Chapter 7

The Sun and Civilization

In This Chapter

- The Sun and Stonehenge
- Who found sunspots?
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- The Sun as a cathedral
- The Maya and the Sun

It would be interesting to be able to travel back in time to ask people what they thought the universe was like. Books and other writings show us early views of the universe formulated over the last couple of thousand years. But what did people before that think? We have only the monuments and other things that they left behind.

Stonehenge as an Observatory

If you drive west and a little south from London, England, for a couple of hours, you spot some huge standing stones alongside the roadway on Salisbury Plain. You needn't stop, but you will be glad if you do. These stones are monuments from 4,000 or 5,000 years ago.

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The stones are now protected by fences, although visitors used to be able to walk among them. In any case, they stand in a circle and two horseshoe shapes, with a few odd stones in various directions. In all, there are over a dozen stones twice as tall as a person. Each stone weighs about 25 tons.

Stonehenge, in England, with tall standing stones, some of which were oriented more than 4,000 years ago so that pairs were aligned to astronomically significant points.

(Jay M. Pasachoff)

The site is Stonehenge, one of Britain's National Heritage locations. It was built in several stages. The oldest stage, known as Stonehenge I, began about 3000 B.C.E. when holes in the ground were dug and wood posts were placed in them. Several hundred years later, about 2450 B.C.E., Stonehenge II was built, with the giant stones we see today brought in from distances as great as hundreds of miles.

The circle of stones is over 30 yards (27 meters) wide. Stone lintels link pairs of these giant stones. The horizontal links had to be raised 12 feet (4 meters) above the ground, probably a tiny bit at a time.

What were these giant stones? Why are they here? Why are they arranged as they are? Tradition holds that Druids prayed there, and modern-day Druids again meet there at certain times of year.

A key to understanding Stonehenge comes from the alignment of the stones. We have already seen that the Sun sometimes rises due east and, most of the time, rises north or south of due east. It rises due east at the days of the equinoxes. As we approach the summer solstice on June 21, the sunrise occurs as much as 23½° along the horizon north of due east. It can't be just a coincidence that the sightline from the center of the circle of stones toward an outlier stone almost 200 feet (60 meters) away points

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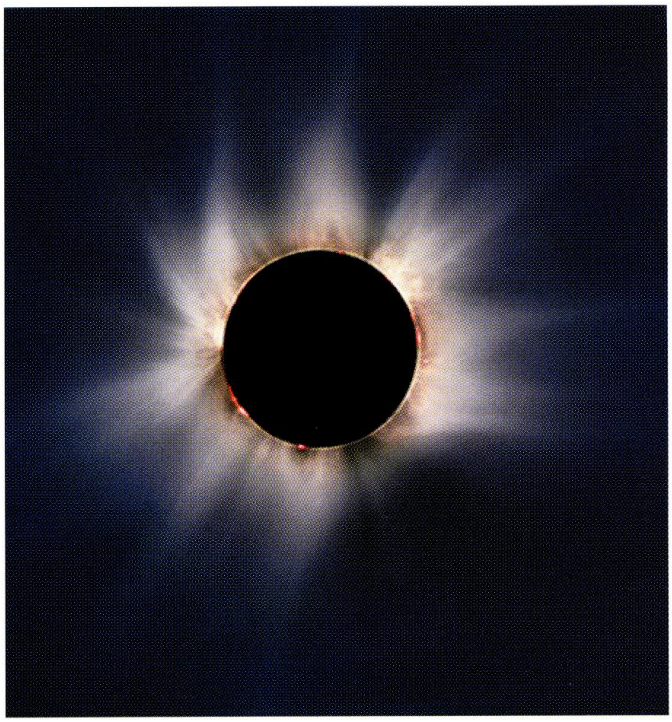
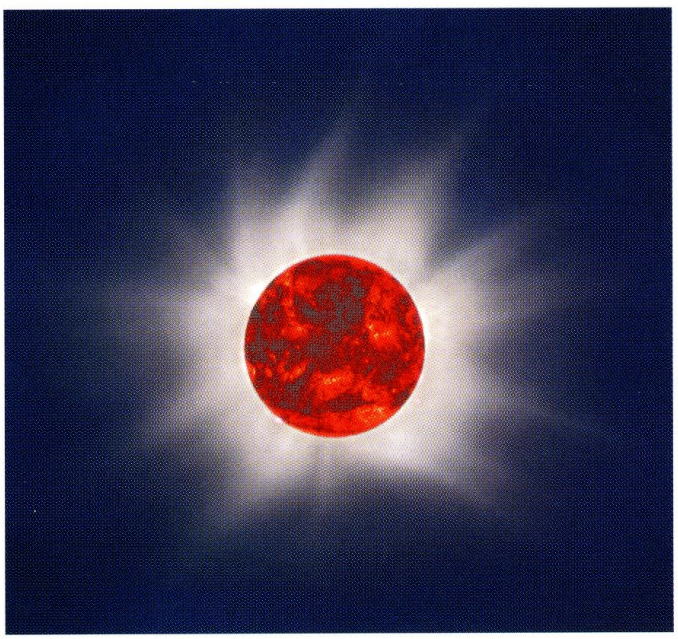


(Wendy Carlos, Jay M. Pasachoff, Stephen Martin, and Daniel B. Seaton/Williams College Expedition)

The 1999 total eclipse of the Sun, in a composite made from electronic and photographic images to bring out the inner coronal structure.



(Jay M. Pasachoff and Wendy Carlos; center: SOHO/EIT Team)

A false-color space image of the corona over the face of the Sun has been inserted at the center of the image.

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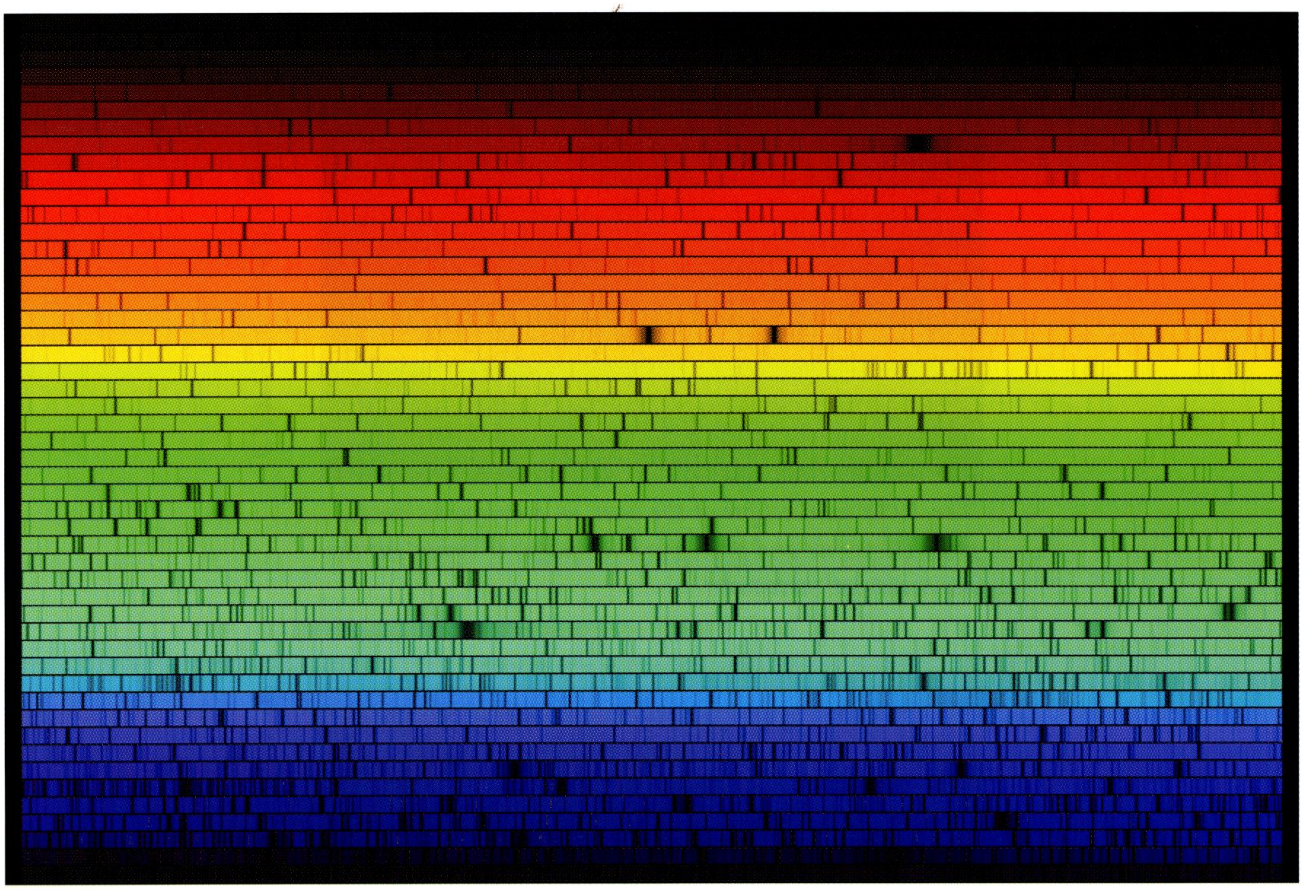

(N. A. Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF)

The solar spectrum, cut into a set of strips. The left side of each strip, except for the first, would really be joined to the right side of the one above it.

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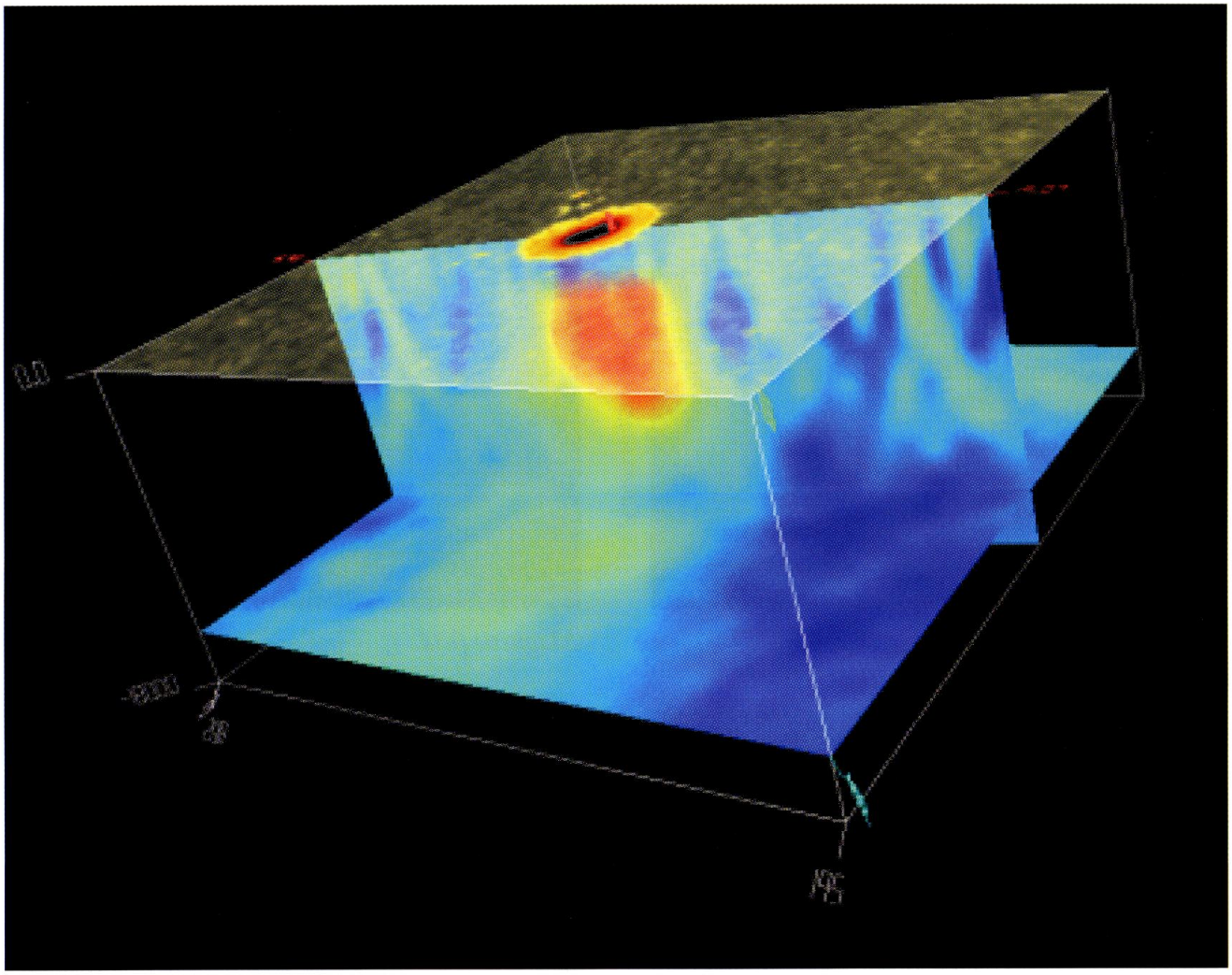

(MDI on NASA/ESA Solar and Heliospheric Observatory)

The speed of sound below a sunspot, measured by the Michelson Doppler Imager experiment on the Solar and Heliospheric Observatory. These results of helioseismology show the sunspot on the top, with its dark umbra surrounded by a lighter penumbra. Below it, we see to a depth of 24,000 km (15,000 miles). Faster sound speed shows as red and slower sound speed as blue.

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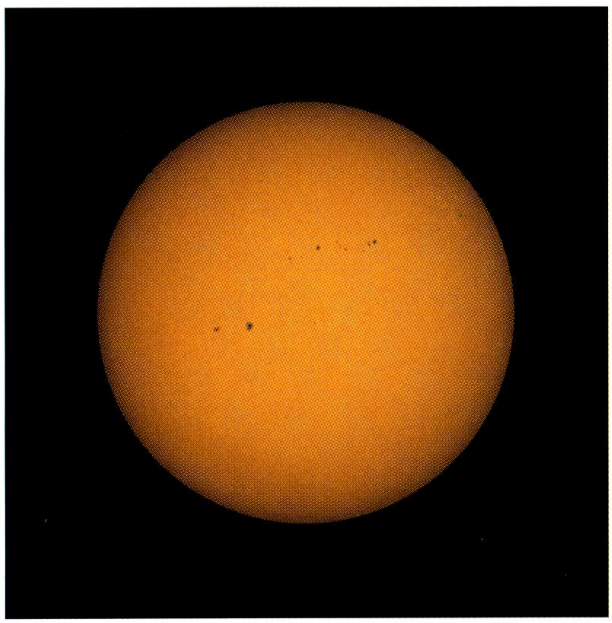
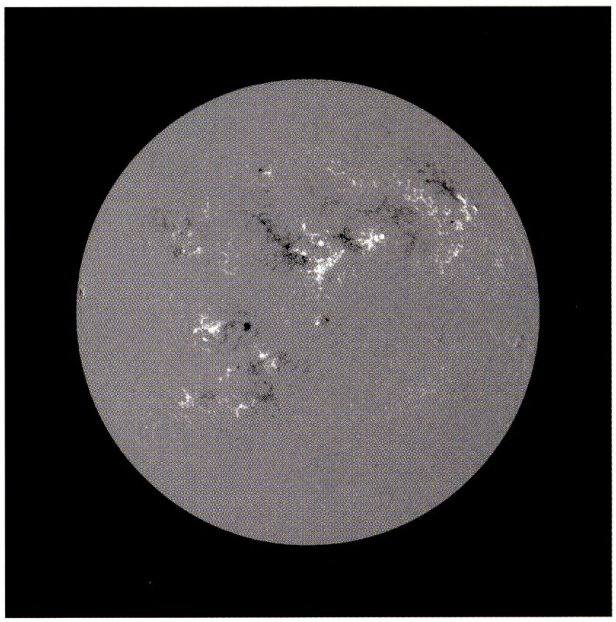
The images on this page and the next show the Sun in different wavelengths or different modes, all on the same day, February 8, 2001.



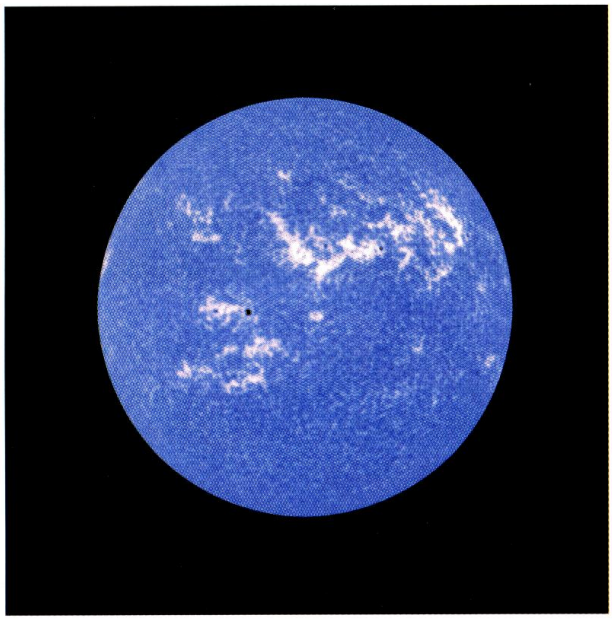
(ESA/NASA Solar and Heliospheric Observatory)

White-light sunspots.



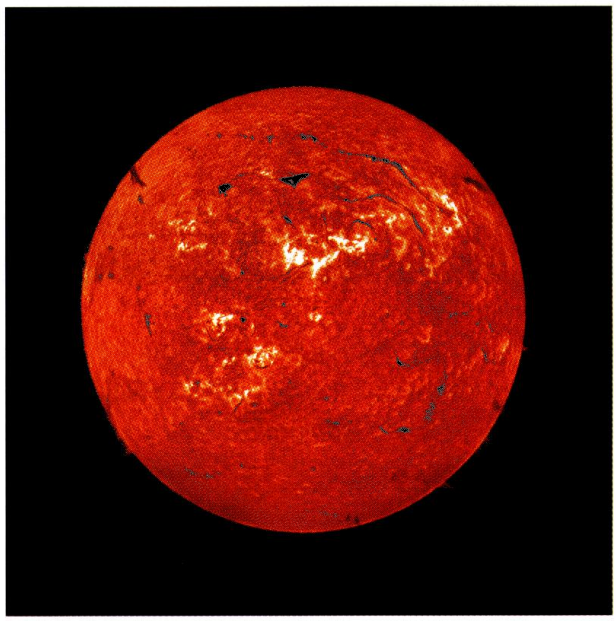
(ESA/NASA Solar and Heliospheric Observatory)

Magnetic field.



(Big Bear Solar Observatory/New Jersey Institute of Technology)

Ionized calcium, showing facular regions.



(Big Bear Solar Observatory/New Jersey Institute of Technology)

Hydrogen-alpha, showing plage regions.

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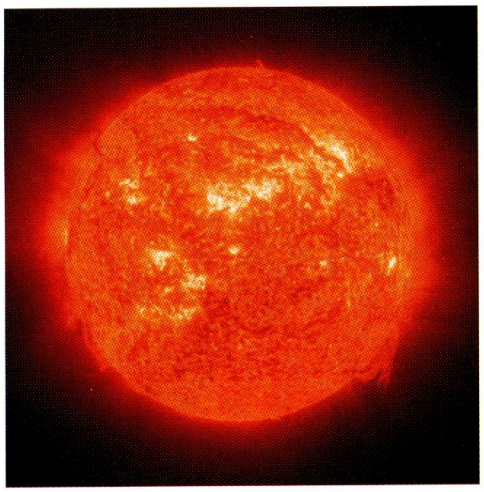
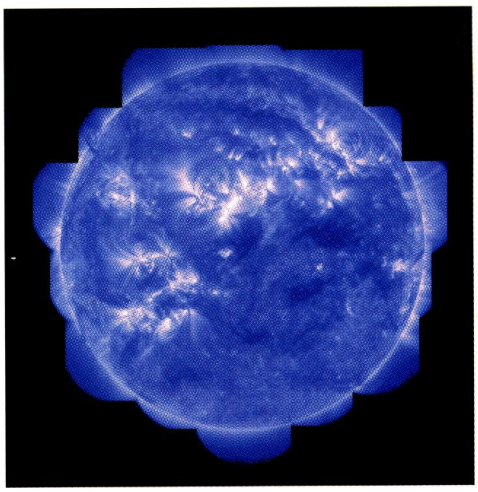


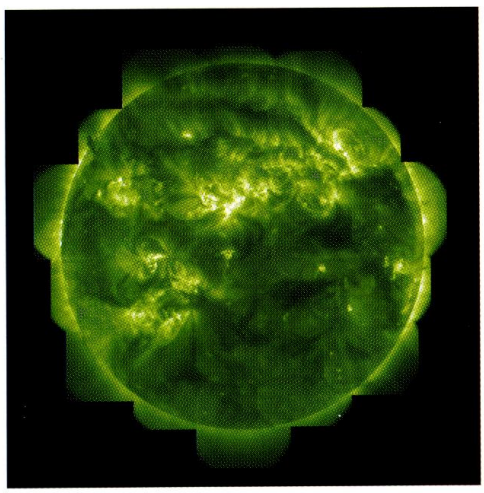
(ESA/NASA Solar and Heliospheric Observatory)

Helium in the extreme-ultraviolet from SOHO, showing the chromosphere at about 50,000°C.



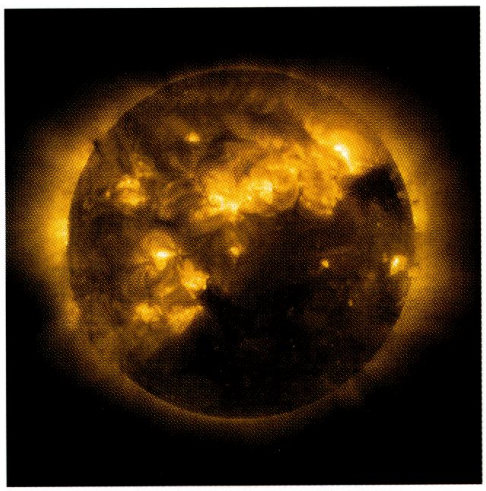
(NASA's Transition Region and Coronal Explorer)

Coronal lines of 1 million°C.



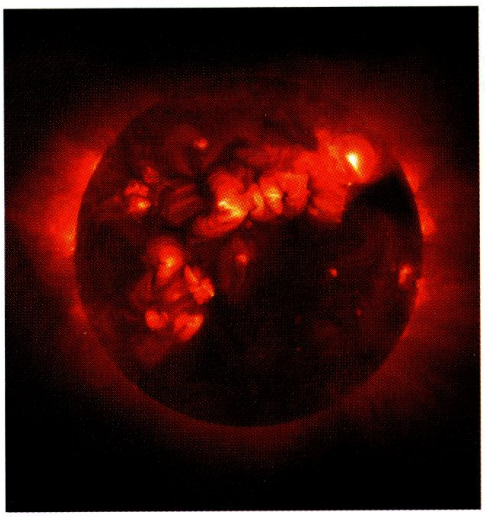
(NASA's Transition Region and Coronal Explorer)

Coronal lines of 1.5 million°C.



(ESA/NASA Solar and Heliospheric Observatory)

Coronal lines of 2 million°C.



(The Japanese-American Yohkoh spacecraft)

X-ray image from Yohkoh at 3 to 5 million°C.

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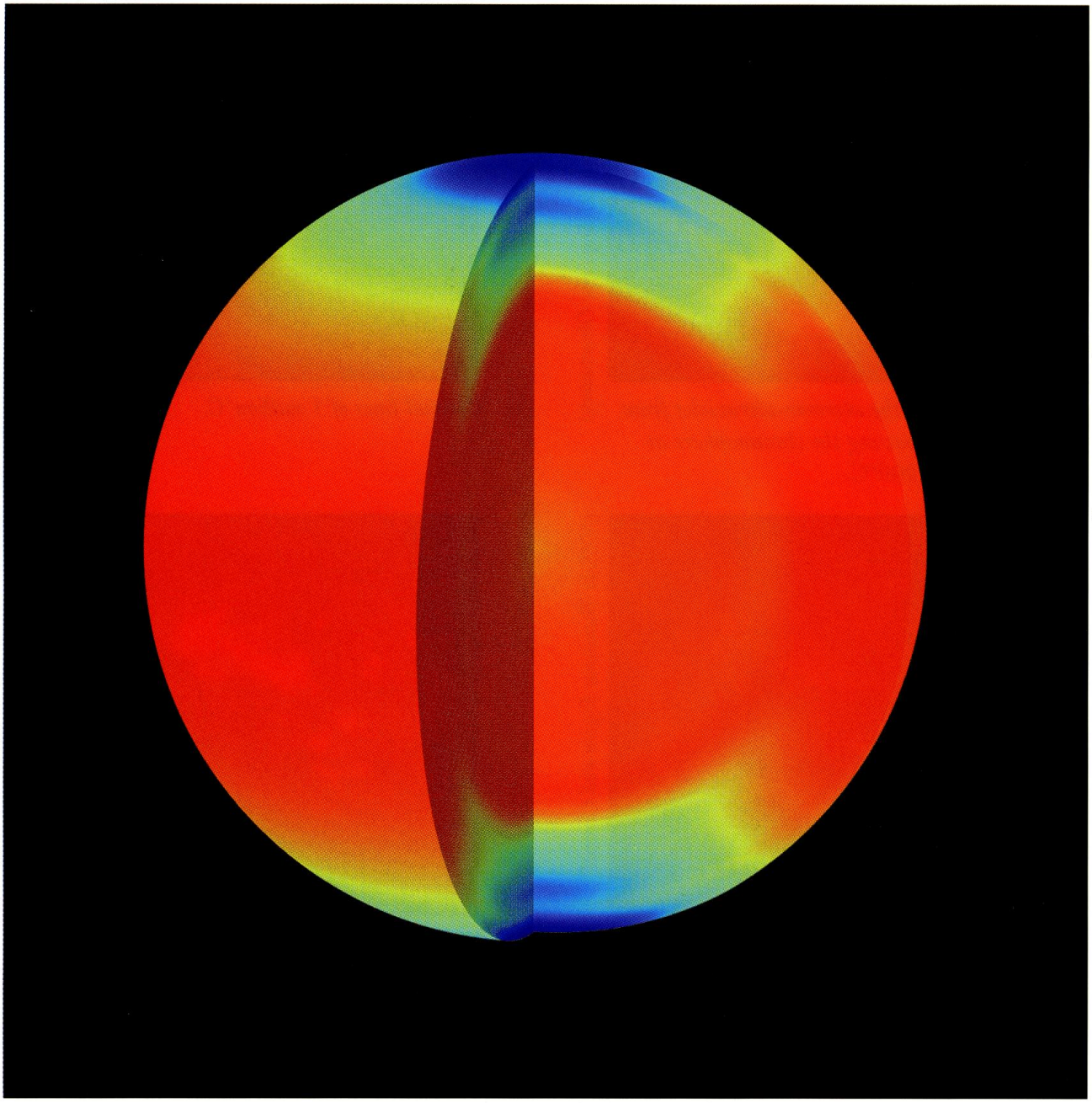

(MDI on ESA/NASA Solar and Heliospheric Observatory)

The speed of sound, measured with helioseismology from SOHO. We see both the equator-to-pole variation and the surface-to-core variation. Red indicates rotation faster than average and blue indicates slower than average. Helioseismology reveals the internal structure.

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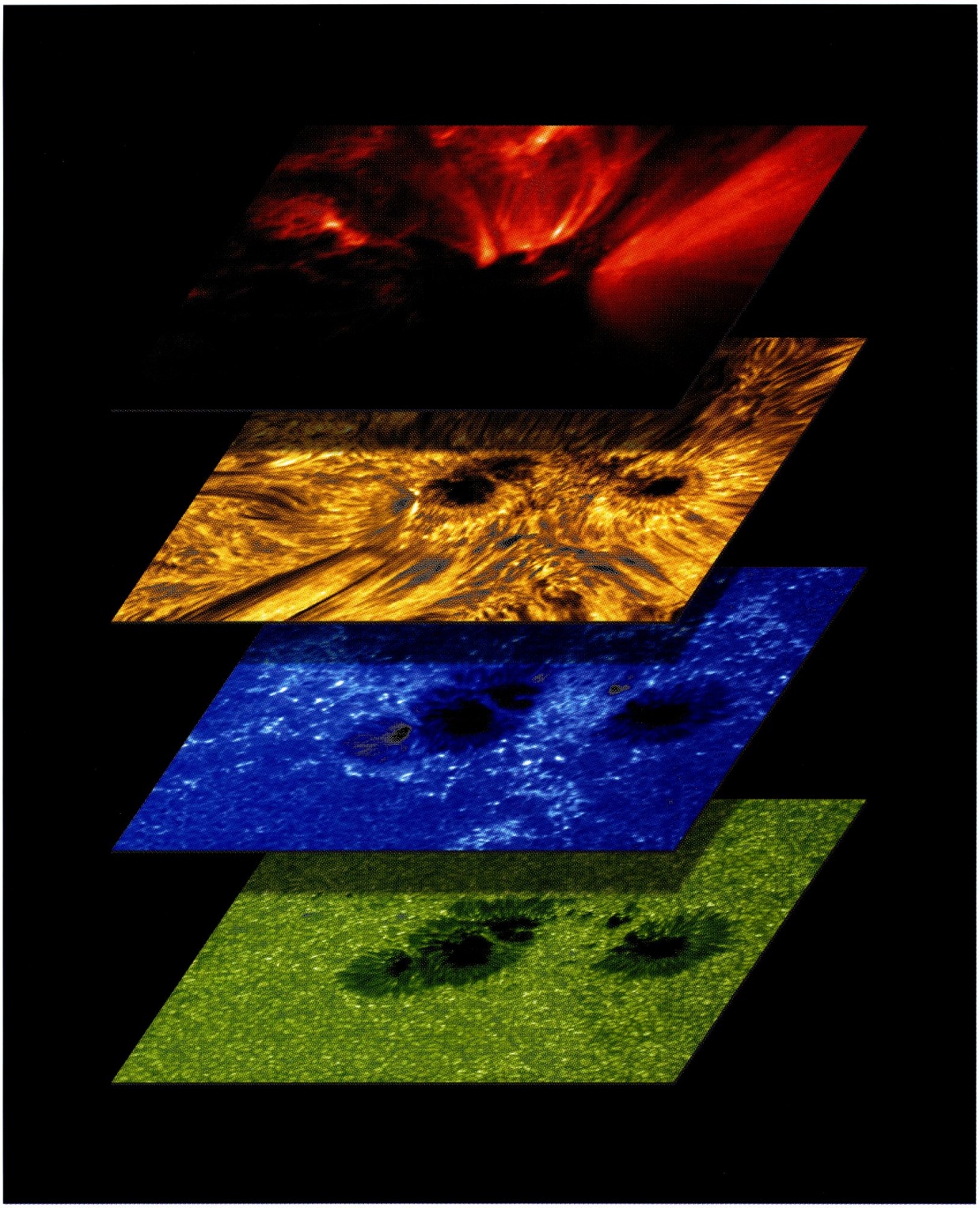

(Swedish Solar Telescope, Royal Swedish Academy of Sciences, with TRACE image, Lockheed Martin Advanced Technology Center, at top)

The Sun, at four different levels in the atmosphere. We see sunspots at the bottom, surrounded by granulation. Above it, we see chromospheric radiation in the light of the calcium K line at a temperature of about 10,000°C. Above that, we see the Sun in hydrogen light, in which features tend to trace the Sun's magnetic field. The top image shows million-degree gas from the corona.

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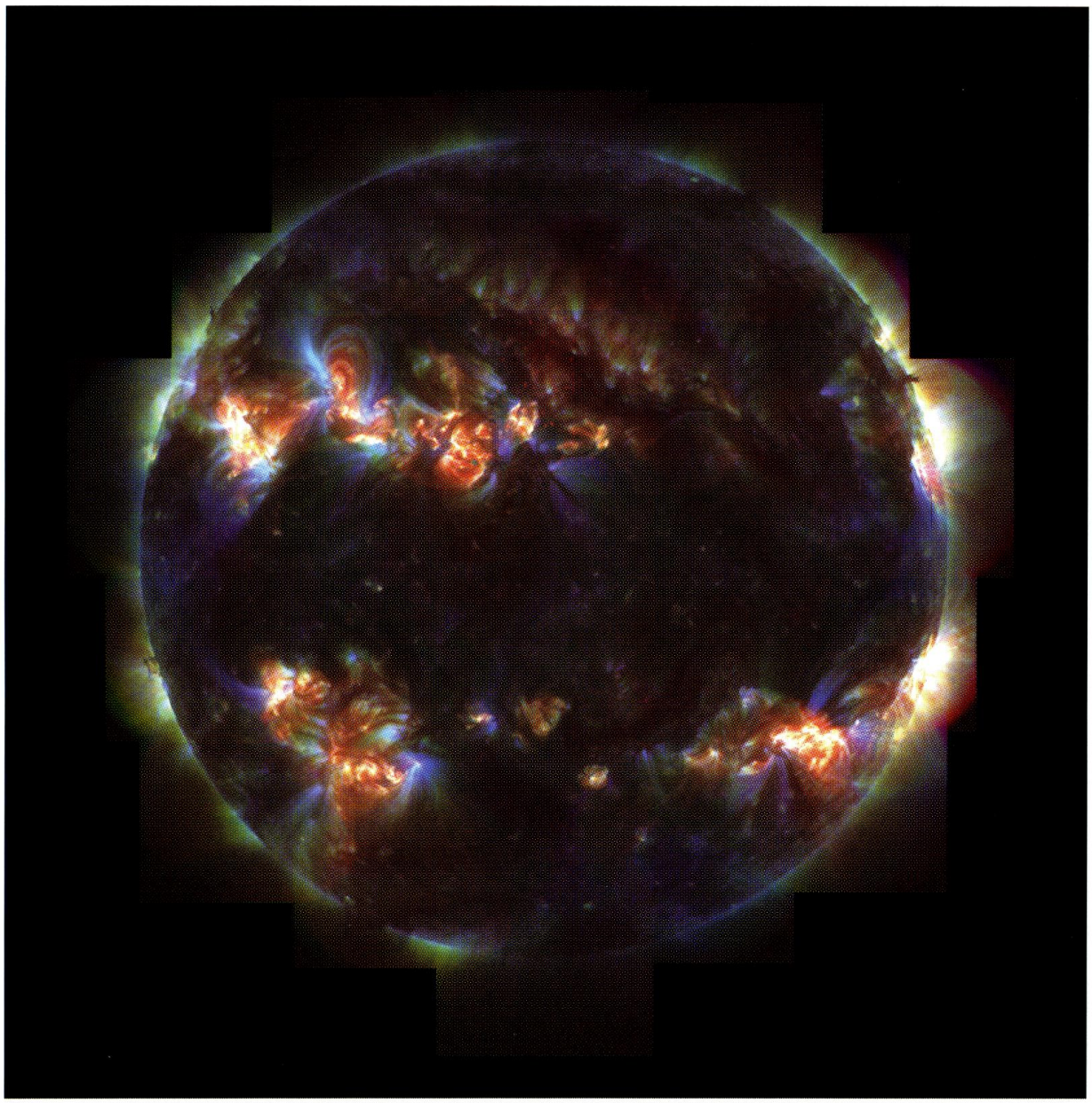

(Lockheed Martin Advanced Technology Center [Solar & Astrophysics Laboratory] and Smithsonian Astrophysical Observatory/NASA)

A false-color image combining the three coronal wavelengths observed by the Transition Region and Explorer (TRACE) spacecraft.

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just to that direction. As was rediscovered in 1771, the Sun rises directly over this heelstone on June 21.

Or can it? There are a lot of stones and, therefore, a lot of directions mapped out by points of them. Archaeologists were skeptical when the astronomer Gerard Hawkins pointed out the coincidences between directions mapped out by pairs of stones and the directions of the Sun at key times of the year. But over the past decades, the idea has been widely adopted. Stonehenge is a type of observatory that marks key directions toward the Sun—not only the direction toward solstice sunrise, but also directions toward the equinoxes. Directions significant for the Moon also exist among the various alignments. The trick is to prove that these alignments are intentional, not just coincidental, given the many ways that paths can be drawn between any two stones in a large collection.

Why were the stones erected in that way? Why did the huge standing stones, known as sarsens, get transported hundreds of miles (hundreds of kilometers) at a time when such transport would have been incredibly difficult? Surely the people there at the time didn't make an observatory for scientific purposes to study the Sun.

Perhaps some religious ritual was involved. It is easy to see that an ancient people, not comprehending the motions of the solar system as we have since Copernicus and Kepler, might have placed great significance on the Sun's slowing of its northern travel from sunrise to sunrise. They may have wanted to celebrate the time when the Sun stopped traveling north from day to day and started traveling south. Indeed, during a few days around the solstice, the sunrise moves imperceptibly from day to day, a period that could have been a celebration. Perhaps the date was important for fixing a calendar that could be used for agricultural tasks, like planting.

One can readily imagine that people marked the direction of the rising sun on the horizon from day to day, perhaps digging holes or erecting small stones or pieces of wood to provide sighting directions. Such activity shows the existence of a stable society, able to stay in one location long enough to carry it out. Only after hundreds of years had passed and the available resources and technology had increased did the people decide to erect huge stones where once they had had flimsier markings.

A less widely accepted idea is that an outer ring of holes, known as Aubrey holes after their discovery by John Aubrey in the seventeenth century, acts as a predictor of solar and lunar

The Solar Scoop

People today can have fun mocking Stonehenge. In Alliance, Nebraska, a site called Carhenge uses cars standing on end and erected as lintels to mimic Stonehenge. Carhenge, like Stonehenge, has popular websites.

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eclipses. The scheme advanced to use the Aubrey holes as eclipse predictors is complicated, and it is by no means clear whether the people of that time could have found it. Among the other difficulties is the fact that, most of the time, at that location in England, the sky is cloudy—even when an eclipse occurred, the people might commonly have missed it. (Even if the weather had been better overall at that time, many eclipses still would have been missed.) It would have taken decades of sightings before any pattern could have been established. The idea that Stonehenge is an eclipse predictor does not find general favor at the present. If it did, some say that scientific knowledge in England would have been more advanced than is currently thought. Accepting this chronology would force historians to change their ideas about which part of the world gained this knowledge first, and therefore about the direction in which knowledge diffused in the ancient world.

Meetings are still held to assess Stonehenge and what we know about it. From the facts on the ground, we try to imagine the minds of its creators. Even when we have a plausible understanding, that doesn't mean that it is accurate. We may be mirroring our own hopes and desires more than what the ancient peoples thought. Referring to the role of individual interpretation, it has been said, "Each generation gets the Stonehenge that it deserves."

Other "henges," circular arrangements of standing objects, have been located elsewhere in Britain. In recent years, a "woodhenge" has emerged in a tidal region, and archaeologists are trying to protect it. Many of these additional henges also have alignments between significant astronomical directions.

Where Comes the Sun?

Stonehenge isn't the oldest monument that has been linked to ancient astronomy. Giant mounds found in the Boyne Valley in Ireland contain huge tombs from more than 5,000 years ago. Newgrange, from 3500 B.C.E. to 2700 B.C.E., is a major stop on the tourist route.

The Solar Scoop

Too many tourists? Go early in the day to get a ticket to enter Newgrange, or the line may be too long for you to get inside.

Newgrange is thought to be an ancient burial place. Much of it has been excavated. A long tunnel leads from the outside into a central room whose ceiling is 50 feet (17 meters) high. On the day of the winter solstice, when the sunrise is as far south as it ever gets, sunlight passing through a slit over the entrance passes down the entire length of the tunnel for about 15 minutes. Surely this must have been on purpose.

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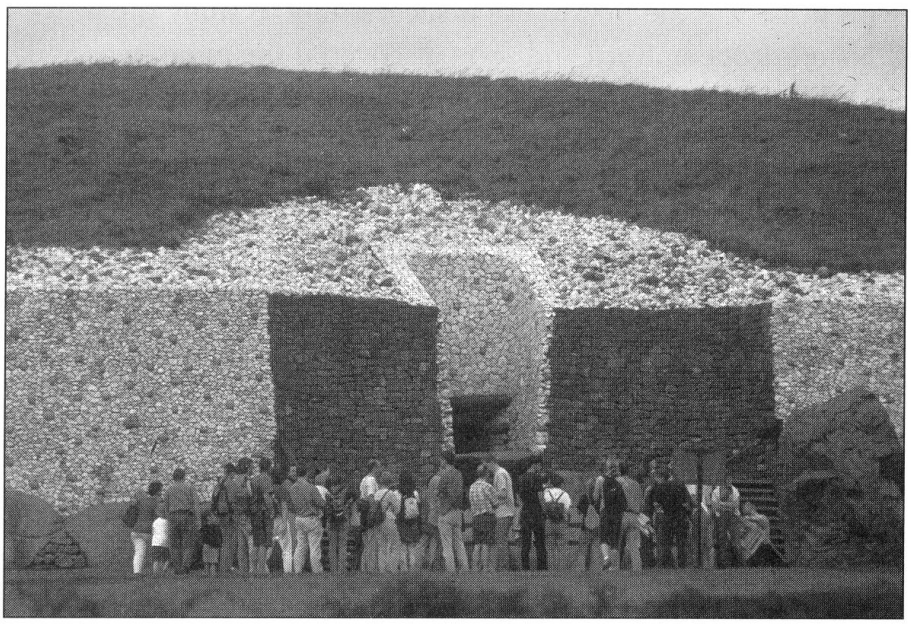
The view from Newgrange and nearby shows many tombs. Among the excavated ones is a substantial tomb known as Knowth. Though tunnels at Knowth are not as long as the entrance one at Newgrange, they are also oriented toward directions significant for the positions of the Sun and the Moon.



The front of Newgrange, as reconstructed, in the Boyne Valley in Ireland. On the winter solstice, sunlight passes through a slit over the entrance shown and illuminates the length of the tunnel beyond.

(Jay M. Pasachoff)

In all these Boyne Valley Stone-Age sites, many of the stones have been carefully carved. Patterns such as whirls were incised. Clearly, a major effort was placed on making these sites ceremonially beautiful, beyond any attempt at mere astronomical significance.

Who Found Sunspots?

It is ordinarily hazardous to look at the Sun directly. Only during a total solar eclipse, when the everyday Sun is completely covered by the Moon, can you safely stare sunward. Usually, the eye's blink reflex prevents you from staring at the Sun, which is too bright. But occasionally the Sun is dimmed by haze to just the brightness at which you can safely look at it without any filter. This situation happens perhaps most often at sunrise or sunset, when the Sun is on the horizon, but it can happen even when the Sun is higher in the sky.

Over the centuries, a sunspot on the Sun occasionally was so large that it could be seen even with the naked eye looking through haze. So the true date of the first sighting of sunspots is impossible to pin down. Ancient Chinese, Korean, and Japanese records recorded sunspots some 2,000 ago.

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With various reports of the first detections with a telescope, though, you might think that the date of the telescopic sunspot discovery might be accurately fixed. Here too, though, there is controversy and uncertainty.

Though Galileo may not have been the first to conceive of the idea of a telescope and to see a distant object with it, he was the first to use it successfully to study the heavens. In 1609, he turned his telescope upward and soon discovered the mountains and craters on the Moon, the phases of the planet Venus, the moons of Jupiter, and many other things. His book *Sidereus Nuncius*, published in 1610, contained all those discoveries. He went on to use the newfangled telescope to study the Sun in 1611.

Galileo, a portrait that appeared in his 1613 book on sunspots.

(Jay M. Pasachoff)

Though at first Galileo looked directly at the sun when it was faint enough at sunset, soon a student of his developed a technique of using the telescope to project an image of the Sun onto a screen. Then he could safely look at the screen. This method of "eyepiece projection" is still a popular and safe way to see sunspots. In his book on sunspots from 1613, Galileo drew the positions of the sunspots every clear day for a while.

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Fun Sun Facts

Galileo studied both the night sky and the Sun with a telescope, and he had good vision up to the ripe old age of 72. So it wasn't true that he went blind because he looked too much at the Sun, given that blindness from Sun watching happens quickly. Galileo undoubtedly went blind from glaucoma and cataracts, which might have been treated had he not been prevented from seeking medical care during his house arrest from 1633 to his death in 1642.

But Galileo was not allowed a triumph over the discovery of sunspots. The Jesuit astronomer Christopher Scheiner also claimed priority. The rivalry between them for credit grew quite bitter and may have played a major role in Galileo's ultimate condemnation by the Roman Catholic Church. Scheiner at first had thought that the dark spots he saw were images of Mercury in silhouette, but he came to realize that they were really on the Sun. He wound up following sunspots carefully for 15 years and became the authoritative source on them. His masterwork on sunspots was published between 1626 and 1630.

Fun Sun Facts

Even earlier than Galileo and Scheiner's fight over credit for discovering sunspots, Johannes Kepler saw a dark spot on the Sun in 1607 when he was trying to observe a transit of Mercury. He probably saw a sunspot instead.

So who first saw sunspots with a telescope? English scientist Thomas Harriot drew an image of one in late 1610 at about the same time that Galileo first saw them. David Fabricius and his son, Johannes, in Germany, and Scheiner first saw them in early 1611. Johannes Fabricius wrote about them in 1611, before either Galileo or Scheiner wrote letters about them in 1612, which were published in 1613 and 1612, respectively.

Solar Scribblings

David Fabricius was killed about five years after discovering sunspots when he accused a peasant of stealing a goose and, in return, was hit on the head with a shovel.

Cathedrals and Sunshine

Stonehenge was not the last of the ancient solar observatories. The Sun was considered a marker of significance in Europe from medieval times through the eighteenth-century Enlightenment period. John L. Heilbron, of the University of California, Berkeley, has shown that many of the most beautiful and significant cathedrals have

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holes in the roof and brass markers on the floor to follow the changing position of a solar beam of light over the year. Some of this astronomical application was fashioned in the seventeenth and eighteenth centuries.

The Roman Catholic Church has long been interested in calendars, especially in order to fix the date on which to celebrate Easter (lest people's souls suffer for celebrating Easter on the wrong day). In order to fix the date properly, the Church needed the best observations possible. So quite aside from its qualms about theories of the universe, the Church methodically, if quietly, saw that excellent data were collected. In particular, the Church used the meridian lines, the north-south brass lines put on the floor of many cathedrals for that purpose, to monitor exactly when the Sun returned to its yearly position in the sky at the time of the vernal equinox, a time not far from Easter. Calculating the date of Easter depended on this interval and on the intervals between full moons. Easter was set for the first Sunday after the first full Moon after the vernal equinox.

Fun Sun Facts

On May 28 and June 6 each year, the rising and setting Sun shines straight down each street in Manhattan's grid.

In 1543, Nicolaus Copernicus advanced his theory that the Sun, not the Earth, is the center of the universe (we now limit that centrality to the solar system), and the Church worried that his theory might contradict the Bible. Still, Copernican theory allowed astronomical events to be predicted more accurately than the earlier theories, so the Church used it all the time. However, as a fiction, the Church supposedly used it merely as a basis for calculation. Indeed, a clergyman (though not a Roman Catholic one) added the phrase "of the celestial spheres" to Copernicus's original title, *On the Revolutions*, to indicate that the work might apply only to calculations rather than to truth. Only with Copernicus's theory based on the Sun at the center could the date of the vernal equinox be predicted.

Among the cathedrals that were used as solar observatories were those in Bologna, Rome, Florence, and Paris. Huge obelisks outside the cathedrals carried sundials. Another meridian is at the Tower of the Winds in the Vatican. The data were used in advancing the Gregorian calendar, promulgated in 1582 by Pope Gregory XIII, which is the common calendar in use today.

Heilbron concludes that the Church's great interest in astronomy disproves the widely accepted notion that it was hostile to science, something that was most emphasized in its battle with Galileo. As long as clerics were able to say that Copernicanism was a theory rather than fact, they could teach any astronomy they liked. Indeed, Owen Gingerich of the Harvard-Smithsonian Center for Astrophysics has examined the 500 extant copies of the first and second editions of Copernicus's

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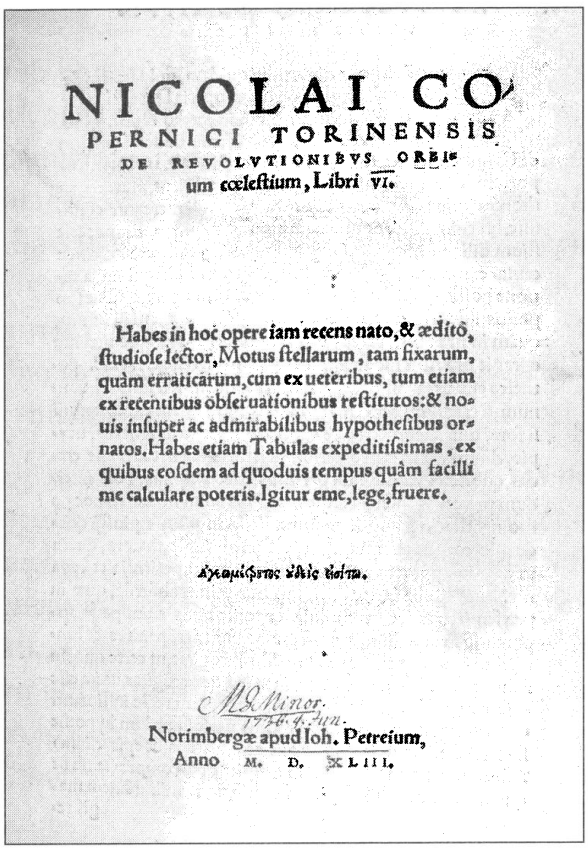
book. He found that only a few of them, and chiefly those in Italy, were censored (with supposedly offending passages blacked out), while the others circulated in their original form.

Even today, moving sunlight can be used in memorials. The winning proposal in 2003 for rebuilding the World Trade Center site in New York has a wedge of sunlight, defined by the new buildings, falling on the memorial each September 11 during exactly the hours that the twin towers stood after being hit on 9/11/01. The idea is reminiscent of solar markers in cathedrals of old.



NICOLAI CO
PERNICI TORINENSIS
DE REVOLVTIONIBVS ORBIS
um cœleſtium, Libri VI.

Habes in hoc opere iam recens nato, & æditô, ſtudioſe lector, Motus ſtellarum, tam fixarum, quàm erraticarum, cum ex ueteribus, tum etiam ex recentibus obſeruationibus reſtitutos: & nouis inſuper ac admirabilibus hypotheſibus ornatos. Habes etiam Tabulas expeditiſsimas, ex quibus eoſdem ad quoduis tempus quàm facilli me calculare poteris. Igitur eme, lege, fruere.

ἀγεωμέτρητος μηδεὶς εἰσίτω.

M. Q. Minor.
1776. 4. Jun.

Norimbergæ apud Ioh. Petreium,
Anno M. D. XLIII.

The title page of one of the fewer than 300 extant copies of the first edition of Copernicus's De Revolutionibus. *This copy of the book is bound in leather, typical of northern European rather than Italian bindings. Its northern-European association is consistent with the idea that the pages have not been censored, something that occurred more frequently in Italy.*

(Jay M. Pasachoff)

Fun Sun Facts

The great thirteenth-century painter Giotto is famous for his set of frescos in the Arena Chapel in Padua, Italy. On one frame in the sequence, a model of the chapel is shown, with the donor of the chapel offering it to the Virgin Mary. Each March 25, the feast of the Assumption and the date on which the chapel was consecrated, a ray of sunlight falls on the model. Before a door was closed permanently, another ray of sunlight through that door lighted up Christ's halo in the *Last Judgment*.

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South of the Border

No sites in North America are older than those in Britain, but we have both monuments and written materials from the Maya. The Maya flourished in what is now Mexico and Guatemala about a thousand years ago. Among the huge structures they left behind are giant pyramids at sites like Chichen Itza in Mexico's Yucatan peninsula, Tikal in Guatemala, and the Pyramids of the Sun and of the Moon outside Mexico City. Archaeoastronomers—people who study both archaeology and astronomy—have measured various positions and angles accurately at these sites and have found many alignments to significant astronomical directions.

These sites are recent enough that we have hope of finding out about the intentions of the creators from written material. The Aztecs made many handwritten books, bound together in fold-out volumes called codices. Unfortunately, when the conquistadors came from Spain, they wanted to destroy and overwhelm the civilizations they found in America. They burned all the codices they could find. Only a handful survived. One is in Madrid, Spain (now called, not surprisingly, the Madrid Codex); another notable one, the Dresden Codex, is in Dresden, Germany. The Madrid Codex once was on display at the Museum of the Americas on the university grounds in Madrid, but now it is kept in a vault and only a high-quality facsimile is on view.

Some of the symbols in the codices are thought to represent the Sun, the Moon, Venus, and eclipses. Unfortunately, we aren't always sure which. Still, the numbers have been decoded, and it is known that the Maya had an accurate calendar that was based not only on the Sun and the Moon, but also on the rising and setting of Venus. The Maya obviously followed Venus's position over many years, a sign of a stable civilization, in order to be able to track how often it rose as the morning star just ahead of the Sun. From this information, known as Venus's heliacal rising, they discovered that Venus had a periodic cycle of visibility. The Mayan calendar was more accurate than European calendars in use at that time.

It is still debated why Mayan civilization failed. Perhaps drought or warfare caused the collapse of their complex interactions. We suspect there is a lesson for our own civilization, even though we don't know what it is.

The Maya were not the only American civilization with astronomical alignments. Substantial constructions at Monte Alban and Mitla near Oaxaca, farther west in Mexico, are also of interest for archaeoastronomers because of solar alignments.

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Astronomy of "The People"

In the thirteenth century, the Anasazi tribe (the world *Anasazi* means simply "The People" in their language) built elaborate dwellings in what is now Arizona and other parts of the American west. Some of the dwellings show astronomical orientations. For example, the setting sun is visible straight through a particular window only on mid-summer night.

One of the best known phenomena is the "sun dagger" found in Chaco Canyon. A spiral was incised on a large rock. On a certain day of the year, a narrow strip of sunlight, like a dagger, descends on the rock after passing through a space between other rocks. It comes right through the middle of the spiral.

The Solar Scoop

Many people have visited the sun dagger and other sites in Chaco Canyon in recent years. Unfortunately, the rocks near the sun dagger have now settled, so the archaeoastronomical phenomenon no longer can be viewed.

Archaeoastronomers such as Edward Krupp, Jack Eddy, and Anthony Aveni continue to study various American sites. A giant circle of stones built between 1400 and 1700, for example, has attracted their attention. This Bighorn Medicine Wheel (here, *medicine* has the meaning of "magic") contains various alignments toward significant astronomical points. In particular, some point to the directions of sunrise and sunset on the day of the summer solstice. Others point to the rising points for bright stars at significant times of year. Krupp concludes from these and other alignments, and from his knowledge of Cheyenne rituals, that the astronomical alignments were put there on purpose. It is at least plausible that they were part of some rituals.

About 50 medicine wheels are known, ranging in size up to hundreds of meters (hundreds of yards) across. Some are thousands of years old, ranging back to the time of Stonehenge in Britain. Many of these other medicine wheels also have solar alignments.

The Least You Need to Know

- Stonehenge demonstrates knowledge of the Sun's motion from 5,000 years ago.
- Boyne Valley tombs show alignment to significant solar directions even earlier.
- Sunspots were first observed through a telescope by Galileo or perhaps by Scheiner.

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- Some medieval cathedrals marked the changing direction toward the Sun.
- The Mayan calendar was based on the Sun, the Moon, and Venus.
- Native American sites from hundreds of years ago had solar alignments.

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