Ancient Observatories - Timeless Knowledge

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Stanford Solar Center

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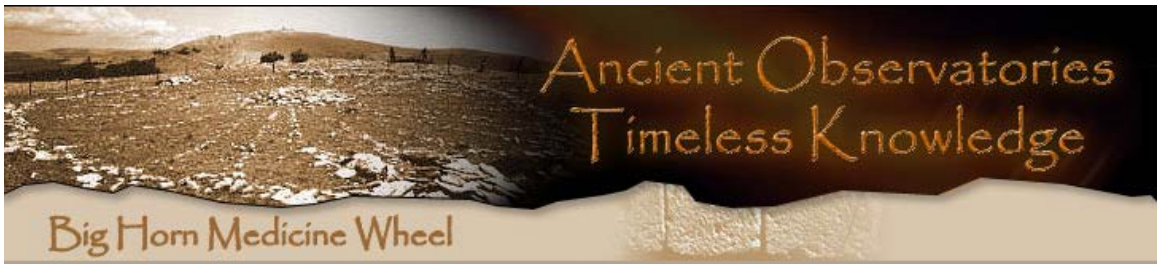


See also the Stanford Solar Center: http://solar-center.stanford.edu/AO/

Introduction to Alignment Structures

Ancient cultures attempted to track the motions of the Sun and Moon, measure time, and relate their world to the world above (and below) through glorious and enigmatic structures they built. This document highlights a collection of sites, prehistoric and otherwise, that include artifacts related to tracking the Sun and often the stars. This is not an exhaustive list, just a sampling. Because few written records exist, we can only surmise from the evidence what purpose these sites might have served for their builders. The sites are listed in approximate chronological order.

To the peoples who built these structures, the complicated and cyclic nature of movements of the Sun, Moon, planets, and stars represents a kind of perfection unattainable by mortals. The regular occurrence of sunrise and sunset, moon rise and set, could have provided the ancients with a dependable and orderly sense of time, a stable pillar on which to anchor their thought and behavior and integrate it into their view of the skies above. The sky god's return to a particular alignment was the time to plant the crops, that the rains would soon come, or that tit was time to prepare a particular ceremony to appease or thank the gods. We cannot overestimate the importance of predicting and following seasonal change among these early peoples (Aveni 1997 p. 82+, 55).
Our forbearers followed their sky gods' movements attentively. By marking their appearance & disappearance with great care, they combined religious worship with practical knowledge. The cycle of planting and harvesting crops was regulated by celestial events; important days of celebration and festivity were marked in a celestial calendar. After generations they learned to predict particular celestial phenomena, such as eclipses, well in advance. Understanding what happens in the sky is the basic prerequisite for appreciating other people's conception of the heavens. What are the significant sky events the ancients may have watched? (Aveni 1997 3-4)

Following is a collection of sites, prehistoric and otherwise, that includes artifacts relating to tracking the Sun and often the stars. This is not an exhaustive list, just a sampling. Because few written records exist, we can only surmise from the evidence what purpose these sites might have served for their builders.

The sites are listed in approximate chronological order

Monuments

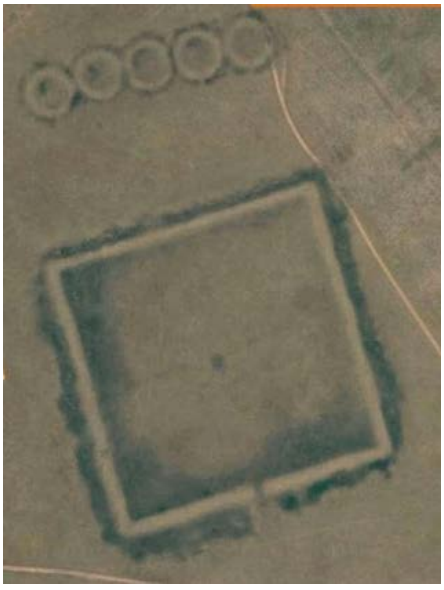
Before Current Era

Steppe Geoglyphs

Location: present-day Turgai, Kazakhstan
Date Constructed: ~8000-2000 BP?
Latitude: 48.0º N
Longitude: 68.0º E
Image credits: All images DigitalGlobe, via NASA

The largest of the earthwork configurations, photographed from space, is known as the Ushtogaysky Square, named after the nearest village in Kazakhstan.

Construction:
The Steppe Geoglyphs are a collection of ~260 earthworks constructions in the Turgai Trough area of Turgai in northern Kazakhstan. Most of them consist of smaller earthworks arranged with each other to make squares, rings, crosses, and even a mysterious 3-armed swastika-like shape. The composite figures range from around 90 meters in length to over 400 meters in diameter. The largest, shown above, is a giant square of 101 raised mounds, its opposite corners connected by a diagonal cross, covering more terrain than the Great Pyramid of Cheops.

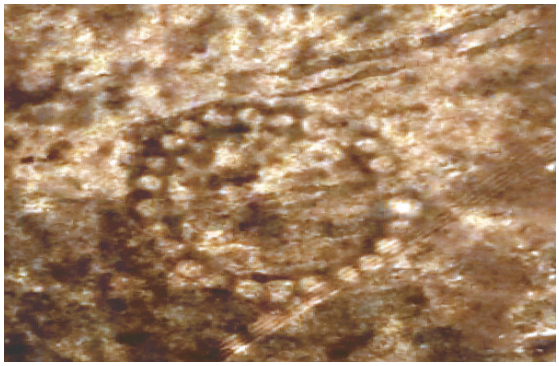


Because of the nature of the clay soil, these massive structures must have required enormous efforts to build.

The oldest of the constructions is estimated at 8,000 years old. Early archaeologists found artifacts of a Neolithic settlement 6,000 to 10,000 years old, including spear points.

One curious mound appears in the shape of a swastika. The swastika symbol is derived from the Sun Cross image (Neubecker 1976. p. 42), and was often conceived of as a symbol of the Sun.

Alignments: A Kazakh economist and archaeology enthusiast, Dmitriy Dey, spotted the mounds on Google Earth in 2007. In 2015, NASA released clear satellite photos of some of the images. "I don't think they were meant to be seen from the air," Mr. Dey, 44, said in an interview from his hometown, Kostanay (NY Times 2015). Dey dismissed outlandish speculations involving aliens and Nazis. Long before Hitler, the swastika was an ancient and near-universal design element (Neubecker 1976 p. 142). He theorizes that the figures built along straight lines on elevations were "**horizontal observatories to track the movements of the rising Sun**" [highlights by the author]. Further studies are necessary to confirm any alignments.

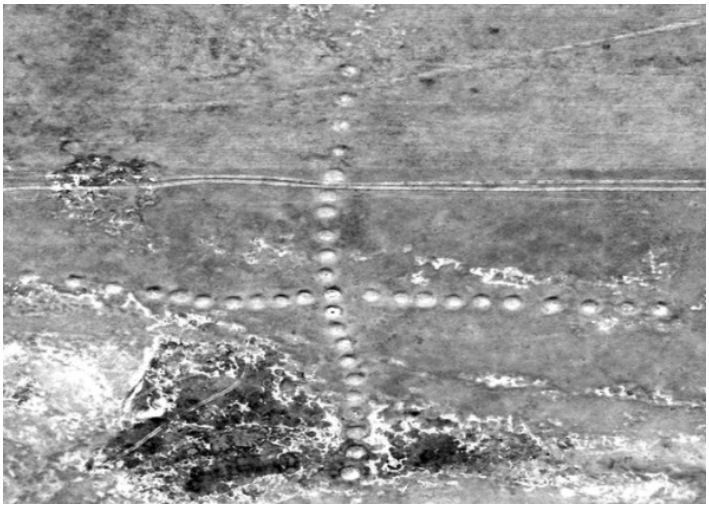


The Bestamskoe Ring

The Turgai Swastika

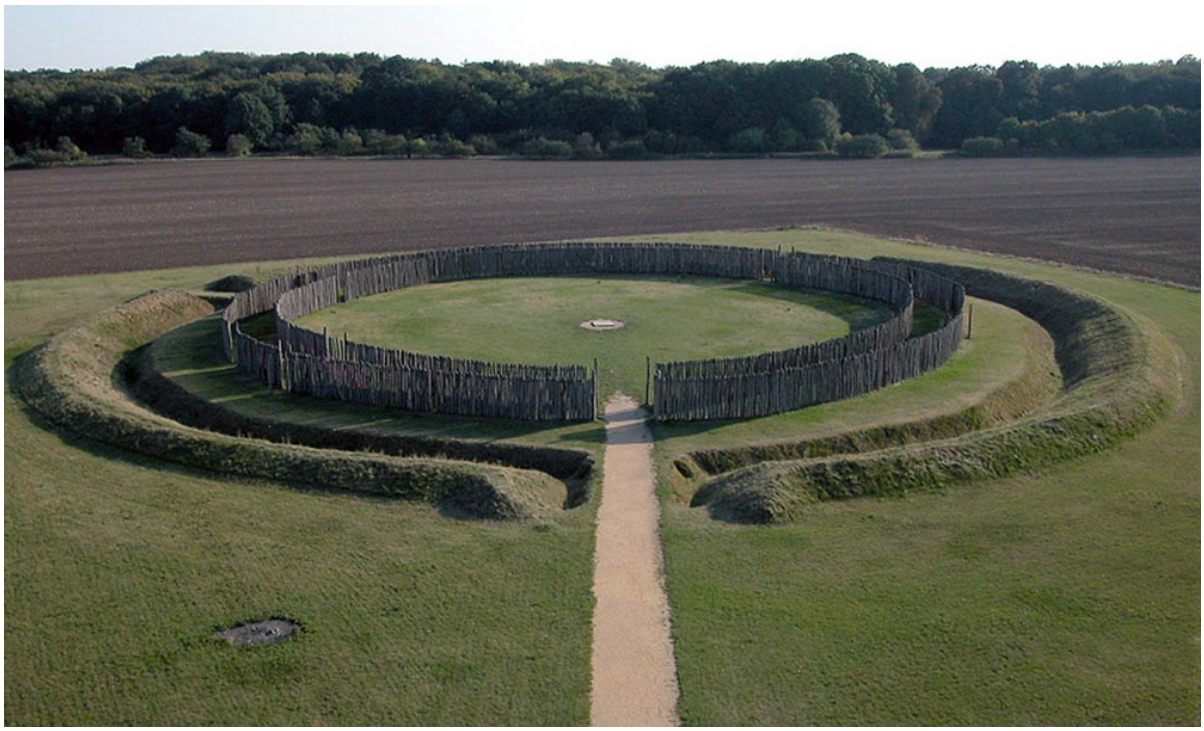
See also:

- Koch, Rudolf (1955). *The Book of Signs* p. 18 (1930, Dover reprint 1955).
- Neubecker, Ottfired (1976). *Heraldry: Sources, Symbols, and Meaning* (New York: McGraw-Hill.
- NYTimes (2015) http://www.nytimes.com/2015/11/03/science/nasa-adds-to-evidence-of-mysterious-ancient-earthworks.html
- http://www.pitt.edu/~super1/lecture/lec53991/index.htm
- https://en.wikipedia.org/wiki/Steppe_Geoglyphs



Goseck Circle

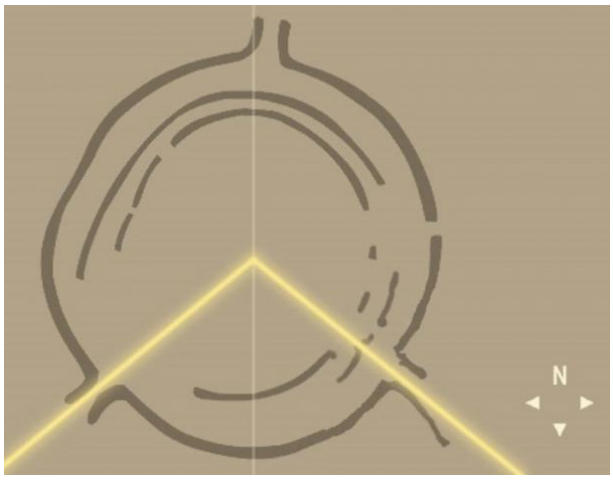
Location: In the current area of Saxony-Anhalt, Germany
Date Constructed: ~6900 BP. Functional for about 200 years, then abandoned.
Latitude: 51º 11' 54'' N
Longitude: 11º 51' 53'' E
Images:
http://www.ancient-origins.net/ancient-places-europe/goseck-circle-oldest-known-solar-observatory-003325
Nebra Sky Disk by Anagoria, Wiki Commons



Construction:
Discovered from aerial surveys in 1991, Goseck Circle may be the oldest and best known of a series of circular enclosures associated with the Central European Neolithic period. It also may be one of the oldest solar "observatories" in the world. It was created about 7000 years ago by one of Europe's oldest civilization, long before the cultures of Mesopotamia and the pyramids of Egypt.

The original consists of a set of four concentric circles, a mound, a ditch, and two palisade rings (fences or walls made by wooden stakes or tree trunks) containing gates in places aligned with sunrise and sunset on the solstice days. The palisades had three sets of gates facing southeast, southwest, and north. Archaeologists also found the remnants of ritual fires and decapitated human bones suggesting that the circle was not just for observation but also for human sacrifice.

The site has been restored and opened to the public on 21 December 2005, the winter solstice.



Alignments:
At the winter solstice, observers at the center would have seen the sun rise and set through the southeast and southwest gates. Archaeologists agree that Goseck circle was used for observation of the course of the Sun during the year. Together with calendar calculations, it allowed coordinating an easily judged lunar calendar with the more demanding measurements of the solar calendar[1]. (More about this below.)

A note on alignments: Goseck Henge is considered to be the oldest official solar observatory in the world. It lies on the same latitude as Stonehenge, just over 1' minute (approx. 1000m) longitude further north, and very close to the latitude of the Majorville Medicine Wheel in Alberta and the Newgrange monument in Ireland. These sites lie at the exact latitude at which the midsummer sunrise and sunsets are at 90° to the Moon's northerly setting and southerly rising. This particular phenomenon is only possible within a band of less than one degree of which Stonehenge and Goseck lie in the middle third. The sites also sit on one of two unique latitudes in the world where the full Moon passes directly overhead on its maximum zeniths. Coincidence?

Curiously, A 3,600-year-old bronze disc, the Nebra Sky Disk, was discovered just 25 kilometers away from the site and is considered to be the oldest concrete representation of the cosmos. It shares a striking similarity with Goseck Circle.

See also: http://www.ancient-origins.net/ancient-places-europe/goseck-circle-oldest-known-solar-observatory-003325#ixzz3oBYPxHXx

[1] The solar calendar, based on Earth's yearly orbit around the Sun, does not work out evenly with the lunar calendar, based on the Moon's orbiting the Earth. Early cultures tried very hard to find ways to correlate these two phenomena.

Nabta Playa

Location: A large basin known as Nabta Playa, located about 100 km west of Abu Simbel near the Egyptian-Sudanese border
Date Constructed: ~6800-5600 BP
Latitude : 22º 32' 00N.
Longitude: 30º 42' 00E
Images:
Wiki Commons; http://www.museumofflight.org/files/NabtaPlaya.jpg
http://www.saveyourheritage.com/megalithic_europe.htm

Construction: Nabta Playa was once a large lush and internally drained basic in the Nubian Desert, located south of modern-day Cairo. Although primarily desert now, beginning about 10,000 years ago this region began to receive more rainfall, filling a lake and attracting humans. Archaeological research reveals that these prehistoric peoples "led livelihoods seemingly at a higher level of organization than their contemporaries who lived closer to the Nile Valley" (Wendorf 2000).

The area was first used around 8100 to 7600 years ago as what may have been a regional religious or ceremonial center, with people coming from various locations to gather on the dunes surrounding the playa. There is archaeological evidence for gatherings that involved large numbers of cattle bones, and cattle were usually only killed on important occasions. Around 6800 years ago a stone circle was constructed, with thin slabs approximately aligned with the summer solstice, near the beginning of the rainy season. More complex structures followed during a megalith period between about 6500 to 5600 years ago.

Alignments: The complex consists of a series of monoliths about .8 miles wide and 1.8 miles long. It includes ten slabs some 9 feet high, 30 rock-lined ovals, nine burial sites for cows, each under a pile of 40 to 50 rocks weighing up to 200 or 300 pounds apiece. Alignments with the bright stars Sirius, Arcturus, Alpha Centauri, and the Belt of Orion have been confirmed. The calendar circle is a 12-foot-wide arrangement of slabs about 18 inches long, most of them lying down. Narrow slabs approximately align with the summer solstice, near the beginning of the rainy season. Two pairs of upright stones stand directly across the circle from each other, defining a view that would have displayed sunrise at the summer solstice. The circle also contains two different pairs of standing stones that defined a north-south orientation.

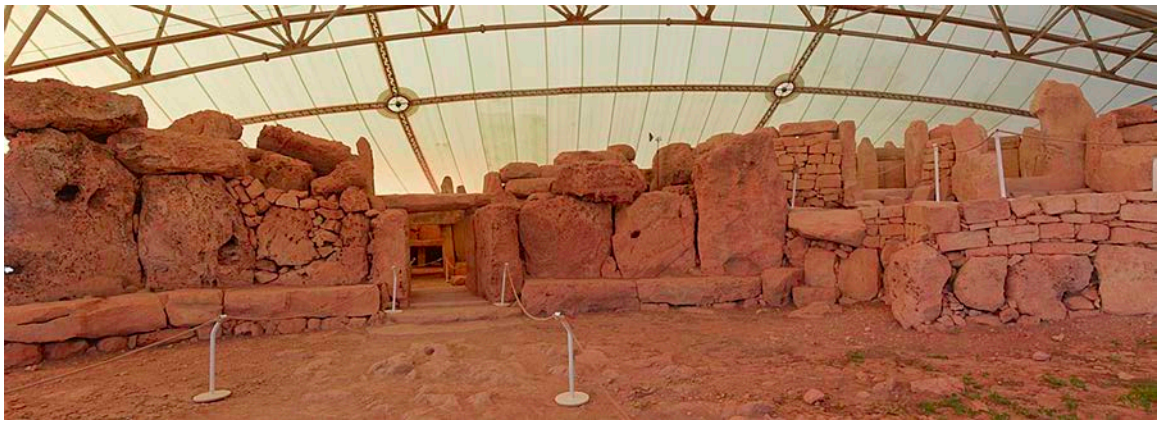
Because Nabta lies near the Tropic of Cancer, the noon Sun is at its zenith about three weeks before and three weeks after the summer solstice, a time in the tropics when upright objects cast no shadows. "These vertical sighting stones in the circle correspond to the zenith Sun during the summer solstice [in temperate latitudes]," said Kim Malville, an archaeoastronomer at the University of Colorado. "For many cultures in the tropics, the zenith Sun has been a major event for millennia."

See also:

- Malville, J. McKim (2015), "Astronomy at Nabta Playa, Egypt", in Ruggles, C.L.N., *Handbook of Archaeoastronomy and Ethnoastronomy*, **2**, New York: Springer Science+Business Media, pp. 1079–1091.
- Scott, J (1998-03-31). *Oldest Astronomical Megalith Alignment Discovered in Southern Egypt by Science Team*. Boulder, CO: University of Colorado. https://web.archive.org/web/20140518031254/http://www.colorado.edu/news/releases/1998/03/31/oldest-astronomical-megalith-alignment-discovered-southern-egypt-science
- Wendorf, Fred; Schild, Romuald (2000), *Late Neolithic megalithic structures at Nabta Playa (Sahara), southwestern Egypt* Comparative Archaeology Web, Nov 26, 2000.
- http://www.colorado.edu/APS/landscapes/nabta/
- http://www.ancient-wisdom.com/egyptnabta.htm
- http://www.saveyourheritage.com/megalithic_europe.htm

"Calendar circle". Note the scale

Temples of Mnajdra

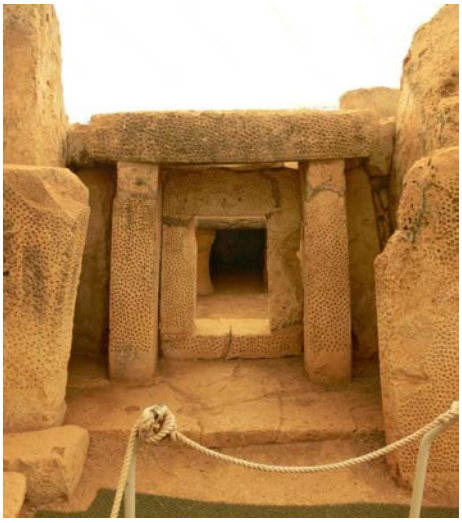


Facade of Lower Temple

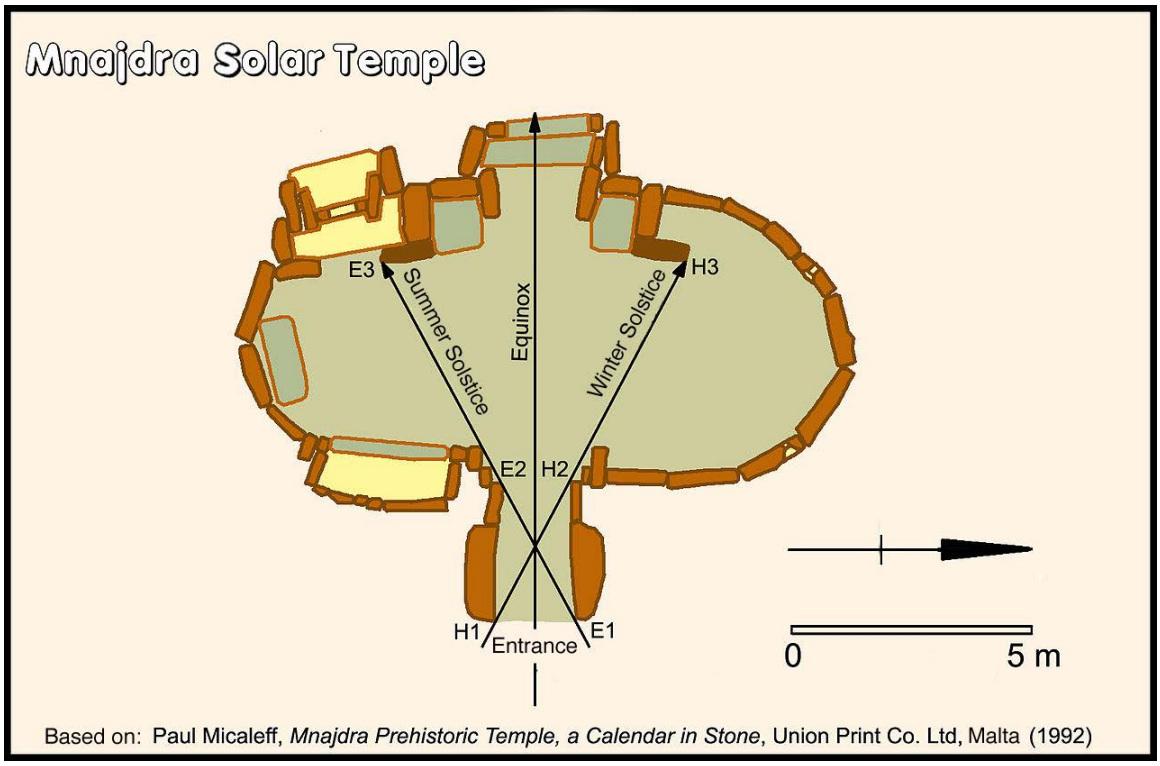
Location: a megalithic temple complex on the southern coast of the Mediterranean island of Malta
Date Constructed: ~5600-4500 BP
Latitude : 35º 49' 3611'' N
Longitude: 14º 26' 11'' E
Images: All images from Wiki Commons
Mnajdra is a UNESCO World Heritage Site: http://whc.unesco.org/en/documents/108130

The Temples of Malta are among the most ancient religious sites known on Earth. The Mnajdra structure consists of three conjoined but not connected temples: the upper, middle and lower. The lowest temple is the most impressive and possibly the best example of Maltese megalithic architecture. It has a large forecourt containing stone benches, an entrance passage covered by horizontal slabs, one of which has survived, and the remains of a possibly domed roof. The temple is decorated with spiral carvings and indentations, and pierced by windows, some into smaller rooms and one onto an arrangement of stones.

The lowest temple is astronomically aligned and thus was probably used as an astronomical observation or calendrical site. On the equinoxes, sunlight passes through the main doorway and lights up the major axis. On the solstices, sunlight illuminates the edges of megaliths to the left and right of this doorway.



Lower Temple door



See also:
http://whc.unesco.org/en/list/132
https://sacredsites.com/europe/malta/temples_malta.html

Newgrange

Newgrange. Credit: Wiki Commons

Location: Drogheda – County Meath, Ireland
Date constructed: ~5200 BP
Latitude: 53.6947º N
Longitude: 6.4755º W
Images: Newgrange – Wiki Commons
Passageway - http://www.worldheritageireland.ie/bru-na-boinne/built-heritage/newgrange/
Spirals - http://www.knowth.com/newgrange.htm
Newgrange is a World Heritage site:
http://www.worldheritageireland.ie/bru-na-boinne/built-heritage/newgrange/

Construction: The Megalithic Passage Tomb at Newgrange was built about 5200 years ago. The large mound is approximately 80m in diameter and is surrounded at its base by a kerb of 97 stones. It was discovered in 1699 and was excavated and rebuilt between 1962 and 1975. The kidney shaped mound covers an area of over one acre and is surrounded by the 97 kerbstones, some of which are richly decorated with megalithic art with solar motifs. The most impressive of these stones is the highly decorated Entrance Stone. Outside the tomb, 12 out of the original estimated 38 large boulders up to 8-feet high form a ring of about 340-feet in diameter. The stone circle was built about 1000 years later than the original structure, dating probably from the Beaker period (~2000 BCE). It is estimated that the construction of the Newgrange mound would have taken a workforce of 300 laborers at least 20 years.

There is a 58-foot long inner passage leading to an internal cruciform chamber. Above the entrance to the passage is a "roof box", a small window-like opening that allows sunlight to fall into the passage at sunset on the winter solstice.

Passageway to the interior of Newgrange. Note the roof box for sunlight to pass through.

Alignments:
The passage and chamber of Newgrange are illuminated by the winter solstice sunrise. A shaft of sunlight shines through the roof box over the entrance and penetrates the passage to light up the chamber, highlighting spirals carved into the back wall. The dramatic event lasts for 17 minutes at dawn from the 19th to the 23rd of December. To the Neolithic culture of the Boyne Valley, the winter solstice marked the start of the New Year-- a sign of nature's rebirth and promising renewed life to crops, animals, and humans. It may also have served as a potent symbol of the inevitable victory of life over death, perhaps promising new life to the spirits of the dead.

Interior passageway at Newgrange

See also:

- http://www.newgrange.com/
- http://www.knowth.com/newgrange.htm
- http://www.worldheritageireland.ie/bru-na-boinne/built-heritage/newgrange/
- http://sunearthday.nasa.gov/2005/locations/newgrange.htm

Carved spirals at Newgrange

Majorville Medicine Wheel

Majorville Medicine Wheel with the 28 spokes highlighted in black. Credit: Gordon Freeman

Location: Vulcan County, Alberta, Canada
When Constructed: 5200 - 4500 BP
Latitude: 50.585167º N
Longitude: 112.410639º W
Images:
Aerial photo-http://www.atlasobscura.com/articles/the-medicine-wheels-of-north-america
Central cairn: http://www.redicecreations.com/article.php?id=20738

Construction: The Majorville Medicine Wheel, the largest and oldest extant medicine wheel, consists of a central cairn that is linked to a surrounding stone circle by 28 spokes, and the cultural landscape that contains this monument. The designation encompasses 160 acres and is situated on a height of land with an expansive view of the surrounding prairie landscape west of the Bow River in southern Alberta. The central cairn is nine meters in diameter and is surrounded by a stone circle 27 meters across. About 28 spokes link the circle and central cairn. In 1971 an excavation yielded artifacts that were dated by stone tool style. This method and radiocarbon dating of bones place the initial construction of the central cairn at some 4500 BP, although another source dates the initial site to 3200 BP. The tool finds indicate a succession of added material over the centuries. Archaeological studies indicate this site has been continuously used for the last 4,500 years, making this one of the oldest sacred sites in the world.

Alignments: Professor Gordon Freeman of Saskatchewan, an Oxford- and University of Saskatchewan- and McGill-trained scholar and Professor Emeritus at the University of Alberta studied Majorville from 1989 to 2006. Freeman found striking similarities between the surface geometry of Stonehenge and the stone patterns at Majorville. He concludes that Majorville stones are the remains of an open-air sun temple that predates both Stonehenge in England and the Pyramids in Egypt. According to Freeman, the Plains Indians used the temple to observe sunrise on the winter and summer solstices.

According to the Canadian Archaeological Association, "Majorville has associated with it outlying rock lines and cairns that accurately mark the Sun rise and set points on the solstices and on the observed equinoxes. The point of the Sun's first flash on the horizon is the rise position, and the point of the last flash on the horizon is the set position. These points move northward from December to June, then move southward again after the summer solstice. Near an equinox the Sun rise and set points at Majorville move along the horizon by 1.3 Sun diameters per day. Near a solstice it takes nine days to move the last diameter to the solstice position.

"We determine the Sun rise and set points photographically to within less than one Sun's diameter, and sometimes to within a fifth of a diameter, along alignments up to 2km long.

"Rock alignments at Majorville mark the Sun rise and set points three days before the vernal equinox and three days after the autumnal equinox.

"These days [the equinoxes] are within two minutes of being exactly 12 hours long. The lens effect of the atmosphere causes the length of the solar equinoctial days to be about 12 hours and 10 minutes long at Majorville. The position of sunrise on the 12.00 hour day is marked by a spoke in the Medicine Wheel, which points to a large white limestone in the East House 61m away, and to a configured part of the eroded river bank 1100m away. Rocks have slid down the eroded bank from the sightline position. The Sun rises over the horizon about 30km distant.

"A more spectacular 12.00 hour day sunrise marker involves two V sights of rocks separated by 70m, on the west side of the Medicine Wheel hill. The sighting line is tangent to the Wheel. Because one is looking up the shaded side of the hill, the Sun becomes visible in the nested bottoms of the V's a half hour after the first flash on the distant horizon. Thus, one can observe the equinox sunrise even if the distant horizon is overcast to a depth of several sun diameters. The 12.00 hour day sunset is marked by a spoke of the Wheel which points to a small cairn on a hillock 1100m away and to a ripple on the horizon about 10km distant. The important part of the Majorville Medicine Wheel site covers 13km. It is 20,000 times larger than previously thought." (Canadian Archaeology Association)

See also:

- Gordon R. Freeman, *Canada's Stonehenge – Astounding Archaeological Discoveries in Canada, England, and Wales*, Kingsley Publishing, 2009.
- Gordon R. Freeman, "*Hidden Stonehenge: Ancient Temple in North America Reveals the Key to Ancient Wonders*, Watkins, 2012.
- Canadian Archaeology Association. http://canadianarchaeology.com/caa/node/2628
- http://www.megalithic.co.uk/article.php?sid=22751

Majorville Medicine Wheel central cairn

Stonehenge

No one knows what the creators of this monument had in mind when, over the course of three renovations spanning 1500 years, they built this famous ring of stones on a wind-swept hill.

Location: Salisbury, England
Date Constructed: 5100 – 3600 BP
Latitude 51º 4' North
Longitude 1º 48' West
Images: Stonehenge image: Wiki commons
Solstice diagram: NOAA - https://scijinks.gov/solstice/
Stonehenge, Avebury, and associated sites are a World Heritage Site:
https://whc.unesco.org/en/list/373

Construction: Stonehenge stood at the heart of a sprawling landscape of chapels, burial mounds, massive pits and ritual shrines, according to a recent survey of the ancient grounds. The researchers have found buried evidence of more than 15 previously unknown or poorly understood late Neolithic monuments: henges, barrows, segmented ditches, pits. These findings suggest a scale of activity around Stonehenge far beyond what was previously suspected.

This famous megalithic structure is only part of a vast collection of constructions that were apparently built in three stages beginning around 4950 BP and extending to 3600 BP. During the first period of construction, it was a circular enclosure with two earthen banks and a ditch. During the second construction phase, about 4,000 BP, the inner circle of small bluestones was set up, but abandoned before completion. The stones used in that first circle are believed to be from the Prescelly Mountains, located roughly 240 miles away, The bluestones weigh up to 4 tons each, and about 80 stones were used, in all. Around 3600 BP, the outer ring of giant Sarsen Stones (as much as 50 tons each) was transported from the Marlborough Downs 20 miles to the north. It was initially thought that ancient Druids built Stonehenge, but the late-Neolithic Beaker People were probably

the builders. Ancient Druids worshiped in forest temples and, presumably, did not need stone constructions, according to some archeologists. In 2014 the University of Birmingham announced findings including evidence of adjacent stone and wooden structures and burial mounds, overlooked previously, that may date as far back as 6,000 BP.

Alignments: On the longest day of the year, the June 21st summer solstice, observers within the monument can see the rising Sun appearing (slightly offset) behind the 'Heel Stone' - one of the main stones, creating the illusion that it is balancing on the stone. The Heel Stone sits along a wide lane called the Avenue, a wide road that measures nearly 3 kilometers, connecting Stonehenge with the River Avon. Recent research has suggested there were 2 Heel Stones, one long lost. If an observer stood on the Avenue looking **into**, rather than out of, the monument at dawn on the Summer Solstice (in 4400 BP), the rays of the Sun would have shone straight through the heel stones to exactly strike the "altar stone" in the center.

Drawing of original Stonehenge with summer solstice Sun. If an observer were looking INTO the monument from the avenue, the Sun's rays would highlight the "altar stone" Credit: NOAA

Archaeoastronomers have also identified other stellar alignments with some of the other stones, however some controversy remains as to whether these stellar alignments were intended, or merely accidental.

See also:

- http://www.smithsonianmag.com/history/what-lies-beneath-Stonehenge-180952437/#FuJz3qUtzRGkJtpo.99
- http://earthsky.org/earth/gallery-the-summer-solstice-as-seen-from-stonehenge
- http://www.theguardian.com/science/2014/sep/10/stonehenge-teeming-chapels-shrines-archaeology-research
- http://scijinks.jpl.nasa.gov/solstice/
- http://sunearthday.nasa.gov/2005/locations/stonehenge.htm
- http://arthistoryresources.net/stonehenge/stonehenge.html
- Gordon R. Freeman, *Canada's Stonehenge: Astounding Archaeological Discoveries in Canada, England, and Wales,* Kingsley Publishing, 2009

Brodgar

A mystical place marked by upright stones, and built by the labors of ancient people. Not even their bones remain to tell us who they were, and for what inscrutable reason they made this temple.

Location: Orkney Islands, Scotland
Date Constructed: 4500 – 4000 BP
Latitude 59º 01' North
Longitude 3º 8.1' East
Images: Standing Stones: https://simple.wikipedia.org/wiki/Ring_of_Brodgar; Above: http://www.northlinkferries.co.uk/your-holiday/guide-to-orkney/orkney-area-guide/ring-of-brodgar/
The Heart of Neolithic Orkney is inscribed as a World Heritage site: http://whc.unesco.org/en/list/514

Construction: Considered to be the most awe-inspiring prehistoric site in Scotland, the Ring of Brodgar (Brogar) is located on a promontory between the Stennes and Harray Lochs in the Orkney Islands. The stone circle is 104 meters (341 ft) in diameter and the third largest in the British Isles. The stones are set within a circular ditch with a width of 300 feet, up to 9 feet deep and 27 feet across, hewn out of the solid bedrock by the prehistoric constructors. The site is laid out very accurately in a perfect circle, with the stones approximately 6º apart.

The surrounding area is full of other standing stones and Bronze Age round barrows, making a significant ritual landscape. The date of the ring's construction is uncertain as the site has yet to be fully excavated and scientifically dated. It was probably built sometime between 4500 BP and 4000 BP. Twenty-seven stones remain of an original sixty in the Ring of Brodgar and set up on a slope facing east. They vary from 6 feet to 13 feet tall.

Alignment: The Brodgar and nearby Stennes rings were referred to by their traditional names until the early 1840's - the Ring of Brodgar became the "Temple of the Sun" and the Stenness stones the "Temple of the Moon". Observations suggest that several alignments with the Sun exist that relate to the solstices and the equinoxes as well as times such as Beltane (Old May Day). At winter and summer solstices, the sunrises and sunsets align with the stones and notches in the hills. At spring and autumn equinoxes, viewed from the Comet Stone, the Sun sets just glancing off the westernmost stone.

See also:

- http://www.historic-scotland.gov.uk/propertyresults/propertydetail.htm?PropID=PL_233
- http://sunearthday.nasa.gov/2005/locations/brodgar.htm
- http://www.northlinkferries.co.uk/your-holiday/guide-to-orkney/orkney-area-guide/ring-of-brodgar/

El Karnak

To ancient Egyptians, the sun god Ra was the bringer of light, and in other incarnations, the creator of the universe. The magnificent temple at Karnak celebrates this unity through its enormous pillars, designed in harmony with the Sun and stars over a span of nearly 2000 years.

Location: Egypt, northeast area of Luxor
Date Constructed: 4055 BP to 395 CE
Latitude: 25.44º N
Longitude: 32.36º E
Image: Above: http://k0k0.8m.com/egypt.htm
Temple entrance: http://www.biblearchaeology.org/post/2009/08/13/The-Bible-According-to-Karnak.aspx

Construction: Built by the Ancient Egyptians in several episodes of construction and enlargement from 2055 B.C to 395 A.D. It was originally surrounded by the famous city of Thebes, which was sacked in 667 B.C by the Assyrian ruler Ashurbanipal. Most of the original temple compound still lies under the city of Luxor and is inaccessible by archaeologists. The primary purpose of the temple complex at Luxor was to honor the god Amon-Re. The main function of the temple was for the Festival of Opet. A statue of Amon would be carried in a solemn procession from the main temple compound, down the Avenue of the Sphinxes, and into Luxor.

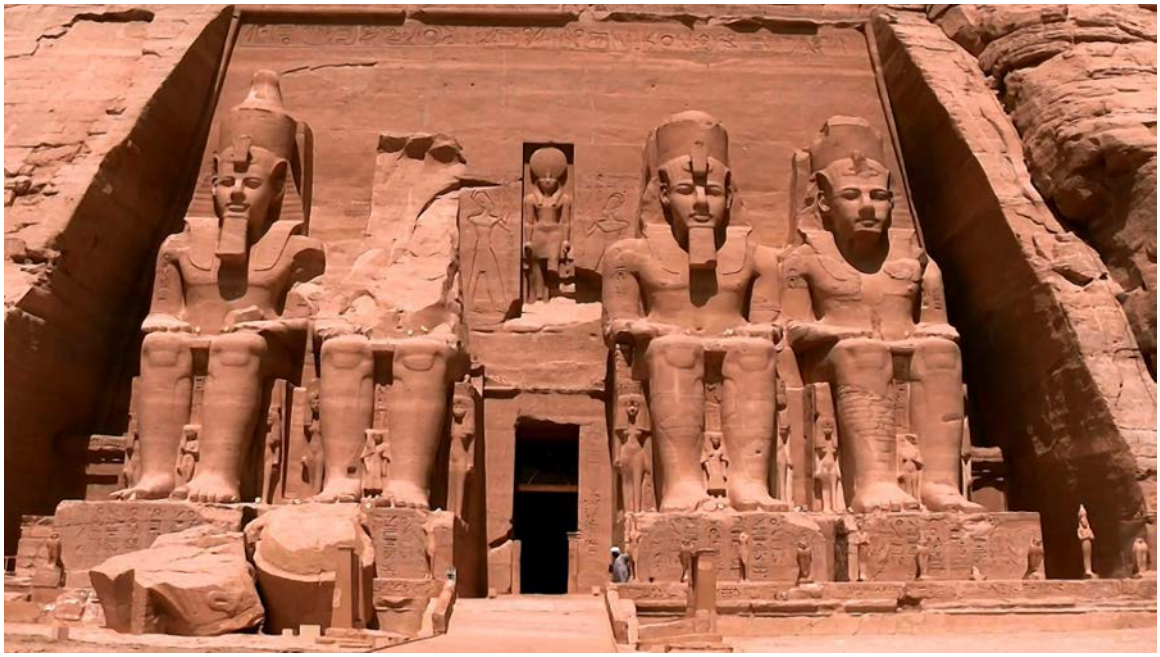
Alignments: The earliest axis included the famous Great Hypostyle Hall built by Ramses II on an east to west alignment. Sir Norman Lockyer (1836-1920) proposed a midsummer sunset alignment of the Main Axis of the Great Temple of Amon-Re (see The Dawn of Astronomy, 1894). As Lockyer noted of Karnak, it was 'a scientific instrument of very high precision, as by it the length of the year could be determined with the greatest possible accuracy.' By some accounts, the temple at Luxor may have no less than four well-defined alignment changes involving stars. Unlike solar alignments which can last for thousands of years intact, stellar alignments are much more critical because of the precession of the equinoxes and last only a few hundred years. Lockyer's measurements showed several Karnak temples had been altered over the centuries to match the precessional changes in their aligned stars. (Space Math)

See also:

- Karnak Wiki. https://en.wikipedia.org/wiki/Karnak
- Lockyer, Joseph Norman 1894. *The dawn of astronomy; a study of the temple-worship and mythology of the ancient Egyptians.* London Cassell.
- NASA 2005. http://sunearthday.nasa.gov/2005/locations/elkarnak.htm
- Space Math. http://spacemath.gsfc.nasa.gov/SED11/P5Karnak.pdf

Temple entrance to Karnak

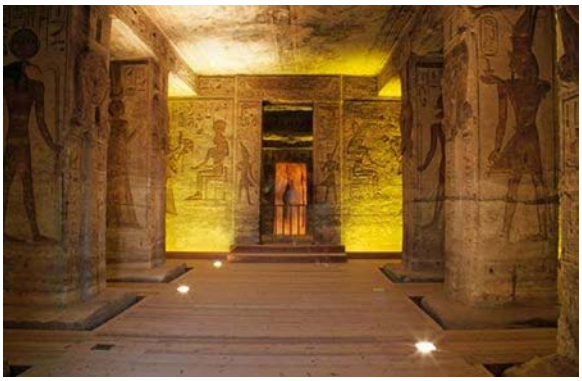
Abu Simbel



Entrance to the Great Temple at Abu Simbel

Location: Egypt, 250 kilometers southeast of Aswan
Date Constructed: 3279 - 3213 BP
Latitude 22º.3372º N
Longitude 31.6258º E
Images: above, unattributed
Small Temple murals - https://www.britannica.com/place/Abu-Simbel
Small Temple after relocation - Wiki Commons
The Abu Simbel temples are part of the "Nubian Monuments" World Heritage Site: https://whc.unesco.org/en/list/88

Construction: The Abu Simbel temples are two massive rock temples at Abu Simbel, a village in Nubia, southern Egypt, near the border with Sudan. Pharaoh Ramesses II carved the twin temples out of the mountainside in the 13th century BC, as a lasting monument to himself and his queen Nefertari, to celebrate his domination of Nubia, and as a sign of his piety to the gods, principally Amun-Re, Ra-Horakhty and Ptah, as well as his own deification.



Small Temple murals. Credit: Mike Cumberbatch/age fotostock

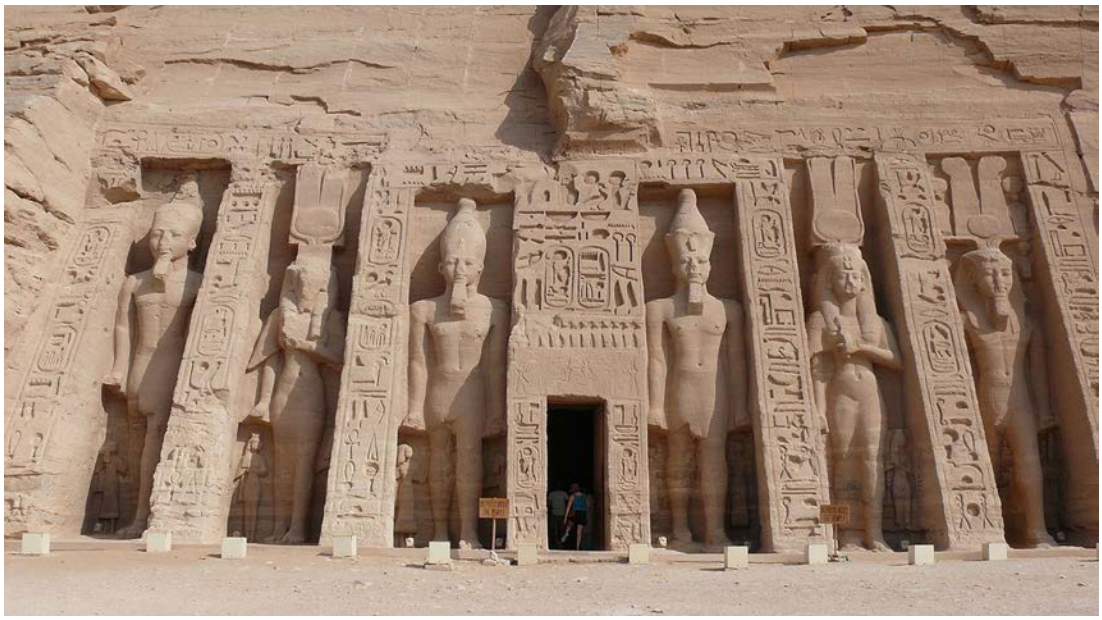
The original temple was positioned on the bank of the Nile, but it was raised up 300 meters by an international relocation project supported by UNESCO between 1964 and 1968 to prevent the flooding of the temple by

the rising waters of Lake Nasser caused by the new Aswan High Dam.

Alignments: Inside the sandstone cliff is the interior of the temple in the form of a human-made cave cut out of the rock. It consists of a series of halls and rooms extending back a total of 185 feet from the entrance. Toward the rear of the temple is the Holiest of Holies, located with four statues of Ra-Harakhte, Ptah, Amun-Ra and King Ramses II. The Sun shines directly on the Holiest of Holies two days a year: February 21, the king's birthday, and October 22, the date of his coronation.

See also:

- http://sunearthday.nasa.gov/2005/locations/abusimbel.htm
- http://www.sis.gov.eg/En/Templates/Articles/tmpArticles.aspx?ArtID=1200#.VhV6u6J61pg
- https://en.wikipedia.org/wiki/Abu_Simbel_temples
- http://witcombe.sbc.edu/sacredplaces/abusimbel.html
- http://www.ancient-wisdom.com/egyptastronomy.htm



The Small Temple after relocation

Gotland Grooves

Location: Gotland, Sweden
Date Constructed: ~3000 BP
Latitude 57.64° N
Longitude 18.30° E
Images: Both by Sören Gannholm, Wiki Commons

Construction: There are grooves carved into rock in many places in Europe, and a great many of them appear on the Baltic Sea island of Gotland. Thousands of grooved stones, scattered throughout the island of Gotland, seem to connect the parts into a vast timepiece. Aligned with the Sun, Moon, and stars, the grooves mark an ancient, human obsession with time and space over 3000 years ago.

Alignments: There are about 3600 known grooves cutd in the bedrock or on big stones scattered throughout the island of Gotland. 700 are scored directly into the limestone bedrock, the rest are found on about 800 stones. The length of the grooves varies from about 0.5 to 1 meter. They are between 5 cm to 10 cm wide and 1 cm to 10 cm in depth. The most important feature of the grooves appears to be in their alignment. A recent study of 1256 grooves showed that they are aligned with certain positions of the celestial bodies, apparently the Sun or the Moon. Most of them are oriented east to west, although the island itself is oriented north south. Some of the grooves were oriented towards the major standstills of the Sun and of the Moon. Others seem to track the passing of the full moon by bright stars on important dates. The system of grooves seems to have been adjusted over time to adapt to the precession of the equinoxes.

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See also:

- Henriksson, Goran (2002). The grooves on the island of Gotland in the Baltic sea: a neolithic lunar calendar. *Astronomy of Ancient Societies of the European Society for Astronomy in Culture*. Moscow 2000.
- NASA 2005. http://sunearthday.nasa.gov/2005/locations/gotland.htm
- Space Math. http://spacemath.gsfc.nasa.gov/SED11/P4Gotland.pdf
  http://www.astro.uu.se/archast/SlipskarorJenam2000Publ.pdf
- https://en.wikipedia.org/wiki/Grooves_%28archaeology%29
- http://www.ancientpages.com/2016/05/11/mystery-of-the-gotland-grooves-ancient-astronomical-observatory/
- http://www.amusingplanet.com/2017/02/the-mysterious-gotland-grooves.html

Chankillo

Location: Ancash Region of current-day Peru
Date Constructed: ~2300 BP
Latitude: 9º 33' 24'' S
Longitude: 78º 14' 9'' W
Images:
http://www.wmf.org/project/chankillo

Construction:
Chankillo is an ancient monumental complex in the Peruvian coastal desert. The complex was constructed from cut stone and includes a fortified temple, a plaza, the nearby Thirteen Towers solar or astronomical observatory, as well as residential and gathering areas. The culture that produced Chankillo is unknown.

Alignments:
The Thirteen Towers of Chankillo could be the earliest known observatory in the Americas. The regularly spaced Thirteen Towers were constructed on top of a ridge of a low hills running near north to south. They form a "toothed" horizon with narrow gaps at regular intervals. There are two possible observation points, to the east and west. From these vantage points, "the 300m long spread of the towers along the horizon corresponds very closely to the rising and setting positions of the Sun over the year, albeit they are not all visible. On the winter solstice, the Sun would rise behind the leftmost tower of Chankillo and rise behind each of the towers until it reached the rightmost tower six months later on the summer solstice" (Wiki). Inhabitants of Chankillo would have been able to determine an accurate solstice date, within an error of a day or two, by observing the Sun rise behind the correct tower.

See also:

- http://wmf.org/project/chankillo
- Wiki. https://en.wikipedia.org/wiki/Chanquillo

Ancient Monuments - Current Era

Rapa Nui / Easter Island

They called it the Navel of the World, and for its inhabitants, Easter Island was the only inhabited scrap of land on an ocean planet. Even most of their enigmatic statues encircle the island with their backs to the sea.

Location: Rapa Nui / Easter Island, off the coast of Chile
Date Constructed: 700-1100 CE
Latitude: 27° 05' S
Longitude: 109° 20' W
Image: Above: Wiki Commons
Below: http://wordlesstech.com/ahu-akivi-with-the-stars/

Construction: Polynesian people most likely settled on Easter Island sometime between 700 to 1100 CE. There are 887 statues called moai found on this isolated island, located 2300 miles from the coast of Chile. The statues range in size from a few feet to over 30 feet and weigh up to 150 tons. Each statue was hewn out of hard volcanic material from quarries near the Rano Raraku volcano. The statues are thought to honor their deity Make Make, or represent chieftains of the two or three tribes that inhabited this island.

Originally the island was heavily forested, but the rapid growth of the human population quickly denuded the island (imagine being the person to cut down the last tree on Easter

Island). About 250 years ago, warfare between the two tribes of 'Easter Islanders' led to the toppling of most of the statues. Very little is known about the earlier inhabitants whose very existence was not realized until 1774 when Captain Cook visited it and gave it its modern name.

Alignments: The vast majority of the moai are located on the beaches and face inland. However, there are seven moai at Ahu Akivi, a sacred place, built around 1460 CE that exactly face sunset during the Spring Equinox and have their backs to the sunrise during the Autumn Equinox. Such an astronomically precise feature is seen only at this location on the island. Each statue measures 14 feet tall and weighs 12 tons. They were restored in 1960 by archaeologists William Mulloy and Gonzalo Figueroa.

It is commonly said that the remarkable aspect of Ahu Akivi is that the moai also are the only ones that face out to sea. However, from their central location on the island, all sight-lines are towards the ocean and new research suggests they were meant to look out over a very large village which today is in ruins. Easter Island oral history from the fewer than 700 remaining natives does not indicate a deep interest in astronomical knowledge. Hieroglyphic writings have survived that might fill-in this information, but have yet to be translated.

See also:

- http://sunearthday.nasa.gov/2005/locations/easter.htm
- https://en.wikipedia.org/wiki/Ahu_Akivi
- http://www.pbs.org/wgbh/nova/easter/explore/ahuakivi.html

Chaco Canyon / Sun Dagger

Location: New Mexico, USA
Date Constructed: 850 - 1150 CE
Latitude 36.06° N
Longitude 107.97° W
Images:
Pueblo Bonita panorama https://www.hotelchaco.com/chaco-canyon
Fajada Butte Sun Dagger, courtesy of Anna Sofaer
Piedra del sol petroglyph & German eclipse sketch
https://www.colorado.edu/today/2017/08/08/chaco-canyon-petroglyph-may-represent-ancient-total-eclipse
Coronagraph image courtesy NASA Goddard Space Flight Center
Man and the Sun - http://solarworship.com/artistic_muse/

Chaco Canyon, along with Aztec Ruins and several smaller Chaco sites, are a World Heritage Site: https://whc.unesco.org/en/list/353

Construction: For over 2,000 years, Pueblo peoples occupied a vast region of the southwestern United States. Between 850 and 1250, Chaco Canyon was a major center of ancestral Pueblo culture, with a focus on ceremonials, trade, and political activity for the prehistoric Four Corners area. Chaco is remarkable for its monumental public and ceremonial buildings and its distinctive architecture. The people there constructed massive stone buildings unlike any that had been built before. These structures soared to four or five stories and contained up to seven hundred rooms and dozens of kivas,

underground rooms used for religious rituals. These Great Houses were feats of engineering and were connected to one another by lines of sight that would have enabled rapid communication. Often built along solar and celestial alignments, they included water-collection systems and were linked to outlying communities by an extensive network of roads. These elaborate buildings evidence a sophisticated and highly organized culture, with Chaco Canyon at its religious center.

Sun Dagger image. Courtesy Anna Sofaer.

Chaco was abruptly abandoned around 1150 CE. It's not clear why people left Chaco Canyon, but climate change or civil unrest are possible explanations.

Alignment: Chaco Canyon is of great interest to archaeoastronomers. Evidence suggests that the Chacoans were expert sky watchers, with a clear knowledge of the cyclic and seasonal patterns of the Sun, Moon, and stars. This knowledge is reflected over and over again in the architecture and alignment of the great houses, and in various observational and ceremonial sites around the canyon" (Exploratorium).

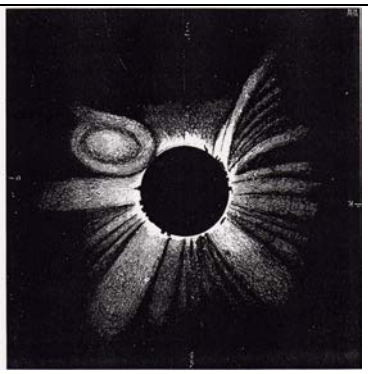
Most famous of the features at Chaco Canyon is the Sun Dagger, a petroglyph discovered by artist Anna Sofaer and designed to mark the cycles of the Sun and possibly the Moon. More about the Sun Dagger in the section on Rock Art.

See http://www.solsticeproject.org/science.htm

Possible Eclipse Representation

A petroglyph on the south face of Piedra del Sol, a free-standing rock in Chaco Canyon, may depict the solar corona observed during the total solar eclipse of July 11, 1097 CE, according to CU Boulder Professor Emeritus Kim Malville. The petroglyph—carved in a rock by early Pueblo people—is a circle that resembles the sun's outer atmosphere known as its corona, with tangled protrusions looping off the edges. The object is unique in rock art, and research indicates it may illustrate the total eclipse of the sun that occurred over the region on July 11, 1097. The petroglyph bears a striking resemblance to a sketch by a German astronomer of the 1860 total solar eclipse. Both the 1860 event and the 1097 eclipse occurred during a period of high solar activity, a time when loops and prominences could have been observable by the naked eye during an eclipse.

Piedra del Sol petroglyph



Sketch of 1860 total solar eclipse

Coronagraph image of the Sun

References and Bibliography:

- http://www.traditionsofthesun.org/
- https://www.solsticeproject.org/
- http://chacomysterycontinues.com/About_the_Film/Anna_Sofaer/index.html
- http://weather.msfc.nasa.gov/archeology/chaco.html
- http://www.nps.gov/chcu/index.htm
- https://en.wikipedia.org/wiki/Chaco_Culture_National_Historical_Park
- http://sunearthday.nasa.gov/2005/locations/chaco.htm
- http://www.traditionsofthesun.org/
- http://www.exploratorium.edu/chaco/
- http://www.angelfire.com/indie/anna_jones1/lost_dagger.html
- http://www.sci-news.com/astronomy/solar-eclipse-petroglyph-chaco-canyon-05116.html
- https://www.colorado.edu/today/2017/08/08/chaco-canyon-petroglyph-may-represent-ancient-total-eclipse
- https://www.nytimes.com/2017/12/01/opinion/chaco-canyon-new-mexico-drilling.html

Chichen Itza

Pyramid of Kulkulkan in Chichen Itza

Location: Pyramid of Kulkulkan. (El Castillo; the ruins of Chichen Itza lie about midway between the towns of Cancun and Merida on the Yucatan Peninsula)
Date Constructed: ~1000-1200 CE
Latitude 20°40' N
Longitude 88°32' W
Images: Wiki Commons
Chichen Itza is a World Heritage Site: https://whc.unesco.org/en/list/483

"For a thousand years, the slanting rays of the setting sun have played a spectacular shadow game with this great Mayan pyramid. At the appointed hour, the shadow of the Feathered Serpent Kulkulkan slides down the northern stairway … and vanishes." (NASA)

The Mayans: The Mayans left us with a written language, making their structures more comprehensible than most west hemisphere groups. They had a sophisticated numbering system, including the unit 0 (zero), and used mathematics and writing to explore the movements of the sky, discovering the precise timing of celestial events. Although they worshipped the Sun, they also established extensive cyclic understandings of the motions of Venus, including its 584-year cycle (Aveni 1997, pp. 93-146).

Construction: Chichen Itza was one of the largest Maya cities and it was likely to have been one of the mythical great cities, or Tollans, referred to in later Mesoamerican literature. The city may have had the most diverse population in the Maya world, a factor that could have contributed to the variety of architectural styles at the site. Kulkulkan is

the Mayan name for the Feathered Serpent God (also known as Quetzalcoatl to the Aztecs). Kulkulkan plays a major role in the light show at Chichen Itza.

Alignments: Around 1000 – 1200 CE, the Mayans constructed a square-based, stepped pyramid approximately 75 feet tall, built directly upon the multiple foundations of previous temples. (It was mysteriously abandoned along with the surrounding city of Chichen Itza by 1400 AD.) The axes that run through the northwest and southwest corners of the pyramid are oriented toward the rising point of the Sun at the summer solstice and its setting point at the winter solstice. The pyramid is unique among all known pyramids, worldwide, for its central role in a dramatic shadow and light display during the equinoxes.

At the appointed hour on the equinoxes, the setting Sun casts a shadow of a serpent, presumably the honored Kulkulkan, "writhing down the northern steps of the pyramid. The sunlight bathes the western balustrade of the pyramid's main stairway and causes seven isosceles triangles to form, imitating the body of a serpent 37 yards long that creeps downwards until it joins the huge serpent's head carved in stone at the bottom of the stairway. Each face of the pyramid has a stairway with ninety-one steps, which together with the shared step of the platform at the top, add up to 365, the number of days in a year. These stairways also divide the nine terraces of each side of the pyramid into eighteen segments, representing the eighteen months of the Mayan calendar." (Space Math)

Serpent descending Chichen Itza on the equinox

See also:

- Aveni, Anthony (1997). *Stairways to the Stars: Skywatching in Three Great Ancient Cultures*. John Wiley & Sons.
- http://whc.unesco.org/en/list/483
- https://en.wikipedia.org/wiki/Chichen_Itza
- NASA. http://sunearthday.nasa.gov/2005/locations/chichen_itza.htm
- http://www.chichenitza.com/
- Space Math https://spacemath.gsfc.nasa.gov/SED11/P3ChichenItza.pdf

Angkor Wat

Front of main temple complex in Angkor Wat

Location: Cambodia
Date Constructed: ~1100 CE
Latitude 13° 25' 48" N
*Longitude*100° 54' 00" E
Image: Above - Wiki Commons
Sun - https://www.angkorphotographytours.com/blog/tag/sunset/
Angkor Wat is a World Heritage Site: https://whc.unesco.org/en/list/668

Construction: Angkor Wat is a temple complex in Cambodia and the largest religious monument in the world. It was originally founded as a Hindu temple for the Khmer Empire, gradually transforming into a Buddhist temple toward the end of the 12th century. The builders of Angkor Wat were not interested in creating a temple merely to honor their deities. In its very structure and orientation, they created a reminder of the greater cosmic order, reflected in both the passage of time and in the changing rays of the Sun at propitious times of the year.

Alignments: In 1976, University of Michigan researchers suggested that the architect of ancient Cambodia's Angkor Wat had encoded calendrical, historical, and cosmological themes into their architectural plan for the temple. Published in the journal Science (Stencel 1976), the study demonstrated how Angkor Wat's architect had established solar alignments between the temple and a nearby mountaintop shrine that took place during the summer solstice. For example, standing at Pre Rup, 6 kilometers away, on the winter

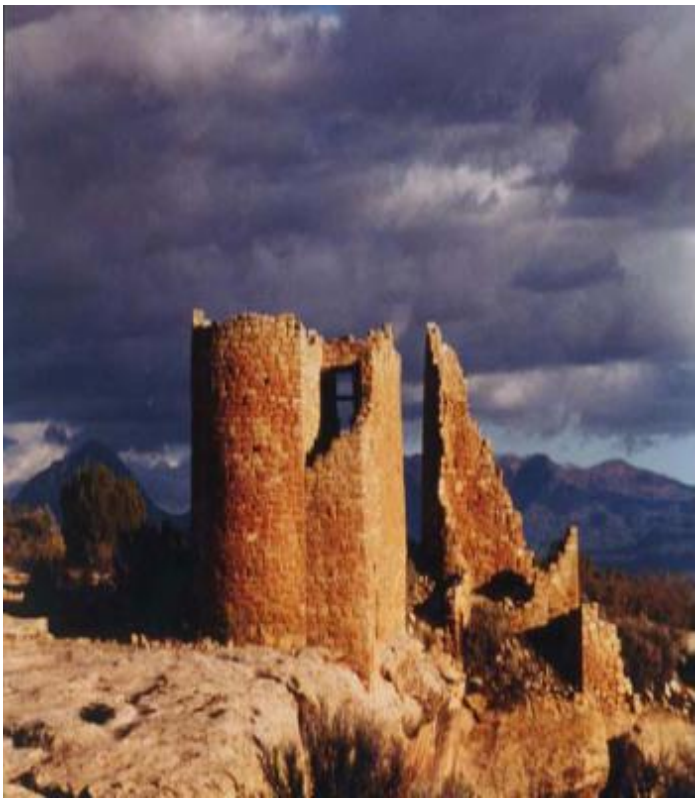
solstice, one would see the setting Sun over Angkor Wat. Standing near the southwestern corner of Angkor Thom, the rising sun at the summer equinox will be visible through, or over, the eastern gate. Six months later, the alignment has shifted to its northern point of sunrise on the winter solstice.

See also:

- Stencel, Robert, Fred Gifford, Eleanor Moron (1976). Science 193(4250), 218-287.
- http://whc.unesco.org/en/list/668
- https://en.wikipedia.org/wiki/Angkor_Wat
- http://sunearthday.nasa.gov/2005/locations/angkorwat.htm
- Angkor Wat (2015) https://www.thingiverse.com/thing:936045

This unique picture was taken on 9 March 2016 during a partial eclipse of the Sun over Angkor Wat Temple. The date of the eclipse was less than 2 weeks away from the spring equinox so the photographer was able to find a shooting location where the Sun stood just above the central tower at the maximum of the eclipse. Credit: Angkor Photography Tours https://www.angkorphotographytours.com/blog/tag/sunset/

Hovenweep Castle



Location: Hovenweep National Monument straddles the southern Utah-Colorado border.
Date Constructed: 1177 – 1277 CE
Latitude 37º 23' 09'' N
Longitude 109º 04' 49'' W
Altitude 5,200 feet
Images:
NCAR/UCAR/HAO:
https://www2.hao.ucar.edu/Education/SolarAstronomy/hovenweep-castle
Spiral & final image:
http://snailhollow.cobabe.net/2013/05/hovenweep-is-fascinating-site-for-those.html

Construction: Human habitation at Hovenweep dates to over 10,000 years ago when nomadic Paleoindians visited the Cajon Mesa to gather food and hunt game. These people used the area for centuries, following the seasonal weather patterns. By about 900 CE, people started to settle at Hovenweep year-round, planting and harvesting crops in the rich soil of the mesa top. By the late 1200s, the Hovenweep area was home to over 2,500 people who created terraces on hillsides, formed catch basins to hold storm run-off, built check dams to retain topsoil that would otherwise wash away, and constructed storage granaries under the canyon rims to protect harvests of corn, beans and squash for later use. (NPS) The masonry at Hovenweep is as skillful as it is beautiful. Even the cliff dwellings of Mesa Verde rarely exhibited such careful construction and attention to detail. Some structures built on irregular boulders remain standing after more than 700 years. Buildings at Hovenweep have a marked fortress-like appearance - they are often tower-shaped, with only small openings or "ports".

By the end of the 1200s, it appears a prolonged drought, possibly combined with resource depletion, factionalism, or possibly warfare forced the inhabitants of Hovenweep to depart. Ancestral Puebloans throughout the area migrated south to the Rio Grande Valley in New Mexico and the Little Colorado River Basin in Arizona. Today's Pueblo, Zuni and Hopi people are descendants of this culture.

Alignments: Long after the massive Hovenweep Castle building was created to shelter them, Native Americans evidently realized it could serve another purpose as well. Within an ancient room added almost as an afterthought, a shaft of light shines through an opening in a massive wall and connects its dwellers with the Sun's springtime cadence. Tree-ring dating of timbers used in the construction of the 'Sun Room' suggest that it was

added in 1277, about 100 years after the main structure, the Castle, was completed. Two ports, or windows, in the large tower admit the rays from the Sun into the interior room, and it has been proposed that this arrangement was used as a solar calendar. The equinox port points to the sunrise azimuth 4 days after the vernal equinox. One explanation for this is that this is the consequence of a method for establishing the equinox azimuth by counting and halving the number of days between the winter and summer solstices.

Sunlight illuminates a spiral petroglyph

See also:

- https://www2.hao.ucar.edu/Education/SolarAstronomy/hovenweep-castle
- NASA. http://sunearthday.nasa.gov/2005/locations/hovenweep_castle.htm
- NPS. http://www.nps.gov/hove/index.htm
- http://darksky.org/idsp/parks/hovenweep/

Bighorn Medicine Wheel

Scattered across the upper Great Planes and into Alberta, rings of stones bare mute testimony to ancient rituals and purposes long since lost in legend and folklore. For 4000 years, some have watched the passage of time and a million sunsets.

Location: Bighorn National Forest, Wyoming
Latitude 44° 49.6' N
Longitude 107°55.7' W
Date Constructed: 1200-1700 CE
Images: Above-wiki commons
Medicine Wheel sunset photograph by Tom Melham. Used with permission.

Construction: For centuries, the Bighorn Medicine Wheel has been used by Crow youth for fasting and vision quests. Native Americans also go to Bighorn to offer thanks for the creation that sustains them, placing a buffalo skull on the center cairn as a prayer offering. Prayers are offered here for healing, and atonement is made for harm done to others and to Mother Earth. A detailed account of ceremonial use of the Bighorn Medicine Wheel by the Arapaho was related in 1993 by Paul Moss (Cowell and Moss).

The wheel has 28 spokes, the same number used in the roofs of ceremonial lodges. The wheel was built between 1200 and 1700 CE. The central cairn is the oldest part. Excavations have shown it extends below the wheel and has been buried by wind-blown dust. Alberta has about 66% of all known Medicine wheels (46) suggesting that Southern

Alberta was a central meeting place for many Plains tribes who followed Medicine Wheel ceremonies (usually on the Summer Solstice - June 21st). (NASA)

Alignment: At the center of the wheel there is a raised central cairn, and several others on the periphery of the wheel. These have been alleged to have astronomical alignments. Astronomer John Eddy suggested that a line drawn between the central cairn and an outlying cairn at the Bighorn Medicine Wheel pointed to within 1/3 of a degree of the rising point of the sun at the summer solstice. The actual astronomical purpose of the design of these wheels remains controversial. The design may also have assisted in the performance of specific rituals and ceremonies that have been lost to us. The 28 spokes could indicate the lunar month, or the length of the female menstrual cycle. (NASA)

See also:

- Cowell, Andrew and Alonzo Moss, Sr., eds. and transl.; *Arapaho Historical Traditions* (Winnipeg, 2003: University of Manitoba Press), pp. 251-287. Stories are bilingual in Arapaho and English.
- NASA. http://sunearthday.nasa.gov/2005/locations/bighorn.htm
- (Wiki) https://en.wikipedia.org/wiki/Medicine_Wheel/Medicine_Mountain_National_Historic_Landmark
- Williamson, Ray A. (1978). *Living the Sky: The Cosmos of the American Indian*. U of Oklahoma Press.

Rising Sun over Bighorn Medicine Wheel on Summer Solstice. Note alignment. Credit: Tom Melham, used with permission

Gaocheng

Location: About eight miles from Dengfeng - China
Date Constructed: 1276 CE
Latitude: 34° 30' N
Longitude: 113° 6' E
Image: Wiki commons
Gaocheng is a World Heritage Site:
https://whc.unesco.org/en/list/1305

Construction: Established in 1276 CE by the famous astronomer Guo Shoujing, it is the oldest of 27 ancient observatories in China. Built with bricks and stone, the building has two parts - the platform and the stone Chinese sundial. On the 28 foot high platform, there are two small cottages on each side. To the north of the platform is an entry and exit, which are symmetrically arranged. Linking the entry and exit to the platform are stairs and pathways. Between the two pathways is the 93 foot long stone Chinese sundial, which was paved by 36 slates. According to historical records, a total of 27 observatories were built in the Yuan Dynasty but only the one in Dengfeng is known to have survived. Gaocheng Observatory is the oldest facility of its kind in China. (NASA)

Alignment: Ancient Chinese astronomers brooded over solar eclipses and sunspots to divine future events for The Emperor. Observatories were the launching pads for exploring the mystical ties between the mundane and the cosmic. (NASA)

Gaocheng was designed originally for use in predicting the time of the solstice each year. Astronomers at the site were able to calculate the actual length of the year to 365.2425 days some 300 years before Europeans managed to develop the Gregorian calendar. (NASA)

See also:

- (NASA) http://sunearthday.nasa.gov/2005/locations/gaocheng.htm
- https://en.wikipedia.org/wiki/Gaocheng_Astronomical_Observatory

Machu Picchu, Cuzco, & the Incans

Location: Northeast of Cuzco in the district of Machu Picchu, Urubamba, Peru
Date Constructed: ~1450 CE
Latitude 13º 07 South
Longitude 72º 35 West
Elevation: 7972'
Images: Above: Wiki Commons; Mirror stones from Dante Salas Delgado; Intihuatana photo by Deborah Scherrer; Koricancha photo by D. Stanley. Inti Mach'ay and Sun Temple images from Wiki Commons
Machu Picchu is a World Heritage Site: https://whc.unesco.org/en/list/274
Cuzco is a World Heritage Site: https://whc.unesco.org/en/list/273

Construction: Machu Picchu is an enigmatic Incan structure set high in the Andes Mountains in Peru, above the Urubamba River valley and near to Cuzco, the Incan capital. The Incans, highly sophisticated and skilled architects and engineers, built Machu Picchu for their Inca emperor Pachacuti Inca Yupanqui, (1438–1472), who claimed to be descended directly from the Sun. Machu Picchu was abandoned after the

Spanish Conquest, and had evidently never been discovered by the invaders. It is renowned for its sophisticated dry-stone walls that fuse huge blocks without the use of mortar, its engineering feats of building drainage into the mountaintop, and intriguing buildings, many of which have astronomical alignments. The Incans worshipped the Sun, and these beliefs integrated the design of all their key cities with their religious worldview.

Alignment: A large number of features distributed throughout the site are aligned with the June winter solstice, the December summer solstice, the zenith dates when the Sun is directly overhead, and the nadir dates when the Sun was directly "below". The solar alignments, and the importance of solar-related ritual to the Inca suggest they were primary ceremonial considerations of the site.

The *Intihuatana* (image on right) is a huaca, or sacred object, many of which were strategically placed within the Incan empire. The name of the stone derives from the Quechua language: *inti* means "sun", and *wata*-, "to tie, hitch (up)". The Inca believed the stone held the Sun in its place along its annual path in the sky. At midday on February 14 and October 29, give or take a day, the Sun stands at its zenith, almost exactly above the pillar, casting no shadow. On the 21 June solstice, the stone casts the longest shadow on its southern side, and, on the 21 December solstice, a much shorter shadow on its northern side.

Intihuatana stone. Credit: Deborah Scherrer

Nearby are two mysterious circular holes carved into the rock. Once erroneously thought to be for grinding corn, researchers have determined they may have been used as "mirrors" to track the Sun overhead. When filled with water, they will reflect the Sun only when it is directly overhead, at the zenith, on about February 14 and October 29.

Mirror Stones. The one on right shows reflection of Sun at noon on Zenith Day. Credit: Dante Salas Delgado

Architecturally, Inti Mach'ay is the most significant structure at Machu Picchu. It is a special cave used to observe the Royal Feast of the Sun, celebrated during the Incan month of *Qhapaq Raymi*. Entrances, walls, steps and windows are some of the finest masonry in the Incan Empire. The cave also includes a tunnel-like window unique among Incan structures, which was constructed to only allow sunlight into the cave during several days around the December summer solstice. For this reason, the cave was inaccessible for much of the year. The Royal Feast of the Sun was an Inca festival celebrated by the nobility around the December solstice. It began earlier in the month and concluded on the December solstice. On this day, boys of the nobility were initiated into manhood.

Inti Mach'ay - cave entrance

The Temple of the Sun at Machu Picchu has an elliptical design similar to a Sun temple found at the Inca capital of Cuzco (described more below). It is a semi-circular building that sits above the Inti Mach'ay and was built into the natural environment with a large stone forming the foundation of the structure. Only the priest and the Inca ruler could enter the Temple of the Sun. It is thought that the Temple of the Sun was used as a solar "observatory", with the two windows in the structure related to the Summer and Winter solstices. The tower has several niches for placing offerings and a large rock in the center. During the Summer/December Solstice, the rising sun shines directly through one of the temple's windows and onto the rock. Sculptures carved out from the rock bottom of the Sun temple are interpreted as "Water mirrors for observing the sky", that is, ways to track when the Sun (or stars?) might be directly overhead (mentioned above)

Machu Picchu Sun Temple

Cuzco

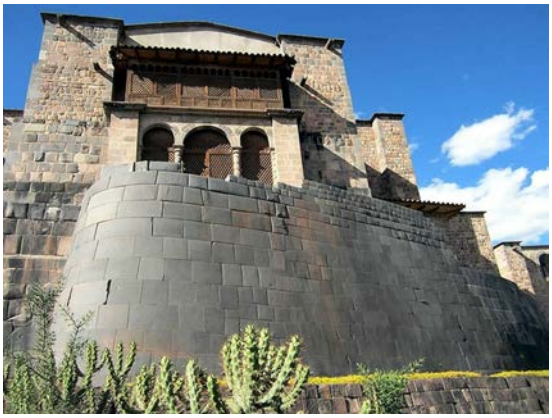
In the Incan capital Cuzco, imaginary sight lines radiated like the spokes of a wheel, reaching out from the Temple of the Ancestors, the center of the Incan world, to the extremities of the empire and universe. These invisible lines (*ceques*, meaning rays)

divided the Incan universe into kin-related groups. Cuzco's great urban plan also tied together the sacredly held organization of the world graphed and plotted on top of the world itself, cast in a reference frame of religious worship based on sacrifice and offering to a living entity of which all people were a part (Aveni 1997, p. 8)

The people of Cuzco believe nature and natural forces to be powerful deities. Most structures in Cuzco and many nearby landmarks were structured with the Incan view of the deities and their universe in mind. Quechua, talented "astronomers" built temples and "observatories" around the area. The most famous is Koricancha, a sacred temple built to honor the Incan Sun god, Inti. Not only did it honor the god, but its alignment allows for a precise stream of sunlight to appear through its windows every June winter solstice for Intiraymi, "sun festival", the most important of four ceremonies celebrated in Cuzco.

When intact, the Koricancha temple walls were plated with 700 sheets of gold. According to chroniclers of the time, each sheet depicted one of the exalted Gods of Koricancha: Inti (the Sun), Killa (the Moon), Chaska (stars) and Illapa (thunder-lighting-rainbow). Unfortunately, the wealth of Koricancha was ransacked by the Spanish during the Conquest. A Catholic church was built over the temple and very little of the Koricancha remains.

Reconstruction of exterior of Koracancha



References and Bibliography:

- Aveni, Anthony, *Stairways to the Stars: Skywatching in Three Gre*at Ancient Cultures; Wiley, 1997
- Malville, J. Kim, "Passages Between Worlds", *Culture and Cosmo*s, 21 nos. 1-22 (2016).
- Salas Delgado, Dante, *Cosmic Wisdom and Sacred Architecture: Machupicchu;* Alimpresiones de Maria Luz Becerra Ancalla, Cusco, Peru
- Stanley https://www.peruforless.com/blog/cusco-treasures-koricancha-the-golden-temple-of-the-sun/
- http://whc.unesco.org/en/list/274
- http://www.machupicchutrek.net/machu-picchu-facts/
- https://sacredsites.com/americas/peru/machu_picchu.html
- https://www.swissfamilygallagher.com/40-things-before-40-the-wonder-of-machu-picchu/
- https://en.wikipedia.org/wiki/Machu_Picchu

Jantar Mantar

Location: New Delhi, India
Construction Date: 1738 CE
Latitude: 28° 37', N
Longitude: 77° 13' E
Images:
Misra Yantra-Wiki commons; Sun dial – Tripadvisor.


Misra Yantra at Jantar Mantar

Construction: The Jantar Mantar monument of Jaipur, Rajasthan is a collection of nineteen architectural astronomical instruments completed in 1738 CE. It features the world's largest stone sundial. The great Indian astronomer-king Maharaja Jai Singh II of Jaipur built five astronomical observatories between AD 1724 and 1730, during the period generally known as the dark age of Indian history. He was inspired by the 15th-century Afghani ruler Ulughbek's observatory at Samarkand. The structures consist of brick and marble towers and pillars, with no telescopic elements at all, yet through solar shadow movements and careful sightings, the local time, and positions of the moon, stars and planets could be determined with great accuracy. (NASA)

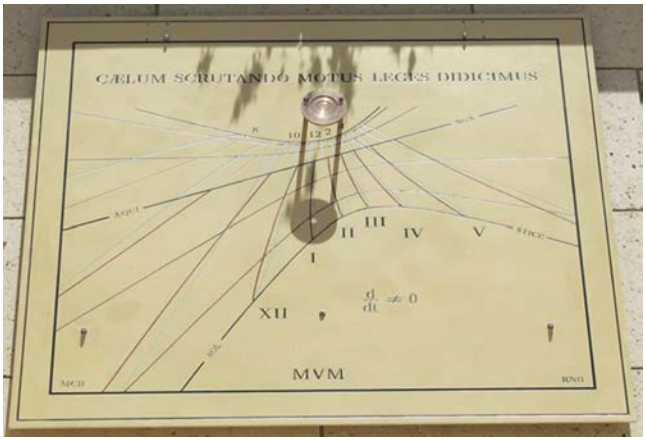

Sundial at Jantar Mantar

Alignments: The Jantar Mantar consists of a number of masonry instruments for predicting time, measuring the position of a celestial body and determining the latitude. These instruments include the Brihat Samrat Yantra, the Rama Yantra, and the Jai Prakash Yantra. The Brihat Samrat Yantra is a huge sundial that gives the local time in New Deli very accurately. The Rama and Jai Prakash Yantras measure precise positions of celestial bodies in the night sky. When the Sun is high in the sky, the pillar at the center of Rama Yantra casts a shadow either on the vertical well surrounding the pillar or the raised floor segments radiating from the pillar. These segments and the walls have fine graduations. The two pillars on the southwest of Mishra Yantra were designed to determine the shortest and longest days of the year. In December one pillar completely covers the other with its shadow while in June it does not cast any such shadow at all. (NASA)

See also:

- NASA. http://sunearthday.nasa.gov/2005/locations/jantar_mantar.htm
- Wiki. https://en.wikipedia.org/wiki/Jantar_Mantar_%28Jaipur%29
- Crystalinks. http://www.crystalinks.com/indiastronomy.html
- Tripadvisor. http://www.tripadvisor.in/LocationPhotoDirectLink-g304555-d311635-i23345388-Jantar_Mantar_Jaipur-Jaipur_Rajasthan.html

Bracewell Sundial, Stanford University



Location: Palo Alto, CA
Construction Date: 1997
Latitude: 37º 25.669 N
Longitude: 122º 10.429 W
Images: on right: from Sundial, Huang Engineering Center (1997), unattributed; end photo from Wiki commons

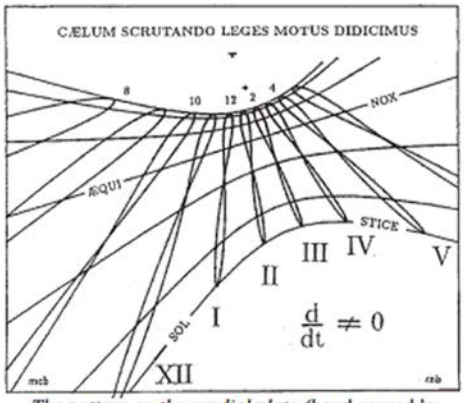
Construction:
Designed by Professor Ronald N. Bracewell and built by his son Mark in 1997. Professor Bracewell describes it this way (Bracewell 1997):

NEW SUNDIAL FOR TERMAN BUILDING

Ronald N. Bracewell
Lewis M. Terman Professor of Electrical Engineering, Emeritus

Sundials of various kinds have been known since antiquity when they served as public indicators of civil time. The sundial, depending as it does on the rotation of the Earth, offers fundamental accuracy.

On looking at the new sundial on the wall of the Terman Building (see figure at right) one is struck by the elongated figure-eight curves, one for each hour. What are these curves? If you had a south-facing office in the building you could place a camera on the window sill and take a photograph of the sun at twelve noon by your watch. If you did this once a week for a year, making all the exposures on the same frame of film, your final print would be a figure-eight curve, pricked out by 52 dots. This curve is called the analemma.



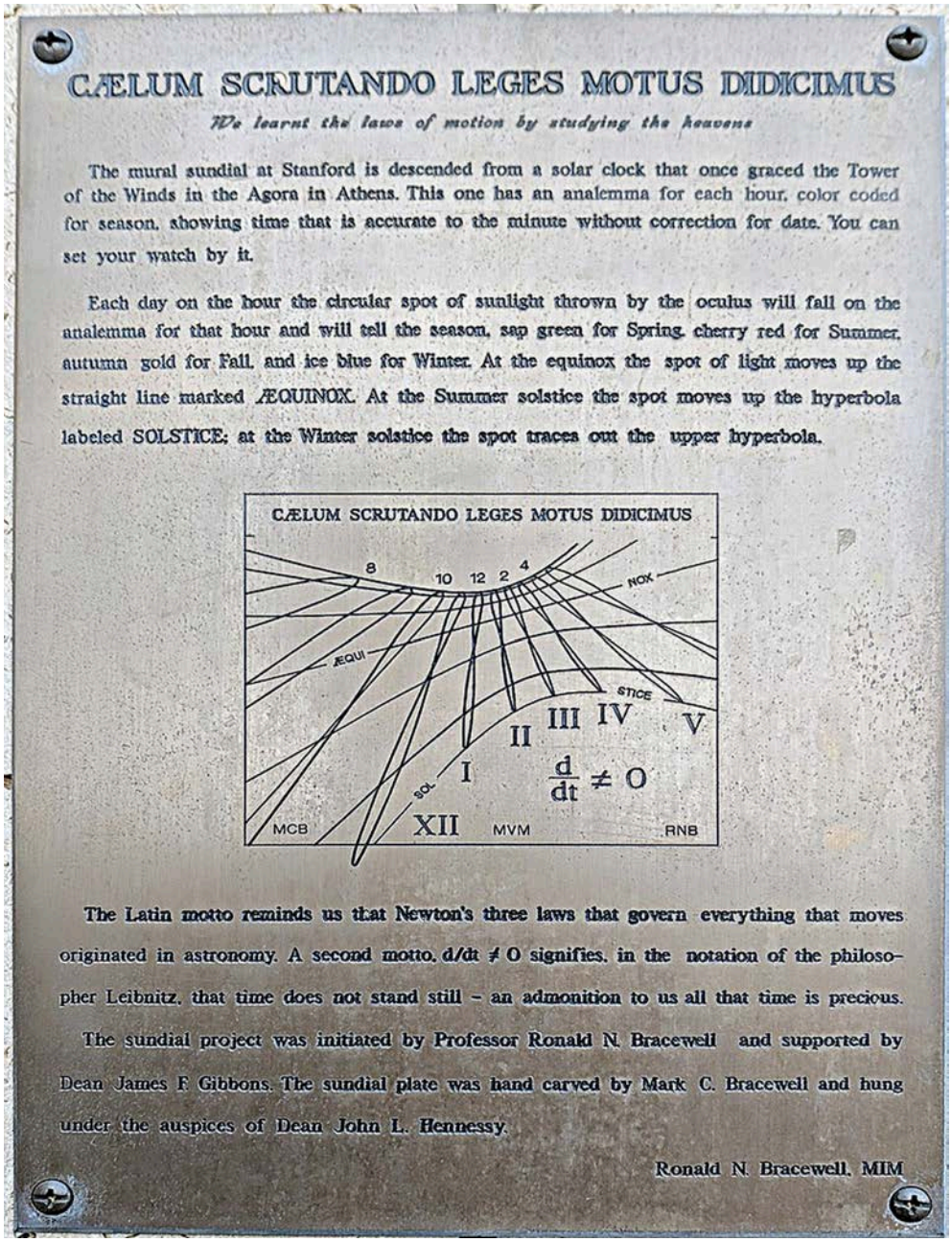
The pattern on the sundial plate (hand carved by Mark Bracewell). The small circle shows the position of the oculus, the small cross shows where a line through the center of the oculus parallel to the Earth's axis intersects the plate.

The central hole in the disc that stands 3.16 inches out from the new sundial corresponds to the camera lens while the substrate that receives the spot of light through the hole, or oculus, corresponds to the film plane. Therefore, each day when it is noon the spot of sunlight on the sundial will be on the analemma, and similarly for other hours.

There are two moments each day when the light spot crosses the analemma. Which gives the right time? That depends on the season. Green indicates Spring (starting from the vernal equinox on March 20/21 and ending at the Summer solstice on June 21/22), red is for Summer, orange for Autumn, and blue for Winter. On March 20 or September 22 you would notice that the spot of light moves upward along the straight line labeled AEQUINOX, while at the Summer solstice (June 21/23) the spot would move along the lower hyperbola labeled SOLSTICE. At the Winter solstice (December 21/23) the spot would advance up the top hyperbola.

The next time you are visiting the Terman Building on a sunny day, stop by and check out the new sundial. The sundial project was supported by Dean James H. Gibbons and hung under the auspices of Dean John L. Hennessy.

The sundial was originally installed on the Terman Building, but has since been moved to the Huang Engineering Center. Beneath the sundial hangs this small plaque:



See also:

- Bracewell, Ronald N. (1997). *Civil Engineering at Stanford University*, 3 (March 1997). p. 17.
- http://www-ce.stanford.edu/Newsletter/archive/CENL0397.PDF
- http://www.waymarking.com/waymarks/WMH5D4_Sundial_Huang_Engineering_Center_Stanford_CA
- https://en.wikipedia.org/wiki/Ronald_N._Bracewell

Bracewell Radio Sundial

Location: Very Large Array, Magdalena, NM
Construction Date: 2013
Latitude: 34.0784º N
Longitude: 107.6184º W
Image: Wiki commons

Construction: In 1961 Professor Ronald Bracewell of Stanford University established an array of 32 10- foot-in-diameter radio antennas to form a radio spectroheliograph. This large and complex instrument produced daily temperature maps of the Sun for an ll-year period, one full solar cycle. This array was one of the first in the world. NASA used these maps to help plan the Moon landing, using the information to predict solar storms that could have endangered the astronauts.

In 2013, the world's first and only radio sundial was erected at the Very Large Array (VLA) Radio Telescope Observatory in New Mexico. The radio sundial was constructed using 10 of the concrete pillars from the famous 1961 array at Stanford and named in memory of Professor Bracewell, who died in 2007. The 10 piers were covered with historic signatures from visitors to Bracewell's original 1961 array.

Bracewell was one of the heroes in the field of modern giant radio arrays.

Alignments:
In addition to aligning with markers that tell the time of day, the shadows from the sundial's gnomon also indicate the approximate time of year. And, the shadows fall on markers that point to important dates in the history of radio astronomy and to celestial objects in the history of radio astronomy.

See also:

- Carey, Bjorn (2013). World's first radio sundial dedicated in memory of Ron Bracewell. *Stanford News*. https://news.stanford.edu/thedish/2013/10/02/worlds-first-radio-sundial-dedicated-in-memory-of-ron-bracewell/
- Bracewell radio Sundial. Atlas Obscura. https://www.atlasobscura.com/places/bracewell-radio-sundial
- VLA Sundial Memorial (2013). http://sundials.org/index.php/all-things-sundial/memorial-sundials/230-vla-sundial-memorial

Rock Art

Paint Rock

Location: Concho County, Texas, USA
Date Constructed: somewhere between 1300 and 1700 CE
Latitude: 31.34º N
Longitude: 99.81º W
Image Credit: Gordon Houston
http://www.bradshawfoundation.com/news/cave_art_paintings.php?id=Rock-art-depicts-solar-event

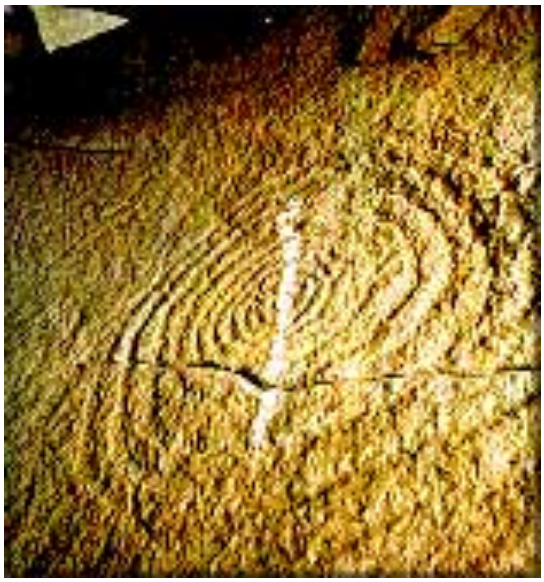
In Concho County, Texas there is a rock art site with about 1500 pictographs. 12 of these appear to have a solar connection. It is unclear who created these. The image below shows a pictograph at a height of 20 feet above the ground. On solar noon of the Winter Solstice, a shaft of light strikes the pictograph.

The Sun Dagger

Location: Chaco Canyon, New Mexico
Date Constructed: 850 - 1150 CE
Latitude 36.06° N
Longitude 107.97° W
Image credit: Sundagger - Anna Sofaer, used with permission
Figure 2 from https://www.solsticeproject.org/images/category/3-mocc_study_guide.pdf
Fajada Butte from Wiki Commons

Anna Sofaer, an artist, discovered the now famous Sun Dagger at Chaco Canyon. This petroglyph was carefully crafted to mark the cycles of the Sun and possibly the Moon.

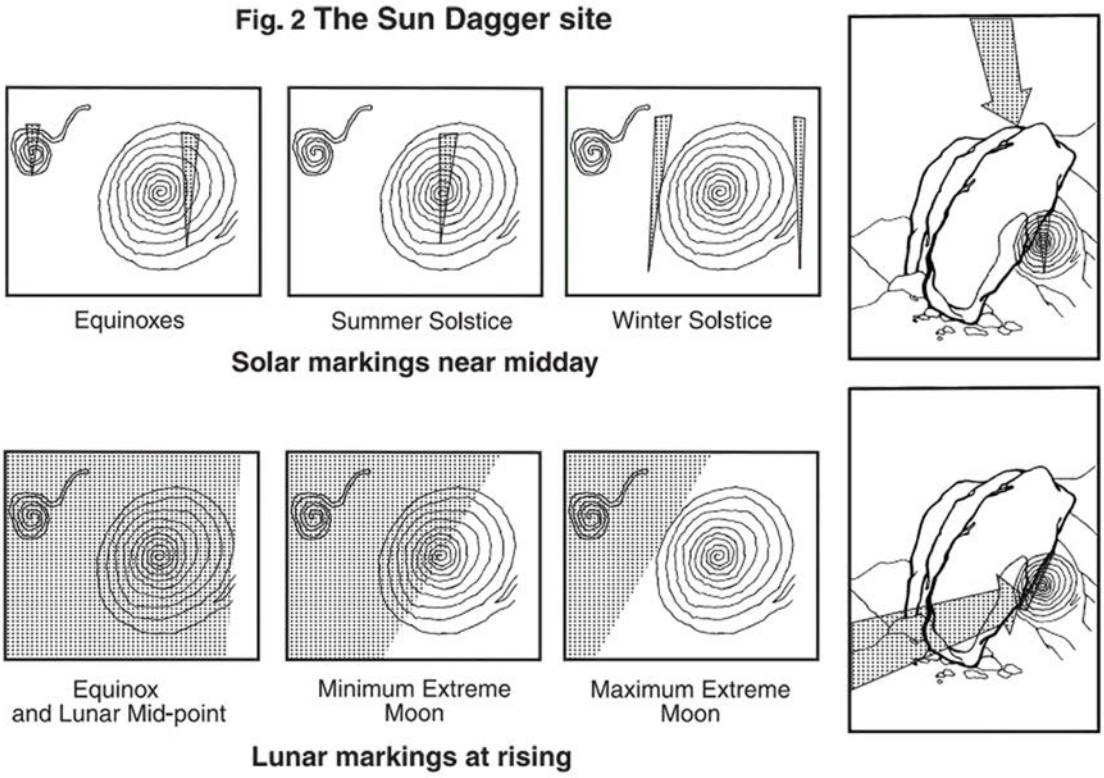
According to Anna Sofaer: "Near the top of an isolated butte in Chaco Canyon, New Mexico, three large stone slabs collimate sunlight in vertical patterns of light on two spiral petroglyphs carved on the cliff behind them. The light illuminates the spirals each day near noon in a changing pattern throughout the year and marks the solstices and equinoxes with particular images. At summer solstice a narrow vertical form of sunlight moves downward near noon through the center of the larger spiral. At equinox and winter solstice corresponding forms of light mark the spirals. The relationship between the shape and orientation of the slabs and the resultant light patterns on the cliff is a complex one and required a sophisticated appreciation of astronomy and geometry for its realization. The site is unique in employing the varying height of the midday Sun during the year to provide readings of solar declination. In this respect it is clearly different in concept from the many archeoastronomical sites throughout the ancient New and Old Worlds that tell the passage of the year by marking the rising and setting points of the Sun and Moon."



Sundagger at noon on Summer Solstice

The shaft of light imagery marks not only the summer solstice, but also the winter solstice, the equinoxes, the equinox and lunar midpoint, the maximum lunar extreme, and the minimum lunar extreme. See Figure 2.

Unfortunately, this site was destroyed when an archaeologist was climbing on the rocks that created the image and knocked them down.



See also:

- The Solstice project; http://www.solsticeproject.org/science.htm
- The American Rock Art Archive: http://www.bradshawfoundation.com/america/index.php
- https://www.texasbeyondhistory.net/plateaus/images/he4.html
- (Sofaer) http://www.stone.com/Qouija/Sundagger.html

Fajada Butte, home of the Sundagger

Ancient Navigation by the Sun – Sunstones

Modern navigation by the Sun is relatively easy. We all know that the Sun rises in the east and sets in the west. However, due to the tilt of the Earth, the direction might not lead you in a true east or true west direction. The Sun rises and sets virtually due east-west only during the equinoxes (March and September). During the summer, the Sun will rise in a more north-eastern direction and set in the north-western direction. During the winter, the Sun will rise in the south-east and set in the south-west.

Want to find north (without a compass)? Hold your watch horizontal and level to the ground. Point the hour hand directly towards the Sun. The imaginary line that sits between the hour hand and the 12 o'clock mark will run north to south.

Or you could use a shadow test. Place a stick in the ground and mark where the shadow of the stick is on the ground. Wait about 15-30 minutes and place another rock where the shadow has moved. If you line up those two rocks it will point roughly east to west.

These are easy. However, what do you do if you cannot see the Sun? This was a dilemma for ancient Vikings and Icelanders, who needed to navigate in the North Sea area where the Sun was often not visible. And, although Europe did not have magnetic compasses until around 1400, even if the Vikings had had them, they would not have been very useful in the northern areas. (Why?)

According to a recent article (Yirka 2018): "For the time period 900 to 1200 AD, Vikings, by nearly all accounts, ruled the northern Atlantic. Their skill in building strong boats and in navigation allowed them to travel throughout the North Atlantic. Prior research has suggested the Vikings used a type of sundial to navigate, which was apparently quite accurate. But what did they do when it was cloudy or foggy? Viking tales passed down through the generations claimed it was through the use of *sunstones,* which allowed Viking navigators to find the Sun even on cloudy days. But proving the tales true has been problematic—no sunstone has ever been found on or near a Viking shipwreck. A crystal was found on a 16th-century English shipwreck in 2002—and English sailors could have learned to use them from the Vikings—but much stronger evidence is needed."

The assumption is that a sunstone was some sort of crystalline rock, something like calcite, cordierite, or tourmaline. These crystals can split sunlight into two beams even when it is cloudy—and when the crystal is turned, splitting the two beams at the same brightness, a navigator could see the polarized rings around the Sun—effectively showing its placement in the sky. It's actually a complicated procedure, but you can imagine its effects by taking a pair of polarized sunglasses, pointing them at a blue patch of sky overhead, then looking through them while turning them. The brightness of the blue will change as you rotate the glasses.

Using sophisticated computer model simulations, researchers (Száz & Horváth 2018) have now simulated 1000 voyages between Norway and Greenland with varying cloudiness at summer solstice and spring equinox. Under varying weather conditions, they simulated a 3-week-long journey between Norway and Greenland and found that the sunstone-simulated technique was surprisingly successful. The navigator would have been required to determine a direction every 3 hours, which is reasonable for such a voyage.

Iceland spar, possibly the medieval sunstone used to locate the Sun in the sky when obstructured from view. Credit: ArniEin/Wikipedia/CC BY-SA 3.0

See also:

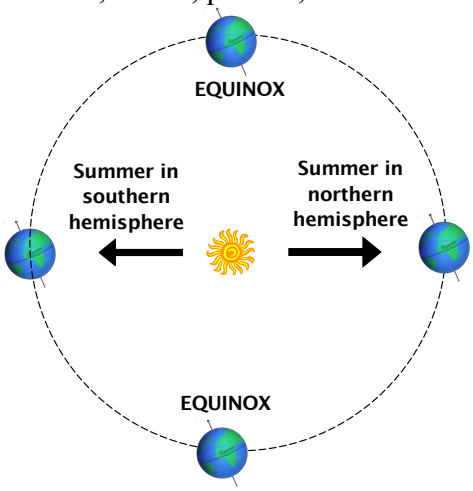
- Harding, Stephen (2016), Did the Vikings use crystal "sunstones" to discover America?, *Phys.org*, https://phys.org/news/2016-02-vikings-crystal-sunstones-america.html#nRlv
- Száz, Dénes and Gábor Horváth (2018), Success of sky-polarimetric Viking navigation: revealing the chance Viking sailors could reach Greenland from Norway. *Royal Society Open Science*. http://rsos.royalsocietypublishing.org/content/5/4/172187
- Yirka, Bob (2018), Computer simulations show Viking's sunstone to be very accurate. *phys.org*, https://phys.org/news/2018-04-simulations-viking-sunstone-accurate.html
- Yirka, Bob (2017), Experimentation suggests Vikings could have used sunstone to navigate, *Phys.org*, https://phys.org/news/2016-07-experimentation-vikings-sunstone.html
- The Viking Sunstone, http://www.polarization.com/viking/viking.html
- Sunstone (medieval), Wikipedia: https://en.wikipedia.org/wiki/Sunstone_(medieval)
- https://www.thereadystore.com/survival-tips/6425/how-to-navigate-using-the-stars-sun-and-moon/

Solstices, Equinoxes, and Zeniths, oh my!

To understand ancient observatories, it is important that one understands the motions of the Sun and Earth through the seasons. This document is intended as an introduction to that topic.

Introduction

Many pre-technological cultures were quite sophisticated in tracking the movements of the Sun, Moon, planets, and stars in the sky, as you have learned from reading the previous accounts. Although ancient (and some modern) cultures were acutely aware of the movements of the celestial bodies, few modern-world people understand them. Most are aware that the Sun "rises in the east and sets in the west". But few understand that the sunrise and sunset locations on the horizon change slightly each day. Why?



The Earth in its various positions in orbit, showing its tilt. Credit: Deborah Scherrer

It all has to do with Earth's tilt. If the Earth spun around without a tilt, there would be no seasons and no solstices.

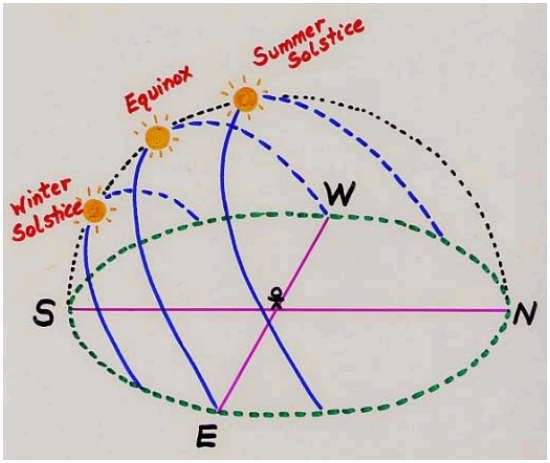
Seasons

Do you know why the Earth has seasons? Many people don't (A Private Universe). It has nothing to do with being closer to or farther from the Sun.

Because the Earth is tilted, sometimes the Northern Hemisphere gets more sunlight (e.g. summer in the north). 6 months later, the Earth has moved to the other side of the Sun and the Southern Hemisphere gets more sunlight (e.g. summer in the south). In between, both hemispheres get about equal amounts of sunlight, and we experience the equinoxes.

The Sun's apparent path in the sky

From our perspective on Earth, we see the Sun rise in the eastern sky and set in the west. But each day the Sun moves a little on the horizon from where it rose/set the day before. For each latitude, the Sun's march along the horizon is a little different. The figure to the right approximates the Sun's paths at the solstices and equinoxes for a site in the northern hemisphere (north of the tropics).



Credit: umass.edu

Solstices

In the northern hemisphere, summer solstice occurs on the day the Sun has reached its northernmost rising and setting points, marking the beginning of summer. This is around 21 June. Winter solstice occurs on the day the Sun reaches its southernmost rising and setting points, the beginning of winter, around 21 December. For more details, check out http://scijinks.jpl.nasa.gov/solstice/

Winter solstice was of particular interest to many pre-technological cultures. Ceremonies were held, perhaps to encourage the Sun to resume its journey northward, or to celebrate the change to longer days and rebirth from winter. Many modern solstice and winter celebrations have descended from these events.

The equinoxes are defined as either of the two moments in the year when the Sun is exactly above the equator. We experience this as the Sun rising due east and setting due west. The Vernal Equinox, marking the beginning of spring in the Northern Hemisphere, occurs about March 21, when the Sun moves north across the celestial equator. The Autumnal Equinox falls about September 21, as the Sun crosses the celestial equator going south.

The word "equinox" derives from the concept of equal day/night. However, at almost **no** place on Earth are the daylight and nighttime hours equal on the equinox. If you are curious why, see *http://www.timeanddate.com/astronomy/equinox-not-equal.html* and the book *Canada's Stonehenge* by Gordon R. Freeman (http://canadastonehenge.com/)

Zeniths & Nadirs

Many people believe the Sun goes directly over their head at noon. Actually, for most people on Earth, the Sun NEVER gets directly over their head. Many patio umbrella designers get this wrong.

This doesn't work, as you can see by the shadows

This does work, since the Sun is rarely directly overhead

The highest point the Sun gets at a particular latitude is called its Zenith. Except in the equatorial regions, this occurs at noon on the Summer Solstice. Cultures outside the tropics are rarely concerned with tracking the Sun's zenith crossing, since the Sun never appears directly overhead. They focus more on solsticial and equinox timings.

However, in the tropics (latitudes between 23.5º S and 23.5º N) the Sun will appear directly overhead (~90º) twice yearly. In those equatorial regions, the Sun is not always highest in the sky at the solstice but rather sometime between the summer solstice and equinox. This is demontrated in the image to the right.

With cultures that live in the equatorial zones, like the Incas, the date the Sun appears directly overhead is easy to track and quite important to them. This was the date many tropical cultures started their calendrical systems (Green 2016). Opposite to the Sun's zenith is the Sun's nadir, or anti-zenith. This is the conceptual time that the Sun is directly beneath a particular site.

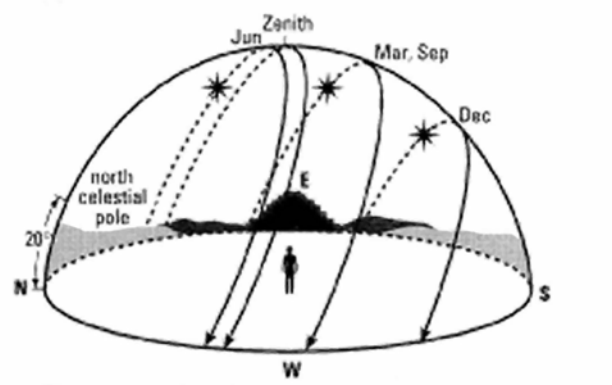
Opposite to the Sun's zenith is the Sun's nadir, or anti-zenith. This is the conceptual time that the Sun is directly beneath a particular site.Obviously this is not directly observable, but with continuous tracking of the sunrise and set times of the zenith, it could be computed. It also reflects the notion that there is an Above, ta Middle-the Earth, and a Below that many indigenous cultures share.

Illustration 4 - 1 The Sun's path in the tropics, showing solstices, equinoxes, and the zenith directly overhead. Credit: Deborah Scherrer

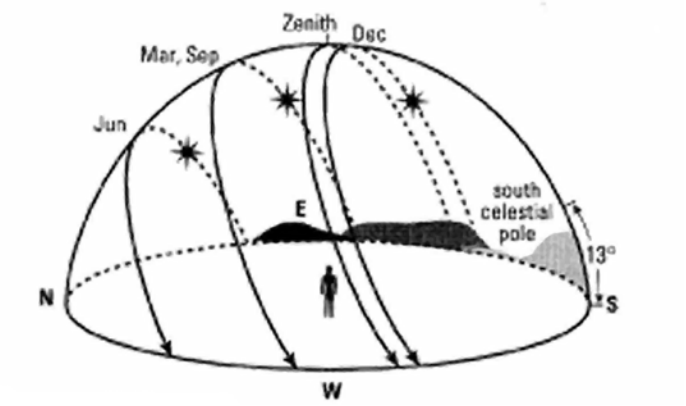
Hence there are fundamental differences between tropical and temperate zone astronomies. "Nearly all tropical cultures that developed indigenous astronomical systems…gravitated toward a reference system consisting of zenith and nadir as poles and the horizon as a fundamental reference circle. Such an arrangement stands in remarkable contrast to the celestial pole-equator (or ecliptic) systems developed by ancient civilizations of the temperate zone" (Aveni 1981)

Putting it all together

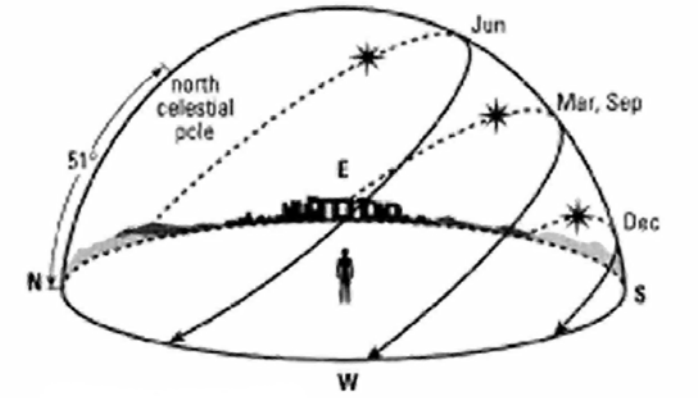
Below is an example of the solar paths for 3 archaeoastronomy sites, Stonehenge, England (northern hemisphere), Chichen Itza , Mexico (just north of the equator), and Cuzco, Peru (just south of the equator). Note that the zenith for Chichen Itza and Cuzco does not coincide with the equinox. Note also that when one is in the southern hemisphere (e.g. Cuzco), the paths tilt towards the north, not the south as in the northern hemisphere.



Solar paths at Stonehenge, England
(latitude 51º N)



Solar paths at Chichen Itza, Mexico
(latitude 21º N)



Solar paths at Cuzco, Peru
(latitude 13º S)

Imagery from (Aveni 1997, page 21).

Lunar Cycles

Although this report focuses primarily on cultural understandings of the Sun, the Moon has similar cycles that feature prominently in archaeoastronomy sites. The most important, of course, is the monthly cycle. After that, is the 19 year period when the Sun and Moon repeat their disunited dance together. A third is the lunar standstill cycle. The

Moon's rising and setting points on the horizon on are more complex than the Sun's. The Sun cycle of rising/setting in its farthest north and south positions, takes one year. The equivalent lunar cycle, going from the farthest north point it rises/sets to the farthest south point (in the Northern Hemisphere) takes 18.6 years. These extreme points are called the Lunar Standstill, because, as with the solar solstices, the Moon stays at these points for several days before starting its march back the other direction.

Illustration 4-12 is a photo taken by Anthony Ayiomamitis in Greece (Avyiomamitis 2018). It shows the solstices and equinoxes for the Sun, which occur every year. I have added the lunar standstill points, occurring every 18.6 years.

Illustration 4 - 2 Rising points of the Sun at solstices and equinoxes, as well as the lunar standstill points for the Moon. Credit Anthony Avyiomamatis, with adaptions by Deborah Scherrer.

These lunar standstill points were marked by many ancient cultures. For a good example, a dramatic one occurs at Chimney Rock, Colorado (Major Lunar Standstill).

References and See also:

- A Private Universe. https://www.learner.org/resources/series28.html
- Aveni, Anthony (1997). *Stairways to the Stars: Skywatching in Three Great Ancient Cultures*. John Wiley & Sons.
- Aveni, Anthony F., "Tropical Archaeoastronomy", *Science,* 213 no. 4505 (1981), pp. 161, 167, 168.
- Freeman, Gordon, *Canada's Stonehenge*; see http://canadastonehenge.com/
- Green, Harold H., "The Zenith Sun as an Organizing Principle of the Constructed Sacred Space and Calendars of Central Mexico*", Culture and Cosmos*, 20 no 1-2 (2016) pp. 59-78.
- Moon Teachings for the Masses at the UMass Sunwheel and Around the World http://www.umass.edu/sunwheel/pages/moonteaching.html
- The Sun and the Seasons: http://physics.weber.edu/schroeder/ua/SunAndSeasons.html
- http://facstaff.gpc.edu/~pgore/Earth&Space/GPS/motion_of_objects_in_sky.html

- To calculate exact times of solar zenith, the solstices and equinoxes, see https://ssd.jpl.nasa.gov/horizons.cgi and https://www.timeanddate.com