Galaxies: Structure, formation and evolution

Lecture 2

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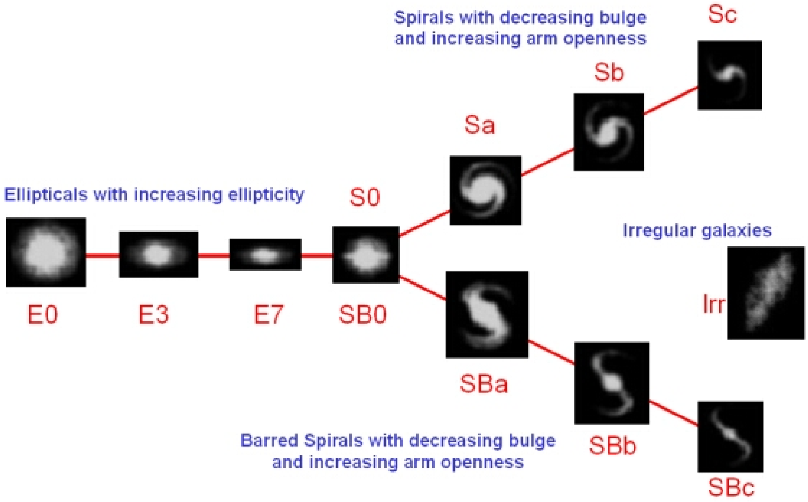
Hubble tuning fork diagram



Elliptical

Elliptical Galaxies

- About 20% of field galaxies are Ellipticals, but most E's are in clusters
- There are a number of different subtypes:E's (normal ellipticals), cD's (massive bright ellipticals at the centers of galaxy clusters), dE's (dwarf ellipticals) dSph's (dwarf spheroidals - like extremely faint dEs, small size, spherical)
- Smooth and almost featureless. no disc, no spiral arms nor dust lanes. Generally lacking in cool gas, and hence few young blue stars
- Elliptical galaxies are denoted En where:$b/a = 1 - n/10$ i.e. an E4 galaxy has an axis ratio of $b/a = 0.6$, and E0's have circular isophotes.

Lenticular

Lenticular

- are characterised by the presence of a central bulge and disk and the absence of spiral arms i.e. little or no ongoing star formation
- intermediate in many of their properties between ellipticals and spirals.

Grand Design Spiral

What is the diameter of the Milky Way Galaxy?

Flocculent Spirals - NGC 2775

Spiral

Named for their bright spiral arms, which are prominent due to emission from bright O and B stars (evidence for recent star formation) and absorption to dust lanes.

Which are more massive, O or B type stars?

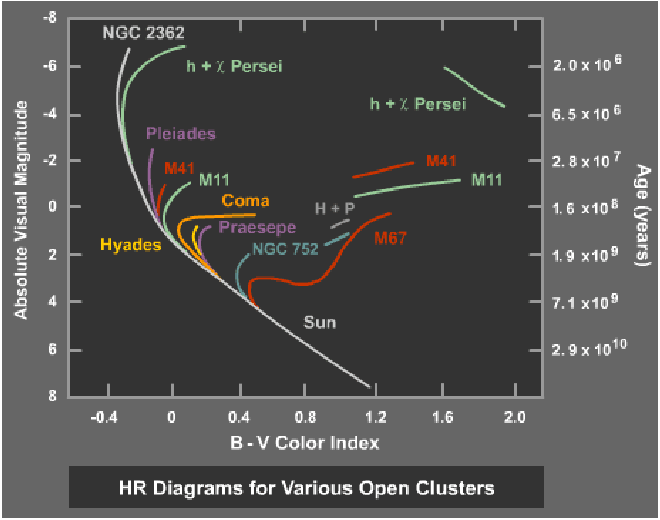
Distance to Andromeda galaxy

If the Andromeda galaxy subtends an angle of 4.96 degrees on the sky and is 67 kpc in diameter what is its distance?

Distance to Andromeda galaxy

If the Andromeda galaxy subtends an angle of 4.96 degrees on the sky and is 67 kpc in diameter what is its distance? Ans: 780 kpc

Age of open clusters via main sequence turnoff



How to use the HR diagram to find age of open cluster?

M/L ratio for stars

For main sequence stars, we have $L \propto M^{3.5}$, giving : $(M/L) \propto M^{-2.5} \propto L^{-0.71}$ showing, as one expects, later spectral types have higher M/L. eg K stars : $M \sim 0.4M_\odot \rightarrow M/L \sim 10$; A stars : $M \sim 2.5M_\odot \rightarrow M/L \sim 0.1$

Mass to light ratio M/L of a galaxy

M/L defined in units of $M_\odot/L_\odot$
For galaxies, M/L reflects the average M/L over the population
Pop I (young) : massive stars dominate light; low mass stars dominate mass Pop II (old) : giants dominate light; M.S. stars dominate mass
Typical spiral galaxy (& solar neighborhood) has $M/L_V \sim 6$, $M/L_B \sim 10$ In general : M/L increases with age and metallicity
Maximum range : $2 < M/L_B < 20$.
What are Pop III stars?

Initial Mass Function IMF

The IMF $\xi(M)$ specifies the distribution in mass of a newly formed stellar population and it is frequently assumed to be a simple power law: $\xi(M) = c\,M^{-(1+x)}$. In general, $\xi(M)$ is assumed to extend from a lower (M_1) to an upper cutoff (M_2).

Initial Mass Function

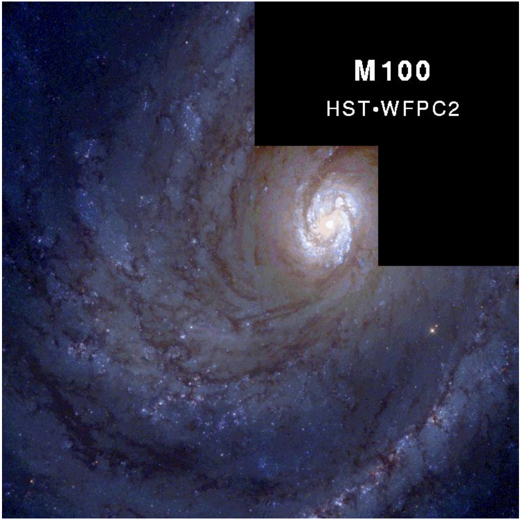
IMF	M_1	M_2	x
Salpeter	0.10	125.	1.35
Scalo	0.10	0.18	-2.60
	0.18	0.42	0.01
	0.42	0.62	1.75
	0.62	1.18	1.08
	1.18	3.50	2.50
	3.50	125.	1.63
Miller & Scalo	0.10	1.00	0.25
	1.00	2.00	1.00
	2.00	10.0	1.30
	10.0	125.	2.30

Other IMFs in use include Chabrier (2003) and Kroupa (2001). See review by: Bastian et al. (2010).

Problem

For a Salpeter IMF, what is the relative number of K and A stars in a cluster *that has just formed?*

M100 nucleus



Barred galaxies

- Roughly half of all disk galaxies - Milky Way included - show a central bar which contains up to 1/3 of the total light Bars are a form of dynamical instability in differentially rotating stellar disks
- S0 galaxies also have bars – a bar can persist in the absence of gas
- Bar patterns are not static, they rotate with a pattern speed, but unlike spiral arms they are not density waves. Stars in the bar stay in the bar
- The asymmetric gravitational forces of a disk allow gas to lose angular momentum (via shocks) compressing the gas along the edge of the bar. The gas loses energy (dissipation) and moves closer to the center of the galaxy.

Barred Spiral NGC 1300