Notes by the visiting professor, Dr. Scott Engle

The Geocentric Model

- Greek philosopher Anaximander (c. 610–547 B.C.) proposes the geocentric model, placing Earth at the center of the universe, to explain the observed regular motions of the sky.
- Earth is surrounded by the celestial sphere; a massive sphere on which Sun and the stars are placed, moving around Earth.
- Geocentric model is highly successful at explaining most astronomical phenomenon, except planets.
- Sun, Moon, planets on circular orbits centered on earth
- Orbital speeds constant

  Assumptions:
  Earth centered
  Circular orbits
  Constant speeds
  (based on philosophical preferences!) – accurately gives positions of stars, but not planets

The Problem with Planets

- Planets almost always move eastward with respect to stars, called prograde motion.
- Curiously, they change directions periodically, growing brighter, apparently larger in the sky, and moving westward with respect to stars, called retrograde motion.

The Ptolemaic Model

- Actually, it's not that simple!
- "Retrograde motion" of planets requires orbits on orbits to explain!
- High precision predictions required orbits-on-orbits-on-orbits!

  Ptolemy's (100-170 AD) model made pretty good predictions of planetary positions (~1-2°).
  Accepted for nearly 1500 years!

The Heliocentric Model

- Not all Greek astronomers agreed with geocentric model
- Aristarchus of Samos (c. 310–230 B.C.): knows the relative size and distance of both Sun and Moon.
- Produces a simpler heliocentric model (Sun centered); if smaller Moon orbits larger Earth, smaller Earth should orbit larger Sun.
- Planets undergo retrograde motion because different orbital paths lead to planets periodically "lapping" other planets, causing their apparent motion to change.

  Earth is moving!! BUT!!! IF Earth is moving…
  …THEN positions of stars on celestial sphere should change with a yearly cycle
  Draw the parallax diagram
  This was not observed – so heliocentric model was rejected

The Copernican Revolution

- Nicholas Copernicus (~1540)

  - revives the heliocentric idea
- Tycho Brahe (~1580)
  - most precise naked eye observations of planetary positions
  - accuracy ~1/60 of a degree!)
- Johannes Kepler (~1610)
  - detailed analysis of Tycho's data: discovered the heliocentric model works best
  - 3 LAWS OF PLANETARY MOTION: 1. planet orbits are ellipses 2. planet orbital speeds vary 3. bigger orbits have slower speeds → longer periods
- Galileo (early 1600's)
  - first telescopic observations favored heliocentric model
  - early understanding of physics of motion

  Observes moon around Jupiter and the (draw) phases of Venus
- Isaac Newton (~1700)
  - discovered physical principles behind Keplers' results
  - mathematically describes the physics of motion
  - Newton's Three Laws of Motion

But what about Extraterrestrial Life?

- Some Greeks (the "atomists") believed the heavens to be composed of same element as Earth, and populated by life.
- Others ("Aristotelians") believed Earth to be unique – the special center of the Universe

  The Copernican Revolution showed that Earth does not occupy a special place in the Universe…

  What happens here probably happens in lots of other places…

  Made it easier to believe the life might exist elsewhere. So it seems like a reasonable assumption, but we need to approach it scientifically.

The Scientific Method

"science" = the view that the physical Universe is governed by a well-defined set of rules (i.e., is a "rational" place) = the endeavor to uncover those rules

The rules that govern the physical Universe can be expressed mathematically

(The right-hand figure, upper right, deals with Occam's Razor or Ockham's Razor, attributed to
"Entities must not be multiplied beyond necessity" - William of Ockham (c. 1287–1347)
Aristotle, "We may assume the superiority ceteris paribus [other things being equal] of the demonstration which derives from fewer postulates or hypotheses."
Ptolemy (c. AD 90 – c. AD 168) stated, "We consider it a good principle to explain the phenomena by the simplest hypothesis possible."
So, our approach to Life in the Universe will be a "scientific" one.
We will utilize only reliable & repeatable observations. If we formulate any conclusions, explanations, or theories, they must be testable and falsifiable!

Isaac Newton

- Newton first realized that an attractive "force" (gravity) could explain many different phenomena

Falling apples, rocks, cows, Earth's orbit around Sun, Moon's orbit around Earth, etc.

- Strength of force depends only only on masses & separation!
- Successfully predicted comet orbits, existence of Uranus,…
- But what the heck is a "force"
- "Action at a distance" sounds a bit like magic.
- Newton's Universal Law of Gravitation really doesn't tell us what gravity is

Albert Einstein

- Suggests gravity results from curvature of space!
- mass distorts space
- orbits are straight lines in curved space!
- "General Relativity" reproduces all of Newton's results – plus - it works in places where Newton's theory didn't
- General Relativity has passed all tests, and has made many subsequently-verified predictions
- But is it right? Do we understand gravity? Probably not!
- GR not consistent with quantum mechanics (the study of the subatomic world)

There's probably a bigger theory out there, but we don't know what it is yet
And when discussing gravity under Newton, we went over $F_g = G ((M1*M2)/(d^2))$