Topics: Galaxies – and measuring their distances; the Hubble Law

Summary of reading:

- Read the beginning of Ch. 20 and the first three paragraphs of sec. 20.1, then skim the rest of sec. 20.1.
- Read the first two pages of sec. 20.2, through the end of the paragraph that contains eqn. 20.8, and skim the rest of the section.
- Read secs. 20.3, 20.4, 20.5
- Look over the slides posted on the website in the same paragraph as the assignment link.
- Skim section 3 of Ch. 17: pulsating variables as "standard candles"

Note: Focus on the first item (and the slides). There will be no new reading for our last class, next Tuesday. Just a continuation of this material and a review of...anything students want to discuss.

Summary of work to submit:

- Nothing to submit for Thursday's class.

Here are the things you should be thinking about:

Galaxies are the building blocks of the Universe – among other things, they are beacons of light that give us information about the nature (expansion rate, geometry) of spacetime. Galaxies come in a variety of shapes, sizes, and composition, but pretty much all of them have a super-massive central black hole. Their properties are organized around: morphology and color, metallicity, net angular momentum, stellar age distribution, and star formation rate. Galaxies are big compared to the typical distances between galaxies and so galaxy interactions are common – and may be vital for generating spiral structure, initiating bursts of star formation, and stirring up gas that feeds the central black hole.

Commentary on the reading:

The three broad topics we'll discuss are:

(1) Galaxy properties and classification (spirals vs. ellipticals): note that in some sense elliptical galaxies are like the haloes of spiral galaxies (but without the bulge and disk). In other words, ellipticals are relatively gas-free with only old stars and those stars orbit on "plunging orbits" – with very high eccentricity – leading to a spherical distributions of stars with little net angular momentum. Spiral and irregular galaxies have gas and star formation (and so a population of younger, bluer stars).

(2) Distances to galaxies (§20.4) – make sure you understand what a *standard candle* is in the context of distance determinations using the inverse square law. The period-luminosity relationship for pulsating variable stars (see Fig. 17.7 on p. 404) is a classic technique, where the measured period (again, Fig. 17.7) is used to infer the luminosity of the star (so that a flux measurement gives the distance via the inverse square law). Figuring out that galaxies were really very far away (and thus very big – like the Milky Way) was a milestone achievement of the early 20th Century.

(3) The other major consequence of being able to measure/estimate the distances to galaxies was the discovery of a correlation between a galaxy's distance from us and it's redshift – the Hubble Law of the

expanding universe (§20.5). This discovery was the gateway to cosmology, the study of the universe as a whole. Equation 20.30 is one of the most important equations in astronomy. Are you comfortable with the idea that a constant (uniform) expansion leads to a situation where velocities aren't the same everywhere but rather are proportional to the distance between the observer and any given galaxy that's moving away from them? OK with the units of the Hubble constant, H_o? And with the idea that the Hubble constant's value gives us an estimate for the age of the universe?