Cosmogony

- A **cosmogony** is theory about one's place in the universe.
- A **geocentric** cosmogony is a theory that proposes Earth to be at the center of the universe.
- A **heliocentric** cosmogony is a theory that proposes the Sun to be at the center of the universe.

Which is the geocentric cosmogony and which is the heliocentric cosmogony?

Ancient Greek Universe

- Earliest available (and mostly complete) recorded attempt to explain the heavens

Philosophical Ideas

- The heavens represent perfection.
- All heavenly bodies are perfectly formed.
  - Spherical
  - Unblemished
- The heavens are unchanging.
- The circle is the perfect shape.
- All heavenly motions must be circular.

Ancient Greek Model

- Stars reside on celestial sphere
- Celestial sphere rotates once a day
- Sun follows path called ecliptic going around Earth once in one year

->accounts for most observations!!
But there was a complication …

- Some stars appeared to move across the sky without staying in a constellation
- WANDERING STARS
  - “Planet” comes from Greek word for “wanderer”

Planets were often called wandering stars because they seem to slowly move from one constellation to the next.

Ptolemy’s Solar System

- Earth in the middle, unmoving
- Stars fixed on the Celestial Sphere, which rotates around Earth
- Planets & Sun also orbit around the Earth along deferents and epicycles

Prograde and Retrograde Motion

- Prograde Motion (normal) – Apparent West to East motion over many nights
- Retrograde Motion (irregular) - Apparent East to West motion over many nights
- Motions occur against backdrop of stars
Retrograde Motion Lecture Tutorial: Page 97

• Work with a partner or two
• Read directions and answer all questions carefully. Take time to understand it now!
• Come to a consensus answer you all agree on before moving on to the next question.
• If you get stuck, ask another group for help.
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Retrograde Motion: A Problem

• Epicycles explained why planets would sometimes move backwards
• More and more epicycles were needed to fine-tune the model
  – Predictions were always a bit off
  – Some versions had hundreds of epicycles!

Epicycles & Deferents in Action

Copernican Model (published 1543)

• The Sun is in the middle (Heliocentric)
• The Earth and other planets orbit the Sun in perfect circles
• Retrograde motion is caused by the planets orbiting at different speeds
  – Planets closer to the Sun orbit faster
  – Planets farther from the Sun orbit slower

Retrograde Motion in a Heliocentric Solar System

Copernicus: ALMOST right!

• Planets orbit around the Sun: correct
• Planets orbit in circles: incorrect!
• Copernicus’s predictions weren’t any better than Ptolemy’s!
Heliocentric Model Demo

Enter Galileo (1564-1642)

• Telescopes were being made by glassworkers in the Netherlands
• Galileo hears about them, builds his own around 1610
• Made many important observations:
  – Sunspots
  – Jupiter’s four largest moons
  – The phases of Venus
Phases of Venus

- In a geocentric model, Venus orbits Earth
  - Venus’s orbit is inside the Sun’s
  - So Venus is never opposite the Sun
  - So Venus will never look Full

- In a heliocentric model, Venus orbits the Sun
  - Venus can show all phases from Full to New

Tycho Brahe (1546-1601)

- Danish nobleman with an interest in astronomy
- Very comprehensive, very accurate measurements of planet & star positions
- Moved to Prague in 1596, hired a mathematician named Kepler
- Developed his own geocentric “Tychonic” model of the universe

Johannes Kepler (1571-1630)

- A believer in the Copernican model
- Tried to explain the spacing of the planets using geometrical shapes
- Began in 1600 as an assistant mathematician to Tycho

Galileo’s telescope revealed that Jupiter had moons which orbited Jupiter instead of Earth.
Tycho and Kepler

• Upon Tycho’s death, his family sued Kepler to get back Tycho’s things
• Kepler gave back the instruments, but not the books
• Tycho’s observations helped Kepler deduce laws describing planetary motion

Kepler’s First Law

Planets orbit the Sun along elliptical paths with the Sun at one focus.

\[ r_1 + r_2 = \text{constant} \]

Kepler’s First Law

A: semimajor axis
B: semiminor axis

• An ellipse is like a squashed circle
• Eccentricity (e) : How squashed is it?
  – If e = 0, it’s a circle (not squashed at all)
  – If e = 1, it’s a line (completely squashed)
• Most planets have very low e (A almost = B)

Kepler’s 2nd Law

A line joining the Sun and a planet sweeps out equal areas in equal amounts of time.

If \( t_2 - t_1 = t_4 - t_3 \), then \( A_1 = A_2 \)

Kepler’s 3rd Law

The square of the period is proportional to the cube of semi-major axis (or average distance from the Sun).

• Period: Time to orbit the Sun once
• Semi-major axis: Large distance from center to orbit

\[ P^2 = k \times a^3 \]

• k is a constant
  – k = 1 if P is measured in years, a in AU

Astronomical Units (AU)

• AUs are based on the average distance between Earth & the Sun
• 1 AU = 1.5 x 10^8 km
• Easy way to compare semimajor axes of planets
  – Earth: 1 AU
  – Jupiter: 5 AU
  – Saturn: 10 AU
  – Neptune: 30 AU
Demos of Kepler’s Laws

Example: Kepler’s 3rd Law

An asteroid has an average distance to the Sun of about 3 AU. What is its period in years?

\[ P^2 = a^3 \]

\[ (P^2)^{1/2} = (a^3)^{1/2} \rightarrow (x^{1/2}) \text{ is the same as } \sqrt{x} \]

\[ P = a^{3/2} \]

\[ P = (3 \text{ AU})^{3/2} \]

\[ P = 5.2 \text{ years} \]

Kepler’s Third Law Lecture Tutorial: Pg. 25-27

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