Astronomy 11 — Fall 1998 (S.T. Myers)

Homework Set 3

Due Thursday October 22, 1998 (5pm)

1. Jupiter orbits the Sun with a semi-major axis of 5.2 AU. The Galileo spacecraft is currently in orbit around Jupiter, and requires around 500 Watts of power to run the instruments and on-board systems. How large a solar panel would be needed (in m^2) to generate this amount of power at Jupiter, assuming all of the solar flux could be converted into electricity at perfect efficiency? If the panel acted as a blackbody and was in thermal equilibrium with the solar radiation, at what temperature would it be (in K)?

2. The *habitable zone* is defined to be the region around a star in which life-bearing planets might be expected to exist. Roughly, we might define this to be the orbital radii at which the equilibrium temperature of a planet would be within 100° C of freezing water: $T_{eq} = 273 \pm 100$ K. Calculate the inner and outer radii of the habitable zone (in AU) around our Sun. (You may assume the albedo and greenhouse factors are equal.) Which planets are in the zone?

3. The albedo of the Moon is about 7%, that is, 7% of the incident light is reflected back into space. What would you expect the temperature of the sunlit side of the Moon to be? (There is no atmosphere to transport the energy to the dark half!) Compare this to the expected average temperature of the Earth.

4. Venus is swathed in a thick cloud deck, with the real surface completely hidden from our view in visible and IR light. The thick clouds act like insultation, and thus the apparent temperature of Venus (as far as its blackbody spectrum) should be the equilibrium temperature at its distance from the Sun, setting the albedo and greenhouse factors equal. Calculate this temperature (assume the orbital semimajor axis for its distance from the Sun).

On the real surface, however, the clouds act like an immense runaway greenhouse! The Russian *Venera* lander found a surface temperature of 700K! If the measured albedo of the clouds is $A = 0.76$, and the surface temperature is 700 K, what is the greenhouse factor G? This is an example of a *runaway greenhouse effect*, where all the available surface water and CO_2 in the rocks has gone into the atmosphere.

5. There have been many hypotheses of planets further from the Sun than Pluto. For example, if we apply *Bode's Rule* (see Lecture 8) to find the next planet out from Neptune, ignoring Pluto, we would expect it to have an orbital semi-major axis of 77.2 AU. As for composition, might assume that it is like (A) a gas giant, or (B) an iceball like Pluto. In the questions below, consider both these possibilities.

(a) What would we expect the temperature of such a hypothetical Planet X to be for these two possibilites?

(b) Using Wien's Law, what would the wavelength of the maximum emission be? What part of the electromagnetic spectrum would this be in?

(c) Assume (optimistically) that this Planet X is the same size as Neptune. What would the total blackbody luminosity from Planet X be? What would the flux be from Planet X at the Earth? (Assume circular orbits at closest approach.)

(d) What would the angular diameter of this planet appear to be on the sky from the Earth (in arcseconds, at closest approach)? (Hint: The angular diameter is the angle corresponding to the diameter of the planet at the given distance from the observer, or the angle subtended by the physical diameter. In practice, it is calculated using the small angle approximation to the triginometric functions, and is similar to the parallax calculation.)