

## Physics 20083 - Spring 2007 Exam #6b

### Instructions:

1. Answer the following four questions in the space provided. If you need extra space, please use the back of the page and make an appropriate notation on the front of the page so that I will know where to look for your complete answer.
2. Each question is worth a total of 25 points.
3. Each question requires an answer that is typically no more than two or three sentences long or perhaps a diagram and 1-2 sentences. Some questions do not require explanations. This will always be explicitly stated.
4. You may not use your own paper, book, notes or a calculator for this exam.
5. You will have 30 minutes to complete the exam and turn it in.

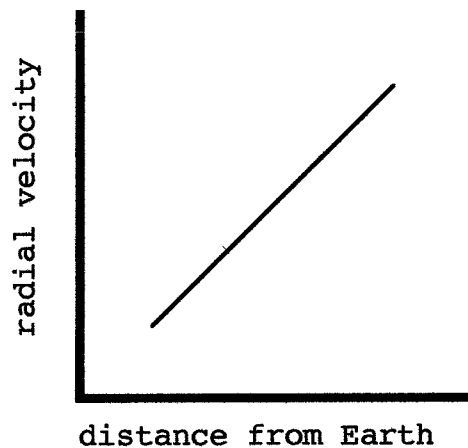
Inverse Square Law:  $L_{\text{app}} \propto \frac{L_{\text{abs}}}{r^2} - X$

Hubble's Law and Age:  $\text{Age} = \frac{1000}{H_0}$  billion years

Density Equation:  $\text{Density } (\rho) \propto \frac{\text{Mass (M)}}{R^3}$

1. Assume for this question that there is no cosmological constant present in the Universe, no force making the expansion accelerate but instead only gravity operating on large scales. Below is a Hubble Law diagram for a Universe with a constant expansion rate.

On the graph below, draw in how Astronomers expected the graph to look for a Universe in which the density is below the critical density but not zero. If you think the graph would look the same, just write "no change" on the graph. Either way, explain why you drew (or didn't draw) the graph the way you did in the space provided.



2. Two important observations that support the Big Bang theory are Hubble's Law and the Cosmic Background Radiation. Explain (a) why Hubble's Law is not a violation of the Copernican Principle (it might help if you state the principle first so you can see how to explain this) and (b) why the discovery of the CBR was so crucial to the credibility of the Big Bang theory, compared to Hubble's Law.

3. The constellation Cygnus contains the first black hole ever indirectly discovered by use of the binary orbits technique we discussed previously in class.

a) (12 pts) Give the approximate altitude and azimuth of Cygnus in the evening sky at this time of year, and also name the two brightest stars in Cygnus.

b) (13 pts) Name and explain two lines of evidence that tell us quasars are likely powered by supermassive black holes at their centers.

4. As recently as 20 years ago, Big Bang cosmology was still struggling with the so-called "age crisis". Explain (a) what the age crisis was. The crisis was resolved by careful study of the ages of some clusters, which were modified thanks to observations made by the Hipparcos satellite. For part (b), explain what the Hipparcos satellite measured and why this affected our age estimates of certain star clusters.