Announcements

- **Reading Quiz due tonight!** The Reading Quiz for Week 13 (“Week13_quiz”) is due tonight, Tuesday, December 2, by 11:55 PM.

- **Final exam in two weeks.** As stated in the course syllabus (i.e., p. 5 in your Reader), the final examination in this course will take place at the following times and locations:
  
  **Section 5 (11 AM class):** Tuesday, December 16, 10:30 AM → 12:30 PM,
  Room PS-130 (normal lecture room).

  **Section 7 (2 PM class):** Tuesday, December 16, 1:00 PM → 3:00 PM,
  Room NE-060 (normal lecture room).

Details about the nature of the final exam will be given next week, but do note the following:

1. The final exam must be taken at the scheduled time, and no makeup (or early) exams will be given.
2. *The final examination is cumulative*, and will cover the entire course’s content with equal emphasis (roughly; there will be a slight emphasis given to the content since the second midterm – i.e., the last 5 lectures).
3. As with the midterm exams, you will again be permitted to bring an official “cheat sheet” to the final exam.

Reading Guide and Homework Assignment

(Week #14 On-Line Reading Quiz Due: Thursday, December 11, 11:55 PM)

Note: This is the final reading assignment of the course, and covers all of the material to be presented during the final two weeks of class. Since it goes beyond what we shall cover this week alone, the full reading assignment is formally not due until the last day of class, next Thursday, December 11. I am giving you the full remainder of the readings now, though, since I want you to know what you will be responsible for on the final exam well in advance. It is strongly advised that you complete this reading by the last day of class, since your final exam is only five days later. So, onto the readings:

Here we finally tackle the really BIG questions, and they concern our study of cosmology: Did the Universe have a beginning? Will it come to an end? What is it doing right now? These readings present to you the scientific answers to these questions. Note that I am having you (again) read some sections slightly out of order in the text, since it better reflects the way the material was presented in lecture; you may, of course, read the text in any order that you like – just be sure to read it!

1. **Text — Chapter 17, Sections 17.1 and 17.2: The Great Nebula Debate and Types of Galaxies.**

   Start by reading the introduction on page 383 as well as the caption to the picture of the Hubble Deep Field on page 382. Section 17.1 opens the chapter by recounting the “Great Nebula Debate”, and how it was resolved by Edwin Hubble’s discovery that the spiral nebulae are, in fact, large stellar systems separate from our Milky Way Galaxy (itself a large spiral galaxy). §17.2 walks you through the different *types* of galaxies. Focus attention on the differences among the three basic types.

2. On-line tutorial: On the “Week14_tutorial” section of the textbook website, look at the Active Figure called “Galaxy Types”. This is a nice interactive applet that allows you to explore the differences among elliptical, spiral, and barred-spiral galaxies. Notice in particular how a spiral galaxy rotates, whereas the stellar motions in an elliptical galaxy are much more randomized.

3. **Text — Chapter 16, Section 16.3: The Mass of the Galaxy.**

   Read here about the discovery of *dark matter*, both in our Galaxy (the Milky Way) as well as throughout the Universe. Notice, in particular, that it is the use of Newton’s version of Kepler’s
Third Law that provides the main evidence for the existence of dark matter in the Milky Way. The end of §16.3.2 goes into a bit more detail on the possibilities for dark matter than we did in class, but the bottom line is, as of now, we don’t know what it is and a number of seemingly “likely” candidates have been shown to be incorrect. Any ideas?

4. On-line tutorial: On the “Week4_tutorial” section of the textbook website (note: this is the tutorial from Week 4!), look again at the Astronomy Exercise called “Orbital Motion”, and simply do the following: Adjust the mass of the Sun so that it is 0.5 $M_{\odot}$. Notice how slowly the planet orbits it. Then, increase the Sun’s mass so that it is 2.0 $M_{\odot}$. Look how Earth’s orbital velocity speeds up! Conclusion: The greater the mass interior to an orbit, the faster that orbit will be. This concept is crucial to an understanding of how dark matter is detected in galaxies.

5. Text — Chapter 17, Section 17.3.1: Masses of Galaxies. Read here about how the masses of galaxies are derived by analyzing the spectra of objects (stars) or material (interstellar gas) in the galaxies. Note that dark matter is inferred to exist in both spiral and elliptical galaxies.

6. Text — Chapter 16, Section 16.4: The Center of the Galaxy.

Here you take a somewhat more detailed journey to the center of the Milky Way galaxy than was presented in class, and read about all of the evidence that a “supermassive” black hole exists in the very center of the Milky Way. Pay particular attention to the fact that it is the orbits of stars very close to the center that provides the main “proof” for the existence of a black hole in the galaxy’s center, and recall our class discussion on this subject.

7. Text — Chapter 18, Section 18.3.1: Observational Evidence for Black Holes.

Read here about the evidence for supermassive black holes lurking at the centers of nearly all galaxies, not just the Milky Way! And especially, note again that the main evidence comes from studying the orbital properties (i.e., Newton’s version of Kepler’s Third Law strikes again) of stuff (stars, gas, dust, etc.) located very close to the centers of these other galaxies.

8. Text — Chapter 17, Sections 17.4.1 and 17.4.2: The Extragalactic Distance Scale: Variable Stars and Standard Bulbs.

These sections continue the discussion of how distances are measured in the universe by recapping the use of Cepheid stars (which we did not discuss in detail, other than to say they can be used as standard candles), and then moving on to discuss the use of Type Ia supernovae as standard candles (or ‘bulbs’). Type Ia supernovae have turned out to be astronomers’ most precise distance indicator at very large distances – distances well beyond where Cepheid stars can be used.

9. Text — Chapter 17, Section 17.5: The Expanding Universe.

Read here about how the observations of Hubble, Humason, and Slipher led to Hubble’s discovery of the expanding universe. Really make sure that you understand just how Hubble’s original velocity-distance relationship, as shown in Figure 17.18, leads naturally to the conclusion that our Universe has been expanding since a primeval explosion occurred at a specific point in time in the past.


Read this brief section on the cosmological principle: the assumption that, on large scales, the universe at any given time is the same everywhere; that is, it is isotropic and homogeneous.


We conclude our reading for the course with excerpts from the final pages of the popular astronomy textbook by Jay Pasachoff and Alex Filippenko, The Cosmos: Astronomy in the New Millennium. This text gives an excellent presentation of the latest results in cosmology, and is somewhat more up-to-date than our course textbook. The first part, from p. 210 – 216, is essentially a recap of material presented by your textbook, and read earlier in this assignment. The last two sections, on
p. 217 – 221, concern the ultimate fate of our Universe, and are essentially what will be covered by
the final lecture in the course, on Thursday, December 11.

→ Optional Astronomy Podcast, from Astronomycast.com: Episode 5: *The Big Bang and Cosmic
Microwave Background*, available at http://www.astronomycast.com/, as well as through iTunes.
Nicely presented, and goes beyond what we considered in class to include a discussion of the Cosmic
Microwave Background, which is additional evidence for the Big Bang cosmology.

12. **On-line reading quiz (Due: 11:55 PM, Thursday, December 11):** Take this week’s *reading
quiz* by clicking on the “Week14_quiz” assignment at the on-line textbook web-site. The
Reading Quiz will become available to you at 12:05 AM, Wednesday, December 3. **It consists of
only *1* question**, which is an essay of a rather philosophical nature. You will receive full credit
(i.e., 100%) for *any* answer that you give, but you must take the quiz to get your 100%! **You must
complete this on-line quiz by 11:55 PM Thursday, December 11** (note the extension to
a Thursday due date – the last day of class). You need only take the quiz one time, as you are
guaranteed a 100% the first time!

Dr. Elliot Krauss with Einstein’s jarred brain in Princeton, NJ., c. 1996.
(Details for the curious are at the class website’s “Web Links” page.)