Things to do today

- After this lecture, please pick up:
  - Review questions for the final exam
  - Homework#6 (due next Tuesday)
- No class on Thursday (Thanksgiving)
- Final exam on December 2 (next Thursday)

Terminal, “Astronomy is Fun”

November 23: The Science of Astronomy
November 25: No Class Day
November 30: Telescopes

Lecture 24
The Science of Astronomy
Reading: Chapter 3

Scientific Thinking

- It is a natural part of human behavior.
- We draw conclusions based on our experiences.
- Progress is made through “trial and error.”
Ancient Astronomy

- Many cultures throughout the world practiced astronomy.
- They made careful observations of the sky.
- Over a period of time, they would notice the cyclic motions of:
  - Sun
  - Moon
  - planets
  - celestial sphere (stars)

Stonehenge (completed 1550 BC)
This famous structure in England was used as an observatory.

- If you stand in the middle:
  - the directions of sunrise & sunset on the solstices is marked.
  - the directions of extreme moon rise & set are marked.
- The Aubrey holes are believed to be an analog eclipse computer.

Mayans (fl. A.D. 400 – 1200)

- lived in central America
- accurately predicted eclipses
- Venus was very important
  - Still standing observatory at Chichen Itza has a window strategically placed for observing Venus.
- marked zenial passages
- Mayan mathematics
  - base 20 system
  - invented the concept of “zero”
Why did they do it?

• archeologists & anthropologists surmise:
  – to keep time
  – for agricultural purposes
  – for religious purposes
• As far as we can tell, none of these ancient cultures tried to build a physical model based on their observations.
• Instead, they created myths to explain the motions of the objects in the sky.
• The origin of modern science -- Greek philosophers

Plato (428 - 348 BC)

• All natural motion is circular
• Reason is more important than observation
• His idea led to the “geocentric universe”

Aristotle (384 - 322 BC)

• Physics
• elements
  – earth
  – water
  – air
  – fire
  – quintessence

Eratosthenes (276 - 195 BC)

• He measured the circumference of the Earth.
• The Sun is at the zenith in the city of Syene at noon on the summer solstice.
• But at the same time in Alexandria, it is 7° from the zenith.
• Eratosthenes inferred that Alexandria was 7° of latitude north of Syene.
• The distance between the two cities is 7/360 times the Earth’s circumference.
• His result of 42,000 km is very close to the right number: 40,000 km.
Claudius Ptolemy (AD 100-170)

Almagest
– star catalogue
– instruments
– motions & model of planets, Sun, Moon

His model fit the data, made accurate predictions, but was horribly contrived!

How does one explain retrograde motion?

Over a period of 10 weeks, Mars appears to stop, back up, then go forward again.

Ptolemy’s Geocentric Model

• Earth is at center
• Sun orbits Earth
• Planets orbit on small circles whose centers orbit the Earth on larger circles – [the small circles are called epicycles]

• This explained retrograde motion
• Inferior planet epicycles were fixed to the Earth-Sun line
• This explained why Mercury & Venus never strayed far from the Sun!
Nicolaus Copernicus (1473-1543)

He thought Ptolemy’s model was contrived
Yet he believed in circular motion

Copernican Revolution

Tycho Brahe (1546-1601)

• Greatest observer of his day
• Naked Eye!!
• Charted accurate positions of planets
• Observed a “nova” in 1572
  • It was actually a supernova

Copernicus’ Heliocentric Model

• Sun is at center
• Earth orbits like any other planet
• Inferior planet orbits are smaller
• Retrograde motion occurs when we “lap” Mars & the other superior planets

• But, it didn’t do so much better than the geocentric model because Copernicus believed the “perfect circle” conjecture.

• He observed a planet through the rectangular hole in the wall.
• An assistant used a sliding marker to measure the angle on the protractor.
Johannes Kepler (1571-1630)

- Greatest theorist of his day
- a mystic and very religious
- Believed a perfect circle
- there were no heavenly spheres
- forces made the planets move
- Could not stand 8 arc-minutes difference between his predictions and Tycho’s data - discard a perfect circle

Kepler’s Laws (later explained by Newton)

1. Each planet’s orbit around the Sun is an ellipse, with the Sun at one focus.

Kepler’s Laws

2. A planet moves along its orbit with a speed that changes in such a way that a line from the planet to the Sun sweeps out equal areas in equal intervals of time.
Kepler’s Laws

3 The ratio of the cube of a planet’s average distance from the Sun to the square of its orbital period is the same for each planet.

\[ \frac{a^3}{P^2} = 1 \]

\[ a^3 = P^2 \]

Galileo Galilei (1564-1642)

- First man to point a telescope at the sky
- wanted to connect physics on earth with the heavens
- *Dialogue Concerning the Two Chief World Systems* [written in Italian]

This book got him in trouble with the Church!

Galileo’s Observations

- Galileo saw shadows cast by the mountains on the Moon.
- He observed craters.
- The Moon had a landscape; it was a “place”, not a perfect heavenly body.

Galileo’s Observations

- Galileo discovered that Jupiter had four moons of its own.
- Jupiter was the center of its own system.
- Heavenly bodies existed which did not orbit the earth.
Galileo’s observation of the phases of Venus was the final evidence which buried the geocentric model.

Geocentric

Heliocentric

No gibbous or full phases! All phases are seen!

Galileo observed all phases!

The Scientific Method

1 Question  
2 Hypothesis → a tentative explanation  
3 Prediction  
4 Test  
5 Result → confirm, reject, or modify should be the same no matter who conducts the test

Hallmarks of Good Science

• Science seeks explanations for observed phenomena that rely solely on natural causes.
• Science progresses through the creation and testing of models of nature that explain the observations as simply as possible.
  ! Occam’s Razor
• A scientific model must make testable predictions that could force us to revise or abandon the model.

Theory -- a model which survives repeated testing

Bad Scientific Practice

• pseudoscience – masquerades as science, but does not follow the scientific rules of evidence
• nonscience – establishes “truths” through belief
Astrology

• claims to study how the positions of the Sun, Moon, & planets among the stars influence human behavior
• was the driving force which advanced ancient astronomy
• Kepler & Galileo were the last astronomers to cast horoscopes… since then astronomy grew apart from astrology into a modern science
• modern scientific tests of astrology fail …it is a pseudoscience

The last lecture: Telescope (Chap 7)

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