Detecting Extrasolar Planets (An Investigative Simulation of Detection by Transit) – Teachers' Guide

This is a very straightforward activity illustrating how exoplanets (planets outside of our Solar System) have been discovered by their transits across their neighbouring stars. All that is required is a Light Sensor to simulate the photometer used in professional instruments, coloured light sources to act as the stars, and a series of different diameter beads to represent the exoplanets. Whilst the use of only two diameters is made in the activity, it could be extended to much smaller ones so that the students could investigate what was the smallest detectable.

The instructions suggest the use of 0.01s and 1s between each item of data collection. Professional data collection would probably be every few minutes with a real exoplanet, but of course its speed of transit would cause it to take several hours to cross a star's disc rather than the few seconds in this simulation.

Ideally coloured spherical bulbs would have been used to model suns but these are not readily available, hence the use of the dichroic bulbs. Their reflectors produce rich colour and the beam they produce is still divergent though not with spherical symmetry. If bulbs with near spherical symmetry emission of light had been available, then an investigation of the effect of distance of the exoplanet from the sun could also have been looked at.

You will have noted the non-use of Autoscaling. This was necessary to avoid the 'noise' associated with it.

Some d.c. power supplies may need smoothing units attached to them. If they are needed you will notice a small a.c. trace superimposed on the Light Curves.

One of the key requirements of discovering an exoplanet by the transit method is that the planet, star and detector must be in line with each other. Unfortunately it seems likely that many exoplanets would not satisfy this condition and so other techniques are employed for which weblink references are provided.

Typical results

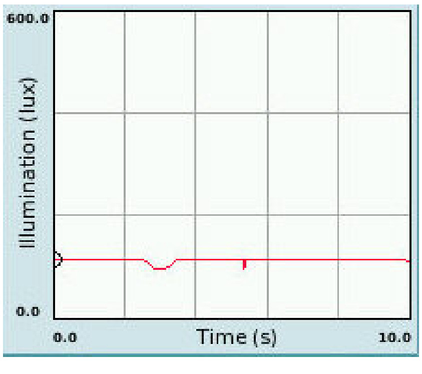

Figure 1 4.5V red bulb, 100 samples/s, 1cm bead

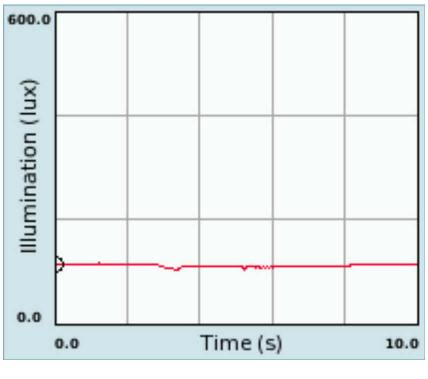

Figure 2 4.5V red bulb, 100 samples/s, 0.5cm bead

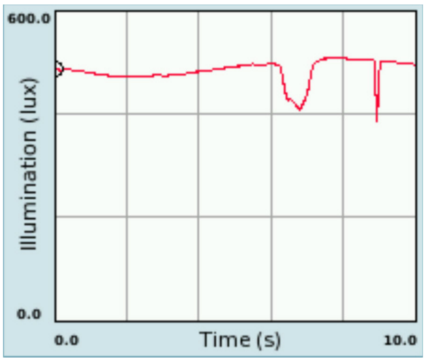

Figure 3 7.0V red bulb, 100 samples/s, 1cm bead

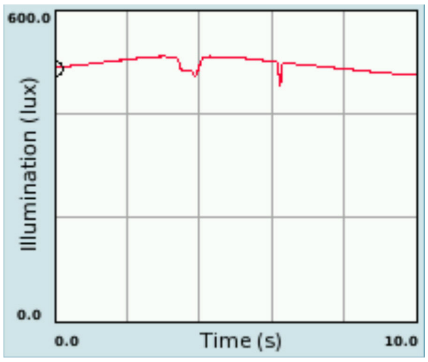

Figure 4 7.0V red bulb, 100 samples/s, 0.5cm bead

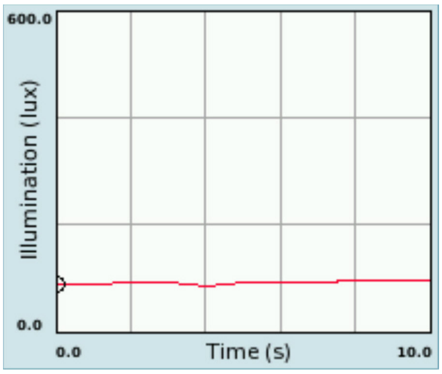

Figure 5 4.5V red bulb, 1 samples/s, 1cm bead

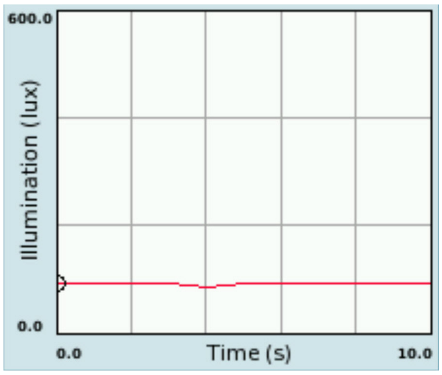

Figure 6 4.5V red bulb, 1 samples/s, 0.5cm bead

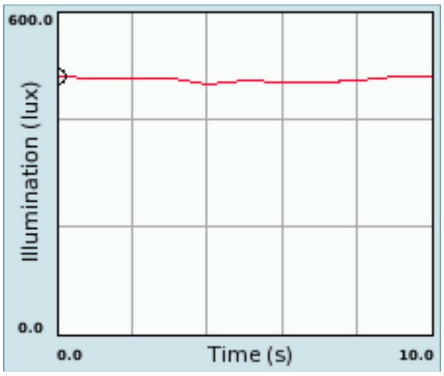

Figure 7 7.0V red bulb, 1 samples/s, 1cm bead

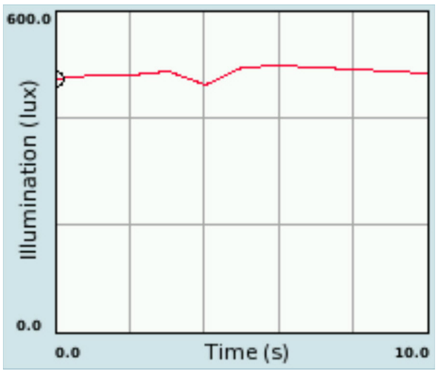

Figure 8 7.0 red bulb, 1 samples/s, 0.5cm bead

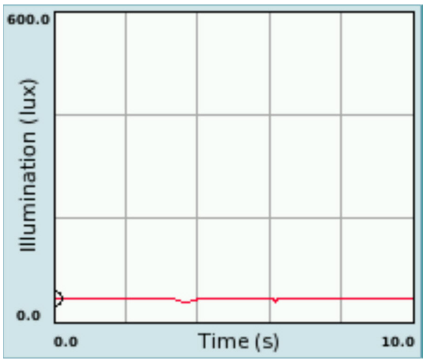

Figure 9 4.5V blue bulb, 100 samples/s, 1cm bead

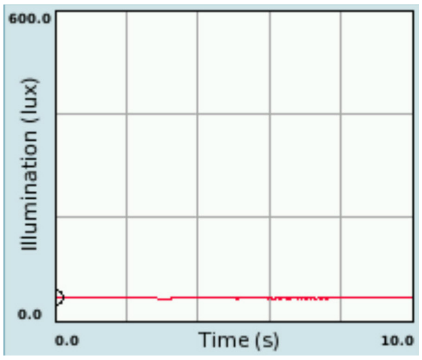

Figure 10 4.5V blue bulb, 100 samples/s, 0.5cm bead

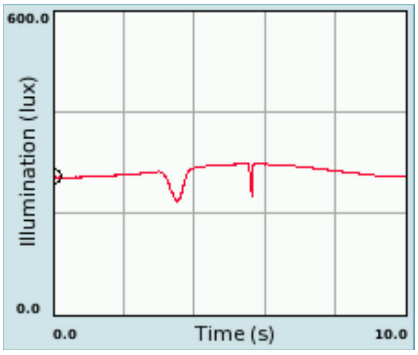

Figure 11 7.0V blue bulb, 100 samples/s, 1cm bead

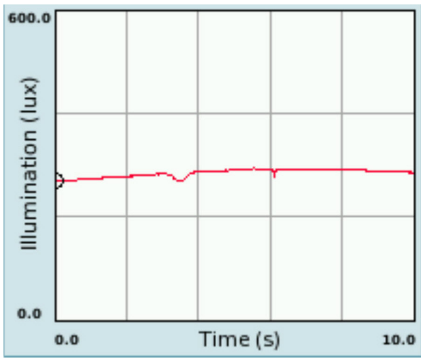

Figure 12 7.0V blue bulb, 100 samples/s, 0.5cm bead

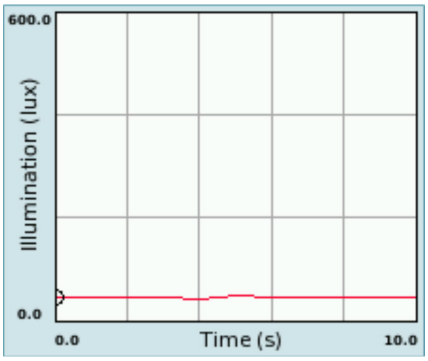

Figure 13 4.5V blue bulb, 1 samples/s, 1cm bead

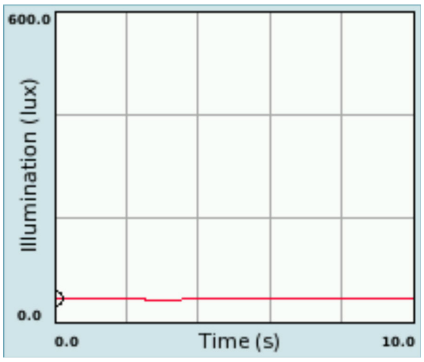

Figure 14 4.5V blue bulb, 1 samples/s, 0.5cm bead

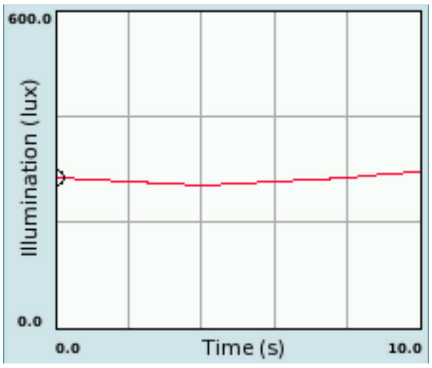

Figure 15 7.0V blue bulb, 1 samples/s, 1cm bead

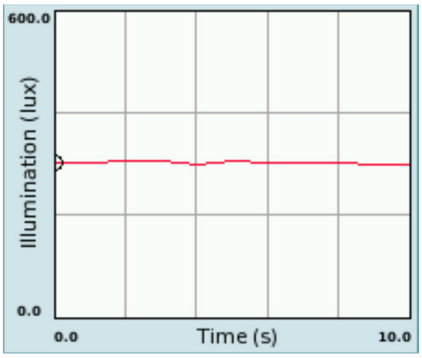

Figure 16 7.0V blue bulb, 1 samples/s, 0.5cm bead

Answers to questions

Obviously the students' answers will depend entirely on what they observed, but below are answers based on my observations.

Q1 It was easier to detect the slower moving model exoplanet.

Q2 It was not so easy to detect it producing a smaller change of light intensity in transit.

Q3 This makes the 'Sun' much brighter.

Q4 At higher light intensities it was easier to detect the model exoplanets.

Q5 At the much slower sampling rate it was much more difficult to detect the model exoplanets. A case of sampling too infrequently so that often the model exoplanet was not there to be detected.

Q6 Not much difference as the slow sampling rate made detection difficult regardless.

Q7 It was slightly more difficult to detect the model exoplanets with the model star emitting blue light. This may have been because the photodiode sensor was less sensitive to blue light than it was to the red light.

Useful weblinks

COROT
http://sci.esa.int/science-e/www/area/index.cfm?fareaid=39
COROT stands for Convection, Rotation and Planetary Transits and is an Earth-orbiting telescope with four CCD imagers detecting changes in the brightness of stars due to starquakes – a technique known as astroseismology. It was launched in December 2006 and is a mission led by the French National Space Agency CNES.

Extrasolar Visions – An Extrasolar Planets Guide
http://www.extrasolar.net/
This is excellent for the latest news of discoveries of extrasolar planets but, additionally, it has information on the science involved in such exoplanets and their discovery, plus a useful booklist and weblinks.

Hamamatsu Si Photodiode S1133
http://sales.hamamatsu.com/en/products/solid-state-division/si-photodiode-series/si-photodiode/part-s1133-01.php
Here is provided the Spectral response graph for the photodiode in the Vernier Light Sensor.

How to Find an Extrasolar Planet
http://www.esa.int/esaSC/SEMYZF9YFDD_index_0.html
This European Space Agency (ESA) website has brief but useful details of the key techniques being used to detect exoplanets.

Kepler Mission – Search for Inhabitable Planets
http://www.kepler.arc.nasa.gov/
This NASA website is a key one for information on the Kepler Mission, its purpose and importance. It includes detail on the instrument itself, of the transit method of detecting extrasolar planets (and other methods), together with a number of educational resources including simulations and a card model.

PlanetQuest- The Search for Another Earth
http://planetquest.jpl.nasa.gov/index.cfm
This Jet Propulsion Laboratory website has lots of news, history of the search from centuries back to the present day, a 3-D atlas of discoveries, games, simulations, movies and weblinks including those to educational resources.

STARE Project
http://www.hao.ucar.edu/public/research/stare/stare.html
This is the website of the Stellar Astrophysics and Research on Exoplanets. It has details of their discoveries, together with associated light curves, but also a little of the history of this quest and the various techniques employed.

Useful books

Distant Worlds: The Search for Planets Beyond the Solar System. Bruce Dorminey. Springer-Verlag New York Inc. 2000. ISBN 0387950745

Extrasolar Planets: The Search for New Worlds. Stuart Clark. John Wiley and Sons. 1998. ISBN 0471976342

New Worlds in the Cosmos: the Discovery of Exoplanets. Michel Mayor, Pierre-Yves Frei and Boud Roukema. Cambridge University Press. 2003. ISBN 0521812070