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 = 1.5×10^{13} cm
1 pc = 3.26 Ly. = 3.1×10^{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

Henry

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

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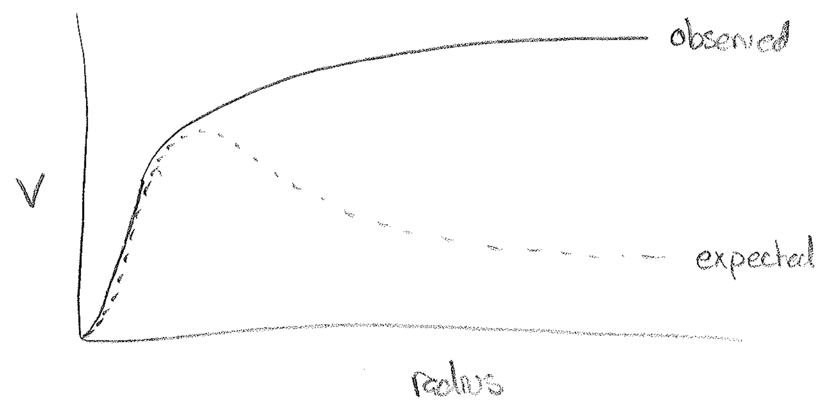
Astro #1

a) Dark Matter - evidence from galactic rotation curves



b) Thin + Thick disk - Differences in stellar populations at various scale heights w/in the disks of spiral galaxies. Differences includes: specific velocity, metallicity, stellar density, stellar age

c) Bulge - Seen in COBE infrared maps of galaxy

d) Halo - Distribution of globular clusters and field stars w/ high specific velocities suggests there is a halo of stars spherically surrounding the galaxy. We also know that there must be a dark matter halo to explain the motions of stars outside of the solar radius R_0 w/in the galaxy

e) Cold ISM -

Wang

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)

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Astro #2

a) The Hubble parameter H_0

Dai?

PROBLEM 3

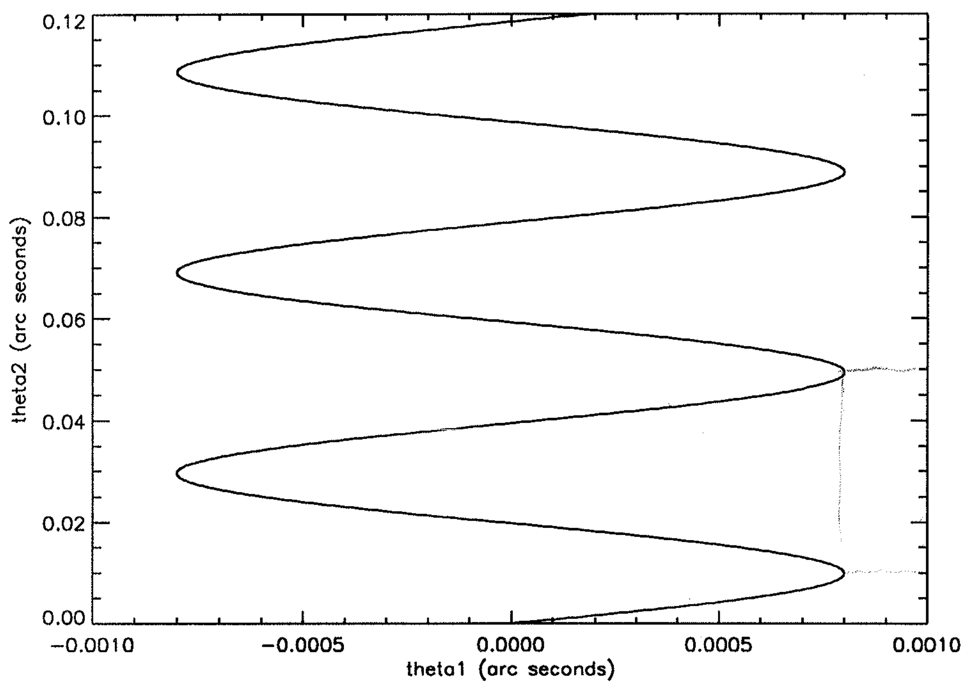
A new pulsar is discovered. It is observed to have a period of 1.3 seconds. It is observed for several years, and its motion on the sky is shown in the plot below, where the axes are orthogonal.

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)



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Astro #3

a) $d = \frac{1}{\alpha}$ pc

$= \frac{1}{.008}$

$= 125$ pc

Kilic

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.

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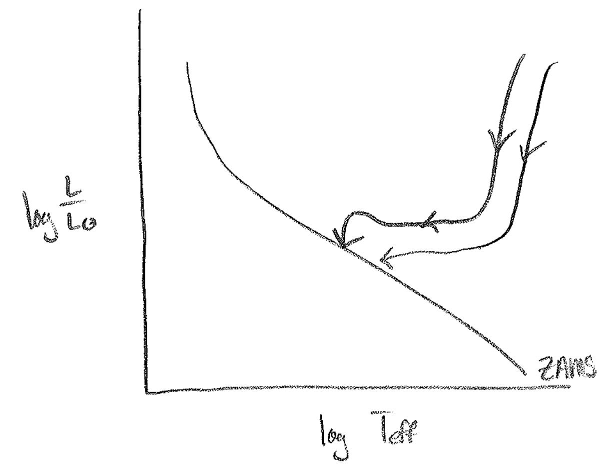
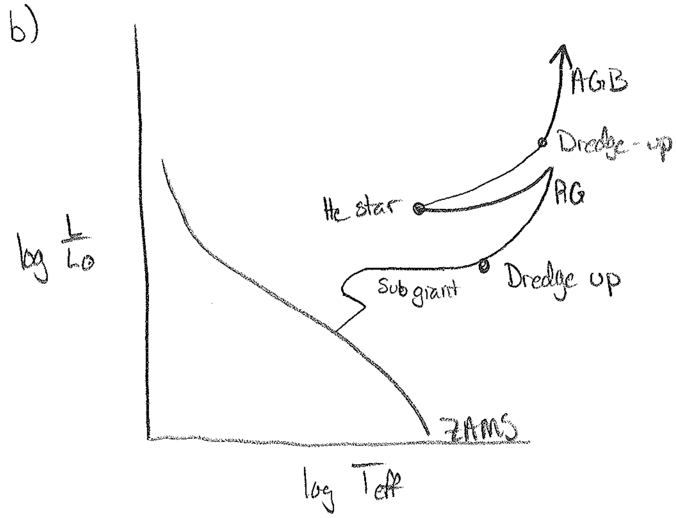
Astro #4

a)



These lines are known as Hyashi tracks, and they describe the pre-Main Sequence (PMS) evolution of a proto star. As the proto-star forms from a gas cloud, it changes from an object that is cool, has a high opacity, + is fully convective, into a warmer object w/ a radiative core.

b)



As the 5 $M_\odot$ star leaves the main sequence, due to its convective core, it must burn up almost all of the H in the core before becoming a shell burning star. Once this transition occurs, the He ash core begins to contract, and the envelope of the star becomes convective and grows. The star is now in the Red Giant (RG) phase of its life. During the phase, the convective enevelope will reach into the core and dredge up material and bring it to the surface, all the while the core continues to contract. Once the central temp reaches ~ 10^8 K, He fusion begins, where the core stops contraction and the envelope shrinks while the star stabilizes as a He-burning star. Once the He in the core is depleted, the C/O core shrinks until it becomes degenerate, while the envelope continues to grow and is eventually expelled from the star. The star ends its life as a C/O white dwarf.

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#4 (cont.)

c) There are only minor differences b/w the evolution of a $1 M_\odot$ star and that of a $5 M_\odot$ star, as they go through the same evolutionary phases, but the transition of the $1 M_\odot$ to a He burning star is different, as the core must first become degenerate before He fusion begins, leading to He flashes instead of a smoother transition. Both end as C/O WD.

However, due to the higher mass of the $25 M_\odot$ star, its evolution is quite different. The $25 M_\odot$ star is massive enough to begin fusing elements all the way up to Fe with very little change in radius or temperature. While there is some mass loss, as the star begins to approach the Eddington limit in the Red supergiant phase, there is still enough mass left to die as a Type II SN.

The effect of metallicity on a star is important, but it only plays a small role in a stars evolution. Due to the additional energy levels to absorb photons provided by the metals in a star, metal rich stars have a higher opacity and appear dimmer than their metal poor companions of a similiar mass. Metal poor stars also tend to live shorter lives than metal rich stars.

d) $1 M_\odot$ - radiative core, convective envelope

$5 M_\odot$ + $25 M_\odot$ - convective core, radiative envelope

Energy source of all MS stars is H-fusion and gravitational collapse energy being radiated away

Time on MS: $1 M_\odot$ ~ 10 billion yrs

$5 M_\odot$ ~

$25 M_\odot$ ~

Dai? / Leighly?

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.

$$\frac{M_*}{L} = \gamma \qquad \frac{1}{\cancel{2}} M_* v_c^2 = + \frac{G M_* M}{\cancel{2} R}$$

$$\gamma L = M_* \qquad M_* + DM = M_T$$

$$a_c = \frac{v_c^2}{r} \qquad M_T = \gamma L + \qquad L \cdot t = \frac{-GMm}{2r}$$

$$a_c = \frac{G M_T}{R^2} = \frac{v_c^2}{R}$$

$$\frac{GM^2}{r} = M v_c^2$$

$$M_T = \frac{v_c^2 R}{G} = \gamma L + M_{DM} \qquad \gamma L = M_*$$

$$= \frac{v_c^2 R}{G} \frac{\gamma L}{\gamma L}$$

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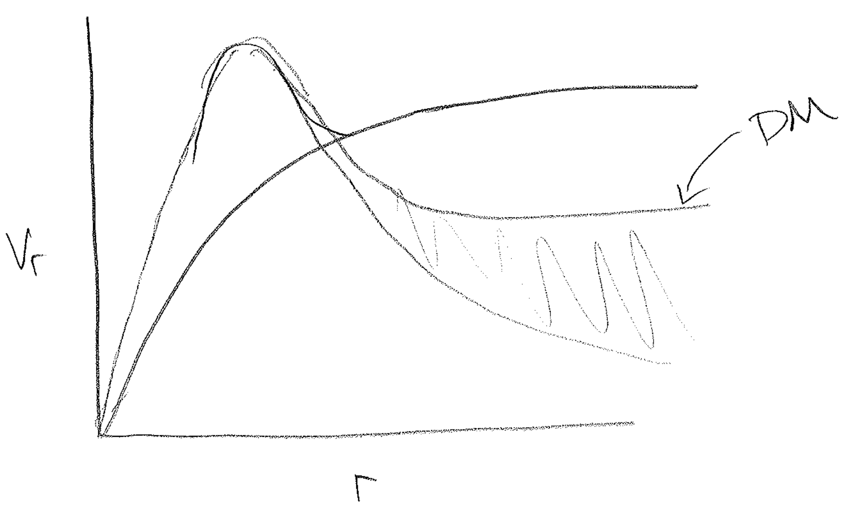
Astro # 5

a)



The flat rotation curves of spiral galaxies at large radii tell us that $\rho \propto \frac{1}{r^2}$
The increasing interior part corresponds to rigid body rotation and $\rho \propto$

b) The Tulley - Fisher relationship describes a relation b/w the maximal rotation velocity and luminosity of a spiral galaxy based on the galaxy's Hubble type. By combining this relationship with other measurement it allows us to estimate the masses and distances to spiral galaxies.

c) $\gamma = \frac{M}{L}$

* Virial Thm states:

$$T = -\frac{1}{2}U$$
$$E = \frac{1}{2}U$$

Eddie? / Henry? / John?

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?

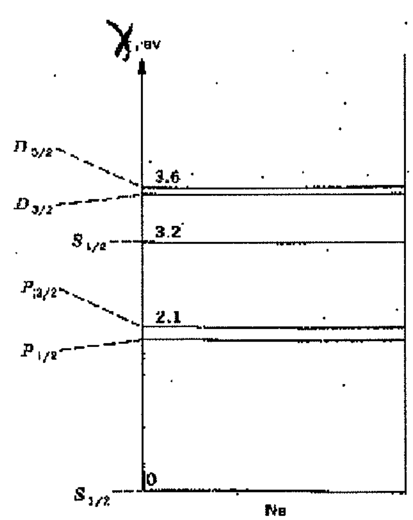


Fig. 1-7 An approximate term diagram for the electronic configuration of the element sodium. The excitation energy above the energy of the ground state is labeled by the quantum numbers of the configuration. The letter designates the orbital angular momentum of the electrons (in this case of a single-valence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

Figure 1: