

ASTRONOMY 12

Problem Set 2 – due Thursday, Feb. 9, 2012

Longer problems

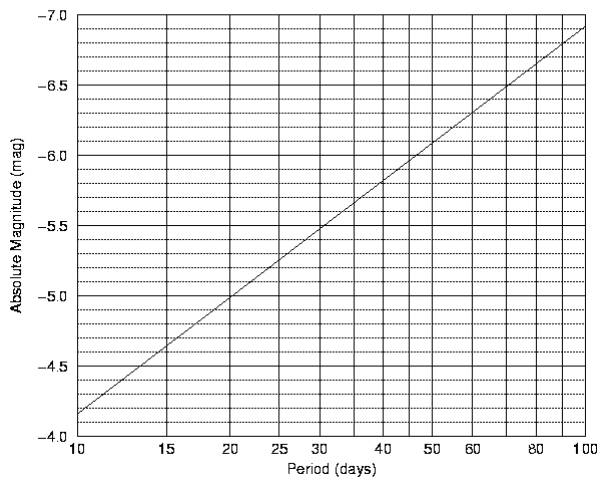
1) Supernovae are very bright, but do you think that they pose a biological hazard? Consider a typical (Type II) supernova with $L_{\text{peak}} = 10^9$ solar luminosities. (This kind comes from the death of a massive star and is more common than the brighter Type Ia supernovae discussed so far in class). At what distance, in parsecs, would that supernova have a brightness equal to that of the sun? At what distance would it be 10 times fainter than the sun? Compare that to the distance to the nearest star, Alpha Centauri. (nb. $1 \text{ AU} = 1/206265 \text{ pc}$).

2) A nearby star has a parallax angle of 10 milli-arcseconds, i.e., $p = 0.01''$. If that star has an apparent magnitude of $m = 6.0$, what is its absolute magnitude? Is it more or less luminous than the sun? (Ignore bolometric corrections.)

3) a) Given below is the approximate period-luminosity relation for *Type I* Cepheid Variables. If a Type I Cepheid variable star is observed (in another galaxy) with a period of 50 days and if that Cepheid has an apparent magnitude $m = 20.0$, what is the distance to that Galaxy in parsecs?

b) Suppose another Cepheid also with $m = 20.0$ had that same period, but was actually *Type II* and thus had an *absolute* magnitude 1.5 magnitudes larger (i.e., less negative and therefore fainter) than plotted here, [or alternatively the diagram had been miscalibrated by 1.5 magnitudes due to the neglect of dust and reddening], what would be the revised distance? By what factor does your answer in b) differ from that in a)?

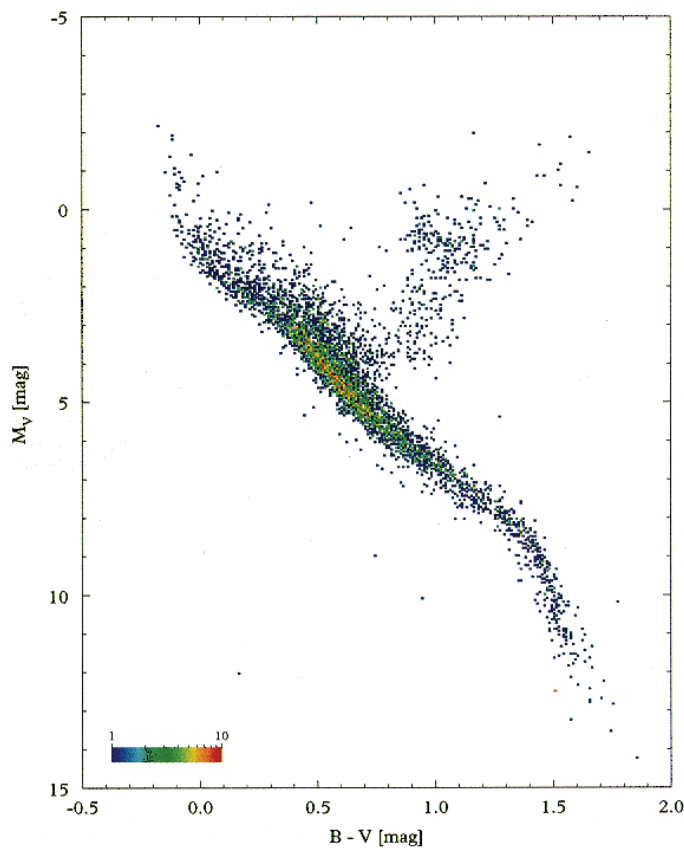
Cepheid Period–Luminosity Relation



4) Given below is a HR-diagram prepared from data taken by the Hipparcos satellite using 4477 stars whose parallax distance is accurately determined. Consider a *main sequence* star with color index $B-V = 0.65$. What would be its absolute magnitude (as accurately as you can read the graph)? If another main sequence star much farther away had the same color index (i.e., $B - V = 0.65$) and was observed to have an apparent magnitude of 15.0, what would be the distance to that star in parsecs?

b) The $(B-V)$ for the star Wolf-28 is 0.55 and its absolute visual magnitude is 14.19. Look where this point would be on the graph. What is special about this star compared to all the others? For example, how would its radius compare to the sun (qualitatively, no calculation necessary).

c) Betelgeuse, obviously one of the brighter stars in the sky has $(B-V) = 1.85$ and absolute visual magnitude -5.9, just off scale here. Again, how would its radius compare with that of the sun - qualitatively, not a number?



5) The average temperature of the earth worldwide, night plus day, is 288 degrees K (15 degrees C). Assume that the earth radiates like a perfect blackbody and ignore the Earth's atmosphere. a) At what wavelength would most of the energy come out? Is this wavelength in the optical, radio, uv, microwave band or what? b) The radius of the earth is 6.38×10^8 cm (6380 km). What is the luminosity of the earth in erg s^{-1} ?

How does that luminosity compare to the heat flux diffusing out from the interior of the hot core of the earth, $4.5 \times 10^{20} \text{ erg s}^{-1}$ (see problem 6 of homework set 1)?

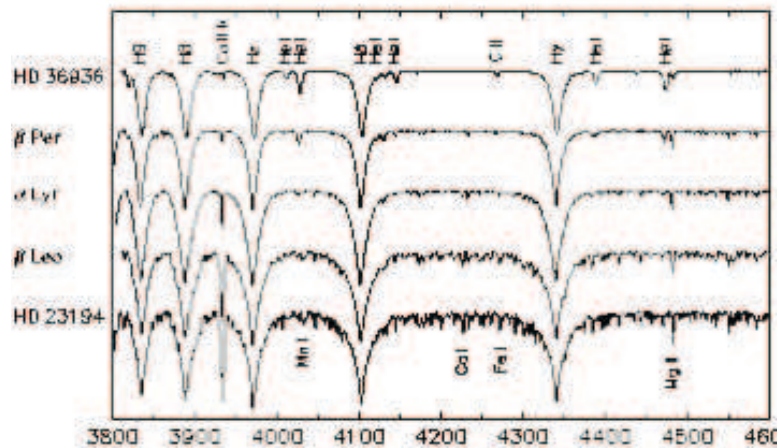
6) a) Star A and Star B both have the same luminosity. If Star A has a higher surface temperature than Star B, how do the radii of both stars compare to each other? No numbers are needed, but justify your answer using a relation/equation from class.

b) The star Betelgeuse has a luminosity approximately equal to $10^5 L_{\odot}$, and its radius is about $10^3 R_{\odot}$. How does its effective surface temperature compare with that of the Sun? Use ratios to solve this problem, and give your answer relative to the sun's surface temperature $T_{\odot} = 5800 \text{ K}$.

c) Would Betelgeuse appear redder or bluer than the Sun? Explain your answer.

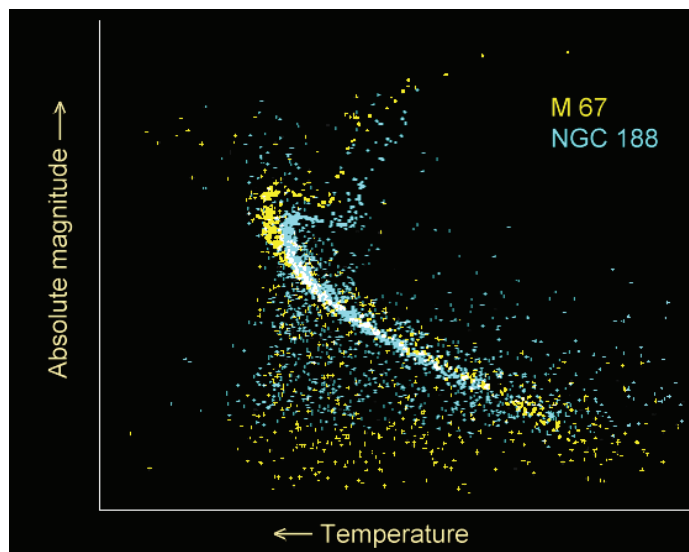
7) What are the spectral types and approximate luminosities relative to the sun of *main sequence* stars whose spectra show the following characteristics?

- He I lines predominate. He II absent. H I lines weak.
- Ca II lines strong. H I lines very weak. TiO lines not present. CH strong.
- Strong lines of TiO (titanium oxide) and VO (vanadium oxide).
- The star alpha-Lyra, also known as Vega, whose spectrum is given here.



Shorter problems

- 1) A new planet is discovered orbiting a nearby star, not the sun. The star is a little lighter than the sun and therefore has a lower luminosity, in this case $1/2$ that of the sun. Assuming circular orbits and that the earth is 1 AU from the sun, how many AU would the newly discovered planet need to be from its parent star to receive the same *flux* as the earth receives from the sun? Other factors, notably rotation and the greenhouse effect can change your answer, but this would be roughly the “habitable radius” for that star. We will make this estimate more quantitative later.
- 2) Optical light has a wavelength of about 5500 Angstroms. What frequency of electromagnetic radiation does this correspond to?
- 3) A very hot oven at home is about 500 Fahrenheit. What is that temperature expressed in Kelvin? At what wavelength would the oven chiefly radiate if you opened the door quickly?
- 4) The present temperature of the microwave background radiation is now 2.73 K so the typical wavelength of a photon is given by Wiens Law, $\lambda_{\max} = 0.289 \text{ cm/T} = 0.106 \text{ cm}$. What will be the typical wavelength of the microwave background radiation some date in the distant future when the size of the universe (as measured e.g., by the scale factor R in the notes) has doubled? What temperature would we infer for the microwave background radiation then?
- 5) The Hertzsprung Russell diagrams for two clusters are plotted on the same scale below. Which contains the most massive main sequence stars? Which is the older cluster?



- 6) Spectroscopic analysis of a star shows it to be a main sequence star of spectral class A5. From the tables in the notes, what is the absolute visual magnitude of the star and its bolometric correction. What would be its apparent visual magnitude at 10 pc?
- 7) How many electrons are still bound to the atoms a) H I, b) He I, c) H II, d) He II, e) C IV ?
- 8) A star moving away from you at 400 km s^{-1} has a spectrum containing the Balmer series of hydrogen. The Balmer-alpha (H_α) line in the laboratory from hydrogen at rest is found at a wavelength of 6564 Angstroms. At what wavelength would that line appear in the star's spectrum as observed from the earth (because of the Doppler shift)?
- 9) What transition in the neutral hydrogen atom gives rise to Lyman beta in emission? That is, what energy level changes to what energy level?
- 10) The mass of the electron is 9.11×10^{-28} gm. According to the uncertainty principle, what is the wavelength of an electron moving at 1 km s^{-1} (i.e., 10^5 cm s^{-1})? [Planck's constant is 6.63×10^{-27} erg s]. Which is smaller, one Angstrom (10^{-8} cm) or this wavelength? Does the electron's wavelength get bigger or smaller when the electron moves faster?