3 Nov 2008 **Ay 20** E.S. Phinney

Basic Astronomy and the Galaxy

Problem Set 4

Due **in class** *Monday* 10 November, 2008

Readings: Carroll & Ostlie Chapters 8 and 9.

Homework Problems:

1. Figure 1 shows the radial velocity as a function of time for the star 51 Pegasi, which is a star just a little bigger and brighter than the sun. The surface temperature of 51 Pegasi (estimated from its colors and spectrum) is 5660 K. Its luminosity (computed from its flux and parallax) is $1.3L_\odot$.

   a) Estimate the mass of 51 Pegasi to two significant figures, using C&O figure 7.7. (*Hint:* fit a straight line to $\log L$ vs $\log M$).

   b) Find the radius of 51 Pegasi to two significant figures.

   c) What is the full range of variation of the wavelength of the $H\beta$ spectral line in 51 Pegasi, in Ångstroms?

   d) Look at the spectrum in Figure 2 (of the sun, but 51 Pegasi is pretty similar), and consider the problem of determining its central wavelength. Decide if Hβ is a good line to use to study the radial velocity. What would be a better method, and which lines in the figure do you think would contribute most to the signal?

   e) The radial velocity modulation repeats every 4.231 days. Assuming that this is caused by an orbiting planet, compute

      i. the semi-major axis of its orbit.

      ii. a lower limit to the mass of the orbiting planet.

   f) Assuming that the planet reflects half of the starlight incident on it, and reradiates the other half (absorbed) of the incident starlight as a black body, what is the surface temperature on the equator of the planet at high noon?

2. a) Suppose a planet just like Jupiter orbited a distant star just like the sun in a circular orbit just like Jupiter's. Estimate the fractional decrease in the brightness of the star when the planet transits (passes in front of the star). You may assume you are observing a flat disk of constant flux, with a temperature of $T_e = 5777$K.

   b) Given a whole collection of such star-Jupiter systems with *randomly oriented orbits* (i.e. direction of the angular momentum axis randomly oriented on the unit sphere with polar axis pointing toward earth), what fraction of them will have planet transits as seen from earth? What fraction will be be grazing transits (with depths less than you estimated in part 2a) instead of full transits?

   c) If the planet orbiting 51 Pegasi (problem 1e) were to have the same size as Jupiter, and its orbit were oriented so as to be edge-on to the earth, what would be the fractional decrease in the brightness of the star during the planet's transit?

d) Given a whole collection of such 51-Pegasi like systems *randomly oriented orbits* (i.e. direction of the angular momentum axis randomly oriented on the unit sphere with polar axis pointing toward earth), what fraction of them will have planet transits as seen from earth?

e) Look up some information on the French COROT space mission (launched Dec 27, 2006) and the NASA Kepler Mission (to be launched 2010) and write a paragraph explaining their capabilities.

3. Carroll & Ostlie problem 8.5

4. Carroll & Ostlie problem 8.9

5. Carroll & Ostlie Problem 8.14

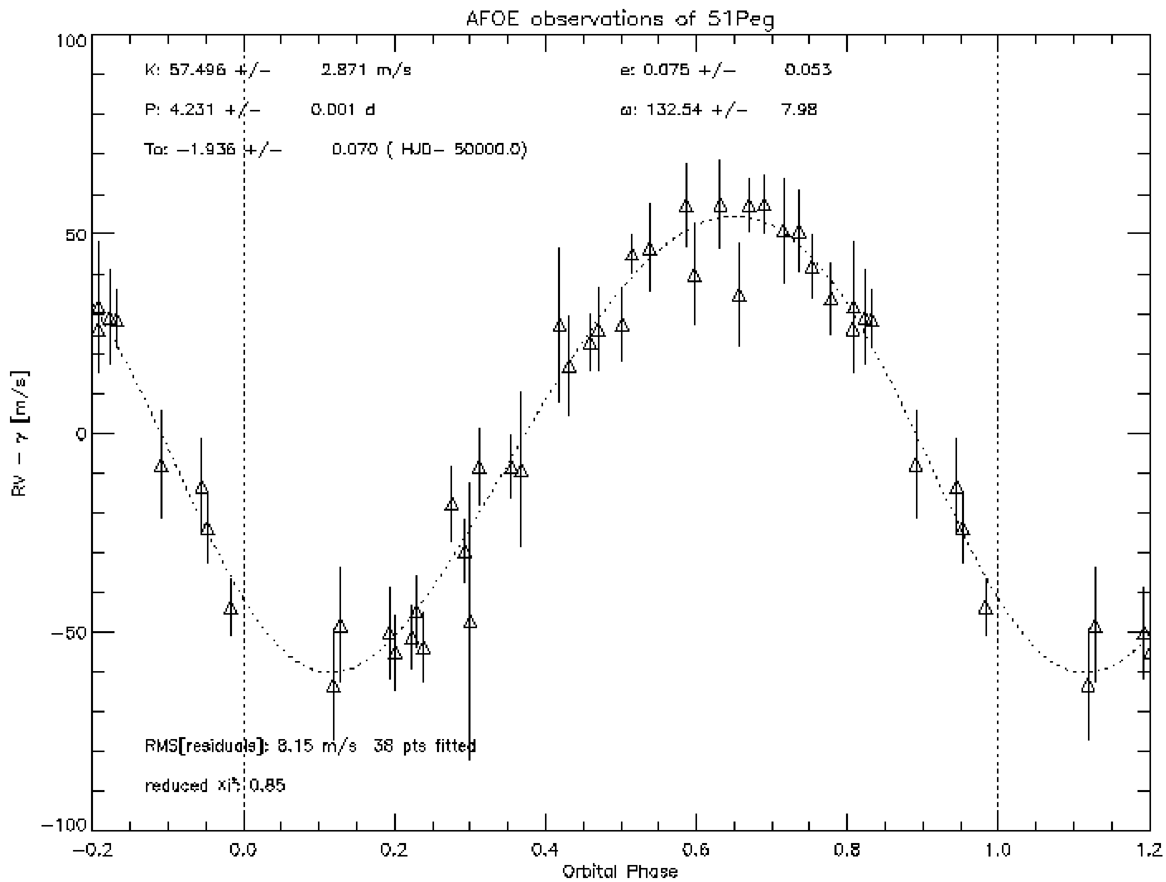

Figure 1: Radial velocity curve of 51 Pegasi. Vertical axis is in meters per second. Horizontal axis is time divided by the period $P = 4.231$ days.

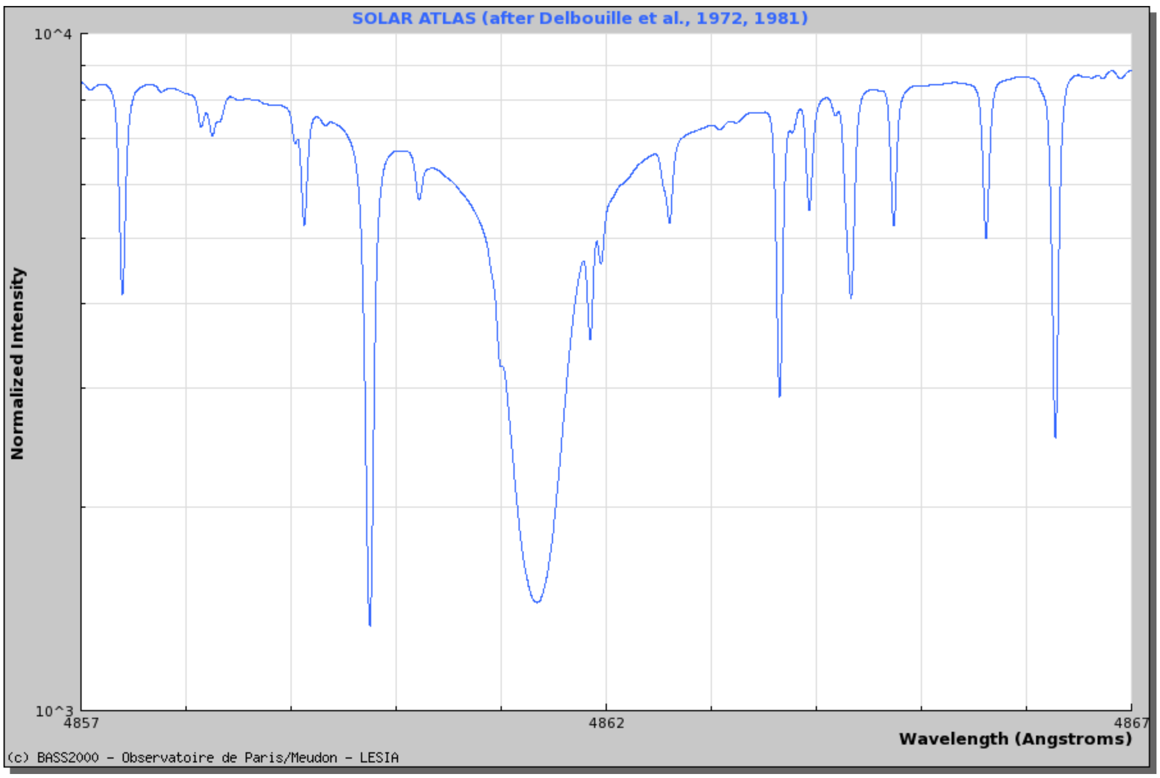

Figure 2: Spectrum of the sun near the Hβ line (4861.3Å), as a function of wavelength in Ångstroms.