What the Ancients Observed

People of ancient civilizations all around the world would gaze up at the heavens, their sight always limited by the distant horizon, and wonder at the moon, the Sun, and the stars as they wheeled across their vision. The great expanse of the unknown spread above them in a great dome. They built sky myths to try to explain some of what they saw, to make order of it, to try to understand. Many cultures made gods of the Sun and stars: in Greek culture, the god Apollo was said to parade his sun chariot across the sky. They felt a closeness to and depended on these markers of time and change much more than we do today.

> "The heavenly motions are nothing but a continuous song for several voices … landmarks in the immeasurable flow of time" -- (Joahnnes Kepler, 1620)

Across a wide variety of cultures, they began to observe and record and gradually to predict some of the movements. Why did they do this? One practical reason: they needed some kind of calendar to know when to plant their crops, when a river would usually flood its banks, or when certain ceremonies should occur to assure good fortune from the gods. Religion and culture were closely tied to nature and the changes of the seasons, often marked by movements of the Sun and stars.

As they began to record their observations, some cultures developed quite an accurate body of astronomical knowledge. They developed calendars based on their long-term observations. The Mayan priests were able to calculate the cycles of the moon with exacting precision. For some, this knowledge began to play a part in the design of their living areas and in the construction of siting points or even elaborate observatories to get it right. Many cultures built markers to align with sites on the horizon to mark the summer and winter solstices, then began to build permanent observatories with openings to catch the first light precisely on those mornings. This seems to be a major factor in the building of Stonehenge (see next section). Others more simply set stones in long rows towards the solstice sunrise.

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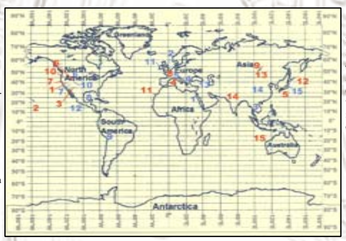

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Mysteries of Chaco Canyon and the Western U.S.

This long north wall at Chaco Canyon stood four stories tall and had an almost exact northward alignment

Nowhere is the sense of mystery more profound than at the desert ruins at Chaco Canyon, New Mexico. Built over a thousand years ago by the Anasazi, these stone walled towns were carefully planned. The largest of these was Pueblo Bonito, large enough to house thousands of people, but it is not clear that many lived there for very long. Perhaps its purpose was mostly ceremonial. There had to be a strong governing community to create the orderliness with which it was constructed.

Its walls contained a number of circular structures called kivas, built into the ground with benches, a roof, a fire pit, wall holes and posts all of which were neatly aligned. The largest was 64 feet in diameter. Elements of the structure may have represented supernatural forces and the circular dome, the sky. A tremendous amount of effort went into the planning and construction in Chaco Canyon.

More telling was the discovery in 1977 of the spiral markings on rock face high up on a rock formation where the sunlight, passing between three large vertical rock slabs, marks the solstices as well as the equinoxes (see right). Priests or other officials must have been in charge of the sun watching. To establish such markings, as well as other astronomical rock carvings, in a ceremonial setting such as this, clearly reveals that information about the sun's changing motions was important to this culture.

Credit: National Park Service

On a high butte in Chaco Canyon, the "Sun dagger" of light strikes through the middle of the large spiral on the summer solstice

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Hovenweep Castle, built around 1200 A.D. in Utah by the Anasazi, was at least partly used as a solar observatory

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At Hovenweep, the Anasazi Indians drew spirals on stones to mark where, in the shadows of rock slabs, shafts of light meet on the summer solstice.

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Like our ancestors from other cultures over thousands of years, modern scientists still cast their eyes up to the skies in the hopes of learning more about the Sun, moon, planets and stars. Although the ancient peoples lacked the modern tools that we possess today, they were able to observe and record and use that information to guide them and predict events.

Today scientists rely on ground-based observatories around the world and a significant number of spacecraft to observe the sun, its effects on Earth, and stars. Over the years scientists have built on the knowledge gained from earlier generations, and with exciting new tools, they can gather new information about the universe that few could imagine possible just a hundred years ago. For example, sunspots were first observed by telescopes in the early 1600's. We have fairly good records of their numbers since then. In the mid-1800s astronomers discovered that when they tabulated and graphed them, their numbers increased and decreased over time in a repeatable cycle (the solar activity cycle or the sunspot cycle). Ancient Chinese astronomers also kept track of naked-eye sunspots 2,000 years ago, and that's how we know that sunspots have been a common feature of the Sun for millennia.

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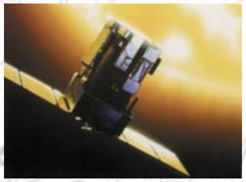
The McMath-Pierce solar telescope on Kitt Peak, AZ is the world's largest solar telescope

We also know from the records that sometimes the Sun just stops making sunspots. This happened in the 1600s, also the time when Europe was in the grip of what they called a mini-Ice Age.

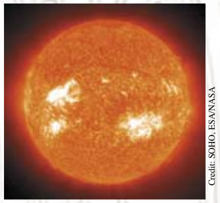


The SOHO spacecraft monitors the Sun 24 hours a day with 12 instruments

With spacecraft like SOHO (Solar and Heliospheric Observatory) launched in 1995, solar scientists can observe the Sun 24 hours a day. Its instruments can generate images of the Sun in ultraviolet light, can measure particles that emerge from it, and can even tell what is going on inside the Sun. Another spacecraft from NASA called TRACE can take close-up images of the Sun in different wavelengths of light to learn more about the activity on or just above its surface. Other spacecraft like ACE and Polar can detect and measure the impact of storms of particles from the Sun. Such storms can damage satellites, upset navigational equipment, and present a danger to astronauts.

Ground-based observatories also contribute to our understanding of the Sun. Their images and measurements from around the world are provided for everyone to use via the Internet. Great improvements have been made in the quality of their images so that new details never seen before can now be observed and studied.

Looking back, we can see that it all began with groups of people trying to learn more about the events that they were able to observe in the sky above them.



Credit: SOHO, ESA/NASA

The Sun in ultraviolet light in which the white areas show intense activity

Astronomy of Ancient Stonehenge

Stonehenge is probably the most famous astronomically aligned structure in the world, though there are over 1,000 stone circles in Great Britain alone. For over 1,500 years beginning in 3000 B.C., generations of people dragged huge stones from up to 20 miles away to build and re-build the site in southern England. The stones were arranged in a large circle with marker points and a path radiating out from this central structure. In the 18th century William Stukeley had noticed that the open horseshoe shape of interior stones faced in the direction of the mid-summer sunrise. It was reasoned that the monument must have been deliberately planned so that on mid-summer's morning the Sun's first rays shone into the center of the monument between the open arms of the horseshoe arrangement.

These are the remaining stones at Stonehenge, England, where the horseshoe structure opens to the morning light of the summer solstice

This alignment implied a ritualistic connection with sun worship and it was generally concluded that Stonehenge was constructed as a temple to the Sun. It was argued that the summer solstice alignment cannot be accidental. Since the Sun rises in different directions in different geographical latitudes, it must have been observed for Stonehenge's latitude. The alignment must have been fundamental to the design and placement of Stonehenge.

The builders of Stonehenge must have had precise astronomical knowledge of the path of the Sun and must have known before construction began just where the Sun rose at dawn on midsummer's morning. This particular location was so important that stone circles and horseshoe arrangements were constructed to mark it and that some of the very large stones were dragged there from a great distance away. The famous stone circle and horseshoe arrangement were added later to the monument and are not essential to the lunar and solar observations.

Holes placed at precisely regular intervals around a concentric circle of about 285 feet in diameter served as fixed reference points and their number was essential to astronomical calculations. Some who have studied these stones argue that various alignments could have been used in tracking different kinds of cycles of the moon. Others suggest that it might have been possible that the same holes were used to learn where the path of the moon and the Sun would intersect and create an eclipse. Disagreements continue to this day.

Numerous researchers have tackled the problem of what these possible alignments meant and how precisely the builders of Stonehenge understood the movements of the Sun and moon, but all agree that the site was used to express their interest in the sky.

Amazing Sites in Central and South America

In the civilization of the Incas, an entire city was built and structured on radial lines of sight, and several observatories were erected. In the capital city of Cuzco stood the Temple of the Sun, Coricancha, decorated with gold sun images. On the other side of the Andes stands the ruins of Machu Picchu, a large and interesting site in South America. High in the remote Andes Mountains in Peru stands the ruins of Machu Picchu. Building began in the 1460's and continued for the next 80 years or so until the Incan empire collapsed. A window in one of the central buildings seems to have been positioned to observe the winter solstice sunrise and related constellations that would be seen at the time.

Credit: Jeff Gilbert

High in the remote Andes Mountains in Peru stands the ruins of Machu Picchu where evidence of solar and astronomical alignments were found

The Mayan culture thrived between 200 and 900 A.D. in the Yucatan peninsula and beyond. For them, sky observing, and especially of Venus, became something of an obsession as it was central to the development of their very precise calendar, which was very important to their culture. One odd building at Chichen Itza (*see below*), with its viewing shafts and red and black colored columns (associated with Venus), was possibly the source of careful observations of the extreme movements of Venus along the horizon. Venus, their god of war, was important to their culture. They offered sacrifices to Venus to obtain the bounties of nature.

Credit: Clive Ruggles

The Caracol of Chichen Itza built around 800 A.D. by the Mayans. This odd building seems to have been designed to observe the movements of Venus, important to their culture

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The Mayan pyramid of Castillo in Yucatan

Near the Caracol, a pyramid called the Temple of Kukulcan or the Castillo was built with the knowledge of solar alignments. It was carefully aligned so that in late afternoon on either equinox the shadow from the Sun forms a wavy line almost like a snake from the head of a stone serpent at the bottom to the doorway at the top. This demonstrated sacred knowledge to their people.

Hands-On Exercise: Finding Solar North

Context: A compass uses the Earth's magnetic field to find north and therefore points toward magnetic north, which is not in the same place as geographic or due north. A shadow plot can help you obtain a feel for how the Sun's path changes across the sky from day to day. During the course of only one day a shadow plot can help you determine which direction is due north at the location where the shadow plot is made.

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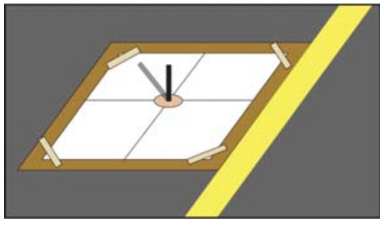
Starting as early in the morning as possible, trace the shadow of the stick every half hour until the end of the day, labeling the time after each tracing. Find two shadows that are the same length. They should be on different sides of the paper (either one towards the top and one towards the bottom, or one towards the left and one towards the right). Trace the angle of these two lines, then bisect the angle. On the original sun plot draw the bisector angle. When the plot is in its established position on the parking lot, this line points towards true solar north. Check the newspaper to find the times for sunrise and sunset; determine the midpoint between these two times. Check the midpoint on your plot to determine your accuracy.

This activity is part of the complete activity designed by NASA Connect for 2005 Sun-Earth Day. The complete activity can be found at -- **http://connect.larc.nasa.gov.**



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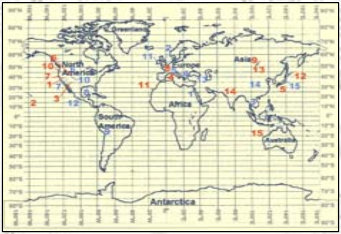

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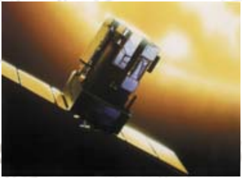

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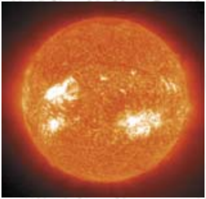

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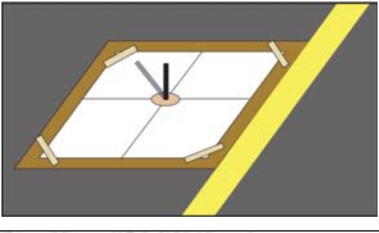
Activity: Tape the larger piece of paper to the piece of cardboard. Mark the center of the paper with a dot using the marker. Through this dot draw two lines that are perpendicular to each other: one from top to bottom across the paper, and the other from left to right across the paper. Insert the pointed end of the stick through the center dot and into the cardboard. Use tape to secure the stick on the bottom of the box. Using the protractor, verify that the stick is straight. This is very important.

On a clear day, find a large open area outside (a parking lot area works best). Place the longest edge of paper along the edge of the parking lot or along a painted mark on the parking lot. (Remember this orientation of the box and the way your orientated your paper or tape the box to the ground.)

Starting as early in the morning as possible, trace the shadow of the stick every half hour until the end of the day, labeling the time after each tracing. Find two shadows that are the same length. They should be on different sides of the paper (either one towards the top and one towards the bottom, or one towards the left and one towards the right). Trace the angle of these two lines, then bisect the angle. On the original sun plot draw the bisector angle. When the plot is in its established position on the parking lot, this line points towards true solar north. Check the newspaper to find the times for sunrise and sunset; determine the midpoint between these two times. Check the midpoint on your plot to determine your accuracy.

This activity is part of the complete activity designed by NASA Connect for 2005 Sun-Earth Day. The complete activity can be found at -- **http://connect.larc.nasa.gov.**



EW-2004-9-020-GSFC