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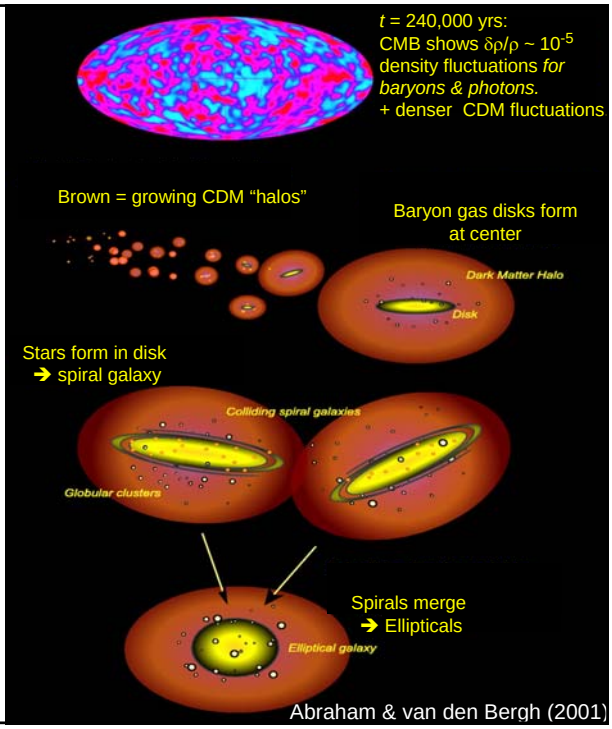
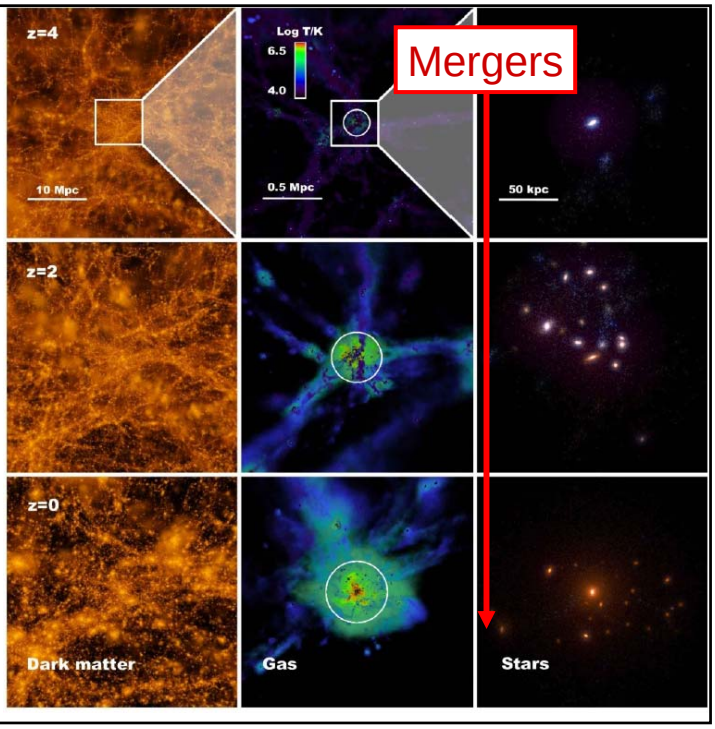


Simulation of E galaxy formation.

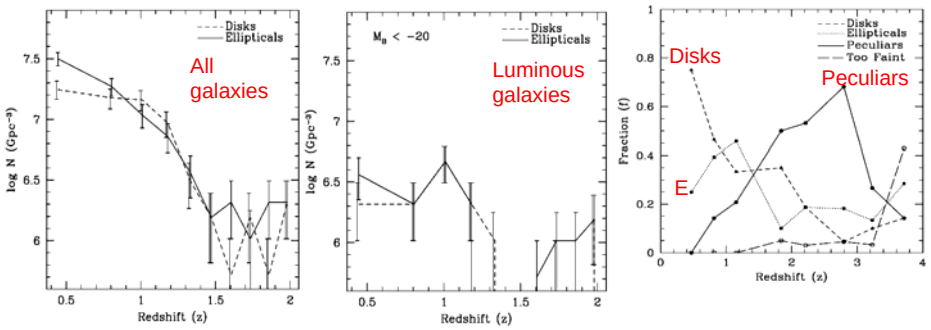


From:
Cattaneo et al. 2009
Nature review article
arXiv:0907.1608
Excellent 7 page summary

See also
Bell et al. 2009
Sections 1-2 (2 pgs)
arXiv:0903.3404

Slide by Chris Conselice

Co-moving density of Hubble Types with Redshift



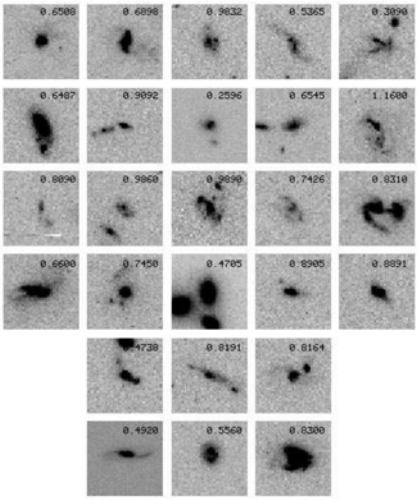
Co-moving density drops from z ~ 1 to 1.5, even when considering only bright galaxies

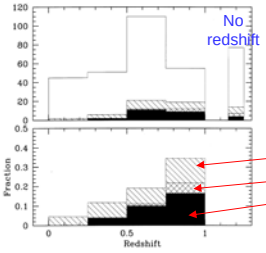
Did peculiar galaxies merge to form today's massive E and S galaxies?

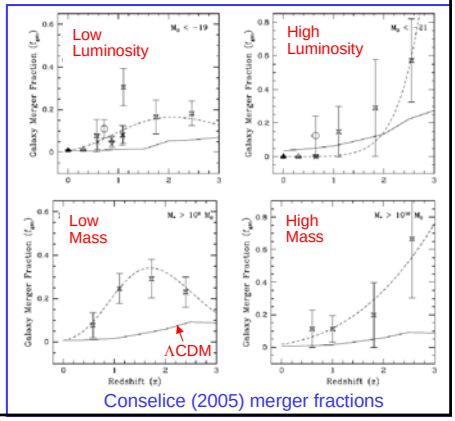
Are these high redshift peculiar galaxies mergers?

LeFevre et al., 2000, MNRAS, 311, 565

- 285 galaxies.
- HST images, CFHT spectra.
- Merger fraction increases with redshift







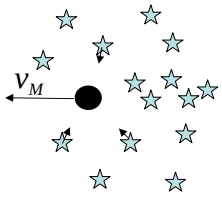
Conselice (2005) merger fractions

Merger Processes

- **Dynamical Friction** - A slow accretion process.
  - Massive body moving through uniform distribution of stars
    - Pulls stars in behind it.
    - Creates high-density wake.
    - Gravitational pull from wake slows down massive body.
    - If massive body is in orbit in a galaxy, it will gradually spiral into the center.
    - Force on massive body is $f_d \simeq C\frac{G^2M^2\rho}{v_M^2}$ ⇨ $t_c = \frac{2\pi v_M r_i^2}{CGM}$

$$r_{\max} = \sqrt{\frac{t_{\max} CGM}{2\pi v_M}}$$

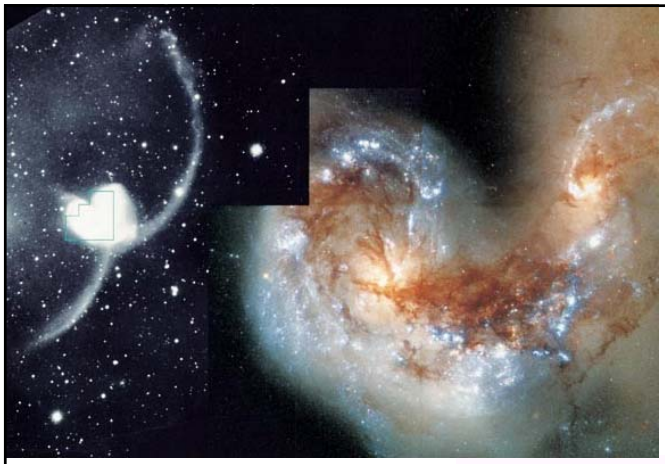
[CO eqn. 26.3]



r_i = initial distance from center of galaxy.

t_c = time to spiral into center due to dynamical friction.

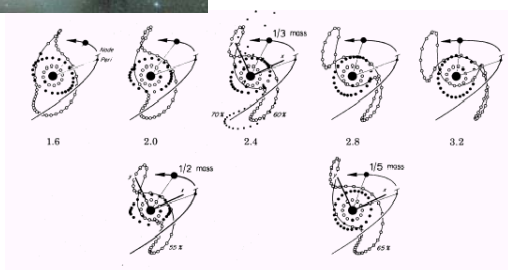
r_{max} = max radius for capture within age of universe. (= 4 kpc for M31 and t = 13 Gyr)

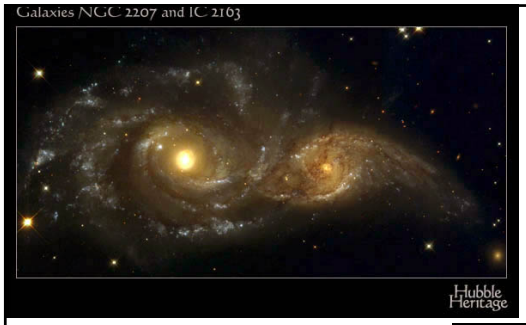


The Antennae Galaxies

NGC 4038
NGC 4039

- **Galaxy collisions** – "impacts".
  - Numerical simulations
  - Toomre & Toomre, 1972, ApJ 178, 623.
    - Tidal tails, etc.





Do collisions between spirals make ellipticals?

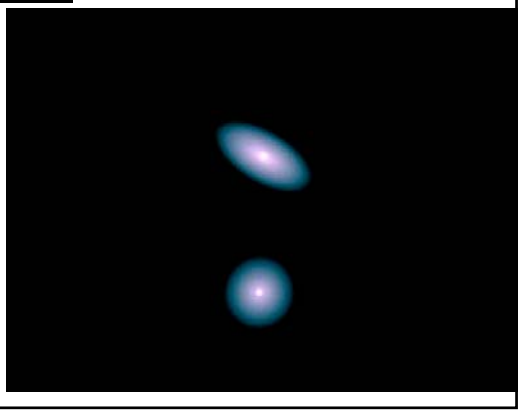
The Milky Way Meets Andromeda

2.5 million ly away

Approaching at 500,000 km/hr

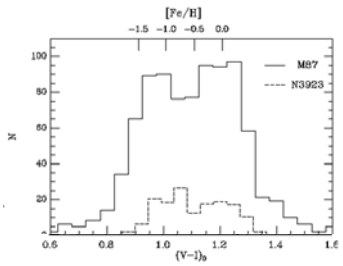
➔ Collision in 3 billion yrs

Movie lasts 1.3 billion yrs.

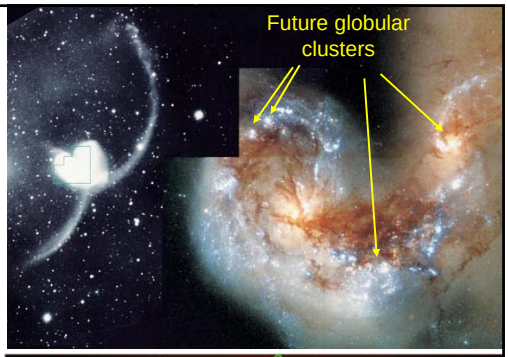


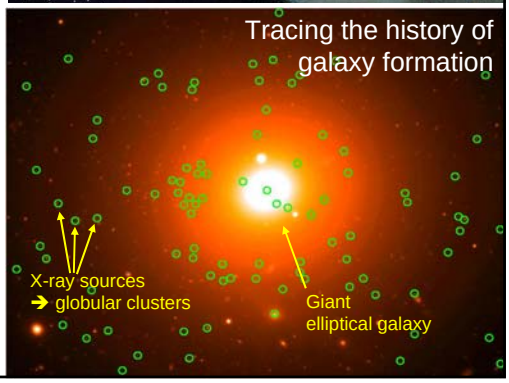
Globular Clusters as Merger Tracers

- Galaxy collisions ➔ bursts of star formation.
- Product includes globular clusters.
- E galaxies have several different generations of globular clusters.



Zepf & Co.





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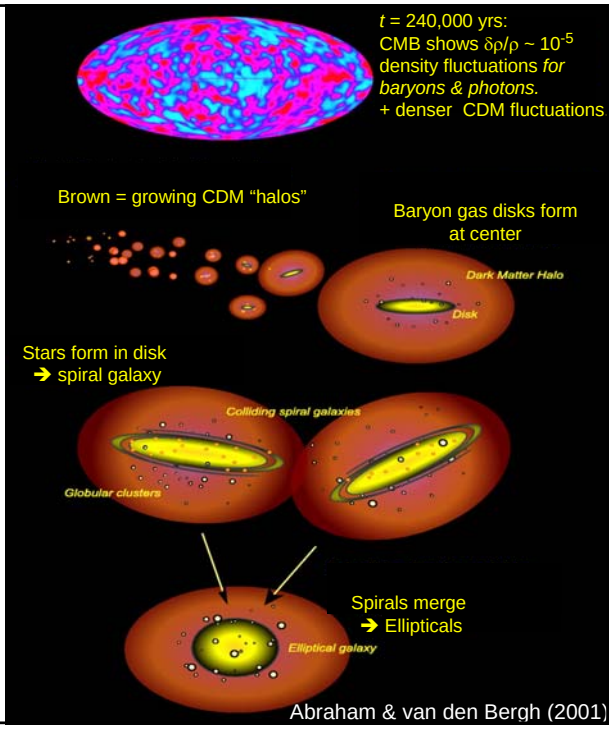

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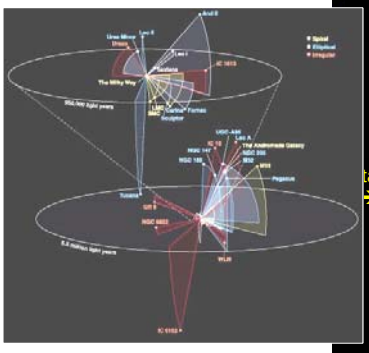
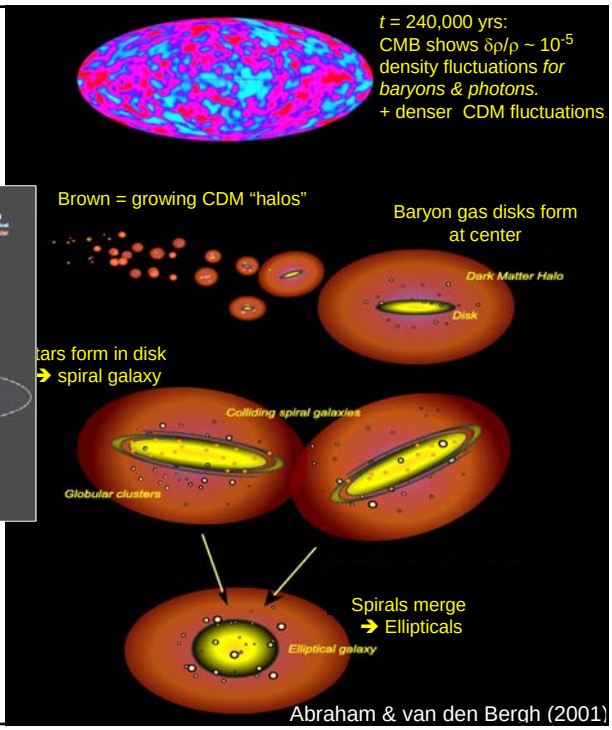


Too few low-mass galaxies observed in Local Group.

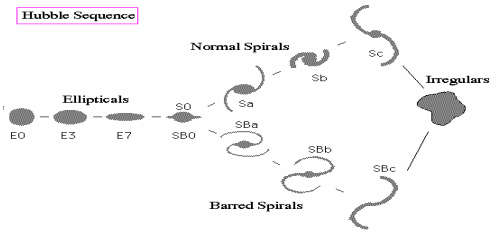
Did Pop III SN winds clean out gas?



Slide by Chris Conselice

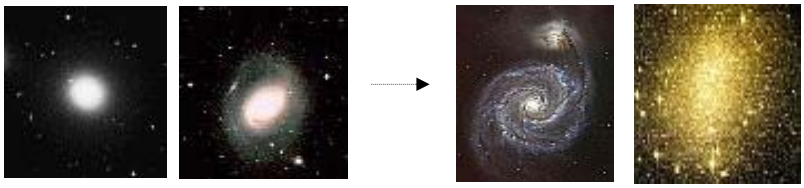
Hubble Types

98% of all nearby bright galaxies can be placed into a Hubble type



Hubble types are the z = 0 final state of bright galaxy evolution

Ellipticals have old stellar populations, spirals have both old and young components while irregulars are dominated by young stars

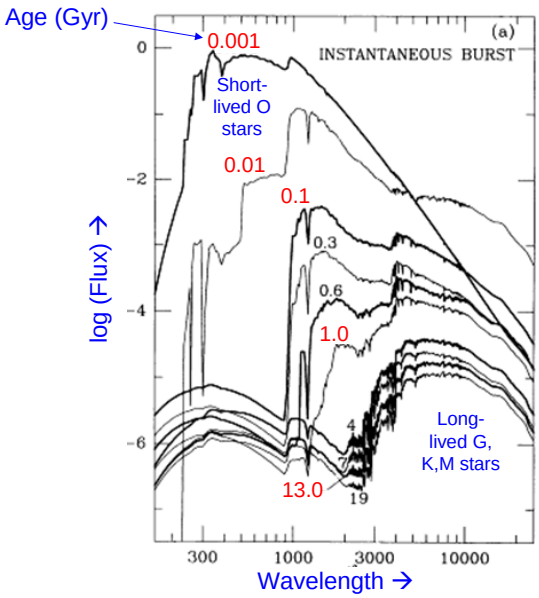


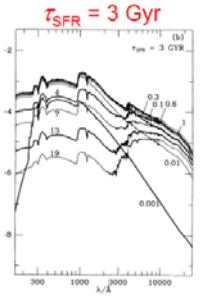
Old stars

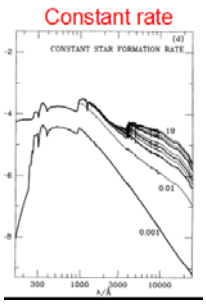
Young stars

A significant amount of star formation must have occurred in the past for Es, but some young stars clearly exist in spirals

Predicted evolution of galaxy spectrum over cosmic time

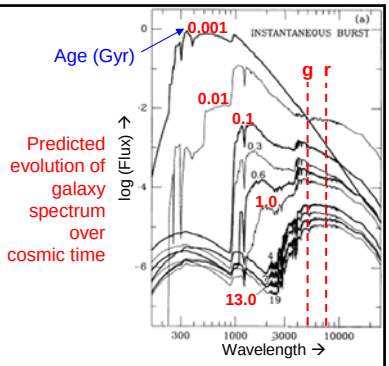




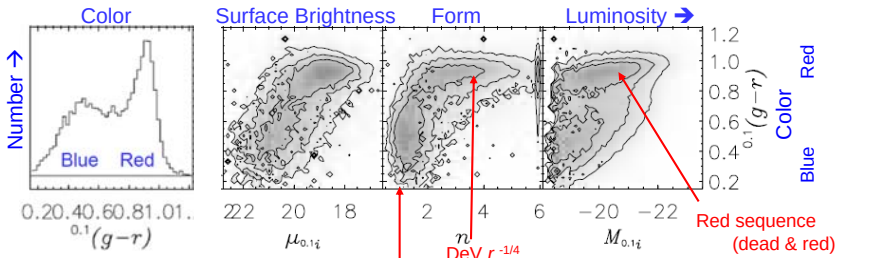


Present day galaxies

- SDSS (Sloan Digital Sky Survey)
  - 10^6 targets, mostly galaxies,
    - selected for spectroscopy
  - 10^4 deg^2 of sky
  - $m_r < 17.8$ mag



- 115,000 SDSS galaxies:



Red sequence (dead & red)
Largest galaxies ended star formation long ago. *Why*????

DeV $r^{-1/4}$ (ellipticals)

Exponential r^{-1} Disks (spirals)

Blanton et al. 2005, ApJ, 629, 143