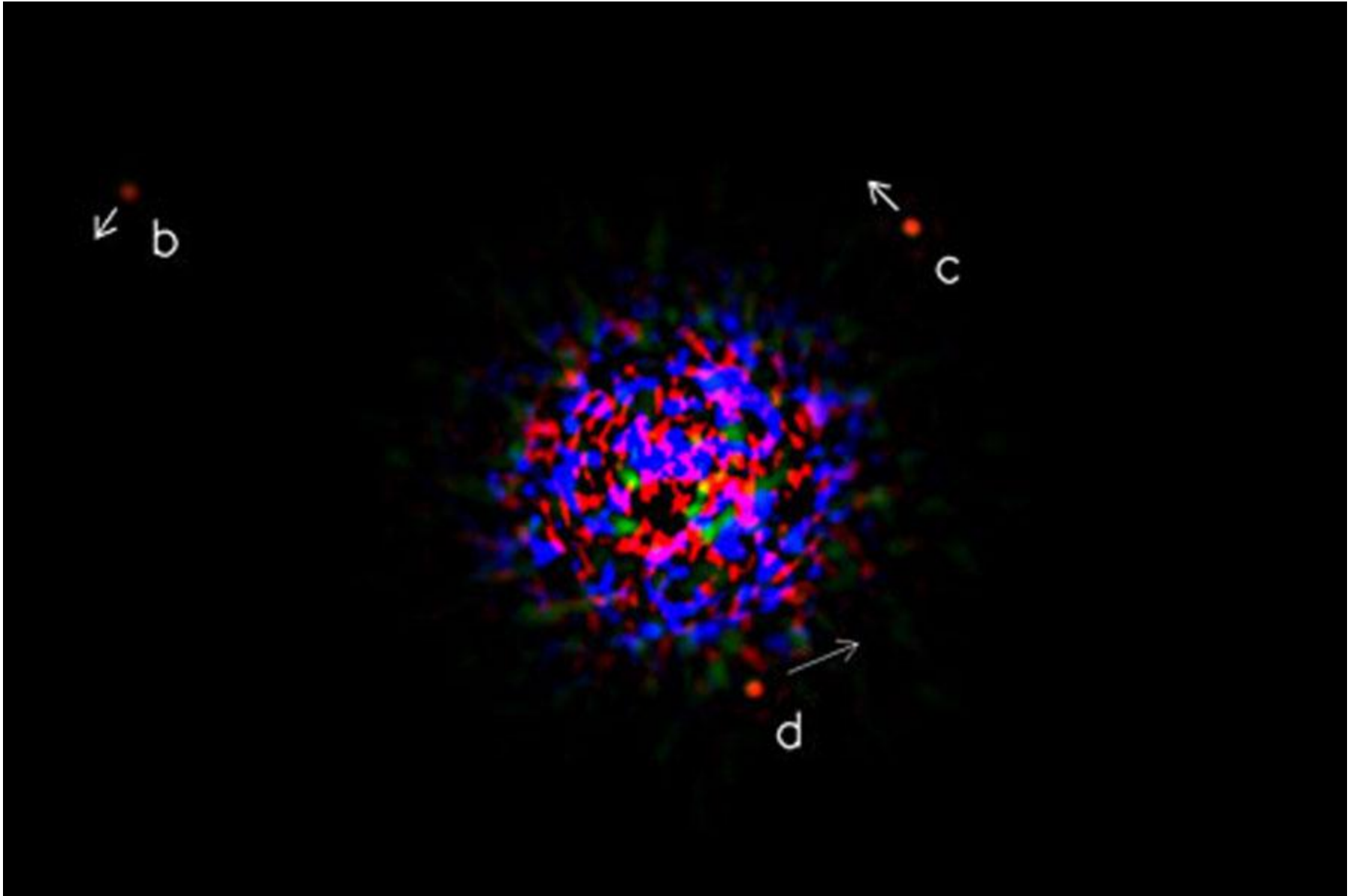
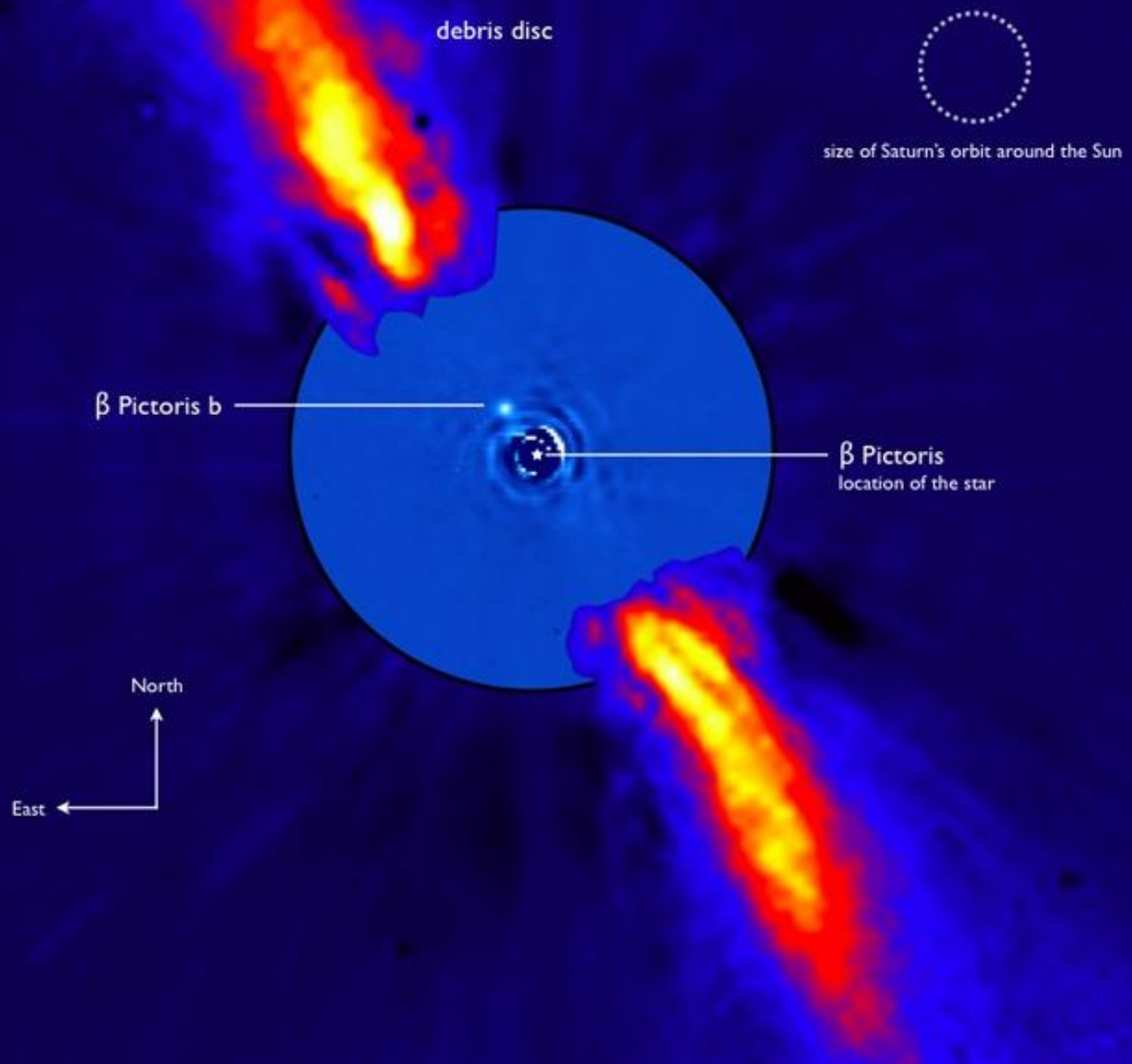


# Kepler's Laws





# Before Kepler

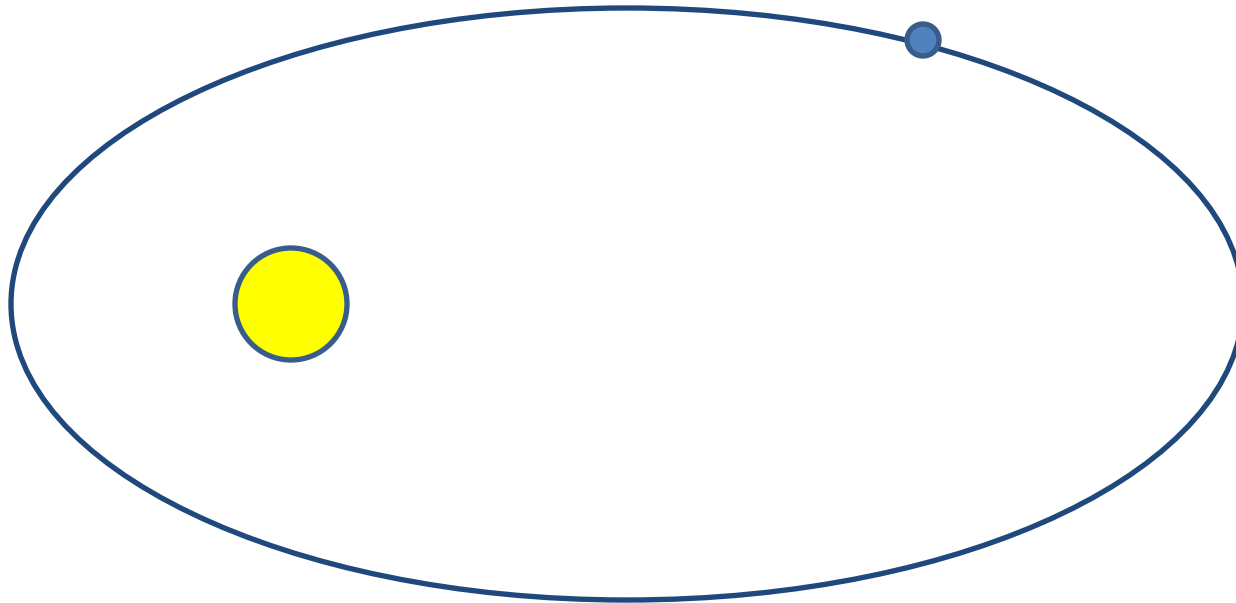
- Ancient Greeks – Geocentric, Circular Orbits
- Did not work very well
- Ptolemy - Geocentric, Epicycles
- Better, but still not perfect
- Copernicus – Heliocentric, Circular orbits
- Did not work as well as Ptolemaic Theory

# Kepler's 1<sup>st</sup> Law

- Anyone remember?

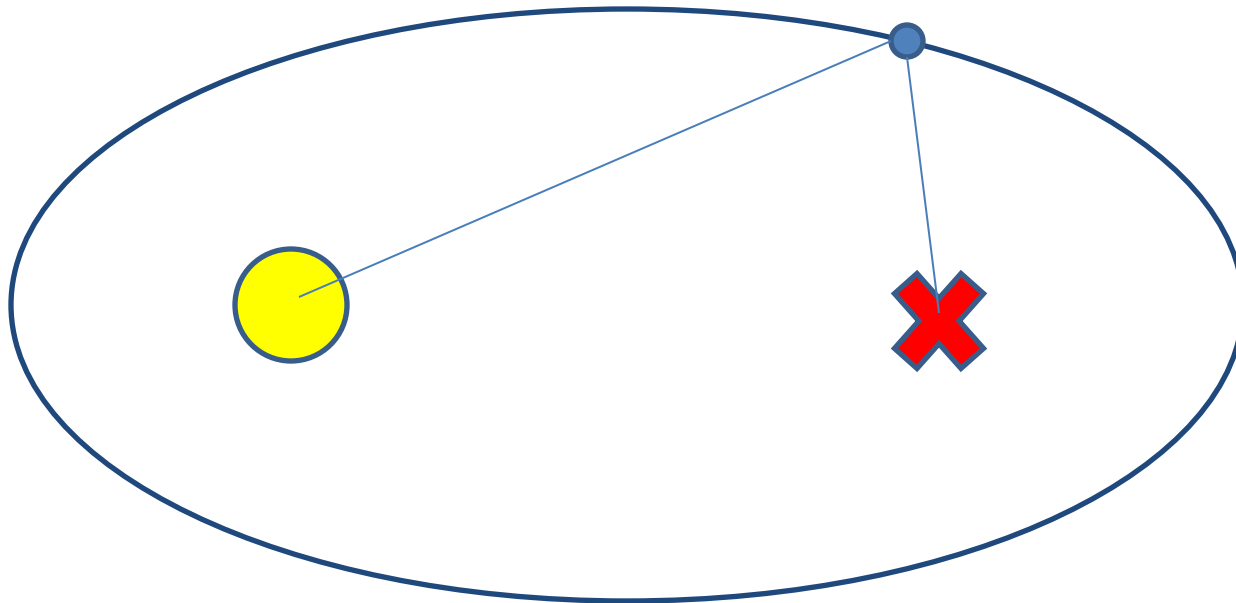
# Kepler's 1<sup>st</sup> Law

- Anyone remember?
- Planets orbit the Sun on elliptical orbits with the Sun at one focus



# Kepler's 1<sup>st</sup> Law

- Conic Sections – ellipses, circles, hyperbolas, parabolas
- Foci – special points such that for any point on the orbit, the sum of the distance from the two foci is the same

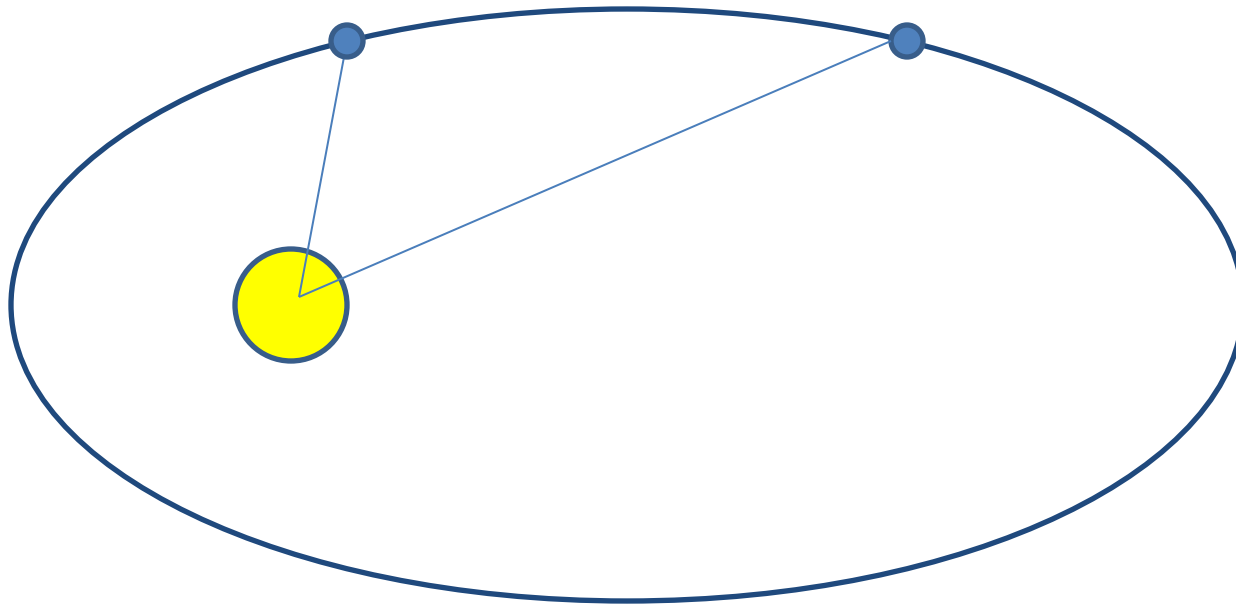


# Kepler's 2<sup>nd</sup> Law

- Anyone Remember?

# Kepler's 2<sup>nd</sup> Law

- Anyone Remember?
- A line connecting a planet and the Sun sweeps out equal areas in equal amounts of time



# Kepler's 3<sup>rd</sup> Law

- Anyone Remember?

# Kepler's 3<sup>rd</sup> Law

- Anyone Remember?
- The period squared is proportional to the orbital semi-major axis cubed, or

$$P^2 \propto OSA^3$$

- Can turn proportional into an equal sign if we work in units of Earth years and AU

# Gravity!

- Kepler knew his laws worked, but didn't know why
- Newton's theory of gravity
- $F = GM_1M_2/R^2$
- Newton's Modification of Kepler's 3<sup>rd</sup> Law – generalizes to any object in orbit around another object

# Beyond the Solar System

- Binary Stars
- Center of Mass –  $M_1X_1 = M_2X_2$
- $q = \text{mass ratio} = M_2/M_1$
- Exoplanets
- Stable Orbits vs. Unstable Orbits

# A Few Tips

- Exercises #1 and #2 are NOT done on the computer
- Exercise #3 – Vectors are added in right panel
- Exercise #4 – Set  $G(M_{\text{sun}} + M_{\text{planet}}) = 1$  for comparison purposes
- Number of orbits shown in “Time” window for Third Law exercise
- Don’t forget to fill in table 5.1!
- For binary star planet, look between  $q=0.5$  and  $0.6$
- Be sure to try planet star distance of  $0.4$  to eject it from the system!