

Native American astronomy



Maya Venus ephemeris. Pictured here are facsimiles of two pages of the Dresden Codex, a Mayan book made of painted bark parchment. Time flows from left to right. Intervals between observable celestial events are recorded at the bottom, while the dates of occurrence of these events in the 260-day ritual count are tabulated in the top 13 rows. At the bottom of each page are four two-digit base-20 dot-bar numbers, with each pair of digits arranged vertically. With each bar representing 5, each dot representing 1, and the blimp-shaped symbol as a place filler, one can easily read the four numbers as 236, 90, 250, and 8, the Venus station intervals. The two- and three-digit numbers just below the middle of each page are cumulatives of intervals. Just above these numbers are the hieroglyphic symbols of Venus. (Photograph courtesy of the American Philosophical Society, Philadelphia, Pennsylvania.)

Figure 1

Archaeoastronomers are documenting the work of the astronomers of pre-Columbian America, drawing on such evidence as ancient written ephemerides and precise astronomical alignments of surviving architecture.

Anthony F. Aveni

Looking into the past, we find cultures very different from our own, yet we find people doing many of the things we do—discovering celestial order through observation, developing calendars, creating cosmologies. As scientists, we often endeavor to explain the unknown by seeking likenesses with known phenomena. However, we must be particularly careful when we use this strategy to study the astronomy of other cultures, for we often become enticed into thinking that their motivations and goals were the same as ours. Warning of this “presentist” trap in the thick of the Stonehenge controversy two decades ago, a historian commented that every age fabricates the Stonehenge it desires. Perhaps we gain a measure of security if we convince ourselves that prehistoric Newtons and Einsteins were preaching and practicing our outlook millennia ago. But were they?

An eminent Mayanist once casually dismissed the notion that the ancient inhabitants of Yucatán could have been serious mathematicians and astronomers by suggesting that Maya astronomy was astrology pure and simple. However, in civilizations such as that of the Maya, world views featured a close connection between nature and the divine. In these cultures, religion and ritual behavior were not detrimental to the development of astronomy, but were the vital driving force behind it. Moreover, history teaches us that the desire to prognosticate human affairs motivated those who laid the foundation of our own scientific edifice. Astrology lay behind Kepler's drive to know the precise courses of the planets, and it served also as the principal motivation of the Babylonians—both our predecessors in astronomical science.

In ancient civilizations there was no bond between technology and the acquisition of precise knowledge, and our western notions of scientific progress and man's control over nature appear to have been almost entirely absent. Thus, if we are to gain a clear understanding of the astronomical pursuits of those civilizations, we must be prepared to view their activity through the

oddly colored glasses of their cultures.

An excursion through the basics of New World archaeoastronomy, a field that has undergone explosive development this past decade, will show us that beyond the mere listing of the objects observed and the precision with which they were reckoned, there is much to be learned from examining the astronomies of other cultures. Research in native American astronomy is particularly significant because, until the Spanish conquest, American cultures lay isolated by two oceans from all significant outside influence. Thus, we have a rare chance to learn how people in different times and places developed a knowledge of nature. Understanding this may give us special insight into our own science.

Archaeoastronomy is the study of the indigenous written and unwritten record relating to the practice of astronomy in the ancient world. The breaking of ground in this modern interdisciplinary field began in the early 1960s with astronomer Gerald Hawkins's pioneering work¹ on Stonehenge, which rekindled the idea that the great megalithic edifice was built to serve as a storehouse of alignments to key solar and lunar positions at the horizon. After more than a decade of debate between astronomers and archaeologists over the role of astronomy in the design of ancient ceremonial centers (a confrontation with territorial overtones), there has emerged in the 1980s a spirit of cooperation across the disciplines that has resulted in the formation of a number of research teams to which physical scientists have contributed enormously. A historical branch of the American Astronomical Society now lists papers on archaeoastronomy at the society's national meetings, and in the past two years physicists and astronomers have contributed to three international meetings on the subject.

A developed system of astronomy can be characterized by the systematic gathering, classification and storage of precise astronomical data accompanied by the creation and refinement of a methodology for reaching important future dates—what we would call a calendar. We expect to find such astronomy among high civilizations,

which need uniform time systems to delineate formally the timing of festivals, planting and the payment of tributes. The time base maintained by a developed state allows the collection of astronomical observations and the recognition of the periodicities necessary for setting up a calendar. Moreover, an organized society usually develops a means of transmitting acquired knowledge about the heavens, often through a written record. This tells us where to look to find developed astronomies in the Americas: among those civilizations that by all definitive standards achieved a high state of development—the Mayas and Aztecs of Mexico, and perhaps the Incas of Peru.

This article is an introduction to native American astronomy. Pre-Columbian astronomers were active in South America, Central America, Mexico and North America. It is not possible to cover all their activity in detail in one short article and still illustrate the depth of current research in the field. Therefore, we will devote much of our discussion to one example, the Maya of Mexico, a group whose astronomical activity is rather well documented. First, we will look at the Maya written record, which includes a very accurate Venus ephemeris. Then we will survey the architectural record—the astronomical alignments of surviving structures. We will go on to take a brief look at North American Indian astronomy, on which much research remains to be done. Finally, we will discuss some implications of the growing recognition that the key to understanding an astronomy is understanding the cultural context in which it is practiced.

Mesoamerican written record

Perhaps what excites us most about the ancient Maya of Mesoamerica (the latitudes of eastern Mexico that include the Yucatán) is that in addition to creating monumental architecture and exquisite sculpture and painting, they also had developed a system of writing and numeration. When we examine the handful of books (see figure 1) that

Anthony Aveni is Dana Professor of astronomy and anthropology at Colgate University, in Hamilton, New York.



Temple of the Sun, one among many buildings at the ruins of Palenque. Located on the fringe of the rain forest of Central America, this ceremonial center, erected about 600 AD, displays numerous calendric references linking the lives of rulers buried there to the occurrence of astronomical events. Inset: Calendric inscriptions on a tablet inside the building. (Photographs by Horst Hartung.)



survived the Spanish conquest and the scores of carved monuments that the Maya once displayed publicly in ceremonial centers such as Tikal and Palenque (figure 2), we discover a grammar like our own and a syllabary composed of more than 800 hieroglyphs. Some of these symbols represent astronomical objects and concepts. The symbol for Venus, for example, appears in figure 1.

Epigraphic studies shortly after the turn of the century^{2,3} revealed that the Maya had a numeration system with place-value notation and a concept of zero. Though we might be frightened away by the grotesque-looking pictorial accompaniments to the dot-bar numerals and hieroglyphs that appear in the Maya calendar of figure 1, a penetrating look at the page reveals that, like most Maya documents, astronomy bears its presence behind the veil of ritual. Adjacent to the Venus table in the Dresden Codex, or manuscript, named after the city in whose library it turned up three centuries after the conquest, is an ephemeris that gives the dates of solar and lunar eclipses.

The Maya achieved the eclipse algorithm by grouping lunar phase counts in clusters of 6 and 5, defined canonically as 177- and 148-day periods. Apparently they realized from long experience that it was only after certain combinations of such period-clusters that visible eclipses did indeed occur. Interestingly enough, the Maya

mapped out the entire eclipse program for the future with neither knowledge of nor interest in the concept of the nodes of the lunar orbit or the 19-year nodal regression period that has been given so much attention in megalithic astronomy of the Old World, where it is said to have been detected in the horizon extremes of the rising and setting moon.⁴ Instead, Maya astronomy gives the appearance of an almost purely temporal affair that made no use of orbits, heliocentrism or geocentrism—or indeed *any* centrism. Both the eclipse and Venus tables in the Dresden Codex contain only numbers and cycles that churn together like so many interlocking odometers to give forth predictions.

Precise Venus calendar. A closer look at the Dresden ephemeris may help clarify the Maya astronomical system. The table, which is recyclable, is 37 960 days long (about 104 years), a number the Maya undoubtedly chose because it is a multiple of the 584-day interval between successive conjunctions of Venus and the Sun, a 260-day Mayan ritual count generated by matching 13 numbers with 20 named days, and the 365-day approximation to the tropical year. The Maya were especially aware of the 8:5 ratio between the lengths of the Venus and Earth years, a discovery revealed to them through observation of the 8-year seasonal recurrence of Venus phenomena. Our way of classifying the planets heliocentrically

might lead us to lose sight of the special relationship in the sky between the Sun and Venus that the Maya seem to have emphasized. Unlike all the other planets (save Mercury), Venus follows closely upon the course of the Sun, never deviating by more than 46° from the Sun's position. Thus, the planet appears as the evening star in the west after which it is blocked by the Sun. During this period of blockage, known as inferior conjunction, Venus passes in front of the Sun. Then, one views Venus as the morning star in the east, before sunrise, only to find it disappearing into the Sun once again, this time by passing behind it.

The planet's pre-dawn heliacal rise, or first appearance after invisibility due to conjunction with the Sun, is symbolized by the apparition of Kukulcán, the god of Venus. Kukulcán is a man-god who, like the visible aspects of Venus, symbolizes the cyclic myth of departure and return (or death and resurrection) in the Maya world view. Indeed, in central Mexico the Aztecs confused Cortez with the returning Quetzalcoatl, their version of Kukulcán, whose return they anticipated precisely at the time of the Spanish invasion. Kukulcán is shown in the middle panel of each page of the Venus table flinging spears or dazzling rays of light—evil omens—at victims depicted in the lower panels. The rays represent the incipient light of the resurrected god who had previously absented him-

self from view. Evidently, the reappearance of Venus in different quarters after a prolonged absence carried various evil connotations for the people of Yucatán.

At the bottom of each page of the table (such as the pages shown in figure 1) we find Venus's 584-day synodic cycle broken down, not into the periods we would expect from reading one of our own astronomy texts, but rather into periods corresponding to the planet's four celestial stations described above. Venus is said to spend its 584 days as follows, with the actual mean periods given in parentheses:

► 236 days as the morning star (263 days)

► 90 days in the disappearance interval at superior conjunction (50 days)

► 250 days as the evening star (263 days)

► 8 days in the disappearance interval at inferior conjunction (8 days).

It is after the 8-day disappearance of Venus that the Venus god Kukulcán rises heliacally and flings his spears of light, thus casting evil upon Earth.

At first glance these numbers might lead us to conclude that the Maya were totally incapable of pinning down the great luminary. How else could they misclock one of the disappearance intervals by more than a month? But looking more closely at the calendar we discover that, like so many other numbers that appear in the Maya inscriptions, these intervals are contrived to blend with other numbers; for example, 236 days is 8 lunar months.

Whether this fact reveals a Maya attempt to relate Venus and lunar cycles in concrete observational terms, scholars cannot say at this stage. However, it seems very likely that one motive behind the selection of these deceptive-looking numbers lay in a ritual constraint that was built into the calendar. The Maya believed that only certain of the 20 named days that repeat to make up the 260-day cycle could be used to celebrate the transition of the planet from one celestial station to the next. This notion resembles our calendric habit of insisting that Washington's birthday be celebrated on a Monday even if that day is not the real anniversary of the event.

Examining these named days, which appear written across the table in 13 horizontal lines at the top of each page, historian of science Sharon Gibbs has argued⁵ that the canonic intervals probably were chosen to guarantee celebration of the Venus appearance closest to but not before the planet's actual first appearance. In fact, she showed that the tabulated intervals link specifically designated ritual dates occurring as close as possible to the events of last and first visibility without actually ever occurring during

disappearance. Indeed, such a ritual constraint would have placed a taxing burden upon the astronomer, for not only would he have to observe and record celestial events, but he would also have to worry about displaying his data in such a fashion that it exhibits certain commensurabilities with respect to non-astronomical cycles emanating from another quarter.

Paradoxically, even though Maya chronologists seem to be bowing to ritual by falsifying short-term Venus events, current research indicates that by the middle of the 10th century they had developed a correction scheme to keep Venus's canonic 584-day cycle of events on track with its true synodic period of 583.92 days. Expressed in our terms, the scheme, which called for the periodic omission of certain segments of the count, was accurate to 2 hours in 481 years. Such accuracy exceeds all attempts up to the Gregorian reform of our own calendar to keep an accurate account of the annual solar cycle.

Mesoamerican architectural record

Given such a precise calendar, we wonder: What observations are necessary to predict the heliacal rise of Venus, and is there any evidence in the surviving record about the *modus operandi* of Maya astronomy? Unlike the Babylonians, the Maya appear to have left us no observing logs or "notebooks"

delineating a record of their sightings. The codices seem to represent only the finished product—the public side of their science.

An important clue lay hidden for a long time in the standing architecture. The last decade of Maya research has shown that many structures are aligned toward astronomical events occurring at the horizon. A Spanish historian tells us quite specifically that in ancient Mexico City, King Moctezuma wished to arrange his principal Aztec temple so that the Sun would rise over the middle of it at the equinoxes, and that when the architects failed in their first attempt, they were forced to tear it down and straighten it! Such an act should come as no surprise once we understand Aztec and Maya ceremonial centers as places for the performance of important rituals. Moreover, it is reasonable to anticipate an emphasis on horizon alignments in the astronomies of people living in tropical latitudes. In the higher latitudes, diurnal motion clearly involves circulation about a pole. Celestial objects near the horizon move sideways as well as up and down as they rise or set. However, in tropical skies stars rise and set along tracks that are nearly vertical with respect to the horizon, making it easy for equatorial observers to classify directions on Earth by celestial reference points.



Caracol of Chichén Itzá, Yucatán, Mexico, a 10th-century Maya observatory. Sight lines through various openings are believed to have marked the horizon extremes of Venus. (Photograph by Horst Hartung.)

Figure 3

The precise time and place of the last visibility of Venus at the western horizon (before the planet moves in front of the Sun) constitutes an index of the length of time that the planet will remain obscured by the Sun during inferior conjunction.^{6,12} Therefore, we might expect that any Venus watcher in the tropics would set up horizon alignments to the west. Also, we might anticipate observation of the planet's horizon standstill positions. We find that while these horizon extremes occur on an annual basis as Venus moves more or less with the Sun, a seasonal cycle of *great* extremes repeats almost exactly after an 8-year interval, which is a period given considerable attention in the Dresden Codex.

At Chichén Itzá, the Maya, after their tenth-century AD conquest by the Toltecs, preserved precisely these Venus orientations in the Caracol, the round building shown in figure 3. The Caracol was erected about the same time the Dresden Codex was written, and is said to have been dedicated to the Venus god Kukulcán. Using surveyor's transit and astronomical fix, architect Horst Hartung, Sharon Gibbs and I found that a pair of diagonals in the windows of the turret, and another pair of alignments in the base of the building, point to within $\frac{1}{2}^\circ$ on the average of the places where Venus set over the western horizon at southerly and northerly standstills around 1000 AD, when archaeologists tell us the building was completed. More importantly, the origin of the Dresden Codex can be placed both in space and time quite close to Chichén Itzá. Thus, it is not too large a leap to suggest that the Caracol was the very astronomical observatory that lay behind the written Venus calendar.

Many aligned structures. Other buildings in Yucatán aligned to Venus include the Palace of the Governor at Uxmal. Its long facade and principal doorway face $28^\circ 05'$ south of east, which is within 2 minutes of arc of the southerly standstill position of Venus in 750 AD, when the palace is thought to have been built. Moreover, the entire structure, which was built on an artificial mound 400 meters on a side, is mis-aligned by 20° with respect to the other buildings at Uxmal, thus emphasizing its special nature and lending some force to the astronomical hypothesis. The principal pyramid at the ruins of Nohpat, a 25-m-high structure, is the only visible feature from the Governor's doorway on an otherwise flat horizon. It bears $28^\circ 13'$ south of east at a range of 6 km, or just 15 m off the perpendicular. Moreover, this pyramid accurately marked the "turn-around" point in the 8-year Venus cycle, which occurred at $28^\circ 03'$ south of east.

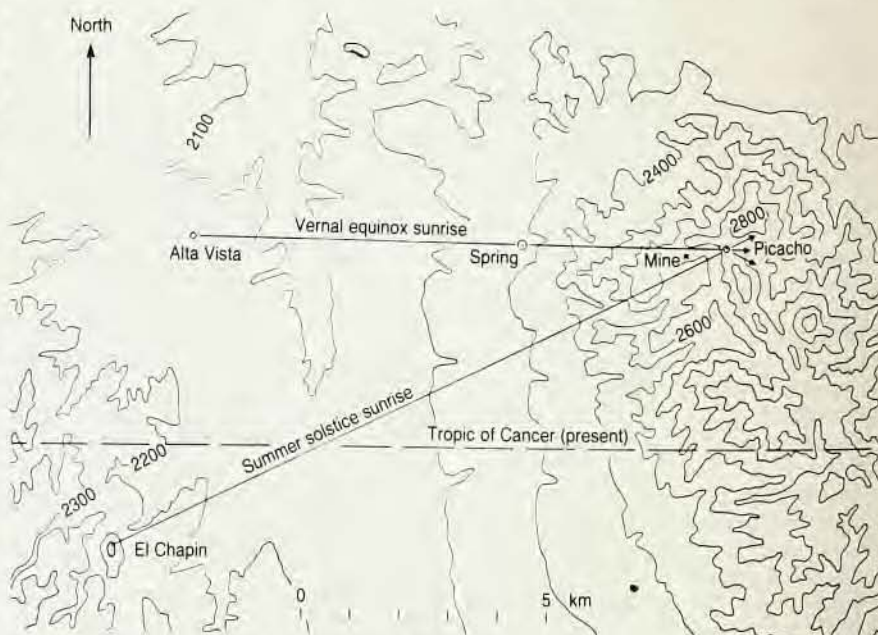
Just as archaeological data reinforced the hypotheses of astronomical orientation both at Chichén Itzá and Uxmal, so too iconographic evidence comes to the aid of astronomy at the Governor's Palace. Close inspection reveals that the cornice of the building is adorned with over 300 Venus glyphs carved in stone—the same ones that appear in the Venus table of the Codex. Also, the figure of a Maya rain god that appears at the northeast cornerstone of the building displays on its forehead the number eight—3 dots suspended from a bar—which may signify Venus's 8-day disappearance before heliacal rise, or perhaps its 8-year cycle.

The use of the surveyor's transit to collect data on the astronomical orientation of sites in central Mexico has revealed the interesting fact that all the sites are skewed clockwise from the north (looking down from above). This habit probably arose from a tradition established at Teotihuacán, the most expansive and influential site in all of Mexico, which flourished about the time of the beginning of the Christian era. Signs of Teotihuacán forms of pottery and architecture are found all over Mexico and Central America, including Maya Yucatán. At Teotihuacán, located near Mexico City, we find both a cardinal grid plan, that is, a grid oriented north-south and east-west, and a plan skewed to align with horizon events that may involve the Pleiades, a group of stars of central importance in Mesoamerican star lore. An equinox

alignment discovered in the 15th-century Aztec ruins of Tenochtitlán also has been documented at Teotihuacán 1500 years earlier, thus suggesting a long astronomical tradition.

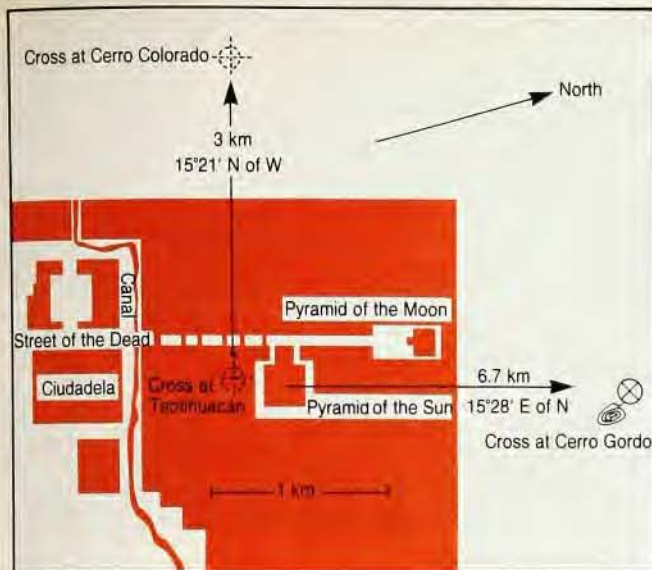
At the ruins of Alta Vista (near Chalchihuites, Mexico) we find evidence that colonists from Teotihuacán had attempted to find where on Earth the Sun turned around, that is, the tropic, where the Sun rises to the zenith at noon only for a day, and then returns to the south of the zenith for all other days of the year. We would identify the day as the June solstice. At Alta Vista, which is very near the tropic of Cancer (see figure 4), and at Teotihuacán we find identical petroglyphs carved in stone and in the floors of buildings to mark significant alignments. These symbols, of which more than 50 are known throughout Mexico, usually appear as a double circle centered on a cross. The curious design, shown in figure 5, is made up of holes hammered into stucco or rock with a percussive device.

These discoveries may indicate a widespread organized attempt to institute calendric principles on a "nation-wide" basis. However, we sense that at least among the Maya, astronomy still was governed by a ritual elite whose secret methods and knowledge were not shared with the man in the field. We can only wonder whether an esotericism of advanced astronomy and a consequent detachment between rulers and people might have contributed to



Double alignment scheme at the ruins of Alta Vista on the Tropic of Cancer. From a cardinally-oriented Sun temple to the conspicuous peak of the mountain Cerro Picacho one views the equinox sunrise. The June solstice sunrise is visible over Cerro Picacho from a pair of pecked circles (each like the one shown in figure 5) on a plateau just south of Alta Vista. In 650 AD, when Alta Vista was founded, the tropic was only about 14 miles north of the site. (Diagram by Horst Hartung.)

Figure 4



Plan of Teotihuacán (near Mexico City) and possible surveyor's mark. Often the grid plans of entire cities were skewed out of line with the natural landscape in order to point to important astronomical events at the horizon. In this case, the north-south and east-west axes of Teotihuacán are marked by sets of pecked circles (right). The E-W axis $15^{\circ}21' N$ of W is directed to the setting position of the Pleiades, which underwent heliacal rise on the day of solar zenith passage. (From reference 6.)

Figure 5

the precipitous collapse of the Maya civilization on the eve of the Spanish conquest of the Americas.

North American Indian astronomy

What of the rest of the Americas? While the civilizations of Mesoamerica have left us a relatively abundant corpus and a great variety of useful data, the cultures of the Andes remain yet alive. For example, ethnologists working in remote regions of the Andes offer evidence that contemporary people, descendants of the ancient Inca, know the same constellations and divide the space of their city according to the same solar observations at horizon made by their ancestors. Nevertheless, the question of the nature and practice of astronomy among the indigenous civilizations of North America presents problems. Our predecessors on the continent were almost totally submerged by the tidal advances of European culture. Nevertheless, archaeoastronomy on the North American continent has developed considerably in the past decade and a half. Archaeoastronomers have made particular progress in understanding the connection between ceremonialism and calendar, as evidenced by the many reports on work in this area at recent conferences at Oxford⁷ and Santa Fe.⁸

Most of the recent studies involve solar motion, but earlier findings indicate the possible recording of the 1054 AD supernova in native rock art, and the possible astronomical use of the Medicine Wheel of the Big Horn Mountains. This spoked circle, shown in figure 6, was fashioned out of large boulders some time after the 12th century. Astronomer John Eddy was the first to note⁹ the wheel's possible

use as a device for timekeeping.

Eddy offers a tight argument by illustrating a coherent alignment scheme. Alignments about the hub of the wheel point not only to the position of summer solstice sunrise, but also to the rising positions of three bright stars whose heliacal risings occur both at intervals of a lunar month and at times that mark each of the three months of the year that are warm enough for the semi-sedentary people who built the Medicine Wheel to occupy the Big Horn Mountains. Thus the wheel may have served to warn of the approach of cold weather.

The idea of employing one set of observations as a check on another, in this case the heliacal risings of stars and lunar events, is similar to but less complex than the Maya scheme described above for interrelating time cycles. Careful reflection reveals that the Inca of South America used the same method when they created an agricultural calendar that correlated their lunar months with both the seasonal year and events associated with the celestial course of the Pleiades. Thus, the Inca orientation system and the North American Medicine Wheel both served to relate solar, lunar and stellar periods by direct observation; that is, both were calendars free of calculation. We know that the Moose Mountain Medicine Wheel in Saskatchewan has a similar layout, but what about the others? There are over three dozen medicine wheels in the Rocky Mountain area that still need to be looked at.

Other astronomical orientation schemes uncovered in North America suggest a concern with precision in marking the time of year and an

interest in relating geometry and astronomy. Physicist Ray Hively and philosopher Robert Horn, both of Earlham College in Indiana, have shown¹⁰ that the prehistoric earthworks of Newark, Ohio, are laid out very accurately and have solar and possibly lunar alignments.

Casa Rinconada, which dates from the 11th-century Anasazi-Pueblo cultures of Chaco Canyon, New Mexico, is a giant circular "kiva," a structure intended for worship. It is perfectly aligned on the pole star and has a special window that may have been designed to admit the light of summer solstice sunrise, as the sketch in figure 7 indicates. The structure very likely had a 28-niche counting device built into it. Incidentally, the number of spokes on the Medicine Wheel also is 28, which may represent a count of the days on which the moon is visible.

At Fajada Butte, also in Chaco Canyon, light enters slit-like openings between a set of vertical slabs, possibly situated intentionally, and falls upon a carved spiral petroglyph in a partially darkened chamber. The elongated light spot, the movement of which reflects the course of the Sun, may have served to mark the equinox at noon and to indicate other times of the year as well. However, the apparent uniqueness of the device and the absence of other archaeological remains at the site suggest the need to search for other examples before we assign this one undue importance. In a huge adobe structure located in Casa Grande, Arizona, investigators have found accurate solar alignments at solstices and equinoxes. Here the light enters through horizontal portals arranged in rows high along the western wall

of the structure.

In Von Del Chamberlain's study¹¹ of the Skidi Pawnee of what is now central Nebraska, we find that even habitation structures may have functioned as observatories. Chamberlain finds that the standardized orientation and architecture of the earth lodges in which the Pawnee lived highlight a number of celestial phenomena, ranging from the movement of the solar disk to that of constellations known to have been named. An unusually rich record on star myths among these people aids our understanding of their ideas about astronomy.

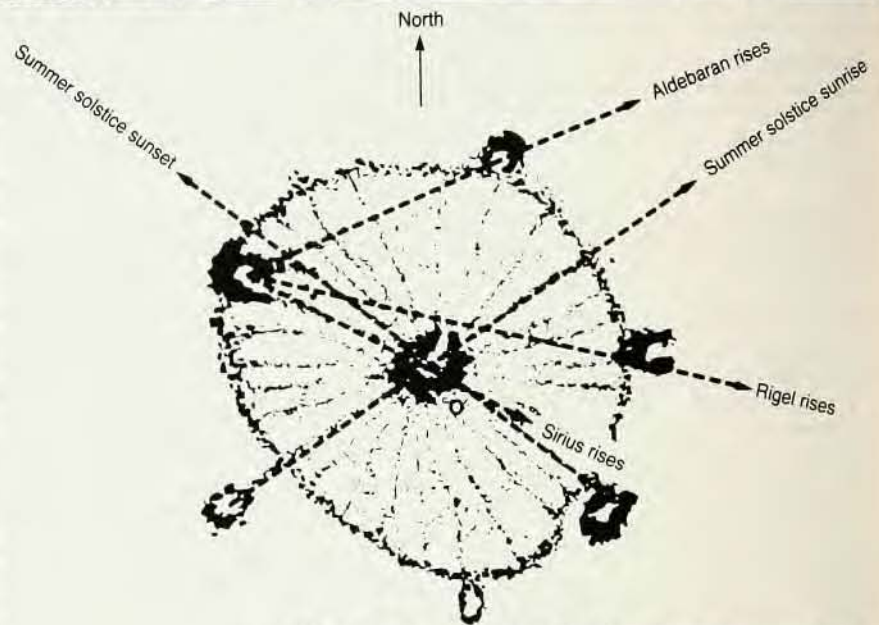
The Chumash Indians of California also had a great deal of interest in astronomy. Their astronomical record, which includes the sighting of comets, appears in the rock art of that area as well as in a handful of accompanying sites with solar alignments.

As the reader can see, evidence on the practice of astronomy in pre-Columbian North America is fragmentary, but fortunately it has begun to receive serious attention by a larger number of American astronomers. Interestingly, we have learned that many modern observatories are located in the same places that our native American predecessors were most active. Perhaps "long-eyes," as the Pima Indians called the astronomers at Kitt Peak National Observatory, gravitate toward the same observing grounds!

Context reveals meaning

The sky presents all of humankind with a set of universals; everywhere the Sun rises and sets, attains its horizon extremes and participates in eclipses. Thus, the sky becomes a laboratory for testing the question: Do all cultures react in the same way to the phenomena that pass before our eyes? However, interpreting reactions is not simple, and archaeoastronomers confront a problem that faces all students of antiquity: Have we exaggerated the degree to which ancient people thought like us? We can avoid the pitfall of creating false images of ourselves in the past only by gaining a broad knowledge of the people whose astronomy we study. We must know about their religion and ritual, their art and sculpture, even the organization of their families. For the researcher trained in the physical sciences, a serious venture into archaeoastronomy requires a substantial commitment, but the experience of learning about another culture's view of nature can be very rewarding.

In the case of British megalithic astronomy, which inspired the rebirth and expansion of interest in ancient New World astronomy, it is no easy task to understand the astronomy in terms of the culture. The stone age



Medicine wheel of the Big Horn Mountains, Wyoming, and its accompanying alignments. The diameter of the wheel is about 90 feet. There are 28 spokes. (USDA Forest Service photograph. Diagram from John A. Eddy.) Figure 6

Britons left us no written record, scant art works and only a few archaeological remains. Indeed, we have little more than the alignments to work with. If we are to believe in the astronomical interpretation of Stonehenge, not only do we need to establish that the claimed accuracy of the alignments is present in the standing stones, but we must also explain why these people would share with us the same penchant for precision. There is no doubt that early hunter-gatherers, semi-sedentary people who might convene for a time at a communal center such as Britain's Stonehenge or Wyoming's Medicine Wheel to trade or worship, would desire to mark events in time. We might well expect them to track the Sun and Moon and, perhaps, the bright planets. Alignments to the rising and setting points of astronomical objects make sense, given the sphere of inquiry of these people—but would they really

care to measure the 9-arc-minute lunar wobble, as some proponents of the astronomical interpretation have suggested?

Those who ask us to believe that these stone-age people, captivated by the finer details of lunar motion, and possessing the time to reflect upon esoteric matters, pursued knowledge for its own sake, are asking us to join them in the assumption that the ancients thought as we do. It may be romantic to think of our predecessors in this way, but our engineering does not make engineers of them nor do our computers make computing devices of their artifacts.

With a growing recognition that the cultural context holds the key to understanding ancient astronomy, New World archaeoastronomy has begun to flourish as evidence from ethnology, epigraphy, archaeology and mythology has joined the alignment data. One

lesson we learn from the interdisciplinary study is that things often turn out to be different from what we might have anticipated. For example, the rebuilt Aztec structure at Tenochtitlán to which we referred earlier is oriented precisely to the equinox sunrise even though it is misaligned with the east-west line by 7°. Only the written evidence tells us that the skew was due to the fact that the observation was made over an elevated surface, so that the Sun was observed only after it had moved some distance along the slanted path on which it rises. This example illustrates how far we may be from arriving at the truth if we follow the simple research path that isolates astronomy from the context in which it actually was practiced.

Was it science? Finally, we will all wonder: Is it correct to call the practice of the ancients scientific astronomy? Asger Aaboe, a historian of Old World science, gives¹³ us one of the most explicit definitions of scientific astronomy. He defines an astronomical theory to be scientific only when it gives us control over the irregularities within each [astronomical] period and thus frees us from constant consultation of observation records.

Such a theory is, essentially, a mathematical description of celestial phenomena capable of yielding numerical predictions that can be tested against observations.

Aaboe uses as examples Babylonian lunar texts from the Seleucid Era. It can be shown that the precise positions of solar and lunar conjunctions given in these texts could not have come from direct observations but rather must have derived from the application of certain purely mathematical functions that Babylonian astronomers had developed. Aaboe distinguishes scientific astronomy from the less advanced primitive astronomy, which is a kind of passive pastoral activity of recognizing constellations and marking the appearance and disappearance intervals of planets as evening or morning stars—the sort of celestial behavior to which one assigns certain “rustic tasks.”

This definition, should we press it, can be fulfilled to varying degrees by the cultures we have examined. The Maya, with their precise Venus warning table, would score high; the Chumash of California, perhaps somewhat lower. But what does it mean to ask of every astronomical pursuit: Is it science? One can argue that Aaboe's definition is culture-laden, specifically, that his standard of science is the result of over 3000 years of evolution along a particular path, during which elements of culture that affect our definition of science have changed. That evolutionary process included the rise of the

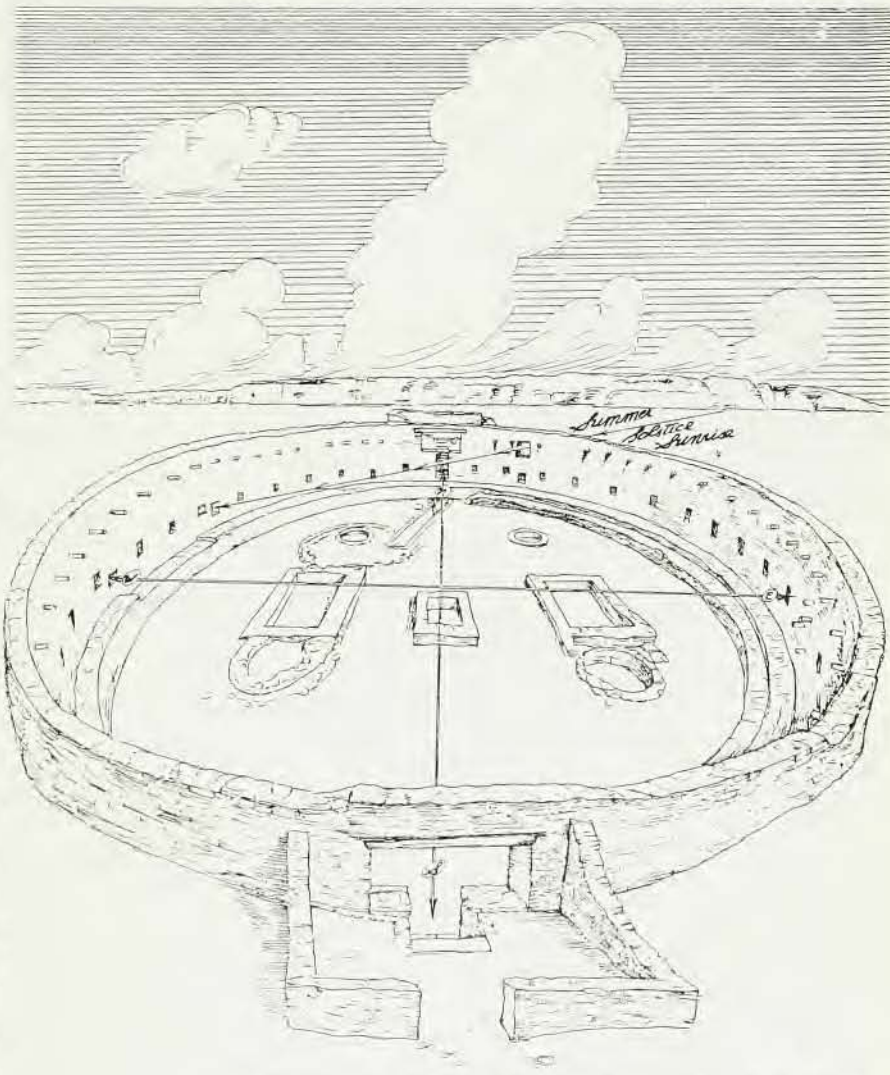
Greek ideal and the industrial revolution, to mention but two important developments that influenced the course of western science. Have we any reason to expect other people to think as we do if they did not evolve along the same cultural lines? From this point of view, to ask “Is it science?” is almost to ask if it is the product of western culture.

There is no space here even to summarize the abundant literature on the contrasts between traditional modes of thought and western science; the differences appear to be vast. For example, as Cornell anthropologist Billie Jean Isbell has suggested,¹⁴ the systems of classification that underlie western science seek similarities against backgrounds of differences; we strive for causal explanations. On the other hand, Native American thought systems seem to be organized around a dialectic that stresses simultaneous interdependence and contradiction. Applied to astronomy, this principle

argues that, for example, Andean astronomical phenomena are perceived only as dual pairs, such as the zenith sunrise and antizenith sunset alignments, which were prominent in the structure of Cuzco, capital of the Inca empire (figure 8).

An awareness of the vast differences between western and traditional modes of thought will lead us to ask different questions. Among some indigenous people of South America, a woodpecker's beak applied to an aching tooth is said to provide the cure. We might ask: How can a bird beak effect a cure? However, as anthropologist Claude Lévi-Strauss commented,¹⁵

The real question is not whether the touch of a woodpecker's beak does in fact cure toothache. It is rather whether there is a point of view from which a woodpecker's beak and a man's tooth can be seen as “going together” (the use of this congruity for therapeutic purposes being only one of its possible uses),

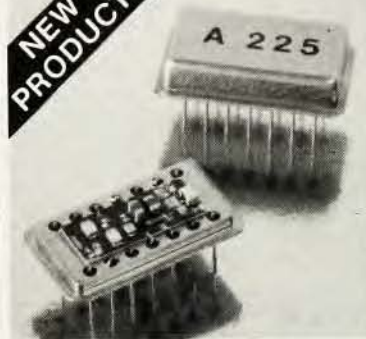


Pueblo Indian kiva Casa Rinconada, Chaco Canyon, New Mexico. This semi-subterranean place of worship is accurately aligned to the pole star. (Drawing by Snowden Hodges, courtesy of Ray Williamson, reference 8.)

Figure 7

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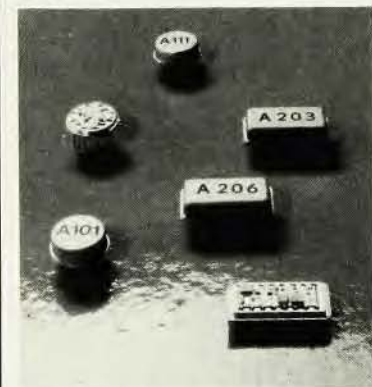
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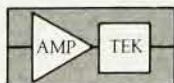
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Inca masons at Cuzco, as pictured in a 16th-century Spanish book¹⁶ about the Inca. The Inca built sun towers to mark the course of the Sun at the horizon. This allowed formalization of graded planting dates for different altitudes in the vertical environment of the Andes.

Figure 8

and whether some initial order can be introduced into the universe by means of these groupings. Perhaps we are finally beginning to ask a few correct questions about Native American astronomies.

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