Normal Galaxies (Ch. 24)

Here we will cover topics in Ch. 24 up to 24.4, but then **skip 24.4, 24.5.** The sections we are skipping are all about processes that occur in the centers of galaxies, so I'd like to keep that separate from the logical progression that leads us from the local galaxies to the large-scale structure of the universe. Please look it over yourself if interested, but it won't be on the exam.

In the outline below, figures are referred to by number alone: e.g. 24.12 is Figure 24.12 in your book.

Hubble sequence—galaxy classification scheme, originally based on appearance, but correlates with other properties as well.

Symbolically: E0….E7..…S0…..Sa..Sb..Sc..Sd…..Irr

Properties (see diagram discussed in class; also table 24.1)
Ellipticals: featureless—no disk or arms; no gas or dust (a few exceptions); huge range in sizes, from dwarfs to giants; yellow-reddish in color.

S0s: Disks, but no gas or spiral arms. So intermediate between Es and spirals.

Spirals: Flat disk with spiral arms, central bulge. Sequence Sa,…Sd corresponds to increasing size of bulge, increasing tightness of arms, and more gas mass relative to stars. Also parallel sequence of *barred* spirals.

Irregulars: Tend to be smaller than spirals. Many are dwarf irregulars (dIrr). Often found as satellites (e.g. Magellanic Clouds). Blue color, lots of gas.

Masses of galaxies: From 10^6 to 10^7 Mo (dE and dIrr) to 10^{12} Mo (giant Es). The smallest are the most numerous galaxies in the universe. (How do you think we get masses of galaxies?)

A few images of galaxies. (See textbook for more, or go online)

Note: Names usually refer to some catalogue. If they are nearby (and so bright) galaxies, they have numbers starting with NGC ("NGC" = "New General Catalog", but from decades ago, one of the earliest catalogues of "nebulae") or M, like M101 ("M"=Messier Catalogue, Messier was the person who compiled the list). Still others retain more descriptive names, like "The Sombrero," or "The Mice." You don't have to memorize *any* galaxy names for the exam

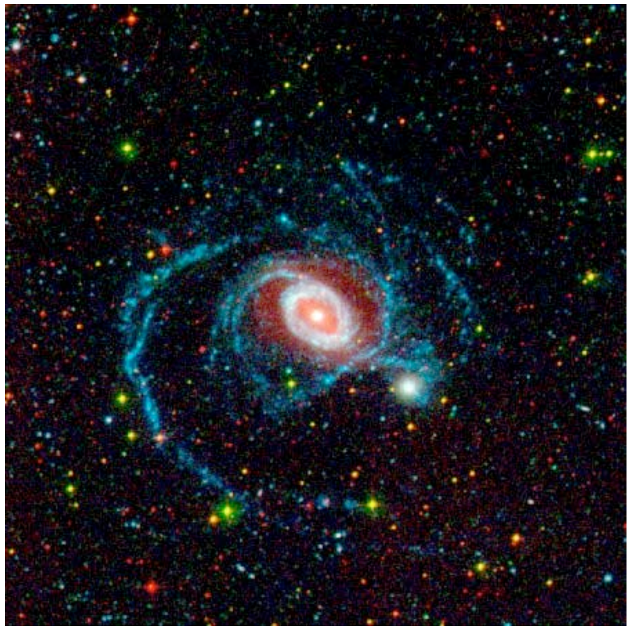
The nearest large disk galaxy like ours is The Andromeda Galaxy, M31

These two views are M31 in two different wavelength bands, ultraviolet (emphasizes the areas of star formation, because massive young stars dominate the light of a young population) and visible (largest contributions from stars covering a range in ages, but mostly 1-5 Gyr).

M31 UV light image (GALEX)   M31 visible light image

GALEX (Galaxy Evolution Explorer): Galaxies in UV Light

GALEX makes observations at ultraviolet wavelengths to measure the history of star formation in the universe 80 percent of the way back to the Big Bang.



M101 = Pinwheel Galaxy, observed with GALEX UV light.

This image of the nearby spiral galaxy M101, better known as the Pinwheel Galaxy, is a three-color combination of images from NASA's Galaxy Evolution Explorer (GALEX) spacecraft. The ultraviolet light, seen in blue in the arms of the galaxy, shows young stars (only 10 million years old), while the diffuse green visible light traces stars that have been living for more than 100 years. The red visible light image shows the stars that formed over a billion years ago.

In this GALEX ultraviolet image, the **M81** spiral galaxy is shown at the center. Notice the galaxy's multiple companions swirling around the disk and central "bulge."

Spitzer observations of M81in the infrared part of the spectrum:

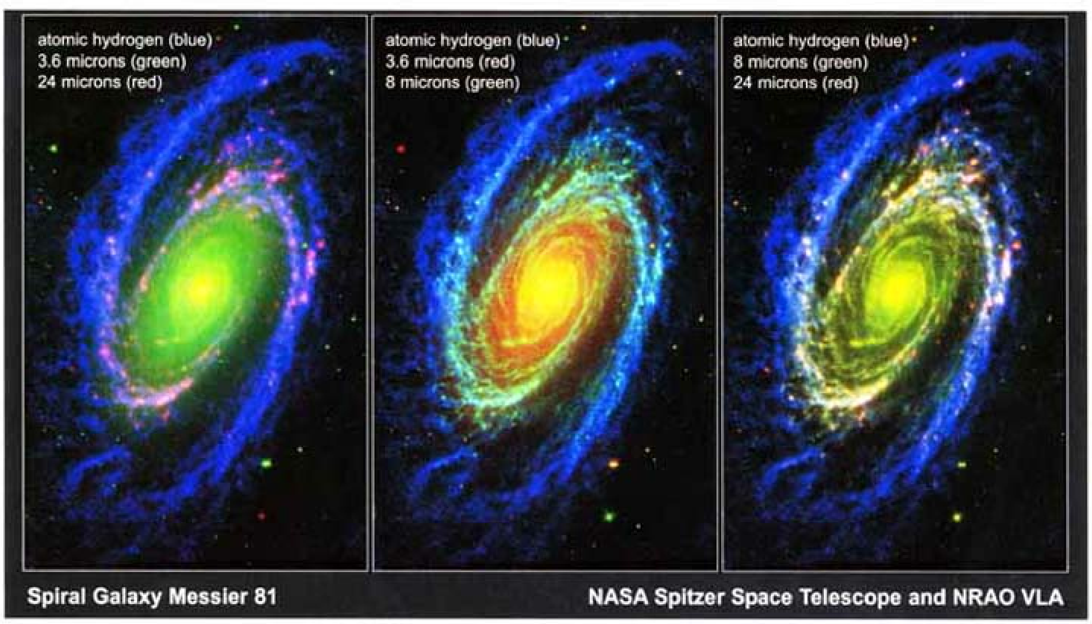
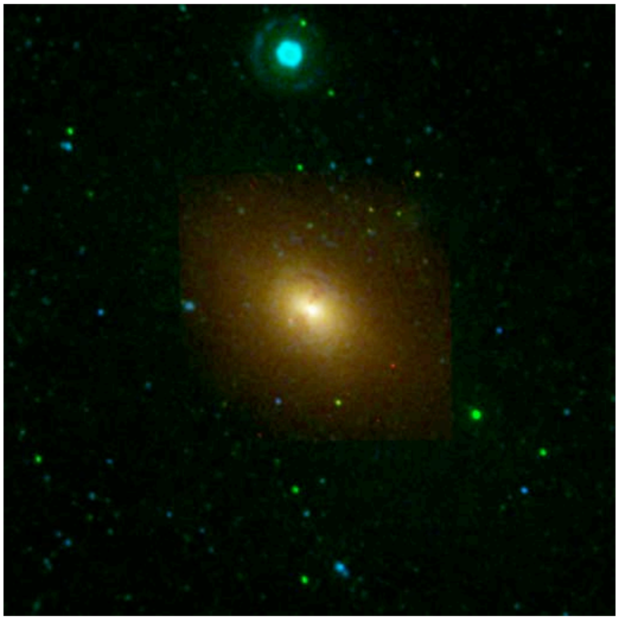
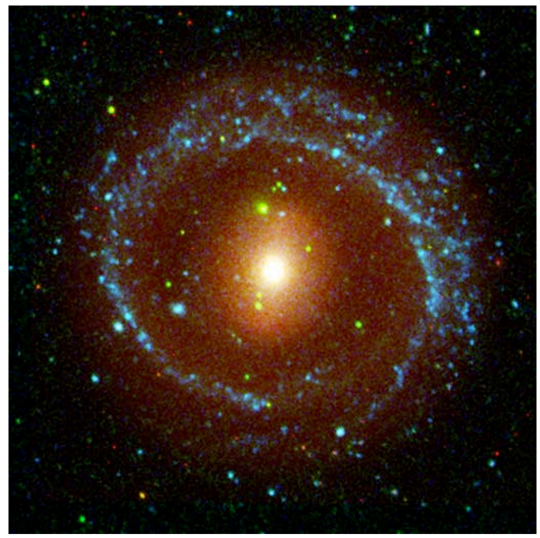


Figure 2. The spiral galaxy M81—the panels show different overlays of Spitzer near- and mid- infrared images taken from SINGS (PI: R. Kennicutt) and the HI map from THINGS.

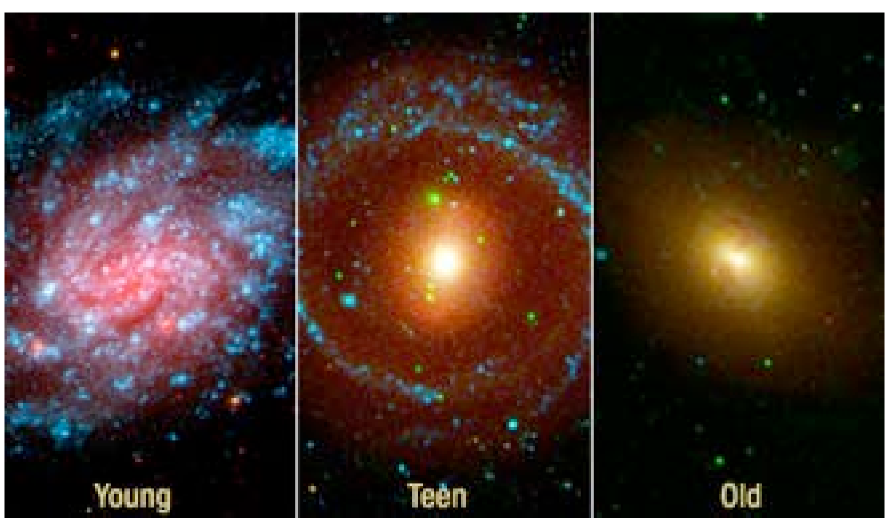


This image from NASA's Galaxy Evolution Explorer shows the galaxy **NGC 1316**, located about 62 million light-years away in the constellation Fornax. The elliptical-shaped galaxy may be in the late stages of merging with a smaller companion galaxy.

NGC 1216, Hubble UV



Watching Galaxies Grow Old Gracefully (will clarify in class—all you can say is that the galaxies are more evolved, from left to right, not that their ages are different.



Maps of galaxies in the neutral hydrogen 21 centimeter line.

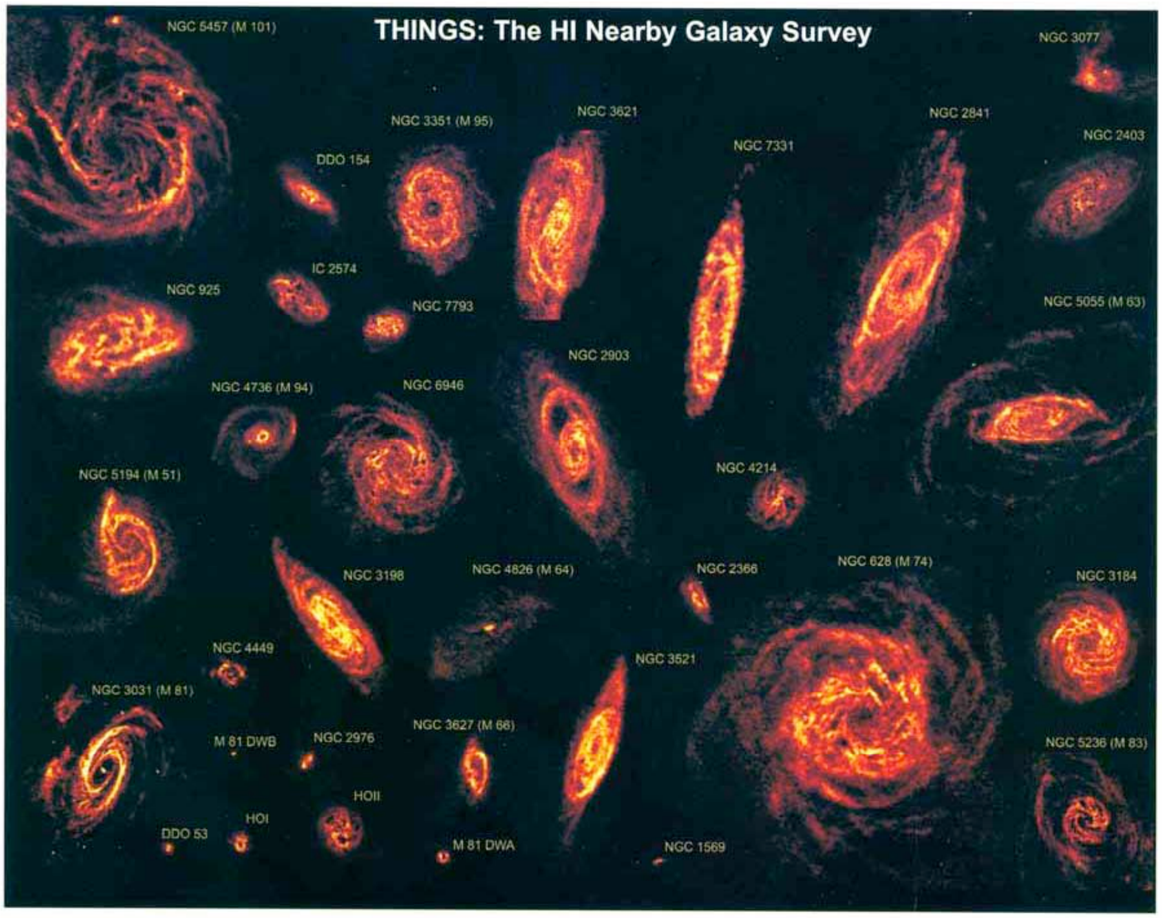


Figure 1. A composite of the atomic hydrogen surface density maps of all THINGS galaxies. All images are shown with the correct relative scale so that their HI morphologies can be compared directly (see http://www.nrao.edu/imagegallery/php/level3.php?id=562).

END of pictures of galaxies.

(Continuation of material at end of Chapter 24):

How are the different kinds of galaxies distributed in space? We are trying to make a map of the entire universe, by locating all its contents. To do this we need big telescopes (to see faint objects, since they are far away), and some way to get distances to *very* distant objects. So we are still "climbing the distance ladder" (the pyramid your book has been constructing).

Groups of galaxies— We can use *Cepheid variables* to make a map of our "local" galactic neighborhood (can get distances out to about 15 Mpc).

Our **Local Group**—About 50 galaxies within about 1 Mpc (=1000 kpc = (roughly) 10 x size of our Galaxy) of each other. Most of the mass is in the large spirals Milky Way and Andromeda. Most of the galaxies are dE and dIrr galaxies. Many are satellites of larger galaxies (e.g. 3 satellites of Milky Way are LMC, SMC, and Sgr dwarfs, a few others that are more distant; Andromeda has several small satellites) Look at Fig. 24.13.

To get to larger distances, must use brighter standard candles. The next technique in the ladder of standard candles is the **Tully-Fisher relation** ⇒ very tight relation (for disk galaxies) between rotational velocity (from broadening of galaxy's spectral lines—see Fig. 24.11) and luminosity. (Think why this makes sense: the galaxy's rotation is balancing its gravity, which is due to its mass, related to its luminosity…)

So for a galaxy too far away to use any other method, just obtain a spectrum (21 cm neutral hydrogen line is best) and measure width of line; the Tully-Fisher relation then gives you the luminosity, so (knowing the apparent brightness) you get the distance.

This method can be used out to about 200 Mpc ⇒ allows us to make a map of the relatively nearby universe.

Before looking at the results, there is one more rung in the ladder of distance indicators or standard candles, called the Hubble relation or Hubble's law, to consider.
[Not sure if this will have to be postponed.]

Hubble's Law –this is the basis for our ideas about how the universe formed (the "big bang" theory), so important to understand it.

Using galaxies of **known** distance (e.g. using Cepheids, Tully-Fisher), find that velocity of recession (redshift) increases linearly with distance (24.16, 24.17). Indicates that universe is expanding.

Recession velocity = constant (H_0) x distance

The constant of proportionality is called the Hubble constant, which is a fundamental measure of age of the universe (next section of course—for now we just want to use it to get distances and map the universe).

See Fig. 24.18 on the "cosmic distance ladder." You should understand what these different distance indicators are, and why each can only be used out to a certain distance.

[Textbook discusses active galactic nuclei, including our own, at this point, sec. 24.4 and 24.5; we are not going to cover that material, either in class or on the exam.]