ASTR 105
Intro Astronomy:
The Solar System

Geocentric vs Heliocentric

Earth-Centered (Geocentric) Sun-Centered (Heliocentric)

Astronomically Important Historians
a.k.a. “Famous Dead White Guys”

The Greeks (600 B.C. ~ 200 A.D.)
- Plato
- Aristotle
- Aristarchus*
- Eratosthenes*
- Ptolemy

Don't bother with all the Greek details… just their overall view: Geocentric

Copernican Revolutionaries
- Copernicus (1473-1543)
- Kepler (1571 - 1630)
- Galileo (1564 - 1642)
- Newton (1642 - 1727) (Ch. 4)

Don't worry about dates - just what they did for astronomy

Next:
The Science of Astronomy
Planets Known in Ancient Times

- Mercury
- Venus
- Mars
- Jupiter
- Saturn

"Planet" = "Wanderer"

Earth at the center of the universe
Heavens must be "perfect":
- Perfect spherical objects moving in perfect spheres or in perfect circles

Why does modern science trace its roots to the Greeks?

- Greeks were the first people known to make models of nature.
- They tried to explain patterns in nature by rational thinking and observations rather than supernatural causes

The idealized scientific method

- Based on proposing and testing hypotheses
- hypothesis = educated guess
- Observations are key
- More accurate observations distinguish between different hypotheses

Greek geocentric model (c. 400 B.C.)

The underpinnings of the Greek geocentric model:

- Plato
- Aristotle

How did the Greeks explain planetary motion?

- Underlying the Greek geocentric model (c. 400 B.C.)

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How did the Greeks explain planetary motion?

Retrograde motion?
Not a problem!

Explaining Apparent Retrograde Motion

- **Easy for us** to explain: occurs when we "lap" another planet (or when Mercury or Venus laps us)
- But very difficult to explain if you think that Earth is the center of the universe!
- In fact, ancients considered but rejected the correct explanation

Why did the ancient Greeks (and everyone else until 500 years ago) reject the real explanation for planetary motion?

- Their inability to observe stellar parallax was the key.
The Greeks knew that the lack of observable parallax could mean one of two things:

1. Stars are so far away that stellar parallax is too small to see (with the naked eye)
   - No way! (they thought)

2. Earth does not orbit Sun; it is the center of the universe

That was the state of astronomy for about two millennia

How did Copernicus challenge the Earth-centered idea?

Copernicus (early 1500s):
- Proposed Sun-centered (heliocentric) model
  - with circular orbits to determine layout of solar system
    - But . . .
  - Model was no more accurate than Ptolemy’s model in predicting planetary positions

Clicker Question

Why didn’t Copernicus’s model accurately predict the positions of the planets?

A. He had the order of the planets wrong.
B. He had the distances to each of the planets slightly off.
C. His model still had the Earth at the center of the solar system.
D. He used perfect circles for the orbits of the planets.
E. Copernicus’s model WAS accurate because he had used a model where the Sun was at the center.
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Tycho Brahe (late 1500s)

**Greatest naked eye astronomer of all time**

More accurate measurements than ever before

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Kepler first tried to match Tycho’s observations with circular orbits

Eventually he decided to try ellipses

These orbits allowed him to match the data (and predict future observations) nearly perfectly

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What is an ellipse?

* An ellipse is just an elongated (or squashed) circle

* Eccentricity = how much is it squashed
  - Eccentricity goes from 0 to 1
    - 0 = not squashed at all (a perfect circle)
    - 1 = very squashed (a flat line)
Kepler's First Law: The orbit of each planet around the Sun is an ellipse with the Sun at one focus.

Kepler's Second Law: As a planet moves around its orbit, it sweeps out equal areas in equal times.

Equal area in equal time implies that:

A. Planets move faster when they are closer to the Sun
B. Planets move faster when they are further from the Sun
C. Planets move fast when they are moving towards but slow when moving away
D. Planets move at the same speed at all times
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Kepler's 3 Laws of Planetary Motion

Kepler's Second Law: As a planet moves around its orbit, it sweeps out equal areas in equal times

The areas swept out during all equal time periods are equal

Kepler's Third Law: Planetary orbits follow the mathematical relationship:

\[ p^2 = a^3 \]

*P* = orbital period in years

*a* = avg. distance from Sun in AU

= semi-major axis of elliptical orbit

*Planet's mass doesn't matter!*

Clicker Question

Which of the following best describes what would happen to a planet's orbital period if its mass were doubled but it stayed at the same orbital distance?

A. It would orbit half as fast.
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Galileo’s observations solidified the Copernican revolution

Galileo Galilei

Final nails in the Geocentric coffin

Part I: Moons of Jupiter

- Day by day observations of motion of “stars” orbiting Jupiter
  - Galileo later realized these “stars” were moons
  - Showed these are objects that do not orbit the Earth

One of first people to turn the new, Dutch invention - the telescope - to look at the sky

Galileo Galilei
Final nails in the Geocentric coffin
Part II: Phases of Venus

• Galileo’s observations of ______ phases of Venus proved that it orbits the Sun and not the Earth

Clicker Question

Since Venus is in various orientations (during its orbit) with respect to the Sun, we see it in various phases. What phases should we be able to see?

A. Crescent only
B. Gibbous only
C. Full & New only
D. New & Crescent only
E. All phases (except maybe full)

Galileo’s observations of many different phases of Venus proved that it orbits the Sun and not the Earth
Some of Galileo’s arguments were more philosophical than scientific proof

- Using his telescope, Galileo also saw:
  - Mountains and valleys on the Moon
  - Sunspots on Sun

Celestial objects were not “perfect”

The Catholic Church ordered Galileo to recant his claim that Earth orbits the Sun in 1633

His book on the subject was removed from the Church’s index of banned books in 1824

Galileo was formally vindicated by the Church in 1992

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What have we learned?

- Ptolemy: geocentric model
  - Worked pretty well

- Copernicus: heliocentric model
  - Worked pretty well but no better than Ptolemy

- Kepler: really good heliocentric model
  - 3 Laws of Planetary Motion

They all created a model and then scientifically tested and revised it to the best of their data

- Galileo: irrefutable observational support for heliocentric model
  - Sent his book to the kings of Europe - along with a telescope!