Astronomy 11 — Fall 1998 (S.T. Myers)

Homework Set 6

Due Wednesday November 25, 1998 (5pm)

Some of these questions appeared on Midterm 2, but are repeated here to make sure you all know how to do them:

1. In the year 2014, and the Extrasolar Planet Survey program at the Daedalus Lunar Farside Observatory found yet another star in the neighborhood of the Sun which has a planetary system! Tentatively designated EPS-451, this system is now the target of a full-scale exploration program.

(a) Observations of changes in the position of EPS-451 against the more distant background stars, or *parallax*, is used to find its distance. In two observations 6 months apart, EPS-451 is seen to shift its position by 0.1 arcseconds, and thus its parallax $p = 0\overset{\prime\prime}{.}05$. How distant, in AU, is EPS-451 from the Sun?

(b) How far away is EPS-451 in light-years?

(c) Spectroscopic observations find that it has a K0V spectrum which is slightly redder than that of our Sun, with a wavelength of maximum intensity of 5882Å. What is the temperature of the star?

(d) Photometric observations over a large wavelength range find that the total flux from EPS-451 is a factor 2.35×10^{-14} of that from the Sun (at 1 AU) as seen from Earth. What is the luminosity of EPS-451 in units of the solar luminosity $L_\odot$?

(e) Using the blackbody relations, calculate the radius of EPS-451, in units of the solar radius ($R_\odot$).

2. The *habitable zone* of a star is the range of orbital radii where the planet temperature is expected to be able to sustain life of some sort. This is generally accepted to be where the temperature is ± 100 K from freezing, or in other words $T = 273 \pm 100$ K. Assuming that the albedo A equals the greenhouse factor G, and thus the temperature is the equilibrium temperature for a spherical blackbody, calculate the habitable zone (in AU) for EPS-451. Compare this to the Sun's habitable zone.

3. The Daedalus Lunar Far-Side Observatory, a 25m UV-optical-IR telescope located in the crater Daedalus on the far side of the Moon, is used to image the EPS-451 system. A series deep images with the coronograph (a disk which blocks out the light from the star on the CCD) were taken by the faint-object team, who found a number of planets orbiting the star.

(a) A large planet is seen to be in an orbit with semi-major axis 0.35 arcseconds from EPS-451, with a period of 20 years 258 days. What is the semi-major axis of this orbit in AU, and what is the mass of EPS-451 in solar masses $M_\odot$?

(b) Derive a relation for the subsolar T_{ss} and the equilibrium temperature T_{eq} at some distance r_{AU} (in AU) from EPS-451. For the equilibrium temperatures assume the albedo and greenhouse factors are equal. Use these relations to determine the expected mean and subsolar temperatures of each planet.

(c) There seem to be at least 7 planets in the system. Unfortunately, the planets are too dim, and the glare of EPS-451 is too bright to get spectroscopy, and thus temperatures, for the planets, but their apparent orbital semi-major axes and periods were determined by monitoring their motions over a 20-year baseline (the longer period planets have poorly determined periods). These are shown in the table below. For each planet, determine the missing information: semi-major axis in AU, orbital period in years, T_{eq}, and/or probable classification (terrestrial, Jovian, iceworld). Be sure to explain your reasoning (especially for classification).

Orbit	**Semimajor Axis**		**Period**	T_{eq}	**probable class**
no.	(arcsec)	(AU)		(K)	
1	0.005		12.9 d		
2	0.08		945.4 d		
3	0.125		4 y 153 d		
4	0.20		8.9443 y		
5	0.35		20.706 y		
6			52.4 y		
7			140 y		
8			$\sim$ 400 y		

In 2039, NASA plans to send a set of space probes to the system, and you have been assigned to teams charged with the responsibility of designing the missions. See the course web-page for your team assignments and for further information.