THE TRANSIT METHOD

In this activity students use a lamp and polystyrene balls to model how astronomers detect exoplanets using the transit method.

Apparatus and Materials

(per group of 2 to 4 students)

- Lamp (one with an opal globe light bulb is ideal)
- Polystyrene balls of assorted sizes
- Bamboo barbecue skewers (with a length of approximately 30 cm)
- Webcam
- Light Grapher software

Each student will require a photocopy of the instructions and worksheet (pages 4 and 5 respectively).

Health & Safety and Technical Notes

Ask students to be careful when building models as skewers may be sharp. Warn students not to stare directly into the lamp.

This activity uses a piece of software called Light Grapher which detects input from a webcam to graphically display the brightness of a model star. The software is available at **spark.iop.org/useful-links-and-individual-downloads.**

Learning objectives

After completing this activity, students should

- understand that the transit of a planet in front of its star temporarily reduces the star's measured brightness.
- understand that a light-curve is a graph of "brightness" against time.
- describe and explain how different factors (including size of exoplanet and orbital speed) affect the light-curve observed during a transit.

Introducing the activity

Introduce the idea of an exoplanet and explain why they are difficult to observe. (They are very distant and much smaller than stars, and they are not sources of light.) Explain that a number of techniques have been developed to observe exoplanets so that we now know of thousands. Explain that they are going to model the transit method in which the brightness of a star is measured as the exoplanet orbits it.

The practical activity

Students should set up a lamp to represent their star and attach a ball to a stick or skewer to represent their exoplanet. They should then move their ball on skewer/stick across the front of their lamp and produce a light-curve. You will need to explain how to use the Light Grapher software. Once students have produced a single light-curve, they should predict how the shape of the light curve will change for a bigger and faster exoplanet. Encourage them to think about which variables they need to keep constant (e.g. radius of orbit) in order to test their predictions.

About light-curves

The brightness is shown as a percentage, with the percentage of brightness on the y-axis and the time on the x-axis. An idealised light curve for a Jupiter-like planet crossing the disc of a Sun-like star is shown in figure 1a.

On their worksheet, students are provided with a light curve and asked to sketch curves for a faster and a bigger planet. These are illustrated in figure 1b. A faster exoplanet moves across the face of the star more quickly and so the dip in intensity lasts for a shorter time. A larger exoplanet obscures more of the star's surface during a full eclipse and so the dip in intensity is larger.

Students are asked to think of a third variable to test. A likely choice is the distance of exoplanet from star. For their model star system, the proximity of the webcam means that increasing the orbital distance may significantly increase the size of the dip. If they move the planet close to the web-cam they may even observe a total eclipse. In practice the distance between an exoplanet and its host star is negligible compared to the enormous distances from Earth. After the activity you could discuss this limitation of their model when discussing relative scales (see *Scale models of star systems* below).

Another variable which will affect the light-curve is the orientation of the exoplanet's orbit around its star. Students are likely to model the orbit so that it is "edge on" when viewed from Earth. This produces a dip in intensity that lasts the longest. For other orbital orientations the transit duration will either be reduced or no transit will be observed at all (Figure 1c). This is an additional complication which students may come up with but which you may not wish to introduce if it does not arise in your class.

Scale models of star systems

Students often hold misconceptions about the relative size of planets, stars and distances between them. You could ask them to look more closely at the vertical axis of light-curve on their instruction sheet. The planet illustrated (Kepler 444f) is similar in size to the Earth and orbits a Sun-sized star 117 light years away. The dip in the brightness is 0.01 %. What does this imply about Earth-sized planets? (They are much smaller than stars).

You could also discuss how large a scale model would have to be to represent the Solar System. Assuming they use a typical 6 cm diameter light bulb for the Sun, the Earth would be the size of a grain of sand about 6 metres away and Jupiter would be the size of a pea at 33 metres. If students were to model observing the transit of Kepler 444f, the exoplanet would be about 50 cm from the light bulb but the observer on Earth (the webcam) would have to be over 48 thousand kilometres away!

Taking it further

Once students have investigated the Transit Method, you could ask them to use the internet to find out about one other way of detecting exoplanets. (There are at least five other techniques used to detect exoplanets although several require an understanding of Physics well beyond Key Stage 3.)

Figure 1a: Predicted light curve for a Jupiter-sized planet transiting a Sun-sized star. The corresponding positions of the planet (a-g) are also shown.

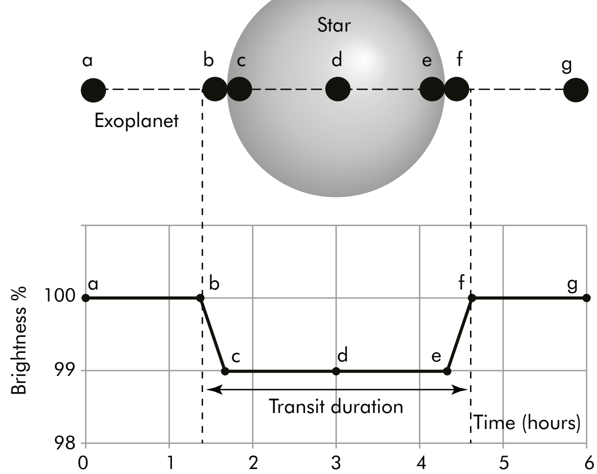

Figure 1b: Predicated light curves for a faster and bigger planet. The examples illustrated are for a planet with (i)1.5 times the speed and (ii) 1.5 times the diameter of that shown in figure 1a.

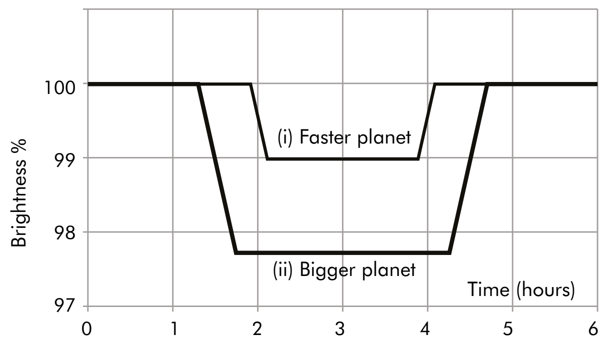

Figure 1c: Light curves for different orbital orientations. Light curve A is for a planet whose orbital plane is exactly edge-on from our point of view. For other orientations the transit duration is either reduced (B) or no transit is detected (C).