ESA TEACH WITH SPACE ONLINE CONFERENCE 2021

Level:
Secondary

Exoplanet Detectives

Splinter Session 12

ESA Education

6 – 8 July 2021

Participate in real time

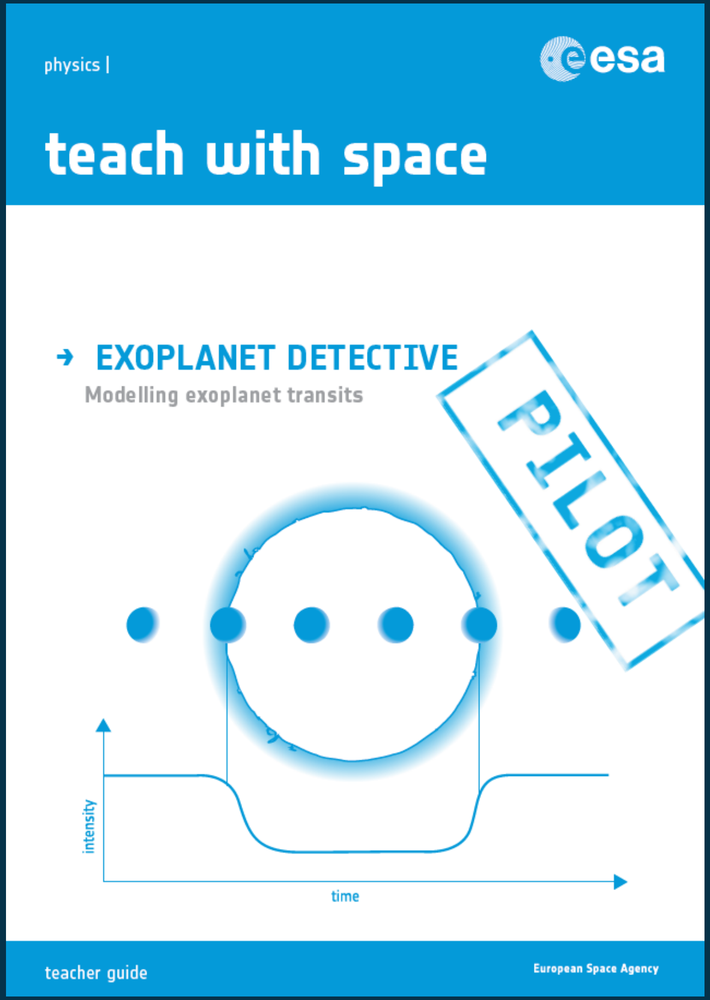
Material

- Cardboard shoebox, or similar with lid
- LED torch
- Light meter (e.g. smart phone with app or datalogger)
- Craft knife / scissors
- Semi-circular protractor
- Clothes peg
- Cocktail sticks or wooden BBQ skewer
- Plane white paper
- Sticky tape
- Modelling clay or similar

Kate Isaak is a physicist working as the Project Scientist for the CHEOPS mission – Characterising Exoplanet Satellite. As project scientist, she is responsible for the scientific management of a science mission at ESA, and have the job of trying to maximise the science return from the mission. This takes many forms, from working on the detailed definition of science requirements all the way through to ensuring that the community has enough technical information to be able to use the satellite to propose and plan their own observations.

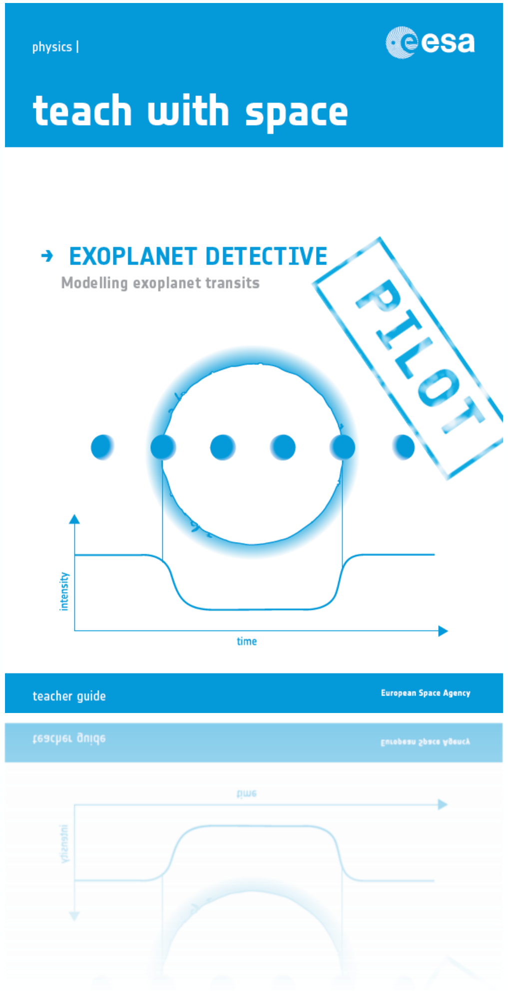
Kate Isaak
Project Scientist

Classroom resources



Exoplanets detective

Curricular topics: Physics, Mathematics, Astronomy



Activity: Exoplanet in a box

This activity introduces the students to the topic of exoplanets. The students will create their own physical model of a transiting exoplanet to understand how variations in observed flux of the host star can be used to detect exoplanets (the transit method). During this activity the students will learn how to use data logging applications and interpret exoplanet phase curve graphs of observed flux from the star as a function of time.

Competences and skills

- General experimental skills
- Problem solving
- Critical thinking
- Understand how to work scientifically.

Learning objectives

- Understand the difference between a star and a planet.
- Learn about the properties of exoplanets.
- Understand how to model the detection of an exoplanet using the transit method.
- Learn how to design an experiment.
- Learn how to use data-logging equipment.
- Translate information between graphical and numeric form.
- Plot two variables from experimental data
- Develop skills for interpreting graphs

Material

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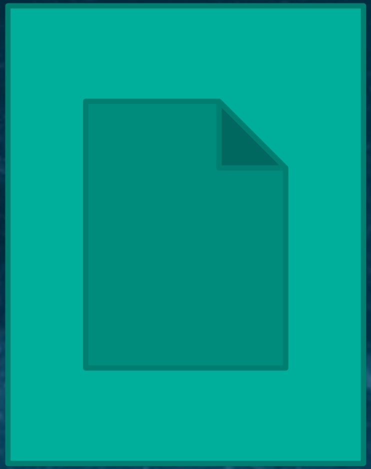
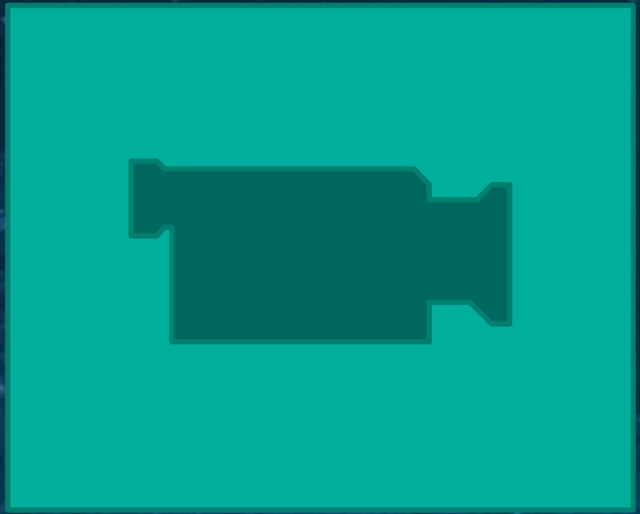
Exoplanets Detective



Download the PDF:

- shorturl.at/qvyDY

Exoplanets Detective



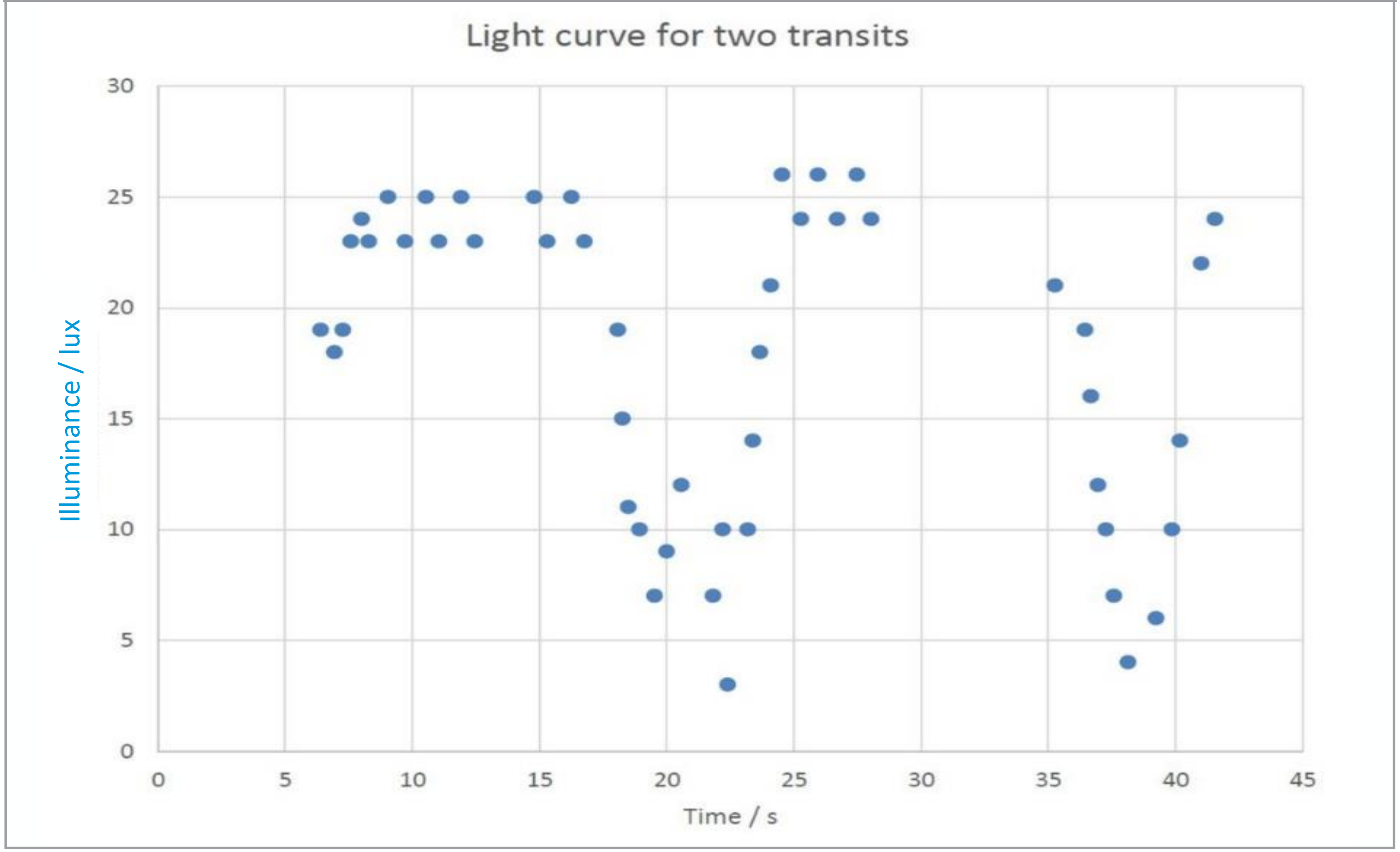
Apps with light sensors

- Physics Toolbox Sensor Suite (vieyrasoftware.net)

- Phyphox – physical phone experiments

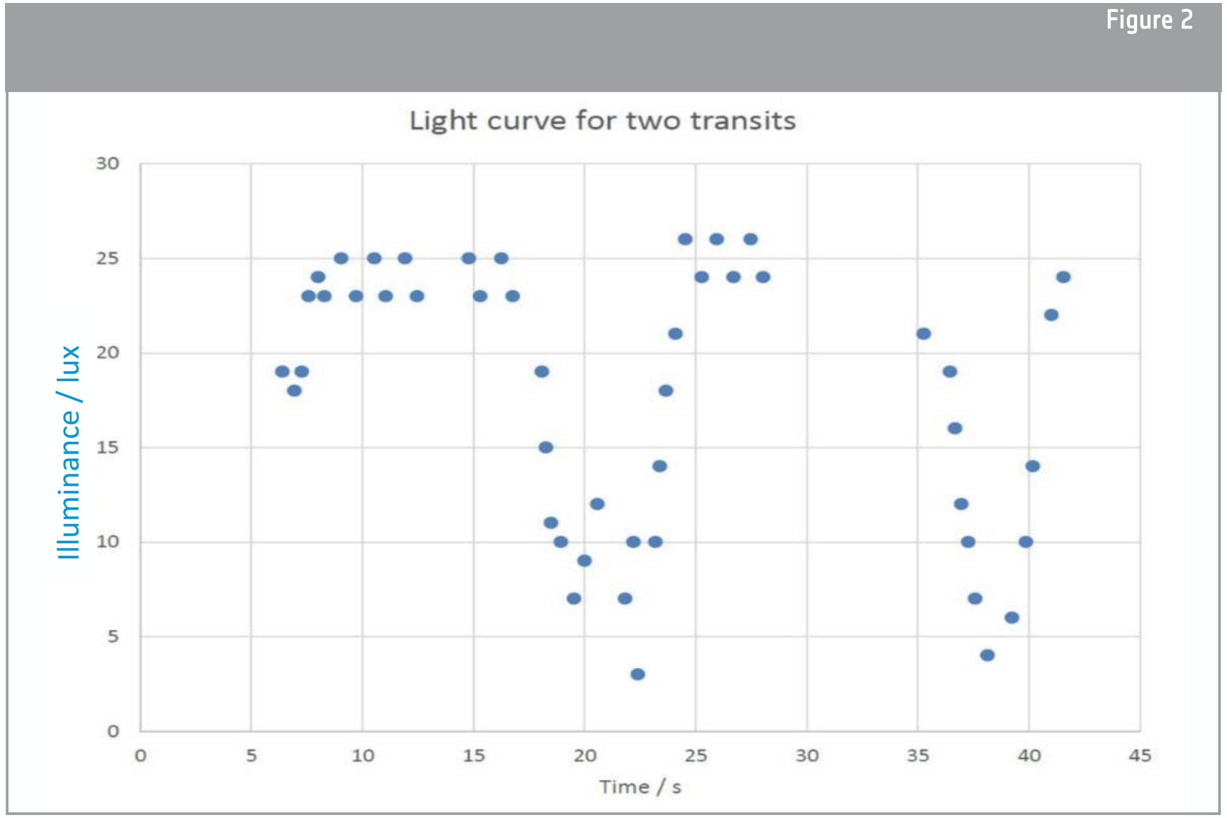
Data Analysis

Figure 2

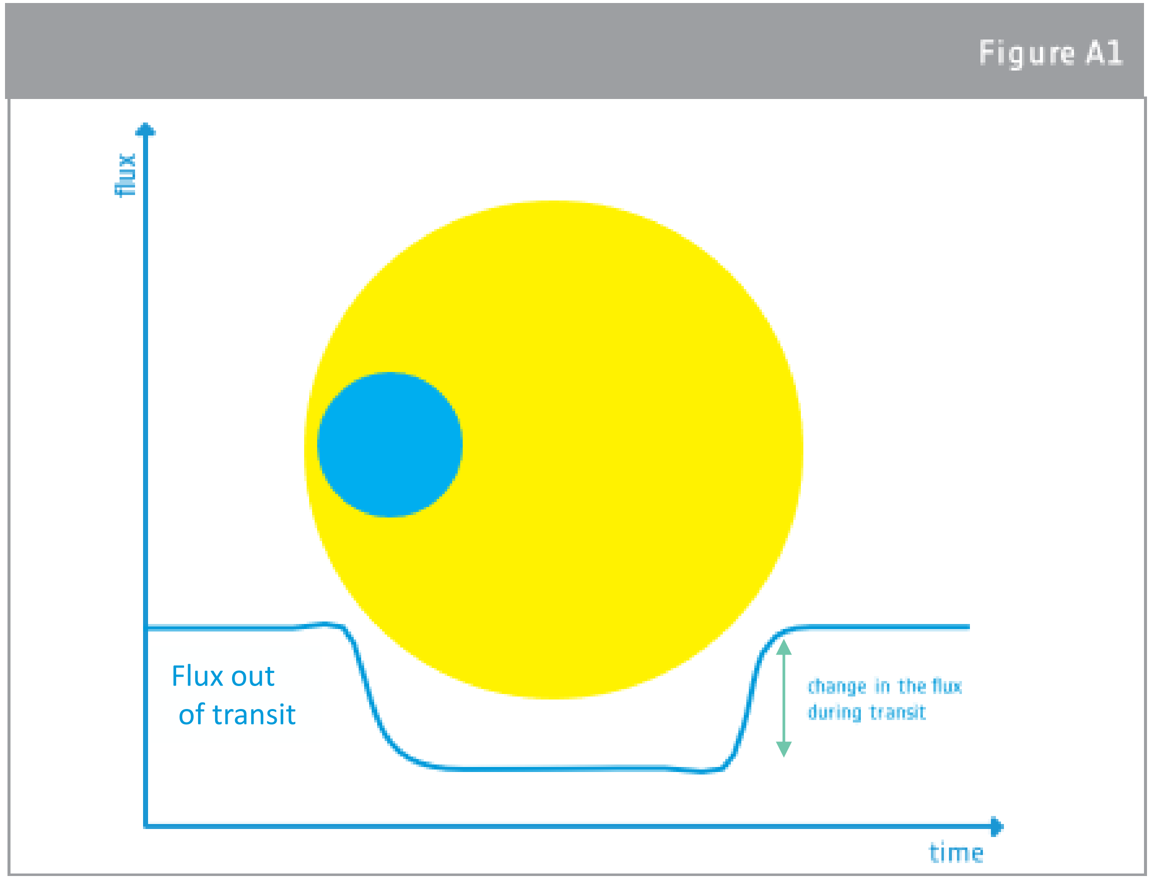


↑ Example of a light curve created using Physics Toolbox app

Data Analysis



↑ Example of a light curve created using Physics Toolbox app



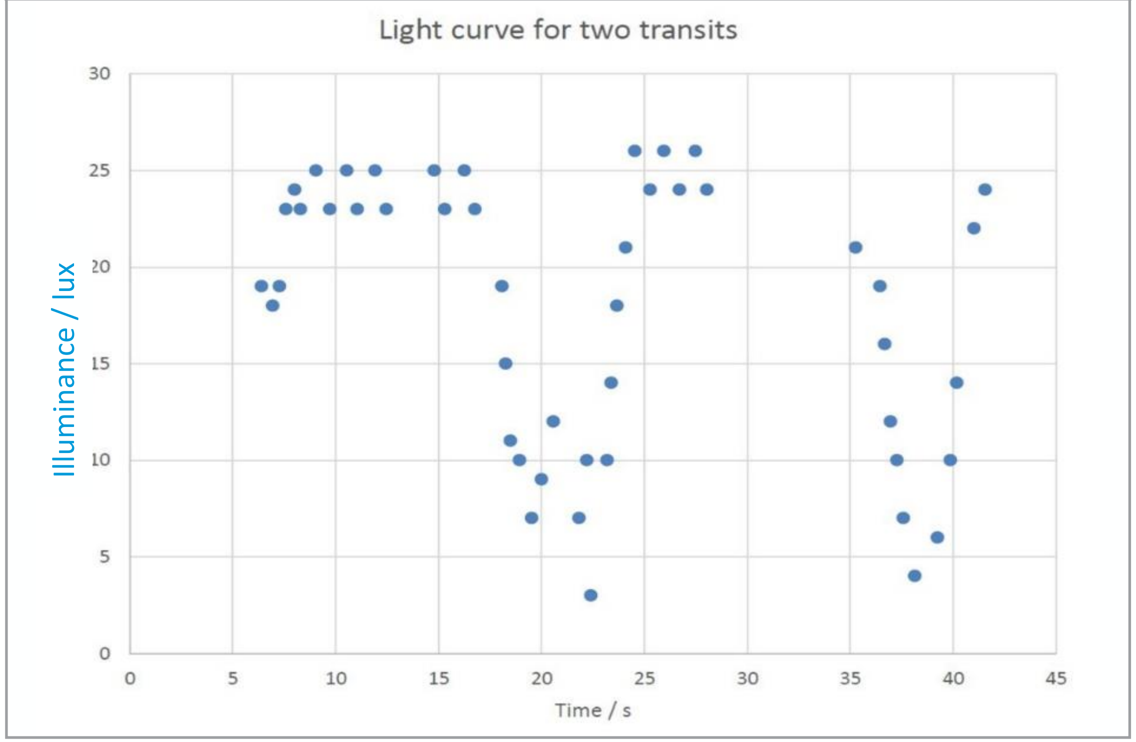
↑ Representation of an exoplanet transit. When the planet passes in front of the star the telescope receives less light and there is a dip in the measurement of the flux.

Data Analysis

- The light curve we constructed using our "planetary system" shows two transits.

- For this example, the illuminance out of transit is approximately 25 lux, with a maximum change in illuminance of approximately 20 lux.

Figure 2



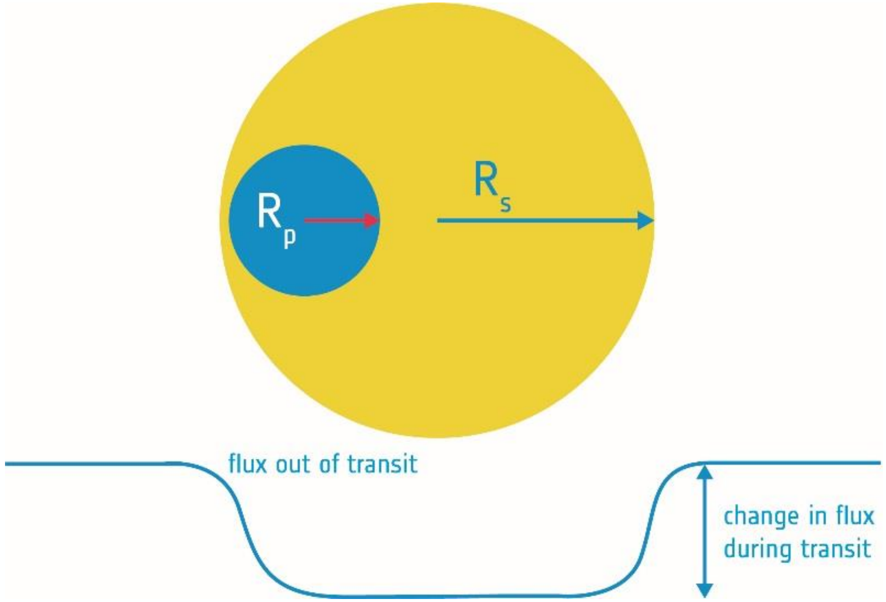
↑ Example of a light curve created using Physics Toolbox app

Calculating the size of an exoplanet

$$change\ in\ flux\ during\ transit = \frac{area\ of\ planet}{area\ of\ star} \times flux\ out\ of\ transit$$

$$change\ in\ flux\ during\ transit = \frac{\pi {R_p}^2}{\pi {R_s}^2} \times flux\ out\ of\ transit$$

$${R_p}^2 = \frac{change\ in\ flux\ during\ transit}{flux\ out\ of\ transit} \times {R_s}^2$$



Proxima Centauri has a radius of 100 900 km

- Calculate the radius if your exoplanet(s) if they were orbiting this star.

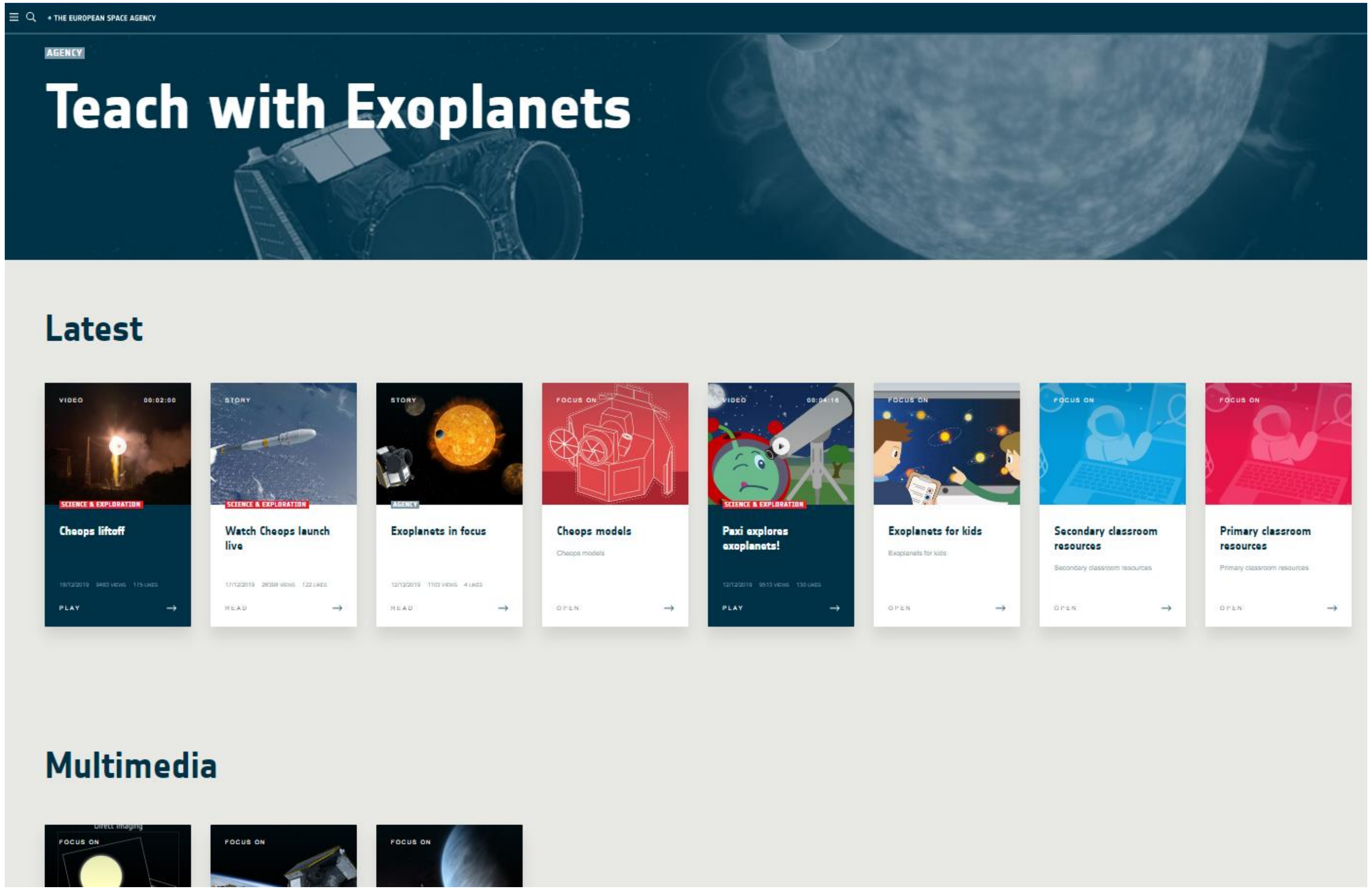
Explore

- Change the size of your “exoplanet”. Can you observe any difference in your transit?
- Change the distance of the planet to the star.
- Change the material used to create the exoplanet

Useful links

Teach with exoplanets:

www.esa.int/Education/Teach_with_Exoplanets



Meet Cheops

https://www.esa.int/ESA_Multimedia/Videos/2019/12/Meet_Cheops_the_Characterising_Exoplanet_Satellite

Q&A session I

•What about exomoon? Is it possible to detect them with Cheops?
An exomoon is a satellite orbiting an exoplanet. Moons are common in the solar system, so it is expected that they will also be found around exoplanets.
Yes, in principle it is possible that CHEOPS could detect an exomoon and it is something that scientists using CHEOPS are looking for.

•Does Cheops include equipment for exoplanet detection using the radial velocity method?
No. We have a single instrument on-board CHEOPS - a very precise photometer that measures changes in the level of light as a function of time. We collect photons from a wide range of wavelengths - from around 330nm up to just below 1100nm, from the visible into the near-infrared.
The radial velocity technique makes use of very small changes in the frequency(or wavelength) of spectral lines that are a result of the star orbiting the common centre of mass of the star and planet. The frequency/wavelength changes are very small —> smaller for low mass planets than for higher mass planets. To measure these changes we use very high resolution spectrometers (which are big and heavy) on ground-based telescopes.

•How is it possible to find out if an exoplanet is suitable for life?
We first need to decide what we mean by life. We typically consider "life" to be what exists in conditions similar to what we find on Earth. For life as we know it to exist on an exoplanet, the temperature and conditions at its surface would need to be able to support liquid water. The planet temperature will depend on the temperature of its host star (which will in turn depend on what type of star it is) and how far away the exoplanet is from the star (or equivalently how long its orbital period is). - the further the planet is away from the star/the longer the orbital period (related by Kepler's 3rd Law), the cooler the planet. The range of orbital periods of a planet around a given star for which the liquid water can exist is called the habitable zone, or sometimes also the "Goldilocks" zone - just right, not too hot and not too cold. If a planet is in the habitable zone of a star it has met the first criterion for being suitable for life (as we know it).

•Have any habitable exoplanets been found yet?
Based on the statistics of exoplanet detection, it is expected that there will be many many potentially habitable planets, that is planets found in the habitable zone of their host stars. By habitable we mean a planet that is able to host life for a sustained period of time. The majority of planets in the habitable zones of their host stars have been found around so-called M-type stars. These are relatively cool compared to the Sun, and so the habitable zone is much closer in that is the Earth to the sun (also shorter orbital periods). The complication then is that these stars are much more active than the Sun, producing much more damaging x-rays and UV radiation than found on earth. This will have an impact on the conditions at the planet's surface, and the chances of existing.
An excellent system for study and the search for life is Trappist-1. Here seven approximately Earth-sized planets are orbiting an M-type star or red dwarf, all of which have the potential to host water at their surfaces.

Q&A session II

•There is any interference radiation or other when doing the measurements?
That is an interesting question.
Looking first at electromagnetic radiation, so interference from light: We are looking for very small changes in light level as the planet moves between us and the host star so are sensitive to changes in the ambient light as CHEOPS moves through its orbit. CHEOPS is orbiting the Earth at an altitude of 700km (somewhat higher than the space station also higher than Hubble Space Telescope, but much lower than for example a geostationary satellite. In certain pointing directions (which depend on where the star that we are observing is in the sky) we will see straylight from the Earth (reflected light from the Earth), and potentially something called airglow (emission from the Earth's atmosphere).
We are also sensitive to particle radiation/cosmic rays. These can cause temporary or permanent damage to the CHEOPS detector (CCD). This can increase the noise levels of our measurements, and in extreme cases can be so high that the observations are not useable.

•How does Cheops stand out with respect to other satellites such as NASA's Kepler?
Kepler also CoRoT, TESS and in the future PLATO all were, are or wil be survey missions - that is they are looking for new planets through surveying parts of the sky. These they detect by monitoring the light from multiple stars in patches of the sky for varying periods of time, looking for the characteristic dips in the measured light as the planets transit. Depending on how long you stare at a fixed patch of sky you are sensitive to planets of different orbital periods.
CHEOPS is a follow-up mission - we observe stars that are already known to host exoplanets (and in the majority of cases that are known to host transiting exoplanets). If we know there are transiting planets (from surveys from the ground (eg. HAT or WASP or NGTS surveys) or also from Kepler, CoRoT, TESS we know exactly when and where to point the satellite — at the time of transit of a given planet around a given star. We can therefore be very efficient, spending 10s hrs to a couple of days to measure the transit (we need to measure the transit and the "baseline" either side) rather than having to stare at fixed patches of sky for days on end. We need to be able to "see" a large fraction of the sky at any given time in order to be able to catch planets as they transit.
We want to focus on planets orbiting bright stars as for these we are able to perform radial velocity observations from which we can get the planet masses. Bright objects are also much easier to follow up (observe in more detail) with other telescopes, for example for studies of planetary atmospheres.
Many of the exoplanets discovered by Kepler are too faint for radial velocity follow-up so we only know there sizes, not their masses.

•Can you know the distance of an exoplanet to a star with any of the methods, especially the light measurement?
Using Kepler's 3rd law we can use the measurement of the orbital period of the transiting planet (time between consecutive transits gives the orbit period) together with the mass of the host star to get the orbital radius, and so the distance of the planet from the star.

•Would it be any difference between the colours? (Same size, different colour)
If you are asking whether you would expect to see a difference in the transit demonstrators that you are using , them no, there would not be any difference between the transit depth of a red-coloured solid planet and of blue coloured solid planet.
In a real measurement of an exoplanet transit things may be different, depending on exactly what you are measuring…

Questions?

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