The Amazing Astronomers of Antiquity
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Scene 1: Rome, Italy

Welcome to Rome, the Eternal City and a living museum of civilizations past and present. The Pantheon, a temple dating back to Imperial Rome is perhaps the most elegant and copied building in the world and a structure with an astronomical connection. The Pantheon's dome is larger than St Peters' and in its center is an open oculus showing day and night. This temple, both open and enclosed, is an astronomical instrument -- a type of solar quadrant. As the sun moves westward across the sky, the sun's light moves across the dome walls - like sunlight streaming through a porthole. The moving image tells both the time of day and the season of the year. The Pantheon was dedicated to the seven planetary divinities - Jupiter, Saturn, Mercury, Venus, Mars, the Sun and Moon -the most important celestial objects in the ancient sky. The Pantheon's design required the collective wisdom of many ancient astronomers.

We have sent reporters throughout the Mediterranean Basin to identify and honor seven of these amazing astronomers.

Scene 2: Saqqara, Egypt

Welcome to Saqqara, home of the world's oldest major stone structure and Egypt's first great pyramid. Imhotep constructed this step pyramid 5,000 years ago for King Djoser. Imhotep was an architect, high priest, physician, scribe and astronomer -- one of the few men of non-royal birth who became an Egyptian god. Saqqara is an immense cemetery for the ancient city of Memphis. The entire complex honors the dead and secures their passage into the afterlife. Imhotep designed the step pyramid to allow the deceased to mingle with the circumpolar stars that arc across the northern sky each night -- to link heaven and Earth. Looking north, we can see how the pyramid captures the turning motion of the northern stars.

As a scientist and priest, Imhotep would have predicted and monitored the flooding of the Nile. With its annual flood, the Nile River nourished Egypt for more than 5000 years. Along its banks, ancient astronomer-priests observed the turning starfield from dusk to dawn. They were looking for a sign to predict the yearly Nile flood. Night after night they studied the constellation of the Egyptian god Osiris, called Orion, the hunter, by the Greeks. They followed its three stars in a row down toward the eastern horizon, lit by the glow of dawn. Each day Orion would be a bit higher before dawn, allowing astronomer-priests to see more stars below it in the predawn sky.

Finally one morning they saw the bright star Sirius for the first time. The three stars had shown exactly where to look. They realized that Sirius would be visible for the first time on the same day each year, just after the summer solstice. This day marked the beginning of a new year in the world's first solar calendar. The first sighting of Sirius also promised that the nourishing Nile flood would soon begin at the Egyptian capital of Memphis.

Astronomer-priests could count the number of days between the annual predawn appearances of Sirius. Year after year the counting continued until they were certain that the solar year is 365 and a quarter day long.

Over 2000 years ago, Julius Caesar visited Egypt and learned how to make a calendar with 365 days each year and an extra day added every 4 years. The resulting Julian calendar became the official calendar of western civilization until the 16th century.

For his discovery of the solar year and the use of astronomy to design pyramids and predict the Nile flood, we honor Imhotep representing the Egyptian astronomer-priest as our first amazing astronomer of antiquity.

Scene 3: Tunis, Tunisia

Welcome to modern Tunis, site of ancient Carthage and home of our second amazing astronomer - the Phoenician mariner. Phoenician sailors from the city of Tyre founded Carthage almost 3,000 years ago. Carthage soon became the commercial center of the western Mediterranean, a position it retained until it was destroyed by Rome. With its capable merchant marine and naval fleet, Carthage controlled the passage between North Africa and the island of Sicily. But its sailors explored far beyond these waters.

On the temple of Ba'al Hammon in Carthage, there was an inscription, which began ....“The Voyage of Hanno, King of the Carthaginians, to the Libyan regions of the Earth, beyond the Pillars of Hercules...” The text goes on to describe Hanno's journey through the Straight of Gibraltar, known at the time as the Pillars of Hercules, and along the west coast of Africa around Cape Verde and perhaps to the equator.

By day, Phoenician sailors navigated using landmarks along the coastline. By night they became astronomers using the “Phoenician star”, also called the North Star in Ursa Minor, the constellation of the Little Bear. They knew that this star would always be in the northern sky. So they kept the North Star starboard, to their right when they wanted to sail west . In contrast, if they wanted to sail eastward, they oriented their ship so that the North Star would be to their left on the port side. Other cultures gave the name 'Phoenike' to the Ursa Minor constellation pattern. The voyages of Hanno illustrate how Phoenician navigators sailed around Africa, discovering distant settlements on the western coast of the continent. They may also have reached the British Isles. When they sailed north toward England, sailors would see the North Star rising over their bow. As they turned south, the North Star would be behind them and would sink lower in the sky as they neared the equator.

For his skill in using the stars to explore new worlds, we recognize Hanno, representing all Phoenician mariners, as one of the amazing astronomers of antiquity.

Scene 4: Alexandria, Egypt

Welcome to the modern Bibliotheca Alexandrina - a major library and cultural center on the Mediterranean Sea at the mouth of the Nile River. ......This library was built on the site of the ancient Royal Library of Alexandria. At the time of Imperial Rome, this library was the largest in the world with an estimated 500,000 scrolls. The works of Aristarchus of Samos, our next amazing astronomer, were archived here. Aristarchus was the first scientist to explain both the Egyptian solar calendar and the role of the Pole Star in navigation. Aristarchus knew that the Earth was a sphere - a curved globe rather than a flat plane. Although his maps showed little beyond the lands surrounding the Mediterranean, he believed that his world was part of a giant turning globe.

To understand Aristarchus's explanation, imagine we could observe the stars from inside the Earth -- seeing the constellations through the ghosted continents. The pole star lies directly over the Earth's North Pole. Slowly the Earth turns eastward and we see that the Earth's North Pole does not move and the Pole Star does not move either. Now how does this rotation look from the Earth's surface? We don't think of ourselves as moving. So let's stop the Earth and watch what happens to the stars. As the earth turns eastward, we do not feel ourselves moving, but observe the stars moving westward instead. The fixed stars seem to circle Polaris as the Earth turns under them. Facing eastward we can see stars seeming to rise along the eastern horizon. Stars seem to set along the western horizon. The Earth's rotation also causes the moon and planets to move westward with the starfield. This turning of the Earth also results in the sun rising in the East and setting in the west - bringing day and night to the planet. As impressive as this discovery was, Aristarchus offered another, more startling theory - one so radical that it would not be widely accepted for over 1500 years. He explained the Egyptian solar calendar by proposing that the Earth circled the Sun once a year - a moving Earth that not only rotated on its axis, but also revolved around the sun.

Aristarchus was the first scientist to propose a sun-centered, or heliocentric, solar system where the fixed stars and the sun remain stationary as the earth circles the sun. Because he did not observe the background stars shifting during the year, Aristarchus also theorized that the sphere of fixed stars is so far away that the distance between the Earth and Sun is insignificant. It was this great distance, more than the Earth's motion that caused other astronomers to reject his sun-centered model.

Aristarchus also knew that the moon orbits the Earth and shines by reflected sunlight. He recognized that the locations of the Sun, Moon, and Earth cause the moon's different phases -- from new moon, to first quarter, to full moon, to third quarter and back to new moon again.

For his understanding of moon phases and the rotation and revolution of the Earth, Aristarchus is our next amazing astronomer of antiquity.

Scene 5: Athens, Greece

Welcome to Athens, capital of ancient Greek culture and civilization. The Parthenon on top of the Acropolis symbolizes the glory of ancient Greece. This elegant temple to the goddess Athena, faces east to capture the first light of the rising sun each day.

Aristotle, our next honoree came to Athens to attend Plato's School of Philosophy when he was 17 and became Plato's most favored pupil. His training focused on philosophical speculation rather than direct observation. Aristotle argued that the universe must be spherical and finite with the Earth at its center. Since he did not observe the stars moving, he concluded that the Earth cannot be moving and that the moving Sun, Moon, and Planets must be circling a fixed Earth.

Aristotle believed that each planet followed a path created by a certain number of heavenly spheres -- a theory that required more and more spheres to explain the observed motions of each planet. Aristotle's spheres had a profound influence on medieval scholars who used them to interpret and support Christian theology. Unfortunately, Aristotle's assumed truths kept scientists from considering the simple and accurate experiential model of Aristarchus.

Nevertheless, Aristotle was an amazing astronomer because his questions stimulated our quest to understand the structure of the universe - a quest that continues today.

Scene 6: Cyrene, Libya

Welcome to the ruins of Cyrene in eastern Libya. Eratosthenes, our fifth amazing astronomer, was born in Cyrene when it was an influential and wealthy Greek colony in North Africa. Founded over 2500 years ago, Cyrene was one of the principal cities of ancient Greek culture. Its Temple of Zeus is the largest outside of Athens.

The Greek intellectual training of Cyrene produced Eratosthenes, one of antiquity's most ingenious astronomers. He was proficient in both astronomy and geometry and excelled in combining the two disciplines. He compared observations of sun shadows made at Alexandria with observations made at Aswan, the first cataract of the Nile River. Aswan is almost due south of Alexandria and is very close to the Tropic of Cancer. Eratosthenes knew that the sun is almost directly overhead at noon in Aswan on the summer solstice, the longest day of the year, when the sun is highest in the sky. When the sun is straight up, vertical objects cast no shadow and the sun's light can reach the bottom of a vertical well.

On the same day in Alexandria, the sun is not quite overhead at noon. Objects cast small shadows. Eratosthenes measured the angle of this shadow and realized that this angle was the angular distance between Alexandria and Aswan, on a great circle of the Earth. Eratosthenes realized that the distance around the Earth was just over 50 times the distance from Aswan to Alexandra. In this manner, Eratosthenes made a very accurate calculation for the circumference of the Earth.

Eratosthenes also observed lunar eclipses and saw the shadow of the Earth on the moon. From this image he determined that the moon's diameter is about one-fourth of the Earth's.

For his measurement of the true sizes of the Earth and Moon, Eratosthenes is our next amazing astronomer of antiquity.

Scene 7: Naples Italy

Welcome to Naples, Italy, home of the National Archeological Museum. Inside is a Greek sculpture of the god Atlas carrying a globe on his shoulder. It is not an Earth globe, but a globe of the starfield. This very accurate celestial globe is probably based on the star map of Hipparchus, our next amazing astronomer.

We can imagine this celestial globe all around us. The constellations mapped by Hipparchus cover all of the sky that could be seen from the Mediterranean. He cataloged all the Zodiac patterns, the constellations near the North Pole, and many other patterns throughout the sky. Using the astrolabe that he invented, Hipparchus produced the first accurate star map with over 850 stars, ranked on the brightness scale we still use today. The Hipparchus globe also shows the celestial equator, a great circle in the sky lying directly over the Earth's equator --- as well as the zodiac path marking the sun's position each day of the year. The Sun is at this intersection on the Vernal equinox in March of each year.

Hipparchus discovered that this intersection drifts very slowly through the starfield - moving backward from Aries to Pisces in the last 2,000 years. A slow wobble in the Earth's rotation axis causes this precession. If we precess the stars back to the time when Hipparchus made his star maps, we discover a placement of patterns that matches the stars on the celestial globe that Atlas carries on his shoulder.

From his home on the island of Rhodes, Hipparchus also developed accurate models for the motions of the sun and moon and learned to predict solar and lunar eclipses. Over 2,000 years ago a cargo ship sailing from Rhodes to Rome sank with its cargo of luxury items. Among the statues and vases was an incredible astronomical device, called the Antikythera Mechanism. Crusted over by 2,000 years at the bottom of the sea, it is difficult to see the traces of gear wheels and written scales. X-rays show the remains of at least 30 interlocking wheels turned by a hand crank.

On the front of the mechanism are two metal dials, one inside the other, showing the Zodiac and the days of the year. Metal pointers indicate the positions of the Sun, the Moon and the five planets visible to the naked eye on a given date. When the crank is turned, all the gears start to move. The moon dial makes twelve turns while the sun gear turns only once.

Through a small window, another dial brings up the correct view of the moon. Separate dials display the position of each planet. The device could also have predicted solar and lunar eclipses. It's a mechanical wonder requiring a very detailed and accurate knowledge of motions in the solar system. This precision technology did not reappear until the mechanical clocks of medieval Europe.

The accurate astronomy in this device is based on knowledge compiled by Hipparchus and taught to his followers on Rhodes. Hipparchus also calculated the distance to the Moon and the length of the solar year to within 6 and a half minutes. He was perhaps the greatest scientific astronomer of antiquity.

Scene 8: Alexandria and then Leptis Magna, Libya

We return to the ancient Library of Alexandria to study the works of our final amazing astronomer, Claudius Ptolemy. Ptolemy lived in Alexandria during Imperial Rome and had access to the extensive works of the Royal Library. He relied heavily on the findings of Hipparchus and quoted him often. He also accepted Aristotle's Earth-centered universe without question. Ptolemy produced two major textbooks, an astrological text defining the western zodiac with its 12 familiar constellations, and an astronomical text, the *Almagest*. The *Almagest* explained and predicted motions of the sun, moon, and planets based on an elaborate system of circles in an Earth-centered universe. Using his system, astronomers and astrologers alike could determine the positions of heavenly bodies far into the past or future.

Of all the amazing astronomers, Ptolemy probably made the greatest impact on every day Roman life. Leptis Magna in northern Africa is one of the best-preserved cities of Imperial Rome and one of the richest at the time of Ptolemy. Buried in sand, are the remnants of roads, markets, temples, an elaborate forum, fountains, public buildings, and lavish baths. During Roman times Leptis Magna became the Mediterranean outlet of a trade route through the Sahara into the interior of Africa. Once abandoned, it was buried and preserved by desert sands.

In their everyday lives, the citizens of Leptis Magna and most of Imperial Rome were probably more aware of Ptolemy's astrology than his astronomy. Affluent Romans incorporated astrology into every aspect of their lives, from religion to politics and daily affairs. Pompey, Mark Anthony and Octavian all used astrologers. Octavian, when he became the Emperor Augustus, had coins minted with the symbol of his Moon sign, Capricorn. The Emperor Hadrian, restorer of the Pantheon, was an accomplished astrologer.

The Roman Emperor Septimus Severus was born in Leptis Magna and honored by this magnificent triumphal arch. He married the daughter of a Syrian priest. Soon Syrian Sun worship became the official religion of the Empire, eventually displacing the Greek gods. When sun worship became the state religion, the Emperor was identified with the Sun -- and astrology and astrological symbolism formed an integral part of government policy. The heavens were thought to control the Earthly affairs of Imperial Rome.

For collecting and synthesizing astronomy and astrology knowledge, Claudius Ptolemy has perhaps played the greatest role in reaching the public and in preserving the discoveries of the amazing astronomers of antiquity.

Scene 9: Pantheon

Seven astronomers and seven amazing contributions: the Egyptian astronomers like Imhotep who developed a solar calendar, the Phoenician Hanno who sailed by the stars, Aristarchus with his sun-centered solar system, the philosopher Aristotle, Eratosthenes who measured the Earth's size, Hipparchus with his eclipse tables and star maps, and the astronomy writings of Claudius Ptolemy. Their legacy would extend through the dark ages to the present.

At the Museum's George Observatory, visitors see a beautiful dark night sky -- almost as dark and clear as the heavens of antiquity -- with star patterns and motions unchanged in thousands of years. Every day we use ancient astronomy --watching sunrises, sunsets and the phasing moon, -- counting days, months, and years, predicting the seasons and eclipses, and gazing at the stars overhead -- all a legacy of the Amazing Astronomers of Antiquity.