ROYAL OBSERVATORY GREENWICH

Radius and Volume of Exoplanets

Key Stage 4

Topics covered: Extrasolar planets, orbits, eclipses, transits, light curves, volume of sphere

Teacher's Notes

This activity uses data from NASA's Kepler space probe to determine the size of an exoplanet, and provides students with an insight into the advantages and disadvantages of the transit method of exoplanet detection.

Equipment: Student worksheets (pages 4-6) and calculators.

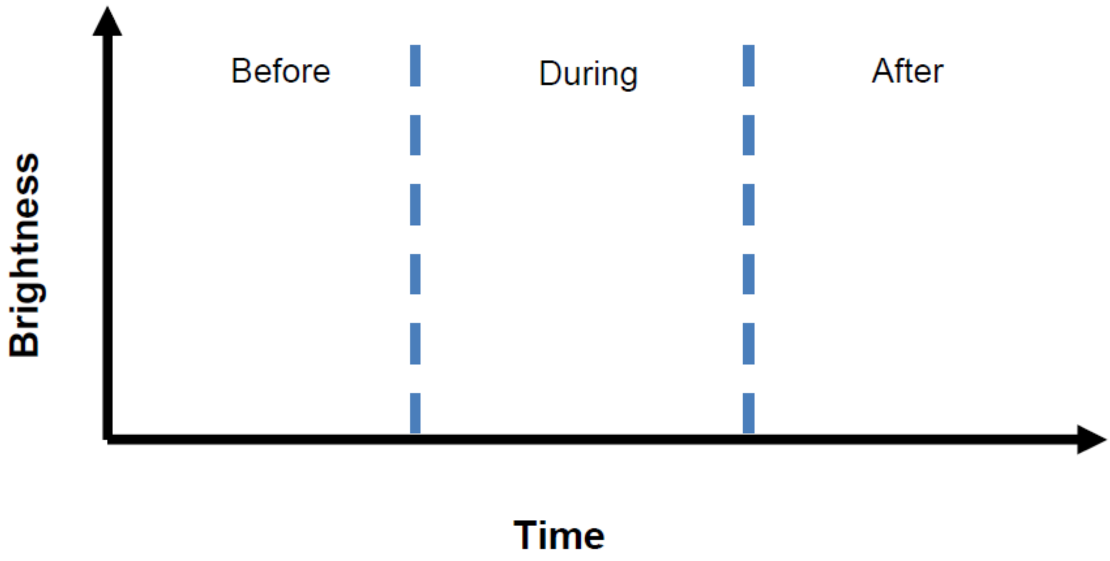
Class discussion before the activity:

Discuss two examples of transits (captioned images on page 3) :

1. A total solar eclipse, in which the Moon blocks all of the Sun's light as seen from our place on Earth, and
2. A transit of Venus, in which the planet Venus moves across the face of the Sun as seen from our place on Earth.

On the board, draw the axes for a graph – with brightness on the y-axis and time on the x-axis. Insert three sections (Before, During and After) as seen in the example below. Ask a student to draw a line on the graph that approximately indicates what happens to the brightness of light from the Sun in those stages of solar eclipse.

ROYAL OBSERVATORY GREENWICH



Erase the first line and ask another student to come forward and draw a line that would indicate what happens to the brightness of light from the Sun in the stages of a transit of Venus.
Answer: Students should reason that almost all light will be blocked by a total solar eclipse; while there will be the slightest dip in the light curve during a transit of Venus.

Class discussion after the activity:

Exoplanets orbiting distant stars cause regular dips in the starlight over time – this is called a light curve. When analysing the light curves of distant stars will exoplanets be easier to detect if they are:

... very large in size?
... further away from their parent star?
... both?
Answer: Typically, an exoplanet that is large relative to its star will be easier to detect. The more distant an exoplanet is from its star does not necessarily make the detection easier. In fact, exoplanets that closely orbit their star are easier to detect in stellar light curves due to their short periods.

Background science

The classroom discussions above illustrate the principle behind the transit method used to detect exoplanets orbiting distant stars. Just as in a solar eclipse or a transit of Venus, an object moving in front of a star blocks some of the starlight. The resulting graph of periodic variation of brightness over time – a light curve – contains enough information to obtain the orbital period and size of an exoplanet.

By noting the time between the first and last dips in a light curve along the x-axis and dividing by the number of dips, the period of the exoplanet can be obtained. Measuring the drop in brightness along the y-axis allows calculation of the radius of the exoplanet and subsequently its volume. This will be the objective for students in this activity.

The student worksheets provide two light curves from NASA's Kepler probe. You will note that these only appear to contain one dip and not a series of dips. The data points from several dips are there, but summed at the same period to improve the quality of the data for a single transit. The y-axis gives brightness in normalised values (unitless) and the x-axis gives the time in hours before and after new phase (where the far side of the planet is fully illuminated by its star).

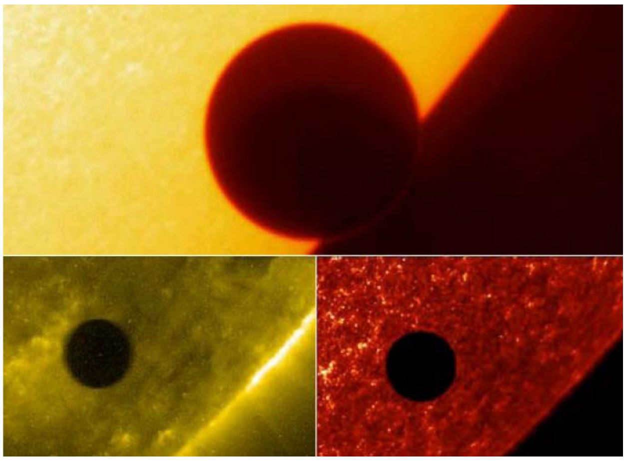
The transit method does not give precise detail regarding the mass of the exoplanet. The radial velocity method is often used to obtain a more accurate figure for the mass of an exoplanet. Also, this method is often used to verify exoplanet discoveries made with the transit method.

ROYAL OBSERVATORY GREENWICH

Captioned images of transits:

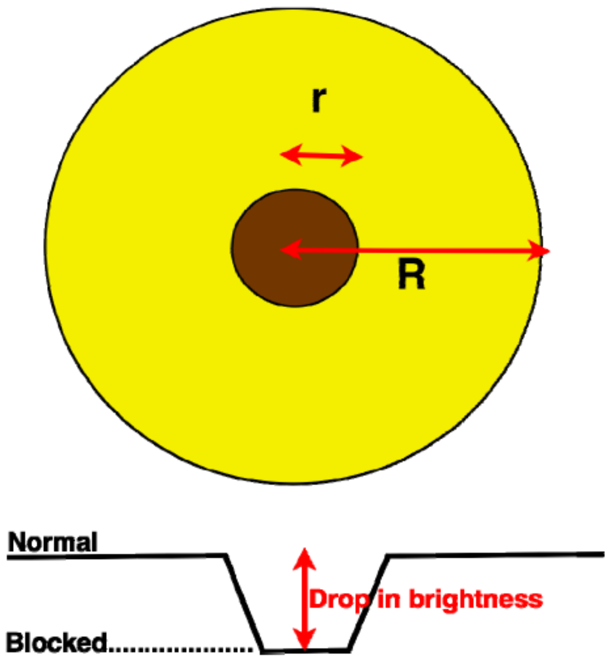
The Moon eclipsing the Sun completely on 1 August 2008. The remaining light is the corona of the Sun. The value for brightness will decrease to very low levels as the event reaches totality.

Image courtesy of NASA.



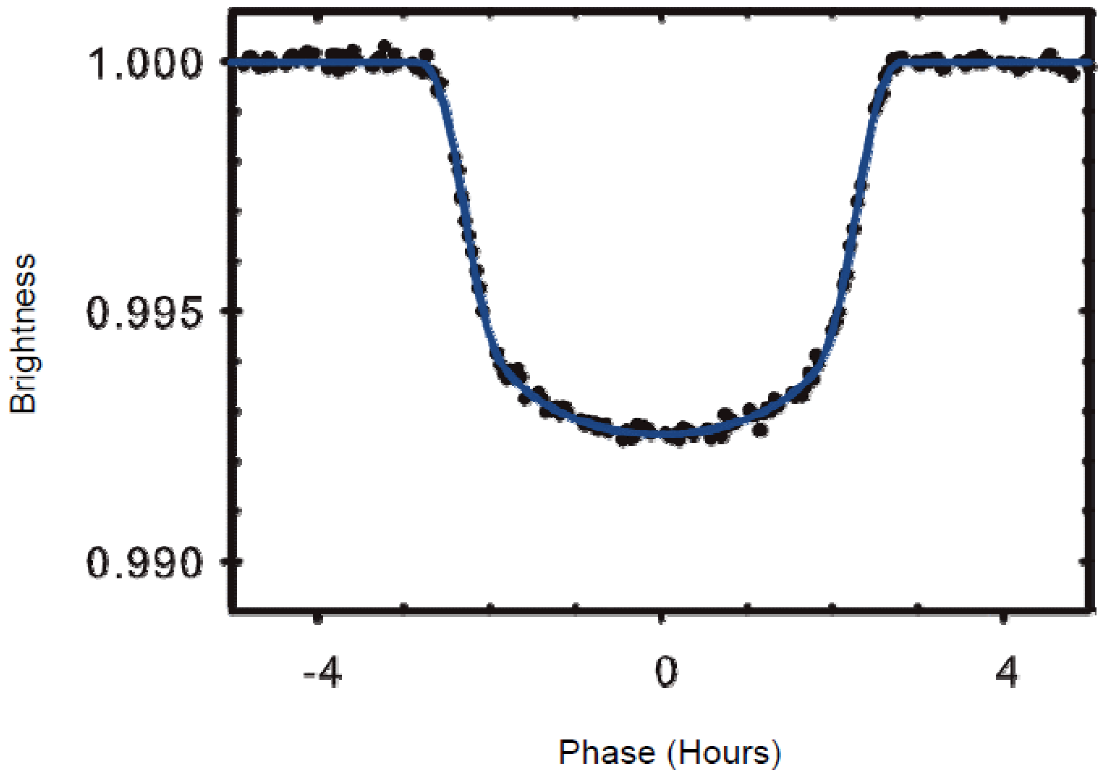
Venus passing in front of the Sun on 8 June 2004. The value for brightness will only decrease slightly during the transit. The images here were taken by the space-based solar observatory TRACE.

Image courtesy of NASA/LMSAL.



Activity: Finding the Radius and Volume of Exoplanets

Kepler 7b



Stellar Radius (R): 1.8 Solar Radii

Drop in Brightness:

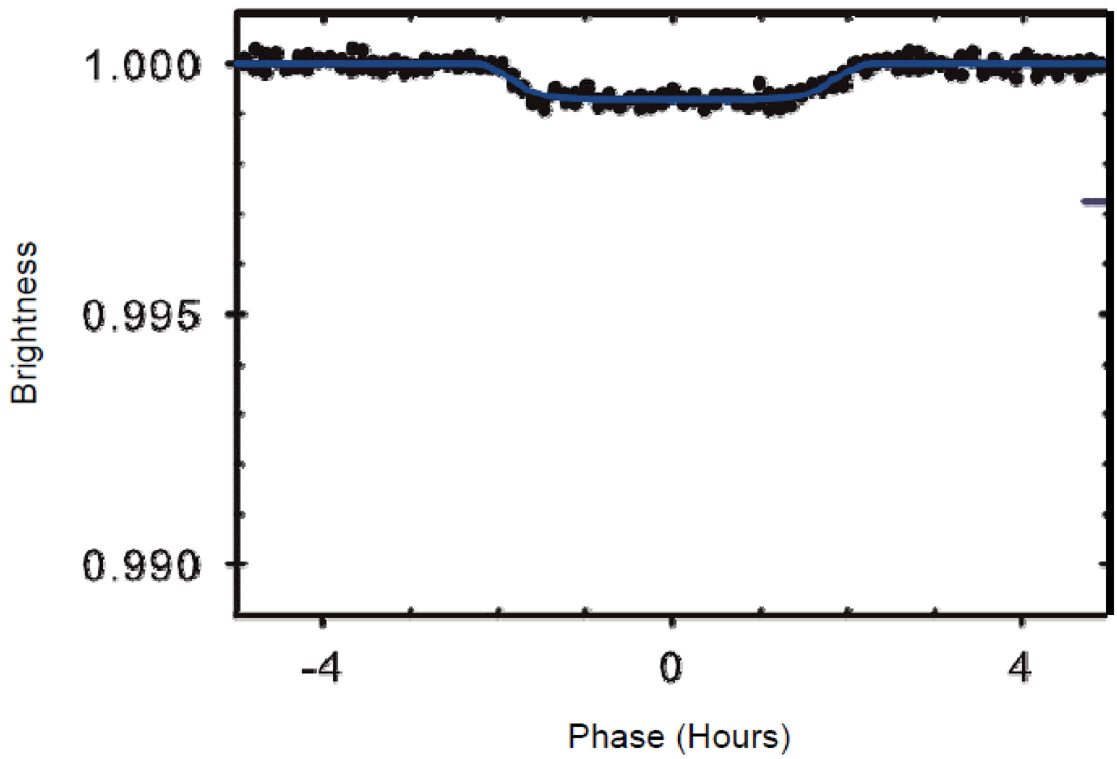
Use the following equation to work out the radius (r) of the transiting exoplanet Kepler 7b.

$$\text{Drop} = r^2 / R^2$$

r = radius of Kepler 7b (exoplanet)
R = radius of Kepler 7 (star)

Radius of Kepler 7b:

Kepler 4b



Stellar Radius (R): 1.5 Solar Radii

Drop in Brightness:

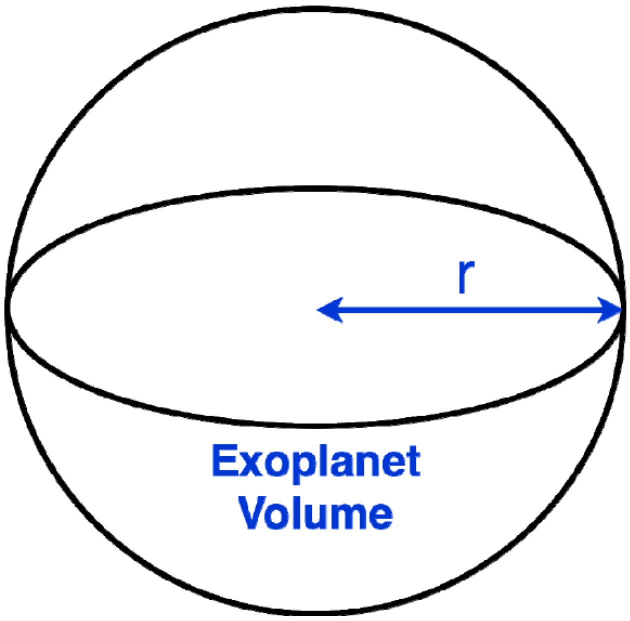
Use the following equation to work out the radius (r) of the transiting exoplanet Kepler 4b.

$$\text{Drop} = r^2 / R^2$$

r = radius of Kepler 4b (planet)
R = radius of Kepler 4 (star)

Radius of Kepler 4b:

Calculate the volume of Kepler 7b and 4b:



$$Volume = \frac{4}{3}\pi r^3$$

Before using the above formula, convert the radius of the exoplanet, which is in solar radii, into Earth radii by multiplying by 109. This will give a direct comparison of these two example exoplanets with our own home planet.

Volume of Kepler 7b: ____________

Volume of Kepler 4b: ____________