Galaxies - Chapter 23

First spiral nebula found in 1845 by the Earl of Rosse.
Speculated it was beyond our Galaxy.

1920 - "Great Debate" between Shapley and Curtis on whether spiral nebulae were galaxies beyond our own. Settled in 1924 when Edwin Hubble's observations of the spiral nebulae showed individual stars in huge numbers.

The Variety of Galaxy Morphologies

Galaxy Classification: "Hubble types" (based on optical appearance)

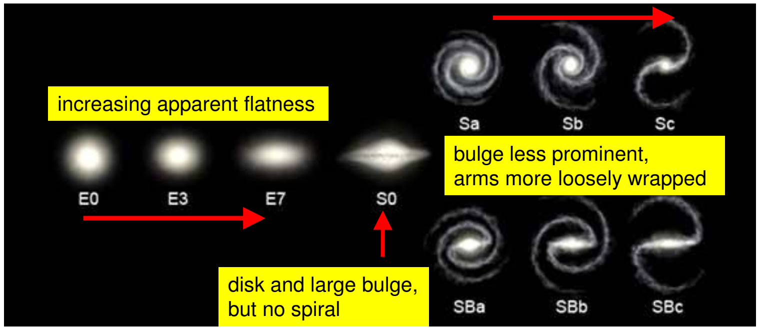
Spirals		Ellipticals	Irregulars	
barred SBa-SBc	unbarred Sa-Sc	E0 - E7	Irr I "hints of structure"	Irr II truly irregular

a barred spiral

an elliptical galaxy

an irregular galaxy

First classified by Hubble in 1924 => "tuning fork diagram":



Hubble types still used today.

Milky Way is an SBbc, between SBb and SBc.

Ignores some notable features, e.g. viewing angle for ellipticals, number of spiral arms for spirals. Many refinements since, but these are the basics.

What the current structure says about a galaxy's evolution is still active research area.

Sa vs. Sb vs. Sc galaxies

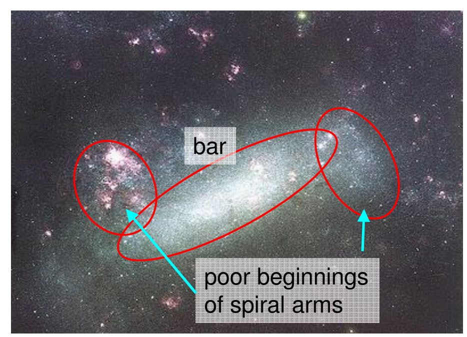
Messier 81 – Sa galaxy

Messier 101 – Sc galaxy

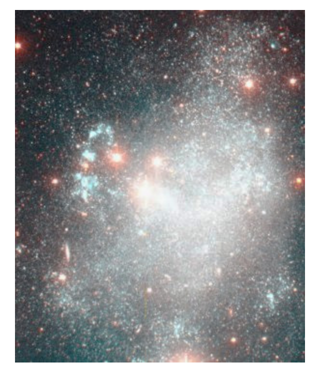
SO Galaxies

M104 – The "Sombrero" galaxy. Technically an Sa, but gives a sense of SO galaxies

Irr I vs. Irr II

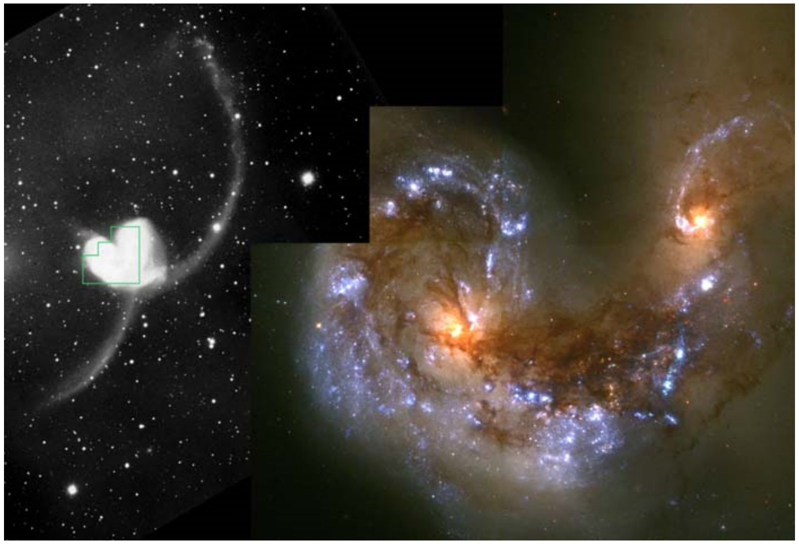


Large Magellanic Cloud – Irr I



Holmberg II – Irr II
(this is a rather heterogeneous class, not so useful)

To be distinguished from irregulars: *peculiars*. Generally interactions and mergers (return to later).

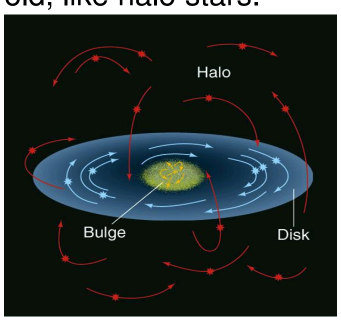


Centaurus A (NGC5128), a collision between an E and an S galaxy.

Ellipticals – basic properties

Similar to halos of spirals, but can be larger than spirals, with many more stars. Stellar orbits are like halo star orbits in spirals.

Stars in ellipticals also very old, like halo stars.



Orbits in a spiral

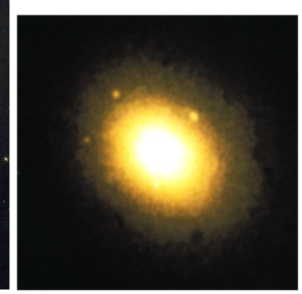
An elliptical

Ellipticity of ellipticals

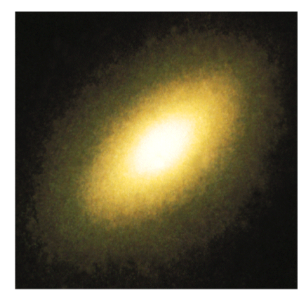
Classify by <u>observed</u> degree of flattening, or ellipticity E0 → E7. In general, En where, if a=major (long) axis, b=minor (short) axis:

$$n = 10\left(1 - \frac{b}{a}\right)$$

EO (M87)



b E3 (NGC 4365)



c E6 (NGC 3377)

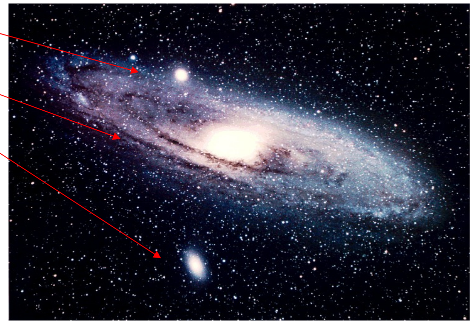
A further distinction: giants vs. dwarfs. For ellipticals:

Giant	vs.	Dwarf
10^{10} - 10^{13} stars 10's of kpc across		10^3 - 10^9 stars few kpc across

Dwarf Elliptical NGC 205

Spiral M31

Dwarf Elliptical M32



Leo I, a dwarf Elliptical orbiting the Milky Way

Most irregulars are dwarfs. Dwarf spirals very rare.

In giant galaxies, the average elliptical has more stars than the average spiral, which has more than the average irregular.

What kind of giant galaxy is most common?

Spirals - about 77%
Ellipticals - 20%
Irregulars - 3%

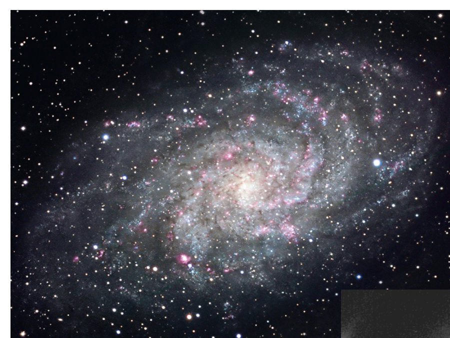
But dwarfs are much more common than giants.

Galaxy Classification Time!

NGC 1073

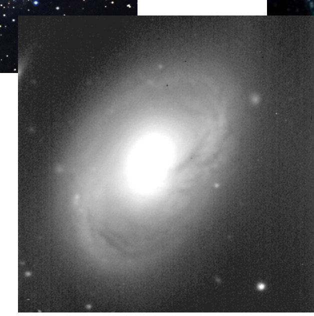
a) Sa
b) Irr I
c) SBbc

Which is the Sa galaxy?



a) M33

b) M74

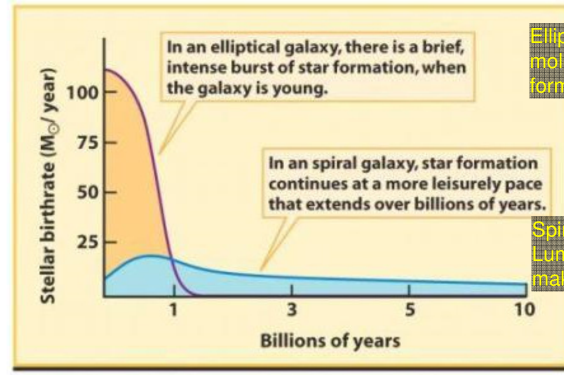


c) M96

M87

a) E0
b) E5
c) E7

"Star formation history" also related to Hubble type:



(c) The stellar birthrate in galaxies

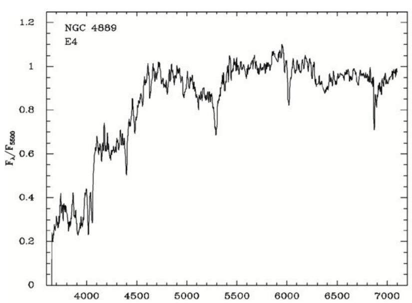
Ellipticals: stars are old, red, dim. Little molecular or atomic gas for any more star formation.

Spirals still have star formation, and gas. Luminous, massive, short-lived stars make spirals bluer than ellipticals

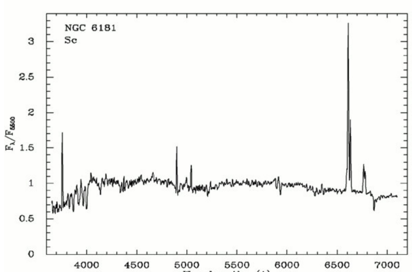
Irregulars have a variety of star formation histories.

Integrated optical spectra of galaxies contain much information about content and history

Elliptical



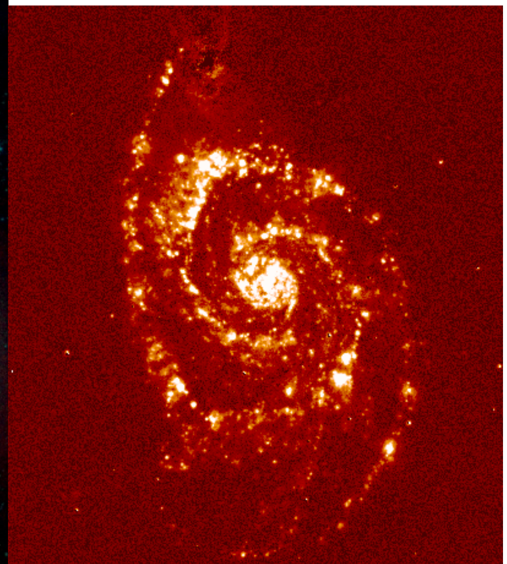
Spiral



Galaxies across the electromagnetic spectrum – M51

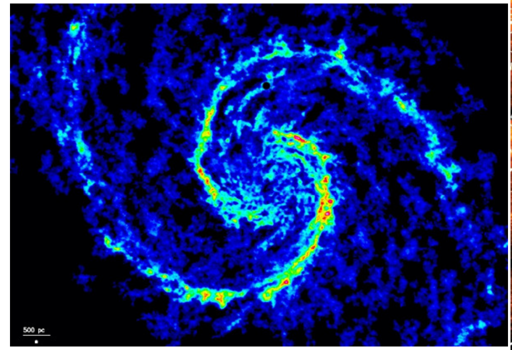
Hubble Space Telescope – showing blue starlight, dust absorption and HII regions

Near-Infrared (2 micron) showing old stars

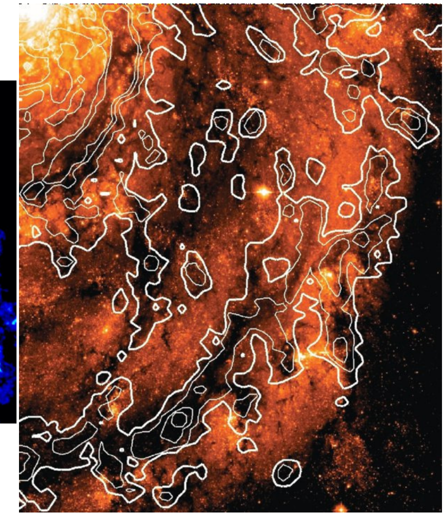


8 micron (Spitzer) showing small hydrocarbon grains

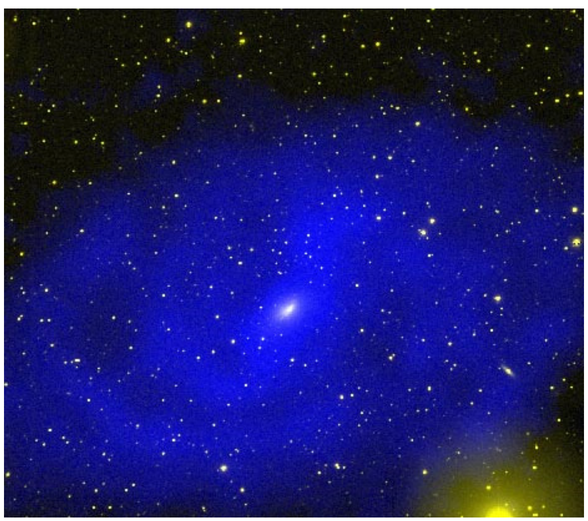
Hα emission showing HII regions



CO (Plateau de Bure interferometer) showing molecular gas



CO contours overlaid on HST blue filter – dust shows you where molecular gas is (there is much more H_2 than HI in this galaxy).



NGC 2915. White is optical showing starlight. Blue is 21-cm image from VLA showing HI. Galaxy is much bigger than you would think from the stars alone!