

Density of a Hot Jupiter

Last Thursday (February 1) in class, Professor Bailyn discussed a “Hot Jupiter” that is aligned in just the right way such that the planet periodically passes in front of the star (i.e. “transits”). We have observed another nearby sun-like star that also transits. In order to determine the composition of the star, you set out to measure the density. Since we know that density (ρ) = mass (M) / volume (V), we need to measure the mass and volume *of the planet* in order to get the density *of the planet*.

$$\begin{array}{lll}
 v = \frac{2\pi a}{P} & a^3 = P^2 M & 1 \text{ AU} = 1.5 \times 10^{11} \text{ m} \\
 v_* M_* = v_p M_p & V = \frac{4}{3}\pi R^3 & 1 M_\odot = 2 \times 10^{30} \text{ kg} \\
 \rho = \frac{M}{V} & A = \pi R^2 & 1 \text{ year} = 3 \times 10^7 \text{ s}
 \end{array}$$

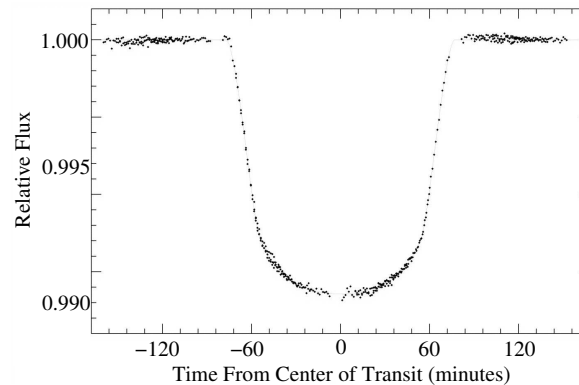
Step 1: Mass

From Doppler measurements, it’s been found that the reflex velocity of the star (due to the planet) is 85 m/s and that the period of the planet’s orbit is 3.5 days (= 10^{-2} yrs).

- What is the semi-major axis (a) of the planet’s orbit?
- What is the velocity of the planet in its orbit?
- What is the mass of the planet?

Step 2: Volume

In addition to the radial velocity measurements made above, you also observe the planet making transits across the star. These transits last for 2.5 hours and, at the point of greatest eclipse, block out 1% of the light from the star.



- Assuming that the *radius of the star* is the same as that of the Sun (7×10^8 m), what is the *radius of the planet*?
- What is the volume of the planet?

Step 3: Density

- What is the density of the planet?
- How does that density compare to that of water (1000 kg/m^3)?
- What does this density tell you about the composition of the planet?

BONUS: How could you have figured out the star's radius if that information were omitted from the problem?

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