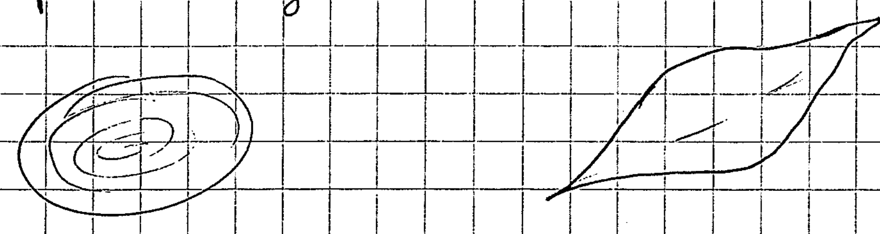
ASTR 333/433 continued – 2nd half of semester

Early Type Galaxies

Elliptical & SØ galaxies



Mostly 3D elliptical blobs where
pressure support is important.
SØs have a feeble disk component (not star-forming)
often hard to distinguish from Es.

Range of Hubble types EØ, 1 ... 7
a combination of intrinsic ellipticity ε
and projection effects (major axis rarely in plane of sky)

Unlike spiral galaxies, Ellipticals are a
natural result of hierarchical galaxy merging.
Most stars formed early (old pops)
either in-situ or in smaller fragments
that subsequently merged ("dry mergers")
→ no gas to make new stars in merger

Anisotropy parameter

In general, orbits of stars in pressure supported systems need not be isotropic, i.e. ($\sigma_{l.o.s.} \neq \sigma_{max}$)

σ is different in different directions

σ_r, $\sigma_t = \sigma_\theta = \sigma_\phi$ radial & tangential

In general

$$M(r) = \frac{r\sigma_r^2}{G}(\gamma_* + \gamma_\sigma - 2\beta)$$

where

$$\gamma_* = -\frac{d\ln n_*}{d\ln r}$$ logarithmic slope of stellar density profile (measurable)

$$\gamma_\sigma = -\frac{d\ln \sigma_r^2}{d\ln r}$$ logarithmic slope of $\sigma_r^2(r)$ [radial, not l.o.s]

$$\beta = 1 - \frac{\sigma_t^2}{\sigma_r^2}$$ anisotropy parameter

σ_t = " " " tangential (θ, ϕ) direction

σ_r = velocity dispersion in radial direction within body

extreme cases

circular orbits	$\sigma_r = 0$	$\beta = -\infty$	
isotropy	$\sigma_r = \sigma_t$	$\beta = 0$	— implicitly assumed in most virial estimates: $\sigma_{los} = \sigma_r = \sigma_t$
radial	$\sigma_t = 0$	$\beta = 1$	

more generally, $\beta < 0$ "tangential" bias

$\beta > 0$ "radial" bias

β can vary with r. This is the biggest systematic uncertainty in mass modeling elliptical galaxies.

Cosmic Overdensities

It is conventional in cosmology to refer to structures by the density contrast they represent with respect to the critical density of the universe. The mass enclosed within a radius encompassing the over-density Δ is

$$M_\Delta = \frac{4\pi\Delta}{3}\rho_{crit}R_\Delta^3. \tag{1}$$

With $\rho_{crit} = 3H_0^2/8\pi G$, this becomes

$$M_\Delta = \frac{\Delta}{2G}H_0^2 R_\Delta^3. \tag{2}$$

By the same token, the circular velocity of a tracer particle at R_Δ is $V_\Delta^2 = GM_\Delta/R_\Delta$. Consequently,

$$M_\Delta = (\Delta/2)^{-1/2}(GH_0)^{-1}\, V_\Delta^3. \tag{3}$$

In ΛCDM, the density contrast $\Delta \approx 100$ marks the virial extent of a dark matter halo. For $H_0 = 72\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$,

$$M_{vir} = (4.6\times 10^5\ \mathrm{M_\odot\,km^{-3}\,s^3})V_{vir}^3. \tag{4}$$

This includes all mass, dark and baryonic, that reside within the radius R_{vir}. This 'virial' radius is entirely notional; we do not really know what is going on that far out from any given galaxy. For historical reasons, it is conventional to reference the notional halo mass to an overdensity of 200, in which case

$$M_{200} = (3.3\times 10^5\ \mathrm{M_\odot\,km^{-3}\,s^3})V_{200}^3. \tag{5}$$

This differs from equation 4 by the factor of $\sqrt{2}$ for the difference between $\Delta = 100$ and 200 seen in equation 3. This is frequently cited as the basis of the Tully-Fisher relation, though bear in mind that this refers to the total mass enclosed by R_{200} and the circular velocity of a test particle at that radius, which are not observed.