Astro 350
Lecture 4
Aug 28, 2011

Announcements:

- Discussion Question 1 due Wednesday nite
- HW1 due at start of class Friday
  turn in paper copy, but can & should upload on Compass
  online submission gives record if question of HW loss
- **register** your iClicker by next time!
  follow link on course page

Last time:

- geocentric cosmology
  Q: which is what?
  Q: why would anyone believe this?
  Q: who was Ptolemy? What is the Ptolemaic system?
- Copernicus & heliocentric cosmology
  Q: what is an AU?

Copernicus: What's New and What's Not

- planets still on spheres
- Copernicus still used epicycles!
- predictions *not* better than in Ptolemy's model
  $\rightarrow$ geometrically equivalent *Q: meaning?*
- Copernicus' model not generally accepted
  and Ptolemaic–Copernican disagreement though to be
  metaphysical, *unanswerable* question

Q: so how do we decide which is right?

Tycho Brahe 1546-1601: Danish Astronomy Extraordinare

in youth: observed "nova stella" (supernova) `www: Tycho sketch`
→ change observed in heavens → corruptible!
observed Sun, Moon, planets for 20 years: careful, accurate data
but not a good number cruncher
→ like any good professor: made grad student do the work!

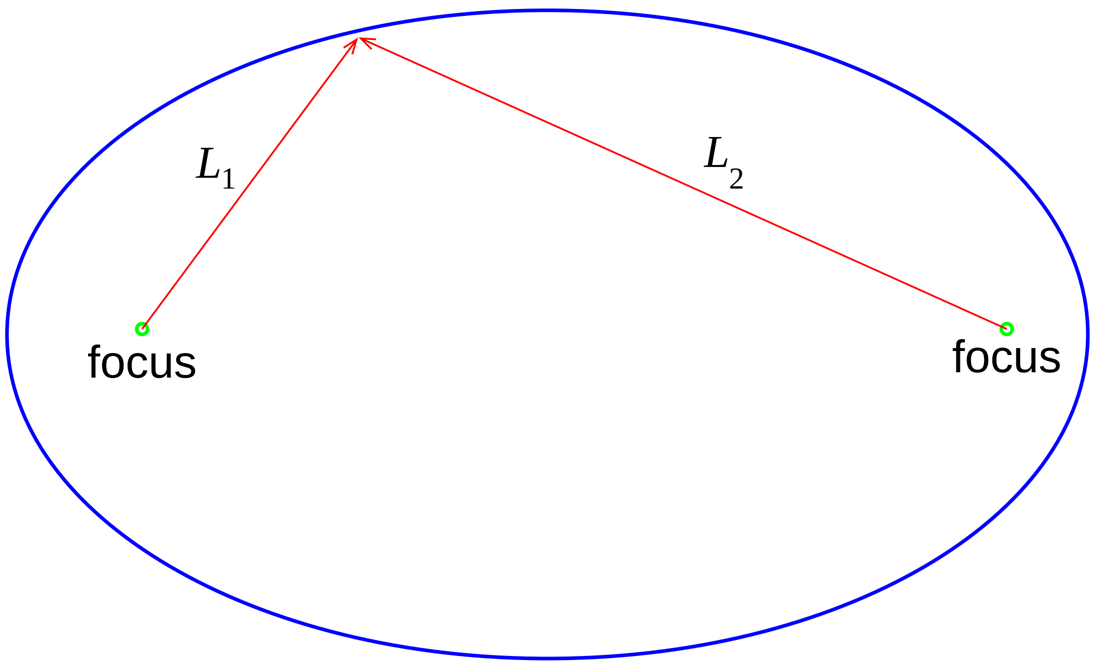
Johannes Kepler 1571–1630: Harmony of the Worlds

Analyzed Tycho's data for **20 years**(!), especially Mars motions
used heliocentric model with circles
but observations didn't quite agree
a small error (few arc min!) remained...took seriously
→ after trial & error:
completely & accurately described planet orbits

Q: Kepler's Laws?

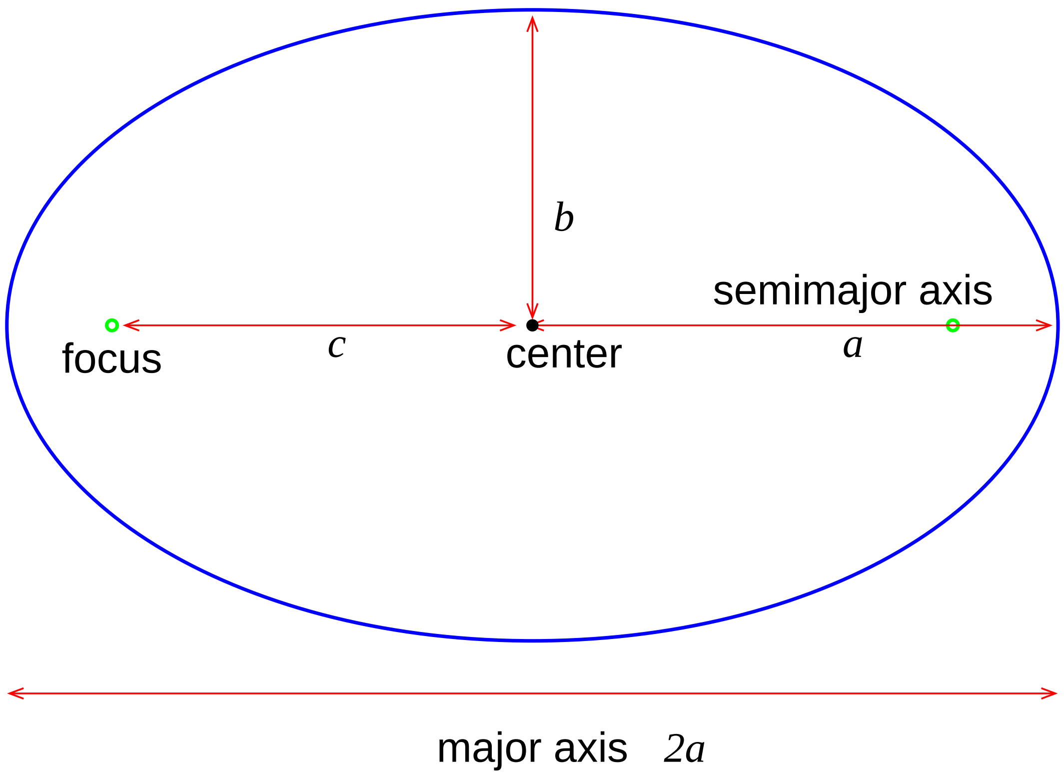
Kepler I: Law of Ellipses

each planet's orbit is an **ellipse**
with the **sun at one focus**



$$L_1 + L_2 = constant$$

Ellipse Anatomy



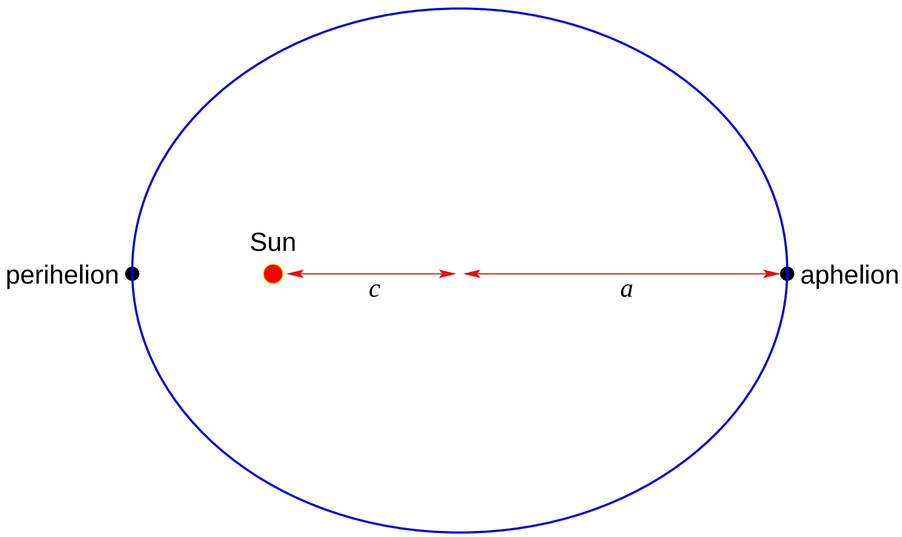
- two foci
- semi-major axis a
- focal length c
- semi-minor axis $b = \sqrt{a^2 - c^2}$

any ellipse fully characterized by:

a and eccentricity $e = c/a$

Q: what do we get for $e = 0$? $e = 1$?

Kepler I: orbit is **ellipse** with **sun at one focus**



Orbit anatomy

aphelion: *farthest* point from Sun

perihelion: *closest* point to Sun

Q: what is aphelion distance in terms of a and e?

$$r_{\mathrm{ap}} = a + c = a + a\frac{c}{a} = (1 + e)a \qquad (1)$$

Q: If the Sun's at one focus, what's in the other focus?

Q: What does Kepler I not *say about orbits?*

At the other focus: nothing! (sorry!)

Note: Kepler I only gives orbit *shape*
but says *nothing* about how orbit evolves in time
$\rightarrow$ need more info to fully describe orbit, hence...

Kepler II: Law of Equal Areas

a straight line from the planet to the sun
sweeps out equal areas in equal times

diagram: sketch areas

note that this amounts to telling about speed of planet
Q: where fastest? slowest?
`www: area animation`

Q: This still doesn't fully characterize an orbits–why not?

Kepler I gives orbit shape in space
Kepler II gives orbit evolution over time

but haven't yet connected the two:
how does spatial character (e.g., semimajor axis a)
relate to time character (e.g., period P)?

Need one last law...

Kepler III: The Mighty Equation

period P and semi-major axis a are related:

$P^2 \propto a^3$

$\Rightarrow P^2/a^3 = const$, holds for all planets, with same constant
and since must hold for Earth:

$$\boxed{P_{\rm yrs}^2 = a_{\rm AU}^3} \quad (2)$$

Q: ok for earth?

where P written in years, a in AU

Very powerful! e.g.:

Asteroids exist with orbits inside 1 AU (and some cross 1 AU!!)

www: inner solar system objects--in real time!

iClicker Poll: Kepler III

Kepler III: $P_{\text{yrs}}^2 = a_{\text{AU}}^3$

Consider an asteroid with an orbit entirely outside 1 AU

Is its period longer or shorter than a year?

A $P > 1$ yr, no matter eccentricity e

B $P < 1$ yr, no matter what e

C can't answer without knowing e

Kudos to Kepler

Several points worth noting...

⋆ An amazing discovery–mathematics underlies the workings of the cosmos!

⋆ Orbits have a simple geometry
...but *not* simplest: ellipse not circle

⋆ Kepler's laws remain (almost) perfectly accurate to this day–indeed, in slightly generalized form will show up in many (most!) situations where motions are controlled by gravity

⋆ Yet note what we still don't have:
an understanding of *why* Kepler's laws hold
→ that is, what is the *mechanism* that makes
planets move this way
...for that, need to wait for Kepler's successors...

Galileo Galilei: Astronomer

First to use telescope in Astronomy

`www: Galileo shows scope to Duke`

contributions:

- mountains on the moon
- moons of Jupiter
- sunspots

These are bad for Ptolemy (but maybe not deadly) *Q: how?*