Name: ______________________________________

Homework 8 – Ast 281 – Spring 2009
Due Thursday 3/19/09 – 12:00pm, Watanabe 420 – 100 points total

Up until the last 15 years, there had been no unambiguous detection of an extra solar planetary system, but now we know of a large number of systems. Attached is a table of some of these planetary systems. The mass is in Jupiter masses (= M_P/M_{Jup}); this is the ratio of the mass of the planet to the mass of Jupiter. The term a is the semi-major axis of the orbit – the average sun-planet distance, and the luminosity class, or star type is listed for some objects. Recall that luminosity class is a measure of the temperature of the star. The spectral, or luminosity classes which run from hot to cold are: OBAFGKM.

1. You have been given a sheet of "graph" paper, attached to this homework. Plot the distance from the star for each extrasolar planet in the table at the end of the homework on the graph. Note that a few planetary systems have more than one planet. Skip these systems on the big plot, and plot them on the small graph paper. Also plot Mercury through Jupiter on the chart (use your constants sheet for the distances). We know that the the mass of the planet is related to its radius in the following manner:

$$M = \frac{4\pi R_P^3 \rho}{3} \qquad (1)$$

where M is the mass of the planet, R_P is the radius of the planet and ρ the density of the planet. We can use this relation to scale the expected sizes of the planets to the size of Jupiter which we know, by using the masses in the table above and the following relation

$$\frac{M_P}{M_{Jup}} = [\frac{R_P}{R_{Jup}}]^3 \qquad\qquad R_P = R_{Jup}[\frac{M_P}{M_{Jup}}]^{1/3} \qquad (2)$$

When you plot the planets as a function of distance from their stars, make the size of the planet symbol scaled properly to Jupiter using the formula above. M_P/M_{Jup} is given in the Table, and R_{Jup} is whatever size you select for plotting Jupiter. [Hint: If the diameter of Jupiter were = 1 cm, the 7th column in the table would be the diameter of the planets in cm. The squares on the graph sheet are ∼0.5 cm in size.] [20]

2. Of the planetary systems listed in the table, which if any are totally unsuitable for life? Define the characteristics of a planet which make it suitable for life. [5]

3. Does the layout of any of the planetary systems surprise you from the point of view of our discussion of star and planetary system formation? <u>Why or why not</u>? [10]

4. Since we believe that liquid water is important for life to exist, we need planets to be at the right distance from the star they orbit so that the temperatures fall between 0-100°C (273-373K, the freezing point and boiling point of water). Around any star, there is a narrow region in distance called the **zone of habitability** where the temperatures are just right and liquid water can exist. The size of this zone depends on the spectral class of star. Table 1 shows the approximate locations of habitable zones around different types of stars:

Table 1: Habitable Zones Around Stars

Star Type	**Temperature**	**Inside Edge** [AU]	**Outside Edge** [AU]
O	35000	115	215
B	21000	40	75
A	10000	5	10
F	7200	2	3.7
G	6000	0.9	1.6
K	4700	0.7	1.2
M	3300	0.1	0.2

(a) Use the small graph paper (included in the homework), and mark the position of the planets in our solar system on the graph. Plot the position of the extra solar planets for the planetary systems which have more than one planet on the graph. There are three such systems: υ And (3 planets), GJ876 (3 planets) and HD 168443 (2 planets). Use their relative masses in terms of Jupiter to scale their sizes. [10]

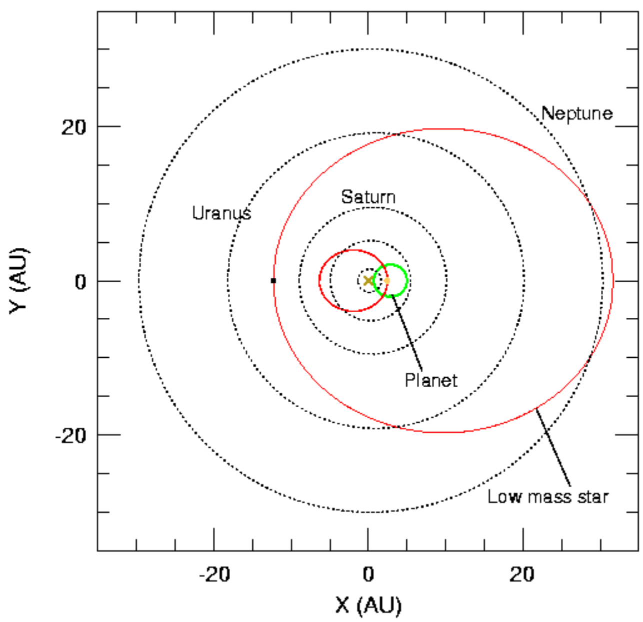
(b) Indicate for each Star system, the zones of habitability. [5]

(c) Do any of the planets in the graph fall inside the zones of habitability? Which? [5]

(d) If you were going to search for life in one of the extrasolar planetary systems, which one would you search and why? [10]

(e) One planet is just outside the zone of habitability. Which one is it? Can you think of any way that this planet might be warm enough for liquid water? [5]

(f) Are there any planets in our solar system which are close to the zones edges? Do they have conditions that would be expected for liquid water? Can you guess why? [10]



5. The star system, γ Cep, is a binary system with stars of masses 1.59$M_\odot$ (spectral class K1) and 0.4$M_\odot$ (spectral class M1) orbiting their common center of mass every 74 years. The orbit of the two stars is quite eccentric (e = 0.44; recall that a circular orbit has an eccentricity of 0 and a parabola an eccentricity of 1). This star system is the first binary to have had a planet discovered. The planet, with mass 1.76M_{Jup}, orbits the more massive star every 2.5 years, in an orbit with an eccentricity of e=0.2, and a semi-major axis of a = 2.03AU. At perihelion of the planet it is at a distance of 1.7 AU from the more massive star, and at a distance of 2.6 AU when it is at aphelion. The planet is 12 AU from the less massive star at perihelion and at 32 AU at aphelion.

(a) Comment on whether or not you believe there is a habitable zone in this system, and if the planet could be within the habitable zone. [10]

(b) Suppose a planet in a circular orbit around a star is orbiting within that star's habitable zone. What will be the effect of an extreme planetary obliquity (*e.g.* something greater than about 60°) on the planet's habitability? [5]

(c) Suppose a planet had extremely slow rotation – that it was in synchronous rotation which means the rotation period is the same as the orbital period. What effect would this have on the habitability? [5]

Table 2: Masses & Orbits of Extrasolar Planets (1/9/01)

#	Star Name	Mass [M_{Jup}]	Period [days]	Orbit Size [AU]	Eccen	**[$M_P/M_{Jup}]^{1/3}$**	Star type
1	HD 83443	0.35	2.986	0.038	0.08	0.7	
2	HD 46375	0.25	3.024	0.041	0.02	0.6	
3	HD 187123	0.54	3.097	0.042	0.01	0.8	
4	HD 179949	0.86	3.092	0.043	0.0	1.0	
5	τ Boo	4.14	3.313	0.047	0.02	1.6	
6	BD-103166	0.48	3.487	0.046	0.05	0.8	
7	HD 75289	0.46	3.508	0.048	0.00	0.8	
8	HD 209458	0.63	3.524	0.046	0.02	0.9	
9	51 Peg	0.46	4.231	0.052	0.01	0.8	
10	υ And b	0.68	4.617	0.059	0.02	0.9	F
11	HD 168746	0.24	6.400	0.066	0.00	0.6	
12	HD 217107	1.29	7.130	0.072	0.14	1.1	
13	HD 162020	13.73	8.420	0.072	0.28	2.4	
14	HD 130322	1.15	10.72	0.092	0.05	1.0	
15	HD 108147	0.35	10.88	0.098	0.56	0.7	
16	HD 38529	0.77	14.31	0.129	0.27	0.9	
17	55 Cnc	0.93	14.66	0.118	0.03	1.0	
18	GJ 876	4.23	15.80	0.117	0.04	1.6	
19	HD 195019	3.55	18.20	0.136	0.01	1.5	
20	HD 6434	0.48	22.0	0.15	0.3	0.8	
21	HD 192263	0.81	24.35	0.152	0.22	0.9	
22	HD 83443c	0.16	29.83	0.17	0.42	0.5	
23	GJ 876c	0.56	30.12	0.13	0.27	0.8	M
24	ρ CrB	0.99	39.81	0.224	0.07	1.0	
25	HD 168443b	7.73	58.10	0.29	0.53	2.0	G
26	GJ 876b	1.90	61.02	0.21	0.1	1.2	M
27	HD 121504	0.89	64	0.32	0.13	1.0	
28	HD 16141	0.22	75.80	0.351	0.28	0.6	
29	HD 114762	10.96	84.03	0.351	0.33	2.2	
30	70 Vir	7.42	116.7	0.482	0.40	1.9	
31	HD 52265	1.14	119.0	0.493	0.29	1.0	
32	HD 1237	3.45	133.8	0.505	0.51	1.5	
33	HD 37124	1.13	154.8	0.547	0.31	1.0	
34	HD 169830	2.95	230.4	0.823	0.34	1.4	
35	υ And c	2.05	241.3	0.828	0.24	1.3	F
36	HD 12661	2.83	250.2	0.799	0.20	1.4	
37	HD 89744	7.17	256.0	0.883	0.70	1.9	
38	HD 202206	14.68	258.9	0.768	0.42	2.4	
39	HD 134987	1.58	260.0	0.810	0.24	1.2	
40	ι Hor	2.98	320.0	0.970	0.16	1.4	
41	HD 92788	3.86	337.7	0.97	0.27	1.6	
42	HD 177830	1.24	391.0	1.10	0.40	1.1	
43	HD 27442	1.13	426	1.15	0.02	1.0	
44	HD 210277	1.29	436.6	1.12	0.45	1.1	
45	HD 82943	2.3	442.6	1.2	0.6	1.3	

Table 3: Masses & Orbits of Extrasolar Planets (1/9/01) – Contd.

#	**Star Name**	**Mass** [M_{Jup}]	**Period** [days]	**Orbit Size** [AU]	**Eccen**	**[M_P/M_{Jup}]$^{1/3}$**	**Star type**
46	HD 222582	5.18	576.0	1.35	0.71	1.7	
47	HD 160691	1.87	743	1.6	0.62	1.2	
48	16 Cyg B	1.68	796.7	1.69	0.68	1.2	
49	HD 10697	6.08	1074.0	2.12	0.11	1.8	
50	47 UMa	2.60	1084.0	2.09	0.13	1.4	
51	HD 190228	5.0	1127	2.3	0.43	1.7	
52	υ And	4.29	1308.5	2.56	0.31	1.6	F
53	14 Her	5.55	2380.0	3.5	0.45	1.8	
54	ϵ Eridani	0.8	2518.	3.4	0.6	0.9	
55	HD 168443c	17.1	1770	2.87	0.20	2.6	G

Table 4: **Multiple ExtraSolar Planetary Systems – Question 1 graph**

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