Announcements

- **Reading Quiz due tonight.** The Reading Quiz for Week 12 (“Week12_quiz”) is due tonight, Tuesday, April 15, by 11:55 PM.

**Reading Guide and Homework Assignment**

(Week #13 On-Line Reading Quiz Due: Tuesday, April 22, 11:55 PM)

This week’s reading is all about black holes and Einstein’s conception of **gravity**, as embodied in his general theory of relativity. The material presented here is among the most conceptually difficult that you shall encounter in the entire course. Of all of the weeks to be sure to attend lectures, I believe this one to be about the most critical. You will no-doubt notice that the text uses somewhat different examples than I did in class – this is on purpose! By being presented a number of different examples that all lead to the same conclusions, I hope you will be able to better grasp the difficult concepts enshrined in the general theory of relativity.

1. **Text – Chapter 15, Section 15.1: The Principle of Equivalence.**

   First, be sure to read the introductory material on pages 337 and 338 that set up the whole chapter (assigned in last week’s reading). Then, delve into your book’s description of the principle of equivalence.

2. **Text – Chapter 15, Section 15.2: Spacetime and Gravity.**

   In this section, your authors attempt to build up an understanding of “spacetime”, a topic that we only briefly covered in class, so be sure to read this part thoroughly. Then, later on in §15.2.2, comes the description of the distortion of “spacetime” around massive objects that is predicted by the general theory of relativity. Remember, though, that the “embedding diagrams” that are shown, such as the one in Figure 15.6, are just displaying the distortion of space; time is also distorted by the presence of mass, but this distortion cannot be displayed in such a diagram.

3. **Text – Chapter 15, Section 15.3: Tests of General Relativity.**

   As discussed in class, there are a few classic tests of Einstein’s general theory of relativity which, to date, have all been successfully passed. This section describes the first two of them: The advance of the perihelion point of Mercury’s orbit, and the deflection of starlight by the Sun.

4. On-line tutorial: On the “Week13_tutorial: Part 1” section of the textbook website, look at the **Astronomy Exercise** called “Escape Velocity”. This exercise might seem familiar to you, since you already looked at it way back in Week 4! So, this is basically a refresher on this important concept. Next, look at the **Astronomy Exercise** called “Black Hole”: this lets you see how the mass, radius, and escape velocity are related for stars of different masses and sizes.

5. **Text – Chapter 15, Section 15.4: Time in General Relativity.**

   Two more strange predictions of general relativity are that time should proceed at a slower pace in a strong gravity field, and that when light leaves a strong gravity field, it experiences a gravitational redshift. Both of these predictions have now been verified by experiment, as described in this section.

6. **Text – Chapter 15, Section 15.5.4: A Trip into a Black Hole.**

   Having read the first three subsections of section 15.5 on black holes last week, now read what it would be like if you actually fell into such an object.

7. **Text – Chapter 15, Section 15.7: Gravitational Wave Astronomy.**

   With this section, we finish off our study of Einstein’s general theory of relativity, and one last (future) test of its truth: The detection of gravitational waves. Pay careful attention to both the
indirect evidence that we have today that strongly suggests that gravitational waves do exist, and the direct evidence that is, at this point, still lacking (although good experiments are underway that should yield an answer soon!).

→ Optional Astronomy Podcast, from Astronomycast.com: Episodes 44 and 71: Einstein’s Theory of General Relativity and Gravitational Waves, available at http://www.astronomycast.com/, as well as through iTunes. The first podcast provides a nice review of the basics of general relativity and covers essentially the same material that we did in class this week, plus a bit more. The second podcast is a really great review of the geometric interpretation of gravity that is provided by General Relativity, and then how experiments coming online in the near future can hope to detect the presence of gravity waves. This second podcast I thought was particularly well done.

8. **Text – Chapter 8, Section 8.1.1: Standardizing Brightness.**
   
   Now, dip back into Chapter 8 to read a quick section on the brightness of astronomical objects. The three most important terms from this section are (be sure to read the introductory paragraph that precedes §8.1.1 as well):
   
   Apparent brightness: How bright an object appears in the sky. A measure of the observed light received from a star or other object at the Earth.
   
   Luminosity: The total energy radiated into space each second by a star or other object.
   
   Standard Candle (or ‘bulb’): An astronomical object of known luminosity.
   
   A key idea is that one can use standard candles as distance indicators: Since their luminosity is known, measuring their apparent brightness will yield their distance when proper account is taken for the “inverse square” diminution of light with distance (recall Fig. 4.4 on p. 89). Spend some time making sure you understand this concept – it is extremely important, as your whole understanding of how distances are measured in astronomy depends on it!

9. **On-line tutorial**: On the “Week13_tutorial: Part 2” section of the textbook website, look at the Active Figure called “Apparent Brightness I”. This tutorial is very important to understand, as it provides a vivid demonstration of the difference between apparent brightness and luminosity. Understanding this difference is the key to understanding how distances are measured in the universe.

10. **On-line reading quiz (Due: 11:55 PM, Tuesday, April 22)**: Take this week’s reading quiz by clicking on the “Week13_quiz” assignment at the on-line textbook web-site. The reading quiz will become available to you at 12:05 AM, Wednesday, April 16. It consists of 10 multiple choice questions. **You must complete this on-line quiz by 11:55 PM Tuesday, April 22.** As always, you may take the quiz twice.

(“Do not worry about your difficulties in Mathematics. I can assure you mine are still greater.” – A. Einstein)