AS3012: Exo-Planetary Science

Tutorial Sheet 1

1. Estimate the flux ratio between the Sun and the Earth, as seen by a distant observer:

   (a) In the visible, by assuming that the Earth directly reflects a fraction A of the Sun's photons back into space. (A is the albedo).

   (b) In the infra-red at 10 μm, by assuming that the Earth absorbs all incident stellar radiation, and reaches the equilibrium temperature at which this absorption is balanced by blackbody emission.

   Possibly useful parameters: the Earth-Sun distance is 1 AU $= 1.5 \times 10^{11}$ m, the Solar radius is $R_\odot = 6.4 \times 10^6$ m, the Solar effective temperature is $T_\odot \approx 6000$ K, the Planck function is

   $$B_\nu(T) \propto \frac{\nu^3}{e^{h\,\nu/k\,T} - 1} \ .$$

2. Consider observing the Earth-Sun system at distance $d = 10$ pc using an optical telescope with diameter D. Approximating the point-spread function as a Gaussian with diffraction-limited angular size $\Delta\theta \sim \lambda/D$, estimate D such that the Earth is detectable against the stellar glare. How can we do better by careful design of the instrumentation?

3. Future astrometric surveys (GAIA, SIM) are designed to achieve an accuracy $\sigma_\theta \approx 10^{-5}$arcsec. For targets at $d = 10$ pc (and 100 pc), show how the minimum detectable planet mass m_p scales with orbital radius a. Estimate the orbit radius beyond which astrometry becomes more sensitive than radial velocity searches.

4. Calculate the angular size of the Einstein Ring for an 0.3 $M_\odot$ star at $D_L = 4$ kpc lensing a source in the Galactic Bulge at $D_S = 9$ kpc. If the source star has a radius $R_S = 10\ R_\odot$, estimate the lens mass M_L for which the finite size of the source star leads to a breakdown of the point source approximation.

5. A planet with radius $r_p = 0.05\ R_\odot$ orbits a main-sequence K star ($R_\star = 0.8\ R_\odot$, $M_\star = 0.8\ M_\odot$) at an orbital radius $a = 0.5$ AU. If the inclination angle of the planet's orbit to the plane of the sky is $i = 89.8°$, calculate the duration and depth of an observed transit. What is the maximum orbital radius at which a transit would be detected?

6. Explain the concept of limb-darkening and how it affects the shape of a transit lightcurve.