ASTRONOMY 161

Introduction to Solar System Astronomy

Class 5
From Ptolemy to Copernicus

Friday, January 12
(1) Aristotle (4th cent BC) showed that the Earth is round.

(2) Greek astronomers developed a geocentric model for the universe.

(3) Ptolemy (2nd cent) used epicycles to explain retrograde motion of planers.

(4) Copernicus (16th cent) proposed a heliocentric model for the universe.

(5) In the model of Copernicus, retrograde motion is easily explained.
Greek scientist Aristotle showed that the Earth is spherical.

Aristotle supported his statement that the Earth is round with **observations**.

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

A sixteenth century woodcut of Aristotle’s argument:

Aristotle (384 BC – 322 BC)
Eratosthenes (ca. 200 BC, Alexandria, Egypt) measured the Earth’s circumference:

Simple proportion:

\[ \frac{\alpha}{360^\circ} = \frac{d}{D} \]

Eratosthenes: 42,000 km
Actual: 40,000 km
Greek astronomers 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.
(3) Ptolemy used epicycles to explain the retrograde motions of planets.

Ptolemy worked in Alexandria, was active around AD 140.

Wrote an astronomy text, later called the “Almagest” (= “the best”).
Basic structure of geocentric model:

Belief in Ptolemy’s geocentric model lasted until the 16th century.

Cosmographia, first published 1524
Geocentric models have problems explaining retrograde motion of planets.

Planets usually move west to east relative to stars; during retrograde motion, they move east to west.
Ptolemy’s explanation of retrograde motion:

The planet (P) moves in a small circle called the epicycle.

The center of the epicycle (A) moves in a large circle called the deferent.
As seen from Earth, the planet moves eastward (direct motion).
As seen from Earth, the planet moves westward (retrograde motion).
The combination of small and large circles produces “loop-the-loop” motion.
Ptolemy’s model: 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 multiplicandae praeter necessitatem*

*entities should not be multiplied beyond necessity*

William of Occam (c. 1285–1347)
Copernicus proposed a heliocentric model for the universe.

Mikolaj Kopernik (1473-1543) Poland

Stated that Sun, not Earth, was at the center of the universe.
Basic structure of heliocentric model:

Sun is at center.
Earth revolves around Sun.
Earth rotates around axis.

De Revolutionibus (1543)
(5) In the heliocentric model of Copernicus, retrograde motion of planets is naturally explained. 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
As Earth “laps” Mars, Mars appears to go backward as seen by observer on Earth.

1 → 2 → 3: prograde (forward)

4 → 5 → 6: retrograde

7 → 8 → 9: prograde again
Heliocentric model of Copernicus met with considerable (scientific) resistance.

Why? It implies that distance from Sun to stars is much greater than distance from Sun to 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.
Radical aspects of Copernican model:

- Earth is not at center.
- 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.
Few closing 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 closing 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?