Chapter 1

Ancient Solar Astronomy

1.1 Mythologies about the Sun

Among cultures of antiquity, the Sun has always occupied a central position. It caught the imagination of early man because the Sun gave him warmth, light, life, and acted as his clock. Because of this, he made the Sun his god and goddess, and worshipped it. Even today, in modern times, the Sun is worshipped in many countries and religions. Number of temples dedicated to the Sun god had been built. Many of the great cities of the ancient world were known as "The City of the Sun", such as Baalbec, Rhodes, and Heliopolis. More then just cult centers, scientists and astronomers of the day who lived in these cities studied the Sun, Moon and planets, in an effort to devise accurate calendar systems. What are the folklore and mythological stories about our Sun from these civilizations? It is of interest to note that many of these stories originated at different times in history, and in far off places, yet they still possess meaning to us.

1.1.1 *In Early Europe*

In early Europe generally the Sun was considered as a male god, but among the Indo-Europeans it was a female goddess, and the Moon was a male god. In German, and Gaelic languages the word for Sun is still female. In many other languages a common solar association is still reflected, for example: in Sanskrit, the Sun is called 'Surya' and Savitra or Savita, in Gaul 'Sulis', in Lithuanian 'Saule', and in Latin and

German 'Sol'. In addition, in Sanskrit the solar year is called 'Sama', which is similar in modern English to the word 'summer', and Celtic words such as 'Samhain' mean summer's end. Commonality is found in the names of the Sun among various cultures.

1.1.1.1 *Norse*

Europe has a long history with celestial deities. It was, in fact, named after the goddess Europa. Long ago a tribe known as Tautens colonized Europe or what is now called the European countries. Tauten people stemmed from an even older people known to us as Indo-Europeans. Early Tautens believed in a Sun goddess, Sol, and a Moon god Mani. Today in the German language, Sun is addressed as Die Sonne, a female noun, and the Moon as Der Mond, male. Like the dawn goddesses of the Greeks, Hindus and Egyptians, the early Germans propitiated a dawn goddess known as Ostara, or Eoster. It is this goddess from which the Christians incorporated a ceremony known as Easter, and her season, lencten in Anglo-Saxon, or literally "spring", became the Christian "Lent", leading to the Easter holiday. This reasoning leads to the medieval belief that the Sun "danced" on Easter day. Yet Eoster's most dominant symbol remains the 'egg', which symbolizes birth and renewal.

Celestial knowledge of the Norse is seeped in symbols and myth. For thousands of years, the most sacred and important symbol was the 'Wheel of the Year', represented by a 6 or 8 spoke wheel, or by a solar cross within a wheel. Such wheels are depicted on the famed silver cauldron of Gundestrup, which shows a horned deity touching a wheel. The Norse people, who lived in what is now known as Yorkshire, often cut out a solar wheel and placed it on the tops of mounds, inserting a pole or pillar to make a solar compass or a sundial. As in many other ancient cultures, the solstices played a key role in their lives, customs, and religious traditions. Solstices refer to the most northern and southern positions of the Sun in the sky. The modern word "solstice" stems from the Latin "sol stetit", or literally meaning that the "Sun stands still", and the official modern name of the Sun. Sol also finds it's origins in Latin, where sol is a feminine noun meaning 'Sun'.

Norse people devised their calendar taking into consideration the

midsummer solstice. Among the Norse, the god Balder is the most closely associated with the solstices. In a myth that explains the actions of the midsummer and midwinter Sun, Balder, the son of the god Odin, was said to die at the hands of his evil brother who, wielded a mistletoe stake each summer solstice. He was reborn at the winter solstice, or what is still known in Germany as Mother Night (the 'mother' in question being the goddess who brings the new born Sun back into existence).

There are a large number of Norse myths about the Sun. In the epic of Sigmund, also known as Sigurd or Siefried, the Sun's magic sword is named Balmung, which means 'Sun beam'. In this tale, the hero comes across a valkrie surrounded in a ring of fire. It is a lovely Brunhild, who symbolizes a dawn maiden. The Saxon god, Saxnot (sax-sword) also had a magic sword, and one was said to have hung in his temple in such a way as to reflect the dawn's first light. Even Odin was associated with the Sun. The tale explains that Odin, in search of wisdom, once went to the well of Mimir (memory) to drink deeply and gain knowledge in the process. The guardian of the well asked one eye as a price for the act. Odin plucked the eye and threw it into the well where it became the Sun.

Presently in Scandinavia, on the eve of the summer solstice, thousands of people flock to the hillsides to light bonfires and to watch the Sun set, following a tradition started in the dawn of time. Though originally a tribute to the Sun, the event has since been assimilated by the Christians and transferred to honor St. John. Another notable, and still living midsummer tradition is the construction of large wheels made of wood or straw which are set on fire and rolled down hills to represent the Sun's journey toward the winter.

1.1.1.2 *England/Ireland/Scotland*

Norse tribes such as the Angles, Saxons, and native people of areas such as the Celts and Picts, invaded and influenced the English-Scottish people. This explains the Irish name for the Sun goddess Grian, a female noun. It indicates a close relationship with the Celts culture and their Indo-European descendents. The Irish concept of the 'solar cross' was prevalent and the 'central mound cosmology' was considered sacred centers known as 'Tara'. They were constructed in such a way that from

a central station extended four divisions or provinces. On holidays such as 'Samhain' (meaning Sun's end), to mark the end of summer, large bonfires were lit in these sacred centers, Tara, on the tops of mounds across the countryside. Another Irish deity is the spring goddess, 'Bride' (bright), who has much in common with the Norse's Ostara. A special temple complex in Kildare, originally known as Cill Dara, was dedicated in her honor. In this temple there was a circular building with an eternal flame burning in it, stoked with sacred oak wood. A holiday in her honor on February 2, known as Imbolc is often associated with the fertility of sheep. However the most important aspect of Bride's reign is the New Year's returning Sun. To mark this event, the modern day Catholic nuns admirably absorbed not only the goddess and her shrine, but follow also the old customs. Once a year, followers of St. Bride still go to the spiritual center where they circle a central pillar with a candle, visibly re-enacting the yearly journey of the Sun. There is another Irish Sun goddess, Aine. In her honor there was an annual festival on each summer solstice day. The legend says that Aine had the ability to transform into a horse, perhaps referring to an ancient memory of the 'horse fetter', the *Analemma* of the Sun. Lugh, a Celtic Sun god, was said to be honored each year at the harvest festival of Lughnasad. His temple site gave a name to what is today called London.

In many Irish passage graves, carvings of the Sun's symbol are seen which support the idea that the ancient Irish associated the dead with the Sun. A multitude of other structures, such as megaliths, stone circles, graves and religious sites, seem to be aligned with solar events, for example with solstices and equinoxes. The famous passage grave is at Newgrange. Liamh Greine, or 'The Cave of the Sun', is aligned such that on the winter solstice day a beam of sunlight at dawn illuminates the inside of the structure for approximately 17 minutes. Such associations have given rise to modern day superstitions in Ireland that those carrying the deceased past a graveyard, or sometimes a standing stone, had to circle it *'sun-wise'* (clockwise) two or there times to avert ill. Otherwise a sunbeam falling on someone at a funeral would foretell of his or her death!

In 17th century Scotland there was a very similar concept of tying life with the Sun. When a child was born, a ceremony called 'saining' was

done. An attendant would carry a candle *sun-wise* around both the mother and baby. Like most other pagan customs, Christianity later absorbed this and the meaning converted from receiving a blessing by the Sun to warding off the devil. In Gaelic we also find the source of the modern day word used by Wiccans when casting a circle. 'Deosil', which means *'sun-wise'*, meant to walk in the clockwise direction of the Sun.

To this day pagans are still tracing the Sun's path. Owing to its diverse history, not much is found in England of ancient pagan sites, culture, and traditions. The Romans left behind some sites, however, such as the Chanctonbury Ring, called 'Mother Goring' by the locals. Archaeologists believe that this site is actually the remains of a Romano-British temple, and the rituals are re-enactment of the hero's quest around the celestial circle and the final victory of reaching the Sun. In Dorset, Cerne Abbas, a giant-Sun deity is carved on a hillside. Some say it is the Saxon god - Heil, Hayle, or Helis, equivalent to the Greek Helios and the Norse Hel. St. Michael's Mont in Cornwall was originally called Dinsul, meaning, 'mount of the Sun'. The mountain is an island, and legend has it that it is the sole remnant of a lost culture called Lyonesse, which many associate with the Celtic Isle of Avalon, or the Norse Summerland. Cornwall has a large number of such historic sites, including the standing stone called the Men-an-Tol, a large circular stone with a central hole. It retains the tradition that to gain health, one must crawl through the hole towards the Sun! At the stone circle Long Meg and Her Daughters, there is an alignment to the winter solstice sunset, and the site of Castlerigg aligns to both the midsummer sunset and February 1, the ancient Imbolc.

1.1.2 *North America*

1.1.2.1 *Among the Navajo Indians*

Tsohanoai is considered the Sun god for the Navajo Indians of North America. As the story goes he is supposed to have a human form and carries the Sun on his back everyday across the sky. At night, the Sun god rests, hanging on a peg on the west wall of Tsohanoai's house.

Tsohanoai had two children, Nayenezgani (killer of enemies) and Tobadzistsini (child of water). They lived separated from their father in their mother's house in the far west. Once adults, they decided to find their father and seek his help in fighting the evil spirits that were tormenting mankind. After many adventures they met Spider Woman, who told them where they could find the Sun god and provided them two magic feathers to keep them safe. Finally, they arrived at Tsohanoai's house where Tsohanoai gave them magic arrows to overcome Anaye, the evil monsters that devoured men.

1.1.2.2 *Among the Pueblo American Indians*

Among the Pueblo tribe, which is the descendents of Chacoan people, the Sun is depicted as carrying a bow and arrow. The bow-and-arrow and arrows are associated with the Sun in the cosmology of the historic Pueblo peoples. In certain Pueblo traditions the arrow is seen as a vertical axis and may refer to nadir and the zenith, or the world below and above. In a version of a Zuni story, the father, the Sun gives his sons bows and arrows and directs them to lift with an arrow the Sky-father to the zenith. In another story, the Sun directs his sons to use their bows and arrows to open the way to the world below so that the Pueblo people can emerge to the Earth's surface and receive the Sun's light. At the solstices the Pueblos give offerings of miniature bows and arrows to the Sun. The Pueblo people had developed an accurate calendar. It has been described as a synchronization of the monthly lunar cycles with the annual solar cycle.

1.1.2.3 *Among the Anasazi Indians*

Anasazi Indian tribes occupied Chaco Canyon from about 400 to 1300 AD. In this arid region these early inhabitants left evidence of a skilled and highly organized society that displayed interest in astronomy. The famous rock painting of the supernova of 1054 AD, several other petroglyphs, and many solar alignment sites found in Native American Indian regions testify to their astronomical awareness. Details of some of these are given later in this section. Through precise observation of

the Sun and the recurrence of solstices and equinoxes, the Anasazi developed an accurate calendar for agricultural and ceremonial purposes. This astronomical knowledge was also commemorated in design and alignment of major buildings of their time.

1.1.3 *South America*

1.1.3.1 *In Aztec Culture*

The Aztec people belong to the most evolved civilized culture of their time in Latin America. They developed astronomy, mathematics, along with a solar calendar, and also they were Sun worshippers. The Aztecs considered Huitzilopochtli as their god of the Sun and of war. He was pictured as a blue man, fully armed with humming bird feathers on his head. His mother was called Coatlicue. It is believed that Aztecs used to offer human sacrifices to propitiate the Sun god, Huitzilopochtli. The victims were usually prisoners captured in the frequent wars that Aztecs fought against their neighbors. The sacrifices were intended to secure rain, harvests and further success in war.

1.1.3.2 *In Mayan Civilization*

More than 2000 years ago the Mayan people lived in the present day Yucatan peninsula of Mexico and Guatemala. They had a very rich scientific and cultural life. Mayan life literally centered on astronomy, mathematics, and the calculation of time and calendars. Mayans based their calendar not only on the Sun and the Moon, but also on rising and setting of the planet Venus. This is mentioned in one of the surviving Mayan books, the Dresden Codex, written more than 1000 years ago. The worship of the Sun figured in their rituals, too. It is believed that many Mayan kings ascended to the throne on May 1, the date when Pleiades and the Sun are in conjunction. The kings were often depicted holding an upright staff, perhaps a sacred gnomon or sundial in their hands, to demonstrate their connection with and understanding of the Sun. On the solstices days in Mayan regions (latitude $\pm$ 23.5°), at noon

the Sun does not cast shadow from upright sticks. This was considered to be one of the most sacred events of the year. Many of their ancient Sun rituals were Christianized by Spanish missionaries and are still followed under that guise today. A good example is in the modern religious holiday called the 'Passions'. This festival is celebrated in honor of the Sun's influence on growing corn (Sun beams from gods). Modern Mayans refer to Jesus as the 'Lord Sun', and demonstrate the annual battle between the summer Sun and the darkness of winter. Several Mayan buildings and cities are aligned keeping astronomical phenomena in mind. At the time of winter solstice, a beam of sunlight falls directly into the famed pyramid of Lord Pascal to light up a carved sarcophagus cover. The most famous of all Mayan cities is Chichen Itzá in Yucatán. This was founded over 1000 years ago and the famous pyramid called 'Pyramid of Kukulcan' was built here. Each year at the spring and autumnal equinox, around 4 p.m., the Sun casts a shadow on the stepped structure. As if by magic, this shadow appears to form a slithering serpent which slides down the face of the pyramid to the Earth below. It is believed that this serpent represents the deity, Quezalcoatl, the "feathered serpent", also known as Kukulcan. Sometimes it is assumed to be a male god. Natives of the area have a long held belief in this divine serpent goddess, who has fostered life on Earth and delivered mankind from evils.

1.1.3.3 *Among the Inca in Peru*

Ancestors of the Inca people lived in Peru, South America. Incas were highly sophisticated in mathematics, astronomy and agriculture. The ancient Incas were known to have had a string "computer", called a *quipu*, and had mastered the science of hydrodynamics through their extensive canal building and experience in irrigation. Incas had abundant gold but made no ornamental use of it. They considered gold as 'tears wept by the Sun'. Incas utilized the metal for its sacred connection to the Sun rather than for its monetary value. In this way gold was prized. The sacred Sun temple in Cuzco was literally covered with gold; it is referred to as Coricancha, the 'Place of Gold'. The western wall of the temple contained an idol made of gold and is positioned so as to catch the

western sunlight. Nearby this temple, the Inca raised special pillars to serve as sundials. At the time of solstices, when no shadow was cast, they declared that 'god sat with all his light upon the column'.

Incas considered Inti as their Sun god. It was believed that Inti and his wife called Pachamama, the Earth goddess, were benevolent deities. According to an ancient Inca myth, Inti taught his son Manco Capac, and his daughter Mama Ocollo, the arts of civilization, and sent them to the Earth to instruct mankind about what they had learned. Even today Inti is worshiped in Peru during the Festival of Inti Raimi in Cuzco.

1.1.3.4 *Among the Mamaiuran Amazon Indian Tribe*

Mamaiuran, an Amazon Indian tribe that lives along the banks of the Xingu River in Brazil, named their Sun god as *Kuat*. According to a Mamaiuran legend, at the beginning of time it was continuously night and the Indian tribes were forced to live in perpetual fear of attack from wild animals. Light could not reach the Mamaiurans because the wings of birds blocked the sky. Kuat and his brother Iae decided to steal some light from the vulture god, Urubutsin, king of the birds. The two brothers hid themselves in a corpse, and waited until the birds approached. As soon as Urubutsin landed on the corpse to eat the maggots, Kuat grasped the vulture god's legs. Unable to get away and deserted by his followers, Urubutsin was obliged to agree that he would share daylight with the two brothers. To make the light last for long time, it was established that day should alternate with night. As a result, Kuat became associated with the Sun and Iae with the Moon.

1.1.4 *Egypt and the Middle East*

1.1.4.1 *In Egypt*

In ancient Egypt, *Re or Ra* was known as the Sun god and the creator of our world. He took many forms, each depending on where he was. Usually Re was portrayed with a hawk's head, wearing a fiery disk like the Sun on this head. Surrounding the disk was a cobra-goddess,

representing his power to bring death. In the Underworld, the Sun god took the form of a ram-head. In this guise, Re even had power over Osiris, the ruler of the Underworld. It is said that in the beginning of time, an egg rose from the primeval waters and from it emerged the Sun god, Re. Once out of its shell, Re had two children, Shu and Tefnut, who became the air and clouds. They had two more children, Geb and the goddess, Nut, who became the Earth and the stars. They in turn had two sons, Seth and Osiris, the father of Horus. It is said that Re wept one day, which lead to the creation of humans from his tears. He also created the four seasons for the Nile, the heart of Egypt. Re combines with Horus to form Re-Harakhte, god of the Sun and the heavens.

According to an Egyptian legend, Het-Heru, or Hathor, the mother of the Sun god Re, was considered as solar dawn. Each morning she gave birth to the Sun and carried it from the east to west, wearing the Sun disk between her horns. She was depicted in prehistoric Egypt by a cow head on a pole. In the 'Hall of the Cycle of the Gods', a temple dedicated to the precession of the equinoxes, serious rituals took place dedicated to Hathor. Here she reigned as a Sun goddess, while mirrors on each side represented the solstices. Another tale involving Hathor says that, as Re grew old and paranoid, Hathor was sent on a mission to destroy her human enemies. Her rage was so great, that she was only stopped by the reflection at dawn of her own face in a makeshift mirror consisting of a pool of beer.

From a detailed study of ancient Egyptian symbols related to solar eclipses, Robin Edgar supports E. Walter Maunder's theory that the ancient Egyptian "winged solar disk" symbol was in all probability inspired by ancient observations of total solar eclipses. A photograph of the winged Sun is shown in Figure 1.1. It is seen in many ancient Egyptian hieroglyphic inscriptions and on the royal seals and cartouches of Egyptian pharaohs.

Egyptian religious symbols are also found carved on obelisks, capstones of pyramids, alabaster bas-reliefs, and painted onto now fading ancient wall murals. A winged Sun disk symbol graces the stone lintels of the entrances to many temples and palaces in Egypt. Numerous Egyptian pharaohs employed this ubiquitous religious symbol of their Sun gods as a royal sign of their divine status. It seems that the early

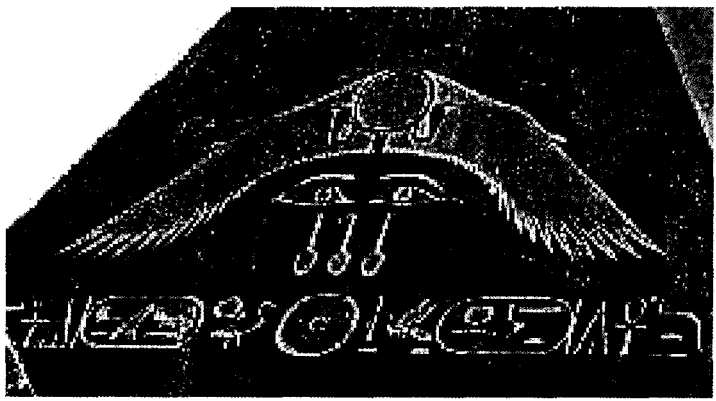

Figure 1.1 Egyptian symbol of a 'Winged Sun'.

Egyptians were inspired from observations to have adapted as a symbol the depiction of a solar eclipse, with equatorial streamers of the solar corona stretching out on either side of a 'black Sun'. This image bears a striking resemblance to the outspread wings of a glorious celestial bird. At the same time the plume-like polar rays distinctly resemble the fanned-out tail-feathers of a gigantic cosmic bird.

1.1.4.2 *Middle East*

One of the greatest and most advanced cultures of all time was that of ancient Sumer. This early civilization had scientists, school teachers, universities, pharmacies, and lawyers who were very advanced in natural sciences. Sumer formed the foundation for the Babylonians and Hebrews. In Sumer it was thought that immortals lived on the primordial mountain of heaven, and the Earth was 'the place where the Sun rose' at the dawn of creation. This later turns into the Garden of Eden concept of the Hebrews, with the Adam and Eve story. The Sun and Moon; Utu and Nanna, were considered to be two special deities that saw everything humans did. This was from their lofty positions in the sky and attended their judgment to give witness to each person's deeds. Babylon took this idea farther, saying that the Sun and Moon, Shamash and Sin, are themselves born from the great mother serpent in the sky, called Tiamat, which is now identified as the constellation Draco. Many thousands of

years ago this constellation once contained the pole star. The Babylonian king Hammurabi credited Shamash for creating the famed Hammurabi Code of laws. In Phoenicia, the Sun god was also known as *Bel* or *Baal,* and had the combination name of '*Baal-Samin*', the great god, the god of light and the heavens, the creator and the rejuvenator. The root word Samin, for Sun later occurs in the Hebrew tale of Samson, the blind and super strong hero, who pulls down the beams of a mill-house. It is known that this tale is a metaphor for the Sun god, Samin, and the precessional cycle of the Earth's axis by which the 'old' Sun cycle comes to an end, with the movement of the celestial pole. The 12 signs of the zodiac are also represented in Hebrew culture by the 12 tribes of Israel, and by the 12 stones that are worn on priest's chest plates. The stones represent the order of the Sun's progress through the zodiac signs, starting with jasper and ending with amethyst. The two sardonyxes on the shoulders represented the two "eyes" of the gods, the Sun and Moon.

1.1.5 *Greek and Roman Mythology*

It has often been said that Greece was the seat of western civilization. The Greeks may be considered as cousins to both the Indian Hindu and the Norse cultures. All three seem to have been much alike in myth, science and practice, perhaps due to their common Indo-European heritage. In Greek mythology, *Apollo* was considered as the god of the Sun, logic, and reason. He was also a fine musician and healer, a son of Jupiter (in Greek, Zeus) and Leto (Letona). The story goes that Apollo's mother, Leto, traveled all over Greece to find a place to give birth to Apollo. She finally came upon an island named Delos. The island agreed to allow the birth of Apollo if she in turn founded a temple on the island. Leto agreed and when Apollo grew up he changed Delos into a beautiful island.

Very early texts of the Greeks mention a goddess associated with the Sun or dawn. It was said that Circe, was the daughter of the Sun, who lived on the sacred primordial island, guarding a magic cup of the gods. Whoever tasted from this cup lost his upright shape and fell downward into a groveling swine. One Deomocritus regarded this ambrosia as the vapour by which the Sun is nourished. Aurora, the dawn goddess, was

said to arise each morning and open the gates of the sky for the Sun god, Apollo. Another Sun deity in Greek mythology is mentioned as a male god, *Helios*, the Sun. Evidence also points, however, to an earlier female Sun goddess under the name of *Helice*, which seems to closely link with the Norse goddess Hel. Two modern words remind us of Helios, whether male or female. The element Helium was named after Helios when it was first discovered on the Sun. And the Christian "halo" comes from the Greek word "halos", or "helos", meaning the circular disk of the Sun or Moon, often depicted over the heads of celestial deities.

1.1.6 *In Asia*

1.1.6.1 *In India*

Sun worshipping existed in India from the most ancient times down to the present day. In the Vedic period (about 3000 BC) the Sun, known in Sanskrit as *Surya*, was worshipped under various names, of which the chief were *Surya* and *Savitra* or *Savita*. The other Sun deities are *Mitra, Pushan* and *Vishnu*. The Sun god, Surya, is described as far seeing, all seeing, a spy of the whole world, he who beholds all beings, and the good and bad deeds of mortals. He is considered as the preserver and the soul of all things, both stationary and moving. Enlivened by him, men pursue and perform their work. The god Surya shines for the entire world, for all men and all gods. He dispels the darkness with his light. He rolls up the darkness as a skin. His beams throw off the darkness as a skin onto water. Even today a religious Hindu is suppose to recite the *"Gayatri mantra"* (prayer), every morning in praise of the Sun god and offer water to it. The Gayatri mantra literally means that, "May we receive the glorious brightness of this (Surya), the creator, the God, who shall prosper our works". Several Indian communities believe that they are the descendents of the Sun god - Surya.

In a popular version, Surya is considered as an anthropomorphic figure, a the son of *Dyaus*, the wide spreading sky, and is described as 'all creating' and 'all seeing'. In this aspect his most ancient and significant name is *Prajapati*, 'the lord of Creation'. He traverses the

heavens in his golden chariot drawn by seven horses, and *Usha*, or the dawn, is the charioteer, with *Asvin*, the twin gods of the morning, his children. By his power, he drives away the demons of sickness and expels diseases and all the subtle and dreaded influence of darkness.

There are several ancient temples in India dedicated to the Sun god, Surya. The best known are at Konark (Orrisa), Gaya (Bihar), Varansi (Uttar Pradesh), Modhera (Gujarat), and Srinagar (Kashmir). Some of these temples are aligned to solar phenomena, such as solstices and equinoxes, and also to Sunrise or at mid day. On certain astronomically important days, the sanctum sanctorum of the temple is illuminated by a sunbeam. In India today, the winter solstice called the *'Uttrayan'*, when the Sun starts its northward journey in the sky, is considered a very auspicious celestial event and is celebrated throughout the country.

1.1.6.2 *In China, Japan and Korea*

Although no records could be found in olden Chinese and Korean literature, wherein the early people of these countries considered the Sun as a god, as in the case of other ancient civilizations of the world, Japan is an exception. According to an ancient belief, the Japanese royal family is descended from the Sun goddess, *Amaterasu*. Even today the Japanese maintain a most sacred Shinto shrine to the Sun goddess at Ise, a city with a 2000 year history. Even the Japanese national flag represents the disk of the Sun. Ancient Chinese were known to have well developed astronomical (and other) sciences. They knew how to calculate the circumstances of solar eclipses, and could predict their occurrence, as indicated by the famous apocryphal story of the two Chinese court astronomers, Hsi and Ho. It is said that, being too drunk, they did not predict the occurrence of the solar eclipse of October 22, 2134 BC, and hence the Emperor beheaded them. To what extent this story is correct is not known, but the idea it brings to mind is that the early Chinese astronomers were well verse in observations and the calculation of eclipses. There is another side of this story that Hsi-Ho was perhaps the name of the Sun deity, who had the responsibility of preventing eclipses. Thus the ancient Chinese also had a Sun deity. There is an interesting story in Chinese folklore about the Sun. That in the very early days, there

were nine suns in the sky, due to which the Earth became terribly hot, and the farmers were extremely miserable as their plants in the fields started dying. The hero Hou-Yi, a very brave and strong man, shot off eight suns by his arrows, leaving only one Sun in the sky. Thus the Earth became safe for life and the farmers got rich harvests.

1.2 Major Ancient Solar Observing Sites

As man evolved through time, he started looking at the Sun and its movement across the sky during the day, weeks, months and year, and discovered that the movement and position of the Sun is related to many phenomena around him. He watched the Sun rise daily in the east and set in the west, he noticed that the Sun does not rise or set at the same place in the horizon, but seems to shift its position from day to day, during the year. Perhaps he also discovered that its position in the sky repeats after about 365 days. Sometimes the Sun appeared quite high towards the north side and sometimes in the south. These positions of the Sun coincided with the seasons. When the Sun was towards the north, it was summer (in the northern hemisphere), quite warm even hot, but when it was towards the south side it was winter, quite cold. As man developed agriculture, it required tiling of fields, sowing and harvesting of crops etc., and he soon realized that the Sun has a profound influence on agriculture and on his daily needs. Thus the early man put the Sun at a pedestal and considered it as his god or goddess and coined folklore and stories to explain many unexplained phenomena. As the Sun was so important for him, he started making observations of the Sun so that he could keep a watch on its movement during the day, during the year, and also help him to make predictions on its position and solar events that may occur in time. For this purpose, he either constructed equipment suitable at that time, or used the natural configurations of rocks, buildings etc., to keep track of the Sun. Let us now take a look at ancient observatories or observing sites built and used by various civilizations around the world, beginning from the early Neolithic period to almost the eighteenth century AD.

1.2.1 *In Europe*

1.2.1.1 *The Stonehenge*

Perhaps the earliest observatory or site for observing the Sun was built around 2950 – 2900 BC, in the Middle Neolithic period on the Salisbury Plain in southern England. It is now known as Stonehenge. In the 1940s and 1950s, Richard Atkinson indicated that the Stonehenge was built over period of many centuries and had three distinct phases of development. The first and the oldest phase was Stonehenge I, dating back to 2950 – 2900 BC, then followed the Stonehenge II period dating from 2900 to 2400 BC, and the third was the Stonehenge III phase from 2550 to 1600 BC.

The earliest portion of the complex was built during Phase I. It consists of a circular bank, or ditch, and a counter-scarp bank of about 100 meters in diameter. Just inside the earthen bank is a circle of 56 'Aubrey' holes.

After 2900 BC and for the next 500 years and until 2400 BC, during the Phase II, the Aubrey post-holes were perhaps used as indicated by the timber settings in the centre of the monument and at the north-eastern entrance. However, the Aubrey holes no longer hold posts and are partially filled. The numerous post-holes around the monument indicate that timber was used for the structures, but no clear patterns or configurations are discernible that would suggest their shape or form. Perhaps these were used for sighting celestial objects.

During the Phase III period, from 2550 to 1600 BC, the monument underwent a complicated sequence of settings with large stones. The first stone setting was comprised of a series of Bluestones placed in what are known as the Q and R holes. This originally had set of 30 stones but now has only 17. These are neatly trimmed upright sets of massive sand-stones blocks, each weighing more than 25 tons. These stones form a circle of more than 33 m in diameter and 4 m in height. They form two horseshoe shaped patterns. Some of the pairs of stones have massive stone lintels, raised four meters above the ground, as shown in Figure 1.2.

Considering that many stones were brought from Marlborough Downs, some 32 km from the present site near the city of Salisbury, enormous work must have gone in building such huge structures. *The question is for what purpose?*

Figure 1.2 (Left) - Stonehenge, showing massive stones arranged in a semi- circular horseshoe shape with cross member lintels. (Right) - Sunrise seen over Heelstone from center of the circle.

Around 1771 AD, it was realized that Stonehenge, in the Neolithic (New Stone Age) period, was used to observe the Sun and to mark the time and day of the summer solstice (at present on June 21/22, when the Sun is in its northern-most position in the sky). When seen from the center of the Stonehenge circle, the Sun rose directly at a particular stone called the 'Heelstone', which is approximately 16 feet high (4.88 m) with another 4 feet (1.22 m) buried below the ground. One of its most misunderstood aspects, however, concerns this Heelstone. For decades it has been debated why it was so named. It is believed that the 'Heel' stone is a corruption of Welsh 'hayil', or Norse Hel, both of which mean Sun. Likewise in the English town of Helston, a stone once stood called the Hel Stone, though it has long since been removed. Alignment of the Sun with less prominent pairs of stones perhaps referred to the sunrise at other significant times of the year, such as the equinoxes, which fall 6 months before and after solstices.

Sir Norman Lockyer got interested in Stonehenge in the 1890s. He worked on the presumption that the midsummer Sun rose originally over the Heelstone at the time of its construction. He calculated back from the

point where the Sun now rose at midsummer dawn (in 1901) precisely over the Heelstone, and thereby established the date Stonehenge might have been built. This turned out to around 1680 BC. However, Lockyer's calculations were flawed, because there were considerable error in his sightings and he used the wrong tables. His results are now usually dismissed. Later in 1950, Gerald Hawkins and Sir Fred Hoyle studied Stonehenge in great detail and proposed that besides being used as an observing site for astronomical sighting for solstices, it was also used to predict the solar and lunar eclipses. From these inferences it seems that the Neolithic people had a good knowledge of astronomy, including the movement of the Sun during the year and also of a calendar, which was required for the timing of agricultural, social and religious activities.

1.2.1.2 *In Ireland at Newgrange*

In Europe, indications of early solar observations came from the burial tombs and similar structures. In Ireland, there is a Megalithic passage tomb at Newgrange. This dates back to about 3200 BC. A 19-m long inner passage leads to a cruciform chamber with a corbelled roof that is surrounded by 97 kerb stones arranged in a circle. The direction of the entrance to the tomb is such that the passage and the chamber at Newgrange are illuminated by the winter solstice sunrise. At dawn, on solstice just after 9 am the Sun begins to rise across the Boyne Valley from Newgrange over a hill known as Red Mountain. For the following seventeen minutes, between 19 and 23 December, the sunbeam stretches into the narrow passage of Newgrange tomb and on into the central chamber. In Neolithic times it illuminated the rear stone of the central recess of the chamber.

With simple stone technology, the Neolithic people captured a very significant astronomical and calendric moment. This tomb at Newgrange was precisely built so that at the time of winter solstice at sunrise, the first Sun's rays would strike the burial chamber at the end of the tomb (Figure 1.3). The timing and location of solstices and other astronomical events were important for the early Irish people for their day-to-day needs in agriculture, calendar, social and religious activities. Such burial chambers have been also found elsewhere in Ireland.

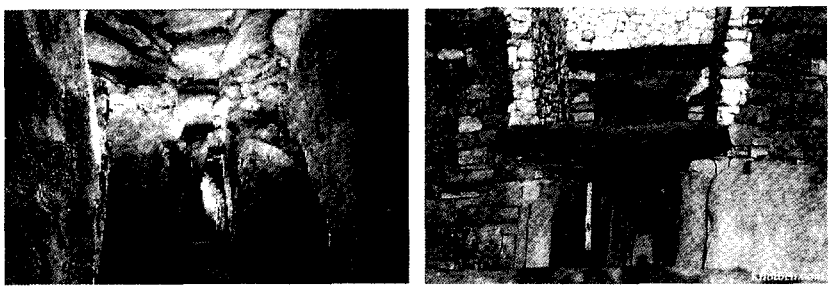

Figure 1.3 (Left) - Light beam shining through the tunnel. (Right) - Entrance to the Newgrange passage tomb.

1.2.1.3 *In Ancient Germany*

In the December 2003 issue of the Scientific American magazine, Madhusree Mukerjee has shown that a vast shadowy circle of 75- meter wide has been also found in a flat field near Goseck, Germany. He suggests that this circle represents the remains of perhaps the world's oldest observatory, dating back 7,000 years. From an etched disk recovered at the site, archaeologists reason that the observatory was used by Neolithic and Bronze age people to measure the heavens. Originally it consisted of four concentric circles, a mound, a ditch and two wooden palisades. In the middle stood three sets of gates facing Southeast, Southwest and North. On the winter solstice day, someone at the center of the circles would see the Sun rise and set through the southern gates. Aerial surveys have identified 200-odd such circles scattered across Europe, but the Goseck structure is the oldest and best preserved of the 20 excavated thus far. This is now called the German Stonehenge; it precedes Stonehenge by at least two millennia.

1.2.2 *In Ancient Egypt*

According to Egyptian mythology, the sky goddess Nut supported (Figure 1.4) the vault of heavens, and the Sun god performed its daily

journey across the sky in a chariot. The Sun spent the night hours going through the underworld from west to east.

As we have said, the Egyptians considered the Sun as one of their gods. Several temples dedicated to the Sun god Re and god Thebes had been built within the modern city of Luxor at Karnak. The main axis of the temple at Karnak of Ammon, Re, is aligned within 3 arc minutes of east-west direction. Even the sides of the some of the pyramids of Gizeb, dating back to 2000 BC, run east-west. Facing east the guarding statue of Sphinx receives the first of the Sun's rays on the vernal equinox.

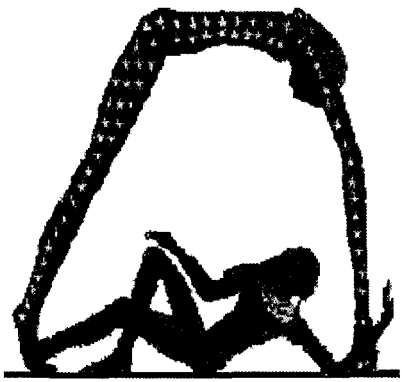

Figure 1.4 Goddess-Nut supporting the vault of heavens and the Sun performing its daily journey across the sky.

Figure 1.5 Great Sun temple of Abu Simbal.

Similarly, there are several other Sun temples in Egypt, like the great temple of Abu Simbal (Figure1.5). It stands as the world's greatest Sun sculpture. Twice a year in this temple, on the equinox days in March and September, the first rays of the Sun illuminates the inner sanctuary, where it lights up a statue of Pharaoh Ramses II, flanked by two Sun-gods. In the Edfu temple, sunlight comes through a carefully executed opening in the ceiling to illuminate pictures of each of the 12 hours on the wall.

Recently, McKim Malville et al., (1998) have shown that during the Megalithic and Neolithic periods (about 3000 BC) astronomy had flourished to great heights in the Nabta Playa region of the southern

Egypt. This is evidenced by the megalithic stone alignments to cardinal and solstice directions. From these findings, it appears that the Stonehenge and many similar Neolithic solar observing sites in Europe were not the only astronomical sites, but that early man had also built such structures in other far off places. Another early site in Egypt has alignments of stone in a circle dating back to perhaps 7000 years ago. Thus Egypt is perhaps the oldest site in the world to have made astronomical observations of the Sun and other celestial events.

1.2.3 *In Ancient Babylon*

The Babylonians surpassed Egyptians in their astronomical knowledge. They confined their observations to the Moon, instead of the Sun. Mesopotamia, now Iraq, in 3000 BC was a great civilization for astronomical studies. They had built observatories, or watch-towers, called *Ziggurats*. The tower of Babel is the best known example. Babylonian astronomer-cum-priests made observations of the planets, Moon and Sun. They kept astronomical diaries by noting down the positions of heavenly bodies using cuneiform writing on soft tablets of clay that were later baked. From these tablets they were able to predict the future positions of these bodies. They knew that solar eclipses occur in cycles, one of these lasts for 135 months, during which there were 23 'dangerous' periods when eclipses were likely to occur. Babylonian astronomer-priests were also aware of the *Metonic* cycle of 19 years, named after Greek Meton of Athens.

1.2.4 *In the Early Americas*

1.2.4.1 *Solar Astronomy among Native American Indians*

As in any other ancient civilization, the native American Indians were not behind in their pursuit of astronomical observations. The well known petroglyph (rock engraving/paintings) by the Native American Indian tribes shows the crescent Moon and a star shape to its left. This petroglyph has been interpreted as a depiction of the Crab nebula

explosion in late June 1054, which reached its maximum brightness on 4-5 July 1054 AD. This petroglyph is located on an east facing cliff and about five hundred metres northeast of the ruins of Peñnasco Blanco in Chaco Canyon. Calculations of the Moon's orbit back to 5 July 1054 have shown that the Moon was waning, just entering the fourth quarter. These calculations also indicate that at dawn on 5 July 1054 in the American southwest, the Moon was within 3 degrees of the supernova, and its crescent was oriented as seen on the pictograph.

Another petroglyph, on the South side of a large boulder near the Una Vida ruins in Chaco Canyon, shows a solid round disk surrounded by elongated features of about the length of the circular disk's diameter and distributed all around it (Figure 1.6). This has been interpreted as a schematic depiction of the solar corona seen at the time of a total solar eclipse. Actually, there were four total solar eclipses visible in the San Juan basin between 700 and 1300 A.D; one on 13 April 804, 2nd on 11 July 1097, 3rd on 13 June 1257, and 4th on 17 October 1259. Scientists believe that this petroglyph may refer to observations of the total solar eclipse of perhaps 11 July 1097. This petroglyph is a reasonably good depiction of the solar corona as seen close to the solar maximum period when the 'helmet' streamers are found at all heliocentric latitudes.

A boulder seen at this site appears to have been used as an ancient solar observing station for anticipating the coming of the summer solstice. This and many other alignments of rocks, windows and buildings for sighting and predicting solstices and equinoxes were used and built by the early American Indian tribes. Among the famous ones is the 'Sun Dagger' (Figure 1.7) on the top of Fajada Butte also in Chaco Canyon. It was discovered by Anna Sofaer *et al.*, (1979) in 1977, through an exercise called 'Solstice project'. It is called 'Sun Dagger' because the sunbeam entering the cave through a set of three rock slabs placed accidentally or intentionally positioned in just the right direction, appears like a dagger. These mark the summer and winter solstices, the Vernal (spring) and Autumnal (fall) equinoxes, and helped to make a calendar.

The 'Sun Dagger' was probably created or conceived by the Anasazi Indian community in the12th century. There were a pair of patterns, one with 9 and half spirals and another nearby smaller one with 2 and half spirals. These are carved on a flat vertical rock wall, oriented north-south

and facing east on top of a bluff near Pueblo Bonito. Leaning against the rock wall, are 3 large stone slabs, which may have been moved there or fortuitously available at the site.

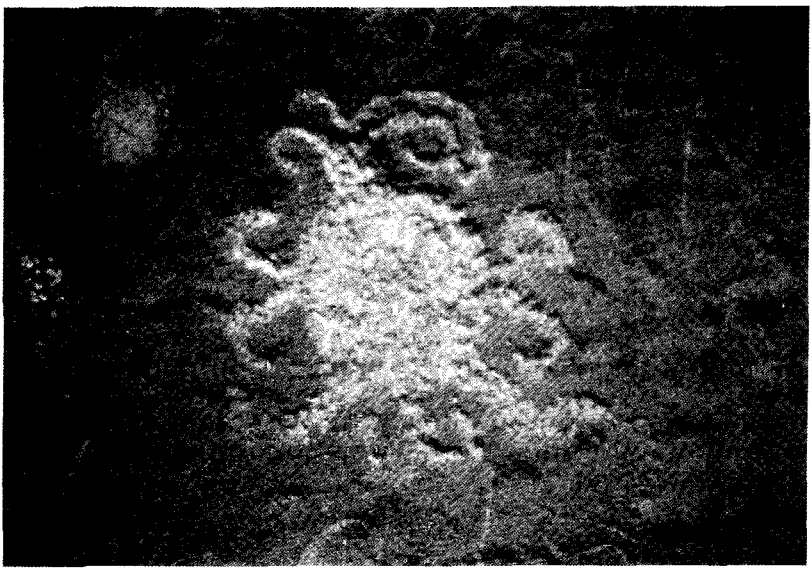

Figure 1.6 Petroglyph showing round circle depicting the Sun and outer lines are coronal streamers, perhaps this refers to the total solar eclipse of 11 July 1097 as seen by Native American Indians.

The dagger-shaped bright light pattern is formed by the Sun's rays, passing through the openings between the stone slabs, and descends vertically through the center of the large engraved spiral at the time close to the summer solstice midday, when the Sun is at its highest point in the sky. On the two equinoxes days, when the sun's altitude is lower, the vertical path of the light dagger shifts well right to the center of the large spiral. A second, smaller light pattern passes through the center of the smaller spiral. On the winter solstice, when the Sun is at the lowest possible midday altitude, the two daggers shift to the right to "frame" the large spiral, as shown in Figure 1.8 and in Figure 1.9.

A number of major buildings in Native American settlements are oriented to the cardinal directions, and also some unusual doorways

Figure 1.7 Showing the 'Sun dagger' as a bright beam of sunlight shining vertically down on a rock which has carvings of two spirals.

for observations to anticipate important celestial events likes solstices and equinoxes. Similar spiral clock-calendars are found as petroglyphs elsewhere in New Mexico and Arizona.

Since discovering the 'Sun dagger', Sofaer, Sinclair and the Solstice Project research team have documented numerous other solar markings on Fajada Butte. In addition, the Solstice Project's survey of the large Chaco buildings revealed that they are all oriented to the Sun and Moon. A possible Sun-watching station has been identified at the South end of Cliff Palace. Looking from this location the south-western horizon is featureless, except for the *Sun Temple* standing some 300 meters away on the mesa top across Cliff Canyon. At winter solstice, seen from the observing station, the setting Sun touches the horizon between the Sun Temple's two main towers. It has also been suggested that the smallest tower in the Temple's West end might have served as the horizon marker

to *anticipate* the winter solstice by some 20 days.

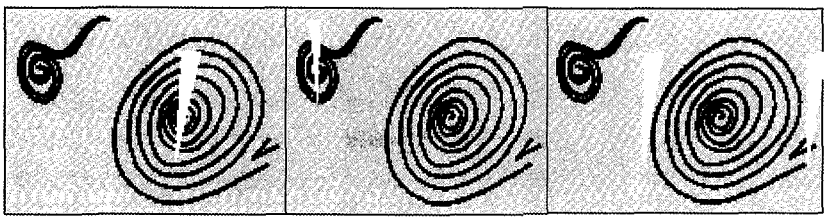

Figure 1.8 Showing drawings of the two spirals and position of 'Sun dragger' on summer solstice, equinox and winter solstice.

(a) (b) (c)

Figure 1.9 Actual photographs of the petroglyph, displaying position of the Sun dagger taken on (a) at near midday summer solstice, on 26 June 1978, at 11:13:15 a.m., (b) at equinoxes midday on 21 September 1978, 10:50:50 a.m., the inset shows the bisection of the smaller spiral by the left light formation and (c) near winter solstice midday on 22 December 1978, 10:19 a. m.

1.2.4.2 *Solar Astronomy among Aztecs*

Most of the astronomical beliefs of the Aztec community of central Mexico are known from the existing literature, in particular from a work written at the time of the Spanish conquest called *Codex Mendoza*. There are many Aztec monuments that prove there Aztec people made observations of the movement of the Sun in the sky, especially in

coordination with Venus. Pillar doors and windows in their stone monuments are clearly seen aligned at sunrise and sunset times on solstices.

1.2.4.3 *Solar Astronomy in Maya Civilization*

The Mayan people inhabited Chichen Itzá in Mexico and Tikal in Guatemala in the early 1000 AD period. They had a rich astronomical, mathematical and scientific knowledge and developed a calendar based on the Sun and Moon. They also used the helical rising and setting of the planet Venus. Many features of their cities and buildings seem to be aligned to astronomical directions and events.

1.2.5 *In Far East – Asia*

1.2.5.1 *In Ancient China*

Astronomy was especially important in the spiritual and academic life of ancient China. There it was truly a science. In fact, mankind's first record of an eclipse of the Sun was made in China in 2136 BC. Early Chinese astronomers made very systematic naked eye observations of the Sun. Sunspot records date back to 28 BC and a few from even earlier times. Rulers in China encouraged court astronomers to make such observations of heavenly objects and to keep precise records. The Chinese observation of the Crab supernova in 1054 AD is a brilliant example. Emperor Zhengtong, a Ming dynasty ruler from 1436 to 1449 AD, had built the ancient Beijing observatory at the south corner of the old city wall. A 46-foot high platform holds 8 Ming dynasty bronze astronomical instruments, two were built in 1439 and another six in 1673. Astronomical alignments figured even in the dwellings of the Chinese emperors. They built a nine square plan of the 'Hall of Light', with four square walls around it to mark the four seasons of the year. The alignment of the walls of the hall was along the cardinal east-west and north-south directions. The observation and location of the Sun played an important role in early Chinese culture. Chinese court astronomers knew

about the precession of the earth's axis and also the position and dates of solstices and equinoxes.

1.2.5.2 *In Early Japan*

In Japan, the Asuka region south of Nara is one of the most historically and culturally rich regions. Reliable historical evidence indicates that as early as the mid-6th century exchanges between the Chinese scholars and the more aristocratic members of the Japanese court occurred in this region. These exchanges not only gave rise to the infusion of technology, religion, and other aspects of Chinese culture, but also helped astronomical calendar reckoning and astrology. From the archeo-astronomy perspective, one of the most interesting of these is the tomb at Takamatsu Zuka Kofun. While the exact date of construction is unknown, this tomb discovered in 1972, provides one of the earliest and most definitive examples of Chinese and Korean astronomical influence on Japan in the 7th century. The two particular stones found in this region and worth mentioning are the *Sakafune Ishi* (literally meaning 'liquor ship rock') and the *Masuda Iwafune* (Masuda was the name of a lake, thought to have been near this stone, hence the translation would literally mean "Masuda ship rock"). These might have been used for alignments with solstices or the cardinal directions. In the 1980 April/June issue of ***Archeoastronomy***, Kunitomo Sakurai claims that the central 'trough' of *Sakafune Ishi* is "well aligned along the true east-west direction, which coincides with the Sun's path at the vernal and autumnal equinoxes." Through triangulation and sightings along the 'troughs' toward distant mountain passes to the west, Sakurai concluded that the primary function of *Sakafune Ishi* was that of a sunset observing station for determining both winter and summer solstices. Sakurai also mentions that Emperor Temmu in 675 AD built an astronomical observing platform there.

1.2.5.3 *In Early Korea*

The golden age of science and astronomy in Korea was during the reign of King Sejong (1412–1450 AD), the fourth monarch of the Choson

dynasty. Perhaps the most noteworthy achievements of this period were the invention of many ingenious instruments for astronomy and horology, as described in *The Hall of Heavenly Records*, compiled by Joseph Needham and other scholars (Cambridge University Press, 1986). During his reign King Sejong also built a Royal observatory in the main palace of Seoul. He arranged a series of astronomical and horological devices around the Kyonghoeru Pond in Kyongbok Palace. These included a simplified armillary sphere, a self-striking clock, a "jade clock", and a 40-foot high bronze gnomon to measure the exact altitude of the Sun. At least four kinds of sundials were invented under King Sejong's reign. The most distinguished is a sundial, shaped like a bowl. None of the original sundials have survived. The peak of astronomical and calendarial advances made during this period was the compilation in 1442 AD of a Korean version of the traditional calendar, called Ch'ilchongsan (on the calculations of the Luminaries). This work made it possible for scientists to calculate and accurately predict major heavenly phenomena, such as solar eclipses and other stellar movements. No mention has been found in the Korean literature of sighting 'stone' structures, like the one at Stonehenge, or the temples in Egypt and or in India, or the *Sakafune Ishi* in Japan.

1.2.6 *In Ancient India*

The Indian contributions to astronomy and mathematics date back to the *Vedic period* that is before 1500 BC. Descriptions of planetary motion, Sun, Moon, equinoxes, solstices and calendar are found in many old Indian treatises available from the *Vedanga Jyotish* period 1500 BC to 500 BC, from the *Jain Puranic period* 500 BC to 400 AD, and from the *Siddhantic period* of 400 AD to 1900 AD. Although the knowledge and importance of equinoxes and solstices can be traced back to the earliest periods in Indian astronomy, no records of actual observations of the Sun, or sunspots, or solar eclipses is found. In India several temples were built to propitiate *Surya*, the Sun god.

For example, the Modhera Sun temple (Figure 1.10) in Gujarat was built around 1026 AD, at the latitude of 23°.6. Another one; the famous Konark Sun temple is on the eastern coast near Bhubneshwar in Orrisa.

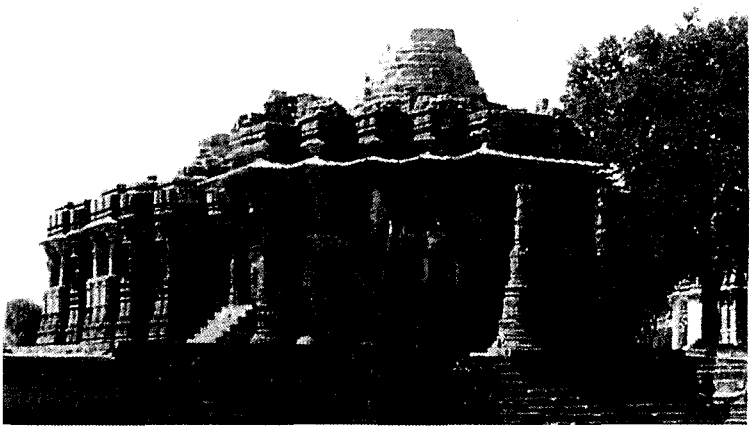

Figure 1.10 Temple dedicated to the Sun god Surya was built in 1086 AD, at Modhera, Gujarat, India to propitiate the Sun god and monitor the movement of the Sun.

The orientation of the Modhera Sun temple is such that the first rays of the rising Sun illuminates directly an idol on equinox days; on the summer solstice day, the Sun shines directly overhead at noon, casting no shadow. These temples were constructed keeping in mind the movement of the Sun during the year and for timing of the passage of solstices and equinoxes for religious, agriculture and calendar purposes.

1.2.7 *Solar Astronomy in the Medieval Period*

1.2.7.1 *Solar Observatories at Maraga, Iran and Samarkand*

In the medieval period in Europe, Middle Eastern and Asian countries, solar astronomy was a part of the larger discipline to study the Sun, stars, Moon and the planets. During this time several astronomers had built observatories for making precise astronomical observations to record the position of celestial bodies. Nasir-ul-din al tusi, a Persian astronomer, built an observatory at Maraga in 1259 AD and published his laborious work in the form of tables, cataloguing the position of stars and the

Moon. This is known as '*Ilkhamic tables*'. Ulugbek, the grandson of *Timur the lame*, king of Persia, devoted at Samarkand in about 1425 AD. From his numerous observations of the Moon, planets and 1018 stars made with amazing precision, he compiled a set of useful tables which

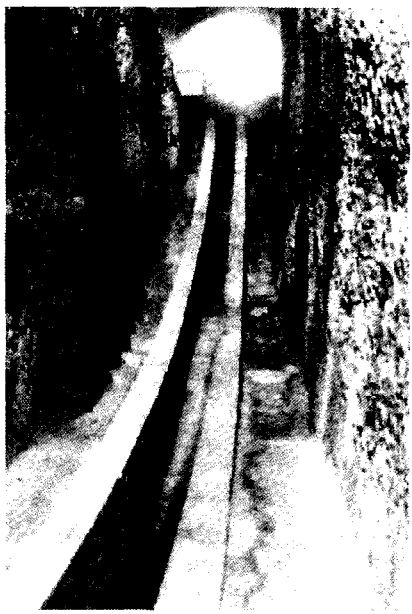

Figure 1.11 Ulugbek's Observatory in Samarkand, a sextant built in 1425 AD.

superseded those of Ptolemy's tables known as 'Syntaxes'. Its Arabic translation is known, as '*Al Mayista'*. These tables were the principal source for Arabic astronomy for centuries. It reappeared later under the name of '*The Almagest'*, which means in Arabic – *greatest.* At present the only structure left at Ulugbek's observatory in Samarkand, is the underground giant marble sextant, as shown in Figure 1.11.

1.2.7.2 *Solar Observatories in India*

Around the beginning of the 18th century, Sawai Raja Jai Singh II,

Maharaja of Jaipur built several observatories. He was well versed in the Indian astronomy and the astronomical treatise known as the '*Surya Sidhanta*' (Solar principle), composed by the famous Indian astronomer Aryabhatta in the 4th century AD. Jai Singh II was also aware of the Arabic astronomy of that period and was much impressed by Nasir-ul-din's observatory built in the thirteen century, and by Ulugbek's observatory built in the fifteenth century at Samarkand. Based on Ulugbek's astronomical instruments, Jai Singh II built much larger and massive masonry instruments at five places in India. Their purpose was to measure precisely the position of stars, planets, Sun, Moon and the zodiacal signs. Although Jai Singh II also extensively used a small metallic Astro-lab, but he was convinced that the brass instruments being small in size and the divisions marked on them being very small they could never give high accuracy. So he built huge instruments of stable masonry structures. The first Jai Singh's major observatory was built in Delhi in 1724 AD, and another one in Jaipur in 1734 AD. Three more observatories were built at Ujjain, Benaras (now known as Varansi), and Mathura. The last one does not exist now. For stellar, planetary and solar observations, he constructed 12 or 13 astronomical instruments at each of these five observatories. For solar observations there are four main instruments; *Samrat yantra* (instruments), *Jaiprakash yantra*, *Ram yantra* and *Shasthanisa yantra*. *Samrat yantra* is shown in Figure 1.12. It is essentially a huge equinoctial sundial with a 90-foot high gnomon to determine the local solar time, to an accuracy of about 1 second. The *Jaiprakash yantra* is the most versatile instrument. It is a hemispherical bowl of 27 feet in diameter at the Delhi observatory, and 24 feet at Jaipur. This instrument was used to locate the particular zodiac sign in which the Sun appears at the moment of observation. *Jaiprakash yantra* can be said to be an elaborate version of the "bowl of Berossus," the Babylonian who flourished in about the 3rd century BC. The *Ram yantra* at Delhi has a diameter of 55 feet and is 11 feet high. It was used to determine the azimuth of the Sun and stars. *Shasthanisa Yantra* or the sextant instrument is a huge concave arc of 60 degrees and 28 feet 4 inches of radius, lying in the meridian. There are 2 pairs of graduated arches built into the masonry that supports the east and west end of *Samrat* quadrant. Small holes in roof of each structure allow the sunlight

to fall on the graduated arcs at local noon, giving an image of the Sun of about 75 mm in diameter, acting like a pin hole camera. Large sunspots can be seen on the solar image, but there are no past records of sunspot sightings, if made from this instrument. The records of the altitude and declination of the Sun on each day were maintained. This instrument gives the altitude of the Sun at local noon, or the declination of the Sun at that moment. The instrument is capable of giving accurate results of the altitude, but the readings for transit time are said to be an error to about 4 minutes.

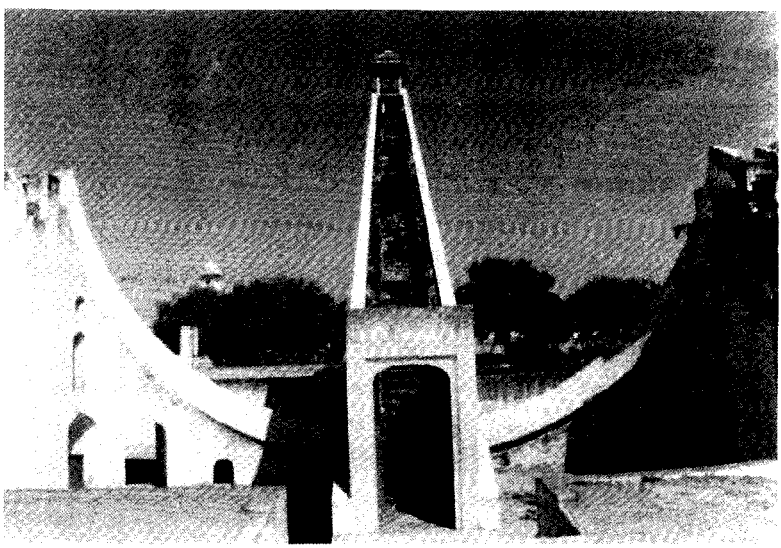

Figure 1.12 Samrat yantra, the largest sundial in the world, at Jaipur Observatory.

These massive 18th century masonry astronomical instruments were regularly used until the early twentieth century, but are not used now. For more details readers are referred to the monograph by M F. Soonawala on *Maharaja Sawai Raja Jai Singh II of Jaipur and his observations,* Published by the Jaipur Astronomical Society, Jaipur, 1952 and to *'The Astronomical Observatories of Jai Singh'* by G. R. Kaye's classic treatise published by the Government Press, Calcutta in 1918.