Astro 205. Midterm Exam, Wednesday October 22, 2003

Please write and sign the pledge on your exam booklet. Be sure to be explicit about the units of all numbers and show your work. The exam is closed-book, and calculators are allowed. Good luck!

Constants, formulae etc.

Sun's mass = 2×10^{33} gm = 1 $M_\odot$
Sun's radius = 7×10^{10} cm = 1 $R_\odot$
Earth mass = 6×10^{27} gm
Jupiter mass = 10^{-3} $M_\odot$
Jupiter radius = 0.1 $R_\odot$
constant of gravity G = 6.7×10^{-8} $\mathrm{gm^{-1}cm^3s^{-2}}$
Energy released by hydrogen fusion in stars: E = 0.007 m c^2
Luminosity of a black body: L = 4 $\pi R^2 \sigma T^4$
R = radius, T = temperature, σ = 5.7×10^{-5} erg $\mathrm{cm^{-2}\ s^{-1}\ K^{-4}}$
speed of light c = 3×10^{10} cm/sec
Planet orbits:

$$\frac{\mathrm{m_p v_p^2}}{\mathrm{r_p}} = \frac{\mathrm{GM_\star m_p}}{\mathrm{r_p^2}}$$

where $\mathrm{m_p}$ is the mass of the planet, $\mathrm{v_p}$ is its speed, $M_\star$ is the mass of the star, r_p is the distance between the planet and the star and G is the constant of gravity.

1. (10 points) True or false?

a. The only possible orbit for a planet bound to a star is circular.
b. The Earth's seasons are due to the inclination of its axis of rotation to its orbital plane.
c. Although the gravitational microlensing technique would allow detection of distant extrasolar planets with masses as small as that of the Earth via observations with ground based telescopes, none have yet been found by this method.
d. The Sun's luminosity varies periodically by about a factor of two with a period of 11 years.
e. Most of the planets which have been found outside the solar system to date have been detected by direct imaging, where you see faint points of light near the star.

2. (20 points) Briefly describe two different methods which have been suggested to detect planets around other stars. For each, describe one limitation of the method, and roughly how many planets (if any) this method has detected to date. Three sentences per method should be adequate. Please write in complete English sentences.

3. (20 points) Consider two stars, of masses A and B:
mass of star A = 2 $\times$ mass of star B
photospheric temperature of star A = 2 $\times$ photospheric temperature of star B
radius of star A = 1.1 $\times$ radius of star B

Calculate the ratio of the main sequence lifetimes of the two stars, assuming that each can use all of its available fuel. Assume also that the stars are initially composed of pure hydrogen, that they radiate like black bodies, and that their temperatures and radii stay constant with time.

4. (50 points) You discover the transit of an object with the same radius as Jupiter across a star of the same radius and mass as those of the Sun.
a. Calculate the fraction of the star's light that is blocked by the object.
b. The object's orbital period around the star is three days (that is, days measured in Earth-time!), and its orbit is circular. What is the distance between the object and the star? Express your answer in kilometers or centimeters.
c. You observe this orbit exactly edge-on. How long does the transit last? Express your answer in seconds.
d. We have said several times in class that the largest possible cold object has approximately the radius of Jupiter, and that objects with this radius range in mass from about 1/3 of Jupiter's mass to about 75 Jupiter masses. Objects of mass greater than about 10 Jupiter masses are brown dwarfs. Does your transit observation tell you whether you are observing a brown dwarf or a planet? If not, what additional observation(s) would you have to carry out to determine this?