AST 301 Fall 2007-Scalo
Review sheet for exam #7

Exam 7 covers sec. 24.3 (Hubble's Law), and chapters 25 (NOT 25.4), 26, and 27. As on previous exams, emphasis is on understanding the basic ideas and their implications and connections, not on memorization of details or on numerical values. I will not test you on any of the "More Precisely" or "Discovery" sections *except* Discovery 26-1, p. 752. Read them if you are interested (e.g. you will learn how strange "string theory" is).

There will be a number of questions related to deuterium and helium as produced in the era of nucleosynthesis and how those provide tests of cosmological models. However you do not have to memorize any of the nuclear reactions involved.

As usual, a few of the exam questions will be versions of some of the questions found at the textbook web site multiple choice self-tests. Also as usual, I strongly suggest that you do not try these questions until you have thoroughly studied. Another suggestion that bears repeating: Test yourself by seeing if you could explain most of the material, or the answers to the questions at the end of the chapter, to someone who hasn't taken the course, without consulting the book at all. Not being able to do this (and it should be pretty clear when you can't) is a sure sign that you don't understand the material enough and need further study.

The end-of-chapter questions are also useful review tools. I am unable to give you a list of which ones are most important. You should look through all of them and see if you are familiar enough to answer them.

Liubin Pan (our TA) will have office hours Thursday 2-4 (unless I send you an email note telling you differently--I have not checked with him on this yet). I will have office hours on Thursday from 4 to 6. I'll have to send you email if there is some meeting that day that I have forgotten to put on my calendar.

If you want to meet on Wed., let me know--2:30 or 4:45 are possibilities.

I will be available for phone consultation from 9am to 9pm Wed. and Thurs., if I am home—otherwise, leave a message, feel free to call back, etc.; you won't be disturbing me because I'll just be reading or working. But please don't call after 9 pm.

Sec. 24.3. This is a leftover from the last exam, but one of the most important topics you'll encounter. Here the Hubble Law is introduced as a "standard candle" that can be used to obtain distances to very distant galaxies. Later, it is revisited in another role, as the first evidence suggesting a model for the evolution of the universe called the Big Bang.

Chapter 25. You should read and study all this material except for sec. 25.4, Black Holes in Galaxies. You might find it interesting to look it over, because it describes observations and theories about the supermassive black holes that lurk in the centers of galaxies, but I will not include it on the test. However you *are* responsible for the long section at the end of the chapter discussing the evidence for dark matter, including mapping dark matter with gravitational lens techniques. Don't worry if you don't quite understand gravitational lensing, as long as you are willing to accept that it happens.

We began with sec. 25.5 (p. 696), on mapping a large part of the observable universe using different techniques, finding evidence for clustering up to extremely large scales. We then returned to sec. 25.1, which presents still more evidence for even larger scale structure and "dark matter." You should be able to explain in simple words what this evidence is—generally it is all the same kind of evidence (except for using gravitational lensing), but using different objects.

A new theme in this chapter is looking back in time by observing very distant galaxies to learn something about how they have evolved. How are galaxies at large redshifts (means very distant—review the Hubble relation if this is not clear to you!) different from nearby galaxies? This is the crucial clue about how the Hubble sequence of galaxy types (ellipticals, spirals, irregulars) are related. Notice the emphasis on starburst galaxies, and galaxy collisions when you go back to sections 25.2 and 25.3. You should be familiar with the role these play in the formation and evolution of galaxies, as well as be able to describe the various lines of evidence we have now amassed for dark matter (sec. 25.1) and how its mass compares to the mass of "normal" ("baryonic") matter in the universe.

If "baryonic" is confusing, just remember that many people think that dark matter consists of exotic fundamental particles that exist in quantum theory but have not yet been produced in accelerators, and that we are made of "normal" matter—neutrons, protons, electrons—those are "baryons."

Chapter 26 (Cosmology). I won't enumerate the sections--all of them are important. Don't be too worried if you feel like you don't understand the material on the curvature of space: very few people really understand that. But do remember the 2-dimensional analogies so that you'll know what we're talking about if you encounter the terms "closed" and "open" universe, the significance of Hubble law and CBR discovery.

Chapter 27 (The Early Universe). This is a challenging but extremely interesting chapter because of all the strange phenomena and physical conditions discussed. Sec. 27.2 is probably the most difficult, but don't worry about the zoo of fundamental particles and types of particles that are introduced—they are just trying to explain how particles form as the energy (temperature) passes through the energy that corresponds to the particle's mass (E = mc^2). I am mostly concerned that you get the basic ideas—I realize it is too much to digest in a week. In particular, you don't have to memorize the numerical or other details of Table 27-1 (and I won't ask you about much terminology, like what is a hadron or a lepton, etc.). But we did go over a simpler version of this "time line" in detail in class, so I do expect you to know what went on and when (i.e. roughly how old the universe was when this or that occurred) during the following key phases:

1. Inflation; 2. Nucleosynthesis; 3. Decoupling of matter and radiation (and why that implies that there must be a cosmic background radiation); and 4. The formation of structure from fluctuations.

Basically, understanding the significance of these eras of the universe, and the observational evidence they are related to, comprises most of what you have to learn for the exam. The horizon and flatness problems are difficult to understand intuitively for most people, but you should be able to say what they are, and why inflation solves them. You should also be able to explain the evidence that supports the big bang theory in general, and inflationary cosmological theory in particular, and which evidence indicates the presence of a large component of "dark energy." Finally, you should be able to explain what the cosmic background radiation is, and what properties of it are important as a test of the big bang theory, or as a diagnostic of dark matter and energy (for example its temperature, its spectrum, and especially the analysis of its "blotchiness").

We will try to get the scores at eGradebook by the night of the exam, but as usual there is a chance they won't get done until Monday. Final averages will take a few days longer, but you can compute these yourself. Here is a prescription (already online at the course web site, along with how to compute what your final average will be for a given score on exam 7) for computing your final average, using the fact that we are weighting your lowest score (score means percentage score) by half: Take your six highest scores and add them. Add to this half of your lowest score. Then divide by 650.

Sample questions follow.

Here are eleven sample review questions; they are of the more difficult variety, so don't be too discouraged if you have to think a while to come up with the answer. On the other hand, if you think you are guessing at many of the answers, or if it seems to you like more than one answer could be correct, you probably need more studying. (Note: I decided number 9 below was a little too difficult, but left it on this review sheet anyway.)

1. Compared to "baryonic" matter like the nuclei and electrons that make up normal matter, how does the amount of dark matter in the universe compare?
a. There is 10 times more dark matter.
b. There is 10 times less dark matter but its influence through its large gravity overwhelms baryonic matter
c. What we formerly interpreted as baryonic matter is all part of the dark matter.
d. The dark matter is much more abundant by mass in disk galaxies, but not in galaxy clusters.
e. The dark matter is much more abundant by mass in galaxy clusters, but not in disk galaxies.

2. How are galaxies at large redshifts (means very distant—review the Hubble relation if this is not clear to you!) different from nearby galaxies?
a. They are more massive
b. They contain redder stars
c. They contain more dark matter
d. They are more irregular in form than nearby galaxies.

3. How large (roughly) is the largest coherent "cluster" of objects, or single structure, that has been discovered in the observable universe?
a. 1-3 Mpc b. 10-30 Mpc c. 100-300 Mpc d. 1000-3000 Mpc

4. Whether or not the universe will expand forever can, in principle, be determined by
a. an accurate measurement of the Hubble constant.
b. an estimate of the average density of the universe.
c. observations of the cosmic background radiation.
d. measurements of the helium abundance in very old stars.

5. If the expansion age of the universe was determined to be 8 billion years,
a. it would be difficult to understand how galaxies had time to form.
b. it would be difficult to understand how globular cluster stars could be as old as we think they are.
c. it would be difficult to understand the cosmic background radiation in terms of the big bang theory.
d. it would be difficult to understand the observed abundances of the elements.

6. Five billion years in the future the predominant wavelength of photons in the cosmic background radiation will be ________ (Assume the universe will expand for at least this long.)
a. ultraviolet b. visible c. infrared d. radio

7. What happened during the epoch of the big bang that gave rise to the cosmic background radiation?
a) Strong, weak, and electromagnetic forces were no longer one single force.
b) Neutrons and protons were formed.
c) Dark matter and baryonic matter no longer interacted.
d) Electrons and nuclei combined to form atoms.
e) Galaxies formed, emitting large amounts of light.

8. What primary role was played by dark matter in the early universe?
a) It gave rise to the period of inflation.
b) The cosmic microwave background radiation is the result of dark matter decoupling from baryonic matter.

c) Its density fluctuations determined the overall large-scale structure of the universe.
d) It limited the nucleosynthesis of heavy elements during the Big Bang.

9.The density fluctuations in the normal (not the “dark”) matter component of the early universe must have been very small because otherwise
a) the deuterium abundance would be larger.
b) the deuterium abundance would be smaller.
c) their imprint on the cosmic background radiation would have been larger than observed by COBE.
d) galaxies and larger structures would have formed too early compared to observations.

10.The current deuterium abundance tells us that
a) the dark matter cannot be baryons.
b) a phase transition probably took place.
c) the universe is probably closed.
d) the universe is probably open.

11. Be able to explain the several ways in which the cosmic background radiation not only demonstrates the validity of the big bang model for the origin of the universe, but accounts for several other observed properties of the universe, and in addition gives us the fraction of dark matter and dark energy. This is probably the most important topic in cosmology, because it allows us to see back to a time earlier than when there were galaxies. How early? What is it, what event does it represent?