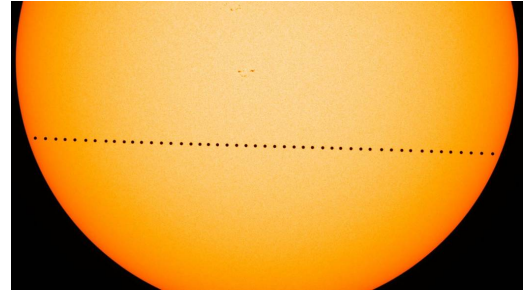# Discovering Exoplanets

With Transit Photometry

Introduction

- Consider the multiple billions of stars in our universe. What's your best guess, what percent of them have planets orbiting them?

- Explain why you think it may or may not be important to learn about these unknown worlds.

These are some of the questions that astronomers ask themselves in their search for exoplanets, planets outside of our own solar system. Currently, astronomers have found evidence of over 5300 exoplanets.

There are several methods by which astronomers can find evidence of exoplanets. These include both direct observation and indirect methods. One such indirect method is **transit photometry**. A transit occurs when a planet crosses in front of its star, and even planets in our own solar system transit the sun. For example, the transit of Venus is a rare event that occurred in 2014 and won't occur again until 2117. Check out this video of Venus' 2014 transit across the sun, viewed in different wavelengths of light: https://bit.ly/NASA_389

In this experiment, you will be constructing a model of a planet orbiting its star. Your goal will be to measure the change in brightness resulting from the planet transiting across the star.

Materials

- Arudino Nano 33 BLE Sense
- USB to micro USB connection cable
- Device (phone, tablet, iPad) with the *Phyphox* app (with added sensors) installed
- Frosted spherical lightbulb (size between apple and grapefruit)
- Clamp/socket to power the light bulb
- Wooden (or other) spheres of a couple sizes (ping pong ball size and smaller)
- Drinking straw, string, stick, or other means of holding on to your "planets"
- Masking tape
- Meter stick or ruler
- Support for holding Arduino in place (ring stand is fine, or other means of support)
- Laptop or other device with Excel
- Extension cord (if needed)
- White note card

Setting Up

1. Set up your light bulb and Arduino both in fixed positions approximately 1 m apart.
2. Tape the Arduino to a support at a height that matches the center of the bulb.
3. Dim the lights, so that the room is as dark as possible.

Procedure

1. Open the Phyphox app and select **the *Illuminance with Colors*** tool
2. Select your Arduino from the list of Bluetooth devices
3. In Phyphox, hit the ***record*** arrow
4. Rotate the planet in a motion to orbit the light bulb
    a. Make sure you maintain a **constant distance** from the bulb and **constant speed**
    b. Make sure the planet crosses at the **center of the light bulb**
    c. Record data until you have made a 4-5 complete orbits and hit ***stop***
    d. Try experimenting with distances for the Arduino and the planet or speeds until you are happy with your light curve

Note: In order to accurately visualize your transit you will likely need to "**pan**" and "**zoom**" to select a reasonable data range.

Draw your light curve in the table below for your first result, above (trial 1), then repeat the procedure for trials 2 and 3 with the adjustments listed in the table.

Trial	Setup	Sketch of the light curve (include units if you can)
1	Follow the procedure above to generate a light curve and sketch its appearance. From your graph, determine the orbital period of the planet (in seconds)?	
2	Move your planet at a **different** (but still constant) **speed**. Try to keep the **same distance** from the bulb as in trial 1. What is the orbital period of this planet?	
3	Use a different sized planet. Try to maintain the **same distance and speed** as in trial 1.	

Analysis

1. Refer to the graphs of the three trials you drew above.

    a. How did changing the speed of your orbit in trial 2 affect your light curve?

    b. How did changing the size of your planet in trial 3 affect your light curve?

2. Not all planets can be discovered via transit photometry. Under what conditions do you think the transit method might not be useful?

3. What aspects or technique of your data collection process do you think may have an impact on the quality of your graph?

4. What reasons can you think of why, up until recent years, exoplanets have been almost impossible to find?

Making your Own Eclipse

An eclipse is a type of transit where the transiting body completely or mostly covers the object behind it. You can model this phenomenon for yourself. With the existing set-up used,

1. Arrange the Arduino sensor a table length (a meter, more or less) from the bulb.
2. Tape a white notecard behind the Arduino to visualize and locate the shadow cast by the planet.
3. With the Phyphox app running, begin moving the planet away from the bulb toward the Arduino sensor (keeping the planet shadow centered on the Arduino).
4. Observe the graph created to the point at which the flux is reduced to zero.
5. Observe the relative position and size of the bulb and planet.
6. Explain why the flux is reduced to approximately zero.