<u>Extraterrestrial Life: Homework #5</u>

Due, in class, Thursday April 10th

1) Briefly explain the radial velocity (or Doppler) method for detecting extrasolar planets. Why does this technique work best for finding massive planets, and those in short period orbits around their host stars?

   The method is described in lecture #19. It works best for massive planets, and for those in short period orbits, because the amplitude of the radial velocity signal a planet induces on the host star is proportional to the mass of the planet (so more massive planets yield a larger, easier to detect signal), and inversely proportional to the square root of the orbital radius. So short period planets in close orbits also yield stronger signals.

2) What is meant by the term "hot Jupiters"? Why is the existence of these planets surprising in the context of the theory of planet formation that was developed to explain the properties of the Solar System?

   This is described in lecture #20.

3) The planet Saturn has a mass of 5.7×10^{26} kg and orbits the Sun at a distance of 1.4×10^{12} m. If Saturn were the *only* planet in the Solar System, calculate the velocity with which the Sun would move around the center of mass of the Sun + Saturn system.

   Need to use the formula for the stellar velocity caused by a planet that is given in lecture #19:

   $$v_* = \frac{M_p}{M_*}\sqrt{\frac{GM_*}{a}}$$

   Substituting the numbers, remembering that "a" in the above equation is the orbital distance, I find: $v_* = 2.8$ m/s.

4) An extrasolar planet orbits a Solar mass star in a circular orbit at a distance of 0.05 AU. Calculate the orbital velocity of the planet and the orbital period of the planet.

   Calculate the orbital velocity from the formula in lecture 19:

   $$v_p = \sqrt{\frac{GM_*}{a}}$$

   Convering first AU into meters, I get $v_p = 1.33 \times 10^5$ m/s (or 133 km/s).

The orbital period comes from noting that the circumference of the orbit is 2π x (0.05 AU) = 4.7 x 10^{10} m. The orbital period is the distance the planet travels divided by the velocity: 4.7 x 10^{10} m / 1.33 x 10^5 m/s = 3.5 x 10^5 s (or 4 days).

5) The same extrasolar planet (orbiting at 0.05 AU) has a radius of 9 x 10^7 m. If the atmosphere of the planet reflects 50% of the star's light, calculate the fraction of the stellar luminosity that is intercepted and reflected by the planet.

The same considerations described in lecture #6 apply to this problem. The fraction of reflected sunlight is:

$$f = \frac{\text{stellar flux } \times \text{ area of planet seen from star } \times \text{A}}{\text{stellar luminosity}}$$
$$= \frac{L}{4\pi d^2} \times \frac{\pi R_p^2}{L} \times A$$
$$= \frac{R_p^2 A}{4d^2}$$

where d is the planet-star distance and R_p the planet's radius. Note that the stellar luminosity L cancels out. A is the albedo. Numerically, one finds f = 1.8 x 10^{-5}.