1 Exoplanet Race to the Finish: Radius of HAT-P-7b

Recall the demonstration of transiting planet. The amount of light that a planet blocks is proportional to which of the following: its radius, area or volume?

You observe a star that periodically dims in brightness. Plotting its brightness versus time, you get the following light curve:

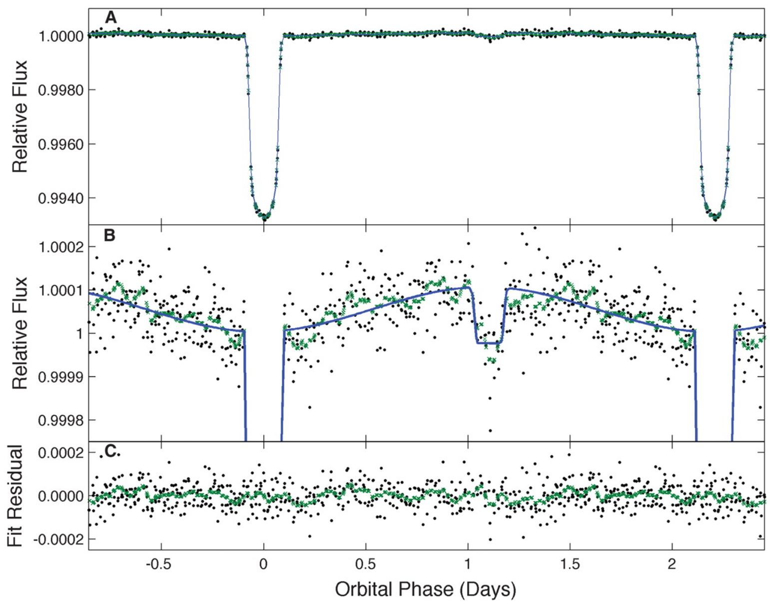

Figure 1: Kepler observations of Hat-P-7b. Plot A shows the full range of data [ignore B and C].

By what fraction does the star dim during its episodes of maximum dimming? Measure the difference between the flat part of curve A and the bottom of one of the dips.

Assume that a planet is blocking the starlight during this time. Find the area and radius of the potential planet in units of the stellar area and radius.

A_p/A_{star}:

R_p/R_{star}:

Jupiter is about 1/10 the radius of the sun. How does this planet compare to the radius of Jupiter (R_J) if the radius of the star is 1.8 times the radius of the sun? Use the following equation:

$$\frac{R_p}{R_J} = \left(\frac{R_p}{R_{star}}\right)\left(\frac{R_{star}}{R_{sun}}\right)\left(\frac{R_{sun}}{R_J}\right) = \left(\frac{R_p}{R_{star}}\right) \times 1.8 \times 10 \quad (1)$$

R_p/R_J:

2 Exoplanet Race to the Finish: Temperature of HAT-P-7b

You observe a star that periodically dims in brightness. Plotting its brightness versus time, you get the following light curve:

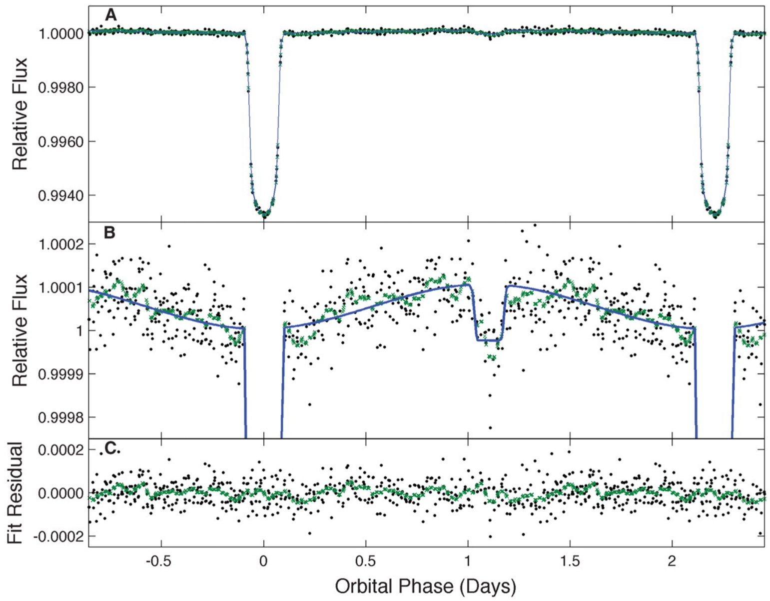

Figure 2: Kepler observations of Hat-P-7b. Plot A shows the full range of data [ignore B and C].

What is the period of this light curve, in days? Measure the time elapsed between two consecutive, identical drops in brightness. What is this period in years? (1 year = 365.25 days.)

Period (*days*):

Period (*years*):

Assume that the star is the mass of the sun. For such stars, Kepler's third law reduces to:

$$a^3/p^2 = 1 \quad (2)$$

where a is the average distance between the planet and the star in AU and p is the orbital period in years. Using this relation, find the average distance between the planet and its star in AU.

a (AU):

What is the average distance between the planet and the star in meters? (1 AU = $1.5 * 10^{11}$ m.)

a (m):

The temperature of a planet T depends on many factors, but the biggest heat contributor to planets near their stars is solar radiation. The solar radiation depends on (1) the power output of the star, L_{star}, and (2) the average distance between the planet and the star, a. This relationship can be expressed as

$$\frac{L_{star}}{L_{sun}} = \left(\frac{a}{a_E}\right)^2 \left(\frac{T}{T_E}\right)^4 \tag{3}$$

where $a_E = 1$ AU (Astronomical Unit) is the distance between the Earth and the sun, and T_E is the temperature of Earth's surface. Assuming $L_{star} = L_{sun}$, and a is measured in AU, this simplifies to

$$T = \frac{T_E}{\sqrt{a}} \tag{4}$$

Using a (in AU) and $T_E = 300$ K, find T in Kelvin.

T (K):

Is this planet too hot or too cold to sustain liquid water?

Do you think this planet is a likely place to find life? Why or why not?

3 Exoplanet Race to the Finish: Mass of HAT-P-7b

You obtain the following plot of the star's radial velocity as a function of time:

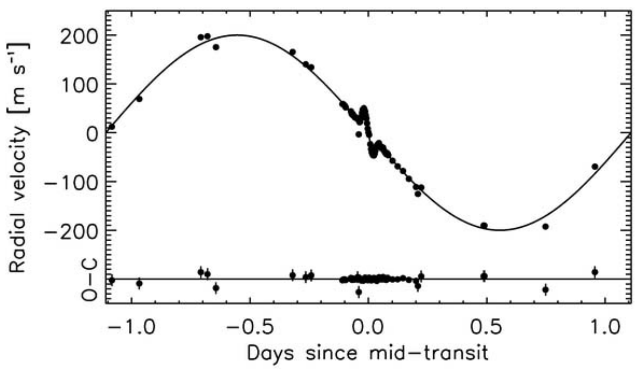

Figure 3: Radial velocity of HAT-P-7b versus time. The dots are the data, and the curve is the best fit to the data.

What is the maximum radial velocity of the star? Measure from zero to the top of the best fit curve.

v_r (m/s):

Newton's law of gravity (and his second law) tell us that a planet in an edge-on circular orbit will have a mass equal to

$$M_p = \left(\frac{P M_s^2}{2\pi G} \right)^{1/3} v_r \tag{5}$$

where M_p is the mass of the planet in kilograms, P is the orbital period in seconds, M_s is the mass of the star in kilograms, G is the gravitational constant, and v_r is the maximum radial velocity in meters per second. Assume M_s is the mass of the sun ($M_s = 2 \times 10^{30}$ kg) and use $G = 6.67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}. [Note: you don't have to convert any units!]

Use this equation to find the mass of the planet in kg.

M_p (kg):

4 Exoplanet Race to the Finish: Density of HAT-P-7b

The volume of a spherical planet is

$$V = \frac{4}{3}\pi R_p^3 \tag{6}$$

where R_p is the radius of the planet.

The density of a planet is

$$\rho = M_p/V \tag{7}$$

where ρ is the average density of the planet and M_p is the mass of the planet.

Substitute the volume (V) in equation 6 into equation 7 to get ρ in terms of M_p and R_p.

Consult with Group 1 to find the radius of the planet in Jupiter radii.

R_p/R_J:

The radius of Jupiter is $7 * 10^9$ cm. Multiply this by R_p/R_J to find the radius of the planet in centimeters.

R_p (cm):

Consult with Group 3 to find the mass of the planet in kg.

M_p (kg):

Convert this to mass to grams (1 kg = 1000 grams).

M_p (g):

Use the mass and radius of the planet to find its density, based on the formula you derived above, in grams per cubic centimeter.

ρ (g/cm^3):

The density of water is 1 g/cm^3. Is this planet more or less dense than water? What do you think this planet might be made of (rock, water or gas)? Do you think life could survive on this planet? Why or why not?