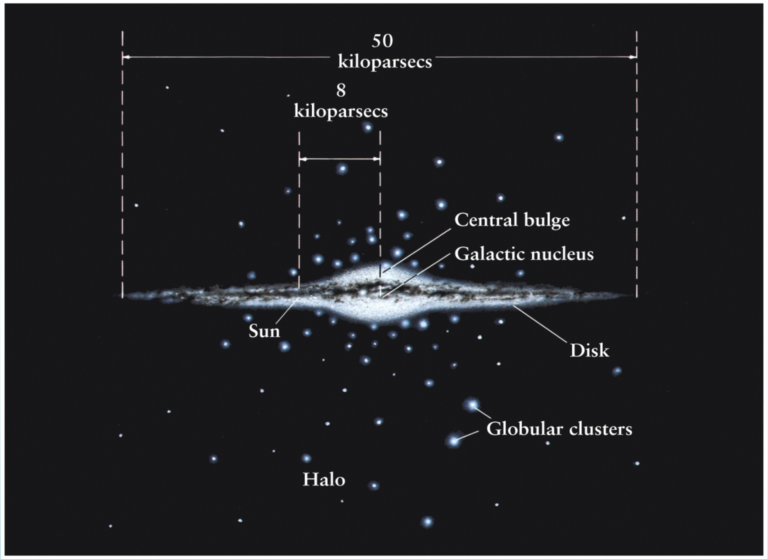
Lecture 2

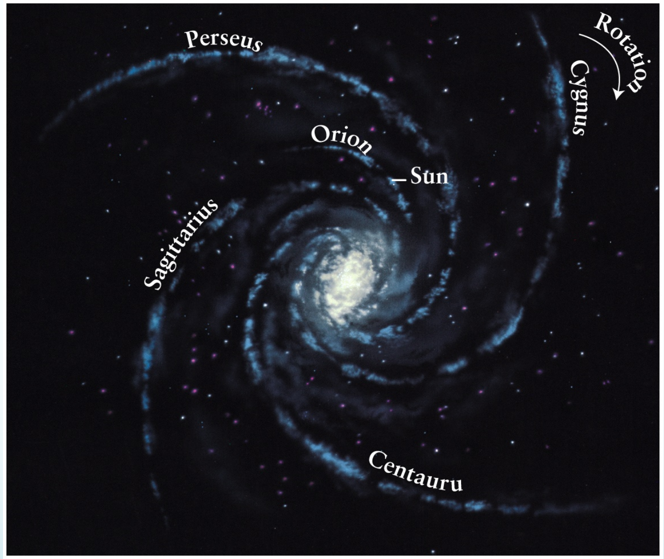
Cosmological Redshift and Galaxies

Galaxies

- The basic structures of the Universe at large scales.
- Galaxies are "cities" of stars.
- Our Milky Way Galaxy:
  - 1,000 billion solar masses, 400 billion stars, 100,000 lyrs radius

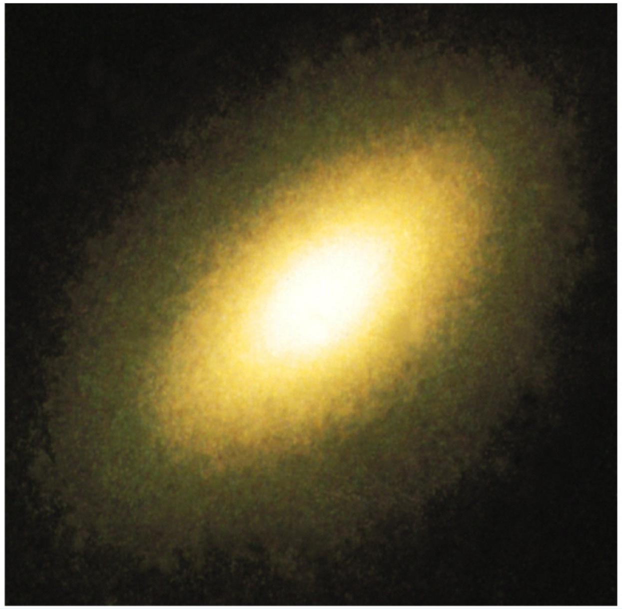


Edge-on: a thin disk



Face-on: a grand spiral

Types of Galaxies

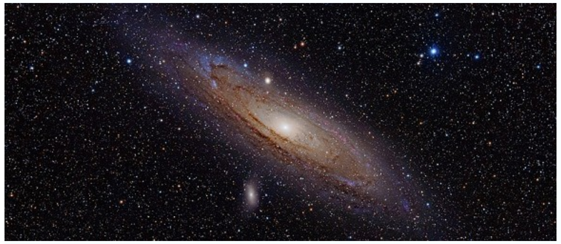


Spiral Galaxy
young & old stars

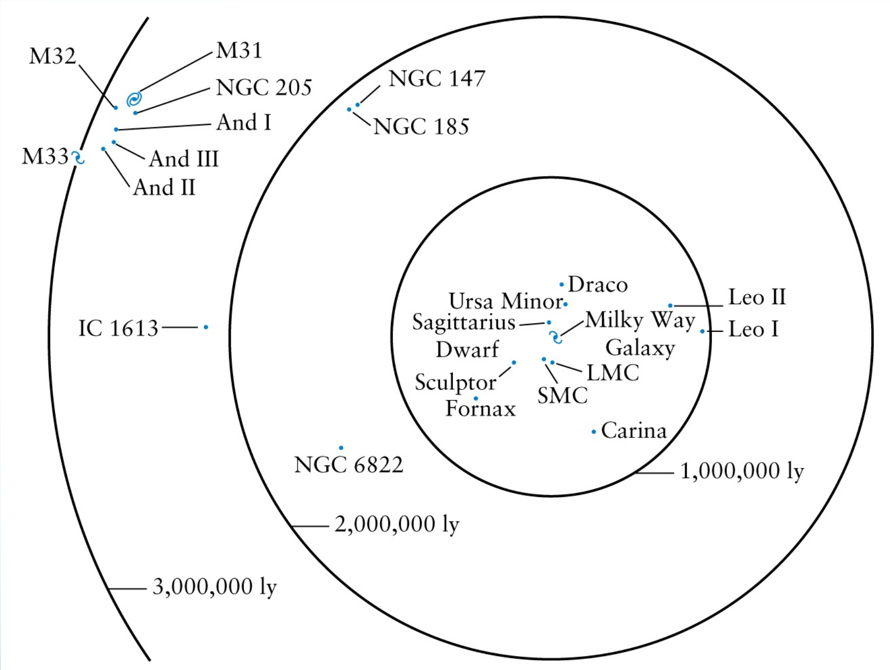
Elliptical Galaxy
old stars

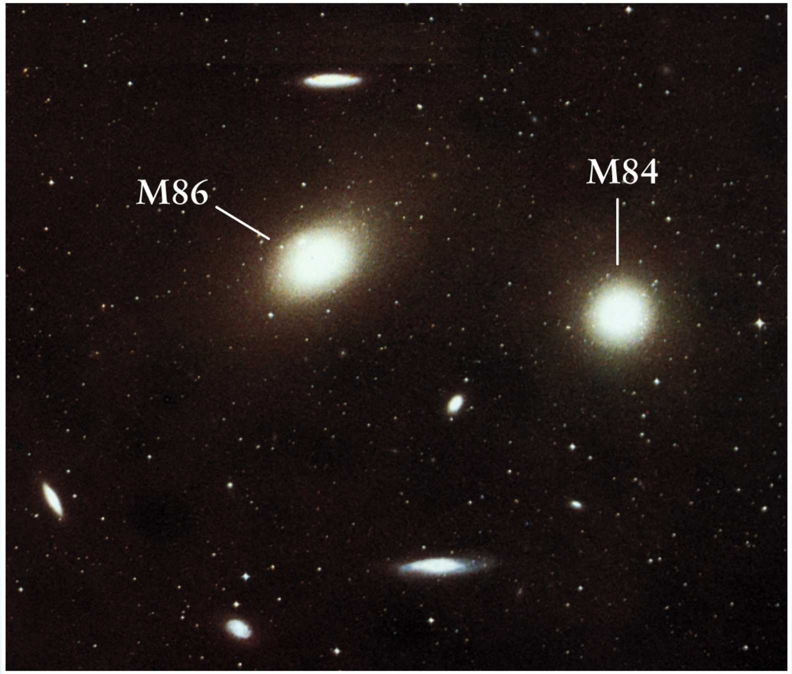
Irregular Galaxy
a mixture

Andromeda



Galaxy Clusters

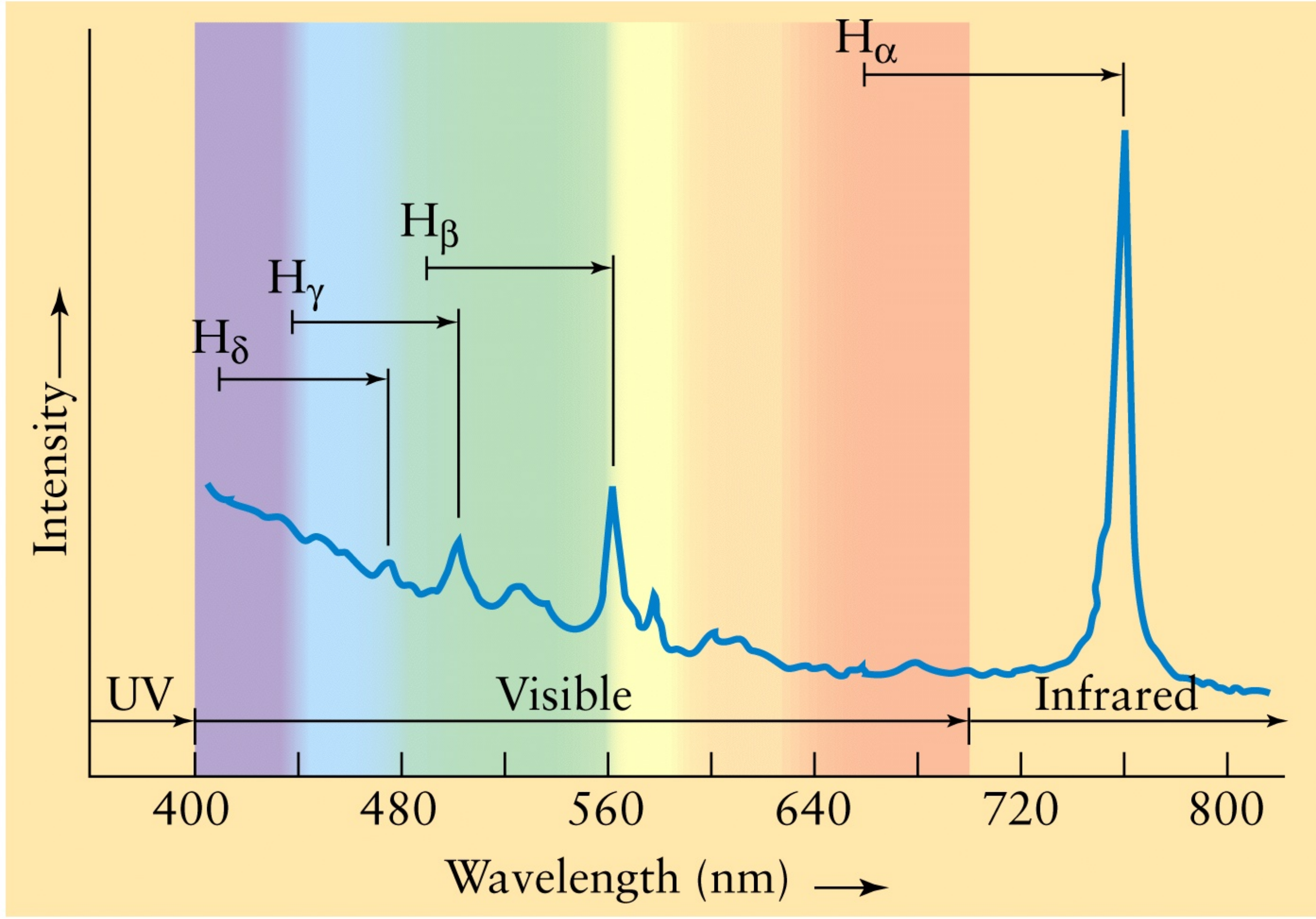




Our "Local Group" of galaxies
Dominated by Milky Way & Andromeda

Virgo cluster
~2,000 galaxies, 16 Mpc away
We are falling towards here at 750 km/s!

Cosmological Redshift: I



For distant galaxies we find that spectral lines are shifted to significantly longer wavelengths.

Cosmological Redshift: II

- As before, we define the Cosmological Redshift parameter, *z*, as the fractional change in wavelength

$$z = \frac{\Delta\lambda}{\lambda}$$

- However, for <u>distant galaxies</u> we find that

Space is expanding between us and the distant galaxy

- i.e. the distance between Earth and the distant galaxy is increasing, <u>not</u> that the galaxy is moving away from us!

- This comes from Hubble's Law – see the next lecture.
  - *See also today's tutorial*

Cosmological Redshift: III

- When the velocity of expansion of the Universe is small
  - i.e. $v << c$, or $v/c << 1$, then

$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$$

- The very same formula as for the Doppler Redshift, but now the interpretation is that space is being stretched at a speed v

- Note: there is an exact formula, but you don't need to know for A-level:

$$1 + z = \gamma\left(1 + \frac{v}{c}\right) \text{ where } \gamma = 1/\sqrt{1 - \left(\frac{v}{c}\right)^2}$$

  - When $v/c << 1$ this reduces to the formula above, $z = v/c$.

Cosmological Redshift: IV

- Doppler Redshift applies for:
  - Motions of planets in our Solar System
  - Motions of stars in our Galaxy
  - Motions of nearby galaxies

- Cosmological Redshift applies for:
  - The stretching of space to distant galaxies