→ Activity 4: How big is an exoplanet?

The dip in the observed flux of the star as the exoplanet transits is a direct measure of the fraction of the disc of the star that the exoplanet blocks. Therefore, the dip in the observed light from the star is directly related to the ratio of the area of the disc of the exoplanet, to the area of the disc of the star.

Students are asked to calculate the radius of their exoplanet, assuming that it is orbiting the star Proxima Centauri. You could ask: "*If we look at this type of graph from Proxima Centauri, what could we discover about this exoplanet?*". The key information they need about the star is its radius (Rs), which is 100 900 km.

From our example light curve in Figure 2, the illuminance measured from the light source measured before, or 'out of', the transit is 25 lx, and during the transit, as the model exoplanet passes between the light source and the detector, is 5 lx. The change is 20 lx. This gives us:

$$\text{change in star light during transit} = \frac{\pi R_p^2}{\pi R_s^2} \quad \text{star light out of transit}$$

$$R_p^2 = \frac{20}{25} \cdot 100900^2$$

$$R_p = 90248\text{km}$$

If this model exoplanet would be orbiting Proxima Centauri, its radius would be 14 times larger than Earth's radius (6378 km) and 1.3 times larger than Jupiter's radius (71492 km).

Discussion

If you wish to take this activity further, ask the students to present their results to the class and to compare the results they obtained in the different groups. The students can also compare their results with real examples of exoplanets such as KELT-3B and TOI-560C.

An interesting extension question to ask is what the mass of the transiting model exoplanet would be if it were to have a similar composition as Jupiter, and if it were to have a similar composition to the Earth? To calculate the masses we need to know what the mean density of Jupiter and the Earth are. Using the relationship between mass, radius and density, the mass of the object can be calculated if it were Jupiter-like or Earth-like in density. You can find a table with the densities of the different planets in the Solar System in the links session.

→ Conclusions

In this set of activities students learned how the transit method can be used to detect and characterise exoplanets. As a plenary discussion, it is useful for students to think about the limitations of the transit method for exoplanet detection and of the model they constructed in particular. Some of these limitations include:

- In their model the size of the light source (star) is fixed. In reality, the size of stars and planets can vary by large factors. What is important is the relative size of the star and the planet.

- In the experiment the measured brightness nearly goes to zero as the exoplanet transits the star. This is not representative of a real-life scenario, where the change in star light during transit is much smaller. In the case of the Earth and the Sun the ratio of the disc areas (equivalent to the ratio of the squares of the radii of the objects) is approximately 10^{-4}.

- A limitation of the transit technique is that it relies on the alignment of the host star, the orbiting planet and the observer – that is, all three being in the same plane. This won't necessarily be the case, and the chances of having this alignment become smaller the more distant the planet is from its host star (longer orbital period). Planets that are closer to the host star are therefore more likely to be detected than planets that are further out, which introduces a so-called bias.

- The period of an exoplanet's orbit could be so long that we would not see a transit for many years, or we could miss it completely if not monitoring the star continuously. In addition, a larger orbit means that there is a lower probability of the planet actually transiting.

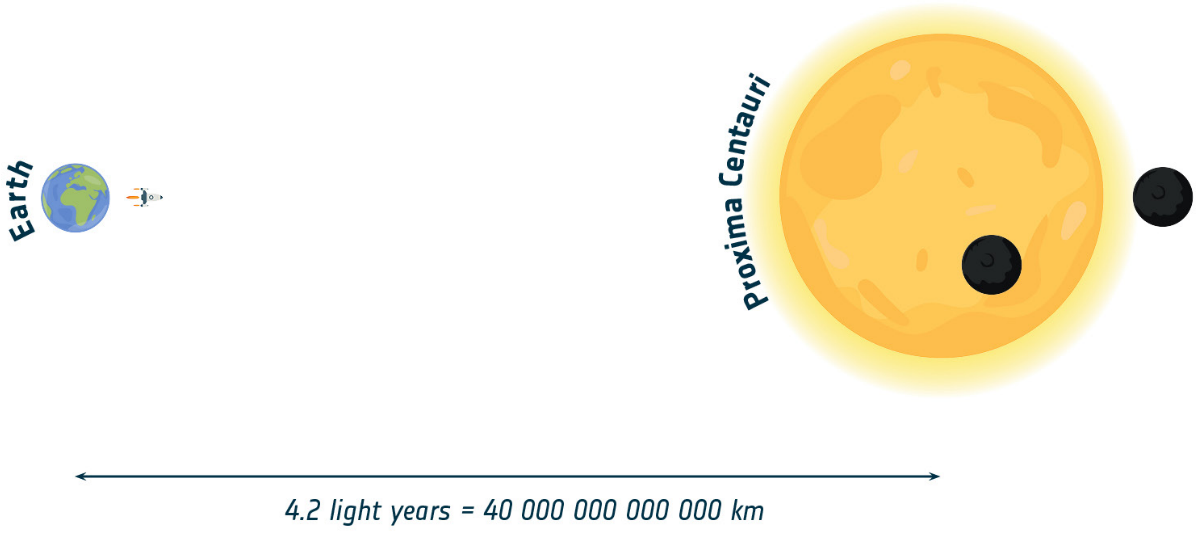
- In general, it is easier for instruments to detect the transits of large exoplanets with short orbital periods around relatively small stars. This could give us a skewed impression of the statistics of exoplanets in our galaxy. There could be many more smaller exoplanets, exoplanets with longer orbital periods, or exoplanets around larger stars that have not been detected (yet).

- The limitations of the transit method could lead on to a discussion of other methods of exoplanet detection. As an extension activity students can be asked to research and explain one other method of exoplanet detection. Other exoplanet detection methods include: radial velocity method, direct imaging, gravitational microlensing and astrometry (https://www.esa.int/Science_Exploration/Space_Science/Exoplanets/How_to_find_an_exoplanet).

As a bonus activity if you would like to continue analysing light curves with your students you can complete the activity ***Exoplanets in Transit***, where students can compare model and a real satellite data from ESA's Cheops mission.

→ Activity 4: How big is an exoplanet?

Imagine that your model exoplanet orbits around Proxima Centauri, the closest star to our Sun. Using the image and information below, what could we discover about the exoplanet?



During a transit, the dip in the observed flux is a direct measure of the fraction of the disc of the star that the exoplanet blocks.

$$\text{change in star light during transit} = \frac{\pi R_p^2}{\pi R_s^2}\ \text{star light out of transit}$$

Where R_s is the radius of the star, and R_p is the radius of the exoplanet. πR_p^2 is the surface area of the disk of the planet and πR_s^2 is the surface area of the disk of the star. Telescopes normally measure the star's flux or apparent brightness. In this activity we will consider the illuminance of the light source in your model as an approximation of the star light to exemplify the method.

Exercise

Rearrange the equation above to calculate the radius of your exoplanet (R_p), as if it was orbiting Proxima Centauri. Proxima Centauri has a radius of 100 900 km.