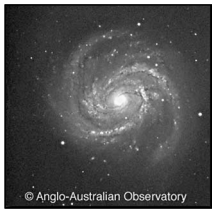
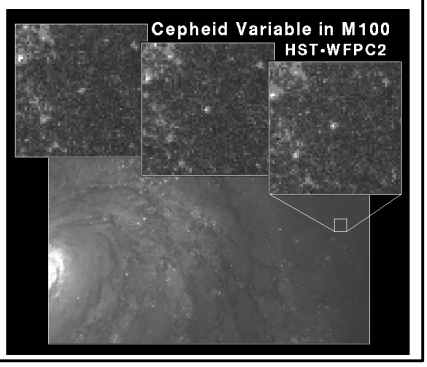
Other galaxies

- Telescopic images of the night sky reveal many other galaxies
  - What do they look like?
    - are they all like the Milky Way?
  - Where are they?
    - spread randomly through space, or grouped?
  - What can we learn about the Universe?

A long time ago in a galaxy far, far away...

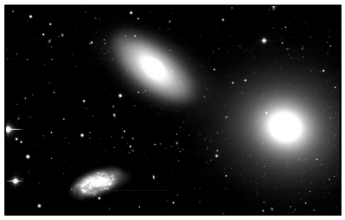
- How do we know these fuzzy blobs are distant galaxies?
  - some types of star (especially variable stars) have well-known intrinsic brightness
  - by measuring how bright they appear to be we can infer their distance
  - ***"standard candles"***

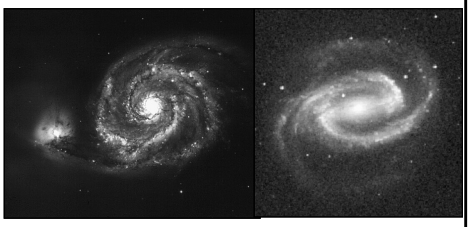




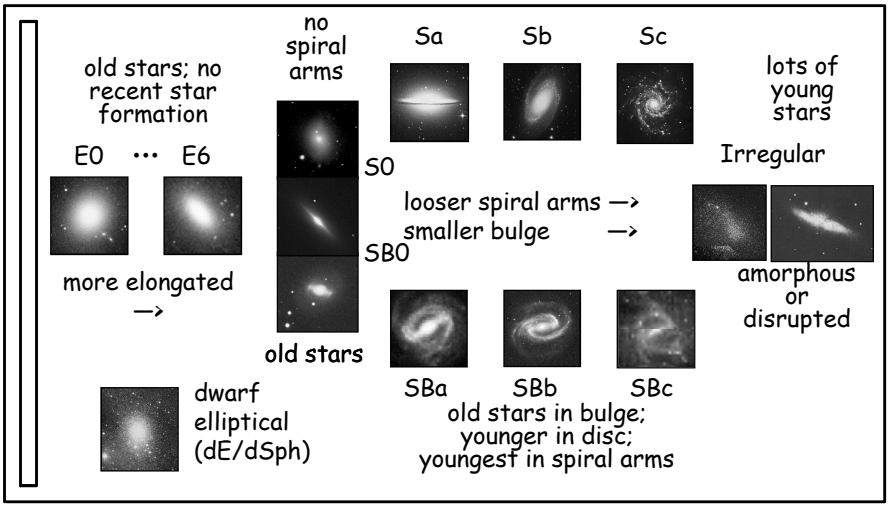
Types of galaxies

- Galaxies seem to come in two basic types
  - smooth, featureless elliptical galaxies
    - circular or elongated
    - made of old, reddish stars
  - spiral galaxies like the Milky Way
    - some with round bulges, some with bars



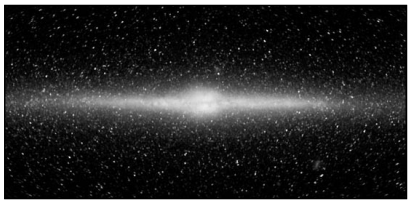


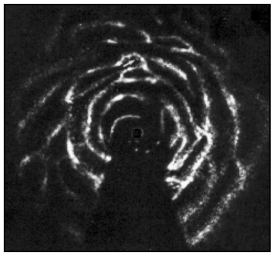
Hubble's tuning fork



Where do we fit in?

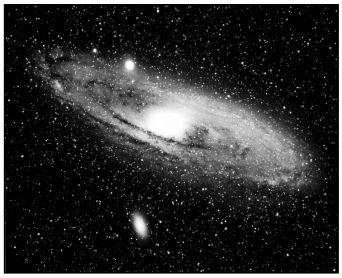
- The Milky Way is clearly not an elliptical galaxy
  - it has a disc, and contains young stars
- It has spiral arms
  - so, not S0
  - size of bulge and arm pattern suggest Sbc
    - between Sb and Sc
- There is evidence for a small bar
  - SBbc, or SABbc
    - SAB means intermediate between barred and unbarred

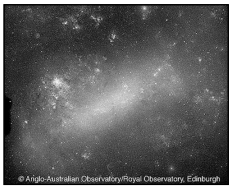




The Local Group

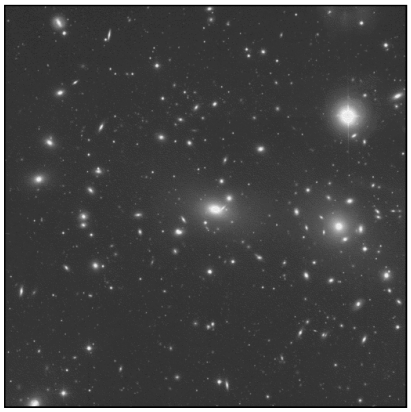
- The Milky Way is not alone: it is part of a small group containing
  - M31 (the Andromeda galaxy)
    - a large Sb spiral, bigger than us
  - M33
    - a small Sc spiral
  - the Large Magellanic Cloud
    - an irregular satellite of the Milky Way
  - at least 30 dwarf irregular and dwarf elliptical galaxies
  - but ***no*** large elliptical galaxies





Galaxy groups and clusters

- The Local Group is small: some rich clusters contain thousands of large galaxies
  - elliptical and S0/SB0 galaxies are much more common in rich clusters
  - spiral and irregular galaxies are much more common in small groups and the outskirts of clusters



Galaxy properties

- Elliptical galaxies
  - contain old stars
  - have little net rotation
    - star orbits are randomly directed, as in our halo
  - have little internal structure
  - are much more common in galaxy-rich environments
  - include the most massive galaxies (but also some with very low mass)
- Spiral galaxies
  - show recent star formation (in disc)
  - have rotating discs
    - stars all orbit in same direction
  - have complex internal structure
  - are more common in low-density environments
  - have a smaller range of masses

Lenticular (S0/SB0) galaxies are like spiral galaxies with no gas
Irregular galaxies are mostly like spirals too small to become organised

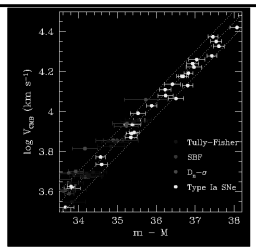
Galaxy problems

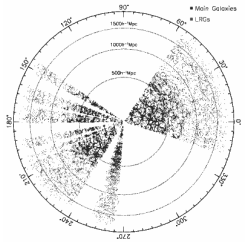
- What makes some galaxies elliptical and others spiral?
  - their mass?
  - their age?
  - their rotation?
  - their history?
- How do spiral galaxies avoid "winding up" their spiral arms?
- How does the evolution of galaxies relate to the presence of central supermassive black holes?
  - the Milky Way's is, if anything, less massive than most!

…next lecture!

Galaxies and cosmology

- Almost all galaxies are moving away from us
  - and the greater their distance, the faster they recede (Hubble's law)
- Clusters of galaxies group to form huge superclusters, separated by vast voids
  - how does this large scale structure develop?
- What is the dark matter?





…next section!