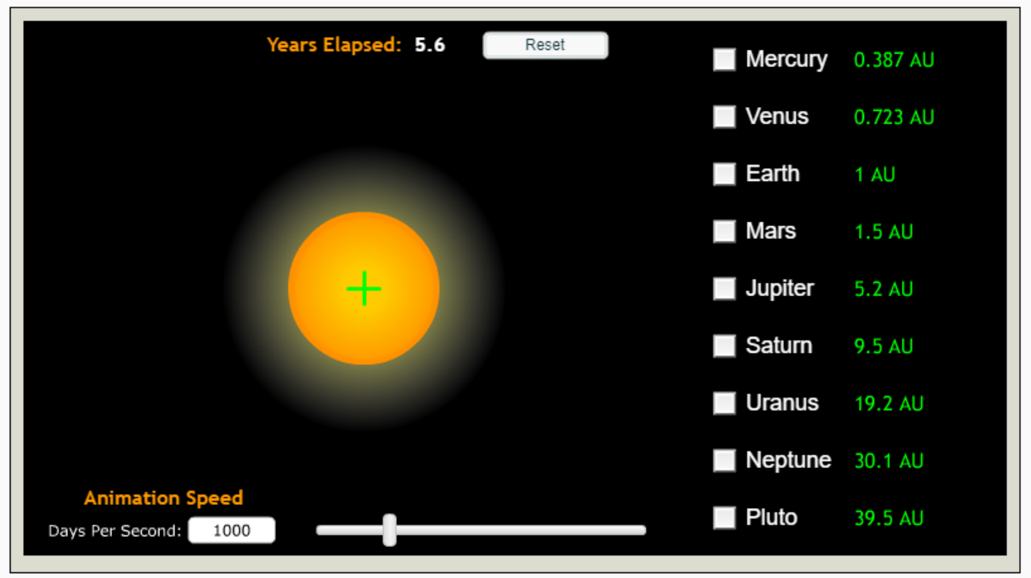
Winks and Wobbles Workshop

Student worksheet

All of the resources and links needed for this workshop can be found at
https://warwick.ac.uk/fac/sci/physics/research/astro/people/dbrown/transitworkshop

Part 1: Centre-of-mass

Open the centre-of-mass demonstration. Select each planet one-by-one, and see what effect they have. Then try the planets in various combinations.



CM1: Which planets cause the Sun to noticeably orbit around the centre-of-mass? What type of planets are these? ____

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Now select all of the planets that cause a noticeable movement. You may also want to increase the animation speed.

CM2: What is different about the Sun's movement when all of these planets are selected, compared to when only one is selected? ____

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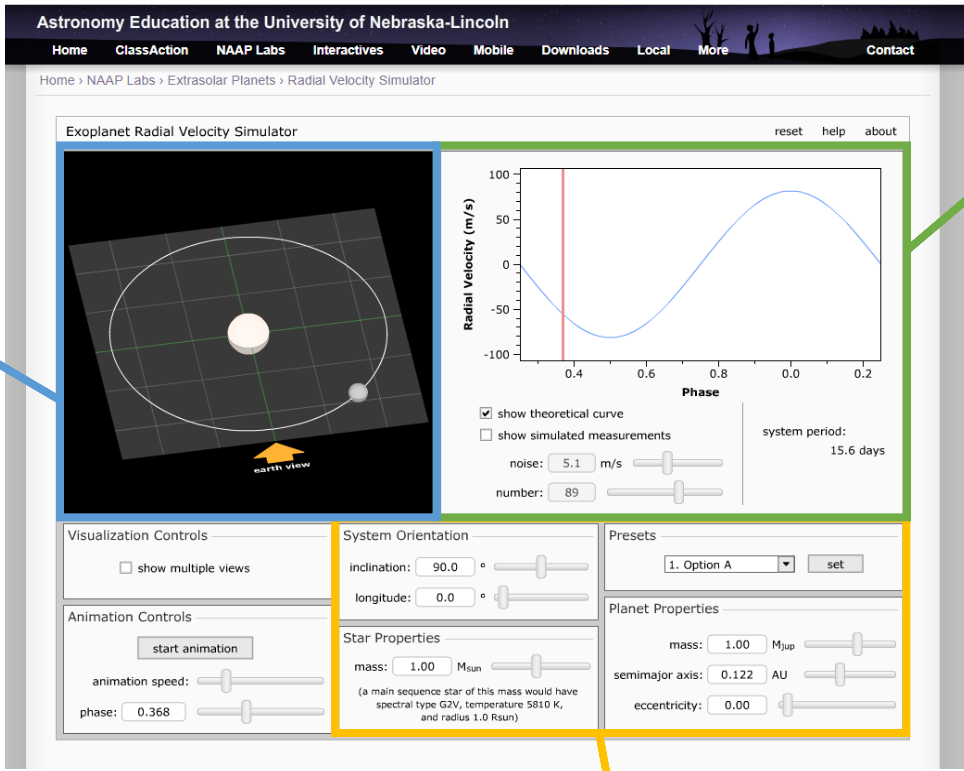
Part 2: Wobbles - radial velocities

Open the exoplanet radial velocity simulator. You'll notice several distinct panels:

3D visualisation of the star, planet, and orbit (zoomed in). The arrow shows the direction from which we're looking.



Radial velocity curve.

You can toggle the theoretical curve and the measured data.

The red bar shows what's measured for the current setup in the visualisation panel.

Panels to control the system properties. Here you can change the mass of the star, the mass of the planet, how circular the orbit is, how far the orbit is tilted over, and how far apart the planet and star are.

Where it says "Presets", select 'Option A' from the drop-down list, and click 'set'. This sets up a system that is basically Jupiter but in Earth's orbit around the Sun. Make sure that

- "Show theoretical curve" is selected
- "Show simulated measurements" is not selected
- "Show multiple views" is not selected

You can measure the amplitude of the curve radial velocity curve by moving the mouse pointer onto the curve.

RV1: Describe the radial velocity curve. What is its shape? What is its amplitude?

*What is the orbital period?*____

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Now we're going to try adjusting the parameters to see how the radial velocity curve changes. After investigating the effect of each parameter, reset the simulator by clicking 'set' in the "Presets" panel.

RV2: How is the amplitude of the radial velocity curve affected by changing the planet mass?

RV3: How is the amplitude of the radial velocity curve affected by changing the star mass?

RV4: How is the amplitude of the radial velocity curve affected by changing the distance between the star and planet ('semi-major axis')?

RV5: How is the period of the radial velocity curve affected by changing the semi-major axis?

Reset the simulator again, and select the box marked "Show multiple views".

RV6: How does changing the tilt of the orbit (inclination) affect the amplitude and shape of the radial velocity curve?

RV7: How does making the orbit non-circular (increasing 'eccentricity') affect the amplitude and shape of the radial velocity curve?

Reset the simulator again, and note the amplitude of the radial velocity curve. Increase the mass of the planet to $2M_{Jup}$ and decrease the inclination to 30°. What is the new amplitude? Can you find other values of inclination and planet mass that give the same amplitude?

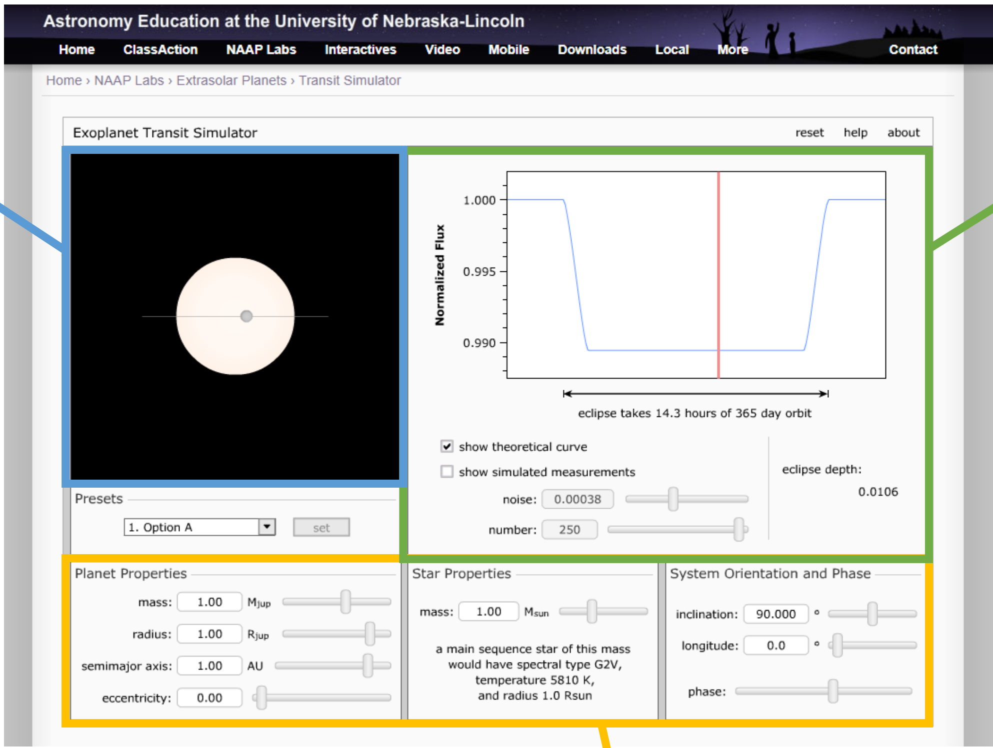
RV8: If the amplitude of the radial velocity curve is known but the inclination of the orbit is not, is there enough information to say what the mass of the planet is? Explain your answer.

RV9: What can astronomers say about a planet's mass even if the inclination is not known? Explain your answer.

Part 3: Winks - exoplanet transits

Open the exoplanet radial velocity simulator. You'll notice several distinct panels:

Visualisation of what the star's disc would look like from Earth if we had a powerful enough telescope. Planet and star are to scale with each other.



Transit light curve

You can toggle the theoretical curve and the measured data.

The red bar shows what's measured for the current setup in the visualisation panel.

Panels to control the system properties. Here you can change the mass of the star, the mass of the planet, the radius of the planet, how circular the orbit is, how far the orbit is tilted over, and how far apart the planet and star are.

Where it says "Presets", select 'Option A' from the drop-down list, and click 'set'. This sets up a system that is basically Jupiter but in Earth's orbit around the Sun. Make sure that

- "Show theoretical curve" is selected
- "Show simulated measurements" is not selected

Note that the duration of the transit is shown underneath the light curve.

Now we're going to try adjusting the parameters to see how the transit light curve changes. After investigating the effect of each parameter, reset the simulator by clicking 'set' in the "Presets" panel.

TR1: How does changing the radius of the planet affect the depth and duration of the transit?

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TR2: How does changing the semi-major axis affect the depth and duration of the transit?

TR3: How does changing the mass of the star affect the depth and duration of the transit?

TR4: How does changing the inclination of the orbit affect the depth and duration of the transit?

Now set the simulation to preset 'Option B'. This sets up a system that is very similar to the Earth around the Sun. Also select "show simulated measurements", set the noise to 0.00008, and add the maximum number of measurements.

The PLATO space mission launches in 2026, and aims to detect planets like this system. It is predicted to have a measurement precision of 80 parts in 1,000,000 (a noise of 0.00008).

TR5: Do you think PLATO will be able to detect a single transit of this system? Explain your answer.

Part 4: Investigate - transit identification

Download and open the transit light curves spreadsheet.

Each tab of the spreadsheet contains data to create a different light curve.

Create graphs from each set of data that show the light curve.

IN1: Can you identify which light curve is caused by each of the following? Explain your choices.

- *Earth-sized planet orbiting a star like the Sun, with an orbital period of 1 year.*
- *Earth-sized planet orbiting a star like the Sun, with an orbital period of 1 year.*
- *Earth-sized planet orbiting a star half the radius of the Sun, with an orbital period of 1 year.*
- *Earth-sized planet orbiting a star half the radius of the Sun, with an orbital period of 5 days.*
- *Jupiter-sized planet orbiting a star like the Sun, with an orbital period of 1 year.*
- *Jupiter-sized planet orbiting a star like the Sun, with an orbital period of 1 year.*
- *Jupiter-sized planet orbiting a star half the radius of the Sun, with an orbital period of 1 year.*
- *Jupiter-sized planet orbiting a star half the radius of the Sun, with an orbital period of 5 days.*

As a hint, here's how the transit depth is worked out.

$$depth = \frac{Area_2}{Area_1} = \left(\frac{R_2}{R_1}\right)^2$$

IN2: There are some light curves that aren't created by transits. What do you think could produce them?