Origin and growth of Astronomy in Indian context[1]

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Abstract

We attempt to create a comprehensive model for the origin and growth of astronomy in a culture. We show that it primarily follows four distinct phases that we classify as initial phase, settlement phase, civilisation phase and technology based phase. Using examples from the Indian prehistory and history, we show that these phases mark distinct steps in the growth of astronomy in a culture. While the examples are taken from Indian culture, we suggest that it should be possible to identify these phases in other cultures too.

1. Introduction

We are what we are because our ancestors were who they were. Their attitudes and approach to problems of existence and understanding of the universe shaped not only their present and future but deeply affected the course of history. Hence, a study of our ancestors is a study about us in the deepest sense of the word.

Normally such a study is done using archaeological means. However, archaeology depends essentially on human remains and residues of ancient life. These may contain some well-preserved examples but largely they are the remains of routine life of ancient people. Hence, they are more representative of their life style and hence of the technological skills. They give few clues to their intellectual growth and hence provide only a limited access to our past, since many intellectual developments are not directly related to technology. The purpose of developing a specific technology and the solution they may have applied for a particular problem are profoundly interesting in their own right but the intellectual needs that drove development of ideas and technologies are also of great interest. One such purpose is astronomy where, technology, mythology and science all merge. In the present paper, we attempt to create a map of how astronomy evolves with time in any culture. For a general discussion on archaeoastronomy and enthnoastronomy see e.g. Baity (1973) and for a broad summary of growth of astronomy in India, see Kaye (1924).

2. Astronomy and myths

Attempts made by humans in trying to understand the heavens are of profound interest and importance. Astronomy[2] is one field, which at one level is highly utilitarian for its ability to predict weather, and at another level is completely abstract, more related to the human place in the vastness of the universe. At one level, rains, thunder lightening and other extraordinary events provide the source of life. At another level, the steady and unaffected

[1] Based on the work done with Srikumar Menon and Nisha Yadav

[2] Initially we use the word 'astronomy' to indicate all events above the earth. It is only with development of ideas and observations will the distinction between earth related events like rains and more heavenly phenomena must have arisen. The word astronomy, as used today, is of course restricted to the latter objects.

movement of stars and serenity of heavens on clear night must have always fascinated humans. Completely arbitrary but spectacular events such as the appearance of comets and meteor showers must have a profound impact on human psyche. Together therefore, the study of astronomy must have attracted the attention of some of the best minds of that time. It must have also profoundly affected the growth of mathematics as humans tried to keep track of these complex, if subtle movements of heavenly objects.

The only activity comparable to astronomical knowledge is the pursuit of understanding the relevance of human life in the wider perspective of nature. That is, creation of myths, creation of fantastic, complex stories of events past and yet to come, all of which place human existence in perspective. These creative works have been used from time immemorial in a variety of ways, from consoling people at the death of their dear ones to explaining the irrational events as activities of more mighty beings and hidden variables that are introduced by gods. In most cases, these myths begin to formalise and revolve around a common, if complex theme of supernatural powers and their relation to humans. Religion, in many ways is a natural evolutionary track for myths (see e.g. Armstrong, 2005 for a more general discussion on the history of myths). Each feed on the other and enrich both for their breadth of reach and profound philosophy and symbolism that they can provide. Just as astronomy fed mathematics, myths and religion must have fed literature and together, the human intellect grew to reach far beyond it was ever designed to go and to achieve what it was never meant to achieve.

Yet, at a more profound level, these two pillars of human intellectual growth, astronomy and mythology, are deeply connected. The life giving ability of the sky, through rain, sun and moon and its ability to invigorate and fertilise earth must have been noticed very early in human existence. Most religions therefore begin with the concept of Mother Earth and Father Sky whose rain invigorates and impregnates mother earth with new life. From this step, to making heavens an abode for gods would have been a linear progression.

The purpose of myths is manifold. These include giving a sense of purpose to life, giving meaning to life's irrational experiences, such as birth and death, by speculating on rebirth or higher existence and so on. In the original form of Hinduism, for example, the structure of the religion is that of a tripartite relation between gods, humans and ancestors (Jamison and Witzel, 1992), where each appeases others by giving boon depending on their powers and receiving favours in turn. Myths also give a sense of purpose to life, especially, by providing heroes whose examples can be emulated by others and provide a yardstick by which actions of others can be measured. Lastly, in many ways, they hold out a promise of manipulating gods who control the cosmos so that they may live under favourable conditions. Together therefore they provide a sense of connectivity between humans and the magnificence of nature, providing a sense of belonging and proportion against this vast expanse of the universe which can often disorient human life. Like all human activities, myths also change and evolve with time as people become more sophisticated.

In many ways, connected with astronomy, many cultures have seen their life's dramas being played out in heaven and have placed their most revered stories amongst the various imagined patterns in the sky. Myths and astronomy therefore have a closer relation than we normally appreciate.

From Mother Earth and Father Sky the myths and skies get interrelated to an extent that most profound beings and gods have a corresponding stellar association and special gods drive the wheel of life, the time, the winds, the rains, the sun, the stars and everything magnificent. Together, it is the heavens that, in many ways, control human life and some of the most creative human arts explore these inter relations. In figure 1 we present an example of such an intermix of images and ideas.

In the present paper, we will explore the complex relation between not only myths and astronomy but also between astronomy and the continuing human struggle to define themselves and to understand the complex set-up of heavenly beauty.

3. Development of astronomical ideas

Advancement in astronomical knowledge of a culture primarily depends on the following factors:

1) Requirement of the society
2) Available technology
3) Available calibre of the people

All these factors are sensitive to the period of the culture. The first two of these are more or less monotonic, with both requirements and available technology becoming more sophisticated with time. We briefly discuss each of these below.

Requirement of the society while linearly increasing with time is a curious entity. The requirement can change in sudden jumps of demand as societies become more sophisticated. In the hunter-gatherer phase for example, rough idea about animal migratory patterns and general feeling of warmth are sufficient. With the initiation of farming, or even pre-farming, a high sensitivity to seasons emerges. Farming requires more precise knowledge and predictability of seasons and sunrise point. Once a society acquires a certain level of sophistication and wealth, preservation of wealth, good fortune and the desire to pass on the wealth and good fortune to their offspring result in development of astrology and attendant studies. Once a civilisation reaches a level of sophistication, where it has enough resources to spare and stability to pursue pure curiosity, cosmogony and other fields begin to emerge.

Available technology is a predictable parameter based on the general technological sophistication of the culture. A specific, inspired piece of technology can result in a critical sudden spurt and history is replete with such examples. Invention of radio receivers and highly accurate clocks are two such examples. But even without such sudden spurts, all societies either acquire or circumvent the needed technology and broadly move towards higher level of sophistication.

Against this, the calibre of people is a matter of greatest vagary and is practically unpredictable. Given a broad idea of the calibre of the most influential people, their

influence on the advancement of knowledge can be estimated. Unfortunately, there lies a rather strong requirement of understanding the calibre of the most influential thinkers at any time in order to understand the growth in astronomy. Such persons can produce dramatic changes but their appearance or calibre is impossible to predict. In societies such as the Indian one, with a rather poor sense of history, most records of important individuals are missing and often, it needs to be inferred from the ideas that emerge at any time. In spite of this limitation, a general idea that people become increasingly sophisticated with time will permit some measure of predictability on the growth of astronomy in a culture.

In all this, we have disregarded sudden catastrophic social and ecological changes which can set societies back by centuries if not millennia. We have also implicitly ignored cross-cultural spread of knowledge which can also allow civilisation to make dramatic transitions to higher levels of learning and sophistication by borrowing the learning of other cultures. While these induced changes are often conspicuous, it is often not appreciated that such sudden spurts can only be introduced to civilisations already prepared (or due) for such spurt of knowledge and external infusion only accelerates the process of knowledge gain rather than change the track of the civilisation.
The combined effect of all this is that societies go through various transitions in their knowledge of astronomy, in a manner that is almost analogous to phase transitions in physics.

3.1 Stages of growth

In light of the above discussion, we can identify four major phases of transition in the evolution of astronomy. These are:

1. Initial phase: Marking of sunrise and seasons.
2. Settlement phase: Marking of stars and constellations.
3. Civilisation phase: Development of astrology and cosmogony.
4. Technology based phase: Modern astronomy with all its trappings.

We discuss these phases in detail below, taking examples from the Indian civilisation.

3.1.1 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.

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

- Identifying Sun as the source of warmth and light.
- Rains, Sun and heavens are identified as crucial life givers. Sky rejuvenates the Earth. This becomes an everlasting image in human (even Neanderthal?) mind.
- Due of its elegance and importance, 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 level of defining seasons and their relation to Sunrise points.

Moreover, these images can often be very sophisticated and complex making it difficult to interpret them, but they are likely to be important in understanding astronomical observations by ancient people.

3.1.2 Settlement phase

Once a population settles down in an area, it lives either by hunting, as long as the population is small and the land rich enough to support an entirely hunting population, or by farming (see e.g. Jain, 2006; p57). With farming, they begin to be far 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 therefore evolve the following astronomical understanding:

- Large structures are created to study the sunrise and sunset patterns. Megaliths become essential for calendrical purposes.
- Various aspects of Moon (and planets?) get studied.
- Constellations, zodiacs and Nakshtra are defined.
- Eclipses are noticed and attempts are made to determine their periodicity.
- Transient events such as comets are recorded.
- New myths are created to explain these observations.
- Cosmogonical ideas emerge.

One of the most conspicuous aspects of Megalithic period[3] 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. However, the moon no longer goes close to all the *Nakshatras.* Bhujle and Vahia (2007) suggested that this may be due to the precession of the equinoxes which produces subtle changes in the apparent path of the Moon in the heavens over time. Using modern astronomical software we calculated the average distance of the path of the moon from all the *Nakshatras* as a function of time and found that the distance was minimum around 3000 BC. We therefore suggested that the *Nakshatras* were probably designed around that period, when the first large settlements were beginning to emerge in the subcontinent (Jain, 2006, p 79).

The oldest of Indian literature is the Rig Veda which forms the basis of Hindu Religion. Its dating has been a rather controversial issue but its antiquity as the earliest Indian document has not been doubted (see e.g. Goodall, 1996, introduction p X). Rig Veda is a document of a settled community with elaborate discussions of rituals and philosophy. It however, has a separate addendum called Vedanga Jyotisa or the astronomical Treatise of the Rig Veda that insists that "Just like the combs of peacocks and the crest jewels of serpents, so does Jyotişa

[3] The term Megalithic period is used in general terms of prehistoric times. The specific historical time will of course be sensitive to the culture.

(astronomy) stand at the head of the auxiliaries of the Veda" (RV - VG 35, see Subbarayappa and Sarma, 1985, p 1).

Subbarayappa and Sarma (1985) have compiled the list of astronomical references in various ancient Indian literatures. 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. Yajur Veda (4.4.11, see Subbayappa and Sarma, 1985, p 50) recommends 2 intercalary months in 5 years. The days are named according to the phases of the Moon. They knew that 12 lunar months amounted to 354 days. The synchronisation was done using *Ekādaśarātra* ceremony. This made 365 days in a year leaving an error of 0.25 days per year. But the Vedic year consisted of 12 months, each of 30 days. This gives the duration of the year as 360 days. This was synchronised to the seasons simply by adding 5 days to the calendar. Solstice days were also noted in literature. The Concept of Yuga was introduced as a more sophisticated attempt to synchronise the Solar and Lunar calendars. The 5 Yugas were, *Samvatsara, Parivatsara, Idāvatsara, Anuvatsara, 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).

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. The most interesting of these is the dating of *Mahabharata*.

Beyond this stage, this intense process of creativity and study takes evolution of astronomy to the next phase of evolution namely that of civilisation.

4.1.3 Civilisation phase

At this stage, the society tends to be far more organised. With organisation comes increased efficiency. This efficiency allows the society to specialise tasks and create specialists. The result is that teachers and pupils fully occupied with generations of knowledge emerge. Such a society can then have people who spend a lifetime studying and speculating on nature. At this stage, the disciplines of astronomical mythology, cosmogony and astrology begin to take root. With increasing wealth, not only does the hierarchy within a society begin to strengthen, but more interesting consequences arise. The owners of wealth become possessive enough to become seriously worried about their future, conservation or increase of their wealth as well as passing it on to their offspring. Hence predicting future becomes an obsession. Astronomy, with its moving sun, moon and planets, provides one of the methods for predicting the future. Astrology therefore becomes the driving force for astronomy. In the absence of other knowledge, such activities gain certain respectability.

Also, by then astronomical information becomes more precise and often, the documents created in this phase can be dated using astronomical information.

The society also begins a *systematic reinterpretation* of old 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.

One of the important aspects of this period is the mix of astronomy and religion in the form of architecture. While megaliths of unknown use are known to exist in India from prehistoric periods (see e.g. Moorty, 2003) an interesting off shoot of the work in this period is the design of temples in a manner that is of significant astronomical interest (see e.g. Kameshwar Rao, 2005). At least some of the Megaliths in Europe are known to be of astronomical significance (Baity, 1973). It seems likely that these megaliths soon acquire a ritualistic importance in the community. They can then acquire a central place in the life of the community, a place that was later occupied by temples. 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.

3.1.4 Technology based phase

Modern astronomy has an equal component of astronomy and a large number of fields, which are integrated into a broad field of study. The first field to be integrated is mathematics where astronomers attempt to make accurate measurements of planetary motion, movement of equinoxes etc. The next field to be integrated is physics where real or imagined properties are attached to all beings, including the ones in heavens and attempts are made to create a physical view of the Universe. Astrology also becomes important at this stage. There are some excellent reviews of astronomy (see e.g. Kochhar, 1999, p 177) and other sciences in this period and we will only discuss this in a broader perspective.

Once a civilisation grows beyond a certain level of sophistication, a culture begins to specialise tasks and not everyone will be required to be proficient in all aspects of life. This translates into specialised education programme that come in a variety of forms. However, a common feature of most of these 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 around 500 AD with the advent of Siddhantic (mathematical or computational) astronomy and great astronomers like Aryabhata. It also has a strong influence of Greek astronomy. Pre-occupation of Indian 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 specialised 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.

5. Summary

Through the human history, astronomy has evolved in a gradual manner. Starting with the first attempts to understand the Sun, Moon and their relation to human life, the journey to telescope and satellite based astronomy has been a long and difficult one. In the present paper, we have attempted to trace this growth dividing the different stages into distinctly identifiable phases. Using examples from India, we have tried to illustrate the various phases.

However, the formulation is general enough to be applicable over a wide variety of cultures.

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