

Comets in Indian Scriptures

Patrick Das Gupta

University of Delhi, Delhi, India; patrick@srb.org.in

Abstract. The Indo-Aryans of ancient India observed stars and constellations for ascertaining auspicious times in order to conduct sacrificial rites ordained by the Vedas. Naturally, they would have sighted comets and referred to them in the Vedic texts. In Rigveda (circa 1700–1500 BC) and Atharvaveda (circa 1150 BC), there are references to *dhumaketus* and *ketus*, which stand for comets in Sanskrit. Rigveda speaks of a fig tree whose aerial roots spread out in the sky (Parpola 2010). Had this imagery been inspired by the resemblance of a comet’s tail with long and linear roots of a banyan tree (*ficus benghalensis*)? Varahamihira (AD 550) and Ballal Sena (circa AD 1100–1200) described a large number of comets recorded by ancient seers, such as Parashara, Vriddha Garga, Narada, and Garga, to name a few. In this article, we propose that an episode in Mahabharata in which a radiant king, Nahusha, who rules the heavens and later turns into a serpent after he kicked the seer Agastya (also the star Canopus), is a mythological retelling of a cometary event.

1. Introduction

Aside from the regular waxing and waning of the Moon, ancient observers seldom witnessed celestial objects undergoing metamorphosis. In the pre-telescope era, our ancestors were treated to such rare spectacles only at times of solar and lunar eclipses, and the occasional cometary sightings, wherein a gradually growing tail appears as the comet approaches the Sun.

Eclipses, of course, have been referred to in many ancient texts (see, for example, Stephenson 1997). Darkness inflicted on the Sun and Moon caused confusion and fear among people, as can be inferred from Rigvedic allusions to a solar eclipse (Kochhar 2010). A proper understanding and reasonably accurate predictions of these periodic phenomena were not possible until the arrival of the Greek astronomer Hipparchus in 190 BC and, in India, of Aryabhatta in AD 476 (Ansari 1977). On the other hand, cometary appearances are sporadic and relatively rare due to their highly eccentric orbits around the Sun. A bright comet, with a tail that grows and arches as it nears the Sun, must have been captivating and mysterious to our forefathers.

Comets are made of dust, organic compounds like frozen methane and ammonia, ice, and dry ice. They have rocky nuclei that are roughly 1–10 km in diameter and masses that range from about 10^{15} – 10^{18} kg. Because of their small mass, comets have very low surface gravity, and the pressure exerted by the solar wind plasma pushes the ionized and volatile substances outwards as they approach the Sun, causing a tail to grow from the comet. Recently, the tail of the comet Siding Spring C/2013 A1 had a brief encounter with Mars during October 19–20, 2014, which was monitored *in situ* by NASA’s fleet of martian spacecrafts (that included MAVEN) as well as the Indian Mars

Orbiter Mission. At the time of this writing, the European Space Agency's *Rosetta* spacecraft, which has been cruising in space for about a decade, succeeded in lowering its lander *Philae* on the roughly four-kilometer-wide rocky nucleus of comet 67P, on November 12, 2014.

Many comets in antiquity were described in the astronomical records of the Greeks and the Chinese (Fotheringham 1919). In the Indian context, it is plausible that comets were referred to in Rigveda, since the Sanskrit word *dhumaketu* (meaning literally "smoke banner") appears in roughly half a dozen hymns, and it eventually came to mean "comet" in Indian languages. In the subsequent Vedic literature, comets have been highlighted with various terms like *ketu*, *dhumaketu*, *shikhi*, and *keshi*, which were employed to describe them (Chandel & Sharma 1991; Iyengar 2006, 2010).

2. Vedic Literature and Comets

Vedas—Rig, Yajur, Saama, and Atharva—composed in archaic Sanskrit are the oldest deciphered Indian texts. The word Veda in Sanskrit means "sacred knowledge," with cognates in other Indo-European languages, such as (*w*)*oida* in Greek, *wit* (witness) in English, and *wissen* in German (Witzel 2003). Rigveda, the oldest of all (circa 1700–1500 BC), consists of about 1,028 hymns invoking mostly nature gods, goddesses, and sacrificial rites. It also includes secular observations and vignettes of Indo-Aryan life—their desires, struggles, and battles (Griffith 1973). From the first mention of iron in Atharvaveda, the mantra portions of this text have been dated to about 1150 BC (Witzel 1995).

Some written documents of the Mitanni dynasty rule (1500–1350 BC), obtained in northern Syria, were found to contain Rigvedic terms. A person from that time named Kikkuli authored a horse training manual involving numerous archaic Sanskrit terms. More surprisingly, a treaty between a Mitanni king and a Hittite monarch around 1380 BC invoked major Rigvedic gods like Indra, Varuna, Nasatya, and Mitra as witnesses for the accord (Anthony 2007). From the Mitanni agreement, antiquity of Rigveda is confirmed (Witzel 1989; Kochhar 2000).

Archaeoastronomical evidence indicates that Vedas have preserved even older traditions. In Vedic texts, *nakshatras* ("lunar mansions," defined to be bright stars and constellations lying along Moon's path) have an exalted status (Subbarayappa 2008). Krittika (Pleiades) is often listed as the first asterism among the twenty-seven or twenty-eight nakshatras which, according to Jacobi (1909), was due to its rising on the east during the vernal equinox when these rituals were established. Because of the precession of the equinoxes, it is Pisces at present, and not the Pleiades, that rises in the east during the spring equinox. This strongly suggests that the Vedic practices began in the period 3000–2000 BC (Jacobi 1909).

Shatapatha Brahmana (1000–700 BC) instructs one to light an auspicious sacrificial fire at the time of Krittika's rise in the east, because the Pleiades "rise invariably in the due east" (Chattopadhyaya 2008). Shatapatha Brahmana was obviously restating an ancient observation that had no bearing on the contemporary location of Krittika during its composition. Even the Chinese annals of 2357 BC recorded that Alcyone, the bright central star of the Pleiades, was near the vernal equinox (Allen 1963; Chattopadhyaya 2008). Moreover, older Vedic literature referred to the Big Bear constellation as *rikshas*, "bears," in archaic Sanskrit, indicating a common Indo-European origin of the

Vedic people. By about 900 BC, the stars of Ursa Major had been identified with seven Rigvedic seers, and hence the name Saptarishi, or seven sages (Ghurye 1972).

Rigveda also tells the story of the Sun getting pierced thoroughly with darkness by a demon's son, named Svarbhanu, until Atri restores the Sun's brilliance through sacred chants and offerings (Griffith 1973). The Atris were a powerful priestly clan, who made substantial contributions to the corpus of Vedic hymns (Kochhar 2010). The Svarbhanu episode portrays the occurrence of an ancient solar eclipse (Sengupta 1947; Markel 1990; Kochhar 2000; Yano 2003; Kochhar 2010; Vahia & Subbarayappa 2011).

Vedic rituals required strict temporal order. Jyotishavedanga (also referred to as Vedangajyotisha), ascribed to the commentator Lagadha, described the movements of the Sun and the Moon with respect to the nakshatras (lunar mansion) and stated categorically that the purpose of positional astronomy is to determine the times for performing Vedic rituals (Pingree 1981; Yano 2003). Although Pingree (1981) had dated Lagadha to about 400 BC, some authors have placed the commentator earlier than 1100 BC (Achar 2000).

Apart from innate curiosity and the determination of time for sacrificial rites, other reasons for keenly observing the night sky may have been the natural tendency to be drawn to the luster and radiance from the Sun and Moon—to eschew the darkness. This is amply evident in Rigvedic verses, as seen in the numerous hymns in praise of Agni (fire), Surya (Sun), Ushas (the dawns), and the Asvin twins or Nasatyas (Beta and Gamma Arietis). The mortal enemies of the Indo-Aryans—Dasas and Dasyus—were portrayed as dark people. Rigveda praises the Asvin twins, the earliest deliverers of light, for saving some of the seers like Atri, Kanva, Rebha, Vandana, and Antaka from deep pits (which may have been abandoned wells dug for drawing water) and for rescuing Tugra's son, Bhujjyu, from drowning in the sea (by delivering a ship to him). These lores may signify the role played by the twin stars in giving a sense of direction and hope to the despondents, before the breaking of dawn.

The above discussion makes it clear that for the seers of antiquity, the night sky and its attendants were sacred. It is highly unlikely that comets from the past would have gone unnoticed. Asko Parpola (2010) has drawn attention to a late Rigvedic verse that speaks of an Indian fig tree whose aerial roots are held up in the sky by the god Varuna (guardian of cosmic law). In the later Puranic texts (containing old Hindu royal genealogies and mythologies), the phenomena of gravity-defying stars and planets going around the fixed Dhruva (polestar) is explained by claiming that these celestial objects are fastened to invisible, ropelike aerial roots growing outwards from the north star (Parpola 2010). This immediately raises the question—were these “aerial roots” simply inspired from the hairy tail of a comet from bygone era?

Because Indo-Aryans praised bright and lustrous metals like silver and gold, one might expect them to be enamored by comets. On the contrary, comets and meteors were often thought to be associated with impending doom as inferred from Mahabharata and Puranas as well as from Varahamihira's *Brihat Samhita* (Bhat 1981). A natural explanation is that appearances of comets and meteors are unpredictable. In the words of the renowned Indian astrophysicist M. N. Saha (1953): “Comets appear from nowhere and on account of their weird appearance had always been taken to portend great calamity.” Meteors, at times, do lead to conflagrations and casualties. It is possible that the comets, with their appendages, were associated with meteors, even in the past. Ketus (in plural) were also discussed in Atharvaveda, which denoted rays of light or fire smoke that may have represented comets or meteors (Kochhar 2010). A verse

from Atharvaveda that links *dhumaketu* (smoke banner) to *mrityu* (death), presumably because of its resemblance to the rising smoke from a funeral pyre (Whitney 1905; Iyengar 2006), may be hinting at yet another wrong reason for comet phobia among our ancestors.

R. N. Iyengar (2010), observing that the word *dhumaketu* appears seven times (mostly associated with Maruts) in Rigveda, and that Atharvaveda contains a hymn about Saptarishi (Ursa Major) being veiled by a *dhumaketu*, has concluded that *dhumaketu* referred to comets even in Vedas. According to him, *dhumaketu* and Maruts represent comets and meteor showers, respectively (Iyengar 2010). However, the standard and more natural interpretation of Maruts is that they were minor gods associated with storms and cyclones who, at times, unleashed calamities on mortals. On the other hand, Indra in Rigveda was by far the most powerful nature god (of torrential rain, thunder, and flood) and was likened to a solitary bull-like warrior, as can be reckoned from a hymn in which the Maruts implore the seer Agastya to intercede on their behalf and request Indra not to slay them (Griffith 1973). This Rigvedic hymn, it has been argued, alludes to seer Agastya's bringing about a reconciliation between two warring tribes—Indo-Aryans (worshippers of Indra) and non-Aryans (who prayed to Maruts) (Ghurye 1977; Mahadevan 1986).

The epics, too, refer to comets. In Ramayana, deadly missiles are likened to comets. For instance, Ramayana mentions that when Dasaratha (father of Rama) and Kaikeyi (Rama's stepmother) were fighting the demons, Dasaratha was gravely injured by a comet-like missile. In another place, Ravana hurls a missile that resembles a small sunlike comet that fatally wounds Lakshmana (Rama's brother). Similarly, in Mahabharata, Veda Vyasa (the author of the epic as well as an editor of Rigveda) warns the blind king, Dhrtarashtra, about the ill-fated Pandava-Kaurava war, citing ominous signs like the nakshatra Pushya (Gamma, Delta, and Theta Cancri) being obscured by the *dhumaketu*, or comet (Kochhar 2010).

3. Of Rahu, Ketu, and Ketus

The name of the eclipse-causing demon, Svarbhanu, of the Rigveda got transformed, over time, to Rahu. As the Sun's foe, Rahu made his debut earlier in Atharvaveda (Kochhar 2010). This possibly led to a mix-up between Svarbhanu and Rahu, as Vedas were traditionally passed on orally. Elaborate myths concerning Rahu were narrated in later texts like Mahabharata, Bhagavata Purana, and Vishnu Purana. Rahu had a serpentine form and, in a clandestine manner, had partaken of Amrita, a celestial ambrosia (making the gods immortal) that had emerged out of the churning of the ocean. However, the Sun and the Moon gods witnessed Rahu's deed, so the demon tried devouring them, whereupon Vishnu severed its head by hurling his deadly discus, the Sudarshan chakra, at Rahu. The head retained the name Rahu whereas the torso with a tail was christened Ketu. By now, comets were already being referred to as *ketus* in the Vedic literature. The obvious reason for naming the torso Ketu is that both have tails.

Because the demon had already consumed some amount of the ambrosia, Rahu and Ketu became immortal. In the absence of a torso, the Sun or the Moon could not be retained for long after being swallowed by Rahu's head, and eventually they emerged from the torso. That was the way Hindu mythology dealt with the phenomena of eclipses. Since Rahu was a seizer of Moon and Sun, it got listed as a *graha* (meaning "seizer" or "grabber," but the term later became synonymous with "planet"). Even the

Sun and the Moon came to be known as grahas in Puranic and astrological texts. Gargyajyotisha, composed at the beginning of the Common Era, probably by a descendant of the seer Garga, includes both Rahu and Ketu in its list of nine planets, with Ketu representing comets, not the severed torso of Rahu (Yano 2003). Was this because Garga, circa 100 BC (Kane 1975), had a penchant for observing comets and made a list of seventy-seven comets that were characterized by a dark, reddish hue, as mentioned in Varahamihira's Brihat Samhita of AD 550? Brihat Jataka, by Varahamihira, lists Rahu and Ketu as planets, with Shikhi, another word for Ketu (Kochhar 2010). Atharvaveda-Parishishtha contains verses not only about grahas, nakshatras, and rahu, but also about ketus, or comets, classified according to seasons (Miki & Yano 2010). And, it should be noted that many of its chapters were composed after Greek astrology was introduced in India around AD 300. Generally, Hindu temples have sculptures representing nava grahas (nine "planets") with Ketu depicted as having an anthropomorphic bust with a tail.



Figure 1. Rahu (left), seizing a partially eclipsed Sun and Moon, and Ketu (right), with its serpentine form. (Redtigerxyz at English Wikipedia)

In AD 499, Aryabhata, dispensing with Rahu and Ketu, gave the correct reason for the eclipses. The plane of the Moon's orbit is inclined with respect to the Earth-Sun orbital plane, leading to a line of intersection. Total eclipses happen only when Moon and Sun are on this line at the same time, that is, only when the Moon is either at the ascending or the descending node. Varahamihira provided a clearer explanation for eclipses, but called the lunar nodes Rahu and Ketu. A great deal of mathematical techniques pertaining to trigonometry flourished in many parts of the world as a result of human preoccupation with eclipses. So, one wonders whether the chance coincidence

of angular diameters of the Sun and the Moon, being almost the same in contemporary times (leading to the total eclipses), played a significant evolutionary role in advancing mathematics.

With regard to cometary records, Brihat Samhita had cited (besides Garga) the texts attributed to ancient seers like Parashara, Vriddha Garga, and Narada. But their compositions on comets are no longer extant and, therefore, one must fall back on the writings of Varahamihira and Ballal Sena's *Adbhuta Sagara* for their work (Iyengar 2006). Brihat Samhita stated categorically that it is not possible to calculate the rising and setting of comets. It described in detail the motion of a comet named Chala Ketu (meaning "moving comet"), underscoring its rise in the west and its increase in size as it moved north, touching Ursa Major (Chandel & Sharma 1991). Brihat Samhita also delineated the characteristics of one thousand comets (Subbarayappa & Sarma 1985). It appears that it added nine to the existing number of comets to make the number a multiple of ten (Miki & Yano 2010). In India, the number nine was auspicious probably because any region could be divided into one central portion and eight other parts based on the subdivision of regions along the four cardinal directions.

It is remarkable that, anticipating periodic orbits, Narada emphatically claimed, "there is only one comet which comes time and again," while Bhadrabahu had reckoned that comets are hundreds in number, each with a different period (Sharma 1987; Chandel & Sharma 1991). Some historians place the Jaina seer Bhadrabahu, around 322 BC, as a contemporary of Alexander the Great, and as a preceptor of King Chandragupta Maurya (Smith 1958). While, according to David Pingree (1983), Bhadrabahu composed his Samhita only about one or two centuries before al-Bīrūnī (AD 973–1048). Parashara (circa 1000–700 BC) listed 101 comets, describing features of twenty-six of them (including Chala Ketu discussed earlier), which were likely to have been directly observed by him (Iyengar 2006). Morbid names like skull, bone, marrow, among others, were attached to some of the comets classified by Parashara in the death group of comets. As remarked earlier, even Atharvaveda associates comets with death since they look like the smoke rising from funeral pyre (Kochhar 2010).

The King of Mithila and Vanga, Ballal Sena (circa AD 1100–1200), had compiled cometary records from seers Parashara, Vriddha Garga, Garga, Atharva, Varahamihira, and Asitadevala in his *Adbhuta Sagara*. Interestingly, it appears that while discussing the comet Dhuma Ketu, Vriddha Garga observes that it has a starry nature and that it ejects a jet of smoke in a direction away from the Sun before setting (Iyengar 2006).

4. Agastya, Nahusha, Saptarishi, and a Possible Comet

Agastya was a seer who composed several hymns for Rigveda. He was referred to as *ugra*, or vigorous, in this Veda (Hiltebeitel 1977). It is curious to note that vigorous or *ojas* is cognate with *aug* (Gonda 1972). Agastya has been associated with the star Canopus, or Alpha Argus, since around 600 BC (Ghurye 1977). The Indo-Aryans could see this bright star only after reaching latitudes lower than 37°. Tradition has it that Agastya was the first Vedic seer to cross Vindhya Range to reach the lower latitudes in the southern region of India. The Rigvedic hymn 191 in book 1, most likely composed by Mana's son Agastya, deplores and complains about stings and bites from poisonous aquatic worms, scorpions, reptiles, and nocturnal insects, and states that it is the Sun who will provide relief by scorching and sucking up the venom. Towards the end, the

hymn mentions that the poison will be carried away by Krittika (Pleiades) like bearer girls transporting water in jars (Griffith 1973).

There are three interesting points about this hymn. First, it claims that the Sun dries up the water and, thereby, swallows the poison and brings about a remedy. A later legend narrates that Agastya drained off an entire ocean to expose the dreadful demons hiding in the water. It is plausible that this myth grew out of this hymn. Second, it mentions the Pleiades in connection with relief from venom. This hints at the origin of the lore of the seven sisters (Pleiades) taking care of the newborns and protecting them from disease. Third, Agastya was said to have been born in a jar, and was short in height. Was this hymn responsible for such a tale? Or, being very tiny as a boy, was he carried around by bearer girls in a jar? One can only indulge in such speculations here.

The epic, Mahabharata, recounts the story of King Nahusha (known to Rigveda, but with no myth attached) who replaced Indra as the king of the gods when Indra went into hiding after slaying the demon Vrtra. After being anointed as king of the gods, Nahusha turned radiant with “five hundred burning lights on his forehead” as he absorbed energy from gods, seers, demons, and goblins and dominated the heavens (Hiltebeitel 1977). To impress Indra’s consort Sachi, he ordered the seven seers (Ursa Major) to carry him in a palanquin. His arrogance infuriated the seer Bhrigu who requested Agastya become a bearer of the palanquin. Because Agastya was short in height, the carriage tilted on one side when he substituted one of the seven seers. The resulting imbalance made Nahusha very angry and he kicked Agastya, whereupon the latter cursed the former to turn into a serpent and fall from heaven.

Hiltebeitel (1977) linked this tale with the origin of Deepawali (festival of lights) in India. However, the episode is more suggestive of Nahusha representing a comet that crossed Ursa Major from the north and kept increasing in size as it moved southward towards Canopus (Agastya), eventually disappearing beneath the horizon. According to the myths, Nahusha was the son of the daughter of Svarbhanu (later associated with Rahu and Ketu) and belonged to the lunar dynasty with ancestors such as Atri (one of the stars of Ursa Major), the Moon, and Mercury (Hiltebeitel 1977). The comet’s overlap with the Big Bear may have conjured an image of Saptarishi carrying the comet. Ursa Major was also referred to as *cart* or *wain* in the past (see Ghurye 1972; Hiltebeitel 1977). As the comet moved southward, its tail gradually elongated, finally making contact with Canopus, which was depicted as Nahusha kicking Agastya. This is a reasonable conjecture. To bolster this claim, we note that Varahamihira prescribed worship of Canopus for kings, and warned that if this southern star is struck by a comet or a meteor, there would be famine (Bhat 1981). Rigvedic hymn 191 of Book 1 already describes Agastya’s aversion towards reptiles, so one could imagine an antagonism between Canopus and comets.

In this legend, Nahusha was anointed as the Lord of the heavens only after Indra went into hiding following Vrtra’s assassination. Could it have been a mythical portrayal of the appearance of a prominent comet with ever increasing size, during which time the variable supergiant star Antares (often linked with Indra) became dimmer or was occulted by the Moon? In addition to comets being linked with the serpentine Ketu (section 3), Varahamihira, while referring to Agastya’s drinking of the ocean to reveal the hideouts of demons and dangerous creatures, likened the gems in the hoods of exposed snakes to comets (Kern 1870).

It is not uncommon for a comet to become brighter as it moves from north to south. For instance, comet C/1853 G1 was discovered on April 5, 1853, south of Rho Aquilae

(now in the northern constellation of Delphinus) by K. G. Schweizer. Then, it appeared in the southern hemisphere on April 30, 1853, with its tail pointing towards Canopus. It grew from about 4° to about 10° in extent within a day, and was last sighted on June 11, 1853 (Kronk 2003). It has an estimated period of about 782 years, and hence, could have been seen around 493 BC and AD 289. There is also the case of a comet having a serpentine shape. The Chinese document of Se-ma Ts'ien recorded that the Standard of Tch'e-yeou appeared in 134 BC. It was comet-like but arched backwards in the shape of a standard (Chavannes 1899). According to Fotheringham (1919), this comet was identified by Hipparchus too, as reported by the historian Pliny in *Natural History*.

Bruce Masse (2007) gave an interesting interpretation of the episode of Vishnu's Matsya Avatara (Fish incarnation) narrated in Shatapatha Brahmana, Mahabharata, and Puranas. In this mythology (very similar to the Bible's Noah's Ark tale), Manu, the progenitor of human race, rescued a tiny but bright fish from a pond and put it in a jar. The fish started growing fast so it had to be transferred first to a river and then to the sea. It grew to become a gigantic horned fish in the ocean and warned Manu of an impending flood, eventually saving him by escorting Manu to safer, high-altitude land. According to Masse, Matsya Avatara represents an ancient comet which was small to begin with, but grew as it neared the Sun and, in the end, crashed into the Indian Ocean resulting in floods and tsunamis around May 10, 2807 BC.

5. Discussions

In the past, our ancestors made use of their terrestrial experiences along with large helpings of imagination to explain celestial phenomena. When they saw the Sun or Moon disappear, inch by inch, during an eclipse, they pictured them being engulfed within the mouth of a demon in the way prey is swallowed by pythons or boas. Darkness was an anathema to the fire-ritual-practicing priests, who monitored stellar positions to ascertain auspicious hours for Vedic rites. Appearance of any bright heavenly object, comets in particular, would have been a cynosure for their eyes. Therefore, one speculates whether the fuzzy nature of a comet's tail led them to conjure up invisible aerial roots of a tree on the polestar which tied up the stars and the planets to keep them from falling to Earth.

Historically, comets in India have been referred to as ketus and dhumaketus. By the time of Varahamihira (sixth century AD), Ketu was depicted as the dismembered serpentine torso of the eclipse-causing Rahu. Because of their tails and the association of the term ketus with comets, it was natural to associate reptiles with comets. I have provided several arguments to support my conclusion that the lore of the arrogant King Nahusha, carried by Saptarishi and ultimately thrown out of heaven for kicking Agastya, is an allusion to a bright comet of antiquity that crossed Ursa Major, moved southwards with an ever-increasing tail, and descended below the horizon after occulting Canopus. As an example, I cited the case of comet C/1853 G1, which was seen in the north near the star Rho Aquilae in 1853, and then appeared in the southern sky with a long tail pointed at Canopus (section 4). If my conjecture is correct, it would imply that the Nahusha episode was added to Mahabharata after comets were associated with serpentine forms.

Comets continue to influence human imagination, be it Giotto's fascination with Halley's Comet, which lead him to depict it as the star of Bethlehem in the fourteenth-century painting *The Adoration of the Magi*, or the space scientists' determination to

effect a soft landing of the *Philae* probe on the nucleus of comet 67P. We are living in exhilarating times when some of the science fantasies that could only be dreamt of in the past are materializing in front of our eyes. Someday, perhaps, we will detect comets in the Oort Cloud, or even exocomets orbiting other stars.

Endowed with memory and cognitive abilities, human beings have perceived and sought patterns in whatever they observed or experimented with. Periodic phenomena like diurnal variations—the apparent circling of stars around the polestar—and changes in lunar phases and the cycle of seasons, to name a few, were all of paramount importance for human survival, explorations, and for practical conveniences. In order to keep track of the functional aspects of these natural effects, time markers and calendars were developed, which, with the help of geometry and angle measurements, led to precise positional astronomy. Thereafter, it was a natural jump to Kepler's laws of planetary motion, which led to Newton's laws of gravitation, encompassing not only cometary motions and stellar dynamics in galaxies, but also galactic dynamics in clusters and dark matter.

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