Characterizing the TRAPPIST-1 Planetary System

Part 1. Planetary Radii

The depth of an exoplanetary transit is given by

$$D = (R_p/R_s)^2.$$

Rearranging terms and solving for the planetary radius gives us

$$R_p = \sqrt{D}R_s.$$

The radius of the star TRAPPIST-1 is 12.8 Earth radii, so in this system, the planetary radius is given by

$$R_p = \sqrt{D} \times (12.8R_e).$$

1. Listen to the "single-transit" light curves of the TRAPPIST-1 planets and rank them from smallest to largest.

2. The provided Excel workbook includes a ranked list of the measured transit depths. Use it to assign the right transit depth to each planet and calculate its radius in units of Earth radii.

Part 2. Planetary Temperatures

The equilibrium temperature of a planet is the temperature it should be given what we know about its host star and its orbit. Assuming that a planet absorbs all incoming starlight, its equilibrium temperature is given by

$$T_{eq} = T_{star}\sqrt{R_{star}/2a},$$

in which T_{star} is the stellar effective temperature, R_{star} is the stellar radius, and a is the planet's semimajor axis, or average distance from the star. Kepler's third law relates the orbital period of a planet to its semimajor axis by

$$P \propto a^{3/2}.$$

Plugging in what we know about the TRAPPIST-1 system and using Kepler's third law to replace the semimajor axis with orbital period gives us the following expression for the equilibrium temperature of a planet in the TRAPPIST-1 system as a function of its orbital period:

$$T_{eq} = \left(\frac{P}{1.51\,\mathrm{days}}\right)^{-1/3} 400\,\mathrm{K}.$$

1. Listen to the "20-day" light curves of the TRAPPIST-1 planets. Each second in these light curves represents one day of observations. With this information, estimate the orbital periods of each of the planets.

2. The provided Excel workbook includes a ranked list of the measured orbital periods. Use it to assign the precise orbital period to each planet and calculate its temperature in Kelvin.

Part 3. The Search for Life in the TRAPPIST-1 System

Characterizing exoplanetary atmospheres requires a lot of resources, so we have to focus on the most interesting candidates.

1. As a group, discuss which of these planets is the most like Earth. Are any of them too hot for life? Too cold for life? For reference, the equilibrium temperature of Earth is 255 K.
2. What other information about these planets would you like to know in order to prioritize follow-up observations?
3. As a group, assign a spokesperson to share with the whole class your answers to the previous questions and your reasoning.