THE NEW MEXICO MUSEUM OF SPACE HISTORY
CURATION PAPER NUMBER TWO
SPRING 2011

‘OOPS (NEVER ENDING),’ THE CONTINUING SAGA OF MILITARY MISHAPS IN THE TULAROSA BASIN, BY LT. COL. WAYNE O. MATTSON USAF (RET.)
AND
PART ONE OF THE ‘ASTRONOMERS BEFORE TELESCOPES’ SERIES, ‘THE AGE OF GIANTS (c. 2650 BC to c. AD 520),’ BY JIM MAYBERRY

LAUNCH OF LITTLE JOE II AT WHITE SANDS MISSILE RANGE, MAY 13, 1964
The New Mexico Museum of Space History, a branch of the Department of Cultural Affairs of the State of New Mexico, was founded in 1976 as the International Space Hall of Fame. The Museum includes the Clyde W. Tombaugh IMAX Dome Theater and Planetarium, the International Space Hall of Fame, the John P. Stapp Air and Space Park, and the Hubbard Space Science Research Building.

Publisher’s Note:

The New Mexico Museum of Space History is pleased to announce publication of the second in a series of papers, Curation Paper Number Two; it features ‘Oops (Never Ending),’ the latest in Lt. Colonel (Ret.) Wayne Mattson’s series on military mishaps in the Tularosa Basin.

Also in this issue is the latest in the series on the early history of astronomy, ‘Astronomers before Telescopes,’ by Assistant Curator Jim Mayberry. The series began with Curation Paper Number One; it can be downloaded from the museum’s website, nmspacemuseum.org.

There are many histories of astronomy in the Old World; few have focused on the people who lived those histories. As the names of astronomers of New World cultures are unknown, these articles will not deal with the Maya or other Native American groups.

The Astronomers before Telescopes series details the rise, and at times the decline, of the science of astronomy prior to the seventeenth century and the widespread use of telescopes.

Each chapter has an introduction, and short biographies in chronological order, as well as other articles. The series consists of:

1) The Age of Giants (c. 2650 BC–c. AD 520)
2) The Not So Dark Ages: the Rise of India and Islam (476-c. 1070)
3) The Pen and the Sword: Translators, Moors, and Mongols (1013-c. 1350)
4) Copernicus, Ulugh Beg and the Golden Age of Jewish Astronomy (1288-1575)
5) The Triumph of Europe (c. 1500-1652).

The lives of the more than 500 men and women discussed illustrate the progress of the science of astronomy, from its earliest days to the Scientific Revolution that led to the birth of our modern world.

In this issue is ‘The Age of Giants’; it is the history of the science of astronomy from ancient Egypt to the fall of the Roman Empire in AD 476, and the end of China’s Classical Period, around the year AD 520. It was first published, in a more limited form, as part of Issue 11 of the Space Journal.

The next chapter in the series is ‘The Not So Dark Ages: The Rise of India and Islam (476- c. 1070).’ It tells the story of astronomy in the ‘Golden Ages’ of India and Islam, as well as the slow return of science to Western Europe after the Early Middle Ages. ‘The Not So Dark Ages’ will soon be published as Curation Paper Number Three.

Curation Paper Number Three will also have an article by museum volunteer Stacie Pritchett on the everyday role of some of the ‘spin-offs’ from NASA’s programs. The ‘Astronomers before Telescopes’ series will then conclude with Curation Papers Four and Five.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oops (Never Ending) by Lt. Col Wayne O. Mattson USAF (Ret.)</td>
<td>1</td>
</tr>
<tr>
<td>Introduction, Astronomers before Telescopes: The Age of Giants</td>
<td>9</td>
</tr>
<tr>
<td>The Age of Giants (c. 2650 BC to c. AD 520)</td>
<td>14</td>
</tr>
<tr>
<td>The Age of Giants: Glossary of Terms Used</td>
<td>35</td>
</tr>
<tr>
<td>Early Astronomers in Contemporary Culture</td>
<td>49</td>
</tr>
<tr>
<td>Astronomical Features and Space Programs Named for Early Astronomers</td>
<td>51</td>
</tr>
<tr>
<td>Selected Bibliography</td>
<td>53</td>
</tr>
</tbody>
</table>

---

**The Stepped Pyramid, Built from 2630 to 2611 BC**

Author: Jim Mayberry, Assistant Curator  
Primary Editor: Stacie Pritchett
The skies over the Tularosa Basin started to reflect increased aerial activity in July of 1963 with the arrival of the 366th Tactical Fighter Wing (TFW). The Wing transferred from bases in France to Holloman Air Force Base and soon their F-84F’s were flitting around the New Mexico sky [1].

In preparation for the Apollo Program’s proposed trip to the Moon and back, the first launch of the Little Joe II missile took place at White Sands in August of 1963.

The plan was for Little Joe II, the abort system for the Apollo-Saturn vehicle, to reach an altitude of 33,000 feet. At that point, a radio signal was supposed to activate the destruct system.

Apparently, the radio signal failed to activate the destruct system, and the missile traveled further than anticipated but did remain within the bounds of the White Sands Missile Range (WSMR). In spite of the failure, the mission was termed a success [2].

As planned, the missiles would fly a distance of 350 miles to impact on the range. The first of these many launches started with a Pershing missile launch that successfully landed on the range [3].

Pershing missile launches occurred not only from Blanding, Utah, but also from Fort Wingate, New Mexico. October 23, 1963, saw the first failure of a Pershing missile in this program. Dennis Mitchell of KGAK, a radio station at Gallup, New Mexico witnessed the launch.

He reported that the missile seemed slower on liftoff than other firings. He said, “It went off at more of an angle than the others and when the second stage ignited, there was a little puff and no contrail.” Range safety destroyed the missile because it apparently would not reach the target [4].

The Alamogordo Municipal Airport was the scene of a fatal crash of a glider piloted by Captain Daniel M. Johnson of the 366th TFW as it was towed aloft one weekend. Witnesses to the accident reported that the craft began to ‘porpoise’ during takeoff; this problem has caused many gliders to break loose from the towline [5].

The first ‘Pad Abort’ test of the Little Joe II occurred in November of 1963. The escape tower rocket motor fired and 155,000 pounds of thrust carried the
dummy Apollo Command module to an altitude of 5,000 feet in eight seconds. Parachutes deployed and the dummy module successfully returned to the desert floor [6].

On the same day as the Little Joe II test, a sounding rocket carried two seven-inch diameter metal spheres to an altitude of 140 miles. At that altitude, the chromium-plated spheres were released to measure the distance between molecules at high altitudes. The spheres plunged to destruction somewhere in the desert of the Tularosa Basin [7].

Captain Jeremy C. Thomas safely ejected from his F-84F Thunderstreak one morning in November of 1963. He reported that the aircraft developed trouble and so he ejected east of Ruidoso, New Mexico. A helicopter picked him up, returning him to Holloman Air Force Base (HAFB) [8].

The Reclamation Unit is a five-man unit in the Aircraft Maintenance Division at Holloman Air Force Base. Their job is to tear apart every irreparably damaged piece of Air Force property and sell the basic materials to put money back in the military coffers. As part of their job, they handle aircraft accidents.

One of their longest and most rugged adventures was the recovery of the wreckage of Captain Thomas’ F-84F in the thickly wooded Sacramento Mountains, near Ruidoso.

The plane had buried itself through eighteen feet of pure hillside peat moss, with its LOX (liquid oxygen) pooled in the nose of the engine and still burning through the tailpipe.

Since the crash site was in the Lincoln National Forest, several forest rangers were present and pointed out the need to remove the entire aircraft inasmuch as a forest fire could result from flames running underground to nearby tree roots. The rangers told the Reclamation Unit to “Dig” and dig they did – through eighteen feet of New Mexico soil [10].

On February of 1964, a light plane carrying four persons crashed on the Don Merritt ranch southeast of the village of Pinion in the Sacramento Mountains. The FAA at Roswell, New Mexico reported that the blue and white Cessna, last seen at Lubbock, Texas, had been en route from Dallas to Nogales, Arizona.

Mr. Merritt reported finding the downed aircraft east of his ranch headquarters. He
found the bodies of the two men and two women aboard and immediately notified the Otero County Sheriff of his findings. The Sheriff and members of the New Mexico State Police left immediately for the scene of the accident [11].

In 1964, the Air Force proposed a series of tests of the Athena missile to solve many mysteries of atmospheric re-entry. An Athena missile would be launched from Green River, Utah, then climb to a very high altitude and simulate re-entry of a ballistic missile while impacting on White Sands Missile Range.

Normal tests called for the Athena to be a four-stage missile. The first test of the Athena had only two-stage missiles for this test. The first stage was for liftoff and the second stage was to carry the missile to the highest point before the return to earth.

A large contingent of the press corps, including the Managing Editor of the Alamogordo Daily News, Arlynn Bruer, attended the launch. Mr. Bruer said that the liftoff was “one of the most beautiful I have ever seen.”

The liftoff may have been nice, but the flight rapidly went sour [12]. The first stage never made it to WSMR, crashing instead sixteen miles east of Durango, Colorado. One nearby rancher reported that missile parts came down about 200 yards from one of his employees.

This resulted in the cancellation of further Athena tests until the cause of the failure could be determined [13]. About ten days later the Air Force announced that a short-circuit caused the Athena missile to veer off course after a mid-flight explosion [14].

During a test of an armed GAR-11 (Guided Aerial Rocket) on February 26, 1964, wreckage of a QB-47 drone was scattered around the White Sands Missile Range.

There were three B-47 aircraft which had been converted to drone aircraft (hence the “Q” in front of the B-47) to be used in tests of the advanced Falcon missile. The missile “kissed” the QB-47; the warhead exploded, scattering wreckage. The test was a “100 percent success” [15].

Later that day, the third in a series of Pershing missile shots from Fort Wingate, however, “fizzled.” The malfunction prevented the second stage of the missile from firing, and it crashed southeast of the launch site [16]. A later report from the Army said that the errant missile had landed in a cow pasture.
Rancher Vance Bond disagreed, saying that a piece of the missile “the size of a pickup truck” fell only 250 yards from Arthur Fox’s ranch home.

Fox, who was in the field feeding his herd, said his 150 cattle scattered over several sections after the wreckage fell. He then drove to Bond’s ranch home and telephoned Fort Wingate to protest [17].

Reports of “flying saucers” and “shooting stars” flooded police stations in West Texas, New Mexico, and Arizona the night of April 8, 1964.

It seems that four RF-4C Aircraft were dropping flares, and shooting pictures of the terrain; they were to do so for several nights in the future.

The tests, which were called “Operation Flashbulb,” centered on dropping flares that had up to 3,000,000 candlepower, from altitudes of 25,000 feet and more. The Air Force estimated that a flare, if dropped from that altitude, would light up an area more than 35 miles in diameter [19].

Later that month, a civilian pilot flying from Colorado to Mexico reported seeing the wreckage of a plane east-southeast of Carrizozo, New Mexico. The report said the wreckage appeared to be near an old mining site.

Lincoln County Sheriff Glenn Bradley accompanied a search pilot in combing the region until darkness halted the operation. Ground search teams also reported that they were unsuccessful [20].

The next day the land-air search revealed that the “downed aircraft” was actually an old military drone. The drone was located just where the civilian pilot had reported seeing the wreckage.

Normally, drones are a vivid orange or red to distinguish them from other flying craft, but this old one had silver wings, which...
caused a glint in the sunlight and attracted the civilian pilot.

To prevent a reoccurrence of the report of a “downed aircraft,” the wreckage was disposed of. However, during the search the sheriff reported that the remains of about half-a-dozen more old World War II drone wrecks had been located [21].

On May 13, 1964, a fiery explosion of a Little Joe II rocket shattered the early morning calm, scattering flaming pieces of the missile over a wide area of White Sands Missile Range. While this sounds like an accident, it was a deliberate explosion to test the Apollo Moon spacecraft escape system.

As the Apollo craft descended, a parachute recovery system was supposed to activate at 7,500 feet, but only two of the eight eight-foot diameter parachutes functioned as advertised. The third parachute broke free from the capsule soon after opening, but authorities considered the test successful [22].

Athena missile problems reared up again on May 28, 1964. The missile, which had been launched from Green River, was another test that would involve igniting only two of its stages.

Soon after launch, the missile “appeared to be straying from its course,” and Range Control had to destroy it in flight. This resulted in an aerial blast, which scattered parts of the second, third and fourth stages in an area about twenty miles northwest of the town of Shiprock, New Mexico [23].

On June 17, 1964, three F-84F Thunderstreaks from the 366th Tactical Fighter Wing were flying an aerial gunnery mission over the White Sands Missile Range.

One of the pilots, Major John C. Darby, was towing a Dart aerial target behind his craft. The Dart is a sixteen-foot, dart-shaped target of metal and wood that was towed by a steel cable behind another aircraft.

Captain John H. Chrietzberg was closing for a firing pass on the Dart. Just as he opened fire with his .50 caliber machine guns, a bolt of lightning from an overhead cloud flashed by the towing aircraft and hit the drone. The electrical charge, after striking the Dart, traveled up the cable to the tow aircraft.
Though this reduced the strength of the initial charge, it still gave Major Darby a hearty jolt, knocking both his hands off the control stick and throttle. It was a momentary shock only, and he regained control of his aircraft. He did experience tingling in both arms for about five minutes after the bolt struck [24].

The electrical charge was not finished with its mischief. The pilot doing the shooting, Captain Chrietzberg, reported the lightning bolt traveled up the path of the projectiles toward his airplane.

He said it looked as if the lightning was hopping from bullet to bullet, making a bright arc as it came toward him. It then hit the .50 caliber machine guns in the aircraft’s nose.

The intensity of the charge blinded him, knocking his hands off the controls, and numbing his left hand and arm. The aircraft then broke right and went into a shallow descending spiral dive.

Though conscious, Captain Chrietzberg had not regained the full use of his faculties and limbs. He thought his aircraft was in a diving turn to the left when in reality it was spiraling right. The substantial electrical shock had disoriented him.

The third pilot, Captain Edward J. Hughes, behind and above the shooting aircraft, sized up the situation and immediately started a line of “chatter” over the radio to raise the stunned Captain Chrietzberg whose vision was fuzzy and physical reactions slow.

Once Captain Hughes received a response from Chrietzberg, he began to talk the dazed pilot into the proper corrective actions to get the aircraft flying straight and level again.

The three pilots then headed back to Holloman, where they landed. Waiting for them were flight surgeons, who gave them a physical exam and then released them back to duty. Captain Chrietzberg reported that for about eighteen hours afterwards he still experienced severe tingling in both arms [25].

In December of 1964 Captain Hughes was selected by Tactical Air Command to receive the December “Pilot of Distinction” award for his quick thinking in saving the life of Captain Chrietzberg during that fateful mission of June 1964 [26].

On September 9, 1964, the U.S. Air Force bombed the community of Boles Acres, south of Alamogordo. It seems that around 2:00 pm, an F-84F Thunderstreak of the 389th Tactical Fighter Squadron, part of the 366th Tactical Fighter Wing was taking off and heading for the Melrose Bombing Range near Cannon Air Force Base at Clovis, New Mexico.

During the turn toward the north and the climb-out to altitude, a Mark-76 practice bomb inadvertently jettisoned. The Mark-76 weighed about 70 pounds, and contained about ten grams of black powder as a spotting charge; it is used by the pilot and the ground observers to score the accuracy of bomb delivery. The black powder charge is equivalent to about two shotgun shells.

The bomb landed on the property of Mrs. Josie Cypret, of Boles Acres. She reported that she saw a flash and called the New Mexico State Police who, in turn, contacted Holloman Authorities.
Explosive Ordnance Disposal personnel from the base responded to the call and found the remains of the bomb. They reported that detonation of the spotting charge had damaged a wire fence [27].

The headline in the Alamogordo newspaper of November 30, 1964 proclaimed “Missile Hit Off Target In Colorado.” A Pershing missile fired from Hueco Range near Fort Bliss, Texas, that was intended to land within White Sands Missile Range had instead made a trip to the mountains of Colorado.

The article stated: “With one loud blast and a series of short ones the missile slammed into the snow-covered area around Creede, Colorado about 75 miles northeast of Durango.”

The sheriff of Creede said that people at first thought it was a dynamite blast while nearby miners thought it was a sonic boom.

The missile was the fourth firing of a two-day series by a missile battalion from Fort Sill, Oklahoma, who were conducting exercises at Hueco Range.

The Army sent a team into the impact area to retrieve the remains of the errant missile [28]. Three helicopters were used in a search for the missile, which had gone about 400 miles off course.

The Army said that the missile’s second stage apparently fired in flight and did not separate as expected; this forced a search of snow-covered mountains.

The Sheriff said that the mountains rise up to 3,000 feet higher than the projected impact point and the snow was at least four feet deep [29].

A day later, a newspaper report indicated air turbulence grounded one helicopter while two rented vehicles from Durango were still searching, though their efforts were hindered as well [30].
NOTES

15. Alamogordo Daily News, February 26, 1964, Page 1
INTRODUCTION, THE AGE OF GIANTS (c. 2650 BC to c. AD 520)

The title of this article refers to the quote by Sir Isaac Newton, “If I have seen further than others, it is by standing upon the shoulders of giants.” He was discussing his predecessors such as Galileo, Kepler, and Copernicus, but some from ancient Greece, China, and other lands had earned his praise as well.

Time has erased much of their words and deeds, but what has survived is a testament to the insights and successful methods of the earliest known Old World astronomers. Their lives and work offer a clear narrative of the growth of astronomy from its origins to a true science.

Cosmology, which is the study of the universe and the role of humanity in it, was a key element of early astronomy; it will form much of this discussion, and those in the rest of the ‘Astronomers before Telescopes’ series (see Curation Papers One, Three, Four, and Five).

The Ziggurat of Ur (built between 2047 and 1982 BC), in the Sumerian city of Ur

From its earliest days, another important part of the science of astronomy was what most would call astrology today. The two fields were closely associated in all of the emerging societies in the Old World.

The Sumerians created the world’s first civilization; it arose in the valleys of the Euphrates and Tigris Rivers, in what is now Iraq, no later than the year 4000 BC. On the banks of both of those rivers, small city-states began to form in or near land that was suitable for irrigation farming.

In the next thousand years, civilizations developed in two more river valleys, first the Nile, and then the Indus. In both of these areas, as well as in Sumer, some of the hallmarks of civilization that govern society to this day began to take shape.

Some of these shared features were organized (more or less) government, intensive agriculture, literacy, and religion, as well as trade and commerce; all of these needed surpluses of food and other goods. This was possible only with the knowledge of natural cycles; much of this, in turn, came only from studying the sky.
In its earliest form, astronomy focused on finding reliable ways to predict the changing of the seasons, the phases of the Moon, and the lengths of the day and night.

Some of the most critical events tied to the heavens were the timing and duration of both rains and river floods, as well as the length of growing seasons for crops. Some evidence suggests that the first systems in both writing and math may have been records of astronomical observations.

A central part of the belief systems of most members of all early societies was the sky and the changes in the vault of the heavens. As eclipses, comets, meteor showers, or other events in the sky occurred every few months, knowledge of such phenomena in the past soon proved crucial in predicting similar happenings in the future.

Those trained in the lore of watching the sky conducted these services. Some of these individuals became leaders in the early civilizations that flourished from the Nile valley to the Indus River.

This process repeated itself in the Bronze Age kingdoms that appeared by 2000 BC in other areas of the Middle East as well as in China. In all of these cultures, astronomers would be aligned with both religious and civic institutions.

Around the year 600 BC, something unprecedented was in motion; it was the beginning of what some have called the ‘Greek Miracle.’ Scholars in the port of Miletus and in other Greek cities and colonies along the coast of the Aegean Sea in what is now Turkey began to question much of the accepted wisdom of their day.

Not only did they study astronomy and other sciences in Egypt and the Middle East, these men, who were the first to use the words universe and philosophy, soon took astronomy far beyond the purview of religion. They made it part of the realm of empirical science. This was the beginning of much of math and science of the Western world. These Greeks thus set in motion events that
reverberate in the lives of almost everyone on Earth to this day.

At the same time, the Greek world was expanding beyond the shores of the Aegean Sea; by 500 BC, Greek colonies covered much of the coasts of the Mediterranean and Black Seas. The Greek cities of Sicily and the south of Italy grew so prosperous that the area was soon known as ‘Greater Greece,’ as the former colonies there had eclipsed the motherland in wealth and power.

By the year 338 BC, Philip II of Macedon, a kingdom on the northern edge of the Greek world, had conquered much of the Balkan Peninsula; this included most of what is now Greece.

From 334 to 323 BC, his son and heir, Alexander the Great, vanquished the vast Persian Empire. In the process, he would help to spread Greek culture to the Indus Valley and Central Asia; to the Greeks, these were the ends of the world.

The conquests of Alexander the Great

One of the most crucial factors in the rise of astronomy in this new, wider Greek world was the founding of the Museion; this included the Library of Alexandria. Both of these were in the new capital of Egypt, the Greek city of Alexandria; it was but one of the twenty cities that Alexander named for himself.

From the early third century BC on, scholars throughout the Mediterranean world would work in both institutions. The Library continued to prosper even though one of the kings of Egypt had the Museion closed in 145 BC. This tradition of learning ended when a Christian Roman Emperor closed the last remnants of the Library in the year AD 391. Soon Christians drove the surviving members, most of whom were pagans, from their homes. In AD 521, in Athens, the Christians closed the last pagan school of note in the Empire.

By 100 BC, much of the science of astronomy as it would be practiced in the West for hundreds of years was in place. This was from the development of both mathematical and spherical astronomy by the Greeks; they had created trigonometry by then as well.

After the year AD 150, the pace of most sciences, including astronomy, in the
Mediterranean world had slowed and in many fields, declined. Much of this was due to the conquest of most of the Greek states west of Persia by the Romans by 64 BC. The Romans may have been the most successful empire builders of all time, but most of them held astronomy in low regard; this was in stark contrast to their love of astrology.

When Constantine the Great began to promote Christianity in the Roman Empire in AD 313, the practice of astronomy was further discouraged. This was due in part to the dominance of pagans in the field. Most of the scholars soon to be expelled by Christians fled to Babylonia; the Zoroastrian Persian Empire ruled that land at the time.

There the exiles would have found, if their paths had ever crossed, astronomers at Jewish Talmudic academies. Babylonia had been the center of the Jewish world since AD 136; that year the Romans had banned the practice of Judaism in their empire.

Joined by the Jewish exiles from Rome, Jews in Babylonia had founded the first Talmudic Academies sometime around the year AD 200. This was the dawn of an astronomical tradition unique to Judaism. It would last for more than a thousand years; only the flames of the Inquisition put an end to it.

The earliest known astronomers in China lived in the Warring States Period (475-213 BC). A great deal of knowledge of the country’s origins disappeared in 213 BC. That year, the founder of the Chin dynasty tried to destroy all books that came before him; this crime took months of burning.

A unified China first emerged in the Chin dynasty, and then from 206 BC to AD 220, under the two Han dynasties (at first, the Western Han, and then the Eastern Han). This was a time of growth for astronomy in that land; the science would be closely associated with the government from then on.

An ‘Oracle Bone’ they are the oldest records in China; many of them, like this one, were carved on turtle plastrons and not on bones (photo credit: Paul Halsall)
The mountains and deserts to its west helped to keep China isolated from most of the rest of the world until sometime around the year 200 BC. That was when the ‘Silk Road’ trade route to Central Asia and the rest of the West began. Even this led to very limited contact with the civilizations of the Middle East and the Mediterranean world.

China’s astronomy soon surpassed that of the Greeks in some ways, but it retained the idea of a flat Earth. This concept had been challenged as early as 500 BC in the Greek world. Despite their belief that the Earth was flat, the precise records kept by the Chinese, and their techniques in observation, would make astronomy there the best in the Old World by the fifth century.

With the fall of Rome in the year AD 476, the ‘Dark Ages’ took hold in most of Europe. The science of ancient Greece was preserved mainly in the Eastern Roman Empire and by the exiled pagan Greeks in Babylonia and Persia.

In the deserts of Arabia, Mohammed (c. 570-632) united the nomadic tribes under the banner of Islam shortly before his death. In the century that followed, they conquered most of the Middle East, North Africa, and Spain.

The Muslim world soon rediscovered much of the lore of ancient Greece and Babylon. Many Muslims had earlier adopted revolutionary ideas in both science and math from the Hindus of India. Astronomy there had entered its own Golden Age at the same time most of Europe was falling into the shadows.

All of this, and the growth of astronomy in China, as well as its rebirth in Europe, are in the second chapter of the ‘Astronomers before Telescopes’ series, ‘The Not So Dark Ages: The Rise of India and Islam (476- c. 1070).’ It is in Curation Paper Number Three; all Curation Papers are on the website of the New Mexico Museum of Space History, nmspacemuseum.org.

The first detailed world map, c. 220 BC
Imhotep (born c. 2650 BC?) was a semi-legendary Egyptian; he is the first architect and astronomer in history, as well as the earliest known doctor and engineer. He was deified in his native land more than 2000 years after his death. He built the 200-foot high Step Pyramid; it was the first pyramid in the world. It is also the earliest finished masonry monumental structure. It was oriented to the Pole star; its six levels or ‘steps’ are aligned with the orbits of circumpolar stars.

En Hedu’Anna (fl. c. 2354 BC) was an Akkadian princess and poet; she was the Chief Astronomer of the Moon Goddess. She built observing stations. She studied the motions of the Moon and planets from them. She is the first known person in history to have signed his or her own work.

Senenmut (died 1463 BC?) was an Egyptian architect; a painting on the ceiling of his tomb may be a record of the conjunction of Jupiter, Mercury, Venus, and Saturn in the year 1534 BC. If this were the case, it is the oldest known star chart. It may be the earliest known record of the retrograde motion of Mars as well; some sources have cast doubt on this.

Lagadha (fl. c. 1350 BC?) was a Hindu philosopher; he was the first man known to have used advanced math techniques to both track and predict the motions of the Sun and the Moon. Hindus used his 30-year calendar for centuries.

Thales of Miletus (c. 636?-545 BC) was the first known Greek philosopher; he lived in what is now western Turkey. He was the first Greek to study math and astronomy in Egypt. He may have learned of some of the astronomy of Babylonia while he was in Egypt. He was the first Greek to calculate the timing of solstices; he had observed the sky for years from his home.

Ancient accounts say that Thales won fame in the year 585 BC as the first man who successfully predicted the year of a solar eclipse. If this is true, he most likely knew of the Saros eclipse cycle. Priests in Babylonia had been the first to use it. The eclipse had stopped a battle, which had been in full swing.

Thales was the first person to say that the Earth, the Sun, the Moon, the planets, and the stars were all physical objects. He said that they were not deities, as most at the time thought. He wrote that the Earth was a flat disc that rested on water. He said that motion of the water led to
earthquakes. He thought that water was the source of all life; he said it was the basis for all matter as well. Thales was the first person who wrote that natural laws could explain the physical world, with no need for supernatural causes.

Thales of Miletus

Anaximander of Miletus (c. 610-c. 545 BC) lived in what is now western Turkey. This Greek philosopher was the first man to have stressed science and not religion. He wrote the earliest known mechanical model of the universe. He was the first man to use the word ‘universe’; he defined it as ‘an ordered whole.’

He was the first to say that the universe was infinite. He was also the first to say that events such as lightning or rainbows are natural; he said that gods do not cause them. He was the first man to write that the stars were other worlds; he said that they were much like the Earth. He was as well the first person to write that there are immutable laws that govern Nature, just as there are universal laws in society.

Anaximander may have been the first Greek, and most likely the first man, to say that the Earth is smaller than the Sun is. He built the first gnomons in the Greek world. He drew up the first true map of the world. He may have invented the celestial globe. He was the first Greek to write that the Earth was not flat; he thought that it was a cylinder three times higher than it was wide. He is most likely the first man who said that the Earth was not flat.

Anaximander (left) and Pythagoras, in Raphael’s The School of Athens (1512)

Anaximenes of Miletus (fl. c. 545 BC) was a Greek philosopher; he lived in what is now western Turkey. He was the first man to write that the (flat) Earth is the center of the universe. He was the first Greek to say that the ‘wandering’ planets were not the same as the ‘fixed stars.’ He wrote that the sky was a dome; most Greeks thought that it was a sphere.

He wrote that the Sun was flat; he said that it floated on top of the Earth’s atmosphere. He is the first man who is known to have done experiments. He was as well the first man to stress empirical observations. He was both a friend and a student of Anaximander.

Pherecydes of Syros (fl. c. 540 BC?) was a philosopher; he was the first Greek to write in prose. He was also one of the first to go to Egypt to study astronomy. He built the first heliotropion once he had returned; it was an advanced gnomon. He
could predict lunar eclipses; he may have taught Pythagoras.

**Pythagoras of Samos** (c. 570-c. 495 BC) was a Greek mathematician, philosopher, and musician. He was the first man to use the word ‘philosophy.’ As a young man, he went to Egypt to study science and religion. He apparently also learned some of the astronomy of Syria. He most likely did not travel to Babylonia, though most sources say that he did; some claim that he went as far to the east as India.

Pythagoras left Samos shortly after he had returned; his former neighbors may have driven him out, due to his ‘foreign ideas.’ One of these was a belief in reincarnation, a second one was a strict ‘vegan’ diet; his followers not only could not eat meat, but they could not eat or touch beans as well. He then moved to a Greek city in Italy. There, he started a school; it mixed philosophy, numerology, and science. He said that ‘all things are numbers.’

Pythagoras was the first Greek, and most likely the first man, to say that the Earth is round. He was the first man to say that the Sun, the Moon, and the five planets were all perfect spheres. He said that they orbit the Earth in paths that are perfect circles; this was a first as well.

His ideas were due for the most part to numerology; he did not base most of his views on the sky watching he had done. He ignored the fact that the planets, the Sun, and the Moon all move at differing speeds; this would have disrupted what he called ‘the harmony of the spheres.’ He or his students may have discovered that the orbit of the Moon inclines to the equator of the Earth.

**Cleobratus of Tenedos** (fl. c. 520 BC?) was an astronomer and poet; he was the first Greek to use the signs of the zodiac. These were from Babylonia; he was also the first Greek to use the solar calendar from there. He helped to bring both of these to the Greek world. He studied the rising and setting of stars and star groups, and the timing of the winter solstices. He was the first Greek to write an eight-year calendar; he had based it on solar and lunar motions.

**Theano of Thurii** (born c. 547 BC) was a Greek mathematician; she lived in Italy. Some sources say that she was a student of Pythagoras. She may have taught at the school that he founded. Some say that she was his wife; a few claim that she was his
successor as the head of the Pythagorean School of philosophy. It may be that her only status there was as a wife of a prominent member of the school; her life is not well known.

Some accounts say that she, and not Philolaus, was the first to say that the Sun, the Moon, the planets, and the Earth all orbit a ‘Central Fire.’ This is most likely the first claim that the Earth moves. Either she or Philolaus were also the first to say that the Earth was the same as the other planets. Much of what the early Pythagoreans believed is not clear, as they did not write it down.

Harpalus (died c. 460 BC) was a Greek engineer and astronomer. He improved the eight-year solar calendar that had been written by his mentor, Cleostratus; he did this by adding a year to it. In 432 BC, the Metonic cycle replaced Harpalus’ work.

Nabu-rimanni (fl. c. 490 BC?) was a Babylonian astronomer; he was one of the first men to calculate the lengths of the tropical year and the synodic month.

Some sources say that he wrote ‘System A,’ but this does not seem to be true. Those astronomical tables are the earliest known attempt to both track and predict the motions of the Sun, the Moon, and the five planets.

Parmenides of Elea (c. 515-c. 450 BC?) was a Greek philosopher; he lived in Italy. He may have been a student of Pythagoras. The claim that one or both of them were the first to say that the morning and evening ‘stars’ were both the planet Venus is unfounded. He thought that the universe was a sphere; some say that he wrote that the Earth was a sphere as well, but this may not be true. He was the first man to write that there was no such thing as a void, with no matter or substance.

Anaxagoras of Clazomenae (499-428 BC) was a Greek philosopher; he was born in what is now Turkey. He moved to Athens after the Persians conquered his home city. He was the first man to write that the Moon and the planets all shine with reflected sunlight. He may have been the first atheist in the West. He said that the Earth was flat. He was one of the first men to say that stars make up the Milky Way. He wrote that it was in the shadow cast by the Earth when the Sun passed below it each night.

Anaxagoras was the first person who understood the causes of both rainbows and the phases of the Moon. He was as well the first man to write that the stars are other suns. He said that the Sun and the stars were made of metal or stone.

He wrote that they rotate so fast they get hot. He said that the stars are too far from Earth for their heat to reach it. The Sun, he thought, was much closer to the Earth. He is said to have predicted that a piece of
the Sun might fall to Earth one day. Later, a large meteorite fell in the north of Greece; this made him famous.

Anaxagoras was the first Greek, and most likely the first man, who knew of the physics behind eclipses. He was the first Greek to use geometry in astronomy as well. He founded a school of philosophy in Athens, but he soon had to flee for his life after a brief imprisonment and threats of death. Some sources say his foes had charged him with ‘challenging established religion’ and other ‘dangerous ideas.’ It may be that he was a victim of political persecution: some say that he had been accused of being a spy for the Persians; they were the enemies of most Greeks.

Oenopides of Chios (fl. c. 450 BC) was a mathematician and philosopher; he was also an astronomer. He was the first Greek to write of the inclination of the ecliptic; he was the first in the Greek world to measure it as well. He said it was at twenty-four degrees; this was close to its true value. He was one of the first Greeks to travel to Egypt to study astronomy; he was also the first Greek to use the Egyptian solar calendar of 365 days.

Oenopides was the first man to define the ‘Great Year’. It is the 59-year long span in which the Sun and the Moon, as well as Mercury and Venus, all cycle through their motions. He wrote a calendar of 730 lunar months that he based on it.

Phaeinos (fl. c. 450 BC?) was a ‘resident alien’ in Athens. He was an astronomer; he observed solstices. He may have learned of the Saros eclipse cycle used in Babylonia. If so, he may have passed it on to Meton, who was a student of his.

Meton of Athens (fl. 432 BC) was a Greek astronomer; one source says that he was the first man in the world to use a purely rational approach to astronomy that was free of magic. He and Euctemon observed solstices; Hipparchus wrote that their data on the solstice of 432 BC were the first from Greeks that could be trusted.

Meton and Euctemon invented a tool for astronomy that was used in much of the Greek world. They wrote the nineteen-year Metonic cycle; some sources claim the two may have said that a Babylonian eclipse cycle was their own. Both the Jewish and Chinese calendars use the Metonic cycle to this day; the timing of the Christian Holy Week does as well.
Philolaus (c. 470-c. 385 BC?) was a Greek philosopher. He was a member of the school founded by Pythagoras; he was the first of them to write their doctrines down. He had to flee persecution of his sect in Italy; he went to Greece. He had taught Archytas before he had escaped to Greece. He wrote a 59-year calendar of 729 months; he based it on numerology, and not on astronomy.

He wrote that he was the first person to say that the Sun, the Moon, the planets, and the Earth all orbit a ‘Central Fire.’ He said that the Earth’s rotation meant that the Central Fire could not be seen. He most likely was the first man to write that the Earth rotates on its axis.

Objects closer to the Fire, he wrote, move faster than did those that were further away. The Earth was the closest to it, and Saturn was the most distant. He was the first person to place the ‘five planets’ in their correct order from the Sun.

Philolaus said that there was a ‘Counter Earth,’ on the opposite side of the Central Fire. Aristotle ridiculed him for this. In 1543, Copernicus revived the theory by Philolaus that the Earth was the same as the five planets. He also credited the Greek with the idea that the Earth orbits a ‘central fire,’ even if it was not the Sun.

Euctemon of Athens (fl. 432 BC) was a Greek astronomer; he was a careful observer of the sky. He and Meton identified the solar anomaly for the first time, but they did not try to quantify it. They made solstice observations; this helped them to find the length of the tropical year. They wrote a calendar that was used in much of the Greek world for years.

Democritus of Abdera (c. 460-c. 370 BC) was a Greek philosopher. He is one of the first atheists in the history of the West; the earliest known atheists lived in India. He was as well the first person to write that the stars were other suns; some of these he said had their own ‘Earths.’

He traveled to Athens, to be a student of Anaxagoras. They were the first men to write that the Milky Way consists of many distant stars. Until then, most in the Greek world thought that it was the ‘spilt breast milk of a goddess.’ Democritus and his mentor were the first to say that the number of inhabited worlds in the universe is infinite. They were also the first to write that the Sun was a ‘fiery stone.’

Democritus then traveled to Egypt, Persia, and Babylon; he returned to Athens to found his own school. He thought that the Earth was a concave disk. He was the first person to say that, as with the Earth, the Moon has mountains and valleys; he wrote that people lived there as well.

A 1992 coin honoring Democritus

Democritus was one of the first men to say that all matter consists of invisible atoms that cannot be destroyed; ‘atom’ in ancient Greek meant ‘uncuttable’ (sic). None of the more than 70 books that he wrote has survived. The story that Plato had helped to burn all of his works may not be true.

Archytas of Tarentum (428-347 BC) this Greek scientist, politician, and general
lived in Italy. He was a member of Pythagoras’ school; he was a friend of Plato as well. He calculated the size of the Earth to within an order of magnitude; this was a significant feat, given the state of math in his day. He said that the universe was infinite. The persecution of his sect meant that his corpse was left to rot on a beach after he had drowned.

Eudoxus of Cnidus (408-355 BC?) was a Greek geographer and philosopher; he is the first-known mathematical astronomer. He may have traveled to Italy to be a student of Archytas; the views of that Pythagorean would influence his work. Eudoxus then founded a school in Athens as a rival to Plato’s Academy. He next traveled to Egypt; he stayed for sixteen months, to study astronomy. He observed the Sun from there.

He returned to his home isle of Cnidus; he built the first true observatory in the Greek world there. From it, he made the earliest known systematic survey of the night sky. He drew the oldest known map of the Greek constellations. He was the first man to calculate the distances to the Sun and the Moon; he made the first estimate of the relative sizes of the Sun and the Moon as well.

Eudoxus was the first man who wrote that the Sun was much larger than the Moon was. He may have said that the Sun was nine times larger than the Moon; in fact, the diameter of the Sun is more than 400 times that of the Moon. He wrote of planetary motions and issues of spherical astronomy; he may have penned an eight-year luni-solar calendar. He may also be the author of a text on eclipses.

He was the first man to try to explain the complex motions of the planets, the Sun, and the Moon with a math-based model of the Solar System. He said that they and the stars were all each inside one or more of 27 invisible crystalline spheres. These he wrote, orbit the spherical Earth in concentric, or ‘nested,’’ circles. He said that the Moon and the Sun each had three spheres, and the five planets had four each. The stars were ‘fixed’ to their own invisible crystalline sphere. Each of the spheres powered part, or all of, the motions of a celestial object.

This concept was a central part of the astronomy of the West for hundreds of years. As opposed to writers such as Ptolemy, Eudoxus said that the spheres were theoretical; he did not think they had a physical form. Much of the Julian calendar, which all of Christian Europe used until 1582, and Russia until the year 1917, uses his data.

Shi Shen (fl. c. 370 BC?) was the court astronomer-astrologer for the King of Wei. Wei was one of the ‘Warring States’ of China at this time. Shi wrote the first Chinese star catalog. It had the locations of 121 stars; it listed the names of 689 more. He is the first man is who is known to have written a star catalog.

He made the earliest record of sunspots as well; he correctly identified them as solar phenomena. Shi Shen and Gan De wrote the third oldest star catalog in China. They were the first to divide the sky into 365.25 degrees. Most in the Old World in this era had divided the sky into 365 or 360 degrees. The system devised by Shi and Gan was more precise, as the year is 365.2422 days long.

Gan De (fl. 365 BC) was a Chinese astronomer-astrologer; he wrote two of the three oldest star catalogs in China. Some
of the data in them, however, is from work done as late as the year 70 BC.  He may have seen a moon of Jupiter; most sources say that it most likely was Ganymede. This was 1975 years before Galileo viewed it with his telescope.

Gan De and Shi Shen calculated the length of the orbits of Mercury, Venus, and Jupiter. They said that Jupiter comes closest to the Earth every 399 days; this was off by only one day. Gan De discovered the convergence cycle of those three planets. He wrote a series of eight books on ‘astronomical astrology.’ He was the author of works on Jupiter, and of the motion of the five planets. He also wrote on how to observe the stars.

Kiddinu (died 330 BC?) was a Babylonian astronomer; he was the first to write of the irregular velocities of the Sun, the Moon, and the planets. He calculated the length of the synodic month to within half a second. He derived the length of the tropical year to within five minutes. Both of these estimates were the best yet, at that time.

He may have written ‘System B’; they are the second oldest known astronomical tables in the world. More than two thousand years after his death, the Jewish calendar still uses his definition of the lunar month. He may have been killed on orders of Alexander the Great.

Hicetas of Syracuse (c. 400-c. 335 BC?) was a Greek philosopher; he lived in Sicily. He belonged to Pythagoras’ school. He was one of the first Greeks to say that the Earth might rotate daily. He wrote that the Earth, the Sun, the Moon, the planets, and the stars all orbit a ‘Central Fire.’ His ideas helped to lead Copernicus to ask if the Earth rotates on its axis.

Ecfchantus of Syracuse (born c. 390 BC?) was a Greek philosopher; he was from Sicily. He was a member of the school founded by Pythagoras. He was one of the first men to say that indestructible atoms comprise all matter. He may have been one of the first in the Greek world to write that the heavens are motionless but the Earth rotates daily. Copernicus was inspired by his views.

Heraclides of Pontus (387-312 BC) was a Greek philosopher; he was born in what is now northeastern Turkey, he moved to Athens to study at its schools. He was one of Plato’s students; he studied with Aristotle while they were both at the Academy.
Heraclides was the first man who won fame in his times for saying that the Earth rotates daily; this, he wrote, produces the apparent motion of the sky. He was as well one of the first men to say that the Earth is the center of an infinite universe. Copernicus and others would think that he had said that Venus and Mercury orbit the Sun, but that was not what he wrote.

**Aristotle of Stagira** (384-322 BC) was Greek philosopher, and a student of Plato; he was in the Academy for twenty years. His works are some of the most enduring in the history of the West. He created the first scientific method; his system was copied in much of the Western world for centuries. It used inductive and deductive reasoning to reach conclusions; he did not test these by doing experiments.

For four years, he taught Alexander the Great while the teen was still a prince. He inspired the future king’s dream of bringing Greek culture to what were then the ends of the known world. Aristotle had to leave Athens in disgrace after Alexander had died; he soon died.

He said that the Earth was a sphere; it was, he wrote, the center of a finite, static universe. He thought that the Earth was the only real world in it. He said that the heavens were ‘perfect and unchanging.’ He wrote that the ‘pure’ celestial objects all orbit the Earth inside of 55 invisible crystalline spheres. These, he said, powered all of the motions in the universe. He wrote that more spheres could account for more motions of the celestial objects than the model written by Eudoxus had.

Aristotle said that ‘stellar gasses igniting in the atmosphere’ of the Earth are the cause of the Milky Way. He wrote that comets traveled in the atmosphere; he thought that meteorites were also from there. His thoughts were at the heart of much of the science of the West for much of the next two thousand years.

**Menaechmus of Alopeconnesus** (c. 380-c. 320 BC) was a Greek mathematician; he lived in what is now northwestern Turkey. He went to the school run by Eudoxus. Menaechmus said that each of the five planets that orbit the Earth is in two invisible spheres. One sphere moved a planet forward; the other moved the planet to the side. This, he wrote, produced the non-uniform motion of the planets.

**Callipus of Cyzicus** (c. 370-c. 300 BC?) was a Greek astronomer; he was born in what is now northwestern Turkey. He moved to Athens; while he was there, he quantified the solar anomaly for the first time. He did this by identifying the four seasons that make up a year. He said that spring was 94 days long, that summer had 92 days, fall was 89 days in length, and winter had 90 days. This was an accurate division of the year, at that time.

He wrote the Callipic cycle; this 76-year calendar was the most precise one in the Greek world at the time. He based it on
his estimation of the tropical year, which he said was 365.25 days in length. The Julian calendar, which most of the Christian world used until the year 1582, used his figure for the length of the year; it was off by being eleven minutes too long.

Aristotle, whom he studied with, had encouraged him to modify the model of the Solar System written by Callipus’ mentor, Eudoxus. Callipus said there were 34 invisible crystalline spheres; this was seven more spheres than his teacher had used. He said that the spheres orbited the Earth in perfect circles; this caused the motions of all of the celestial objects.

Pytheas of Massalia (fl. c. 325 BC?) was a Greek navigator and astronomer; he lived in what is now Marseilles, France. He was the first man to write of exploring the Atlantic Ocean. He may have been the first Greek to enter the Baltic Sea. He appears to have sailed as far north as the Arctic Circle; he may have reached the coast of what is now central Norway. He was the first man to write that the Moon may be associated with ocean tides.

Pytheas penned the first accounts of sea ice, and the first report of the effects of latitude on the stars, the climate, and the length of the day. Most Greeks ridiculed him for his accurate descriptions of what he saw. The longitude that he recorded for his home city was so precise that it was used as the prime meridian for many maps done in the Greek world.

Autolycus of Pitane (fl. c. 310 BC) was a Greek astronomer; he was born in what is now western Turkey. He studied the rising and setting of some of the celestial objects for years; he penned the oldest known spherical astronomy text. He wrote in support of Eudoxus’ model of the Solar System. He was critical of its failure to address the ‘changing sizes’ of both Venus and Mars. He said that this showed they did not orbit the Earth in perfect circles.

Harkhebi (fl. c. 300 BC) was an Egyptian priest and astronomer; he was one of the first from that land to learn the astronomy and astrology of Babylonia. He studied the motions of the planet Venus; he predicted lunar eclipses. He tried to make weather forecasts by observing the stars.

Timocharis of Alexandria (fl. c. 295-270 BC) was a Greek astronomer; he lived in Egypt. He wrote most of the first star catalog done in the Greek world. It listed less than 100 stars and, said Hipparchus, was not accurate; despite this, it was the world’s first true star catalog, as it had star positions in a numeric form.

Timocharis may have been the first man to say that Mercury was one planet, and not two; he gave it its current name. He recorded lunar occultations as well as a stellar transit by the planet Venus. His data on the star Spica in the autumnal equinox helped Hipparchus discover precession. In 1718, Halley cited Timocharis’ work as part of his discovery of proper motion.
Aristillus of Samos (fl. c. 280-c. 260 BC?) was a Greek astronomer. He and his mentor Timocharis were the first Greeks to write a star catalog. They worked at the Museion, in the new city of Alexandria; it was the (Greek) capital of Egypt until 31 BC. He wrote of circumpolar stars and the constellations that they were in.

Aristarchus of Samos (c. 310-c. 230 BC) was an astronomer and mathematician; he did much of his work in Alexandria. He was the first Greek, and most likely the first man, to write that the Earth orbits a large Sun, as do the stars and the rest of the planets. He felt that logic dictated that the smaller Earth should orbit the Sun, instead of the Sun circling the Earth. He wrote that the Earth might rotate daily. Most rejected his ideas for much of the next 2000 years.

A statue of Aristarchus of Samos in Thessalonica, Greece

Aristarchus was one of the first people to calculate the relative sizes of the Sun and the Moon, as well as their relative distances from the Earth; only his estimate of the size of the Moon was accurate. He was the first man to write that the stars were far from Earth. He observed the summer solstice of 280 BC; both his record of it and his eclipse data helped Hipparchus to discover precession. He may have invented two types of sundials.

Archimedes (287-212 BC) was a Greek inventor and mathematician. He lived in the city of Syracuse, on the isle of Sicily; he recorded a solstice from there. The planetarium was but one of his inventions. He created a machine that could calculate the circumference of the Earth; he built another one to help him find the length of the tropical year.

He was one of the first men to estimate the distance to the Sun. He said it was less than 10,000 times the radius of the Earth; this is 42% of the real distance. He wrote that the Sun was 30 times the size of the Earth; the Sun is more than 100 times as large as the Earth. He shared his data with his friend, Eratosthenes. The Romans killed him as they sacked his home city.

Conon of Samos (fl. 245 BC) was a Greek astronomer and mathematician. He worked in the city of Alexandria; he was a member of the court of one of the Greek kings who ruled Egypt from there. Conon came up with the name for the constellation Coma Berenices; Eudoxus had named most of the others. Conon studied solar eclipses and the motions of the planets; he wrote a series of seven books on astronomy.

Sudines (fl. c. 240 BC) was a priest from Babylon; he helped to bring his nation’s traditions in astronomy and astrology to the Greek world. He wrote tables to predict the Moon’s motions.

Apollonius of Perga (fl. 247-205 BC) was a Greek mathematical astronomer; he was born in what is now southwestern Turkey. He moved to Alexandria as an adult; he
was the second director of the library there. He may have been the first to use the concepts of epicycles and deferents. Both of these were a key part of the astronomy of the West for more than 1800 years; Kepler showed that neither concept was real. Apollonius used epicycles and deferents to account for much of the irregular motions and unequal speeds of the Sun, the Moon, and the planets. He built the first sundial that had hour marks.

**Eratosthenes of Cyrene** (276-194 BC) was a Greek scientist, poet, and athlete; he is known as ‘the father of geography.’ He was the first man to calculate the circumference of the Earth. His accuracy in this is unclear; this is due to doubts on the unit of distance, which was called the ‘stadia,’ which he had used.

He may have been off by no more than 98 miles; this is an error of just one percent. If this were the case, his work would be the best in the world for more than a thousand years. If he used a larger type of stadia, his estimate may have been at least sixteen percent too large. He made the first detailed map of the world. Some sources say that he was the first to use both longitude and latitude; it is more likely that Hipparchus was the first to use both of these. After this Greek had made corrections to the map, it was copied in the West for hundreds of years.

Eratosthenes was the first man to estimate the true distances to both the Sun and the Moon. He was as well the first to say that the Sun was far from the Earth. He derived the angle of the ecliptic; he wrote a catalog of 675 stars. He wrote on the origin of the names of the Greek constellations. He may have invented the armillary sphere. It was the main tool of sky-watchers in the Old World until the invention of the telescope more than 1800 years after his death.

Eratosthenes was born in what is now Libya; he moved to Alexandria to be the tutor of the son of the King of Egypt. He then was the third head of the Library of Alexandria; he helped to make it the center of learning in the Greek world. Legend says that soon after he lost his sight he starved himself to death. In life, he was called ‘Beta,’ for being ‘second best’ in all of his many fields.

**Arrianus** (fl. c. 230 BC?) was a Greek astronomer; he wrote one of the oldest known books that dealt with meteorites. He may have been the first man to say that comets were nothing but objects. He wrote that they were not gods or omens; he said that there was no need to fear or worship them.

**Wu Xian** (fl. c. 210 BC?) was a legendary Chinese astronomer; some accounts say that he lived before 1000 BC, but this is an error. He may have been the author of the fourth oldest star catalog in China; it listed 44 constellations and 141 stars. In the year AD 310, Chen Zhuo combined it with Gan De and Shi Shen’s work.
Aglaonike (*fl. c. 200 BC*) was a Thracian priestess. She may have known of the Metonic cycle; this let her predict lunar eclipses with accuracy. Most Greek men called her a witch, or a braggart, or both.

Hypsicles of Alexandria (*fl. c. 175 BC?*) was a Greek mathematician and astronomer; he worked in Egypt. He may have been the first Greek to map the sky as a circle of 360 degrees. His sky map convinced most in the Greek world to adopt this system. He could predict when the signs of the zodiac appear.

Attalus of Rhodes (*fl. 173 BC?*) was a Greek astronomer and mathematician; he wrote in defense of some of the works on astronomy done by Eudoxus. Hipparchus held him in high regard.

Seleucus of Seleucia (*fl. c. 150 BC*) was a Greco-Babylonian astronomer; he lived in what is now Iraq. He was the only man of his day who wrote in support of the model by Aristarchus that the Earth orbits the Sun. He did so as he too thought the Earth was much smaller than the Sun was. He supported Archytas’ idea of an infinite universe as well. If it was not boundless, he asked, what was beyond its edge?

Seleucus was the first man to insist that the Earth rotates every day; other writers had been much more tentative on this. He said that the Moon governs the Earth’s tides; more than 1700 years later, Kepler proved that he was right.

Hipparchus (*fl. 146-127 BC*) is known as ‘the Greatest Greek Astronomer of Antiquity.’ He was a famous astrologer as well. He did most of his research while in Rhodes; he had moved there from his home in Nicea. He did not work in Alexandria, though some sources say that he did. Note the sphinx in the illustration on the following page.

Most know him for his discovery of precession. He observed the stars for years; he then compared his results with more than six centuries of data from Greece and Babylonia that he owned. He thus found that the tropical year was shorter than the sidereal year. He realized that this was due to the annual movement of all of the stars to the west; he said that this was at the rate of more than one degree every 100 years. More than a thousand years later, Copernicus called this the ‘precession of the equinoxes.’

Hipparchus drew up the first trigonometric tables; he did this as a way to track lunar and solar orbits. For this, he is called ‘the father of trigonometry.’ He was as well the first man to write of stereographic projection. He designed some of the best tools for astronomy in the world at the time; the astrolabe may have been one of these. He used these new instruments and methods to make the most precise observations of the sky at that time.

He was able to calculate the length of the synodic month to one-tenth of a second. He measured the inclination of the ecliptic
to within eight minutes of its true value. He mapped 44 stars in order to determine time; his skill with the astrolabe may have made him the first man who could tell both time and latitude by the stars.

Hipparchus

In 134 BC, he was the first Greek to record a ‘new star,’ or what is now known as a nova. As he reported that it moved ‘free of’ the rest of the stars, it was most likely a comet. One did pass the Earth that year; at that same time, the Chinese did document a nova. He used an armillary sphere to make the first comprehensive star catalog. In it, he listed 850 stars; he gave the locations of some of them.

One ancient source said that the ‘nova’ had led Hipparchus to ask if the ‘fixed stars were fixed.’ This may have inspired him to write his catalog, but Ptolemy said no, the true cause was the discovery of precession. This star catalog would be part of all others in the West for more than 1500 years.

Hipparchus was the first man to class the stars by their apparent magnitude; his system is still in use. He built a celestial globe; it showed the main Greek constellations and some of the stars in them. He may have been the first in the Greek world to make an accurate map of the sky. Most sources say that he was the first man to draw a map with both longitude and latitude; he used them to correct the world map by Eratosthenes. He wrote a strong critique of the means used for the original map.

Hipparchus was the first man who could make precise predictions of solar eclipses. He was also one of the first to say that the Sun was far from the Earth. At the same time, he was a critic of the model that the Earth orbits the Sun; he felt that if the Earth moved the stars’ positions should shift more than they did. He did not know that the distance to them was too far for this to be the case.

He showed that the planetary model by Apollonius did not work, due to its use of too many epicycles. He said that planetary motions were too complex for him, or anyone else, to try to explain. He was the first man to write that the Sun orbits a point near the Earth, and not the Earth itself. Now known as the equant, this would be a key part of astronomy in the West for hundreds of years. None of his eleven principal works survives, but his data is the basis for Ptolemy’s model.

As in modern science, Hipparchus built his theories on observed facts; few of his times did so. He was the first Greek since Eudoxus to map the sky in a systematic manner. Some sources say that he was the most prominent astronomer before Copernicus; most call him one of the greatest astronomers of all time.

Sima Qian (145-87 BC) was the royal Chinese historian and astronomer; he was as well a noted poet. In the year 91 BC, he
wrote the first account of the Chinese constellations; he listed 90 of them, as well as 500 of the stars that form them.

One of the Han emperors had Sima castrated, with great cruelty; he then forced his victim to serve in the court for the rest of his life. In 104 BC, Sima oversaw the creation of the Taichu calendar; it was the most precise one in the Old World at the time. He objected to what he saw as its overly complex year; he was ignored.

Yajnavalkya (fl. between c. 100 BC and c. AD 400?) was a Hindu philosopher. Most sources say that he lived in the year 800 BC. Some claim that he lived as much as a thousand years or more before then. If either of these were true, he was the first man to say that the Earth and the other planets all orbit the Sun. As his work shows Greek influence, it is more likely that he lived no earlier than the year 100 BC. Most of those in India had little contact with the Greek world before then.

Yajnavalkya was the first man in the East to say that the Earth was a sphere. He estimated the relative distances to the Sun and the Moon. He knew of the causes of eclipses. He calculated the tropical year to within six minutes. He discovered the 95-year cycle of the Sun and the Moon. He may have said that the Earth rotated; if so, he was the first in the East to say this.

Luoxia Hong (c. 130-c. 70 BC) was a Chinese astronomer and mathematician; Sima Qian had trained him. He built the first armillary sphere in China; it had just one ring. He also built one of the first celestial globes in that realm.

He wrote that the seasons change due to the slow motion of the Earth. He was the main author of the Taichu calendar; all Chinese calendars used much of its rules for the next 2000 years.
Geminus of Rhodes (fl. c. 77 BC) was a Greek mathematician and astronomer; he was the first to write that the number of stars is beyond count. He was the author of an introductory astronomy text; he may have built orreries.

Geng Shouchang (fl. 75-49 BC) was a Chinese astronomer and mathematician; he helped to build the first armillary sphere in that realm that had a fixed equatorial ring. With it, good measurements of the ecliptic were possible for the first time there. Geng also built one of the first celestial globes in that land.

Acoreus (fl. 46 BC) was an Egyptian priest; he knew of the 365-day solar calendar used in ancient Egypt. He helped Sosigenes write the Julian calendar; the Eastern Orthodox Church still uses it.

Sosigenes of Alexandria (fl. 46 BC) was a Greek astronomer who worked in Egypt; he wrote the Julian calendar. It was used until 1752 in Britain and as late as the year 1923 in Greece. He based it for the most part on data from Eudoxus and Callipus. The claim that he found that the planet Mercury orbits the Sun is false; like most in the Greek world, he thought that the Sun, the five planets, and the stars all orbited the Earth.

Jing Fang (78-37 BC) was a Chinese mathematician and theorist; he was the first man there to write that the Moon and planets all shine with reflected sunlight. He was as well the first of his country to say that the Sun and the Moon were both spheres.

Liu Xin (46 BC-AD 23) was a Chinese astronomer and historian; he wrote the first astronomical tables known from that land. He cataloged 1080 stars, in six apparent magnitudes; he is the first man in the East who is known to have used them. He calculated the length of the tropical year. Liu then added lunar eclipse and planetary data to the Taichu calendar; his work was the Santang calendar.

Jia Kui (AD 30-101) was a Chinese astronomer; he was the first in his country to note the inconsistent motion of the Moon through its phases. He was the first man in China to add a third ring to the armillary sphere; this was to better measure the ecliptic. Jia was as well the first man there to measure the Sun and the Moon from the ecliptic. This improved on earlier methods that had been used in China.

Agrippa (fl. AD 92) was a Greek astronomer; he may have lived in what is now northwestern Turkey. He recorded a lunar occultation of the Pleiades cluster; this was while he was doing research on precession. Ptolemy used his data.

Menelaus of Alexandria (fl. c. AD 100) was a Greek astronomer and mathematician; he worked in Egypt. He said that the annual rate of precession was
one degree in a century; it is, in reality, one degree in 72 years. He made advances in spherical trigonometry; he used them to solve problems in mathematical astronomy.

**Theon of Smyrna** (c. AD 70-135) was a Greek astronomer and mathematician; he was born in what is now western Turkey. He may have worked in Alexandria. He calculated when both conjunctions and eclipses occur. He measured the greatest arcs, or distances, of Venus and Mercury from the Sun. He wrote on some of the work that Ptolemy had done.

**Zhang Heng** (AD 78-139) was a Chinese scientist and poet. He was the first in that land to say that the heavens were both spherical and boundless.

**Zhang Heng**

Zhang wrote that the (flat) Earth was at the center of the universe; he said that the Earth was ‘like the yolk of an egg.’ This was the view of most in China for hundreds of years. He invented the hydraulic armillary sphere as well as the hydraulic celestial globe. He mapped more than 2500 stars; he reformed the calendar so it would match what he saw in the sky.

Claudius Ptolemy (fl. AD 127-151) was a Greek astronomer, geographer, mathematician, and astrologer. He lived in Egypt; it was a part of the Roman Empire at the time. Some sources say that he worked in the Library of Alexandria; it is more likely that he lived far to the south, in the valley of the Nile.

Claudius Ptolemy

He was one of the most influential men in the history of astronomy in the West. The catalog of 1022 stars that he wrote was the first that had accurate coordinates. It had, as well, the first tables done in advance for common dates and events in the sky. He used an astrolabe to make the most precise observations of the Moon and its motions at that time. His estimate of the distance to the Moon was off by just three percent.

Ptolemy was the third, and last, Greek of this era who made a systematic survey of the night sky. He used the data to write a book that most call the *Almagest*; it was a summary of much of Greek astronomy at that time. It had the first comprehensive math-based model of the universe; he based it and much of the rest of his work on research that Hipparchus had done.
Ptolemy had to use intricate planetary, lunar, and solar motions in his model. He wrote it so it matched his records, and the work by earlier astronomers. He had much of the astronomical data in the West, but he wrote of only those results that fit his theories. He ignored facts that might contradict his ideas.

He said that Aristotle was wrong when he said that the Earth was at the center of the universe; Ptolemy wrote that the Earth was near the center, but not at it. He said that Aristotle erred as well when he said the celestial objects moved at uniform speeds; Ptolemy knew that their speeds varied. He wrote that each object was in one or more crystalline spheres that powered it.

In 1543, Copernicus used much of Ptolemy’s data for his own model of heliocentrism. Due in part to this he failed to discredit the Greek’s views with most in Europe. Ptolemy’s system, with concepts such as eccentrics, equants, deferents, and epicycles, dominated the astronomy of the West as late as 1610. That year, Galileo used a telescope to see the four largest moons of Jupiter and then the changing phases of Venus. Both of these finds would help to end the acceptance of Ptolemy’s ideas.

**Liu Hong** (AD 129-210) was a Chinese astronomer; he was perhaps the most precise observer in that realm up to that point. Observations of the Moon were his forte. He was the first in China to quantify the inequality of the Moon’s motion; with this find, he was able to write the best calendar there yet. Liu was the first of his land to write a complete theory of both lunar and solar motion.

**Sosigenes the Peripatetic** (fl. c. AD 175) was a Greek philosopher; he worked in what is now western Turkey. He rejected concepts such as epicycles and crystalline spheres. He said that eclipses showed that the orbits (of the Earth) by both the Sun and the Moon were not circular. He wrote that the changes in the brightness of all of the five planets proved that their distances from Earth must also vary.

**Cleomedes** (fl. c. AD 200?) was a Greek philosopher who may have lived in what is now northwest Turkey. He was the first man to write that many stars may be much larger than the Sun. He was as well the first to say that from far away the Earth might look like a small star.

**Samuel of Nehardea** (c. AD 165-c. 257) was a Babylonian rabbi; he tracked the motions of the Sun and the Moon. He then used the data to write a 60-year calendar. He taught astronomy at a Talmudic academy that he had founded.

**Ada Bar Ahaba** (born AD 217) was a rabbi from Babylonia; he measured the length of the tropical year. Jews in much of the Middle East used both his calendar and astronomical tables for centuries.

**Sporus of Nicea** (fl. c. AD 280) was a Greek mathematician and astronomer; he was born in what is now northwestern Turkey. He worked at the Library of Alexandria; he taught Pappus there. He calculated the sizes of both the Sun and comets.

**Chen Zhuo** (c. AD 265-c. 320) was an astronomer for the Chinese King of Wu. Chen was the first of his country to make a comprehensive survey of the night sky. He merged the three star catalogs in use there. His work was the first complete star catalog in that land; it listed 1464 stars as well as 284 constellations; these are still
used in China. It and a star map that he wrote were copied there for centuries.

Chen Zhuo’s star map

Pappus of Alexandria (fl. c. AD 300-c. 320) was a Greek mathematician who worked in Egypt. He wrote of the *Almagest*. He observed an eclipse in the year AD 320; he was the author of a tract on the center of gravity.

Yu Xi (AD 281-356) was a Chinese astronomer; he was the first man in the Eastern world to discover precession. He said that the equinoxes moved at a rate of one degree every 50 years; this was the best estimate of it in the world yet at that time. He most likely did not know of the work by Hipparchus. He urged changing the calendar to account for precession, but his efforts were in vain. The court ignored Yu’s find for more than a century, as it violated the view of the heavens by most of those in China.

Theon of Alexandria (c. AD 335-c. 400/405) was a Greek mathematician who lived in Egypt; he was Hypatia’s father as well as her teacher. He was the last head of the Library of Alexandria; in AD 391, a Christian Roman emperor had it closed. Both father and daughter then taught at a nearby school.

Theon edited a copy of the *Almagest*. He wrote of it and the astrolabe; he praised Ptolemy’s skill with that tool. In AD 364, he had observed solar and lunar eclipses. He was the author of the oldest known text on the theory of trepidation. He said that it was inaccurate; he wrote that precession was a more valid model of the slow motion of the stars.

Martianus Capella (c. AD 365-440) was a Roman author; he was born in what is now Algeria. He moved to what is now Tunisia; there, he penned an allegory that said that Mercury and Venus both orbit the Sun, and not the Earth. His work would influence Copernicus more than a thousand years later.

He Chengtian (c. AD 370-447) was a Chinese mathematician and astronomer. He improved on the ‘Zhang’; this was the name for the Metonic cycle in China. All later calendars there used his reforms. He helped to train Zu Chongzhi; in AD 443, they wrote a new calendar. Qian Lezhi, Zu’s rival, convinced the emperor not to use it, due to its complexity. In five years, after they had simplified it, Qian helped to implement its use.

Hypatia of Alexandria (c. AD 370-415?) was a Greek scholar; she soon surpassed her father, and teacher, Theon in both ability and fame. She helped him edit a copy of the *Almagest*; she invented a type of astrolabe. She taught math and astronomy at the Library of Alexandria; then, when it closed, at a smaller school as well. Her students at both schools numbered many respected men; these were from both the pagan and Christian communities.
The murder of Hypatia

A mob led by Christian monks murdered Hypatia, in a church. Most sources say that they flayed her alive with oyster shells. Some say that they dismembered her; she may have still been alive at that point. While most accounts say that this was due to her pagan (scientific) ideas, it is more likely that she was caught up in a political struggle between pagans and Christians. The prize was control of the city; it was one of the richest in the world at the time.

Ho-Tsheng-Tien (fl. c. AD 440) was a Chinese astronomer; a Hindu priest who had come to China taught him some of the astronomy of India. He learned how to predict eclipses as well as how to find latitude by the meridian height of the Sun.

Qian Lezhi (fl. AD 436-448) was Chinese; he was the astronomer to an emperor in the south of China. He and Zu Chongzhi were rivals. He built a hydraulic bronze celestial globe; it showed 283 constellations and 1464 stars. He had based it on Chen Zhuo’s star map; he had used color-coded stars in it for the three star catalogs that Chen had combined.

Proclus (AD 412-485) some sources call him the ‘last Greek philosopher’; he was a pagan. He was born in what is now the southwest of Turkey; he worked in Constantinople, Alexandria, and then, Athens. There, he was the last head of Plato’s Academy. He had begun a career as a lawyer and then decided that he preferred philosophy. He was the first to write criticisms of Ptolemy and his ideas; Proclus attacked him for his use of concepts such as epicycles and eccentrics. He went so far as to question the integrity of some of Ptolemy’s work.

Proclus said that the Earth and all of the planets might orbit the Sun. He predicted and then observed a solar eclipse; he also estimated the diameter of the Sun. He said that the five planets moved of their own accord; he rejected the theory that their motions come from the movements of ‘crystalline spheres.’ He said that the planets and the stars all rotate; he wrote that the Earth rotated as well.

Proclus wrote of spherical astrolabes and their use. He was the author of attacks on the theory of precession; he said that the ‘fixed stars are fixed.’ He rejected all of Aristotle’s science; his words were not widely known in Europe until the sixteenth century. Copernicus, Kepler, and Galileo all wrote in praise of his work.

Zu Chongzhi (AD 429-500) was a Chinese astronomer and mathematician; he was the best in both of his fields in the Old World in his day. He calculated the length of the tropical year to within 50 seconds. This was the most precise estimate of it in the world for more than five centuries; it was the most accurate figure for it in China until the year 1281.

Zu measured, with precision, the lengths of both the sidereal year and the nodal month; he also derived the length of Jupiter’s year. In 462, he wrote the Da Ming calendar; it was the first one used in
China that dealt with precession. It was the best calendar in that land for more than 600 years; still, royal officials rejected it. They said that this was for ‘for reasons of religion’; some said the real reason was that it was too complex for those in the court to understand.

Ammonius Hermiae (c. AD 440-c. 520) was a Greek philosopher; he was the brother of Heliodorus. They were both born in Egypt; they were as well, both skilled astronomers. Proclus had trained them at his school in Athens for twenty years. They returned to Alexandria, to work in a school there; Hermiae taught some of the work by Ptolemy. The brothers, who were pagans, observed the stars, and Venus and Mercury, with an astrolabe; he wrote of astrolabes as well. He was the author of attacks on astrology.

Heliodorus of Alexandria (died AD 509) was a Greek philosopher; he was the last pagan Greek astronomer of note. He worked with his brother for all of his life; he observed the sky for the last nine years of it. He wrote texts on astronomy.

Zu Geng (c. AD 450-c. 520) was a Chinese mathematician. He was the first in his land to map the Pole star; he had invented a sighting tube to do so. He got the court to use the Da Ming calendar; his father Zu Chongzhi had written it 45 years earlier. They had worked together for years.

‘Zu Chongzhi writes the Da Ming calendar’ (courtesy of Marilyn Shea and the University of Maine at Farmington)
GLOSSARY OF TERMS USED

Akkadian: In the years from about 2300 to 2200 BC, the Akkadians, a group from what is now central Iraq, established the world’s first long-lasting empire; this included control of Sumer. The Sumerians were the founders of the first civilization; it flourished in what is now southern Iraq from c. 4000 BC to the year 2004 BC.

Alexander the Great: This Macedonian king (356-323 BC) conquered the Persian Empire; in so doing, he spread Greek culture to Central Asia and India; at the time, these were the ends of the known world.

The Almagest: Is the Latinized version of a portion of al-kitabu-l-mijisti, which is Arabic for ‘The Great Book’; it has been known by this title for the last 1400 years. Its real title was The Mathematical Syntaxis when it was written c. AD 150 by Claudius Ptolemy. He was a Greek who lived in Egypt, which was part of the Roman Empire at the time. In it, he detailed his math-based model of the universe; he said this was centered near the Earth, but not on it.

An armillary sphere was the first book to have astronomical tables that were completed in advance for common dates and events. It was the most important work in the astronomy of the West for more than 1400 years. Only the efforts of Copernicus, Kepler, and most of all, Galileo, disproved Ptolemy’s model.

Analog computer: In this era, an analog computer was a machine that could be manipulated by mechanical or hydraulic means to solve a problem or perform a function. The first ones were the orreries built by the ancient Greeks.

Apparent magnitude: This refers to the brightness of a celestial object as it is seen from the Earth. When the term was first used by Hipparchus, each object was given an apparent magnitude between one and six, the lower the number, the brighter the object. The stars that he said were of the first magnitude were twice as bright as those of the second magnitude, and so on. This system is still used in a modified form by astronomers.

Armillary sphere: Is a computing and sighting device; some call it a spherical astrolabe or equatorial armillary sphere. It is a three-dimensional model of the sky with a spherical ‘Earth’ at its center. A series of rings that represent the orbital paths of the Sun, the Moon, and the planets, as well as the planes of the equator and meridian, surround the globe.

The armillary sphere was the main astronomical instrument in the Old World until the telescope. The first one was built c. 255 BC, possibly by Eratosthenes.
Astrolabe: Is a sighting and computing device consisting of a circular slide rule-planisphere and engraved data tables that are nested in a hollow disk. It was invented c. 150 BC; some sources say that Hipparchus built the first one. They were used to observe and predict the motions of the celestial objects; astrolabes could also be used in the calculation of the time of day.

Replica of a Roman astrolabe, c. AD 250

Astrology: Is the belief that the positions of the planets and the stars can influence life on Earth, especially their positions when a person is born. From its beginnings in Sumer and Egypt before the year 2000 BC, most viewed astrology as a valid science; it was related to astronomy until the eighteenth century. Many astronomers, such as Hipparchus and Ptolemy, were also astrologers.

Astronomical tables: These mathematical tables are used to in the calculation of the positions of the Sun, the Moon, the planets, and the stars. They have data on lunar phases and eclipses, as well as other calendrical information.

Astronomy: Is the scientific study of objects that are beyond the atmosphere of the Earth; some call it ‘the first science.’ The Sumerians were the first to elevate astronomy to a true science, c. 3500 BC.

c.: Is a symbol meaning *circa*; it is the Latin word for ‘about’ or ‘around.’ It is used when the precise date of an event is unknown; it can be written as *ca*.

Callipic cycle: Is a luni-solar calendar that is based on deducting one day from every fourth nineteen-year Metonic cycle. This produced a 76-year ‘Callipic’ cycle, which had a mean year of 365.25 days. It was used in much of the Greek world until the introduction of the Julian calendar in 45 BC.

Celestial globe: This is a representation of the night sky as seen from the Earth.

Celestial objects: Before the use of telescopes, these were the Sun, the Moon, the stars, and the five visible planets: Mercury, Venus, Mars, Jupiter, and Saturn. In this era, most in the West thought that comets were atmospheric phenomena.

Central Asia: As used in the text, this is the area of what are now Afghanistan and the former Soviet republics of Uzbekistan, Kazakhstan, Tajikistan, Kyrgyzstan, and Turkmenistan.

Chin dynasty: Also known as the Qin dynasty, this was the first imperial state in the history of China (221-206 BC). Though despotic and short-lived, it was of enough significance that the nation took the name of the dynasty as its own.

Chinese calendars: There has been only one change in the calendar used in the Christian world in the last two millennia but there have been many calendars used in China in those same years. This is due to emperors there being seen as receiving permission to rule through the ‘Mandate of Heaven.’
As eclipses and other events in the sky were thought to be threats to the existence of the Earth, rulers often began their reign with a new calendar. This, it was hoped, assured that there would be no such signs of ‘Heaven’s disapproval’ that had not been predicted. In some cases, these could lead to the overthrow of the new sovereign. More often, unforeseen celestial events resulted in the death of the court astronomers who had failed to predict them. This may have played a role in the development of precise methods by Chinese astronomers.

Conon of Samos, a prominent astronomer at court, explained it was now in the heavens as a ‘new’ constellation.

**Coma Berenices (lower right)**

**Conjunction:** Is an event that is caused by two or more celestial objects that appear to be close together in the night sky. They last for a few consecutive nights at most.

**Constantine the Great:** Born c. AD 272, this general became the sole emperor of Rome in 324; he was the first to promote Christianity. He moved the capital of the empire to Constantinople, the city that he founded. Constantine I, who is usually known as ‘the Great,’ died in AD 337.

**Constellation:** Is one of the 88 artificial groups of stars and galaxies that are used around the world; Eudoxus of Cnidus defined most of them. Most cultures have their own system of constellations; Chinese constellations date to the third century AD. Other star groups, such as the ‘Big Dipper’ are called asterisms. All constellations and asterisms are defined by their appearance from Earth; in reality, the stars of most are far apart from each other.

**Nicolaus Copernicus:** Was a famed Polish scientist, administrator, cleric, and doctor (1473-1543); he revived theories from ancient Greece that said that the Earth and the other planets all orbit the Sun. This was a challenge to the dominant
Ptolemaic astronomy of his time, as well as to Church doctrine. He laid the foundations of modern astronomy; many writers credit him with starting the Scientific Revolution.

**Crystalline spheres:** Was a key part of the Solar System model Eudoxus of Cnidus wrote. He said that the Sun, the Moon, the stars, and the planets all orbited the Earth inside of 27 circular, concentric spheres. After Aristotle, Callipus, and Ptolemy made changes to it, most astronomers in the West used this concept until 1577.

That year, the Dane, Tycho Brahe proved that comets traveled far beyond the Moon; this meant that they were not atmospheric phenomena, as Aristotle claimed. If they had been real, he said, the comet of 1577 could not travel through the Solar System, as it would have destroyed, or been impeded by the spheres.

**Deferent:** Is a concept that may have originated with Apollonius of Perga. A deferent was a larger orbit that contained epicycles; these were small, circular orbits. Geocentric models used them to account for the inconsistent motions of planets, the Sun, and the Moon.

**Diurnal motion:** This is the apparent motion of the Sun and the stars as viewed from Earth. It is caused by the rotation of the Earth.

**The East, Eastern world:** See ‘The West, Western world.’

**Eccentricity:** In astronomy, this is an indication of how much an object’s orbit deviates from being perfectly circular. An elliptical orbit is very eccentric.

**Eccentrics:** Per Ptolemy, only the Moon and the ‘stellar sphere’ orbited the Earth. All other objects in the sky had eccentric orbits; he said that these were not centered on the Earth. He said that instead, those objects circled an imaginary point near the Earth; it was called the equant. Eccentrics were a mainstay of his geocentric model. By the early seventeenth century, Kepler’s Laws of Planetary Motion discredited the use of eccentrics. See ‘Equant.’

**The ecliptic or ‘plane of the ecliptic’:** This refers to the path of the Sun, as it appears to move across the sky over the course of a year. It is the part of the celestial sphere where eclipses occur. See ‘Inclination of the ecliptic.’

**Epicycles:** These are theoretical smaller circles in the orbits of some of the celestial objects as they move inside of larger circles; these are called deferents.

Hipparchus, Ptolemy, and others used the concept of epicycles to explain planetary motions; the speed of each object in an epicycle varied. They were a central part of the astronomy of the West until Kepler proved that they did not exist. Copernicus had to use more epicycles in his model than Ptolemy had used in his.
Epicycles, deferents, and the equant

**Equinox:** Is a biannual event when the Sun is directly overhead on the equator. The Vernal (spring) Equinox occurs every March 20 or 21 and the Autumnal (fall) Equinox is on September 22 or 23. On those days, the Sun rises directly to the east and sets precisely to the west on the equator, and the lengths of the day and night are roughly equal.

‘Fixed stars’: The Babylonians and Greeks were the first to distinguish the ‘wandering’ planets from the ‘fixed stars’ that do not appear to move, other than from diurnal motion.

**fl.** Is the symbol for *floruit,* which is Latin for ‘flourished;’ it is used when a person’s period of highest productivity or influence is known, but the dates of their birth or death are not.

**Galileo Galilei:** Was a renowned Italian scientist (1564-1642); Albert Einstein called him the ‘father of modern science.’ Using a homemade telescope, he discovered the four principal moons of Jupiter in January 1610. This, he said, was evidence that celestial bodies could orbit objects other than Earth; it was proof that heliocentrism was correct.

The pope forced him to make a public denial of his heliocentric views in 1633 on threat of death, but he had already broken the hold of the model of geocentrism in the minds of most literate Europeans.

---

**Geocentrism, geocentric model:** Is the belief that the Earth is at, or near, the center of the universe; all of the celestial objects are seen as orbiting the Earth in this system.

---

A portrait of Galileo Galilei by Justus Sustermans (1636)

A geocentric Solar System

In or around the year AD 150, Ptolemy wrote a geocentric model that dominated the astronomy of the West for more than 1400 years; it would take Copernicus, Kepler, and finally, Galileo, to refute it.
Other geocentric models had concentric (nested) orbits; in these, the planets, the stars, the Moon, and the Sun all orbit Earth in circular paths.

**Geometry:** Is the branch of math that deals with sizes and shapes of figures as well as their relative position in space. It is the oldest form of advanced mathematics and is central to astronomy, surveying, and architecture; it was created independently in Egypt, Sumer, and the Indus River valley, all before the year 3000 BC.

**Gnomon:** Is the elevated area at the center of a sundial; it casts the shadow that designates the time of day. In the northern hemisphere, they are usually oriented to point north; gnomons are set so they are parallel to the rotational axis of the Earth.

**Halley, Edmond:** This British scientist (1656-1742) is best known for discovering the orbital period of the comet named for him.

**Han dynasties:** These were the imperial governments of China and much of East and Central Asia; the ‘Western Han Dynasty’ reigned from 206 BC to the year AD 9. The ‘Eastern Han Dynasty’ ruled in the years from AD 23 to 220. The Chinese still call themselves the ‘Sons of Han.’

**Heliocentrism, heliocentric model:** As defined by Copernicus, this is the view that the Earth and the other planets all orbit the Sun; the Sun, he said was at, or near, the center of the universe.

In the third century BC, the Greek, Aristarchus of Samos, had written the first math-based model that the Earth orbited the Sun; for the next two millennia, only a few did not reject it.

The belief that the Sun orbited the Earth would dominate astronomy, even after Copernicus’ model was published. He convinced some of his readers, but most did not accept his ideas.

As refined by Kepler, Galileo, Newton, and others, the idea that the Sun is the center of the Solar System has been a mainstay of astronomy for the last three centuries.

**Heliotropion:** Is a type of sundial that was used to determine midday, calculate the length of the year, and determine latitude. It was far superior to earlier types of sundials.

**Inclination of the ecliptic:** The ecliptic, the Sun’s apparent path across the sky, is not at right angles to the Earth’s axis.

This is due to the Earth’s equator being at an angle of twenty-three and a half degrees toward the Sun at summer solstice and twenty-three and a half degrees away from the Sun at winter solstice; this helps produce the Earth’s seasons.
Irregular velocities of the planets: Due to the elliptical paths they follow, planetary orbital velocities vary. This is due to the gravitational influences of other planets as well as the gravitational pull of the Sun.

Jewish calendar: Is a luni-solar calendar; it is used to determine the dates of Jewish holidays.

Julian calendar: Is a solar calendar that was introduced in the year 45 BC by Julius Caesar; it has a cycle of three years of 365 days each and one leap year of 366 days. Due to its over-estimation of the length of the year, it had an error of ten days by 1582. That year, the Gregorian calendar replaced it in most Catholic lands. With time, all of the lands of Europe abandoned the Julian calendar, but only slowly; Russia used it until the year 1917. The Eastern Orthodox Church still uses it.

Johannes Kepler: Was a renowned German astronomer, mathematician and astrologer; he lived from 1571 to 1630. He proved that the Earth, as well as the other planets, moves in elliptical orbits around the Sun. He showed that the planets and their orbits are all subject to natural laws. His work was a driving force in the triumph of heliocentrism.

**Latitude:** In astronomy, this is the angular distance of celestial bodies to the north or south of the ecliptic. It is also used to reference north-south distances on Earth; the equator is at zero degrees latitude, and both the north and south poles are at 90° latitude.

**Library of Alexandria:** This was the largest library and research center in the ancient Greek world; it was part of the Museion, in Alexandria, Egypt. Founded in the early decades of the third century BC, it was a center for scholars until its final closing in AD 391. Much of it had been damaged by warfare and riots; the first of these was in 46 BC.

**Longitude:** Is a system that is based on imaginary lines called the lines of longitude. They run along the north to south axis of both the Earth and the celestial sphere. They are used for east to west coordinates; Hipparchus seems to have been the first to use both longitude and latitude.

Since the year 1884, the prime meridian, which runs through the Greenwich area of London, England, has been the zero point of the global longitudinal system. In previous cultures, locations such as India’s
Ujjain Observatory or the Greek colony of Massalia (which is now Marseilles, France) were used as the prime meridian.

Lunar eclipse: Is an event when the Earth blocks the light of the Sun from at least a portion of the full Moon. Up to three lunar eclipses can occur in a year.

Lunar month: Is the period in which the Moon cycles through all of its phases. It can be expressed either as a sidereal month or more often, as a synodic month.

Luni-solar calendar: Is any calendar that uses both lunar phases and the Sun’s position. Most of them have a year of twelve months and leap years of thirteen months every two to three years.

Mathematical astronomy: Is the use of advanced mathematics in the field of astronomy; as the disciplines were closely related, it began with the Sumerians before 2000 BC.

Meridian: Is an imaginary circle running from the North Pole to the South Pole of both celestial and terrestrial globes.

Meridian height: Is the height above the horizon (the altitude) of a celestial object at the point that it passes through the north-south meridian; this occurs when the object passes due north, or south, of the observer’s location.

Metonic cycle: This is a nineteen-year luni-solar calendar. It is tied to the seasons by adding twelve twelve-month years to seven leap years; each of these is thirteen months long. It was probably first noted by the Babylonians before 500 BC; it was brought to the Greek world in the year 432 BC by the Athenian astronomer Meton. It is still a part of the Jewish calendar. It is used to this day in China as well; there it is called the ‘Zhang.’

Miletus: This ancient city was formerly on the coast of the Aegean Sea; its ruins are now several miles inland, in what is now Turkey. It was one of the most important Greek cities before Persia conquered it in the early fifth century BC.

Model: This is an idea that allows researchers to create testable explanations of the phenomena being studied.

Museion: ‘The Institution of the Muses’ in Greek, it was a center for research and higher learning that included the Library of Alexandria. It was in the Greek city of Alexandria, Egypt. The Museion was founded in the early third century BC by one of the Greek kings of Egypt; it closed when a later king expelled most of the scholars there, in 145 BC. The Library continued, in various forms, for five more centuries, until the year AD 391. Museion is the origin of the word ‘museum.’

See ‘Library of Alexandria.’

Nicea: Is the former name of what was a Greek city, in what is now northwestern Turkey. It was a prosperous trading center from the fourth century BC until c. 1700. It is now the small town of Iznik. It was the birthplace of Hipparchus.

Nodal month: Is the 27.21-day period in which the Moon returns to the same node of its orbit. Nodes are the two points where the Moon’s orbit intersects with the Earth’s orbit.

Observatory: Is a facility from which to observe the sky. True observatories have both specialized sighting equipment and specialized structures.
Occultation: Is an event that is caused by an object temporarily blocking all or part of the light of a celestial object. Eclipses and transits are both types of occultations.

Order of magnitude: A number’s nearest power of ten (i.e. 1 … 10 … 100).

Orrery: The earliest known type of analog computer in history; it was used to predict the movements and positions of certain celestial objects. Although some sources credit Posidonius of Rhodes (c. 135-51 BC) with the invention of the orrery, it was in use by the year 150 BC.

In 1901, an orrery that is now known as the Antikythera Mechanism was found off the Greek coast in a shipwreck that dated to the years between 150 BC and 100 BC. Analysis showed it had sophisticated features that were not built again until the ninth century, a thousand years later.

Planisphere: Is a flat map of the celestial sphere. It is also known as a star chart.

Plato: Was a Greek philosopher who lived in Athens from the years 428/427 to 348/347 BC. He established the Academy; it was the first institution of higher learning in Europe. In a discussion of astronomy, he told his listeners to ‘save the phenomena,’ by this he meant, ‘explain the movements of the celestial objects.’ He thought that the Sun, the Moon, the stars, and the planets should all orbit the Earth in perfect circles. Eudoxus, a rival teacher, took up that challenge by writing the earliest known mathematical model of the universe.

Pleiades cluster: Is a group of seven (generally) visible stars in the constellation Taurus. In optimal viewing conditions, eleven stars are visible. It is one of the star clusters closest to Earth, as well as one of the brightest.
Pole star: Also known as the North Star; it is the star that is in rough alignment with the Earth’s axis. This makes it appear to be above the North Pole. Due to diurnal rotation, the Pole star is the only star that does not appear to move when viewed from Earth’s northern hemisphere. There is no Pole star in the southern hemisphere.

Precession of the equinoxes: Also called Precession, it is the term for the changes in the positions of the stars. It is caused by the 25,765-year cycle of Earth’s axis of rotation with respect to inertial space i.e. the Earth’s ‘wobble.’ It is due to the gravitational effects of the Sun and the Moon.

The Greek, Hipparchus was the first man to identify this westward movement of the equinoxes along the ecliptic through time. He did this by comparing his maps of the positions of certain stars for more than two decades with those made centuries earlier by Greek and Babylonian astronomers. He found that the tropical year was twenty minutes shorter than the sidereal year. This was from what Copernicus would call precession. One of its effects is the changing Pole (North) star. This was the star Thuban in 3000 BC; it is now the star Polaris. The star Vega will be the Pole star in 12,000 years. See ‘Sidereal year,’ and ‘Tropical year.’

Precession and the changing Pole star

Proper motion: Due to the Sun’s orbit of the center of the Milky Way Galaxy, as well as other factors, the ‘fixed stars’ do, in fact move. The average stars’ motion is approximately one degree for every 350 years. Proper motion is a sign of the continuing expansion of the universe after the ‘Big Bang.’ It is only apparent after long years of observation.

Retrograde motion: Although the five visible planets appear to move from west to east against the background stars most of the time, occasionally each will appear to move from east to west for a short time.

Mars’ retrograde motion, 2003: The faint line is the planet Uranus, also in retrograde (photo credit: Tunc Tezel).
This is due to the planets, including the Earth, circling the Sun at differing rates and distances. Ptolemy, in his geocentric model of the universe, had to use a complex system to account for retrograde motion. Kepler’s Three Laws of Planetary Motion debunked all of his ideas.

**Rhodes:** This is a large Greek island off the coast of what is now southwestern Turkey. From the years 332 BC to 42 BC, it was a center of Greek culture.

**Saros cycle:** This is an eclipse period of eighteen years, eleven months and eight hours; it is the time needed for the Earth, the Sun, and the Moon to cycle through their motions. This makes for solar and lunar eclipses at regular cycles; Babylonian astronomers, who identified the Saros cycle c. 500 BC, were the first to note this.

**Sidereal month:** Is the time the Moon takes to complete an orbit of the Earth with respect to the background stars (27.322 days). As the Earth is constantly orbiting the Sun, the Moon travels less than 360 degrees between one new moon and the next to complete a sidereal month. See “Lunar Month” and “Synodic Month.”

**Sidereal year:** Is how long the Sun takes to return to its original position with respect to the background stars as viewed from the Earth; this is the apparent orbital period of the Earth, or 365.256 days.

Due to precession, this is twenty minutes and twenty-four seconds more than the tropical year. That is the time needed for the Earth to orbit the Sun (365.2422 days). See ‘Tropical year.’

**Solar anomaly:** Most sky-watchers of this era thought that the Sun orbited the Earth in a perfect circle. The Greek Euctemon (fl. 432 BC) was the first to notice the length of the seasons varied, this is called the solar anomaly.

It is caused by the Earth’s elliptical orbit of the Sun; Hipparchus and others who thought the Sun circled the Earth had to use artificial constructs such as equants to explain the solar anomaly.

Around the year 130 BC, he found that spring was the longest season, at 94.5 days, and that summer was the shortest, at only 92.5 days. Due to the Earth’s eccentric orbit, summer is now the longest season at 94 days; winter is now the shortest, with just 89 days.

**Solar calendar:** Is a time-keeping system that is based on the position of the Earth in its orbit of the Sun; in geocentric systems, they measure the apparent journey of the Sun over the course of a year. Most of the world uses solar calendars. These are based on the length of the mean tropical year, 365.2422 days (365 days, 5 hours, 48 minutes and 46 seconds).

**Solar eclipse:** Is an event that is caused by the new moon passing between the Earth and the Sun; this casts the lunar shadow on a portion of the Earth.

**Solar motion:** This refers to the apparent movement of the Sun with respect to background stars. It is due to the solar orbit of the Earth. See ‘Diurnal motion.’

**Solar year:** See ‘Tropical year.’

**Solstice:** Is a biannual event when the Earth’s axis reaches its maximum (Summer Solstice) or minimum (Winter Solstice) tilt towards the Sun. Both solstices mark the day when the Sun is furthest from the Equator.
In the northern hemisphere, the Summer Solstice (on June 20 or 21) corresponds with the longest day of the year and the Winter Solstice (on December 21 or 22) with the shortest day. In the southern hemisphere, the effects are reversed. See ‘Inclination of the ecliptic.’

**Spherical astronomy:** This branch of astronomy is used to find objects on the celestial sphere; it is an integral part of astrology, timekeeping, and navigation.

**Spherical trigonometry:** This type of advanced math was developed to aid the calculation of the locations and motions of the celestial objects.

**Spica:** This is the brightest star in the constellation Virgo; it has been studied since at least 3200 BC when Egyptian records refer to it.

**Star catalog:** Is a systematic listing of stars, usually with their location and other data; Babylonian astronomers wrote the earliest known star catalogs as early as 1530 BC, and no later than 1155 BC. The first man known to have written a star catalog was Shi Shen of China, c. 375 BC.

**Stereographic projection:** Is the method of transferring a depiction of a curved object, such as the Earth or the night sky, to a flat surface, such as a map.

**Sumer:** Was the area that is now the southern portion of Iraq; by the year 4000 BC, the Sumerians had the first urban society.

**Sundial:** This is the oldest and simplest type of time-keeping device, it consists of a gnomon in the center of a circle marked to represent the time of the day. The earliest known sundials were used in Egypt c. 3500 BC. See ‘Gnomon.’

**Sunspot:** Is an intensely magnetic area on the visible face of the Sun. They are caused by magnetic storms that reveal the cooler, lower layers of the Sun; these are darker in color. During periods of extreme sunspot activity, they can be seen from Earth with the naked eye.

**Synodic month:** Also called a Lunar month; it is the period needed for the full cycle of the Moon’s phases as it orbits the Earth (29.531 days). As the Earth is circling the Sun at the same time, the Moon must travel more than 360 degrees each Synodic month. See ‘Sidereal month.’

**Taichu calendar:** Is a luni-solar calendar devised in 104 BC; it was the template for all Chinese calendars that followed, in that each has twelve lunar months, with a leap
year of thirteen or fourteen months every two to three years. There are other shared features as well.

Talmudic academy: Is an institution of higher learning that is devoted to religious and legal scholarship; this is centered on the Talmud. The Talmud is the record of discussions by learned rabbis on issues central to Jewish life. The two oldest Talmudic Academies were founded in Babylonia by the year AD 200.

Thracian: This was the term for the inhabitants of Thrace; it was an area within what are now northern Greece, southern Bulgaria, and European Turkey.

Transit: Is the passage of an object between the Earth and a more distant, larger object. The latter is often the Sun or a star.

Trepidation: This was a theoretical oscillation or irregularity in the timing of equinoxes; it was used as an alternative to the theory of precession. It was a key concept in the astronomy of the West for more than a thousand years.

Trigonometry: Is the branch of math that involves triangles, especially plane triangles. Ancient Egyptians and Babylonians laid the foundations of trigonometry, but it was the Greek, Hipparchus who invented trigonometric tables. He is often called the ‘father of trigonometry.’

Tropical year: Also called a solar year; in heliocentric systems, it is the length of time needed for the Earth to complete its orbit of the Sun. In geocentric models, it is the time it takes for the Sun to return to the same position on the path of the ecliptic as it circles the Earth. The tropical year is 365.2422 days long. See ‘Ecliptic,’ and ‘Sidereal year.’

Universal sundial: Most sundials have gnomons (the raised center on a sundial) that cannot be moved, but the gnomon of a universal sundial can be adjusted so that it will be accurate at any latitude. Many universal sundials were small enough to carry on one’s person; they were the forerunners of modern watches.

Venus’ changing phases: Late in the year 1610, Galileo trained his telescope on the planet Venus. He soon noted that the planet’s appearance changed similar to that of the Moon; both celestial bodies went from dark (new) to very bright (full).

He wrote that this proved that Venus orbited the Sun, and not the Earth. He said that it also showed that Venus was between the Earth and the Sun. This was another error in Ptolemy’s model; he thought the Sun was closer to Earth than was Venus.

Crescent-shaped Venus

Visible planets: Are the five planets that can be seen with the naked eye: Mercury, Venus, Mars, Jupiter, and Saturn. The word ‘planet’ (which is the ancient Greek word for ‘wanderer’) distinguished them from the more numerous ‘fixed stars.’
**Warring States:** This is the term for the period in China from 475 BC to 213 BC; this was when there were seven rival kingdoms in that land. The era saw the rise of many of the institutions in government that would be characteristic of the Chin and Han dynasties that followed there.

**Water clock:** Is a time-keeping device that uses the regulation of water flowing into or out of measured containers. It is the second oldest type of clock after the sundial. The Egyptians and Sumerians both had water clocks by around 1500 BC.

**The West, Western world:** As used in the text, this refers to the populations, as well as the cultures, of Central Asia, the Middle East, North Africa, and Europe. In this context, non-Western groups are those from the Indian subcontinent, China, and Korea.

**Zodiac:** Is the term for the band of the sky eight degrees on either side of the ecliptic; it means ‘Circle of Animals’ in ancient Greek. The zodiac is the apparent path of the Sun through the orbits of the five visible planets and the Moon.

In astrology, the ‘band of the zodiac’ is divided into twelve equal parts each 30° wide. Each of these segments is named for a constellation. These are the twelve ‘signs of the zodiac.’

**Zoroastrian:** Is anything that is associated with Zoroastrianism. This religion is based on the teachings of the Persian priest Zoroaster. He may have lived in the years from 628 to 551 BC. Some say that he was alive much earlier, perhaps as far back as the year 1000 BC.

Before the Muslim conquest of 651, Zoroastrianism was the state religion of Persia. For much of the previous four centuries, that land had controlled what are now Iran, Iraq, Afghanistan, and portions of several adjacent countries. There are more than 200,000 Zoroastrians today. Most of them live in India; there they are called the Pharsis, or Parsis.

A second-century mural of Zoroaster
EARLY ASTRONOMERS IN CONTEMPORARY CULTURE

The first astronomer, Imhotep of Egypt, is better known to most people than are any others from this era. This is due to his role as the villain of several ‘Mummy’ movies, most memorably in 1932 and 1999. In the first film, Boris Karloff played the evil priest Imhotep in *The Mummy* (below).

The character of Imhotep was resurrected as the villain in 1999’s *The Mummy*; this was aided by sophisticated special effects. A South African actor, Arnold Vosloo, brought more athleticism to the title role. Here, he is in a fight scene with Brendon Fraser, who portrayed the movie’s hero. Both actors reprised their roles in two years, in *The Mummy Returns*.

Another astronomer from this era who is relatively well known is Hypatia; she has been a hero and role model to many for more than a century. Since 1999, *Hypatia*, a quarterly review of women in philosophy, has honored her memory. A novel of the same name was published in 1995.

Her life and accomplishments, as well as her gruesome death, have been fodder for artists since 1510. That year, Raphael included her in his painting, *The School of
Athens (below). He was the first to portray Hypatia as a young maiden; it is more likely that she was a 45-year old woman when she met her fate.

Many more people learned of Hypatia with the 2009 debut of a motion picture on her life. Entitled *Agora*, it was directed by Alejandro Amenabar; Rachel Weisz starred as the doomed scholar. It led to controversy at its premiere screening at the Cannes Film Festival that year. Much of this was due to its portrayal of early Christians, especially Saint Cyril of Alexandria; most of Egypt’s Christians revere him to this day. In death as in life, Hypatia continues to both fascinate and provoke debate.

Another astronomer of these years who is still in the popular culture is Zhang Heng (AD 78-139) of China. Most there know him not as the inventor of the hydraulic armillary sphere but rather as the man who built the earliest known seismograph and the first odometer, as well as the first non-magnetic compass. Replicas of his brass seismograph (below) have been rebuilt, most recently in 2005.

Painted in 1885 by Charles William Mitchell, it was an illustration in a reissue of *Hypatia, or New Foes with an Old Face*, an 1857 novel by Charles Kingsley. It shows her appealing for mercy, in vain, at the altar of the Church where she died.

Zhang thought that atmospheric disturbances were the cause of earthquakes; even so, his seismograph can be used to this day. It still shows the both general location of earthquakes and their relative strength.
ASTRONOMICAL FEATURES AND SPACECRAFT NAMED FOR EARLY ASTRONOMERS

**Agrippa**: Lunar crater Agrippa.

**Ammonius Hermiae**: Lunar crater Ammonius.

**Anaxagoras of Clazomenae**: Lunar crater Anaxagoras and asteroid 4180 Anaxagoras.

**Anaximander of Miletus**: Lunar crater Anaximander and asteroid 6006 Anaximandros.

**Anaximenes of Miletus**: Lunar crater Anaximenes and asteroid 6051 Anaximenes.

**Apollonius of Perga**: Lunar crater Apollonius and lunar feature Rimae Apollonius.

**Archimedes**: Lunar crater Archimedes, lunar feature Rimae Archimedes, and asteroid 3600 Archimedes.

**Archytas of Tarentum**: Lunar crater Archytas and lunar feature Rima Archytas.

**Aristarchus of Samos**: Lunar crater Aristarchus, lunar feature Rimae Aristarchus, and asteroid 3999 Aristarchus.

**Aristillus of Samos**: Lunar crater Aristillus.

**Aristotle of Stagira**: Lunar crater Aristoteles and asteroid 6123 Aristoteles.

**Autolycus of Pitane**: Lunar crater Autolycus.

**Callipus of Cyzicus**: Lunar crater Calippus and lunar feature Rima Calippus.

**Martianus Capella**: Lunar crater Capella

**Cleomedes**: Lunar crater Cleomedes.

**Cleostatus of Tenedos**: Lunar crater Cleostatus.

**Conon of Samos**: Lunar crater Conon and lunar feature Rima Conon.

**Democritus of Abdera**: Lunar crater Democritus and asteroid 6129 Demokritos.

**Eratosthenes of Cyrene**: Lunar crater Eratosthenes, asteroid 3251 Eratosthenes, and the Eratosthenian geologic period of the Moon.

**Euctemon**: Lunar crater Euctemon.

**Eudoxus of Cnidus**: Lunar crater Eudoxus, Martian crater Eudoxus, and asteroid 11709 Eudoxus.

**Geminus of Rhodes**: Lunar crater Geminus.

**Harkhebi**: Lunar crater Harkhebi.

**Harpalus**: Lunar crater Harpalus.

**Heraclides of Pontus**: Lunar feature Promontorium Heraclides.

**Hipparchus**: Lunar crater Hipparchus, Martian crater Hipparchus, asteroid 4000 Hipparchus, and the European Space Agency satellite Hipparcos (it was launched in August 1989).

**Hypatia of Alexandria**: Lunar crater Hypatia, lunar feature Rimae Hypatia, and asteroid 238 Hypatia.
**Imhotep**: Imhotep crater on Mercury and asteroid 1813 Imhotep.

**Kiddinu**: Lunar crater Kidinnu.

**Luoxia Hong**: Asteroid 16757 Luoxiahong.

**Menaechmus of Alopeconnesus**: Asteroid 54522 Menaechmus.

**Menelaus of Alexandria**: Lunar crater Menelaus and lunar feature Rimae Menelaus.

**Meton of Athens**: Lunar crater Meton.

**Oenopides of Chios**: Lunar crater Oenopides.

**Pappus of Alexandria**: Asteroid 29448 Pappos.

**Parmenides of Elea**: Asteroid 6039.

**Philolaus**: Lunar crater Philolaus.

**Posidonius of Rhodes**: Lunar crater Posidonius and lunar feature Rimae Posidonius.

**Proclus**: Lunar crater Proclus.

**Claudius Ptolemy**: Lunar crater Ptolemy, Martian crater Ptolemaeus, and asteroid 4001 Ptolemaeus.

**Pythagoras of Samos**: Lunar crater Pythagoras and asteroid 6143 Pythagoras.

**Pytheas of Massila**: Lunar crater Pytheas.

**Seleucus of Seleucia**: Lunar crater Seleucus and asteroid 3288 Seleucus.

**Shi Shen**: Lunar crater Shi Shen.

**Sima Qian**: Asteroid 12620 Simaqian.

**Sosigenes of Alexandria**: Lunar crater Sosigenes and lunar feature Rimae Sosigenes.

**Thales of Miletus**: Lunar crater Thales and asteroid 6001 Thales.

**Theon of Alexandria**: Lunar crater Theon Junior.

**Theon of Smyrna**: Lunar crater Theon Senior.

**Timocharis of Alexandria**: Lunar crater Timocharis and lunar feature Catena Timocharis.

**Zhang Heng**: Lunar crater Chang Heng and asteroid 1802 Zhang Heng.

**Zu Chongzhi**: Lunar crater Tsu Chung-Chi and asteroid 1888 Zu Chong-Zhi.
SELECTED BIBLIOGRAPHY


Lunar crater Aristarchus (left) photo taken during the Apollo 15 lunar landing mission, 1971 (photo credit: NASA)
THE SATELLITE HIPPARCOS (PHOTO COURTESY OF THE EUROPEAN SPACE AGENCY)