Exoplanet Exploration

Week 6

What are exoplanets?

Exoplanets—or extrasolar planets—are planets found outside our solar system and orbiting stars other than the Sun

Questions to consider:

- Why look for and study exoplanets?
- How do we find and characterize exoplanets?

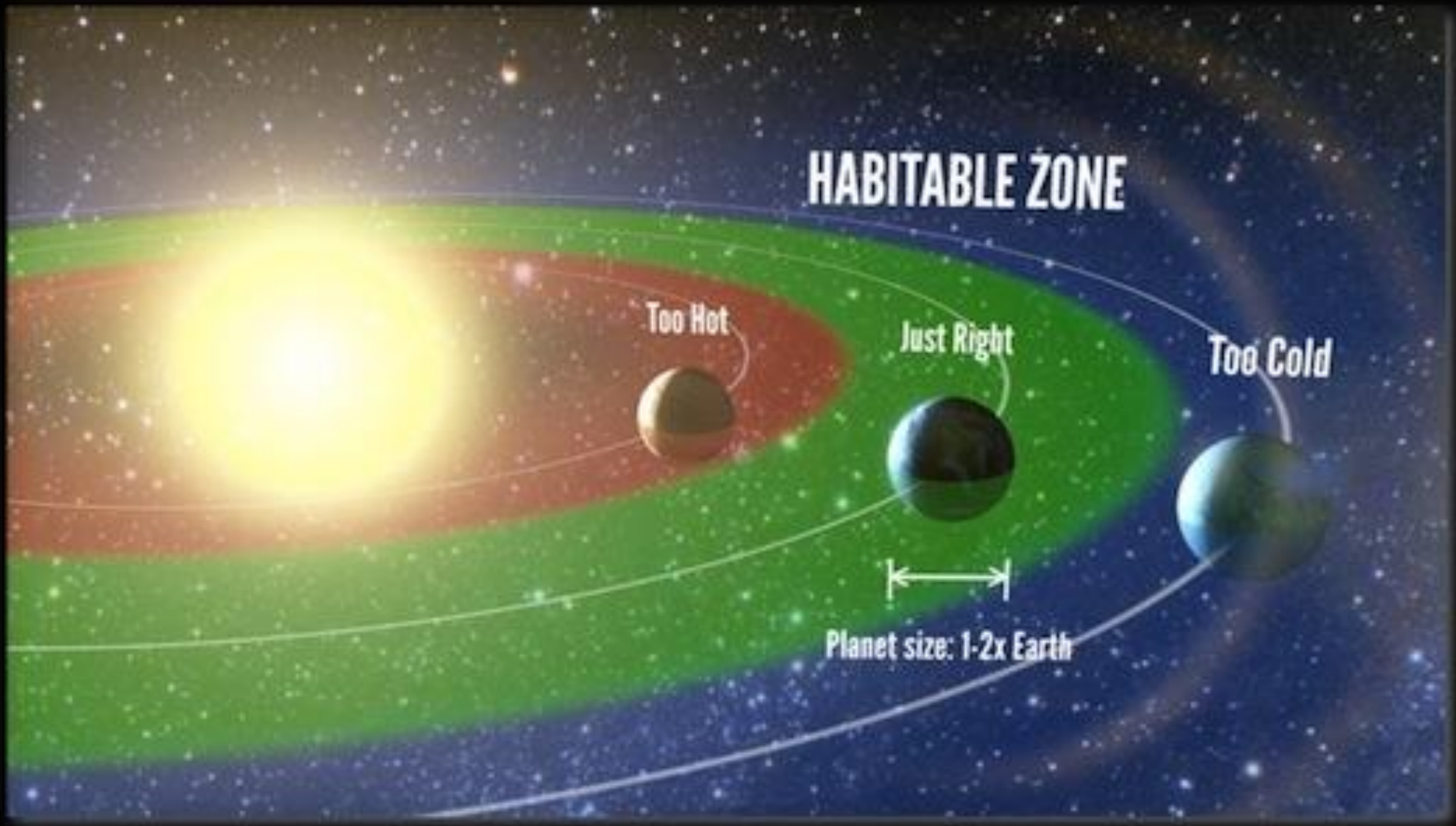
Why study exoplanets?

- Learn more about planet-forming processes
  - Do planets commonly form as stars form?
  - How common are planets and what are their characteristics?
  - Is our solar system usual or unique?

- Search for extraterrestrial life
  - Are there other Earths out there?
  - How common are Earth-like planets and where are they?

- Search for other intelligent life
  - Where might we find intelligent aliens?
  - Do Tatooine and Romulus really exist?

How



The habitable zone corresponds to the range of orbital distances where liquid water can exist on a planet's surface.

How do we explore for exoplanets?

1. Direct imaging of exoplanets
2. Radial velocity monitoring
3. Transit measurements
4. Gravitational microlensing

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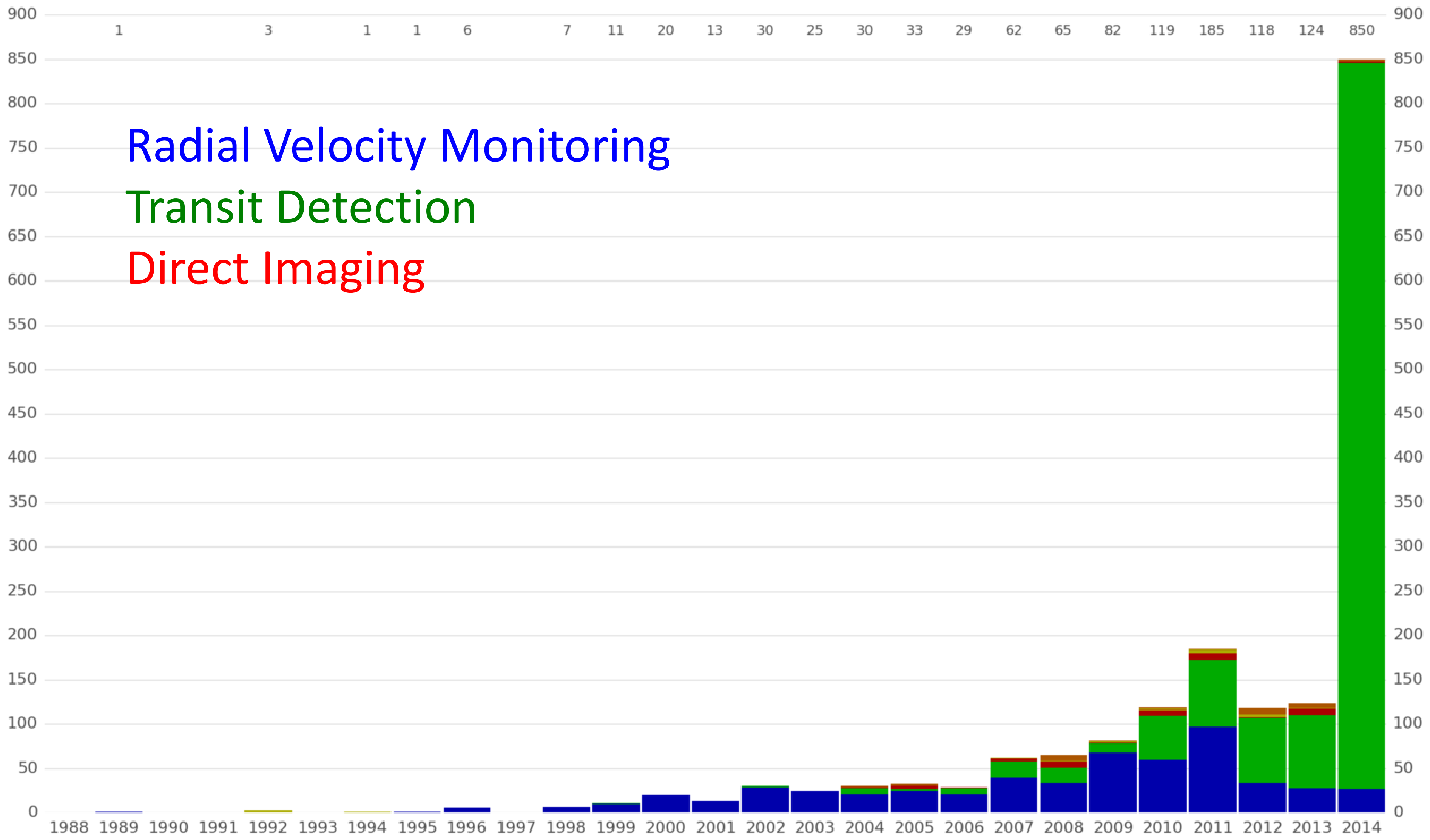
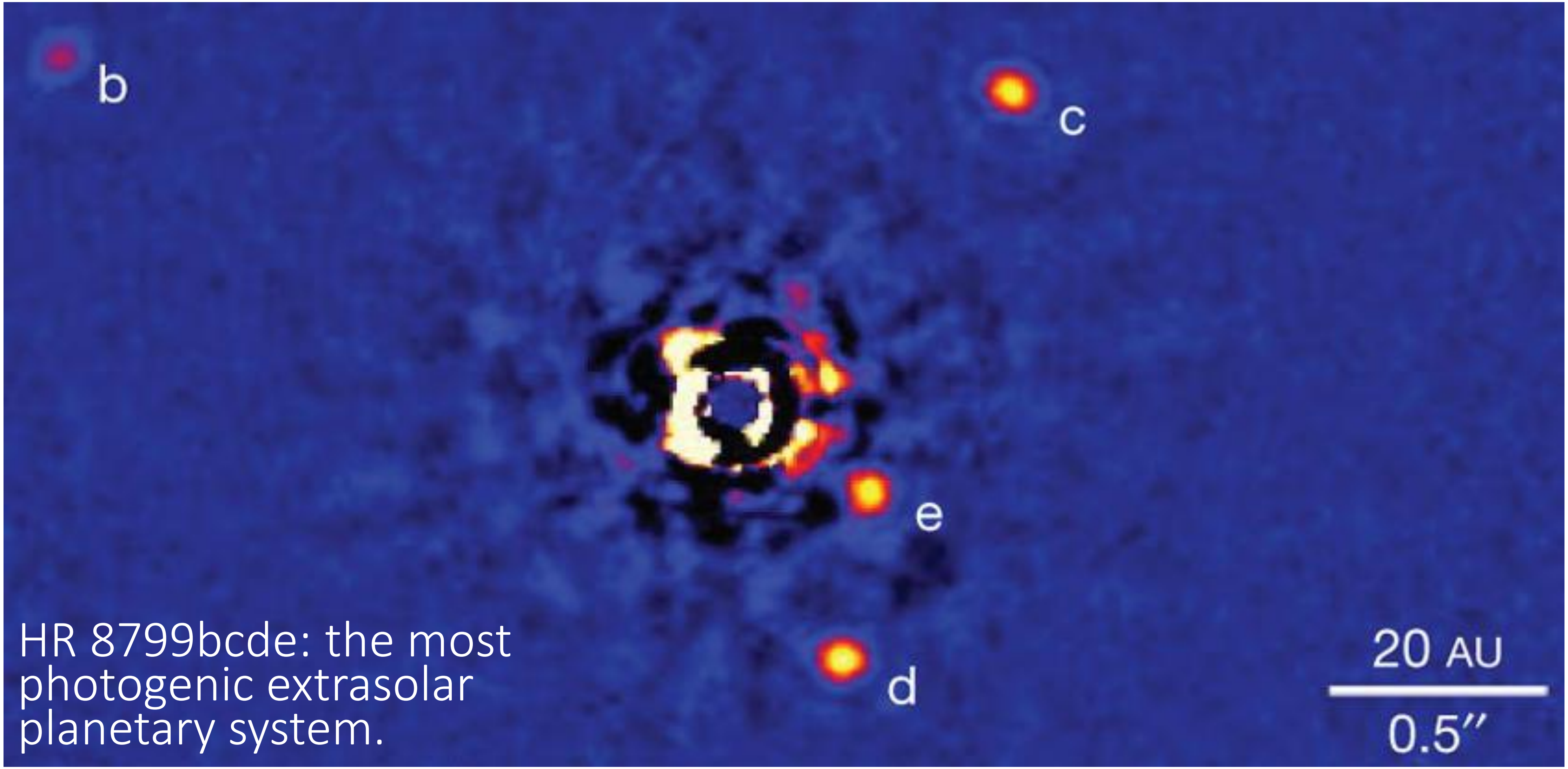
1. Direct imaging of exoplanets
2. **Radial velocity monitoring**
3. **Transit measurements**
4. Gravitational microlensing

We will concentrate on these!

The Kepler Mission: greatly expanding our census of exoplanets!



Direct imaging



HR 8799bcde: the most photogenic extrasolar planetary system.

Radial velocity monitoring

- *Measure planets indirectly by measuring the stars they orbit*
- How do planets affect their starts?
- Orbit simulator:
  http://save-point.herokuapp.com/orbits/?mission=gravitykit&

Both planet and star orbit around the common center of mass

$$P^2 = \frac{4\pi^2}{GM}a^3$$

Remember combined Kepler+Newton Laws

Valid approximation for $M \approx m_{star}$

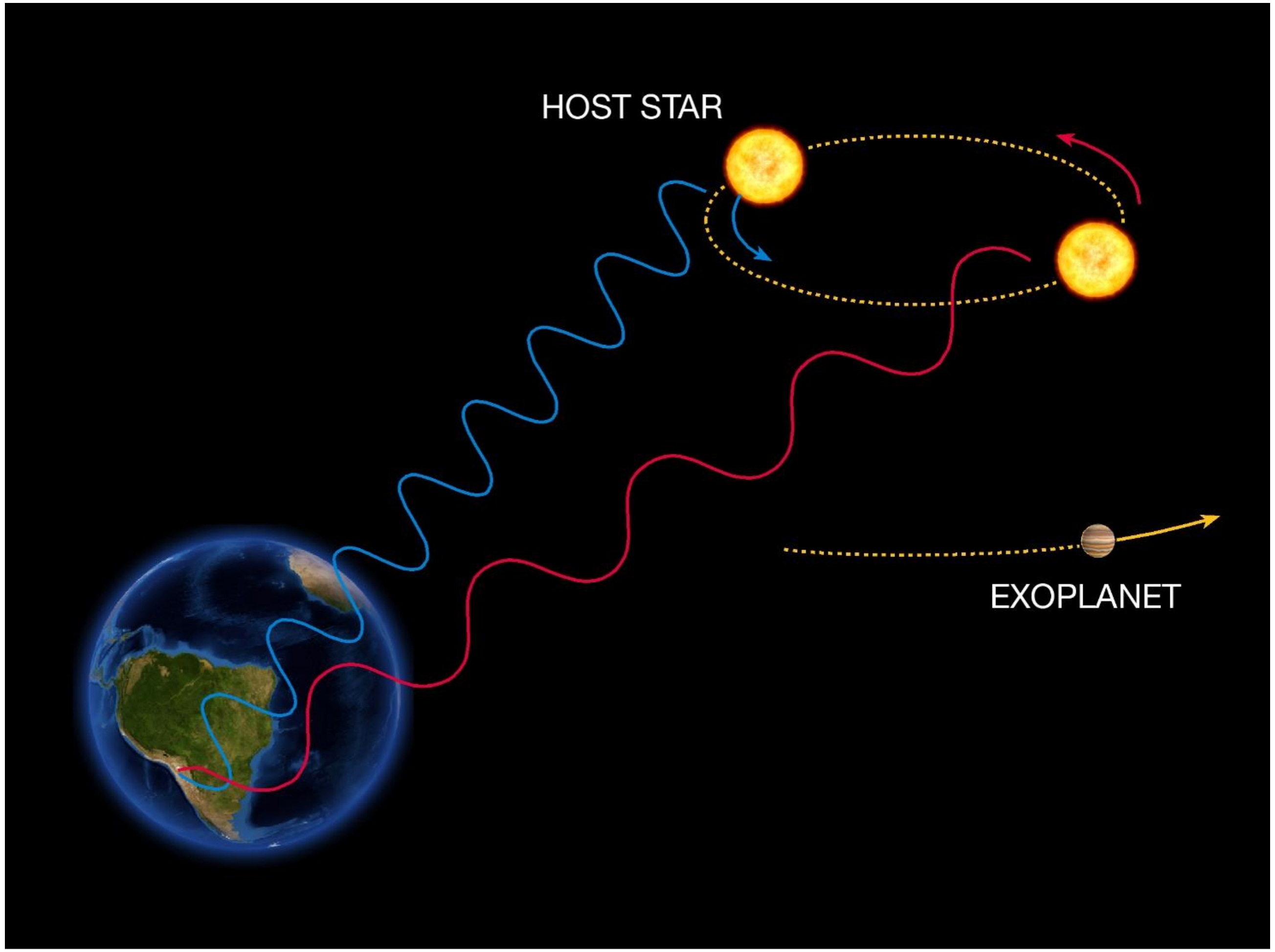
$$P^2 = \frac{4\pi^2}{G m_{star} m_{planet}} a^3$$

Radial velocity monitoring

- *Measure planets indirectly by measuring the stars they orbit*

- Because the star revolves around a point, we can measure the effect on the star even though we cannot see the planet

- HOW?
- Using Doppler Shift!



The Radial Velocity Method

ESO Press Photo 22e/07 (25 April 2007)

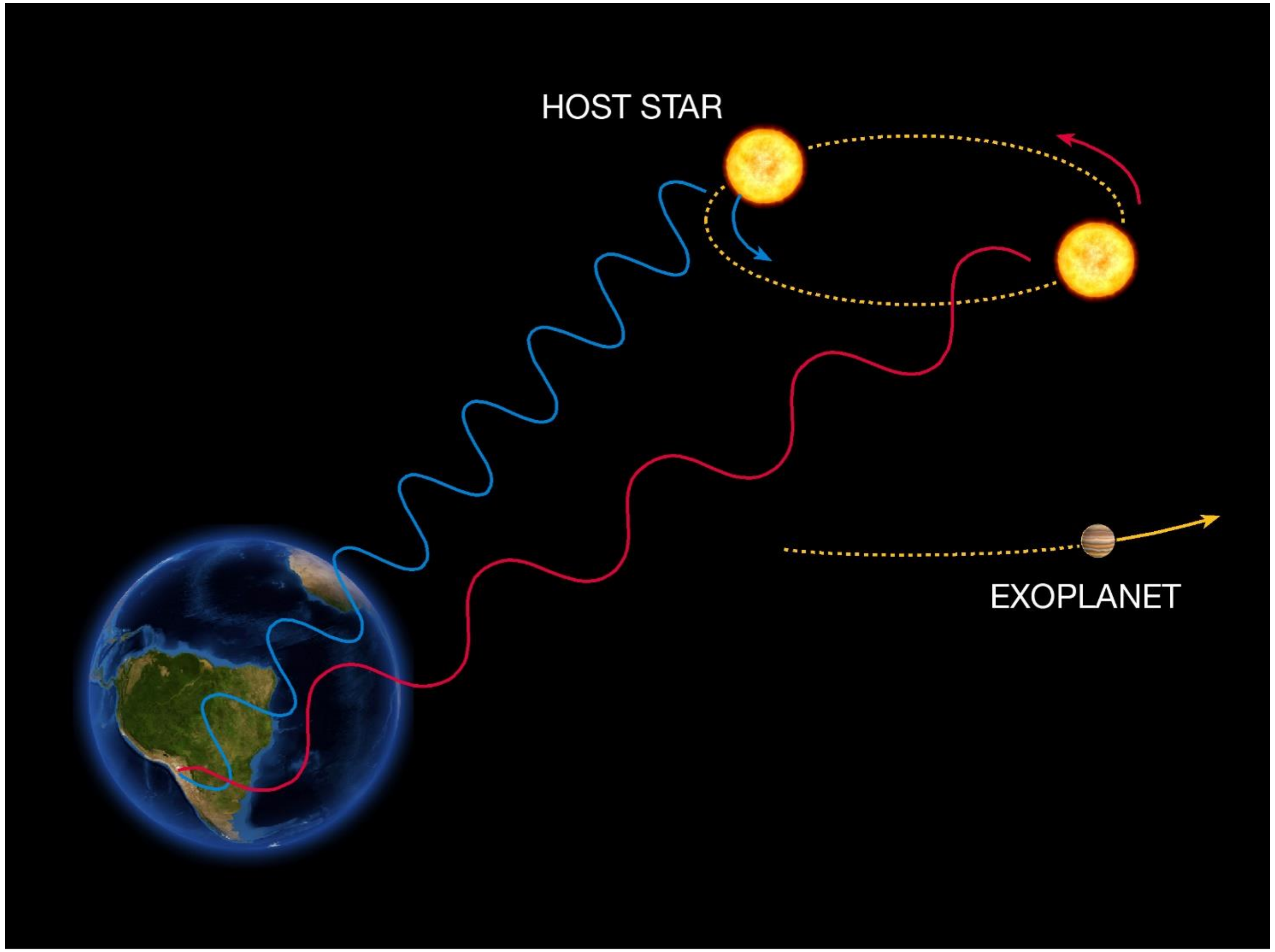
Radial velocity monitoring

- *Measure planets <u>indirectly</u> by measuring the stars they orbit*

Doppler Shift!

http://astro.unl.edu/classaction/animations/light/dopplershift.html

- Light shifted to **blue** wavelengths as star moves toward us
- Light shifted to **red** wavelengths as star moves away from us



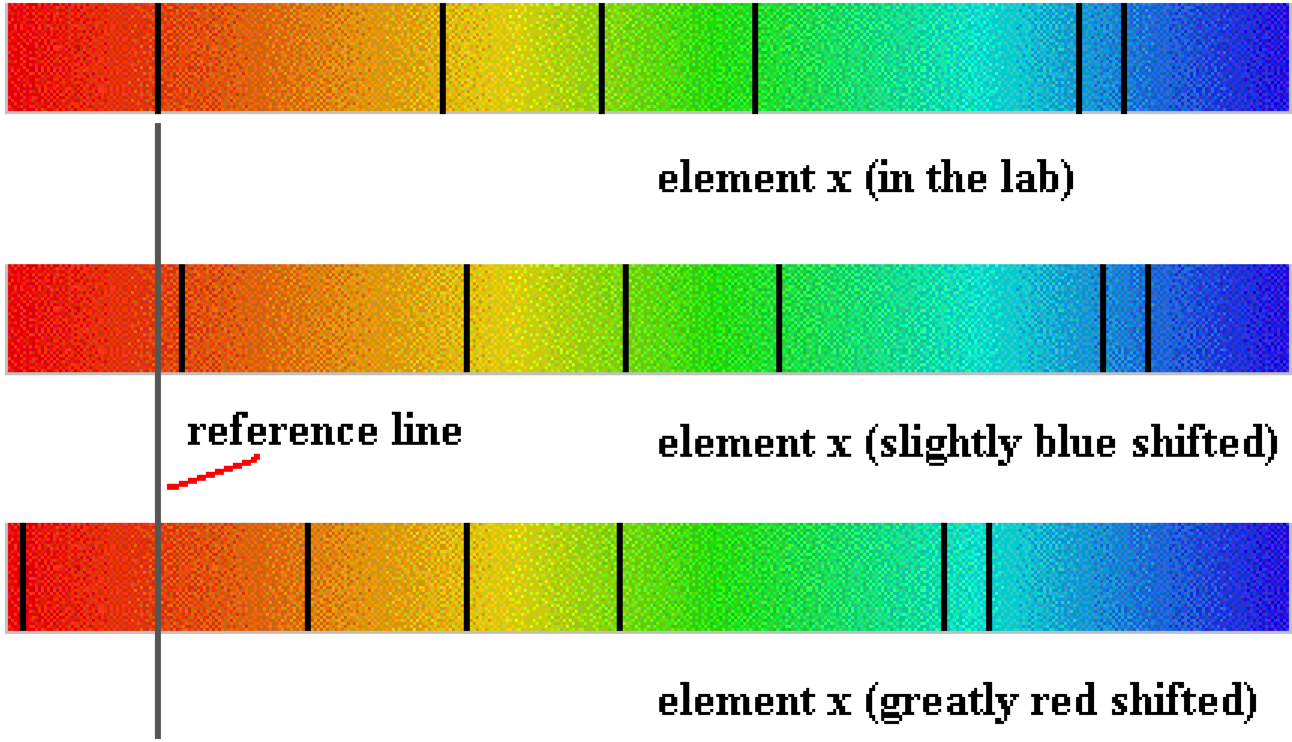
The Radial Velocity Method

ESO Press Photo 22e/07 (25 April 2007)

Radial velocity monitoring

https://youtu.be/d4CnneMrcmY

- *Measure planets <u>indirectly</u> by measuring the stars they orbit*



How do we observe Doppler Shift?

- *Element lines shifted in absorption spectra toward red or toward blue*

- *Requires very precise, high-resolution spectral measurements*
- *Requires repeated observations of the same star*

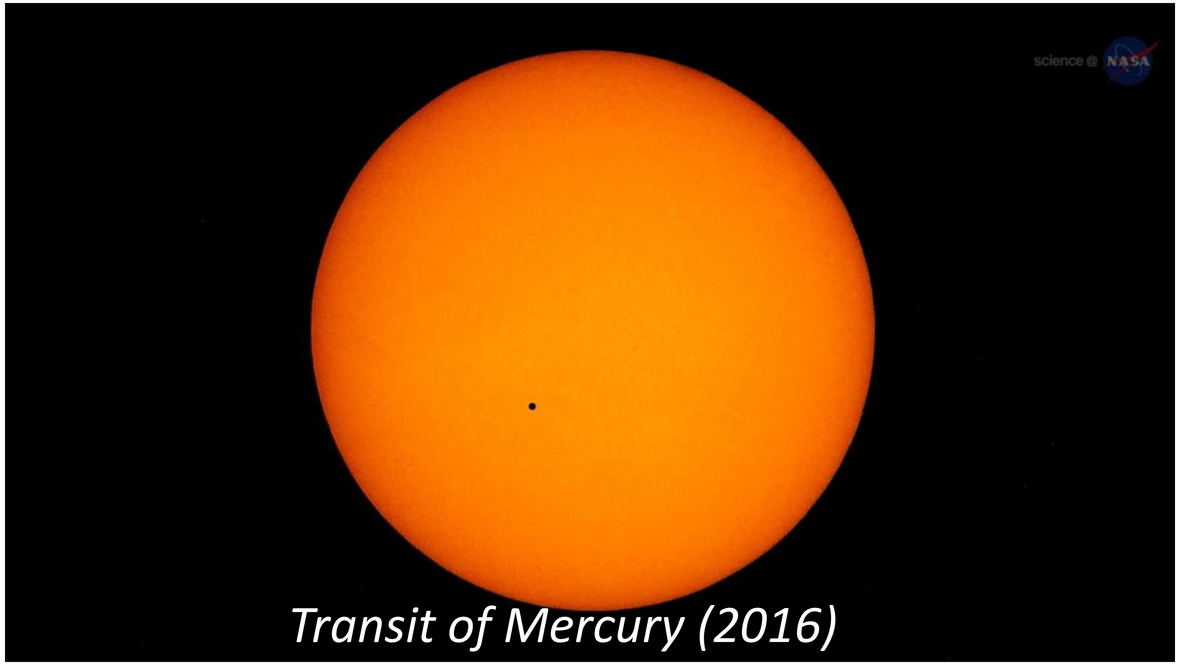
- *Calculate period and mass of planet from the shift*

Transit method

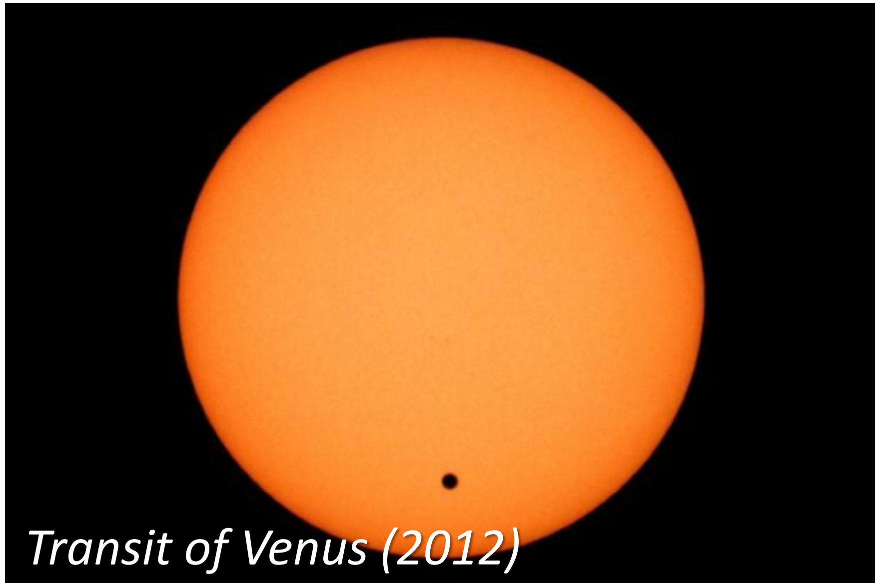
- *Observe planets passing in front of their stars*

How do we observe planet transit?

➢ *Measure the drop in the amount of light coming from the star*

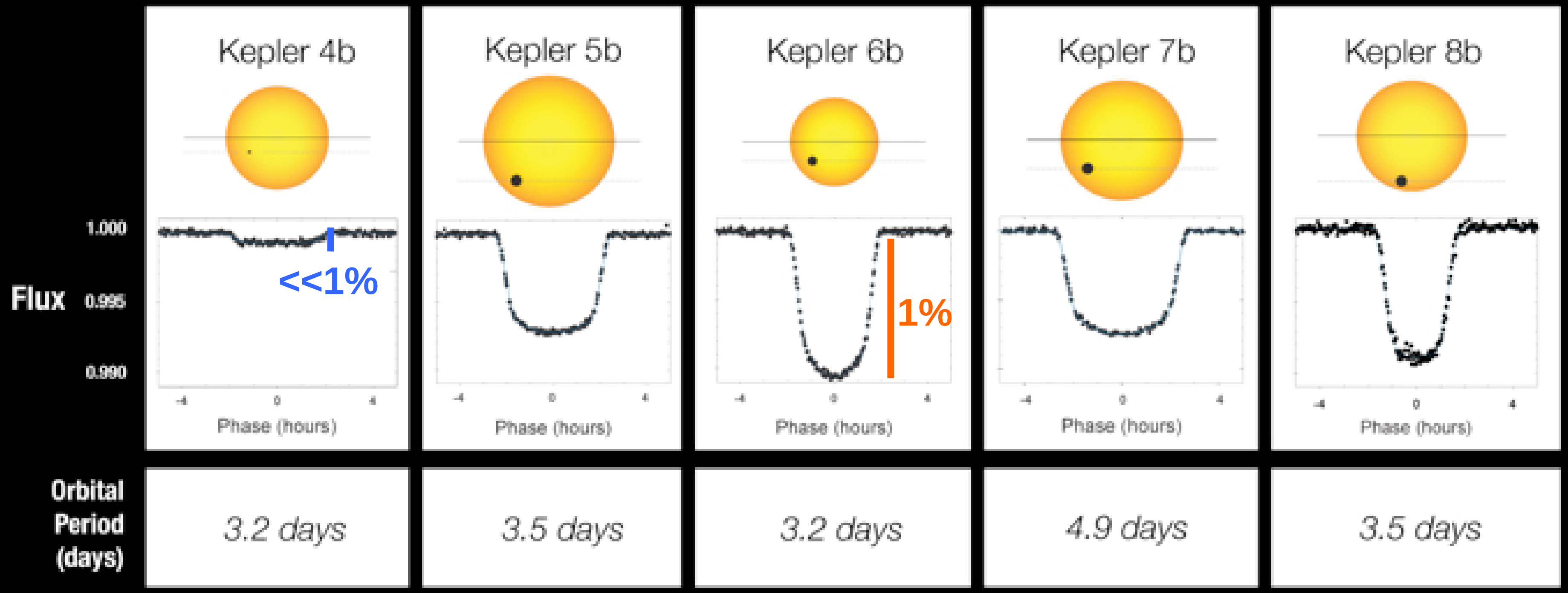


Transit of Mercury (2016)



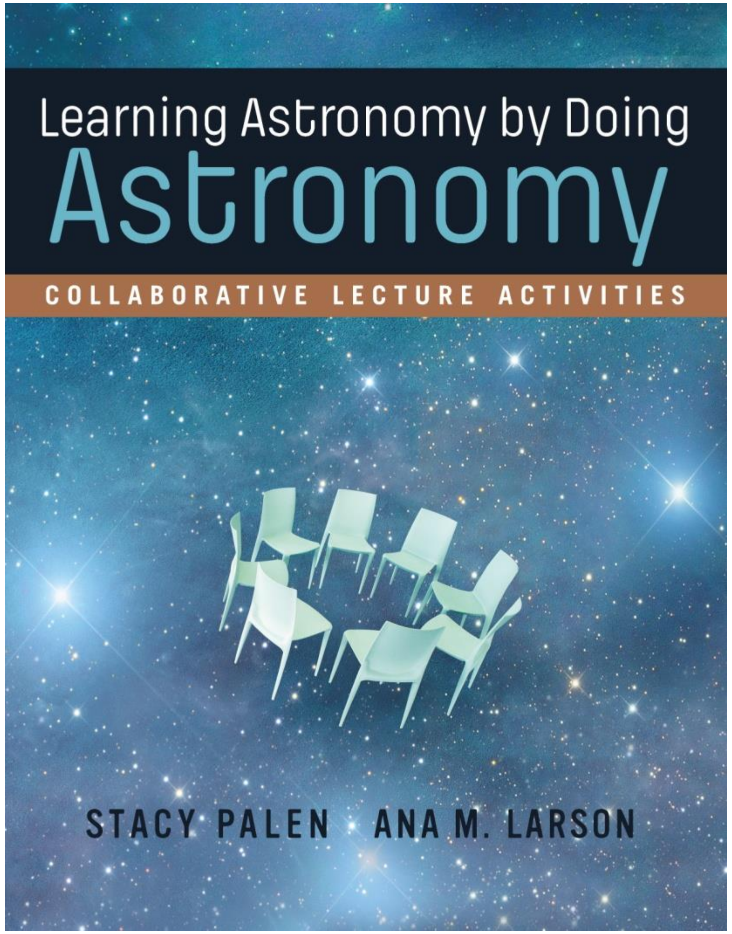
Transit of Venus (2012)

Transit Light Curves

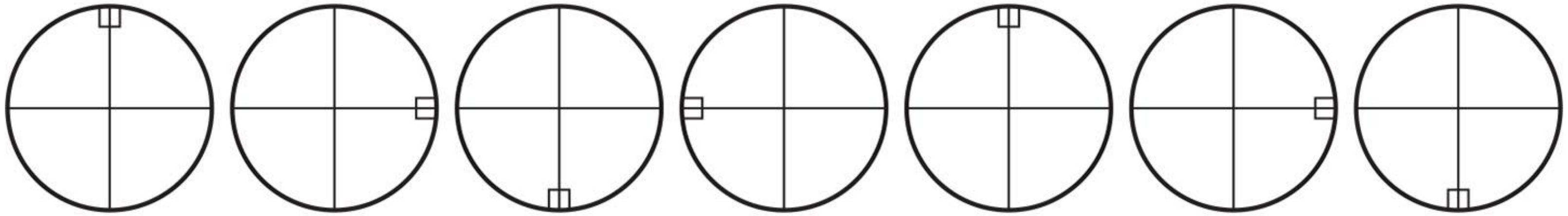


Identifying & measuring transits requires *very* precise measurements of stellar brightness: often significantly better than 0.1%

Activity 10: 51 Pegasi: The Discovery of a New Planet



Pre-10.1: The figure below represents the position of a block on a wheel as it rolls down a hill. How many turns did the block make?



a. 4
b. 7
c. 1.5
d. 3

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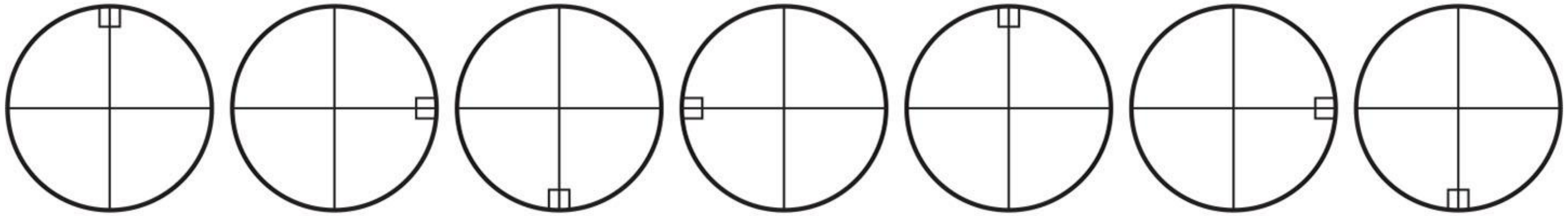

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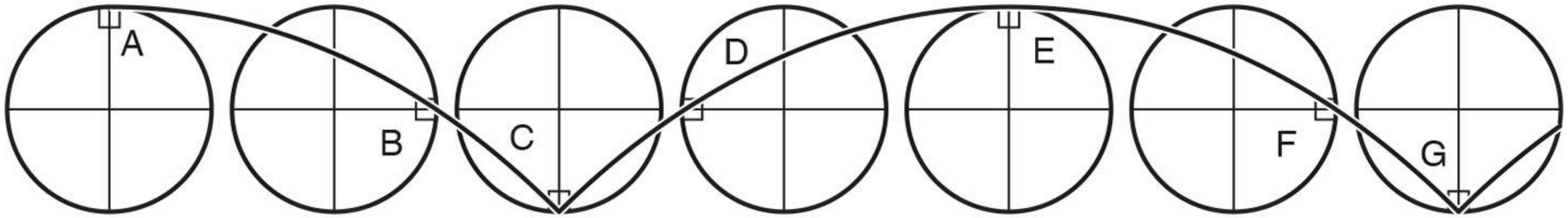
Pre-10.2: The figure below represents a block on a wheel as it rolls down a hill. Which set of letters represents a complete turn?



a. A–E
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c. C–G
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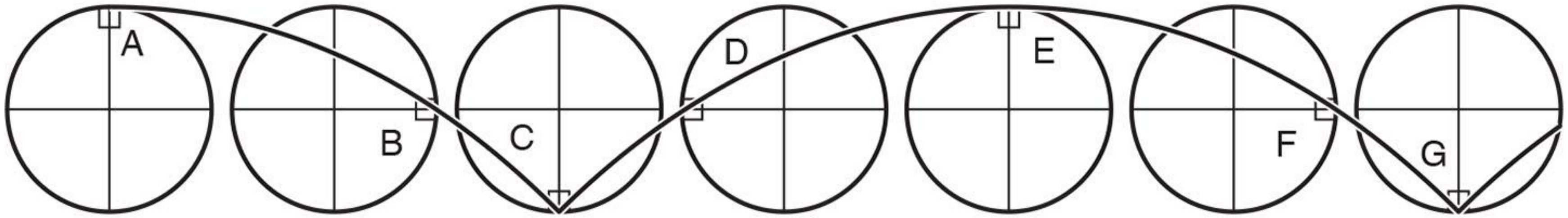

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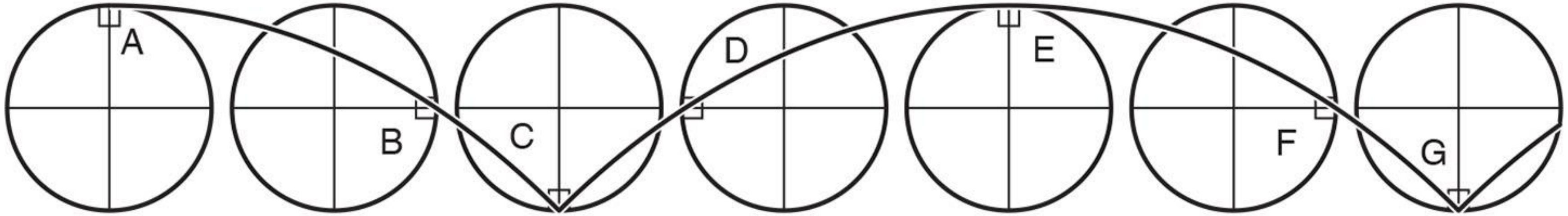
Pre-10.3: If we define a cycle as one complete turn, how many cycles did this wheel go through from its start?



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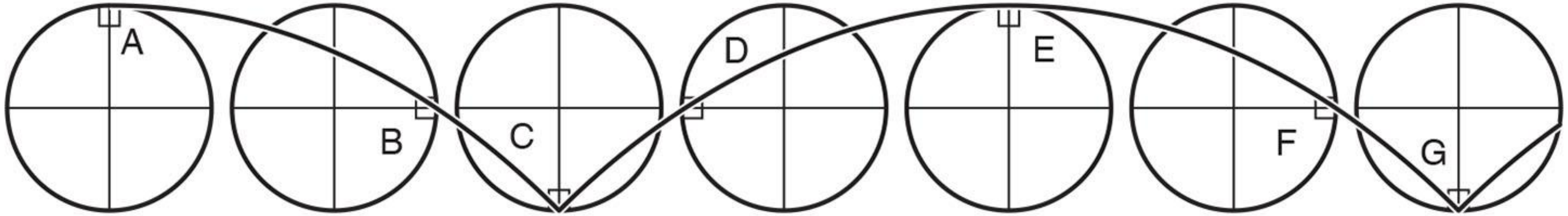

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Pre-10.4: You run an experiment and measure the value to be 10. If the accepted value is 6, what is your percent discrepancy? The formula for calculating percent discrepancy is

$$\text{Percent discrepancy} = \frac{\text{Measured value} - \text{Accepted value}}{\text{Accepted value}} \times 100\%$$

a. 33 percent
b. 54 percent
c. 67 percent
d. 75 percent
e. 90 percent

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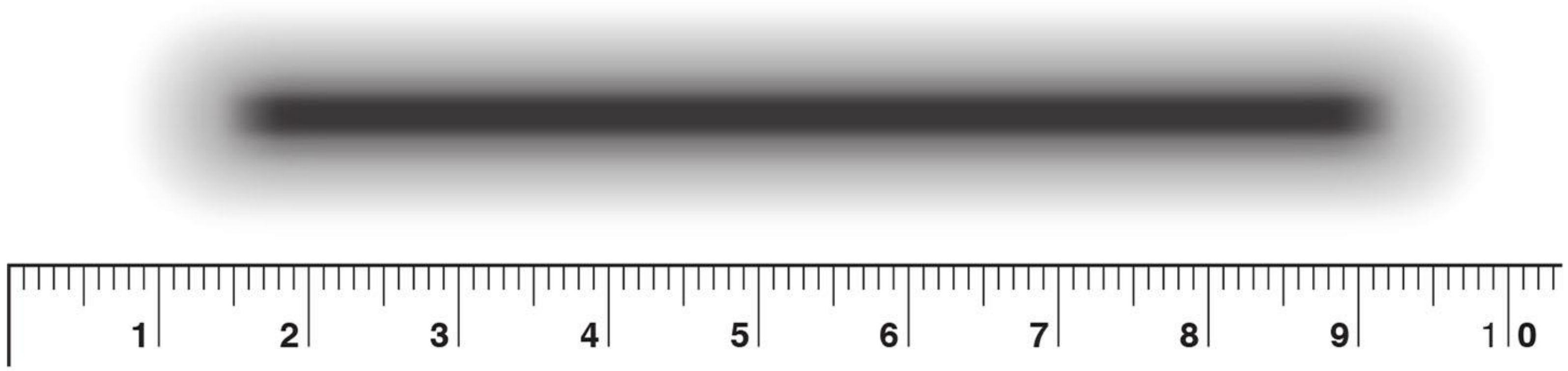
Pre-10.5: Although we may reach higher precision and greater accuracy in our measurements, there will always be an uncertainty attached to our answers. What is the uncertainty in the measurement of the length of the rectangle in the figure below?



a. 10 mm

b. 5 mm

c. 1 mm

d. it depends

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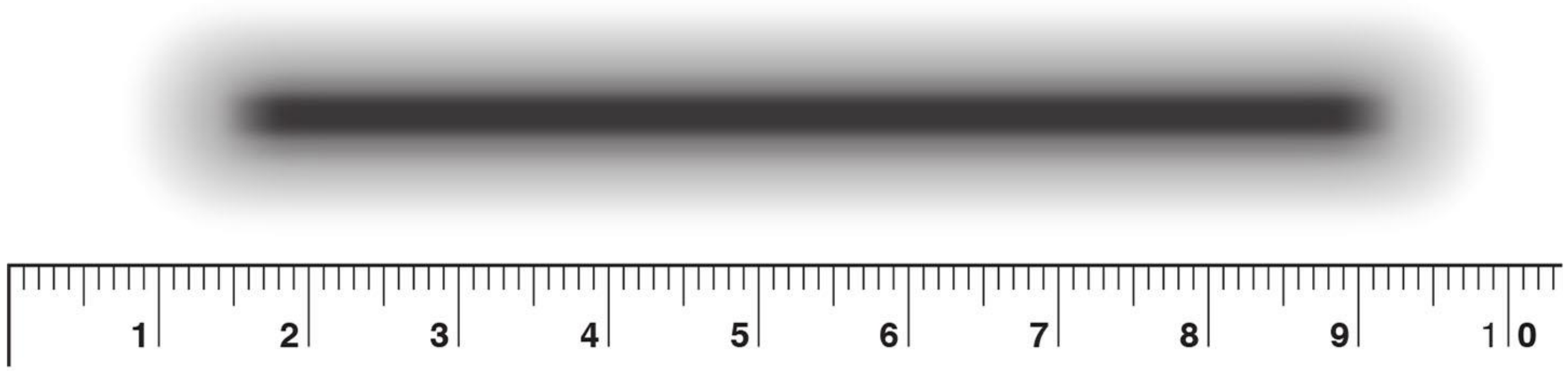

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Activity 10

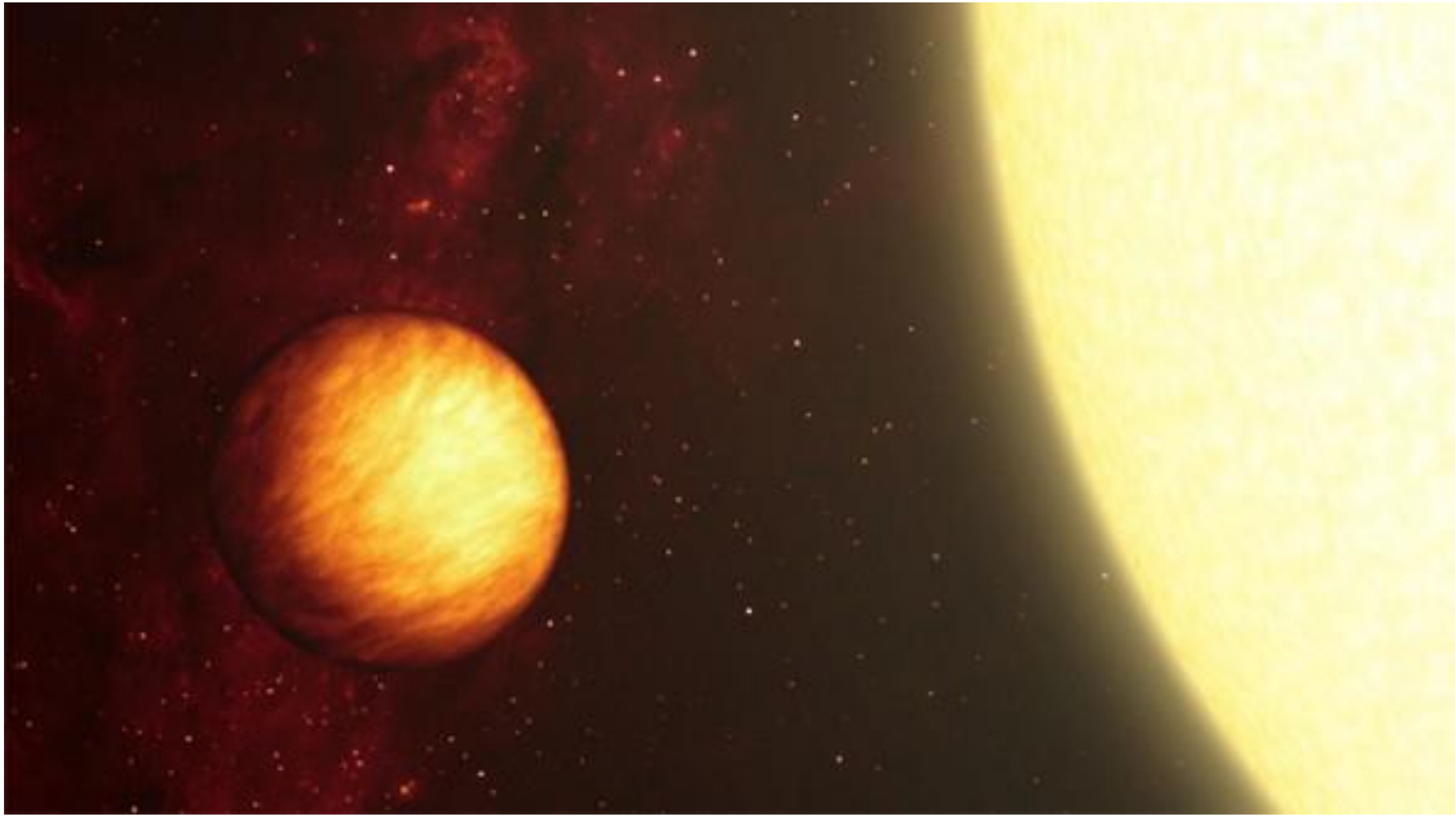
- Complete in your workbooks
- Complete and turn in photocopy of Activity 10 (pages 44-45), one per letter group
- Make sure to include:
  - all group members first and last names
  - Group letter

Activity 10 Questions:

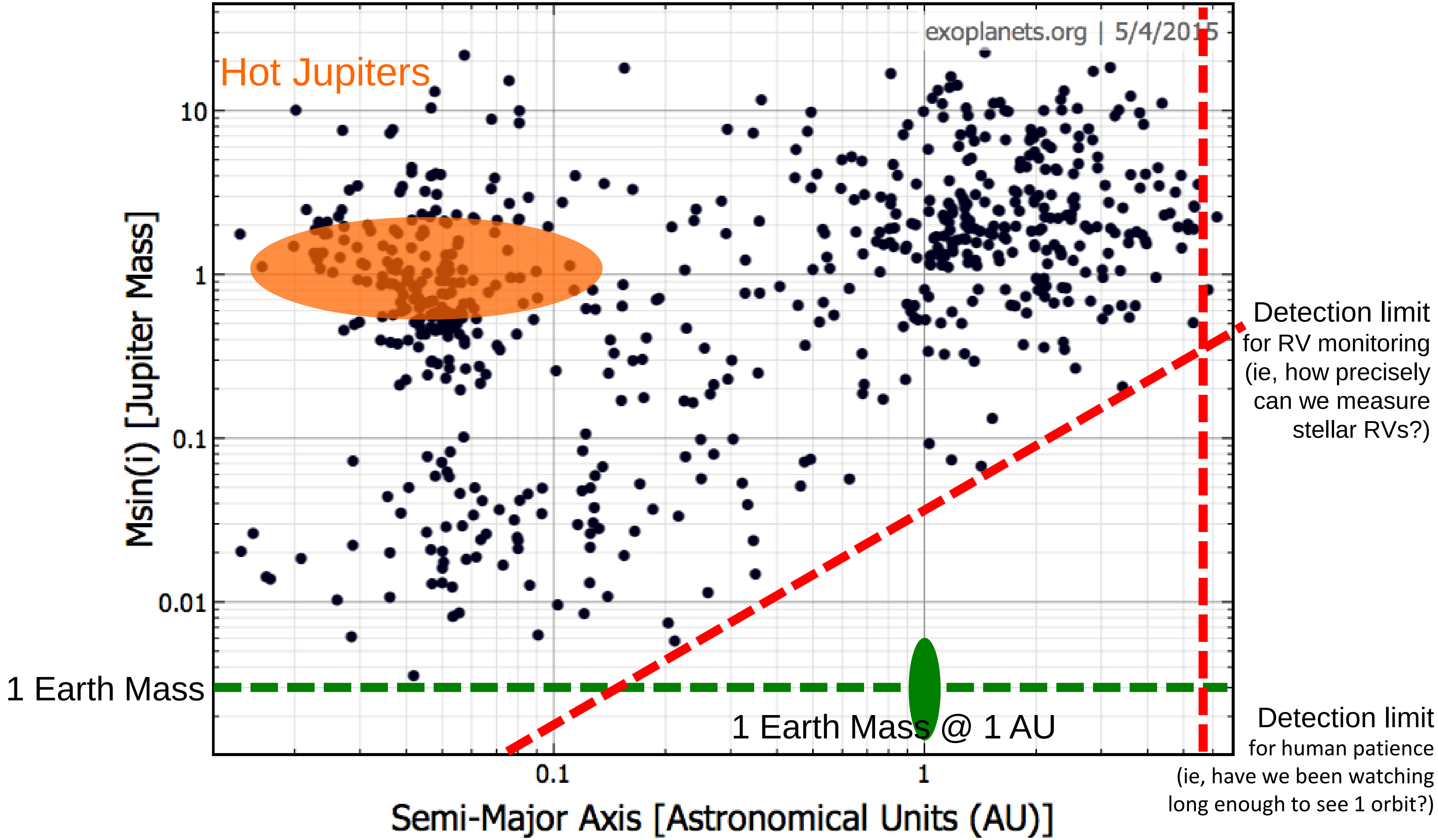
11. Consider the mass of this planet as well as its distance from its star. Why was the discovery such a surprise when compared to our Solar System?

12. If this actually is a planet, is it hospitable to life?

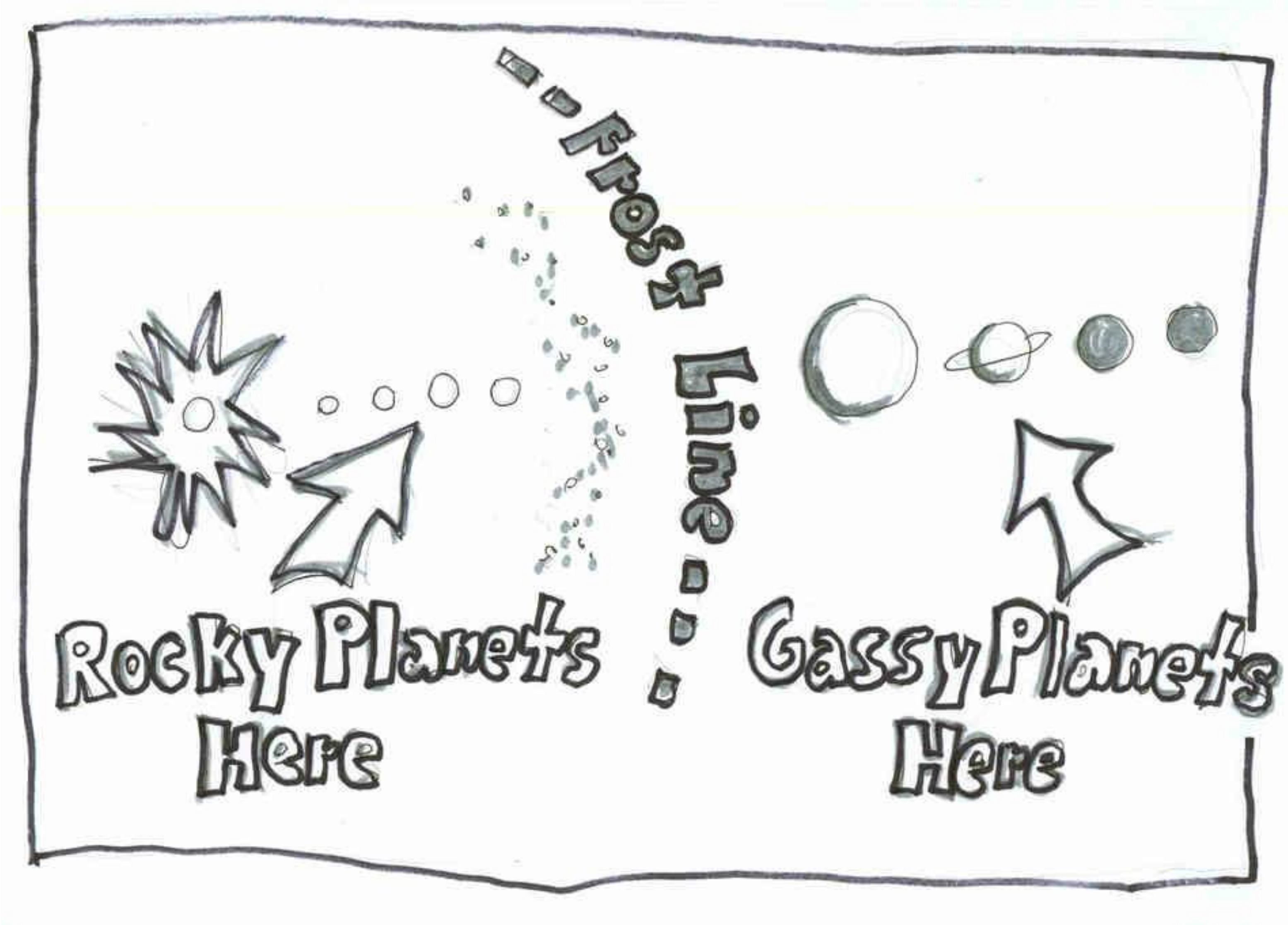
Hot Jupiters: very massive planets, very close to their host stars.



Some of the first planets we found were some of the most unexpected: Hot Jupiters.



Hot Jupiters broke our old models of solar system formation (which were designed to explain the only solar system we knew about: ours).



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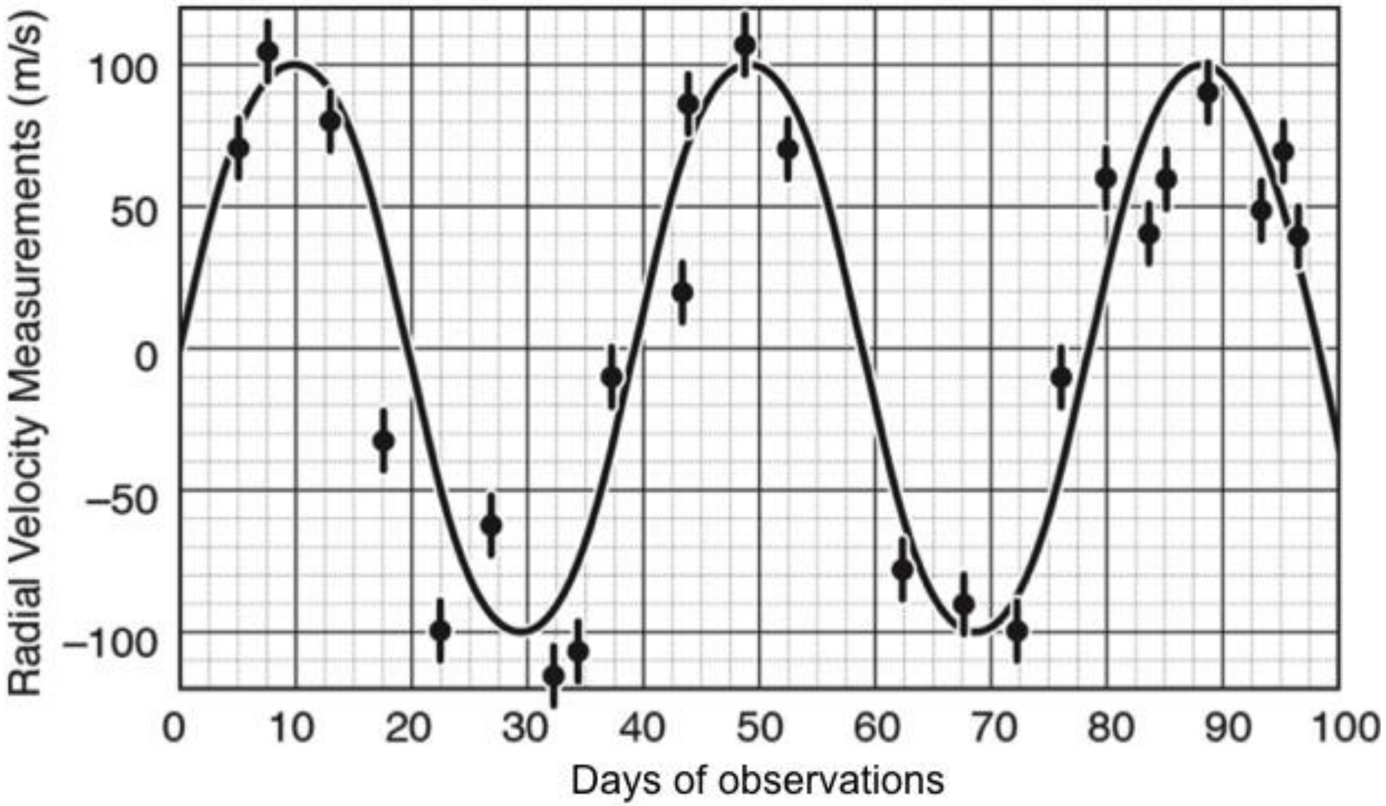
Hot Jupiters show us that while rocky & gas giant planets probably form in different zones of the young solar system, they don't have to stay there: planets move around early in a solar system's life.

Post-10.1: Here is a plot of the radial velocities versus time for a possible extrasolar planet. What is the approximate period of this planet (in days)?



a. 38 b. 18 c. 100 d. 0.35 light-years

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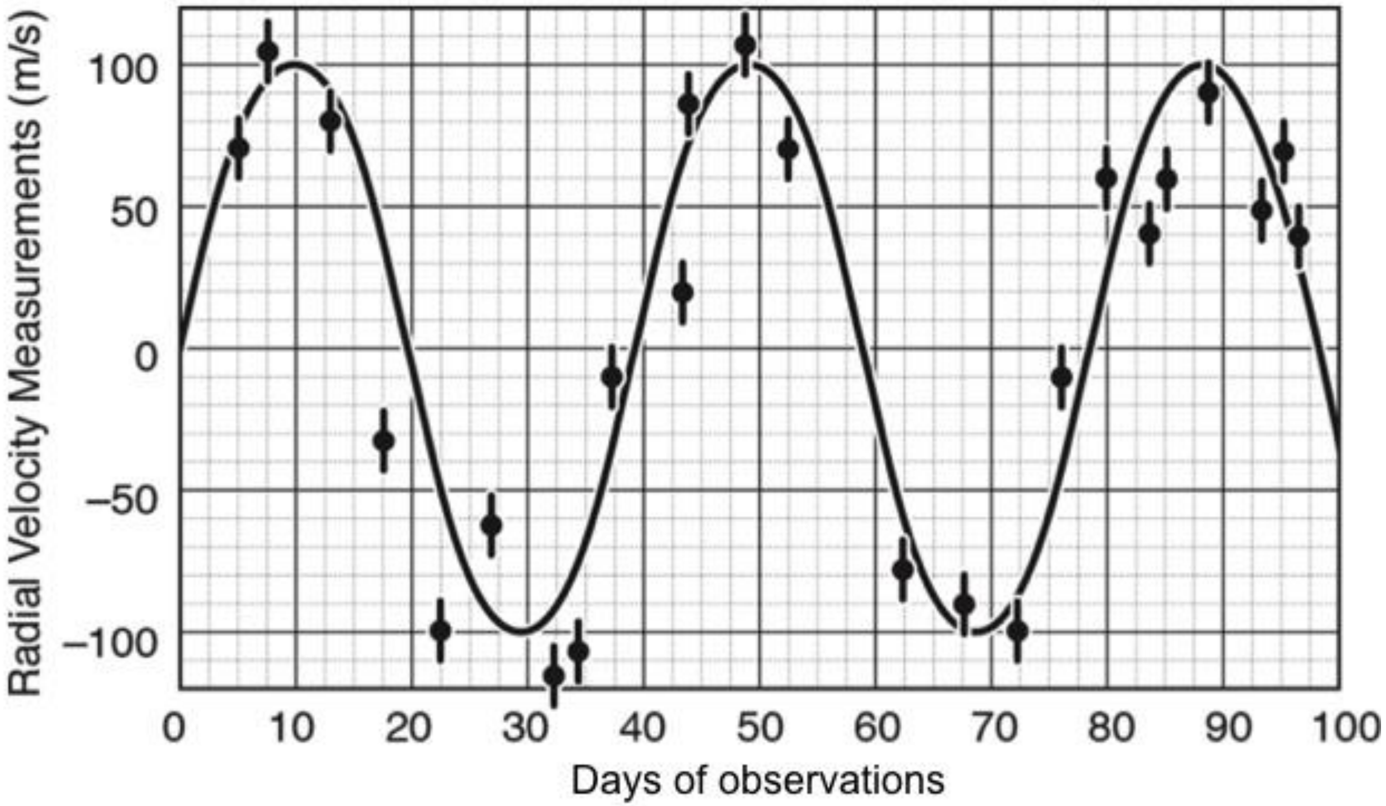

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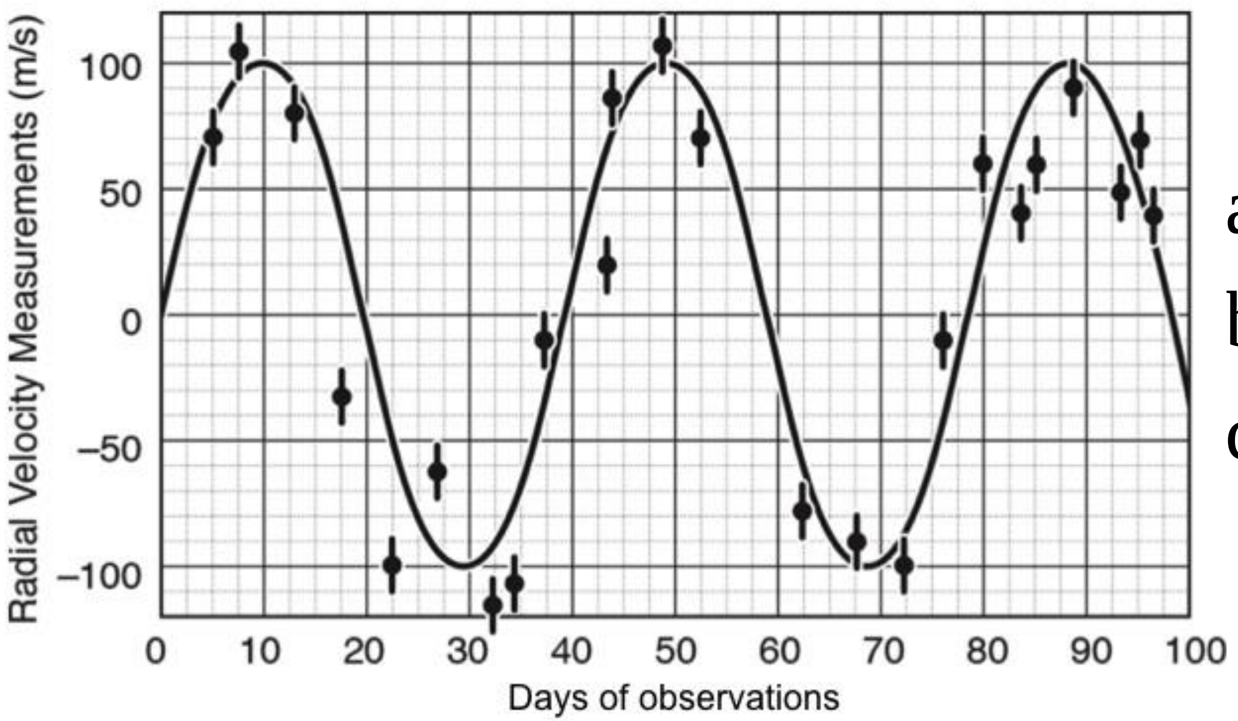
Post-10.2: The vertical lines associated with each data point represent the uncertainties in the measurement. What is this approximate uncertainty?



a. ±20 m/s
b. ±40 m/s
c. ±10 m/s

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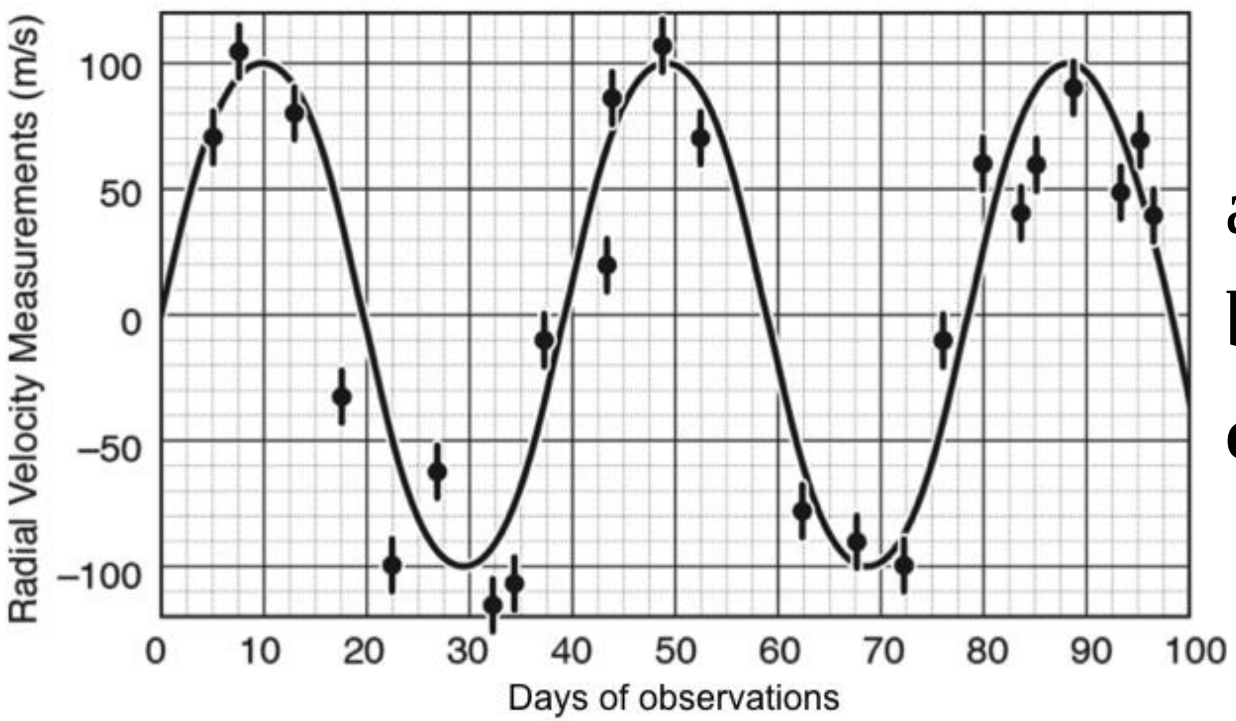

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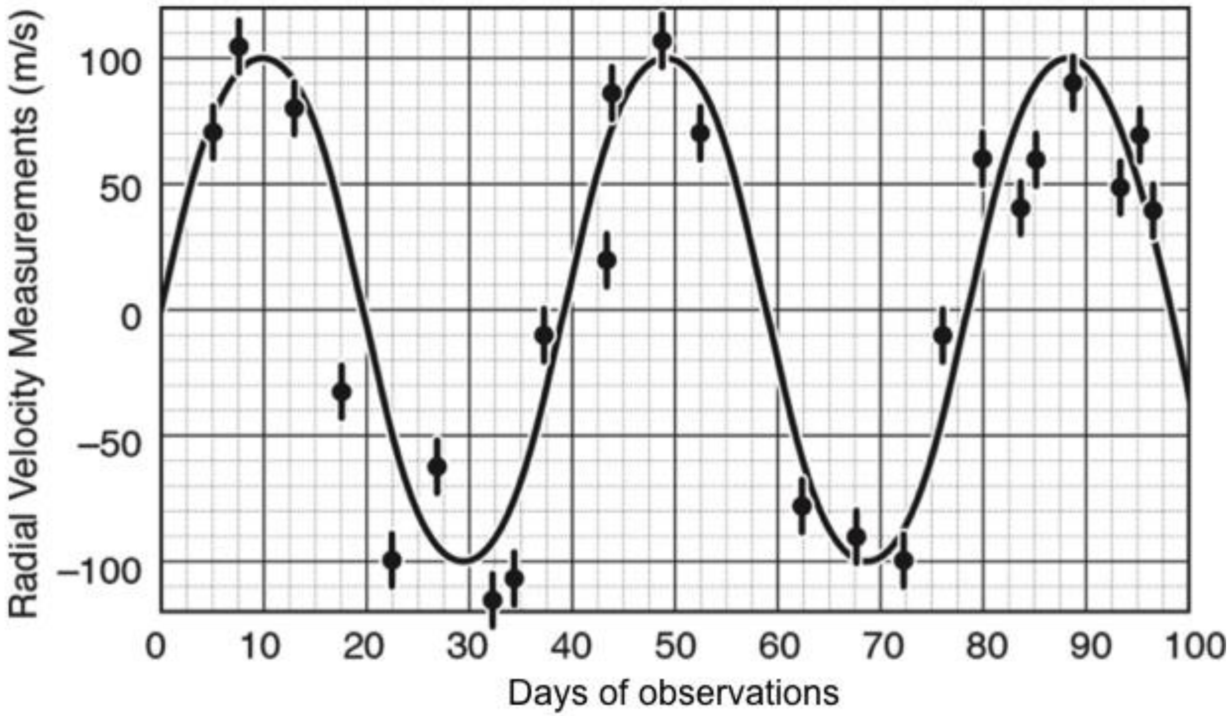
Post-10.3: What is the amplitude, *K*, for this orbit?



a. 200 m/s
b. 100 m/s
c. 110 m/s

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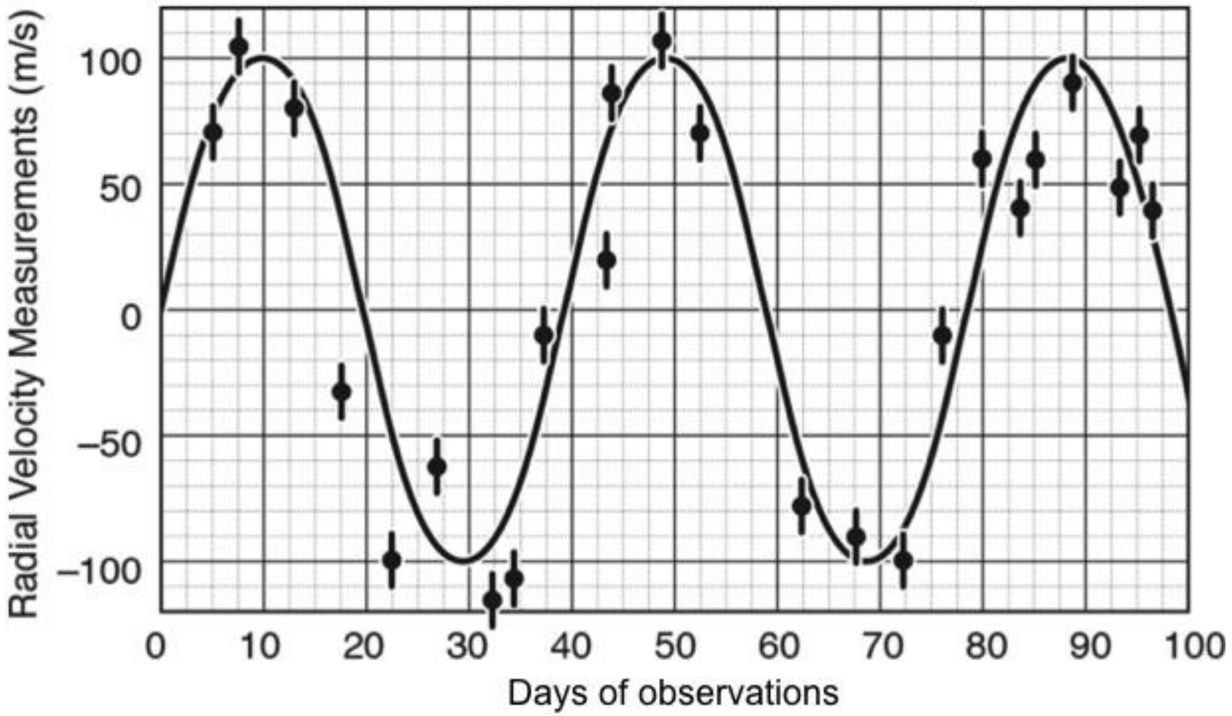

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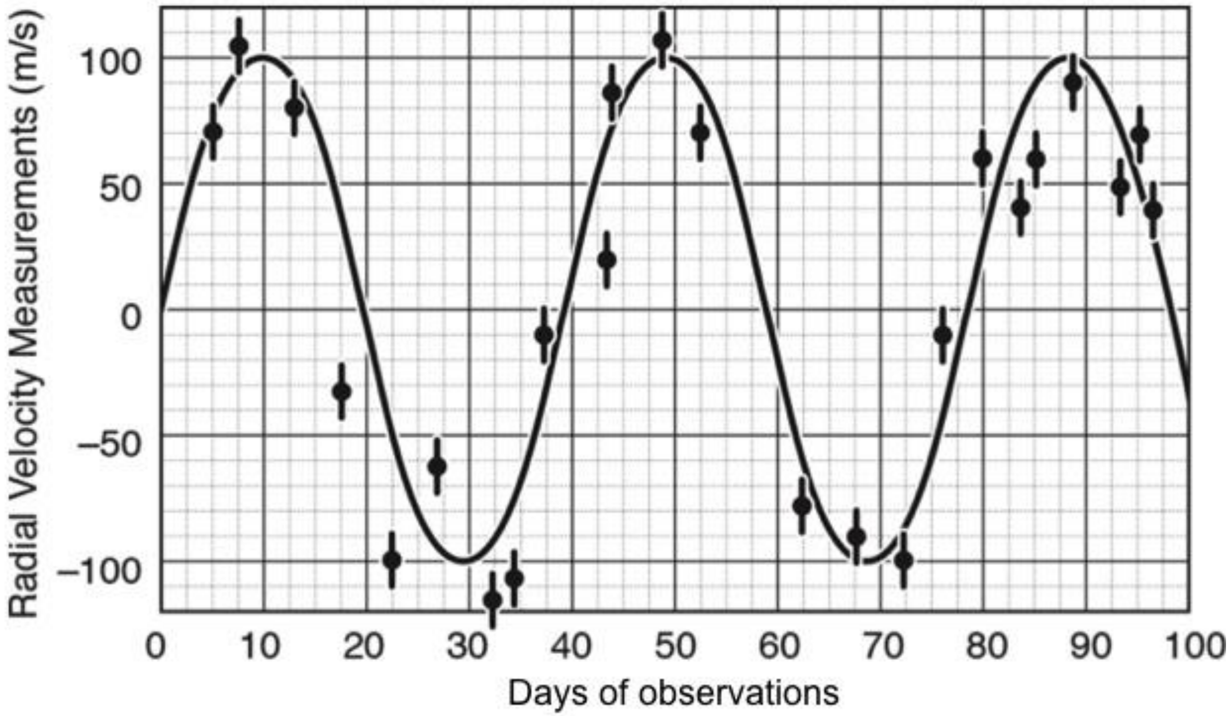
Post-10.4: The planet orbiting the star 51 Pegasi is about 0.05 AU away from its star and has an orbital period of ~4.4 days. How does the distance of this exoplanet from its star compare?



a. closer
b. about the same
c. farther

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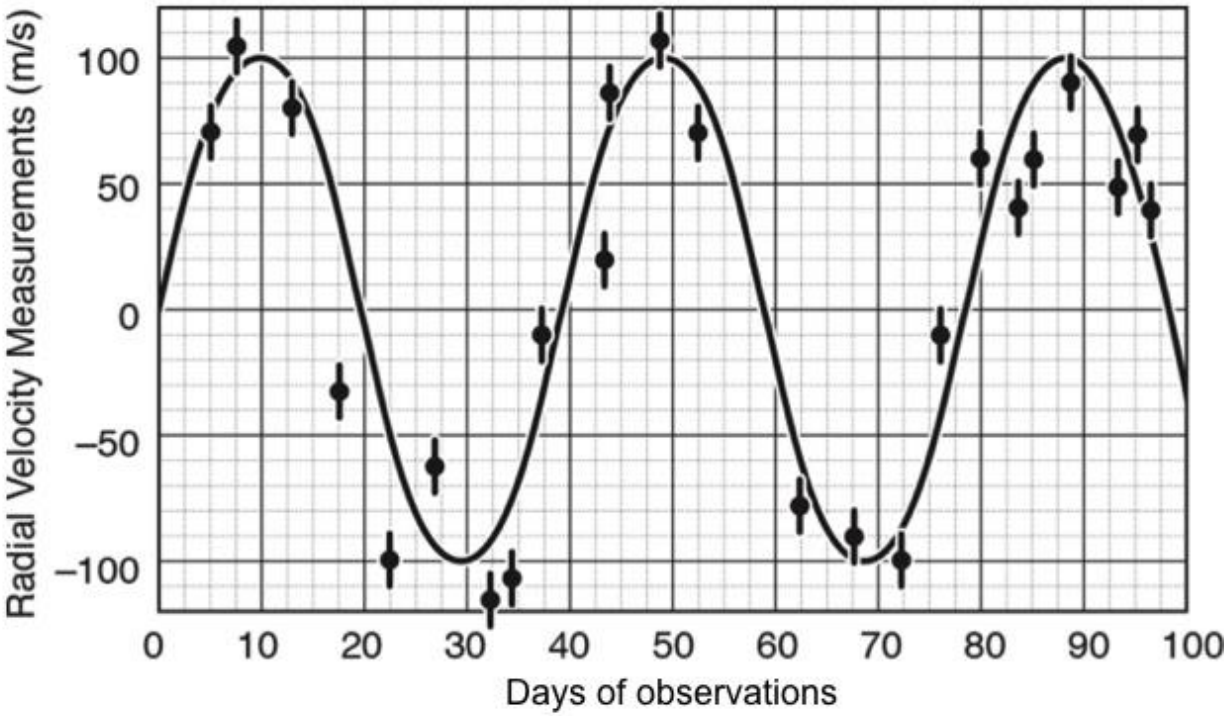

a. closer
b. about the same
c. **farther**

Post-10.5: The orbital period of this exoplanet is 38 days; the amplitude, *K*, is 100 m/s. The orbital period of the 51 Pegasi planet is ~4.4 days; the amplitude, K, is 60 m/s. If the two central stars are very similar in mass, how do the masses of the planets compare? The equation we use is:

$$\frac{M_{\text{planet}}}{M_{\text{Jupiter}}} = \left(\frac{P}{12}\right)^{1/3} \times \left(\frac{K}{13}\right)$$

a. This planet is more massive than the planet orbiting 51 Pegasi.

b. This planet is less massive than the planet orbiting 51 Pegasi.

c. The two planets are equal in mass.

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