Topics: The accelerating universe

Reading:

- Read section 2 of Ch. 24 (pp. 559-64).

Summary of work to submit:

- Nothing to hand in for Thursday's class.

Overview:

We can calculate the acceleration from the Friedmann equation for a given model (by *model* we mean choice of values for $\Omega_{\rm m}, \Omega_{\rm r}$, and Ω_Λ. Only Λ can cause acceleration. Observationally, we measure the acceleration in the Hubble diagram at large redshift. Using the inverse square law is a little complicated in an expanding universe, but we find out how to do it now!

Commentary on the reading, viewing, and other preparation:

You're now used to the idea that the scale factor, $a(t)$, describes a universe and that the density of radiation, matter, and cosmological constant govern the dynamics of the scale factor. We saw even how we can calculate an expression for $a(t)$ if matter dominates and we have a flat universe. We can do the same for other types of universes.

We see what we think is the actual $a(t)$ in Fig. 24.3. And see how the distances to objects are related to redshifts for different "flavors" of universes in the next figure.

We can also compute the acceleration of a given universe either from an expression for $a(t)$ or from eq. 24.36. Of course, what would be expected for a simple, natural universe is *de*celeration.

To measure the de- or acceleration, we have to think about the Hubble diagram. Unfortunately, professional astronomers make Hubble diagrams that look different from the ones we've been thinking about and drawing (which are the v vs. d that Hubble himself used). For one thing, astronomers use *magnitudes* to describe brightnesses. Since magnitudes are logarithmic, differences in magnitudes correspond to ratios of brightnesses. When you look at Fig. 24.5 for example, and see $m - M$ – that's a distance. Every five units of $m - M$ correspond to a flux ratio of 100 and thus a distance ratio of 10.

Note that astronomers put this magnitude-based *distance modulus* on the y-axis, not the x-axis. And the redshift on the x-axis is logarithmic. OK, get comfortable with Fig. 24.5 so you can also understand the very important next figure. Think as you look at Fig. 24.5, if the expansion is slowing down due to gravity as naively expected, the expansion would've been faster in the past. Which curve does that correspond to? For a given redshift, will distances be bigger or smaller in decelerating universe (as opposed to one with constant expansion; no acceleration or deceleration)? And is that trend consistent with the line curving up or down on the right side of the figure? And does that correspond to the matter-only universe (which we know slows down)?

Fig. 24.6 is the Nobel Prize figure – it shows the surprising result: acceleration. The bottom panel averages out the overall trend so you can focus on the curvature differences of the models. We can probably find an updated version, with more data that's more convincing...

Fig. 24.7 is also very important. It is a *parameter space* diagram; a common and useful way to think about any kind of model that has multiple parameters. Observational constraints and measurements can be put on such a diagram. This one shows the two main components of the universe (since radiation isn't very important). A point in that 2-D plane represents our universe (the "consensus model"). But there are error bars on our knowledge of the exact values of those parameters. So those ellipses represent those uncertainties. See how lots of other important characteristics can be plotted in that same parameter space?