Nature of Light Lecture Tutorials

1. Apparent and Absolute Magnitude of Stars
2. Electromagnetic Spectrum of Light
3. Telescopes and Earth's Atmosphere
4. Blackbody Radiation
5. Types of Spectra
6. Light and Atoms
7. Analyzing Spectra
8. Doppler Shift

Solar System

10/17 – Observing Retrograde Motion
10/20 – Structure and Formation of the Solar System
10/22 – Motion of Extrasolar Planets
10/24 – The Great Planet Debate
10/27 – Review for Midterm Exam 2
10/29 – Midterm Exam 2

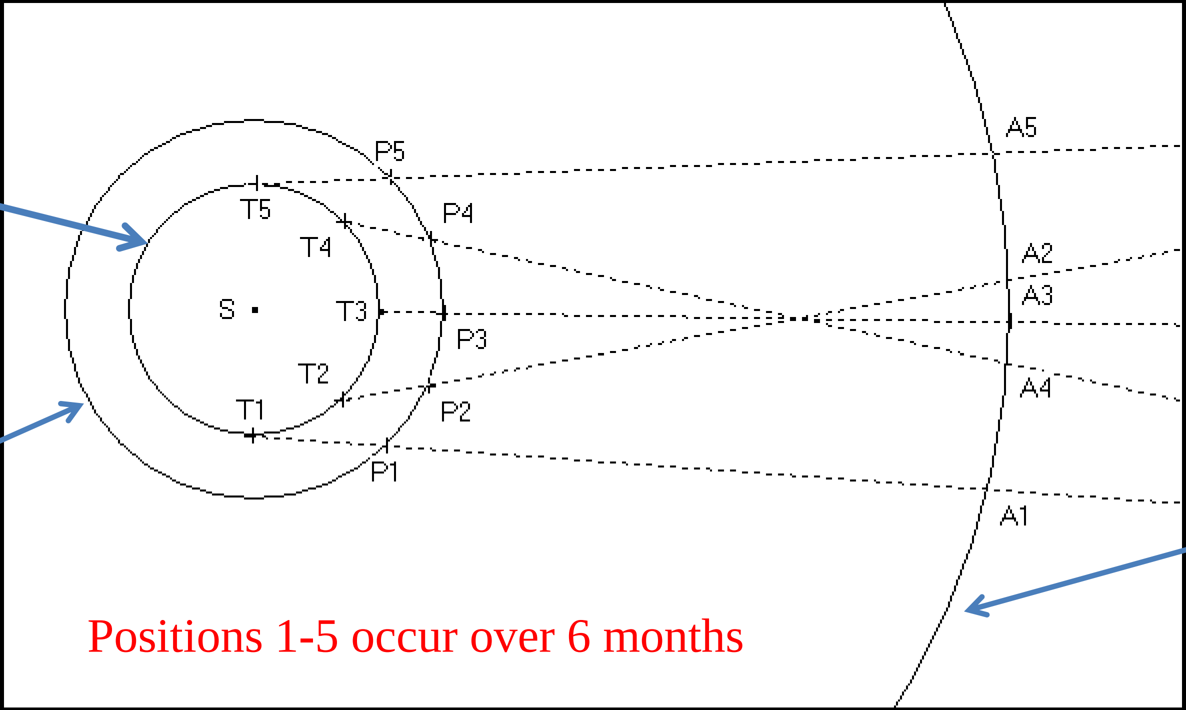
Review of Celestial Sphere Motions

- Over the course of the day, how do stars appear to move?
  - Rise in the east, proceed to their highest point in the southern sky (for us in Laramie), then set in the west…
- If we go out at midnight, night after night after night, and make a quick observation, what motion do we observe for the stars?
  - Rise in the east, proceed to their highest point in the southern sky (for us in Laramie), then set in the west… (similar, but much slower than the daily motion)
  - Do planets do this also?
    - Usually no, but sometimes yes! (WTF?!?!?!?!)

Recall Kepler's Third Law

- Objects orbiting at larger (average) distances from the Sun take longer to orbit…
- So what does this mean in terms of where we see planets on the sky?

Earth's orbit



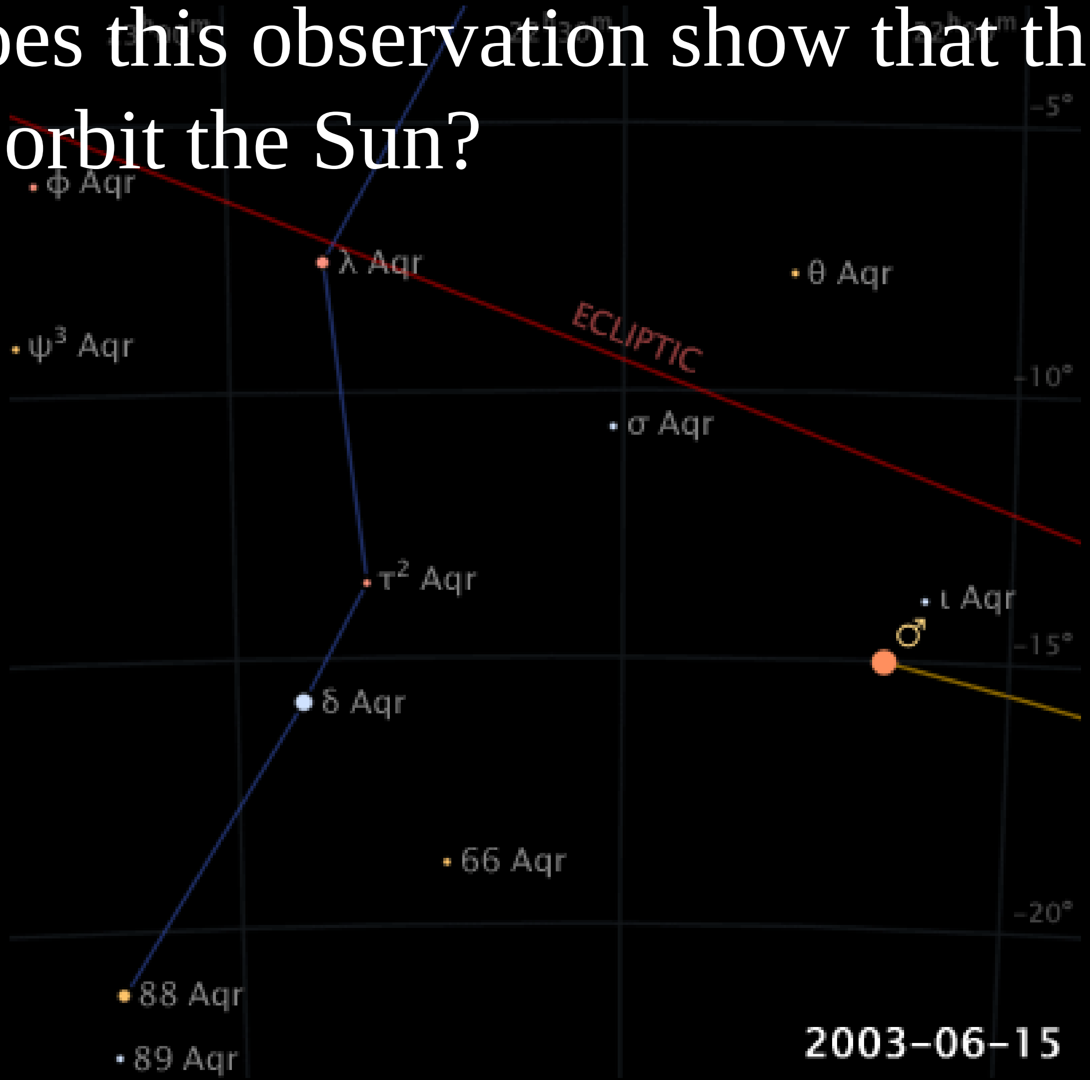
Orbit of an exterior planet (e.g., Mars, Jupiter, Saturn)

Celestial Sphere

What does motion look like on the sky?

How does this observation show that the Earth and planets orbit the Sun?

East



West

Lecture Tutorials

- Break up into groups of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Observing Retrograde Motion (pages 97-98)
  - Discuss the answers – don’t be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

Think
Pair
Share!

Where would you look to see a planet rise when it is in retrograde motion?

A. Near the eastern horizon

B. Near the western horizon

A planet moving in retrograde motion will, over the course of one night, appear to

A. Move east to west
B. Move west to east
C. Not move at all, as planets do not move with respect to the stars
D. Move randomly, as planets move differently than the stars

A planet is moving in retrograde motion. Over the course of several nights, how will the planet appear to move relative to the background stars?

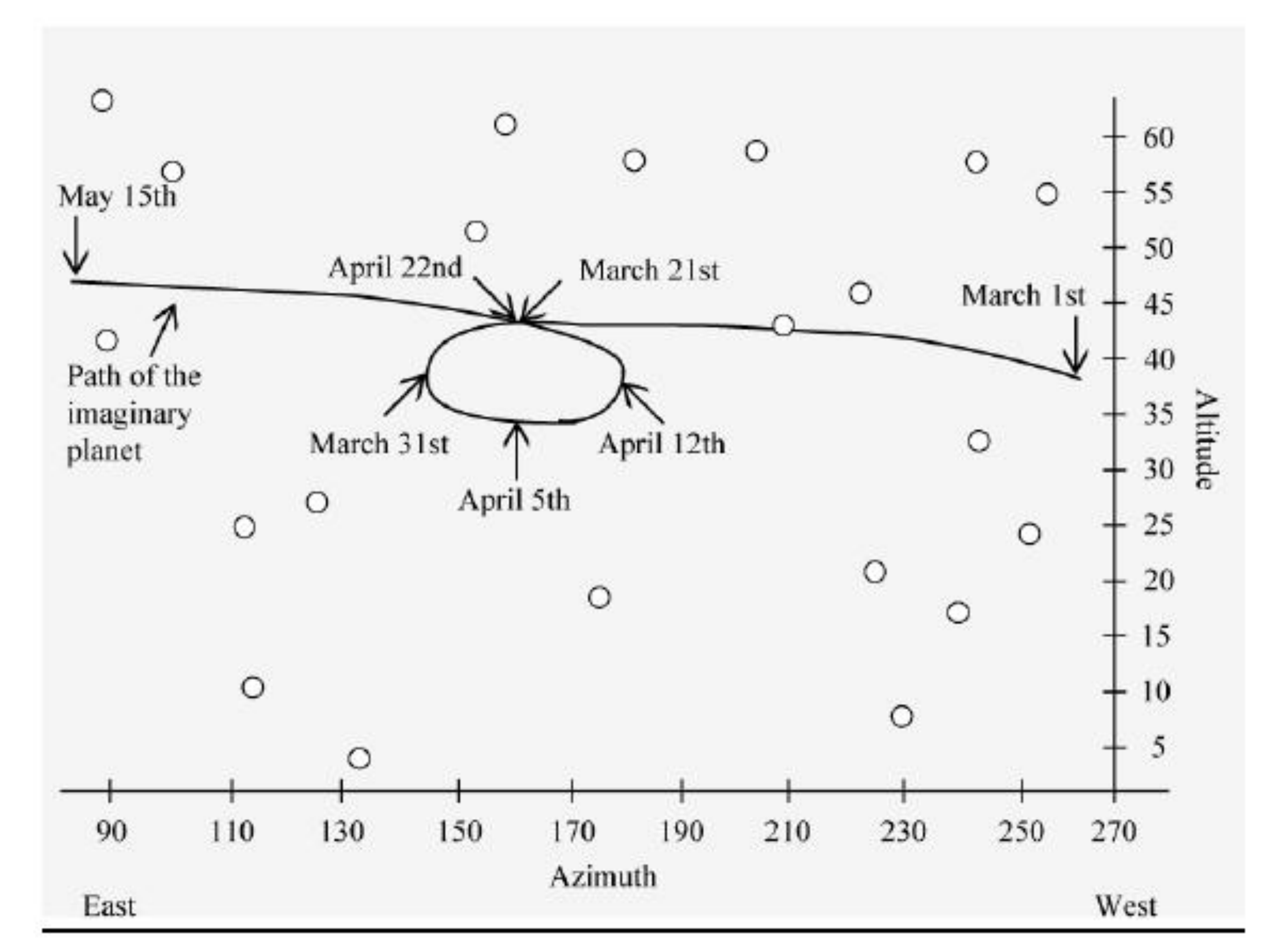
A. East to west
B. West to east
C. It will not move at all, as planets do not move with respect to the stars
D. Move randomly, as planets move differently than the stars

A planet is moving in normal, prograde, motion. Over the course of several nights, how will the planet appear to move relative to the background stars?

A. East to west
B. West to east
C. It will not move at all, as planets do not move with respect to the stars
D. Move randomly, as planets move differently than the stars

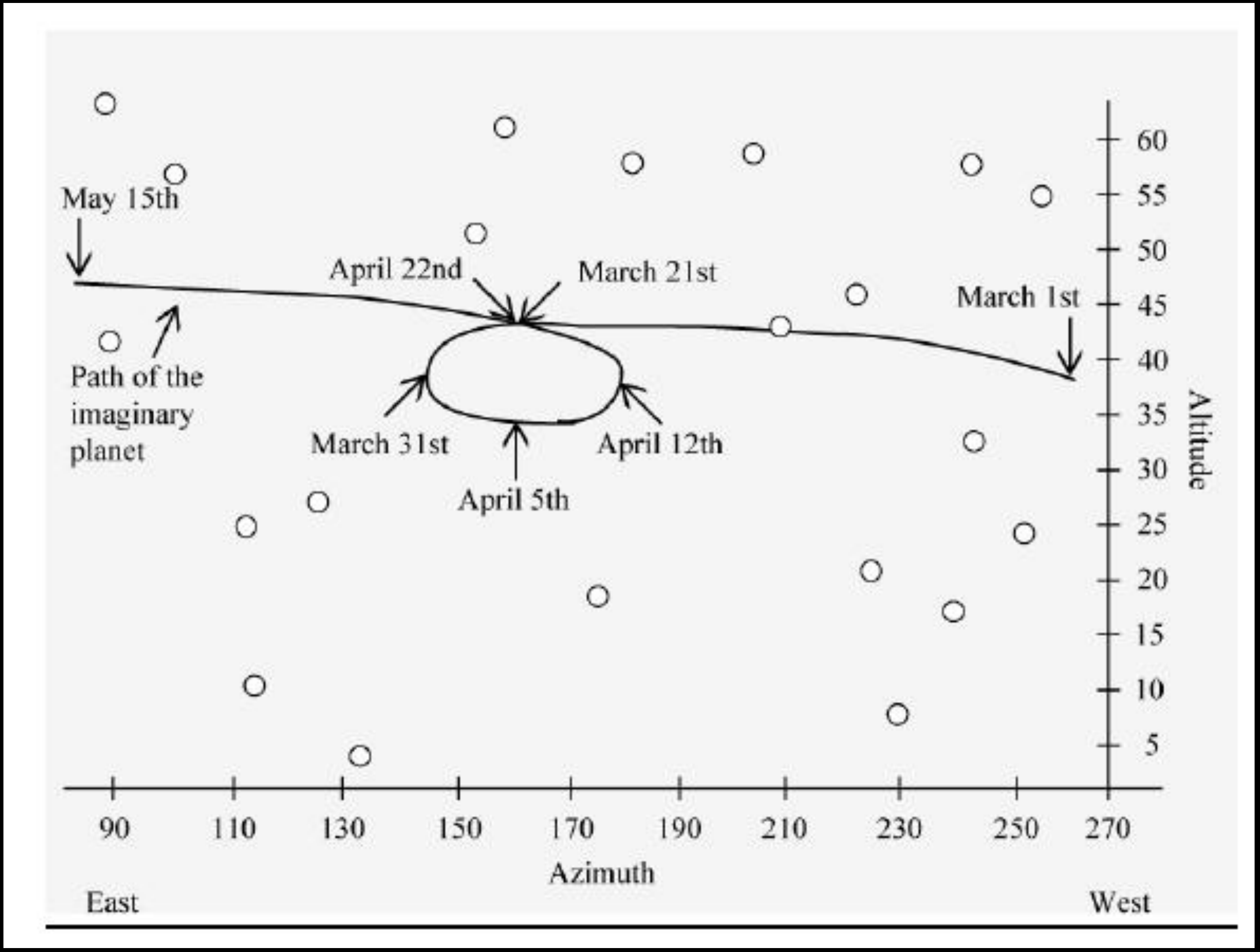
Use the graph to answer the following question. For how many days was this planet in retrograde motion?

A. 10 days
B. 12 days
C. 15 days
D. 17 days
E. 32 days



Use the graph to answer the following question. On which date would the planet appear to rise in the west?

A. March 1
B. March 31
C. April 5
D. April 12
E. Never



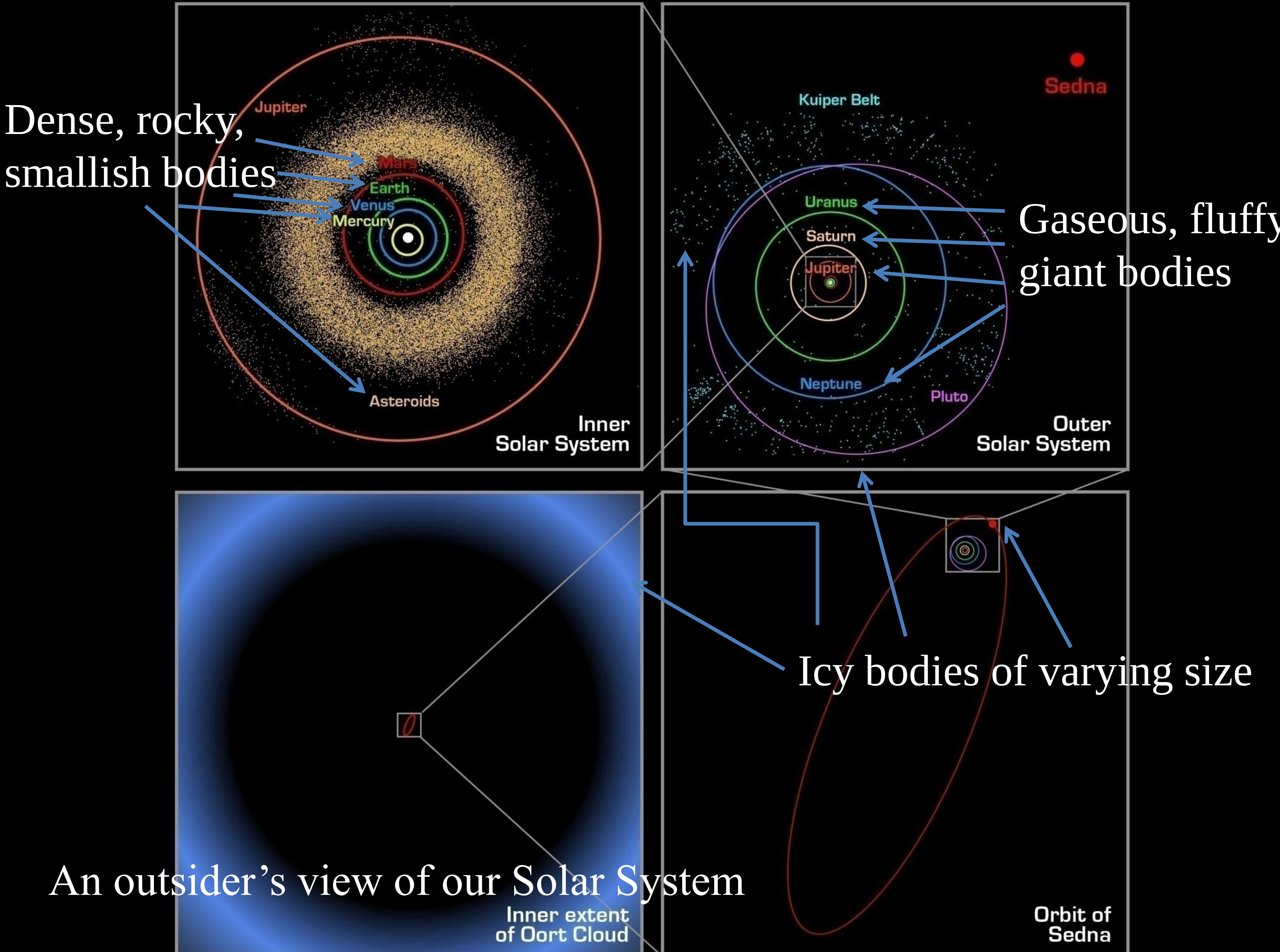
Structure and Formation of the Solar System

10/22 – Motion of Extrasolar Planets

10/24 – The Great Planet Debate

10/27 – Review for Midterm Exam 2

10/29 – Midterm Exam 2

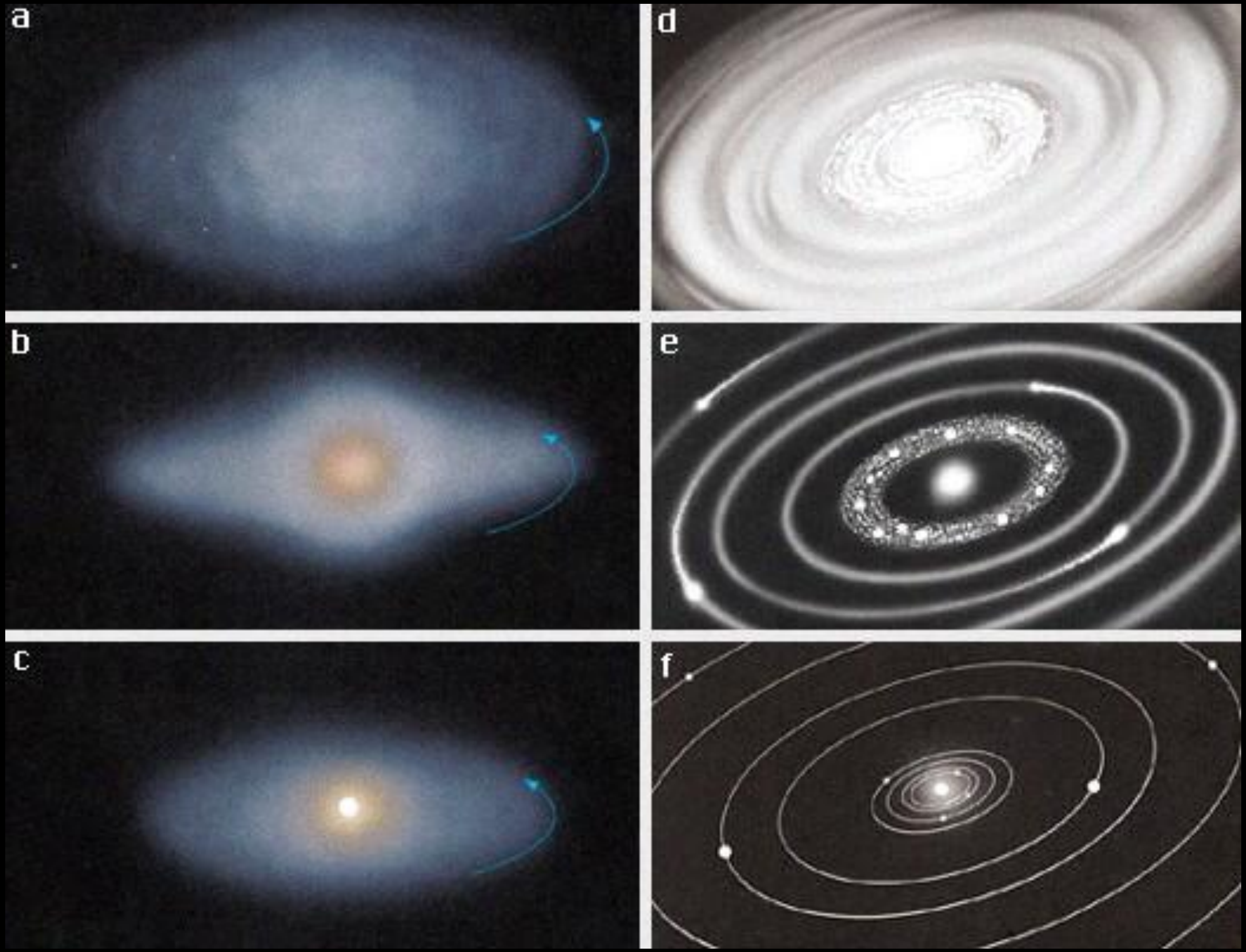


An outsider's view of our Solar System

Some observations…

- Rocky things close to the Sun
- Icy things far from the Sun
- Gasy things in between
- Rocky and Gasy things tend to orbit is very similar planes (not exact, but pretty close)
- “Larger” things to tend orbit in mostly circular orbit (again, not exact, but pretty close)

- How did this form? Is it similar to other solar systems?

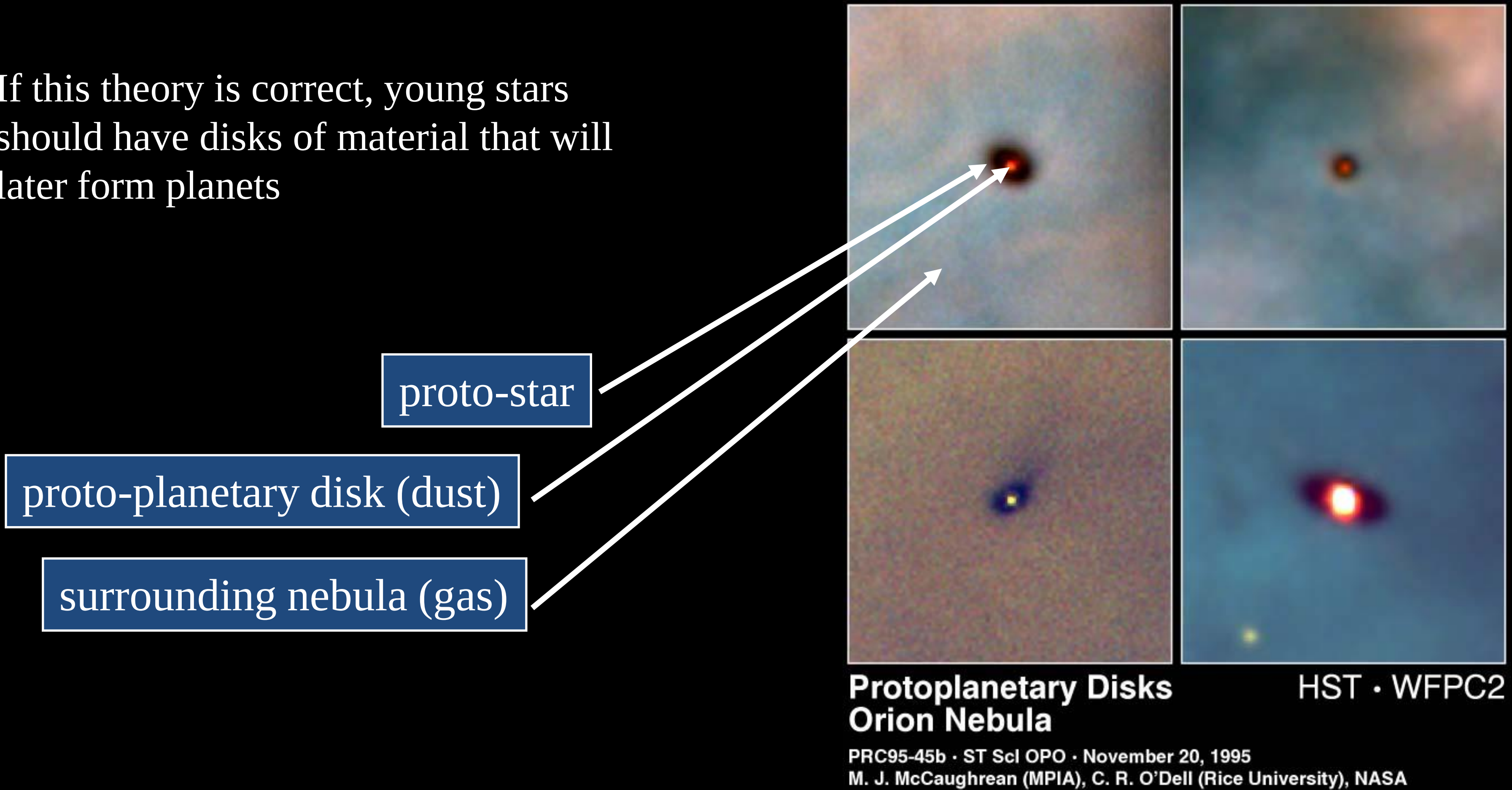


The solar system formed from a large cloud of cold gas and dust called the solar nebula about 4.6 billion years ago

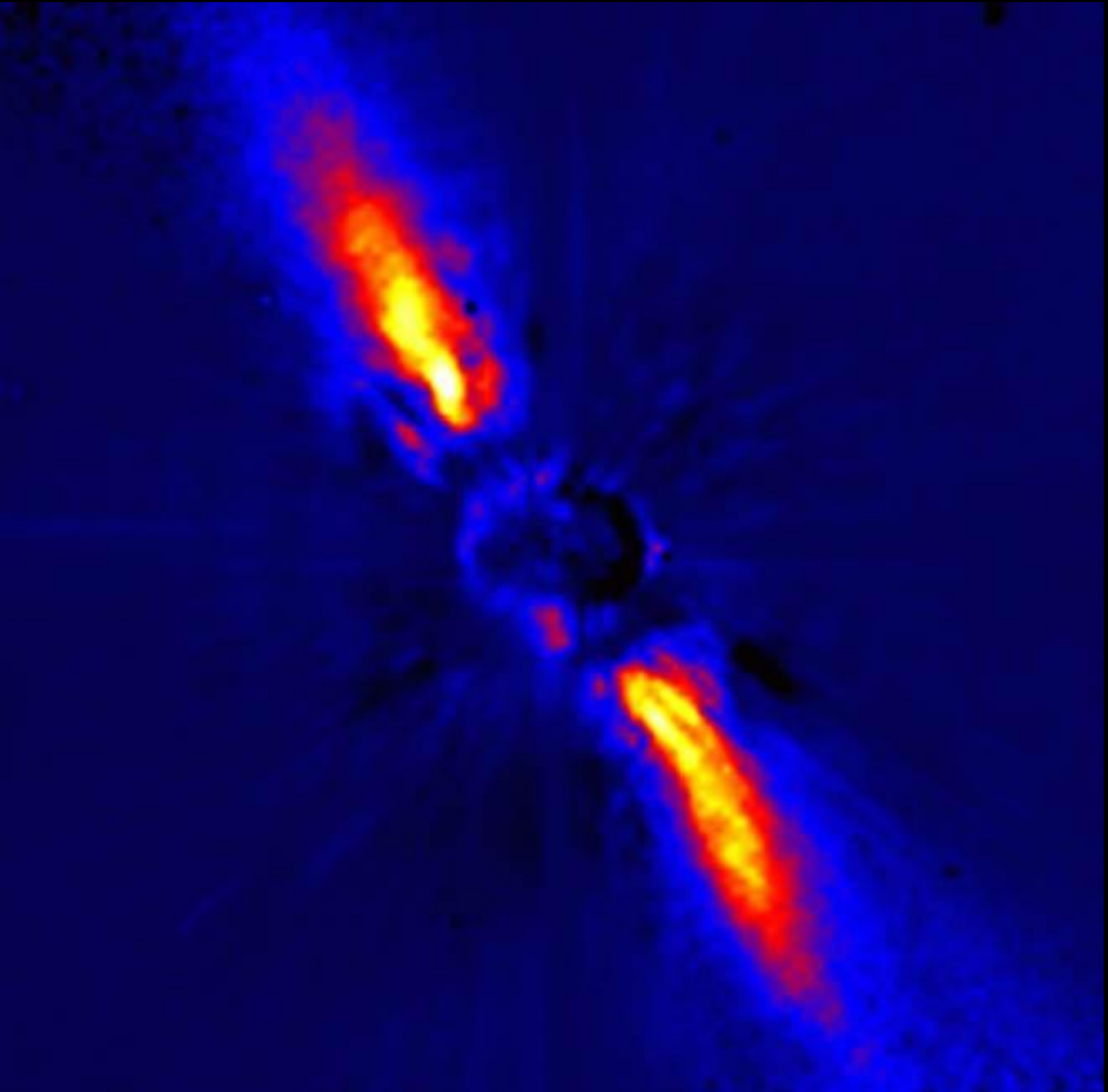
How do we know this happened?

Although we can't go back in time and observe the formation of our own Solar System, we can observe other stars and planetary systems forming today.

If this theory is correct, young stars should have disks of material that will later form planets



Proto-Planetary Disks



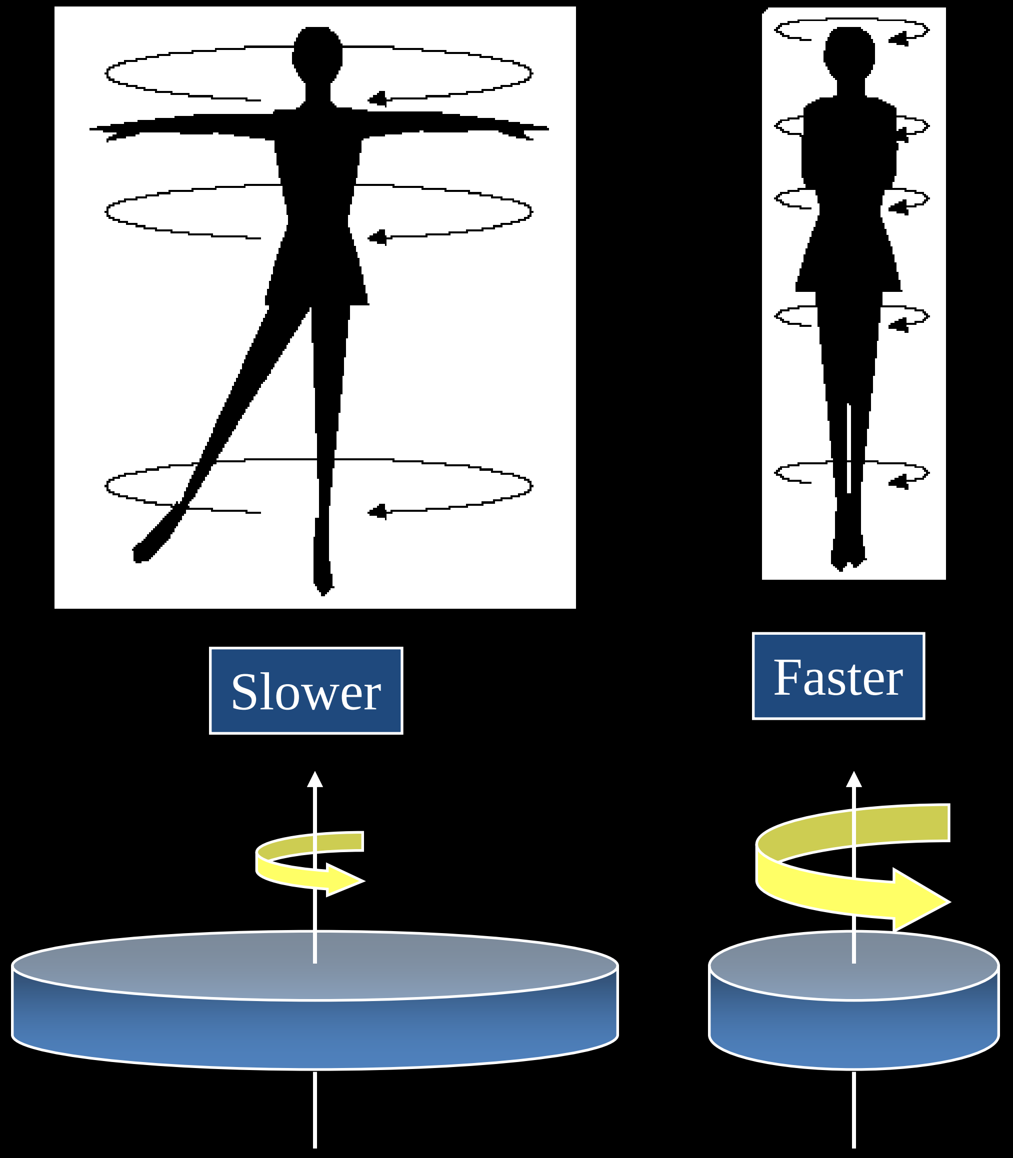
Another disk around the star Beta Pictoris (we are seeing the disk from the side)

(light from star blocked out)

Things that spin tend to flatten out in shape

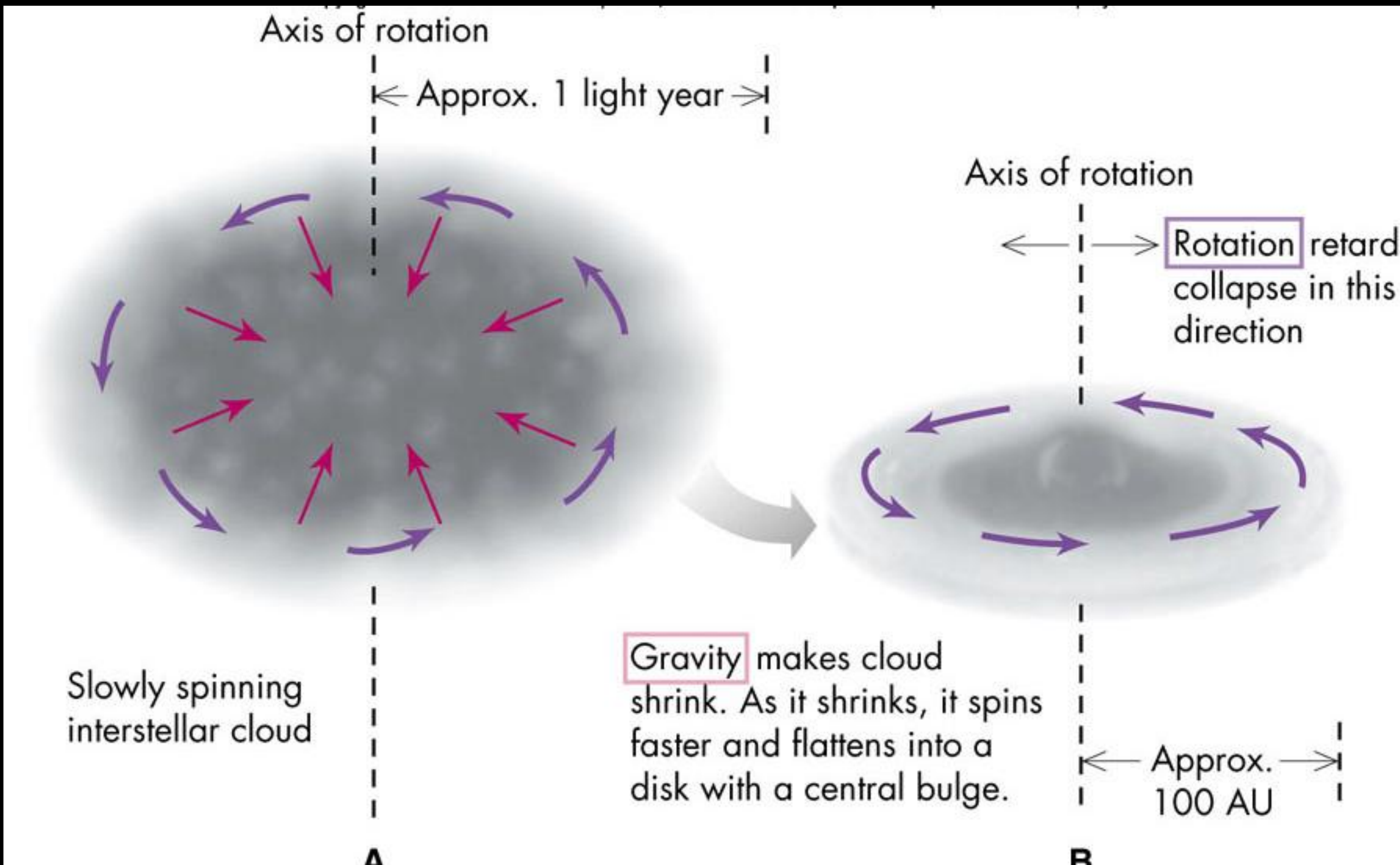
Why does the cloud of gas and dust become disk-shaped?

As a rotating cloud of gas contracts, its angular speed must <u>increase</u> because *angular momentum must be conserved* (a fundamental law of Nature). **Things that spin want to keep on spinning.**



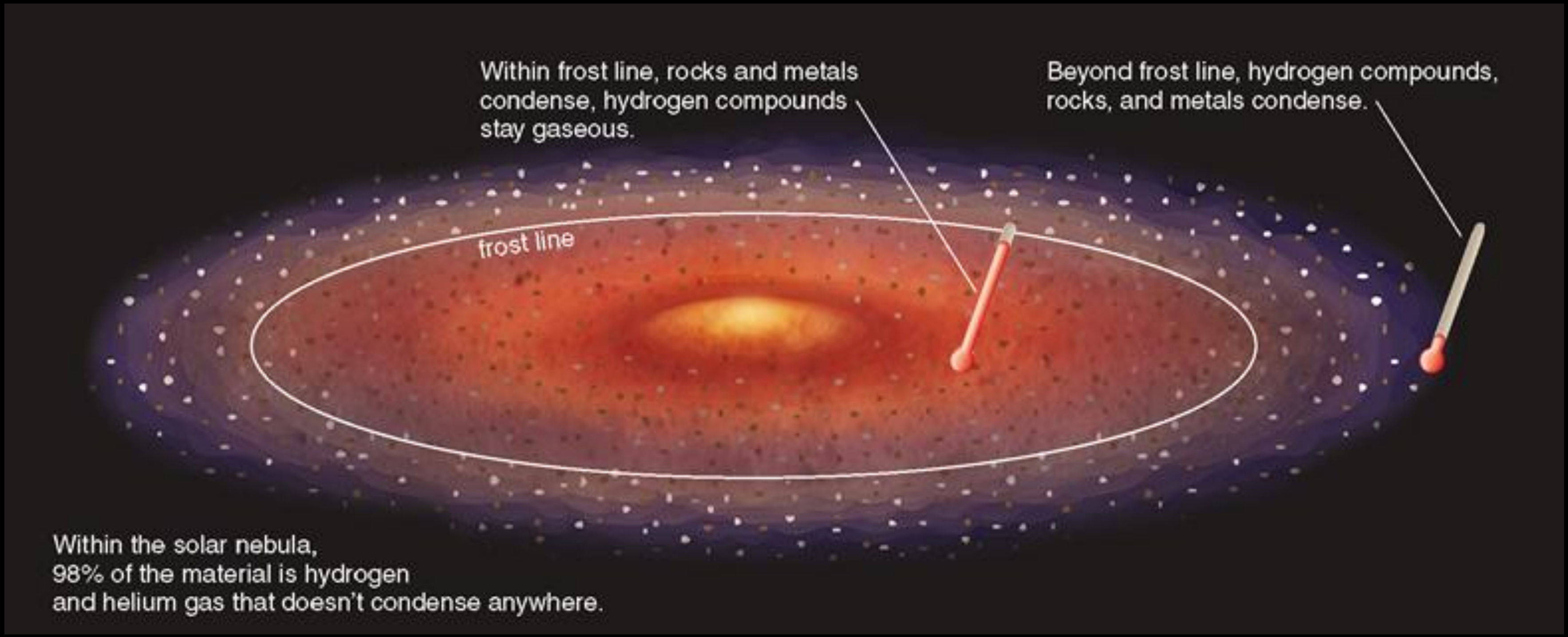
(Kepler's Second Law!!!)

Process 1: A rotating, collapsing ball of gas turns into a disk-like shape

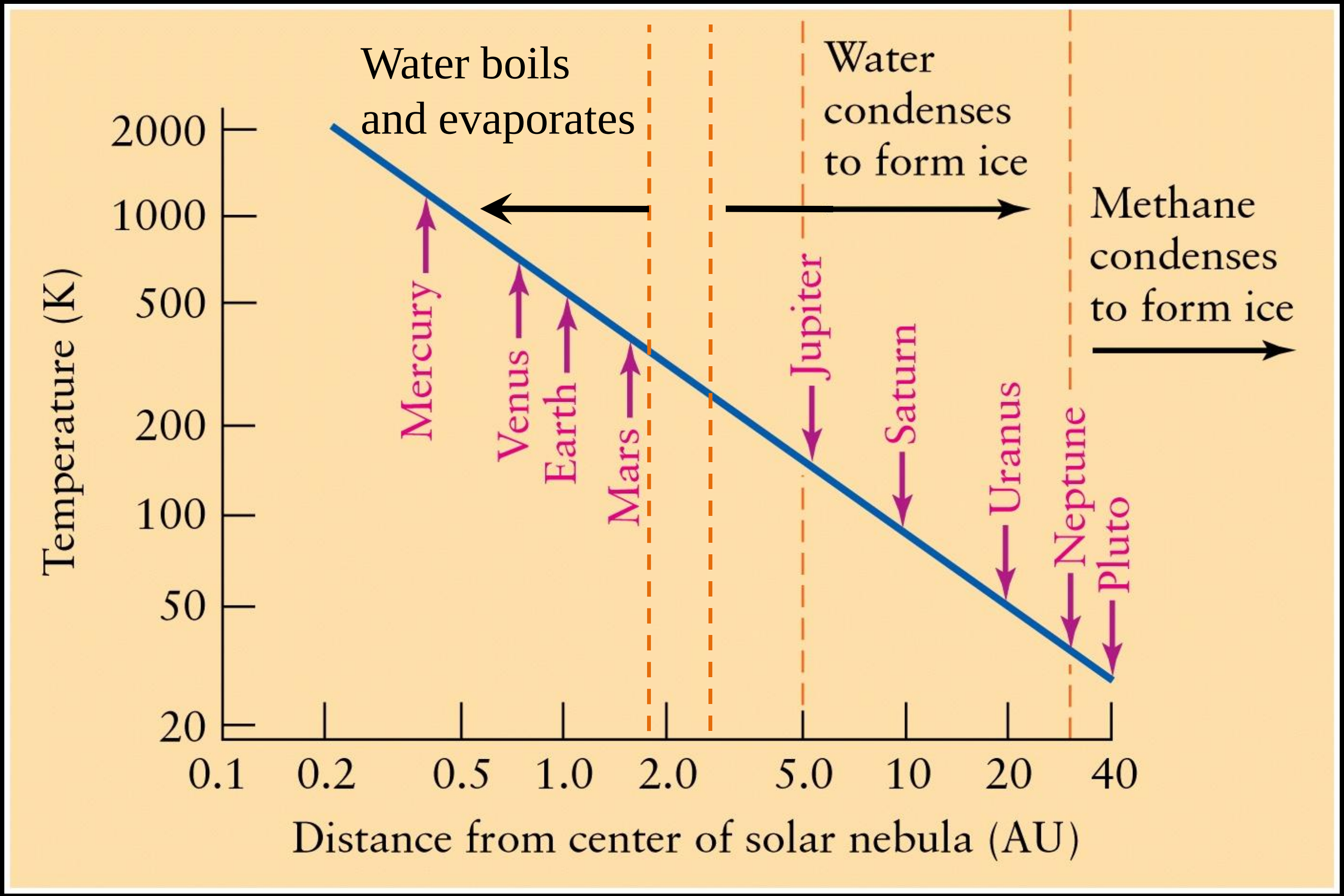


Process 2: Matter collects in the center where the temperatures increase (things are much cooler farther out from the center).

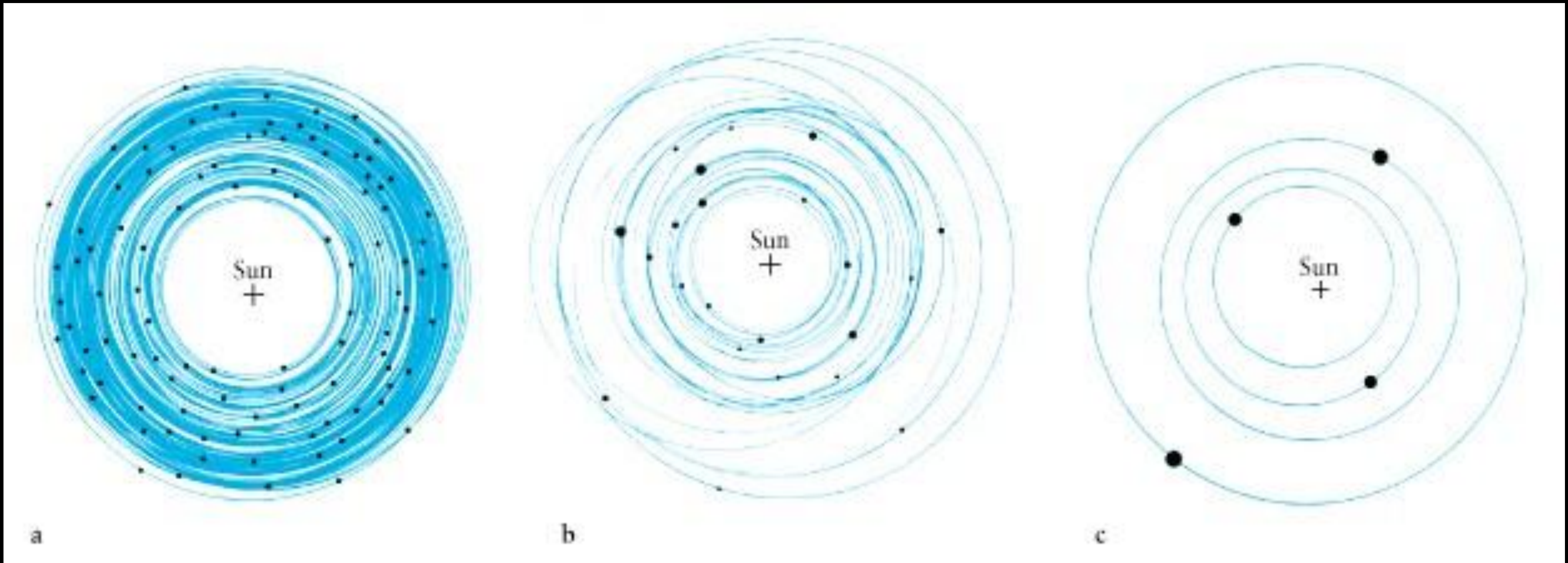
- Material gets separated out
- Rocks near the middle
- Ice and gas farther out



The planets formed by the accretion of planetesimals and the accumulation of gases in the solar nebula



Process 3: Collisions dominated the early solar system



- dust coalesced into planetesimals
- planetesimals accreted into protoplanets
- protoplanets became planets

Lecture Tutorials

- Break up into groups of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Temperature and Formation of the Solar System (pages 103-104)
  - Discuss the answers – don't be silent!
- MarkDanTim, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

Think

Pair

Share!

Which of the following types of bodies would likely have formed in the early solar system at locations hot enough for liquid water to boil into a gas?

A. Rocky terrestrial planets
B. Jovian gas giant planets
C. Pluto/Kuiper Belt objects
D. Comets
E. None of the Above

The standard model of solar system formation offers what explanation for the different compositions of the terrestrial and Jovian planets?

A. During condensation, the heavier elements tended to sink nearer the Sun and, being rare, only provided enough material to build the relatively small terrestrial planets.
B. During the collapse of the solar nebula, most of the material tended to collect far from the Sun because of the large angular momentum, which provided the necessary material to build the large Jovian planets.
C. The large gravitational forces of Jupiter tended to prevent planet formation in the inner solar system and eventually attracted most of the material into the region of the Jovian planets.
D. The terrestrial planets were formed near the Sun where, because of the high temperature, only heavier elements were able to condense.

Which of the following planets was able to form closest to the Sun at temperatures below the freezing point of water?

A. Venus
B. Earth
C. Mars
D. Jupiter
E. Saturn

Astronomers have discovered massive gas giant planets like Juptier orbiting companion stars closer than 0.7 AU (about the distance of Venus' orbit). Why don't astronomers believe that these gas giant planets originally formed at these locations?

A. The planets' gravity would have been too large to form that close to the star.
B. The temperature in the early solar nebula was too high at these distances.
C. Their orbital periods are too long for them to be located that close to their stars.
D. A young star's solar wind would have blown the planets farther away.

Motion of Extrasolar Planets

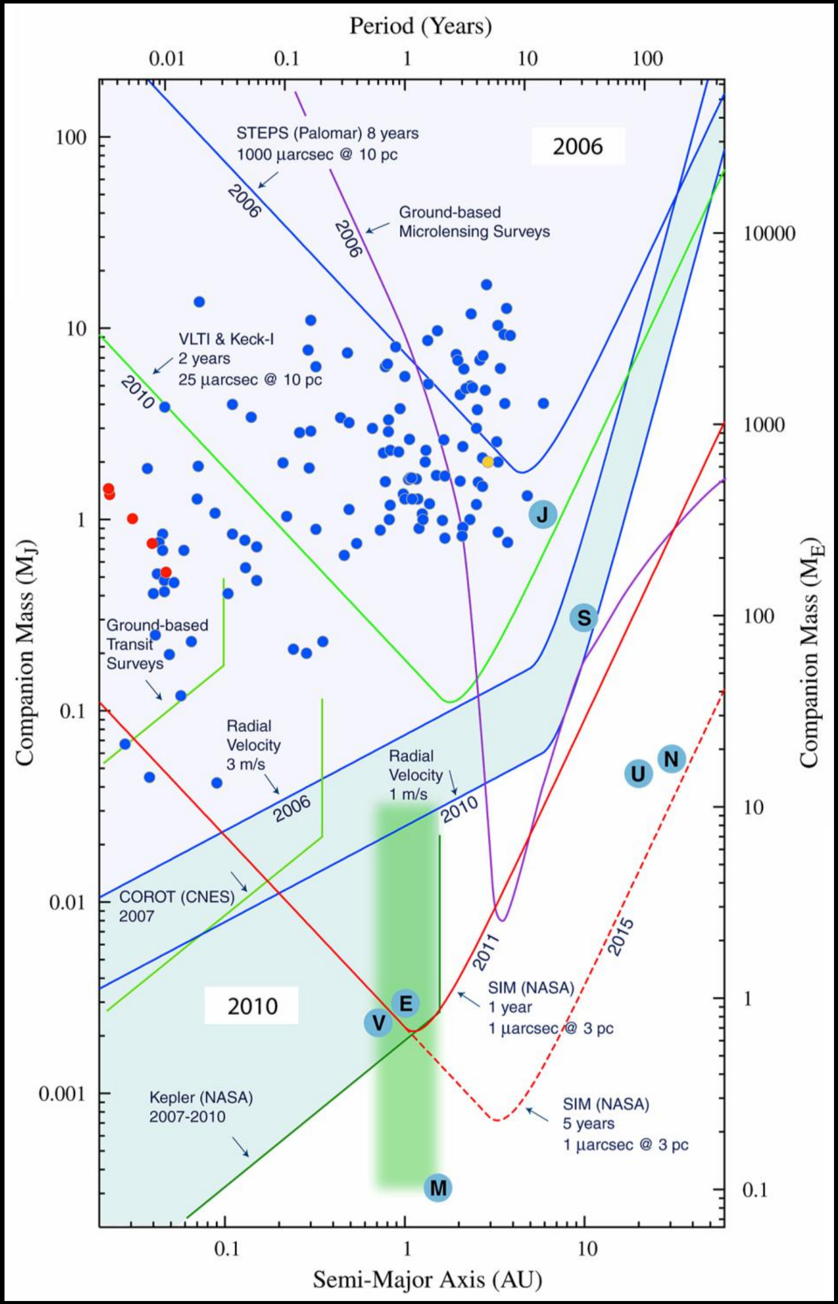
10/24 – The Great Planet Debate

10/27 – Review for Midterm Exam 2

10/29 – Midterm Exam 2

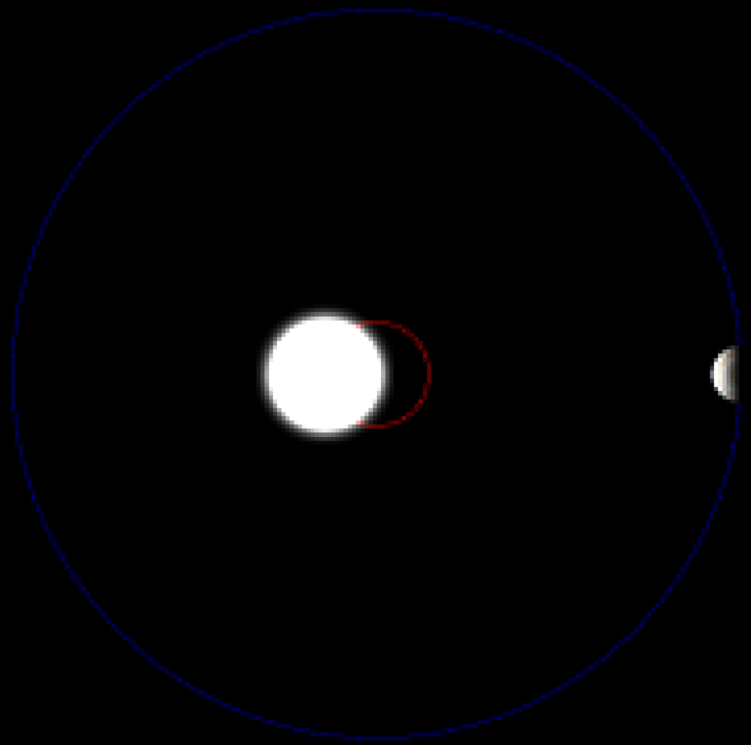
Extrasolar Planets

- To date, astronomers have found over 300 hundred planets orbiting other stars.
- The planets tend to be large gasy planets like Jupiter, Saturn, Uranus, and Neptune, but much larger.
- They also tend to orbit their stars at distances closer than Jupiter! (If they didn't form there, how did they get there???)



How do we find extrasolar planets?

- Primary Method: Radial Velocity
- Other common methods:
  - Direct Imaging
  - Eclipses
  - Sky position of star



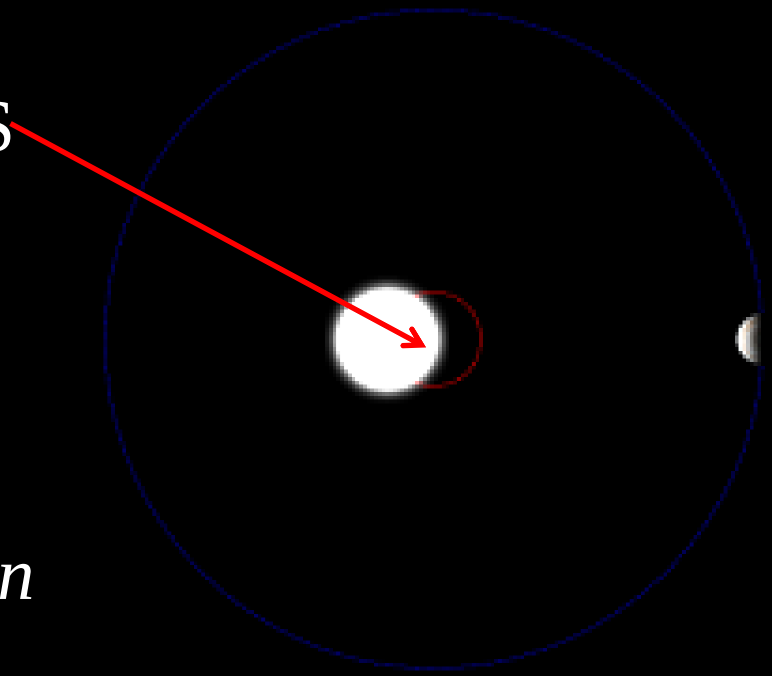
Radial Velocities

- Radial = the part that is toward/away (i.e., not tangential, or side-to-side)
- Need to use three concepts from previous two units:
  - Absorption lines (from the star)
  - Doppler Shift (of those absorption lines)
  - Gravity (to determine the motion of the star)

Radial Velocities

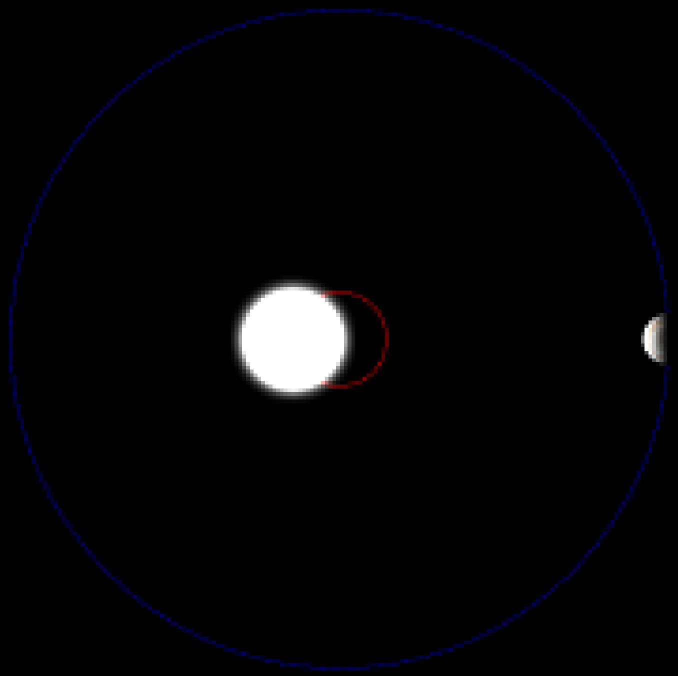
- Gravity: Newton's second law and law of gravity tells us how the star will move as a result of a planet orbiting it.

- Both planet and star will go around the CENTER OF MASS
    - (Our Sun does this too…)
    - (So do Earth and Moon…)
- The C.O.M. always stays between the two objects.
- Both object orbit the C.O.M. *in the same amount of time.*



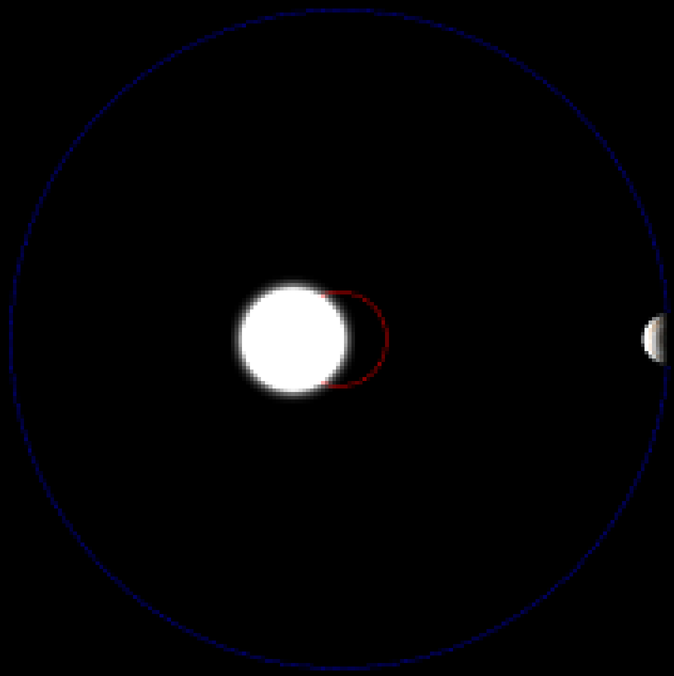
Radial Velocities

- How fast does star go?
- The acceleration of the star is affected by two things:
  - Mass of the planet
  - Distance between star and planet
- The more massive and closer the planet is, the larger the velocity of the star…



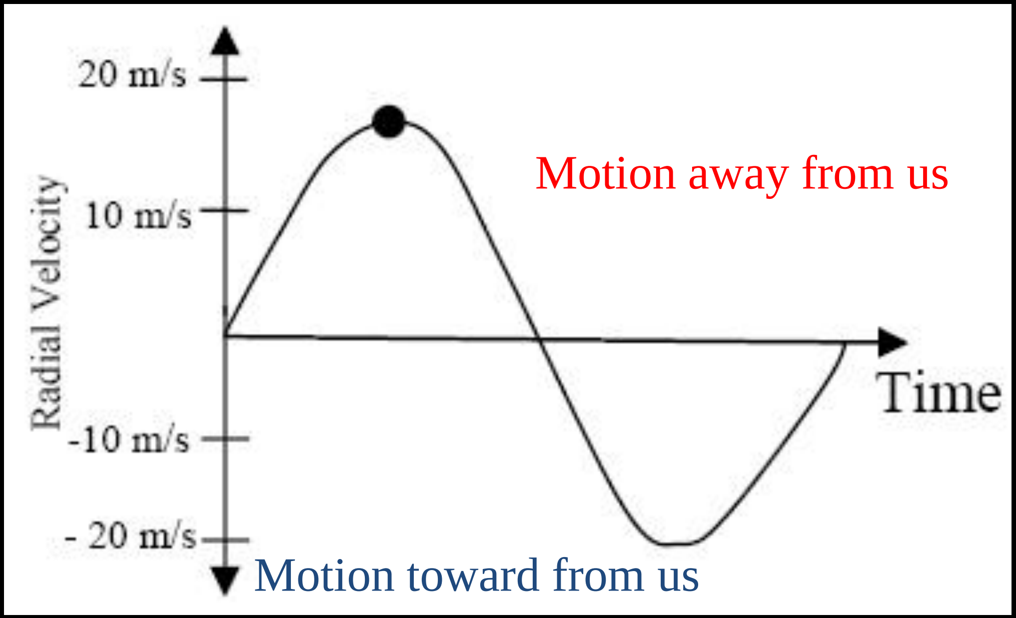
Radial Velocities

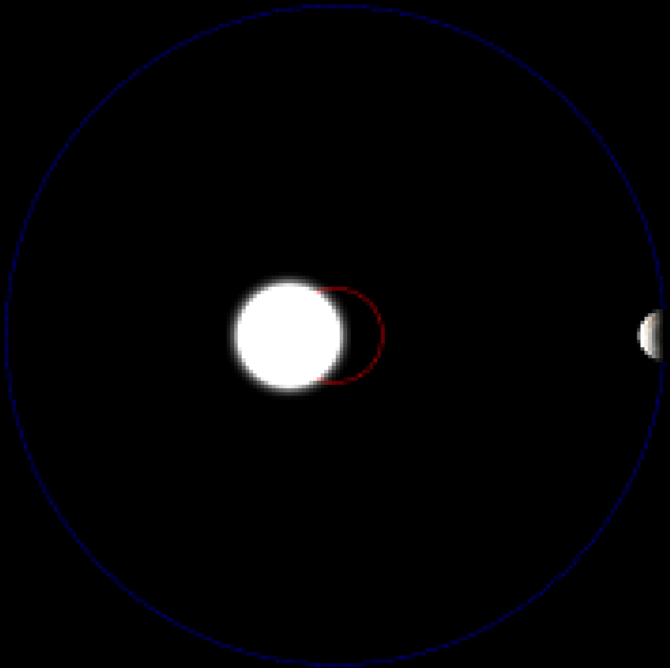
- How do we detect this motion?
- The Planet Hunter's Mantra: Shift Happens
- The absorption lines in a star's spectrum will Doppler shift as a result of this motion of the star!
- But only in systems that are not face-on, or viewed ``from above" …..



Radial Velocities

- Using the Doppler shift, we can measure the radial velocity of the star (i.e., the object sending light to us)



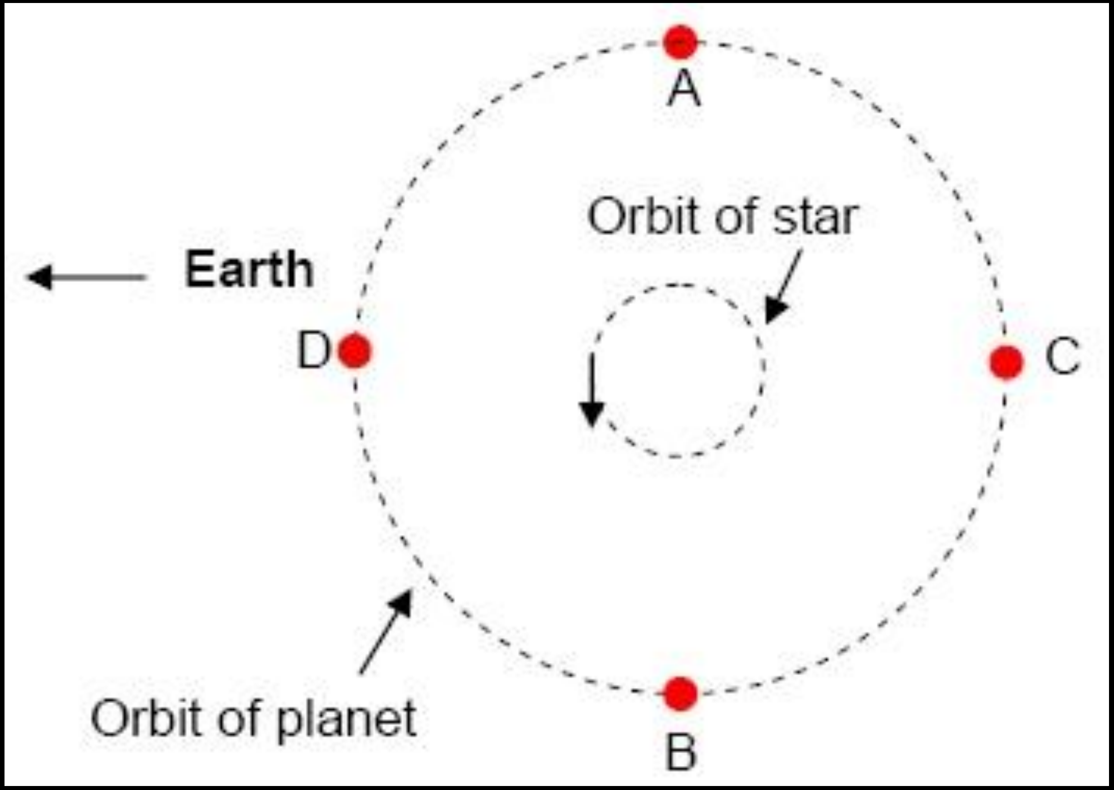


Lecture Tutorials

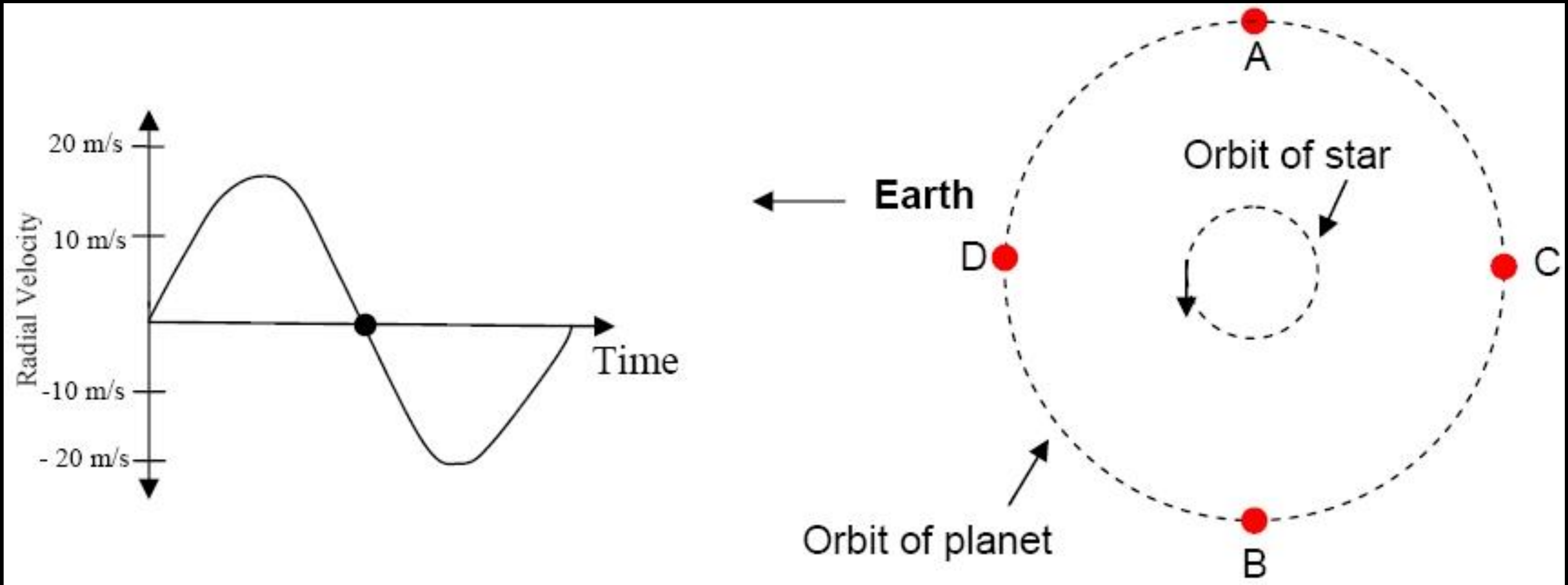
- Break up into groups of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Motion of Extrasolar Planets (pages 117-120)
  - Discuss the answers – don't be silent!
- MarkDanTim, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

Think
Pair
Share!

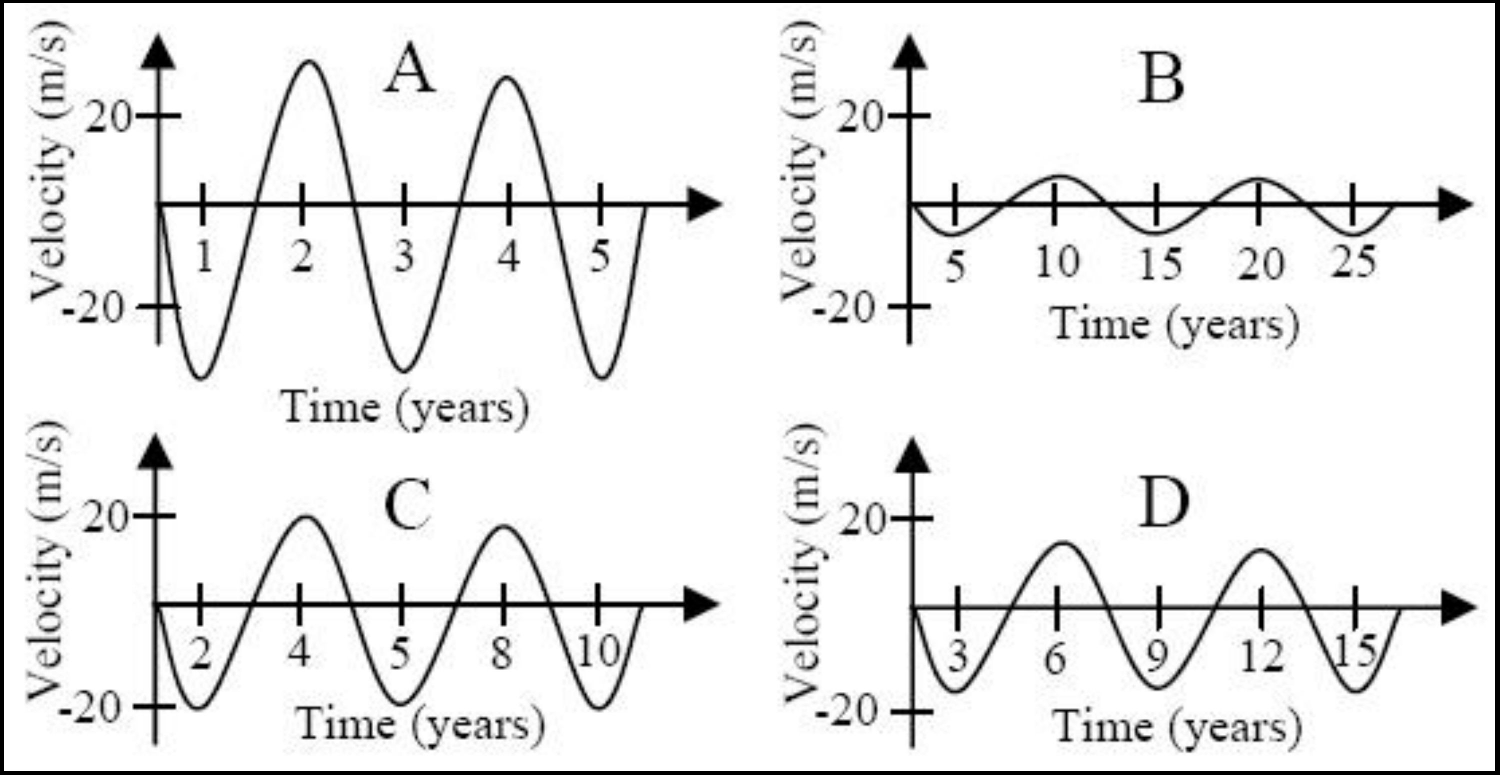
Based on the diagram for the motion of an extrasolar planet and its companion star shown below, at what location (A, B, C, or D) would you expect the planet to be located when light from the star would appear blueshifted for an Earth observer?



Given the location marked with a dot on the star's radial velocity curve, at what location (A, B, C, or D) would you expect the planet to be located at this time?



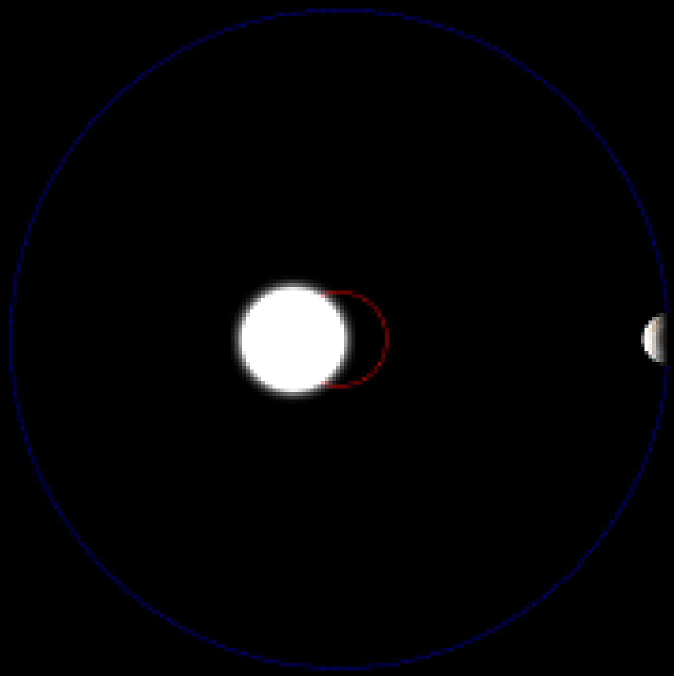
The plot below show radial velocity curves for four different stars with extrasolar planets. The planet of which star would have the longest orbital period? If you do not think the extrasolar planet's period can be determined by the given information, then answer "E."



How does this mesh with Kepler's Third Law?

- Kepler's Third Law says objects that are farther out take longer to orbit… right?

- WTF? Why does the star that is orbiting closer take the same amount of time as the planet that is orbiting farther?



What's on the exam?

- 40 questions, all multiple choice (just like before)
- 30 from Nature of Light, 10 from Solar System
- 27 derived from LT, 13 from AN

What concepts will the exam test?

- Nature of light
  - Apparent and Absolute magnitudes, and the ‘’inverse-square” relationship between flux and luminosity
  - Continuous vs. Emission vs. Absorption spectra, what we can learn from each type of spectrum
  - Blackbody radiation, deriving temperature, and sizes in unambiguous cases
  - Forms of light and their relationships in terms of energy, frequency, wavelength, and speed
  - Doppler shift, and what information we get from it
  - The effect of our atmosphere, and what light will pass through. Where should we place telescopes that are sensitive to different types of light…
  - Atomic structure and how atoms interact with light
- Solar system
  - Retrograde motion (makes use of celestial sphere concepts)
  - Searches for Extrasolar planets
  - Radial velocity (makes use of concept of gravity, and Doppler shift)
  - Formation of the Solar System, how temperature changes, what sorts of objects formed in what part of the Solar System and why
  - No questions from AN Chapter 9. Chapter 1 Section 15 is fair game, though.

The Great Planet Debate

10/27 – Review for Midterm Exam 2

10/29 – Midterm Exam 2

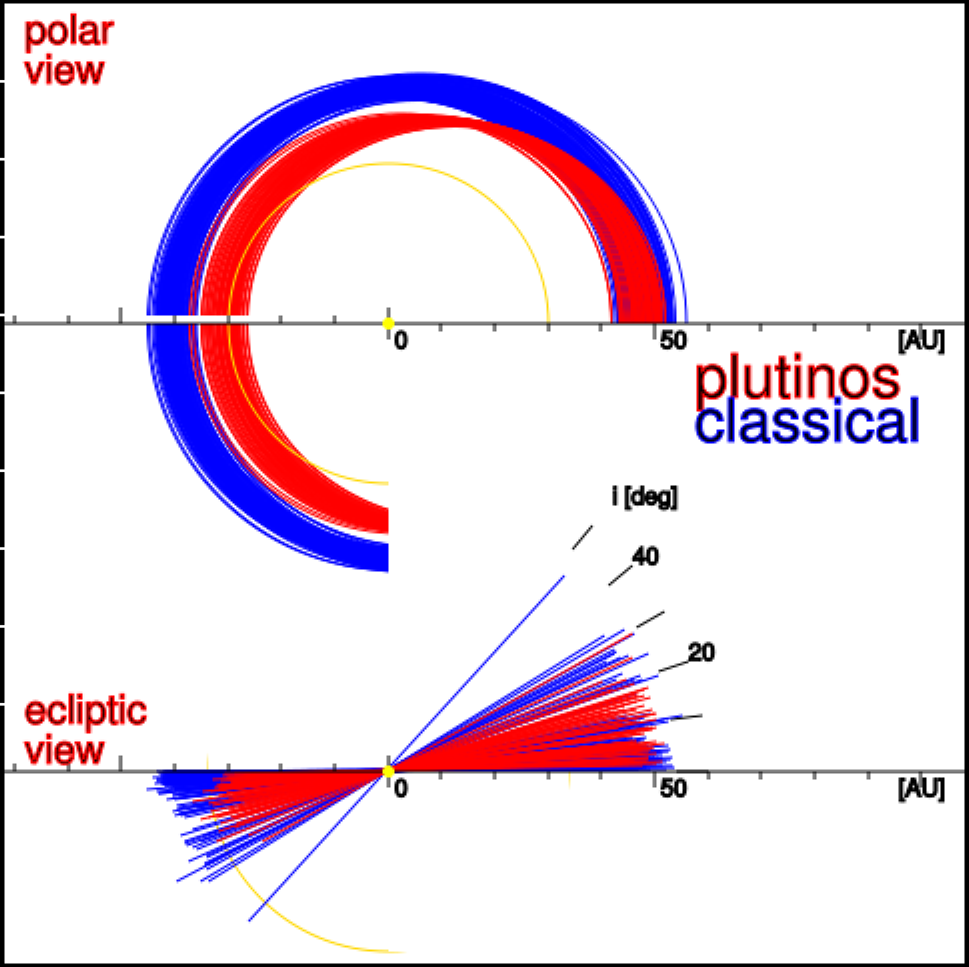
Quiz

1. Write your name on a sheet of loose-leaf paper. (If you do not have loose-leaf paper, kindly ask for one from some one.)
2. In a short paragraph, answer the following question:

   "According to Drs. Mark Sykes and Niel DeGrasse Tyson, what are three important issues to consider when trying to establish the definition of a planet? (They discussed more than three, but you only need only choose three.)"
3. When you are done, ponder the following question: *What observations can you use to establish criteria if something is a planet, and how many objects in our Solar System satisfy those criteria?*
4. We will collect the quizzes after 5 minutes by having everyone pass them to the aisle.

Clues that Pluto Was an Oddball

	Name	Inclination
Terrestrial Planets	Mercury	7.01 deg
	Venus	3.39 deg
	Earth	0 deg
	Mars	1.85 deg
Jovian Planets	Jupiter	1.31 deg
	Saturn	2.49 deg
	Uranus	0.77 deg
	Neptune	1.77 deg
Plutoids	Pluto	17 deg



Huh? Plutoids/plutinos are objects that are in a 3:2 resonance with Neptune. They orbit twice every time Neptune orbits three times.

We can choose many properties to classify objects in the Solar System…

- Density
- Mass
- Temperature
- Magnetic fields
- Composition
- Atmosphere

- Number of satellites
- Rings
- Craters
- Distance from Sun
- Inclination of orbit

"Definition" of a planet

- Old definition: Anything in the sky that moved relative to the stars.
  - Moon, Sun, Mercury, Venus, Mars, Jupiter, Saturn
- With the advent of telescopes, we could start looking for new objects not visible to the naked eye…
  - Gas Giants: Uranus (1781), Neptune (1846)
  - Asteroids: Ceres (1801), Vesta (1807), countless others
  - Kuiper Belt: Pluto (1930), Eris (2003), Haumea (2004), Makemake (2005), several others

“Definition” of a planet

- Newest definition from the IAU… A planet is any object that satisfies the following criteria:
  - is in orbit around the Sun,
  - has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a nearly round shape, and
  - has cleared the neighborhood around its orbit.

“Definition” of a planet

- Eight objects satisfy all three criteria:
  - Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune
- Objects in the Kuiper belt and asteroid belt do not satisfy the “cleared the neighborhood of their orbit” criterion.
  - Earth wouldn’t either if it was in the Kuiper belt
- Moons do not satisfy the “orbit the Sun” or the “cleared…” criteria.

What makes something round?

- One word answer: Gravity
- Multi-word answer: When the force gravity between a molecule and the larger body that the body is part of is stronger than the bonds in that molecule.
- Example: What time is it when an elephant sits on your table?
- Implications:
  - Heavier elements (e.g., iron) will sink to the center of the body, lighter elements will remain at the top. → "differentiation"
  - Depends on the composition of the body… ice is easier to "roundify" than rock…

How many objects satisfy the “round” criteria?

- Lots….
- Actually, to be more accurate…..

LOTS

Something like 30ish

Ok, how about "round" and "orbiting the Sun" ?

- Count 'em
- Terrestrial: Mercury, Venus, Earth, Mars, Ceres
- Jovian: Jupiter, Saturn, Uranus, Neptune
- Kuiper: Pluto, Eris, Haumea, Quaoar, Makemake, Sedna, Orcus, Varuna…
- 17... so far…

Suppose we use just size as a criterion for planetdom…

- After the Sun, the ordering of things in our Solar System by size (from the largest)
  - First Gas Giants: Jupiter, Saturn, Uranus, Neptune
  - Then some Terrestrials: Earth, Venus, Mars
  - And then (as author Salman Rushdie would say) "the proverbial excrement strikes the ventilation system…"


Mars
6804.9 km
Ganymede
5262 km
Titan
5150 km
Mercury
4879.4 km
Callisto
4821 km
Io
3643 km
Moon
3476.2 km
Europa
3122 km
Triton
2706.8 km
Pluto
2390 km
Sedna
~ 1500 km
Titania
1578 km
Rhea
1528 km
Oberon
1523 km
Iapetus
1436 km
Quaoar
1200 km
Diameters of the Terrestrial Bodies of the Solar System
Charon
1186 km
Umbriel
1169.4 km
Ariel
1158 km
Dione
1118 km
Tethys
1059 km
Earth
12,756.28 km

Is there any way we can avoid rewriting the textbooks that tell us that there are nine planets?

- Sure…

  if we abandon the use of the word planet that is defined in some self-consistent fashion

- Would that be useful in making progress toward understanding our Solar System?

http://en.wikipedia.org/wiki/List_of_Solar_System_objects_by_surface_gravity
http://en.wikipedia.org/wiki/List_of_Solar_System_objects_by_mass
http://en.wikipedia.org/wiki/List_of_Solar_System_objects

Do you really understand what we mean by a solar system?

In the case of our solar system – it’s the central star called the Sun and the planets, moons, comets, asteroids….. that orbit the Sun. And that’s it.

Do you really get what we mean by a solar system?

"UA had role in finding galaxies
Its heat imager aboard Spitzer yields excitement"

By Anne Minard

ARIZONA DAILY STAR- (Like the Boomerang)

"The discovery announced this week of 31 new galaxies in the outermost reaches of the solar system has Tucson written all over it.
NASA's Spitzer Space Telescope used a heat-sensing imager developed at the University of Arizona to peer into the constellation Bootes………."

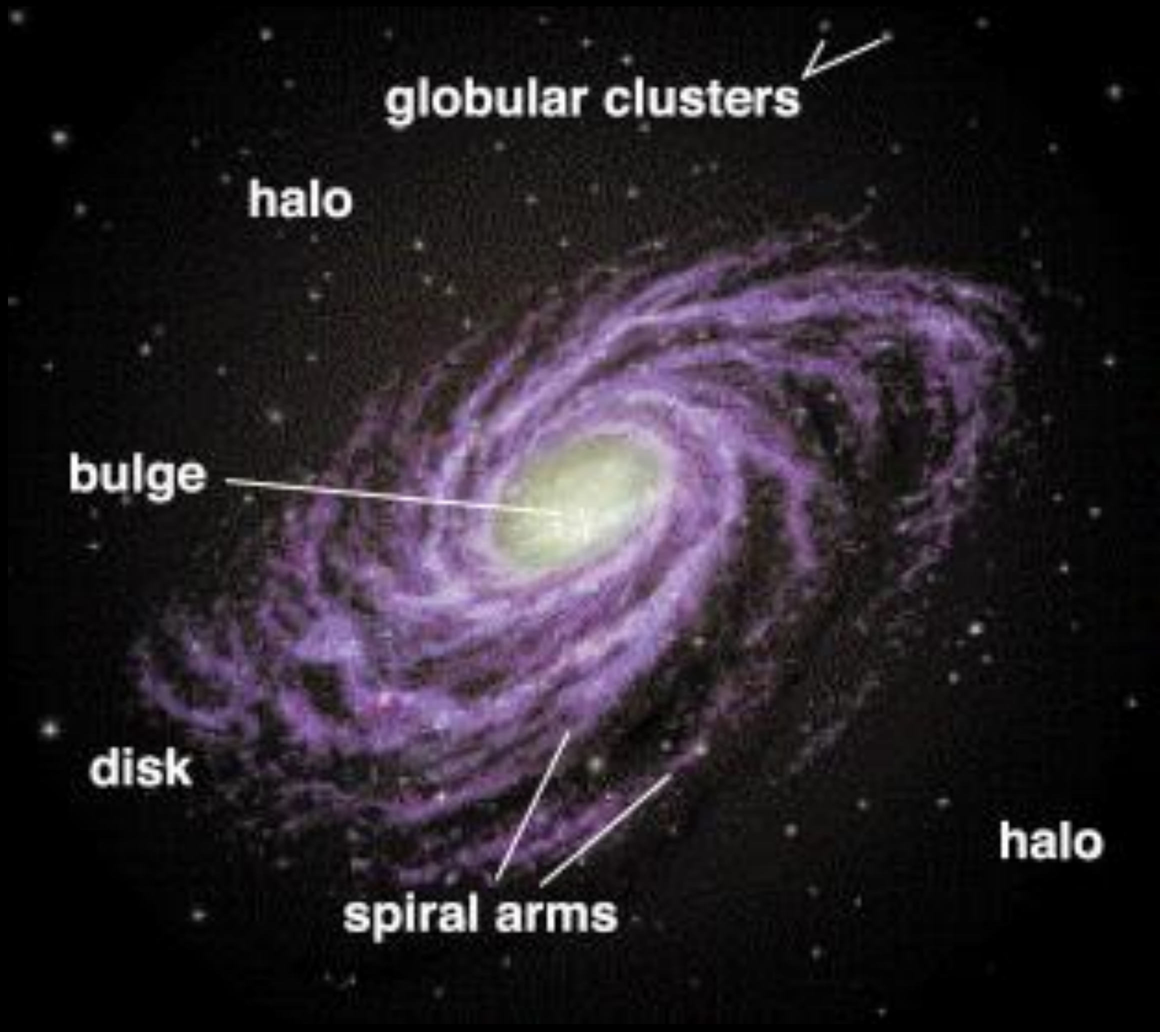
Do you really get what we mean by a solar system?

Taken from CNN.com article, April 25, 2007 on the discovery of an extra-solar planet of nearly Earth mass:

There's still a lot that is unknown about the new planet, which could be deemed inhospitable to life once more is learned about it. ***But as galaxies go, it's practically a neighbor****. At only 120 trillion miles away, the red dwarf star that this planet circles is one of the 100 closest to Earth.*

Our Milky Way Galaxy

- Above average size Spiral Galaxy
- Approximately 100 billion stars



Think
Pair
Share!

Which of the following correctly list characteristics of terrestrial planets?

A. Cratered and gaseous surfaces, few moons, large
B. Solid surface, rings, many moons, small
C. Gaseous surface, rings, many moons, large
D. Cratered and solid surface, few moons, small
E. Solid surface, few moons, rings, small