

# Upon Whose Shoulders We Stand: A History of Astronomy Up to 200 A.D.

Dick Mallot  
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# Who were these “ancient astronomers?”

- Where did “real” astronomy begin?
- What did we know about astronomy 2000+ years ago?
- Who discovered some of our basic principles of astronomy—and how did they do it?
- What tools did they use “back then”?
- Why did they get into astronomy?
- When were maps of the sky created?
- When were constellations “invented”?

# Why was astronomy important?

- Calendars
- Planting/Farming depended upon the knowledge of the seasons
- Religion/ Astrology
- Navigation
- Timekeeping
- Land Surveying



# Timelines:

- Most of us think of Astronomy really starting with Copernicus, Tycho Brahe, Galileo.....
- But a lot of what we know today and take as fact was “known” and measured thousands of years ago.
- This a short history of some of those early astronomers who reasoned and measured out a lot of the universe without sophisticated tools—but with sophisticated reasoning and mathematics.
- And to paraphrase that golf commercial; “these guys were good!!”

# Archaeoastronomy

- The study of the astronomical sites which have left us with no written records or names of the people who set up the ruins that we study today.
- It is understanding how these sites were used, and the determination of what these ancients knew by studying the geometry and alignments of the sites.

# Archaeoastronomy

- What are some of the famous archaeoastronomy sites?
- Nabta: Megalithic Site – 1000 years before Stonehenge.
  - Circle of stones marking solstices and cardinal points more than 6000 years ago in Southern Egypt.
- Stonehenge: 3100 BC to 2000 BC
- Mesoamerican sites: 1500 BC to 1500 AD
- Nazca Lines in Peru: 300 BC to 800 AD

# Nabta



# Stonehenge



# Nazca Lines in Peru



# History of Astronomical Science

- Starts about 600 BC in Greece
- Differs from Archaeoastronomy in that it is documented, written records of events. It is reasoned out (even if wrong) theories of how things work.
- It is attributable to someone/some learning center.
- It is experiential (in most cases) with data and observations.

# Who were some of the “stars”?

- Thales of Miletus, Asia Minor
- Pythagoras of Samos
- Democritus of Abdera, Greece
- Oenopides of Khios, Greece
- Aristotle of Athens, Greece
- Aristarchus of Samos
- Eratosthenes of Cyrene, North Libya
- Hipparchus of Rhodes
- Ptolemy of Alexandria, Egypt

# Thales: 624 to 547 BCE

- Said to have predicted a solar eclipse in 585 BC
- Greeks already knew about the 19 year cycle for lunar eclipses.
- Measured height of the pyramids by understanding “similar triangle” theory: measure the shadow length at the time of day when your shadow is as long as your height.
- Developed the early geometric theorems.

# Pythagoras of Samos: 580 -500 BCE

- Invented some of the math that was needed to get a scientific basis for astronomical calculations –Pythagorean theorem.
- First to note that the morning and evening stars were both Venus.
- Built on Anaximander, who postulated that planets and stars go around in perfect circles.
- Still geocentric thinking at his time.

# Democritus: 470-380 BC

- Developed the concept of the atom: all things were made of microscopic and indivisible, indestructible atomic particles.
- He understood that the Milky Way was a large collection of stars and also thought that space was limitless.

# Oenopides: 450 BC

- Popularized the 12 signs of the zodiac
- Probably copied them the Assyrians in Mesopotamia
- First to fix the angle of the ecliptic with the celestial equator—called it 24 degrees.
- Fixed the year at  $365 \frac{1}{4}$  days.
- Postulated the “Great Year”—the number of years when the motion of the Sun and the Moon exactly repeated their motions—59 years.
- Oenopides' result leads to a lunar month of 29.53013 days which is remarkably close to the modern value of 29.53059

# Aristotle: 384-322 BC

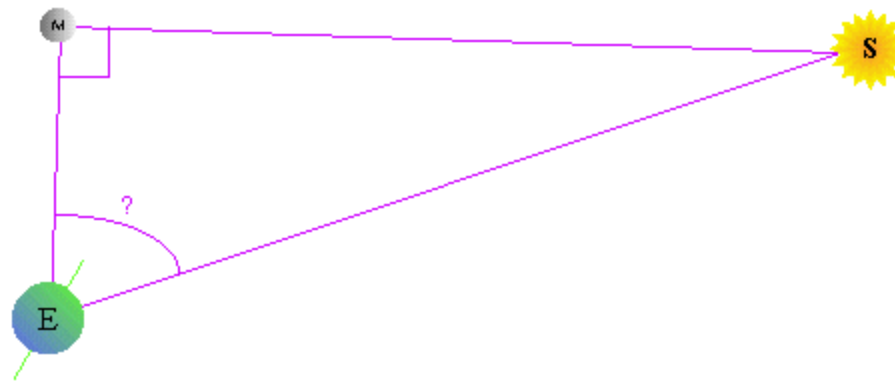
- Did his best work on classifying plants and animals
- Took a qualitative approach to science
- Did not use mathematics in his studies
- Earth, air, fire and water were the elements
- Earth is immobile
- Stars and planets use the Pythagoras' circular spheres model
- Re-discovered in the late Middle Ages, and used to impede observational science.

# Aristarchus of Samos: 310-230 BC

- Believed in a heliocentric universe
- Estimated the distance of the moon and sun
- Utilized excellent mathematical principles but lacked the tools to get the observational data correct.
- All of his written records destroyed in the fire of the library in Alexandria.

# Aristarchus Mathematical Genius

Aristarchus' method of determining the relative distances from the earth to the moon and to the sun

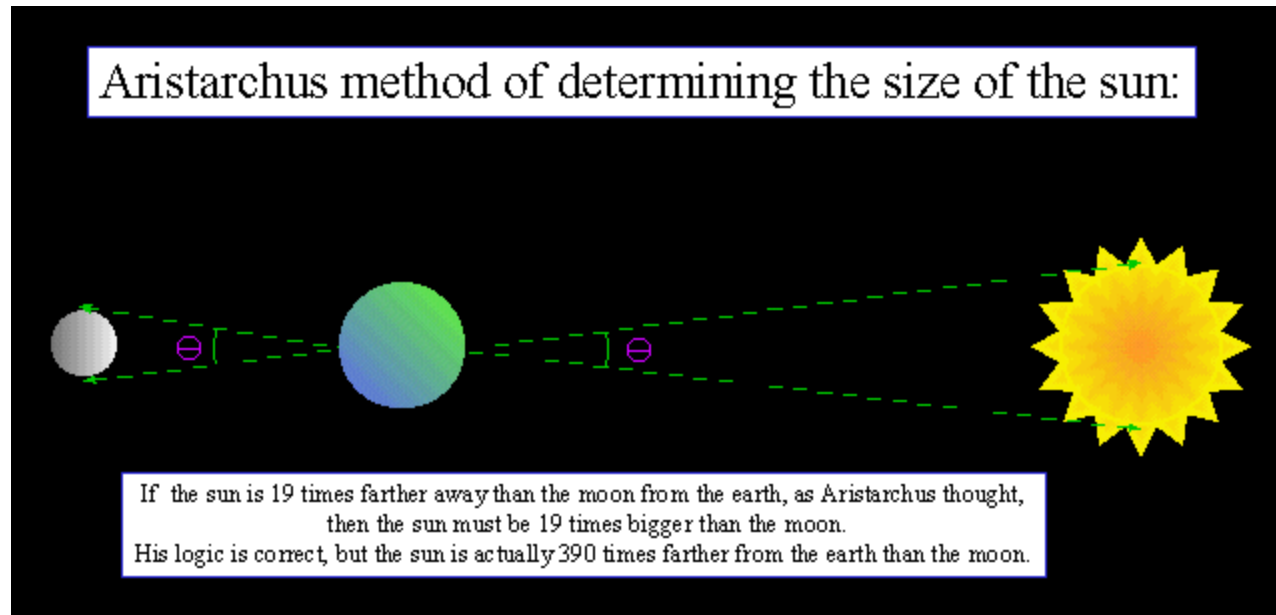


With the measurement of angle MES the ratio of EM and ES can be found.

He found that:  $MES = 87^\circ$  so  $EM/ES = 1/19$   
actually :  $MES = 89^\circ 51'$  and  $EM/ES = 1/400$

# Aristarchus: Measuring the Sun's Size

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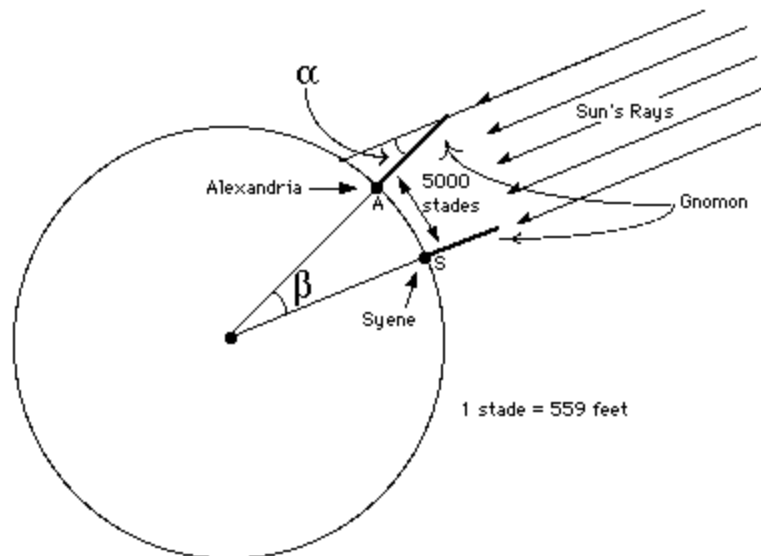


# Eratosthenes of Cyrene: 276-197 BC

- Developed a map of the world
- Developed a way to find the prime numbers
- Estimated the circumference of the earth.
- Measured the tilt of the earth
- Suggested that a leap day be added to the calendar every fourth year.

# Eratosthenes Measurements

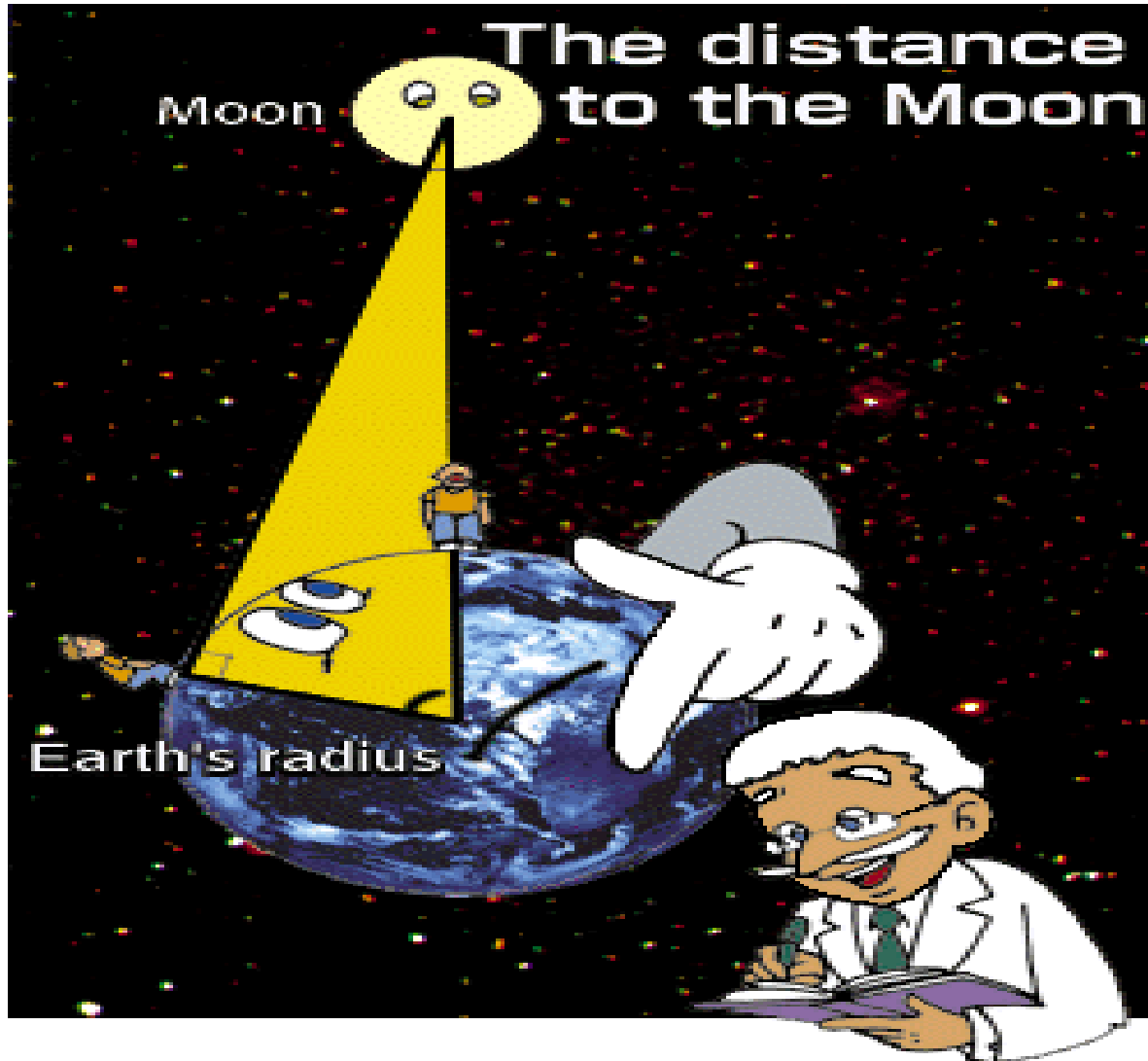
- Working in Syene and Alexandria, which Eratosthenes assumed were on the same meridian, he estimated the distance between the cities to be about 5,000 stades (a stade is believed to be about 559 feet - approximately one-tenth of a mile). At summer solstice, at noon, the Sun cast no shadow in Syene, but in Alexandria a shadow was visible. Using a gnomon (a vertical stick), Eratosthenes measured the shadow's angle to be about one-fiftieth of a circle.
  - Calculated earth radius at 4212 miles vs the 3963
  - Calculated moon radius at 1478 vs. 1080 miles
- » NOT BAD for 220 BCE!!!



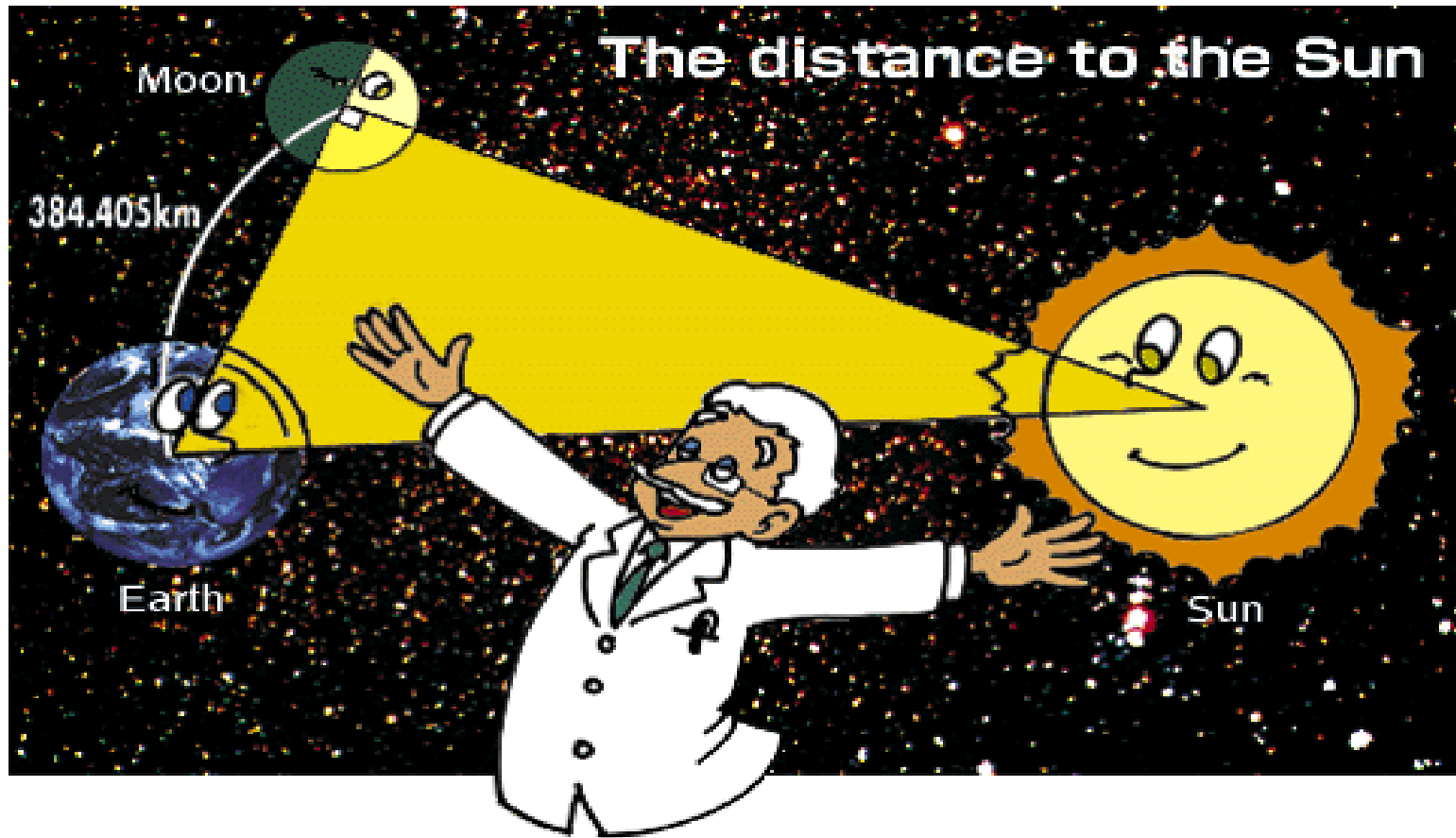
# Hipparchus: 190 – 120 BC

- Introduced the idea of 360 degrees in a circle.
- Calculated the length of a year within 6.5 minutes.
- Calculated the moon's distance at between 59 and 67 earth radii...correct answer: 60
- Discovered precession—and calculated it at 46 seconds per year (vs. the actual of 50.26 degrees per year).
- Develop a star catalogue of 850 stars used later by Ptolemy.
- Developed the currently used magnitude scale of 1-6
- Discovered the first nova.
- Measured distance to moon using a “parallax” method
  - Used different views of a solar eclipse
  - Small angle formula
  - Distance ~240,000 miles

# Hipparchus: Distance to the moon



# Hipparchus: Distance to the Sun



# Claudius Ptolemy: 85-165 AD

- Developed the most sophisticated model of concentric circles (epicycles) to demonstrate star and planetary motions
- He followed a geocentric model
- His *Almagest* had most of Aristotle's ideas in it, with a geocentric approach.
- Because it survived long periods of upheaval and wars, and was "the" astronomy manual until the time of Columbus.

# So, what was known back then....and then lost?

- The earth is round
- Circumference/diameter of the earth/distance to the moon
- The solar system is heliocentric.
- An estimate of the distance to the sun (while wrong, much further than commonly thought)
- Precession of the equinoxes
- Length of the year to a high precision

# The Story does not end here...

- Most of what was known was lost again after this “high” period of astronomy in Greece, Turkey and Egypt.
- Romans were not much interested in astronomy or astrology.
- Arabs conquered many of these countries starting in the 7<sup>th</sup> century, and preserved a lot of the work done by the ancients, refined it, and passed it back to the western world at the end of the Middle Ages..
- Thus it became the foundation of the work and ideas that became prevalent in the 15<sup>th</sup> and 16<sup>th</sup> centuries.