ASTRONOMY QUALIFYING EXAM
August 2013

Possibly Useful Quantities

$L_\odot = 3.9 \times 10^{33}$ erg s^{-1}
$M_\odot = 2 \times 10^{33}$ g
$M_{bol\odot} = 4.74$
$R_\odot = 7 \times 10^{10}$ cm
1 AU = 1.5 $\times 10^{13}$ cm
1 pc = 3.26 Ly. = 3.1 $\times 10^{18}$ cm
a = 7.56 $\times 10^{-15}$ erg cm^{-3} K^{-4}
c = 3 $\times 10^{10}$ cm s^{-1}
$\sigma = ac/4 = 5.7 \times 10^{-5}$ erg cm^{-2} K^{-4} s^{-1}
k = 1.38 $\times 10^{-16}$ erg K^{-1}
e = 4.8 $\times 10^{-10}$ esu
1 fermi = 10^{-13} cm
$N_A = 6.02 \times 10^{23}$ moles g^{-1}
G = 6.67 $\times 10^{-8}$ g^{-1} cm^3 s^{-2}
$m_e = 9.1 \times 10^{-28}$ g
h = 6.63 $\times 10^{-27}$ erg s
1 amu = 1.66053886 $\times 10^{-24}$ g

PROBLEM 1

Briefly discuss the observational evidence for the following components of the Milky Way Galaxy. 1 point per question

1. dark matter
2. thin disk and thick disk
3. bulge
4. halo
5. cold ISM
6. hot ISM
7. magnetic field and cosmic rays
8. central black hole
9. population I and population II stars
10. accretion of dwarf galaxies

PROBLEM 2

Dark energy was discovered using the observations of Type Ia supernovae (SNe Ia).

(1) The measurement of X (using SN Ia observations) led to the discovery of the existence of dark energy. What is X? (2 pts)

(2) Express X in terms of the cosmological parameters that describe our Universe. Explain in as much detail as you can. (2 pts)

(3) If the peak brightness of a very large sample of SNe Ia has an observational uncertainty of 0.05 mag, and an intrinsic uncertainty of 0.12 mag, what is the resultant uncertainty in X? (3 pts)

(4) What are the systematic uncertainties of SNe Ia as a dark energy probe? How can these be mitigated? Explain in as much detail as you can. (3 pts)

PROBLEM 3

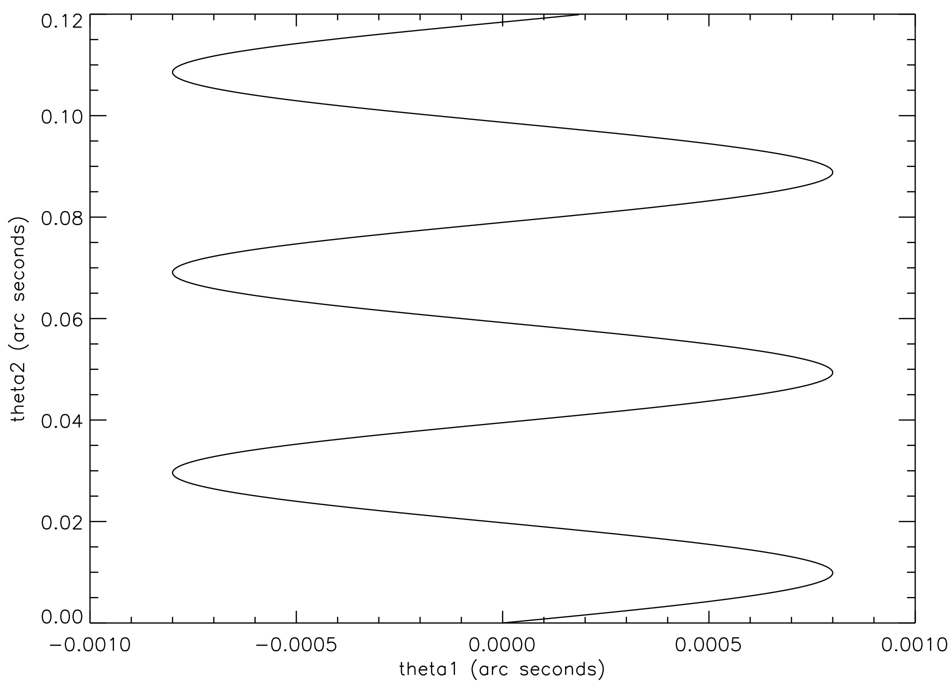
A new pulsar is discovered. It is observed to have a period of 1.3 seconds. It is observed for several years, and its motion on the sky is shown in the plot below, where the axes are orthogonal.

a. What is the distance to the pulsar in parsecs? (3 points).

b. What is the minimum velocity of the pulsar in km/s? (3 points).

c. What is maximum amplitude of the period variability observed during the monitoring time period in seconds? (3 points).

d. What is the size of light cylinder in km? (1 point)



PROBLEM 4

a) [3 pts.] Describe the Pre Main Sequence (PMS) contraction of a 1 $M_\odot$ gas cloud up to the ZAMS stage. Draw the path in the HR diagram. What part of the HR diagram is this? Why is the path here and not in some other part of the HR diagram? Relate what is happening inside of the PMS object to its observable parameters in the HR diagram.

b) [3 pts.] Now describe the evolution of a 5 $M_\odot$ star from the time it arrives on the main sequence until it reaches the top of the second giant branch (or AGB). In particular, give the position in the HR diagram at various stages. Describe in detail the physics of the red giant phase (first ascent of the giant branch). What is the final fate of this star? How do we know?

c) [2 pts.] How does the evolution of a 5 $M_\odot$ star differ from that of a 1 $M_\odot$ and 25 $M_\odot$ star? Compare the evolution of a 1 $M_\odot$ star with solar metallicity to that of a 1 $M_\odot$ star with low metallicity (*i.e.* a Pop II star). What are the final fates of stars of 1 and 25 $M_\odot$?

d) [2 pts.] Assuming that $(L/L_\odot) = (M/M_\odot)^\alpha$ where $\alpha = 3$, estimate the time spent on the main sequence for the 1, 5 and 25 $M_\odot$ stars. Describe the structure (*e.g.* the location of the convection and radiation zones) of these three stars while on the main sequence. Do not forget to indicate the energy sources in these stars.

PROBLEM 5

a. (2pts) Draw a typical velocity rotation curve for a spiral galaxy. What does the observed rotation curve tell us about the matter distribution in spiral galaxies?

b. (3pts) Describe the Tully-Fisher relationship for spiral galaxies and why it is important.

c. (5pts) Assume a spiral galaxy has a mass to light ratio γ. Use the virial theorem to derive an expression for the galaxy's dynamical mass in terms of γ, L, v_c, and R.

PROBLEM 6

1. (4pts) Define and explain the difference between:
   (a) Effective Temperature
   (b) Excitation Temperature
   (c) Ionization Temperature

   To get full credit you need to use both words and equations.

2. (1pt) In what physical situation are all the temperatures defined above exactly the same?

3. (1pt) When in the history of the Universe are the almost exactly the same?

   The Boltzmann formula is:

$$\frac{n_i}{n_j} = \frac{g_i}{g_j} e^{-(\chi_i - \chi_j)/kT}$$

4. (4pts) Figure 1 shows an energy level diagram for sodium. At what temperature is the *total* population of the levels at 3.6eV equal to the population of the level at 3.2eV?

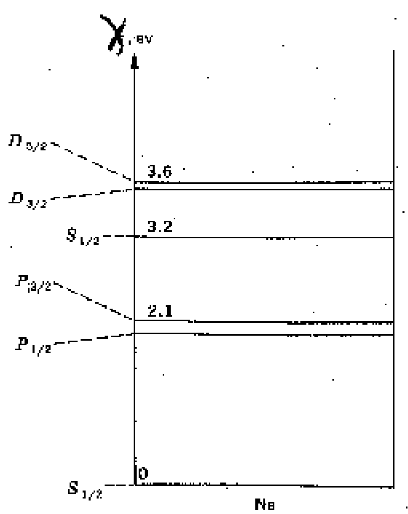


Fig. 1-7 An approximate term diagram for the electronic configuration of the element sodium. The excitation energy above the energy of the ground state is labeled by the quantum numbers of the configuration. The letter designates the orbital angular momentum of the electrons (in this case of a single-valence electron), and the subscript designates the total angular momentum of the states.

Figure 1: