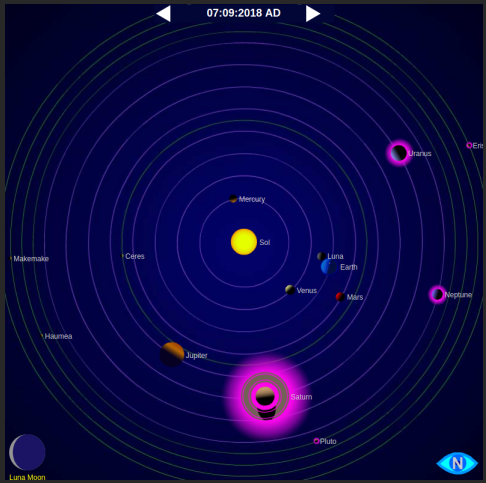
Announcements

- New WebWorK due Monday
- Physics Tea today at 3pm!
- I'm getting auctioned off as part of Phi Delta Theta's Ice Bucket Challenge fundraiser today around 5, so if you want to be part of dumping a bunch of ice water on me... give to the cause! :)
- Poll: `rembold-class.ddns.net`

Observing Events Tonight

- Neptune at opposition today!
- Venus and Jupiter also visible low in the west after sunset
- Mars visible to the southeast
- Saturn to the south



Review Question

The picture to the right was supposedly taken in Sydney (33.9 °S, 151.4 °E), and shows the classic star trails of a prolonged exposure. What is wrong with it?

A. There is no moon in the image
B. The pole is too low in the sky
C. The stars are spinning the wrong direction
D. There is nothing wrong with it!

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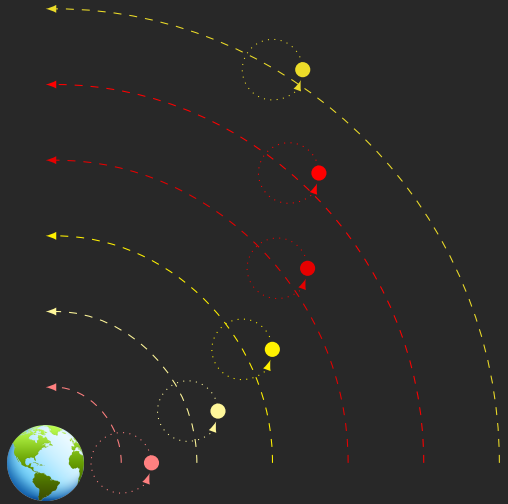
A Corrected Geocentric Model: Ptolemy



The Ptolemaic Model ($\approx$ 150 AD)

- The basic Aristotle idea of the geocentric model is very simple
- In practice though, the Ptolemaic model is actually extremely complex
  - Some circles larger than others
  - Some circles slightly rotating off-center
- It DID, however, quite accurately predict the observed motion of the planets

Enter Copernicus (1473-1543)

- Found that the planetary motion tables based on Ptolemaic model were growing more inaccurate
- Disliked the complexity of Ptolemaic model on aesthetic grounds
- Adopted a heliocentric model with the Sun at the center
  - Naturally explains retrograde motion (See here)
  - Naturally explained Mercury and Venus never being a large angle from the Sun
- The Heliocentric model was not significantly more accurate than the Ptolemaic model at the time.

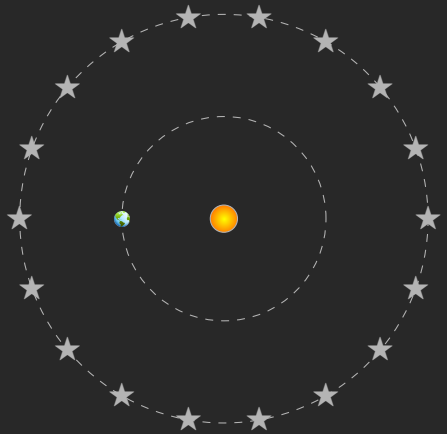
Objection! The Church

There is talk of a new astrologer who wants to prove that the earth moves and goes around, instead of the sky, the sun, the moon, just as if somebody were moving in a carriage or ship might hold that he was sitting still and at rest while the earth and the trees walked and moved. But that is how things are nowadays: when a man wishes to be clever he must needs invent something special, and the way he does it must needs be the best! The fool wants to turn the whole art of astronomy upside-down. However, as Holy Scripture tells us, so did Joshua bid the sun to stand still and not the earth.

-Martin Luther

Objection! Science

- Why aren't we dizzy?
- Why are we the only planet with a moon?
- Why don't we see stellar parallax?



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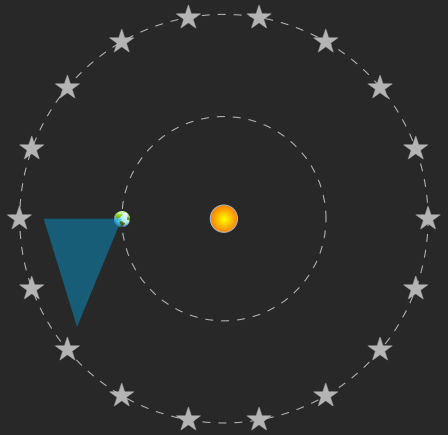

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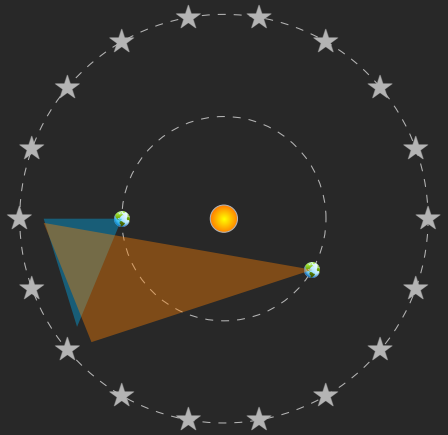


Tycho Brahe (1546-1601)

- Last real "naked-eye" astronomer
- Took very precise angle measurements of stars and planets
- Saw no stellar parallax, and thus thought Copernicus wrong
- Hired Kepler as assistant

Johannes Kepler (1571-1630)

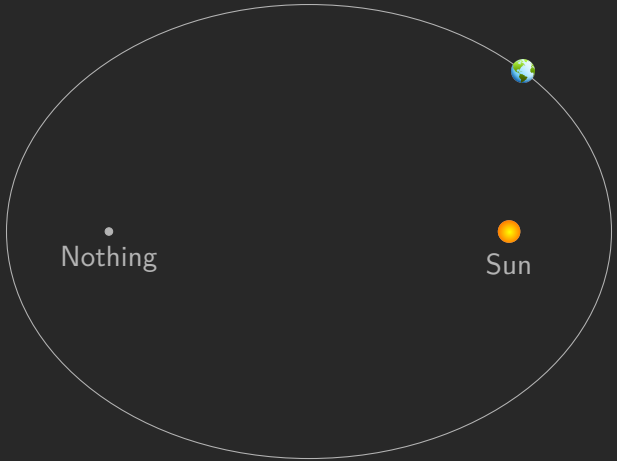
- Spent 8 years trying to reconcile Tycho's Mars observations with the Ptolemaic model

> *Who would have thought it possible? This hypothesis, which so closely agrees with the observed oppositions, is nevertheless false? If I had believed that we could ignore those 8 minutes, I would have patched up my hypothesis accordingly. But since it was not possible to ignore them, those 8 minutes point the road to a complete reform of astronomy...*
>
> *Thou seest now, diligent reader, that the hypothesis based on this method not only satisfies the four positions on which it was based, but also correctly represents within 2 minutes all the other observations.*

- Johannes Kepler, Nova Astronomica

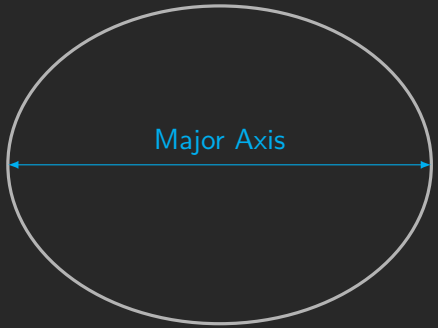
Kepler's 1st Law

- The orbits of the planets are ellipses
  - The Sun at one focus and nothing at the other



Ellipses

- Look like squished circles
- Described by:
  - Major Axis (longest width)
  - Eccentricity (squished-ness)



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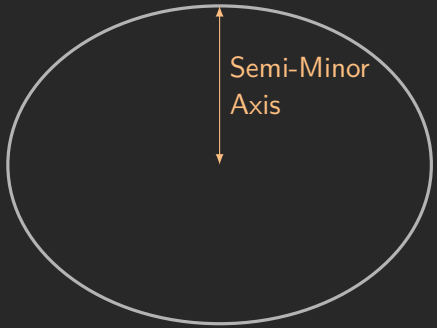

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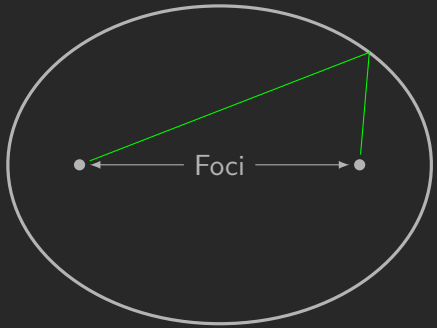

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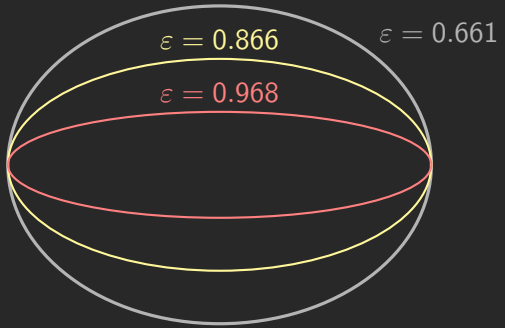


- A circle is an ellipse with eccentricity=0

Ellipse Math

You can always get the foci location and eccentricity from the semi-major and minor axes.

- Foci:

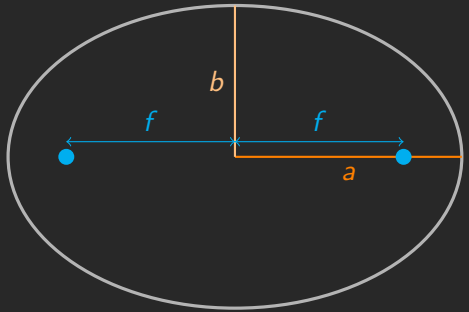
$$f = \sqrt{a^2 - b^2}$$

- Eccentricity:

$$\varepsilon = \sqrt{1 - \frac{b^2}{a^2}}$$

- Area:

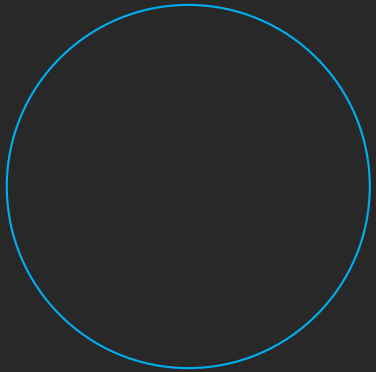
$$A = \pi a b$$



Elliptical Orbits

- Most Solar System orbits are not particularly eccentric
  - Look pretty circular

$\varepsilon = 0$
(circle)



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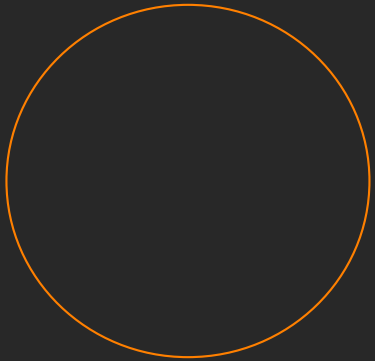

$\varepsilon = 0.24$
(most eccentric planet)

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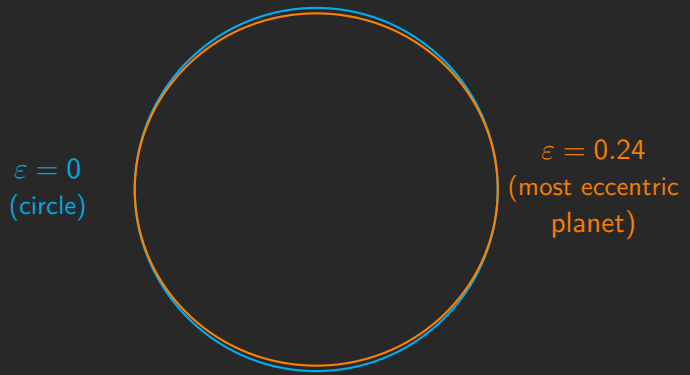
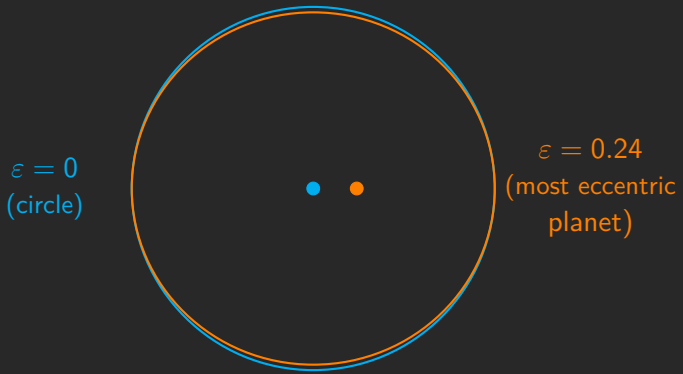


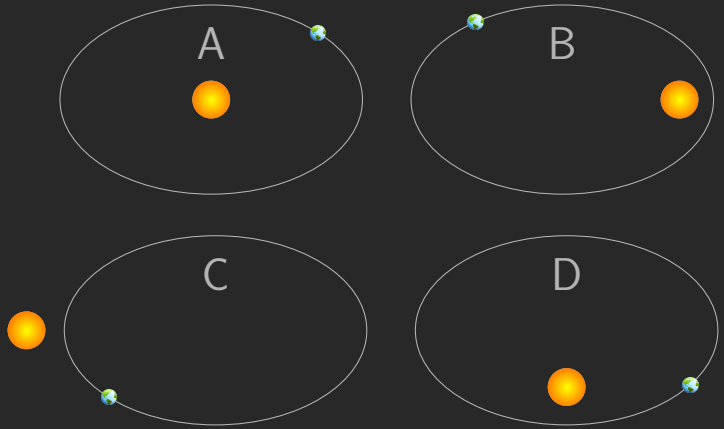
Elliptical Orbits

- Most Solar System orbits are not particularly eccentric
  - Look pretty circular
  - Sun is NOT at center however



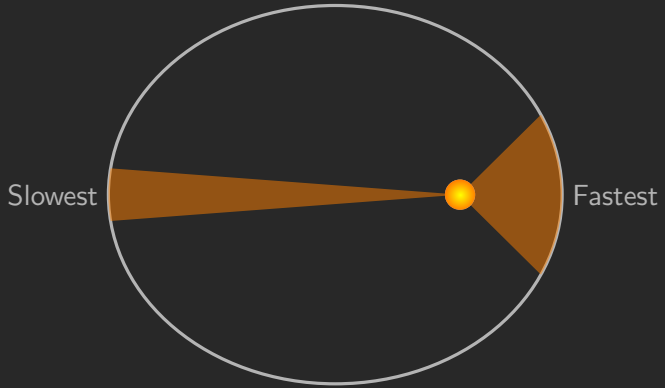
Understanding Check!

Why of the following depicts a possible planet orbit?



Kepler's 2nd Law

- A line joining a planet to the sun sweeps out equal areas in equal times
  - Planets move faster when close to the Sun and slower when far away



Kepler's 3rd Law

- The square of a planet's orbital period is proportional to the cube of its semi-major axis.
  - A planet's period is the time it takes to complete an entire orbit
  - An orbit's semi-major axis we defined earlier to be half the major axis
- Mathematically, this looks like

$$p^2 \propto a^3$$

  where p is the period and a is the semi-major axis
- If you measure period in years and the semi-major axis in AU, then

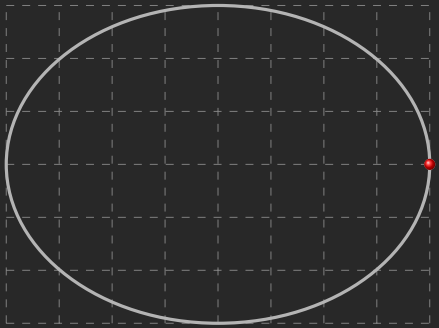
$$p^2 \approx a^3$$

Example!

The below image is the orbit of some astronomical object. Each grid is 1 AU in length. Determine:

A. Where the Sun is located.

B. What the orbital period is.

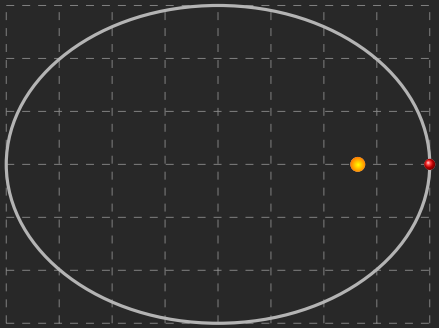


Example!

The below image is the orbit of some astronomical object. Each grid is 1 AU in length. Determine:

A. Where the Sun is located. At one of the foci

B. What the orbital period is.



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The below image is the orbit of some astronomical object. Each grid is 1 AU in length. Determine:

A. Where the Sun is located. At one of the foci

B. What the orbital period is. 8 years