Name:______________________________

# Astronomy 253, Spring 2004

## Final Exam REVIEW

## 2004-April-26

You have two hours in one sitting to complete the exam. Well, OK, it's a review, so you can do it when or for as long as you want. You may not use any notes or other reference material, but you will need a calculator. You may not work with other students on this exam. Well, yeah, yeah, calm down, it's a review, talk to anybody you want to about it, refer to whatever you want. The real final will be solo without reference notes (but will require a calculator).

## Page O' Equations and Numbers

$$\vec{\nabla}\Phi = \frac{\partial \Phi}{\partial r}\,\hat{r}$$

$$\nabla^2\Phi = \frac{1}{r}\frac{\partial^2}{\partial r^2}\,(r\Phi)$$

(with spherical symmetry)

$$\vec{F} = \frac{-\,G\,M\,m}{R^2}\,\hat{r}$$

$$\vec{F} = -m\,\vec{\nabla}\Phi$$

$$\mathcal{PE}_m = m\Phi$$

$$\nabla^2\Phi = 4\pi\,G\,\rho$$

$$2\,\langle\mathcal{KE}\rangle + \langle\mathcal{PE}\rangle = 0$$

(with no external forces)

O B A F G K M

$$R_0 = 8\,\mathrm{kpc}$$

$$V_0 = 220\,\mathrm{km/s}$$

$$L_\odot = 3.6\times 10^{26}\,\mathrm{W}$$

$$M_\odot = 2.0\times 10^{30}\,\mathrm{kg}$$

$$1\,\mathrm{pc} = 3.086\times 10^{16}\,\mathrm{m}$$

$$1\,\mathrm{Mpc} = 10^3\,\mathrm{kpc} = 10^6\,\mathrm{pc}$$

$$m_1 - m_2 = -2.5\log\left(\frac{f_1}{f_2}\right)$$

$$f = \frac{L}{4\pi\,d^2}$$

$$m - M = 5\log\left(\frac{d}{10\,\mathrm{pc}}\right)$$

$$v = H_0\,d$$

1. You observe a globular cluster. You are able to measure that the largest number of bright stars in this globular cluster each individually have a V-band magnitude of 15.5.

   Assume that the total V-band light observed from a globular cluster is dominated by the red giants.

   (a) If the absolute V-band magnitude of a red giant star is 0.8, how far away is this globular cluster?

   (b) If the globular cluster has an integrated V-band magnitude of 4.5, how many red giant stars are there in the globular cluster?

   (c) Make an educated guess at the total number of stars in this cluster given the number of red giants you calculated. Explain your reasoning.

2. In the Local Group, dwarf irregular galaxies tend to have a lot of cool gas, and sometimes are actively forming new stars. Dwarf spheroidal galaxies, on the other hand, are roughly elliptical concentrations of stars that do not appear to have a lot of gas.

   (a) How will the observed colors of dwarf irregular and dwarf spheroidal galaxies compare, and why?

   (b) What distinguishes a dwarf spheroidal galaxy from a globular cluster?

   (c) Supernovae (both thermonuclear and core-collapse) are rare in any kind of system, and as such will be especially rare in a small system that does not have very many stars. If a supernova is observed in a dwarf galaxy, what sort(s) of supernovae might you expect to see in a dwarf spheroidal galaxy, and what sort(s) of supernovae might you expect to see in a dwarf irregular galaxy?

3. You observe two stars in the Milky Way. Both are closer to the center of the Milky Way than the Sun is, but they are several kpc distant from each other. Both are main sequence stars; one has spectral type O, the other has spectral type M.

   (a) Which star is *likely* to have higher metallicity (i.e. a higher fraction of heavy elements)? How do you know?

   (b) Is it possible that the star that you identified in (a) as being likely to have higher metallicity could in fact have metallicity similar to or lower than the other star? If so, under what circumstances could this be true?

   (c) Can you state with confidence which star will die first? If so, explain how you know. If not, what additional information would you need to be able to predict which star will die first?

4. Consider a typical cluster of galaxies which has 50 galaxies the size of the Milky Way.

   (a) What, very roughly, should the mass of this cluster be, in solar masses.

   (b) A Type Ia supernova (absolute peak B-magnitude -19.5) is discovered in this cluster. It is observed to have its peak at a magnitude of 16. (If you know about K-corrections (hi Naved), assume they have been done; if you don't, ignore everything in these parentheses.) How far away is this galaxy cluster in Mpc?

   (c) The core of this cluster is observed to be spread over 1.25 degrees on the sky. What is the physical core radius of this cluster?

   (d) Make a very rough estimate of the potential energy of this cluster, in Joules.

   (e) What is the systemic velocity of this cluster, assuming that the Hubble constant has a value $H_0 = 72\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$?

   (f) What typical line-of-sight velocity do you expect to observe for galaxies relative to the center of the cluster? (If you did this right, this really is roughly typical "peculiar velocity," or velocity relative to the Hubble expansion, seen for galaxies.)

   (g) The Hydrogen-$\alpha$ (H$\alpha$) line has a rest wavelength of $6562\mathring{A}$. What range of $H\alpha$ wavelengths do you expect to observe for galaxies in this cluster?

5. Consider a spherically symmetric stellar system with density profile

$$\rho(r) = \rho_0 \left(\frac{r}{r_0}\right)^{-\alpha}$$

   where $\rho_0$, $r_0$, and $\alpha$ are constants.

   (a) What is $M_{\mathrm{tot}}(r < R)$, the total mass enclosed at a radius $R$? Express your answer in terms of $\rho_0$, $r_0$, $\alpha$, $R$, and fundamental constants.

   (b) What are the limits on $\alpha$ to avoid an infinite $M_{\mathrm{tot}}(r < R)$ for finite $R$?

   (c) What is the circular velocity $v_c(r)$ in terms of the same quantities? Solve this problem without reference to the $\Phi$ given below.

   (d) What must the value of $\alpha$ be to generate a flat rotation curve $v_c(r) = \mathrm{const}$?

   (e) Show that the potential for this system is

$$\Phi(r) = \frac{4\pi G \rho_0 r_0^2}{(2-\alpha)(3-\alpha)} \left(\frac{r}{r_0}\right)^{2-\alpha} + c$$

   where $c$ is a some constant whose value you need not worry about.

   (f) Show that this potential gives you a value of $v_c(r)$ consistent with your answer from part (c). In addition to the constraints on $\alpha$ from part (b), for what values of $\alpha$ is this potential valid?

6. Active Galactic Nuclei (AGN), such as Seyfert Galaxies, Quasars, and Blazars are believed to have a supermassive black hole at their center... but then again, it seems that all big galaxies do.

   (a) What is different between AGN and normal galaxies that makes the nuclei of the former active?

   (b) Some studies have suggested that among galaxies with disturbed morphologies or close companions, a greater fraction are Seyfert galaxies than are among the general galactic population. Give a physical reason that might explain this observation.

   (c) There are many more quasars at high redshift than there are at lower redshift. Suggest an explanation.

   (d) Promise that, for the rest of your life, you will be careful never to omit the f when writing the word "redshift".

7. (a) When Hubble first measured the expansion of the Universe, because of incorrect assumptions about stars he was observing in distant galaxies he came up with a Hubble Constant of about 500 $\mathrm{km\,s^{-1}\,Mpc^{-1}}$, an expansion rate much faster than what today we know it to be. Assuming no dark energy, what limit on the age of the Universe would this indicate? Is this an upper limit or a lower limit?

   (b) The fluctuations in the Cosmic Microwave Background are only about one part in $1 \times 10^{-5}$. Obviously, the contrast in density today (e.g. inside a cluster of galaxies as compared to a void between galaxies) is greater. Explain why this tells you that dark energy must be distrusted through the Universe more smoothly than dark matter.

   (c) An astronomer observes several *standard candles*, and uses them to measure distances with the ultimate goal of determining the Hubble Constant. This standard candle, however, tends to have a small range of absolute magnitudes. Close the astronomer's detection limits, is she likely to be biased towards finding *lower-than-average* or *higher-than-average* magnitudes for the standard candle? If she doesn't take this into account, in which direction will this cause her to misestimate the Hubble Constant? (For the trivia minded, this sort of bias is known as "Malmquist Bias".)

   (d) Grand-design spiral galaxies are frequently observed to have either bars, or companions with whom they have interacted recently (on astronomical timescales). Briefly explain the connection.