

Extrasolar Planets Lab

Turn in one copy of this lab with each group member's printed name and signature. By signing, you certify that you have actively participated in the exercise and have put forth effort in equal share to your fellow group members.

Printed Name

Signature

Part 1: Radial Velocities

Note: Questions 1-16 refer to the planetary transit simulator.

Select the preset labeled **Option A** and click set. This will configure a system with the following parameters – inclination: 90° , longitude: 0° , star mass: $1.00 M_{\text{sun}}$, planet mass: $1.00 M_{\text{jup}}$, semimajor axis: 1.00 AU, eccentricity: 0 (effectively Jupiter in the Earth's orbit).

1. Describe the radial velocity curve. What is its shape? What is its amplitude? What is the orbital period?

2. Increase the planet mass to $2.0 M_{\text{jup}}$ and note the effect on the system. Now increase the planet mass to $3.0 M_{\text{jup}}$ and note the effect on the system. In general, how does the amplitude of the radial velocity curve change when the mass of the planet is increased? Does the shape change? Explain.

Return the simulator to the values of Option A.

3. Increase the mass of the star to $1.2 M_{\text{sun}}$ and note the effect on the system. Now increase the star mass to $1.4 M_{\text{sun}}$ and note the effect on the system. How is the amplitude of the radial velocity curve affected by increasing the star mass? Why does this happen? Explain.

Return the simulator to the values of Option A.

4. How is the amplitude of the radial velocity curve affected by decreasing the semi-major axis of the planet's orbit? How is the period of the system affected? Explain.

Return the simulator to the values of Option A so that we can explore the effects of system orientation. It is advantageous to check **show multiple views**. Note the appearance of the system in the **earth view** panel for an inclination of 90° .

5. Decrease the inclination to 75° and note the effect on the system. Continue decreasing inclination to 60° and then to 45° . In general, how does decreasing the orbital inclination affect the amplitude and shape of the radial velocity curve? Explain.

6. Assuming that systems with greater amplitude are easier to observe are we more likely to observe a system with an inclination near 0° or 90° . Explain.

Return the simulator to Option A. Note the value of the radial velocity curve amplitude.

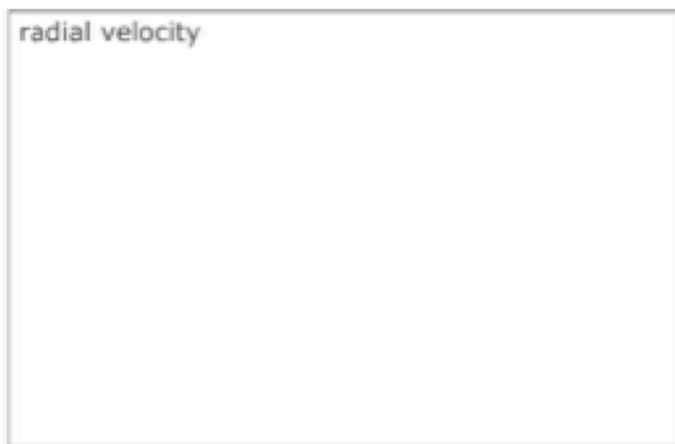
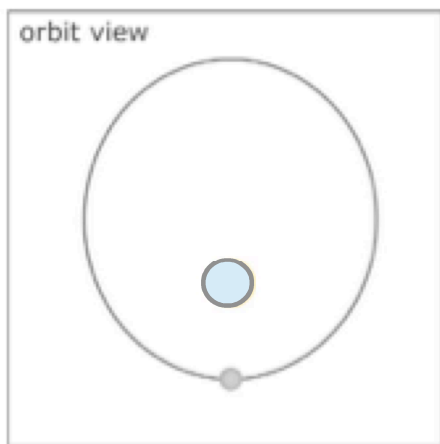
7. Increase the mass of the planet to $2 M_{\text{Jup}}$ and decrease the inclination to 30° . What is the value of the radial velocity curve amplitude? Find at least two different pairs of inclination and mass that give you the same amplitude.

8. Suppose the amplitude of the radial velocity curve is known but the inclination of the system is not. Is there enough information to determine the mass of the planet?

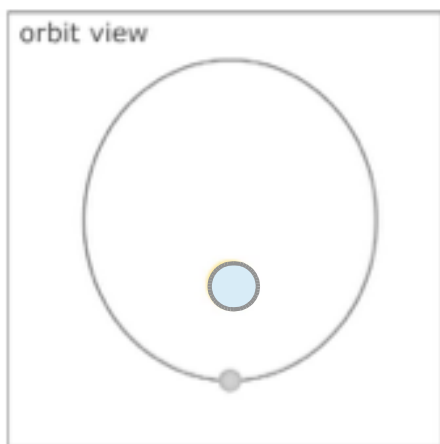
9. Typically astronomers don't know the inclination of an exoplanet system. What can astronomers say about a planet's mass even if the inclination is not known? Explain.

Select the preset labeled Option B and click set. This will configure a system with the following parameters – inclination: 90° , longitude: 0° , star mass: $1.00 M_{\text{sun}}$, planet mass: $1.00 M_{\text{jup}}$, semimajor axis: 1.00 AU, eccentricity: 0.4. Thus, all parameters are identical to the system used earlier except eccentricity.

10. In the orbit view box below indicate the earth viewing direction. Sketch the shape of the radial velocity curve in the box at right.



11. Now set the longitude to 90° . Again indicate the earth's viewing direction and sketch the shape of the radial velocity curve.



12. Does changing the longitude affect the curve in the example above?

13. Describe what the longitude parameter means. Does longitude matter if the orbit is circular?

Part 2: Radial Velocities and Noise

Select the preset labeled Option A and click set once again. Check show simulated measurements, set the noise to 3 m/s, and the number of observations to 50.

14. The best ground-based radial velocity measurements have a noise level of about 3 m/s. Do you believe that the theoretical curve could be determined from the measurements in this case? (Hint: check and uncheck the **show theoretical curve** checkbox and ask yourself whether the curve could reasonably be inferred from the measurements.) Explain.

Select the preset labeled Option C and click set. This preset effectively places the planet Neptune ($0.05 M_{\text{Jup}}$) in the Earth's orbit.

15. Do you believe that the theoretical curve shown could be determined from the observations shown? Explain.

Select the preset labeled Option D and click set. This preset effectively describes the Earth ($0.00315 M_{\text{Jup}}$ at 1.0 AU). Set the noise to 1 m/s.

16. Suppose that the intrinsic noise in a star's Doppler shift signal – the noise that we cannot control by building a better detector – is about 1 m/s. How likely are we to detect a planet like the earth using the radial velocity technique? Explain.

Part 3: Planetary Transits

Note: Questions 17-22 refer to the planetary transit simulator.

Select Option A and click set. This option configures the simulator for Jupiter in a circular orbit of 1 AU with an inclination of 90° . Show the theoretical curve only.

17. Find the phase setting at the bottom right. Slowly slide it all the way from left to right. Repeat while watching the plot of flux and then the diagram of the sun and planet. What is happening? Describe what you are observing as the phase progresses.

18. Determine how increasing each of the following variables would affect the depth and duration of the eclipse. (Note: the transit duration is shown underneath the flux plot.)

Mass of the Planet:

Radius of the Planet:

Mass (and thus, temperature and radius) of the Star:

19. Reselect option A and click set after each comparison.

a) Compare a planet of 1 Jupiter radius to 2 Jupiter radii. Which is easier to detect? By how much?

b) Reset again to option A. Compare a planet of 2 Jupiter masses to 1 Jupiter mass. Which is easier to detect? Explain your result.

Part 4: Planetary Transits and Noise

The Kepler space probe (<http://kepler.nasa.gov>), was designed to detect extrasolar planets during transit in front of their parent star. Its accuracy is 1 part in 50,000 (which means it has a noise of 0.00002).

Select Option B and click set. This preset is very similar to the Earth in its orbit. Now under the plot of flux, select “show simulated measurements.” Then find the slider to adjust the noise level, and slide it around.

20. What happens? At approximately what noise level does an Earth like planet first become detectable?

21. Now set the noise level to 0.00002. Do you think Kepler should be able to detect Earth-sized planets in transit? Why or why not?

22. How long does the eclipse of an Earth-like planet take? How much time passes between eclipses? What obstacles would a ground-based mission to detect Earth-like planets face?