvatsara. Two intercalary months Amhaspati and Samsarpa were added to complete a Yuga. While commenting on Yuga Lagadha, the author of Vedanga Jyotisha of Yajur Veda (dated to 1350 BC, see Sastry, 1985) had a fairly good idea about the year being a fraction of a day (see e.g. Narahari Achar, 1997). At this stage one can also identify the speculations on the origin of the Universe. For example, the Nasadiya Sukta of Rig Veda speculates on the origin of the Universe in the following words (translation from Panikkar, 1977, p58):

- At first was neither Being nor Non-being. There was not air nor yet sky beyond. What was its wrapping? Where? In whose protection? Was water there, unfathomable and deep?
- There was no death then, nor yet deathlessness; of night or day there was not any sign.The One breathed without breath, by its own impulse. Other then that was nothing else at all.
- Darkness was there, all wrapped around in darkness, And all was water indiscriminate: Then That which was hidden by the Void, that One, emerging, Stirring, through power of Ardor, came to be.
- In the beginning Love arose, Which was the primal germ cell of the mind. The Seers, searching in their hearts with wisdom, Discovered the connection of Beings with Nonbeing.
- A crosswire line cut Being from Nonbeing. What was described above it, what below? Bearer of seed there were and mighty forces, Thrust from below and forward move above.
- Who really knows? Who can presume to tell it? Whence was it born? Whence issued this creation? Even the Gods came after its emergence. Then who can tell from whence it came to be?
- That out of which creation has arisen, Whether it held it firm or it did not, He who surveys it in the highest heaven, He surely knows - or maybe He does not!

Rig Veda X, 129

Even in this period, the astronomical observations are accurate enough to permit dating some of the ancient documents based on their astronomical references (table 1). However, it must be added that in many cases, the dating is considered controversial and even the same data has been differently interpreted by different workers.

Civilisation phase

At this stage, the society becomes better organised. With organisation comes increased efficiency. This efficiency allows the society to allot specific tasks to specific individuals, creating specialists. Specialised teachers are supported by the vulture and generations of knowledge becomes more systematic. Also, by then astronomical information becomes more precise and often, the documents created in this phase can be dated using astronomical information (table 1).

The society also reinterpret sold scattered ideas or creation of new ideas. The speculations about astronomy and the universe become more sophisticated. An interesting mixture of religious beliefs, astronomy and architecture emerge, reflecting the cosmogony of the period. With the need to predict and calculate planetary motions and eclipses, some amount of mathematical astronomy also arises at this stage.

Table : Dating of some ancient documents based on their astronomical references (Vahia and Yadav, 2008)

No	Document	Dating (BC)	Comments	Reference
1	Yajur Veda	2300 2950	Vernal Equinox in Kritika	Sastry (1985), p 12
2	Maitreya Bramhana - Upanishad	1660	Winter solstice at midpoint of Sravistha and summer solstice at the beginning of Magha	Sastry (1985), p 12
2	Yajur - Vedangajyotisha	1370	Summer Solstice in Uttarasadha	Sastry (1985), p 12
3	Period of Lagadha	1340	Polar latitude Sravishtha	Sastry (1985), p 12
4	Mahabharata	1200	Saptarshi	Sule et al. (2007)

Post Vedic astronomy

Astronomical references in the post Vedic literature clearly show this to be true. The cosmogony of the Upanishad (post Vedic) period of India is also fascinating. In Brihadaranyaka Upanishad

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(6thBrahmana dated to 8th and 7th Century BC), Yagnavalkya describes Universe to Gargi in the following terms (Max Muller, 1962; p 130):

- Everything on earth is wrapped in water
- Water is wrapped in air
- Air is wrapped in sky
- Sky is wrapped in the world of Gandharvas (planets?)
- Worlds of Gandarvas is wrapped inAditya (Sun)
- The world of Sun is wrapped in the world of Chandra (Moon)
- The world of Moon is wrapped in the world of Nakshatra
- The world of Nakshatra is wrapped in the world of Deva's
- The world of Deva's is enclosed in the world of Indra
- The world of Indra is wrapped in the world of Prajapati
- The world of Prajapati is wrapped in the world of Bramhana

Only the placement of Moon beyond the sun is in error otherwise points 1 to 7 are quite close to our present understanding! From points 8 to 11, we end up with a more metaphysical description of the Universe. The order is also instinctive rather than scientific and the last do three levels - the world of Indra, Prajapati and Bramhana really beyond the physical description.

Temple Architecture

An important aspects of this period is the manner in which astronomy and religion come together in architecture. Some of the megaliths are clearly of astronomical design (Menon, Vahia and Rao, 2012). These megaliths must have had a ritualistic importance in the community. Since, Indian temples are known to be constructed with a certain amount of astronomical accuracy, this may well be a legacy of merger of astronomical megaliths with place of ritualistic and religious focus. An exception to this is the cave temples which have been used in some places.

Temples are designed with two specific aspects in mind. Firstly, the central idol itself and the entrance leading to it are oriented east - west. The light coming from outside is collimated in such a way, that the idol is illuminated only on a specific day. In more elaborately worked out temples, the outer pillars that support the temple structure also cast their shadows at a specific location. Some of these important pillars are also marked with astronomical signs.

Technology based phase

Modern astronomy has arisen not only from astronomical observations but also incorporated a large number of fields. It has integrated mathematics where astronomers attempt to make accurate measurements of planetary motion, movement of equinoxes etc. Similarly physics has also played an important role in advancing our understanding of the Universe. Astrology also becomes important at this stage.

An important feature of this period is the state patronage. Depending on the capability, development of astronomy will be driven by mathematical and technological developments. Interaction with neighbouring cultures can also spur the growth. From here on, the growth of astronomy follows the same growth plan as the rest of the society. In the Indian context, this phase begins with Aryabhataaround 500 AD and is called Siddhantic (mathematical or computational). Pre-occupation of India astronomers for the next millennium was calculation of geocentric planetary orbits and development of algorithms for solving mathematical equations arising in the process with instrumentation and observation playing a secondary role to computations.

With the advent of formal and large- scale education and specialized teachers for example the requirements for a good astronomer become stringent. They are defined in Brihad Samhita of Varahamihira (505 AD) (Subbarayappa and Sarma, 1985, p 10). According to him, an astronomer should be a man of great personal strength and should be able to do the following:

- Know time division of Yuga, year, solstice, seasons, month, fortnight, day, night, yama (90 min), mahurta (48 min), nadi (24 min), prana, truti and calculate their starting and ending times,
- Saura (planetary calendar including the retrograde motion of planets and their different speeds in the sky), Savana (terrestrial calendar),
- Understand and calculate solstices.
- Calculate times of eclipses,
- Earth's rotation and revolution including concepts of difference in the length of day and night,
- Calculate latitude and longitude of a place (from Ujjain),
- Understand Nakshatras and Zodiacs and show them in the sky,
- Teach this to a learned person.
- Note that knowledge of astrology is not one of the requirements.

Time units

The idea of time undergoes significant changes.

We have already given the philosophical ideas about dftime in section 4.1.2. The Vedas define 12 months of Luni - Solar calendar and the fact that there is a discrepancy of seasons and the 12 Lunar months. They therefore propose the idea of intercalary months (two every five years) to resynchronize the two. In Vedangajyotisha, that gives the astronomical aspects of the Vedas, they define (see Subbarayappa and Sarma, 1985, footnote on p 51) 5 solar years as 1 Yuga, 366 day or 12 solar months as one year, 30 mahuratas as 1 day (i.e. 1 mahurata is 48 min), 2 nadikas as 1 mahurata (i.e. 1 nadika is 24 minutes), 201/20 kala as 1 nadika (1 kala is therefore 2.4 min) and the kala itself is divided so that 124 kasthas (about 1.1 sec) make a kala and 5 gurvaksaras or 10 matras as 1 kasthas. However, while these ultrafine steps of time are defined, there is no clarity on how to measure such fine time steps or their utilities. Most of the activities stop at a nadika that is 24 minute though time up to kastha could be measured simply by heartbeat or even recitation of verses of fixed length.

By the time of Vateswara (904 AD, see Subbarayappa and Sarma footnote on page 53 and page 313 for period of Vateswara) the time division has the following stretch: 100 years of Bramha is his life span. 1 year of Bramha is 725,760 human yugas and 1 yuga is 4,320,000 human years. On the lower side, we have 2.5 kusthas or asu make 1 as or 4 seconds (time taken to complete one breath) 1 kastha itself is the time taken to recite 4 long syllables, 1 nimesa is the time taken for the eye to blink and that 4.5 nimesa equals 1 long syllable or ¼ of a kastha. Nimesa itself is divided into 100 lavas and 1 lava is divided ton 100 trutis and 1 truti is defined as the lotus pricking time! While some ideas about the time units are given, they seem to have been designed more for the pleasure of defining them rather than using them for any purpose.

The concept of Yuga is also a complex one that has been significantly modified over time. Indeed, the word Yuga itself has three different meanings (Kochhar, 2007). In Vedic period, it is used for constructing cosmic chronology while in constructing mathematical astronomy it has been applied to calculate planetary periods. In Puranic period, the word Yuga is employed in terms of human period. Even when assigned time, its duration varies from 5 years in the Vedic literature to several millions of years in later literature (see e.g. Sule et al., 2008).

Numerology

The numbers 12, 60 and 360 have astronomical significance. It starts with 12 months a year and hence a movement of 1/12 of sky (by Sun) in 1 month. Sixty Nadikas make a day and 12 civil days make a year. To avoid fractions divide the sky into 360 deg (12 x 30) so that Sun moves 1 unit per day. That is how circle gets divided into 360 deg.

These numbers form the basic units of time and could be astronomical in origin. Also, some of the ancient civilizations used 60 as their base for number system (sexagesima systm), say for example Babylonian. The selection of 60 over other numbers again (as generally believed) could have been to make the calculations etc. easier, as 60 has about 10 integral factors, 2, 3, 4, 5, 6, 10, 12, 15, 20 and 30 i.e. more factors than any other number of comparable size. Thus, we have the division of hours into 60 minutes, minute into sixty seconds, circle into 360 degrees, each of 60 minutes (each minute of 60 arc seconds) and so on.

The drive of technology

Another feature of this period is the creation of large instrument to improve the accuracy and reach of astronomical observations. A refined version of the original megalithic structures now appear as large

Figure 4: Jantar Mantar, New Delhi an astronomical observatory (Source : Web Images credit The Hindu)

observatories which attempt to measure stellar parameters and their variations with great accuracy. In India, these are called Jantar Mantars and one of the finest examples is in Delhi (figure 4). It was built between 1724 and 1727 AD and its primary purpose was to measure stellar parameters. However, by this period, telescopes had been invented and were in regular use. The period of telescopic astronomy is so well documented that we shall not discuss it here.

Navigational astronomy

One of the uses of astronomy is in navigation. In the Indian context, astronomy has been regularly used for navigation and excellent details of use of astronomy from 14th century for maritime purpose are available (Arunachalam, 2002). With this exhaustive study, he has discussed the astronomical tools and methods used by Indian fishermen. The sea farers along the west coast of India

Figure 5: Sky chart used by Indian fishermen

typically made use of a chart of the rising and setting point of various constellations (figure 5) drawn as per their personal preferences. To reach any other port, they would then follow rising or setting location of a particular constellation for a certain period and then turn towards another constellation. In order to determine that they were moving as per the needs, they used simple, knotted floatation devices and other tools.

Summary

Astronomy provides an important marker to understand the intellectual evolution of a civilisation. Astronomy allows us to define the four major phases of intellectual growth which can be mapped to various conventional ways of classifying history and prehistory. The initial steps can be mapped to 50,000 BC to about 5,000 BC (7,000 YBP).Settlement Astronomy can be mapped to 5,000 to 2,500 BC for Harappans and up to 1,500 BC or later for Vedic and other cultures in the Subcontinent. Astronomy of civilisation can be mapped to 2,500 to 1,900 BC for Indus Civilisation and 1,500 BC to 500 AD-Upanishad / Purana period and the technology based, state supported astronomy: 500 AD Aryabhata onwards.

Conclusion

Tracking the history of astronomy can provide a map to the intellectual growth of a civilisation. In order to validate these ideas it is important to set up new facilities which will provide important tool to other fields of activity.

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