[05] Historical Perspectives (9/12/17)

Upcoming Items

1. Homework #2 due now.
2. Read Ch. 4.1–4.2 and do self-study quizzes.
3. Homework #3 due in one week.

Ptolemaic system

http://static.newworldencyclopedia.org/thumb/3/3a/Ptolemaicsystem-small.png/180px-Ptolemaicsystem-small.png

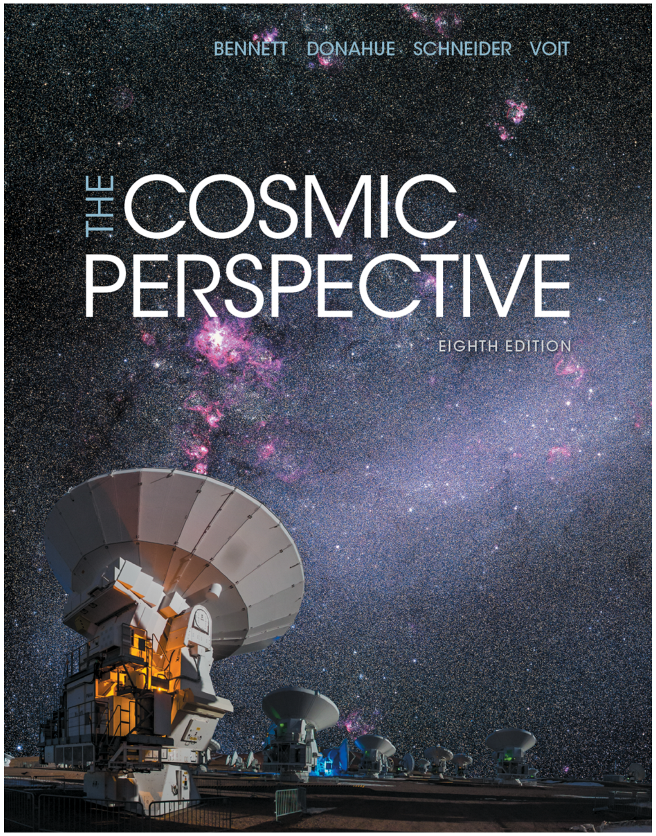
LEARNING GOALS

Chapters 2.4, 3

For this class, you should be able to…

… *explain why scientists eventually favored the heliocentric model of the solar system over the geocentric model, even before the former could be verified;*

… *use Kepler's laws and the properties of ellipses to describe the motion of solar system bodies, and graphically represent each law.*



Any astro questions?

Reminders

- If you have any question about an upcoming lecture, please put your question in the "Muddiest Points" section before the class (still voluntary, but I hope it helps)
- Tutoring is available! See the schedule on the door of ATL 1220. At least two hours are open, every day
  Can get help in geometry (also, Web resources help)
- AstroTerps: first meeting this Wednesday, 6 PM! I'll talk about neutron stars. Pizza is also available ☺
- Please pick up your HWs when Drew brings them to class
- For HW questions, go to tutors (preferably) or Drew
  Start homeworks early to see if you have questions!
  If you have questions on grades, e-mail Drew
- For discussion questions, go to Liz

How well do you understand vectors?

- Magnitude and direction?
- Dot products?
- Cross products?
- A lot of physics is deeply enriched by the use of vectors
- If you don’t feel comfortable with these topics, I strongly recommend that you talk to the tutors and/or use Web resources
- Thanks! This will help in the next few classes and beyond

The Great Debate!

- Heliocentric or geocentric?
- As stated last time: ground rules are that no observations past the time of Copernicus can be used (thus, for example, no telescopic observations are allowed)
- Which side can do a better job with their available material?
- Back third of class takes one side; middle third takes another side (decided by coin flip). Front third judges.
- After points are made, judges decide and say briefly why they chose one side versus the other
- Winning side has first choice of candy; then judges; then losing side (but just for fun!)

The Broad View: Why Do We Care?

- We know that the geocentric model of the Solar System is wrong
- So why should we spend any time on it?
- Answer: because this provides a good case study of how science works

  We have observations and an “obvious” answer

  Data continue to be collected

  The original model has problems

  A different model is proposed that explains the observations better
- Question: does anyone know whether Kepler’s laws explain planetary orbits perfectly?

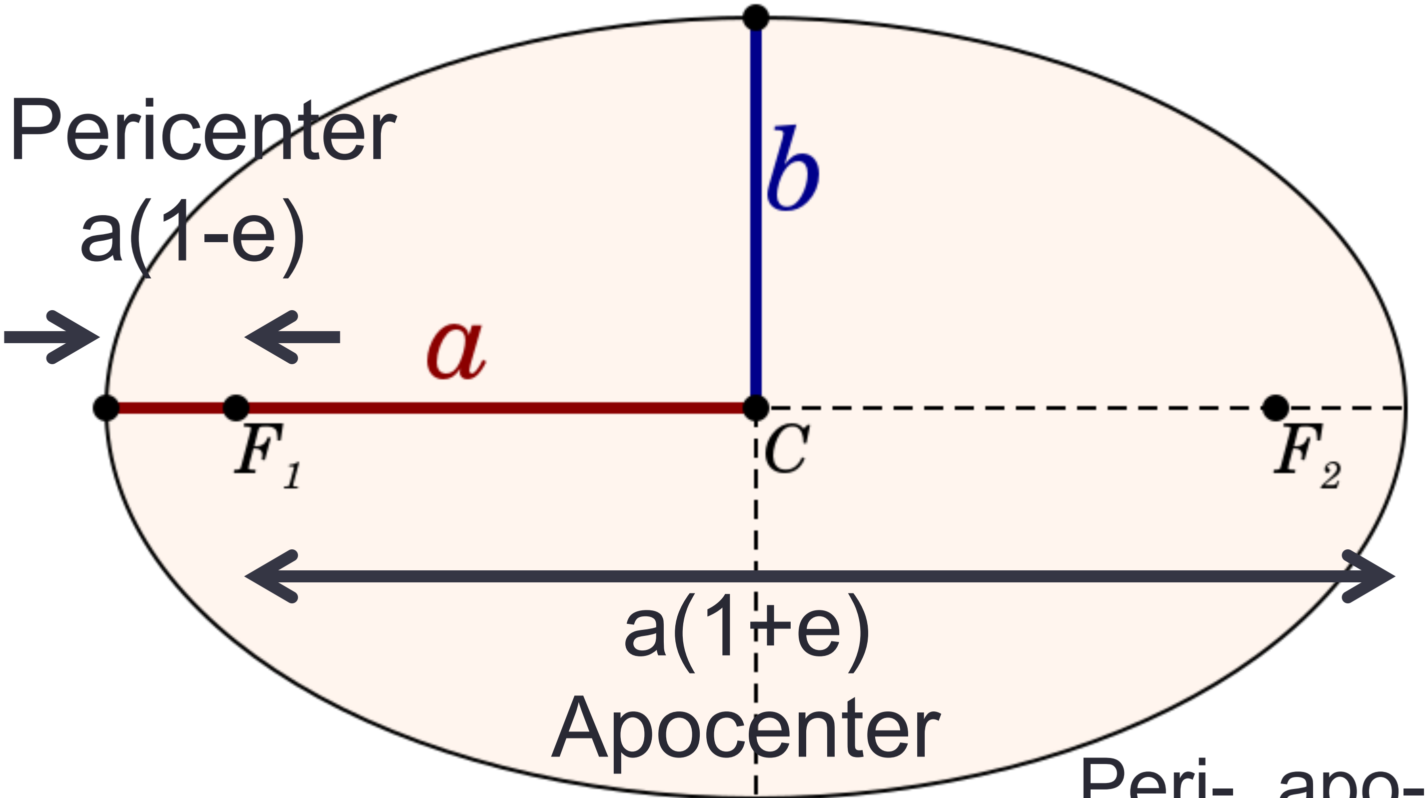
Kepler's 1st law states that planets orbit the Sun on elliptical orbits; however, Venus's orbit is almost perfectly circular. How can this be reconciled?

A. Kepler's Laws aren't actually laws; they're just usually true.
B. This law doesn't apply to planets with small semimajor axes.
C. Our measurements of Venus' orbit must be flawed.
D. **A circle is a type of ellipse; the law holds true.**

An Extra Note about Orbits

- Kepler loved geometry, so he would have been thrilled to learn that the ***full*** set of possible orbits (for Newtonian gravity) are the "conic sections" (shapes you get by cutting a cone with a plane)
- Circle (special case; for a bound orbit, e.g., a planet around the Sun)
- Ellipse (more general for bound orbit)
- Parabola (special case: just barely bound, or barely unbound)
- Hyperbola (general case of unbound orbit, i.e., something that comes close but then goes away and doesn't return)

Properties of Ellipses



Wikipedia

a=semimajor axis
b=a(1-e^2)$^{1/2}$=semiminor axis
e=eccentricity

Peri-, apo- can be for specific objects, e.g., perihelion, apogee.

Kepler's 2^{nd} law states that a line joining a planet and the Sun sweeps out equal areas in equal times. What does this imply about the speed of the orbiting planet?

A. Nothing; the speed is constant throughout.

B. The planet moves faster when it's closer to the Sun.

C. The planet moves faster when it's farther from the Sun.

D. There is an effect, but it can't be explained simply.

A More Physical Basis for 2nd Law

- As we will discuss in more detail in the next class, although Kepler discovered his laws empirically (by looking for patterns), there are deep reasons for the laws.
- As we just stated: the second law says “equal areas are swept out in equal times”
- This turns out to be a reflection of the *conservation of angular momentum*
- In fact, *any* “central force” (where the force points toward a center) conserves angular momentum, so Kepler’s second law would hold for it
  For example, ball on spring attached to central point!
- **Very** general; you’ll explore this more in discussion

Kepler's Third Law

- The square of the orbital period of a planet around the Sun is proportional to the cube of the semimajor axis of the planet's orbit:
  P^2 is proportional to a^3
- Group question: what does this tell us about the average speed of motion of the planets?
  Do planets closer to the Sun move faster or slower than planets farther away from the Sun? By what factor? For example, if Planet B has a semimajor axis four times larger than that of Planet A, but the two orbits have the same eccentricity, then which planet moves faster on average, and by how much?
  Note: not asking how *long* it takes to orbit the Sun, but how *fast* it moves in its orbit

According to Kepler's 3rd law, if the semimajor axis of a planet's orbit increases by a factor of 8, its orbital period increases by

A. 4.

B. $16\sqrt{2}$.

C. $2\sqrt{2}$.

D. 64.

Discussion: How do Kepler's Laws apply to circular orbits?

1. A circle is a special case of an ellipse (Kepler's 1st Law).
2. Orbital speed is constant in a circle (Kepler's 2nd Law).
3. Orbital speed can be computed from Kepler's 3rd Law:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$v = \frac{\text{circumference of circle}}{\text{orbital period}}$$

$$v = \frac{2\pi a}{P}$$

$$v = \frac{2\pi a}{a^{3/2}}$$

← Used Kepler's 3rd Law here (units?)

$$v = \frac{2\pi}{\sqrt{a}}$$

What are the units of v in this case?

Group Q: Why know about the sky?

- For discussion: what are some reasons that it would have been useful for ancient civilizations to know about the night sky?
- Are there any practical reasons now to know about the night sky (i.e., other than curiosity)?

Historical Perspectives

- Ancients kept track of time and seasons by studying the night sky (Moon, stars, planets) and daily path of the Sun.
- The Greeks tried to explain the motions using models.
  - Some models featured a spherical Earth with the Sun at the center of the solar system, but most favored the geocentric model since the stars did not show measurable evidence of parallax motion.
- Renaissance astronomers put forward the heliocentric model as a better match to observations.
  - Detailed measurement of planetary motions led to Kepler's laws.
  - It was not until the 18th century that a ***prediction*** (rather than simply a good fit to existing data) of the heliocentric model was confirmed (by discovering stellar aberration). The first estimate of planetary distances (and so the value of 1 AU) was made in the 17th century by observing the transit of Venus.

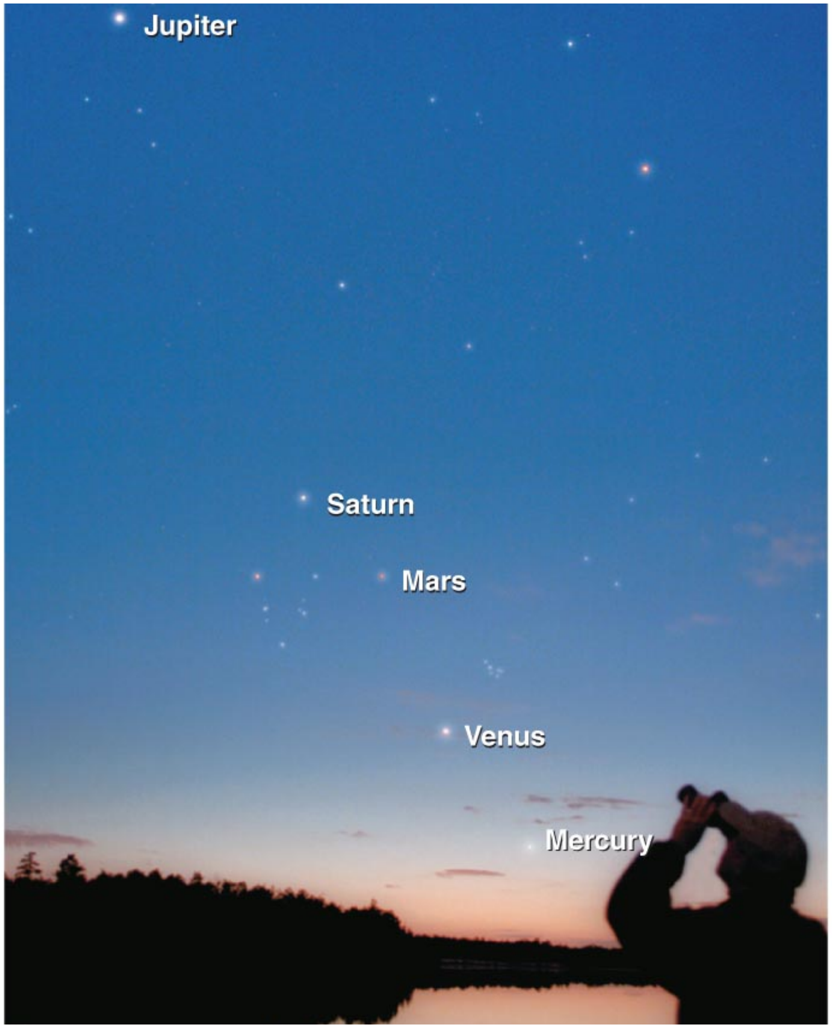
What did the ancients know?

- Stars do not appear to move relative to one another —“fixed” to celestial sphere.
  Although Hipparchos thought the stars might move with respect to each other over long enough times; he therefore constructed an 850-star catalog for posterity
- Sun moves ~1°/day relative to stars.
  - Path it follows called the ecliptic.
- Moon moves ~12°/day relative to stars.
  - Path inclined 5° to the ecliptic.
- Five “wandering” stars visible to naked eye.
  - The planets, following paths close to the ecliptic.

Planets Known in Ancient Times (the "Wanderers")

- Mercury
  - Difficult to see; always close to the Sun in the sky.
- Venus
  - Very bright when visible—morning or evening "star."
- Mars
  - Noticeably red.
- Jupiter
  - Very bright.
- Saturn
  - Moderately bright.

http://www.skyandtelescope.com/observing/sky-at-a-glance/



Achievements in Ancient Astronomy

- Daily timekeeping.
- Tracking the seasons.
- Calendars.
- Monitoring lunar cycles.
- Monitoring planets and stars.
- Predicting eclipses.
- Tools for navigation.
- More?...