Lecture 3:
History of Astronomy

Astronomy 111
Many ancient cultures took note of celestial objects and celestial phenomena. They noted certain patterns in the heavens and were able to construct calendars. The Chinese, Egyptians, Britons, Mayans, and others have left us evidence of their interest in astronomy.
Stonehenge

- Ancient burial mound ca. 3000 BC
- Stones placed on top of burial mound
- Alignment of stones relate to calendar
Stonehenge can be used as an astronomical calculator.
Mayans

• Kept excellent track of time with a calendar: years, months, days
• Predicted eclipses
• World will not end on December 21, 2012!
Chinese astronomy

- Excellent records of astronomical events
- Observed Supernova 1054
- Modern astronomers use these records to study evolution of supernovae
Ancient Greece

• Greek “philosophers” were the first scientists
• Set the stage for the beginnings of modern Western science
Greek scientist Aristotle showed that the Earth is spherical

- Aristotle (384 BC – 322 BC) supported his statement that the Earth is round with observations.

The Earth’s shadow on the Moon during a lunar eclipse is always circular.

The only object that always throws a circular shadow is a sphere.

Columbus did NOT discover the Earth was round!
Eratosthenes

ca. 200 BC
Alexandria, Egypt

Measured the Earth’s circumference

Measured tilt of Earth’s axis
Eratosthenes did this

Without cell phones or a GPS to measure distance!

- Estimated distance traveled on camel from Alexandria to Syene
- Measured angle of elevation of Sun in both places on the summer solstice
- Eratosthenes got 42,000 km
- Modern measurement gives 40,008 km
Question

• Why couldn’t Eratosthenes use measure the angle of Polaris?
  – Sailors use Polaris today to calculate their latitude
Question

• Why couldn’t Eratosthenes use the same method of measuring the angle of Polaris that we did?
Developed a geocentric (Earth-centered) model for the universe.

Basic assumptions of Greek astronomers:

• Spherical Earth is stationary, at the center of the universe.
• Earth is corrupt, heavens are perfect.
• Heavenly bodies move with uniform circular motion.

Bad assumptions → bad conclusions.
Aristotle (384 BC – 322 BC)

Proposed that the heavens were literally composed of 55 concentric, crystalline spheres to which the celestial objects were attached with the Earth at the center.
• Problem: planets don’t move in perfect circles! Sometimes they move *backwards* against background stars—called retrograde motion
Planets usually move west to east relative to stars; during retrograde motion, they move east to west.
Aristotle

• As we’ll see is often the case in Astronomy, there is a way to solve this problem:

More data or observations
Hipparchus of Rhodes (190-120 BC)

Important early astronomer—the first “observer”
• catalogue of 1000 stars
• classified stars by brightness
• discovered precession of the equinoxes
• Determined
  – obliquity of the ecliptic
  – synodic periods of planets
  – inclination of Moon's orbit
  – place of Sun's “apogee”
  – eccentricity of the “Sun's orbit”
  – estimate of the Moon's distance, using the diameter of the Earth as a baseline
• He put astronomy on a geometrical basis.
Ptolemy worked in Alexandria, was active around AD 140.

Used results of Hipparchus’ research and measurements to create a model of how the solar system worked

Wrote an astronomy text, later called the “Almagest” (= “the best”).

Predicted positions of planets far into the future that were adequately accurate.
Belief in Ptolemy’s geocentric model lasted until the 16th century.

Cosmographia, first published 1524
Ptolemy’s explanation of retrograde motion:

The planet moves in a small circle called the epicycle.

The center of the epicycle moves in a large circle called the deferent.
As seen from Earth, planet moves eastward (direct motion)
Planet moves rapidly westward along epicycle

Epicycle moves slowly eastward along deferent

As seen from Earth, planet moves westward (retrograde motion)
The combination of small and large circles produces “loop-the-loop” motion.
Geocentric model is complicated!
Problem: Ptolemy’s model still did not fit data

During the Middle Ages, Ptolemy’s model had to be fiddled with – more epicycles were added.

The model was needlessly complicated because it was based on erroneous assumptions.

**OCCAM’S RAZOR**

*entia non sunt multiplicanda praeter necessitatem*

entities should not be multiplied beyond necessity

William of Occam (c. 1285–1347 ?)
Copernicus

Mikolaj Kopernik (1473-1543) Poland

Proposed a heliocentric model for the Universe.

Stated that the Sun, not the Earth, was at the center of the universe.
Heliocentric model

Sun is at center.
Earth revolves around Sun.
Earth rotates around axis.
Copernican system
Retrograde motions occur naturally if planets further from the Sun move more slowly.

**Example: Earth and Mars**

- Earth’s orbital radius = 1 A.U.
- Earth’s orbital speed = 30 km/sec
- Mars’ orbital radius = 1.5 A.U.
- Mars’ orbital speed = 24 km/sec
Retrograde motion of Mars

As Earth “laps” Mars, Mars appears to go backward as seen by observer on Earth.

- Earth catches up with Mars
  - a-b
- Passes it
  - b-f
  - Apparent westward motion
- Sees it move to east again
  - g
Copernicus met with considerable (scientific) resistance

Why? It implies that the distance from Sun to the stars is much greater than distance from Sun to the Earth:

- Stars do not vary much in brightness over the course of a year.
- Stars do not show a large parallax over the course of a year.
Parallax
The parallax to the nearest stars is about 1 arcsec ("")
Radical aspects of Copernican model

- Earth is not at center of the Universe.
- Earth is moving.
- Earth is just another planet.
- Space is big – REALLY big.
Conservative aspects of Copernican model

- Uniform Circular Motion assumed
- Epicycles still required
- Again, we need more data or observations!
Tycho Brahe (1546-1601)

Danish Astronomer who made accurate measurements of planetary motion
Uraniborg

- Island given to Tycho by the Danish king
- Built an observatory supported by tenant farmers and government subsidy
- Cost the equivalent of $5 billion!
Hven (Tycho's island)
Tycho was an excellent observer!

- Built many instruments
  - Quadrants that measured to ~1 arcminute precision
- Measured as often as possible
- Attempted to evaluate errors
- Among the first to do such things
sextant  armillary sphere
Tycho’s contributions to astronomy

Tycho discovered ‘new star’, or ‘nova’, upsetting ancient notion of perfect, unchanging heavens.

Made very accurate measurements of planetary positions.
Tycho’s model

- Unfortunately Tycho never really believed in the heliocentric model
- Created his own geocentric model that improved upon Ptolemy’s
Tycho’s system
Tycho vs. Copernicus

Copernicus

Tycho
Tycho had great data

• But his ideas weren’t so great
  – He lost his nose after all!

• Luckily, he had an assistant named Johannes Kepler
  – Kepler had no data of his own, but great ideas
Few questions:

1) Do the inner planets show retrograde motions?

2) See picture on the right. Is it real?

3) In that picture, could you have Venus instead of Saturn? (tricky)
Few questions continued:

4) See picture on the right. Is it real?
5) In that picture, could you have Saturn instead of Venus?
6) Could you have Mercury instead of Venus?