Physics of Planetary Systems — Exercises — Set 10

Problem 10.1 *(2 points)*

The transiting planet WASP-19b has an orbital period of 0.79 d, a radius of 1.3 $R_{\rm Jup}$ and a mass of 1.15 $M_{\rm Jup}$. It orbits a G8 V star with an effective temperature of 5500 K , a radius of 0.93 $R_\odot$, and a mass of 0.95 $M_\odot$. Assuming a Bond albedo of 0.1, how many times more (or less) light would you see in radiated light compared to reflected light from this planet at a wavelength of 2 µm?

Problem 10.2 *(2 points)*

Consider an M5 V star ($T_{\rm eff} = 3170$ K, $R = 0.27\,R_\odot$, $\mathscr{M} = 0.27\,\mathscr{M}_\odot$). Calculate the distance from the star (in astronomical units) an Earth-mass planet would have to have for an equilibrium temperature of 323 K (middle of the habitable zone). Assume an Earth-like albedo for the planet. What would be the expected radial velocity amplitude for this star, assuming a circular orbit? Could such a planet be detected with radial velocity measurements with a modern spectrograph?

Problem 10.3 *(1 point)*

Estimate the critical planet mass below which the timescale for type-II migration is as short as the gas accretion timescale.

Bonus problem 10.4 *(3 extra points)*

As you know, a sufficiently massive planet opens a gap in a surrounding gas disk. This happens if the orbiting planet removes gas along its orbit faster than the viscous accretion brings new material into the gap.
Derive an alternative gap opening criterion based on the following assumptions. Imagine a gas disk with a planet trying to eat a gap with a width of (twice) the planet's Hill radius. Assume that the gas is refilling the gap "behind" the planet at the radial gas drift speed of a viscous accretion disk, $v_{\rm r}$. Estimate the minimum planetary mass needed in order to create a gap that is still open when the planet reaches the same region of the gas disk again. How massive has the planet got to be to successfully clear a gap?

Figure 1: Annular gaps in the famous protoplanetary disk around HL Tau.

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