Formation and evolution of elliptical galaxies
- models -

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a part of the course *Formation and Evolution of Galaxies*

Formation of Elliptical Galaxies

General consensus: elliptical galaxies form through mergers of spiral galaxies

Complicated N-body systems, containing gas, DM, stars

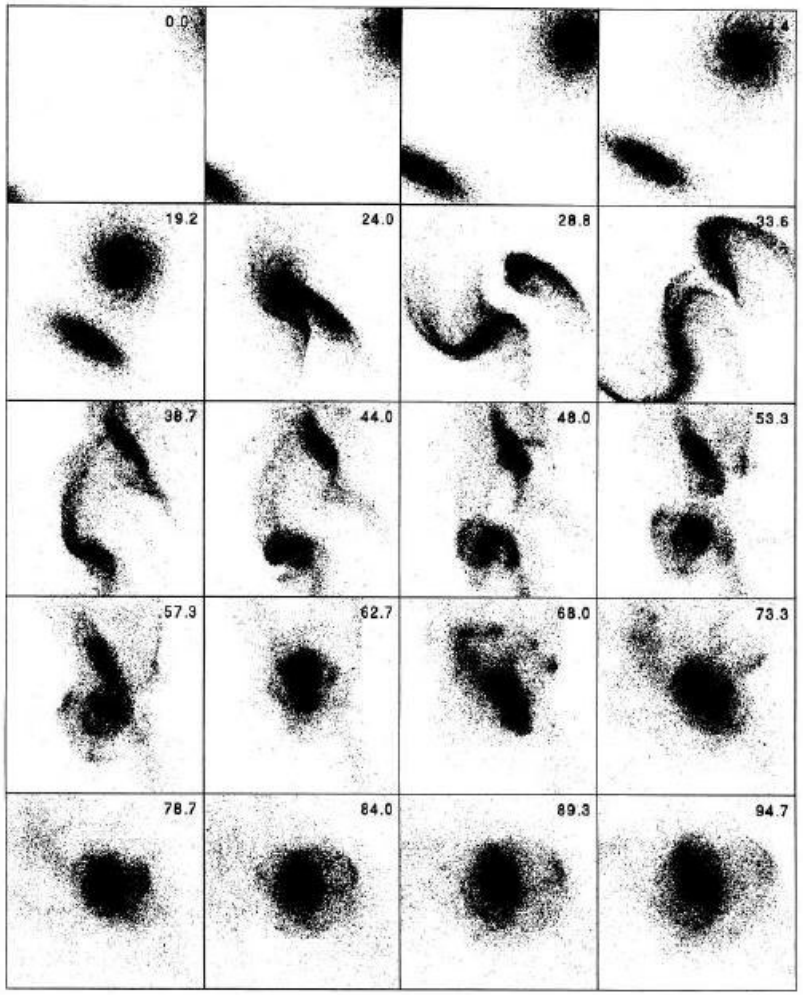
➔ **Numerical simulations**

Mihos & Hernquist (1994-1996) [1]

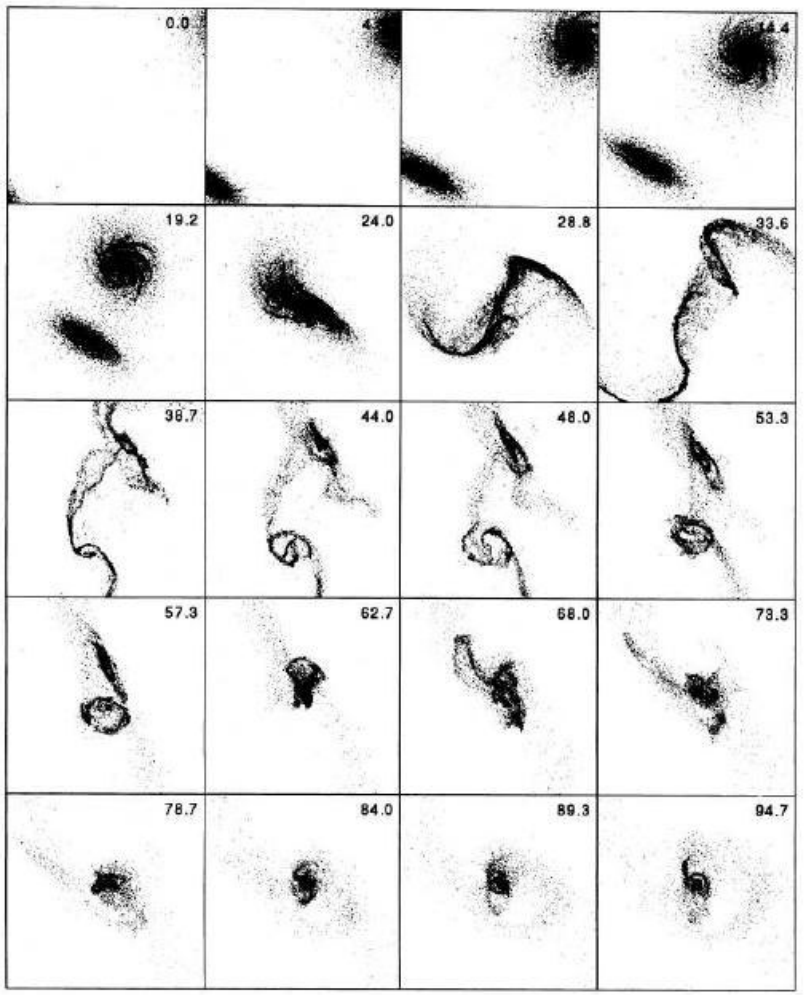
- Mergers of gaseous progenitors:
  - gas dissipates energy
  - gas falls into center and starts forming stars rapidly
- Result: gas poor elliptical galaxies

- Rapid gas inflow and corresponding star formation gives even better ellipticals when the progenitors have bulges

Mihos & Hernquist (1994-1996) [2]



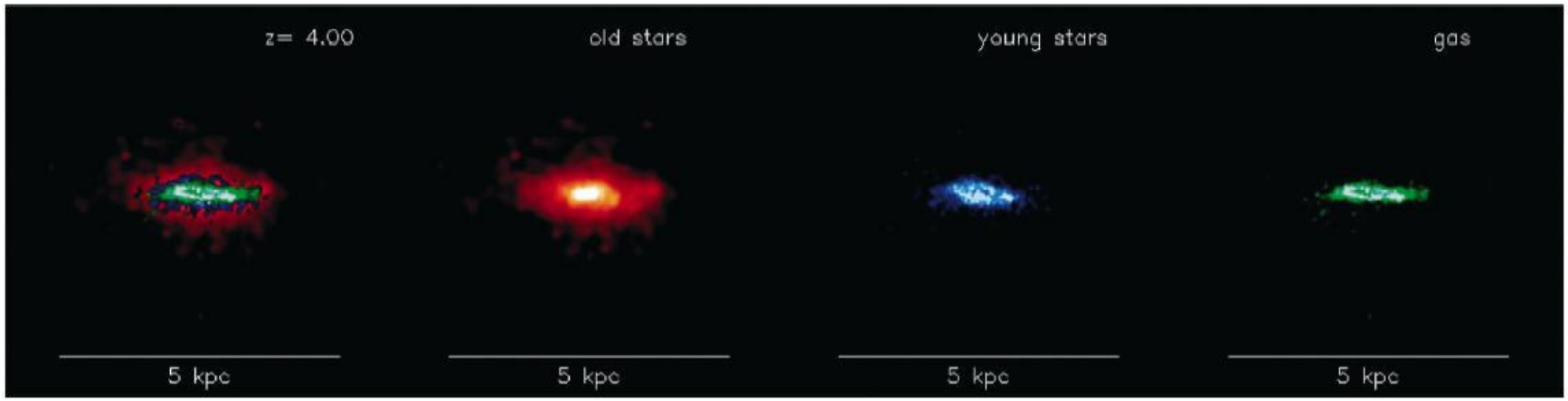
old stars

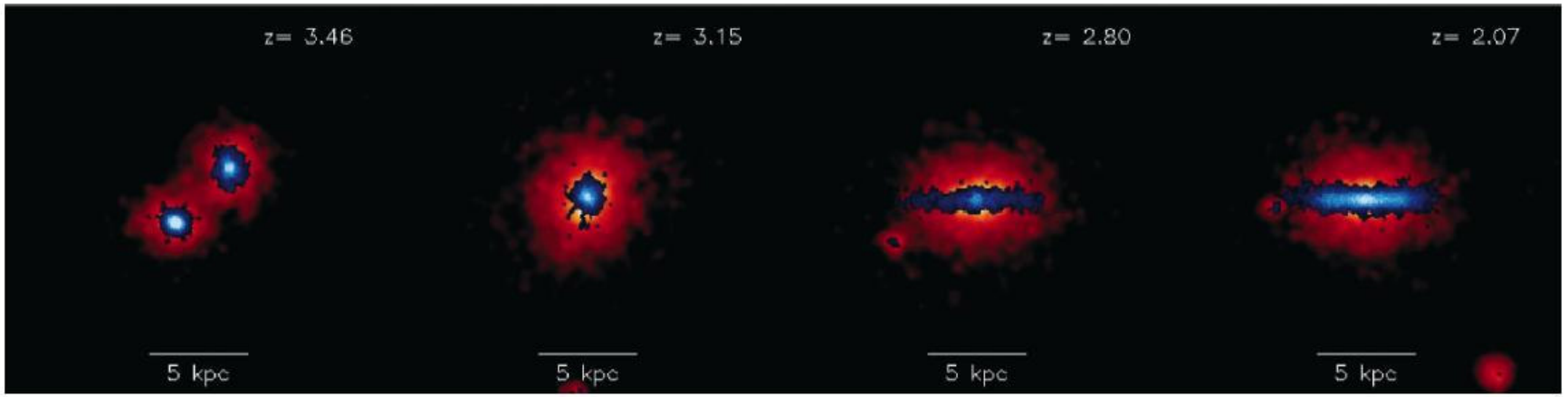


young stars and gas

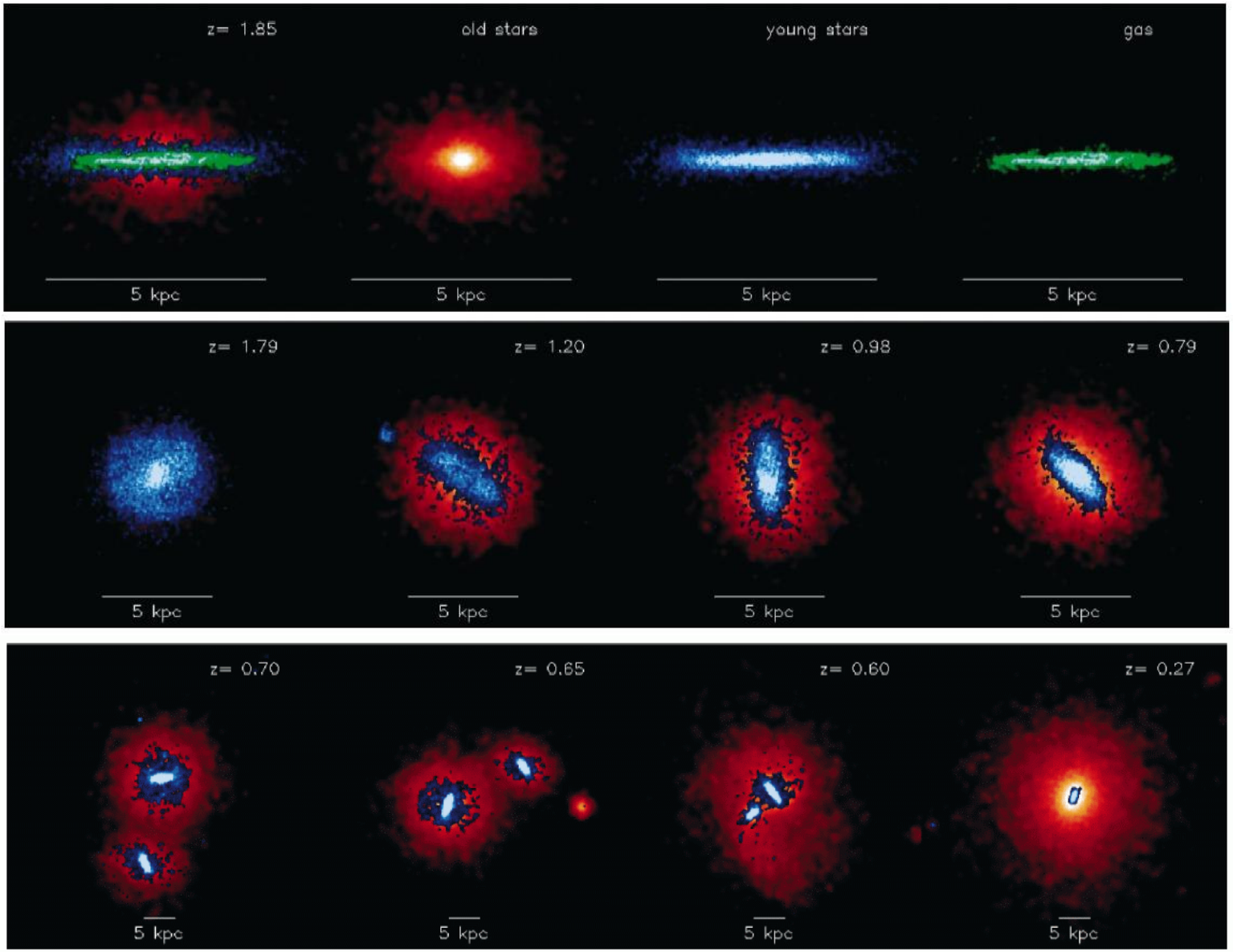
Steinmetz & Navarro (2002) [1]

Evolutionary sequence of consecutive mergers from $z = 4$ to present.

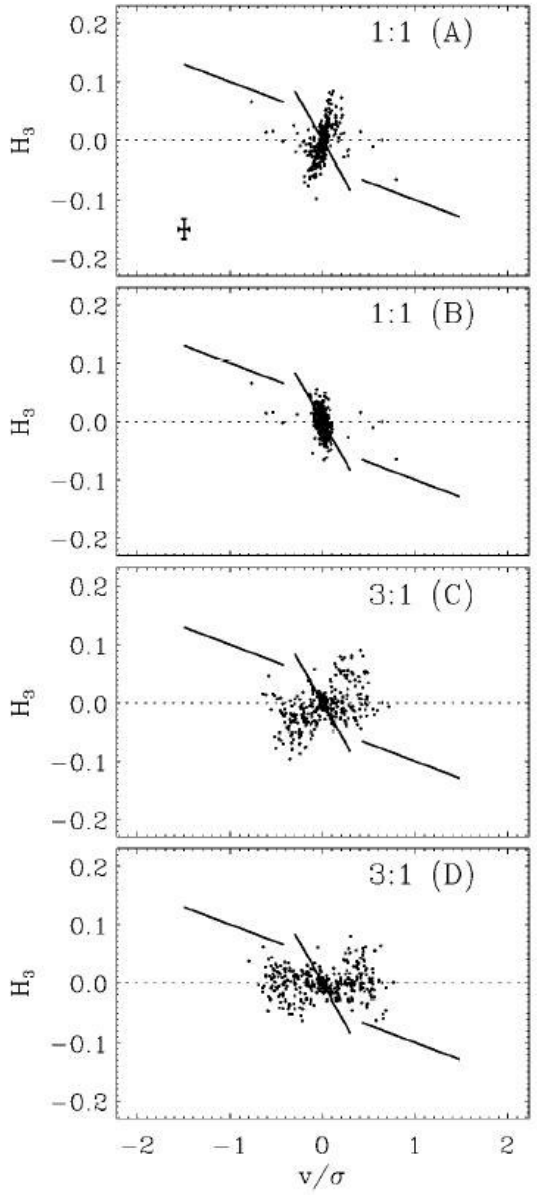




Steinmetz & Navarro (2002) [2]



Naab & Burkert (2001) [1]

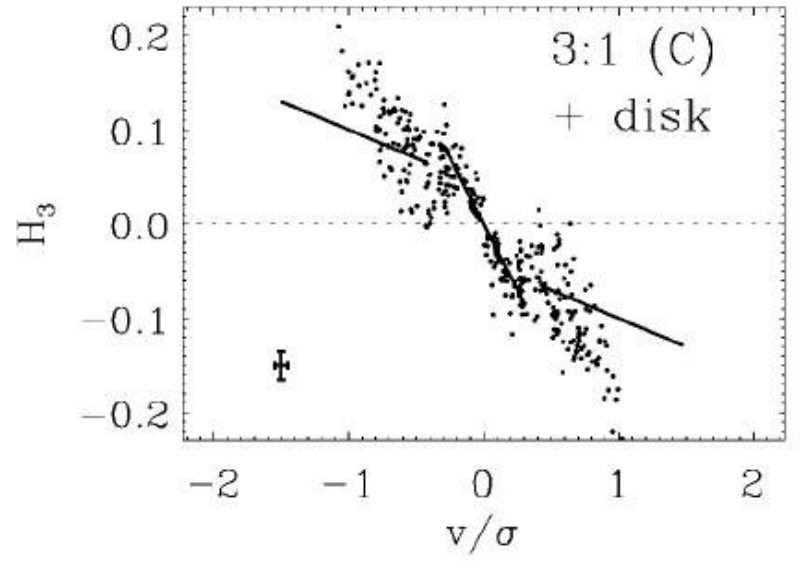


- Line-of-sight velocity distribution (LOSVD) is roughly Gaussian.
- Parameter H_3 measures 'skewness' of the profile.
- Only the points of simulation B (1:1, counter-rotating) match observation (solid line).
- Simulations A, C and D have steeper retrograde wings (H_3 and v/σ equal sign), while observations show H_3 and v/σ of opposite sign.

Naab & Burkert (2001) [2]

A thin cold disk is added to the remnant of simulation C.

- Low mass disks do not change the shape of LOSVD.
- Very massive disks give an exponential surface brightness distribution (is not observed).
- A disk of ~15% of the spheroid mass gives the desired result.



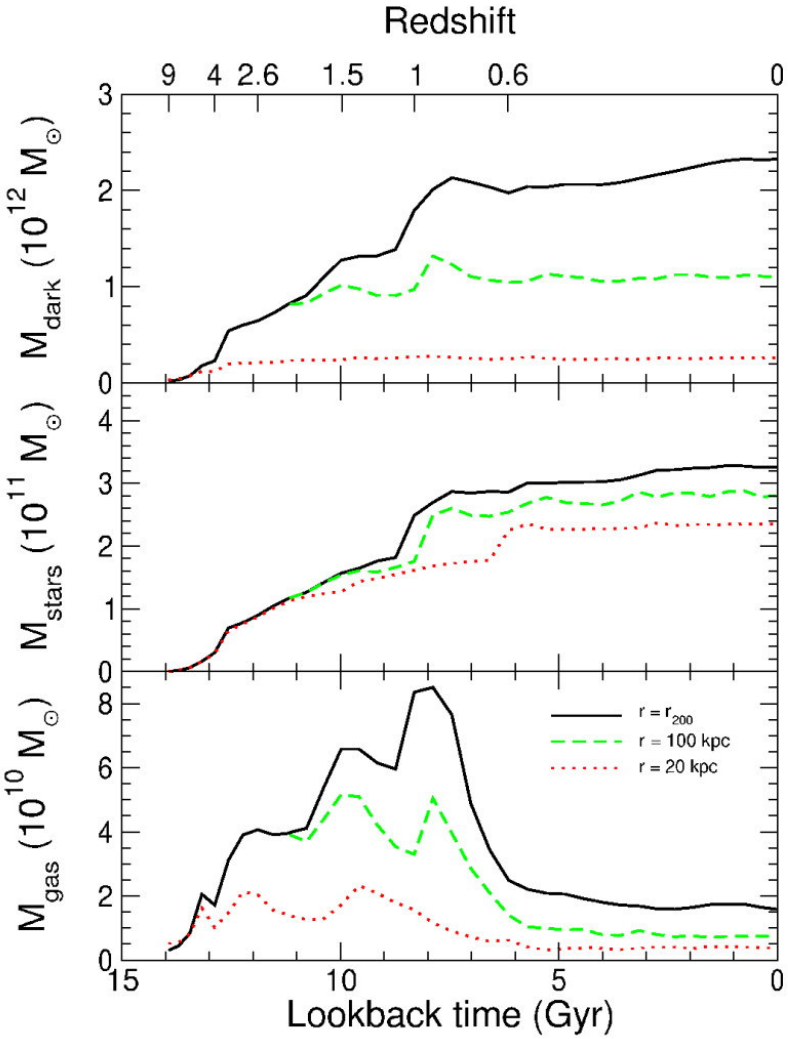
Meza et al. (2003)

Gas-rich mergers, involving dissipation.

Gas condenses into center → SF → gas depletion

The produced surface brightness profiles point to spherical galaxies with sizes 4 to 8 times too small for their luminosity.

Meza et al. are able to reproduce the observed disky and boxy shapes of elliptical galaxies by looking at edge-on and face-on projections of their simulations.

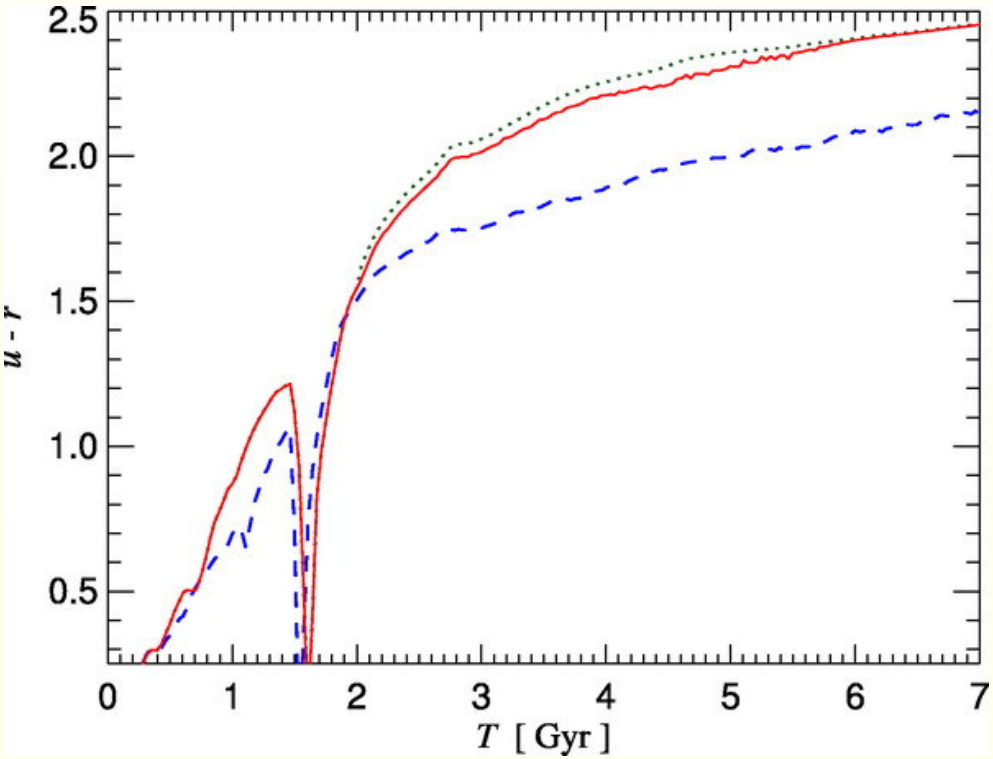


Springel, Di Matteo, Hernquist (2005)

Springel et al. include accretion onto a central black hole into their simulations.

They argue that AGN feedback is required to account for the bimodal colour distribution of elliptical galaxies.

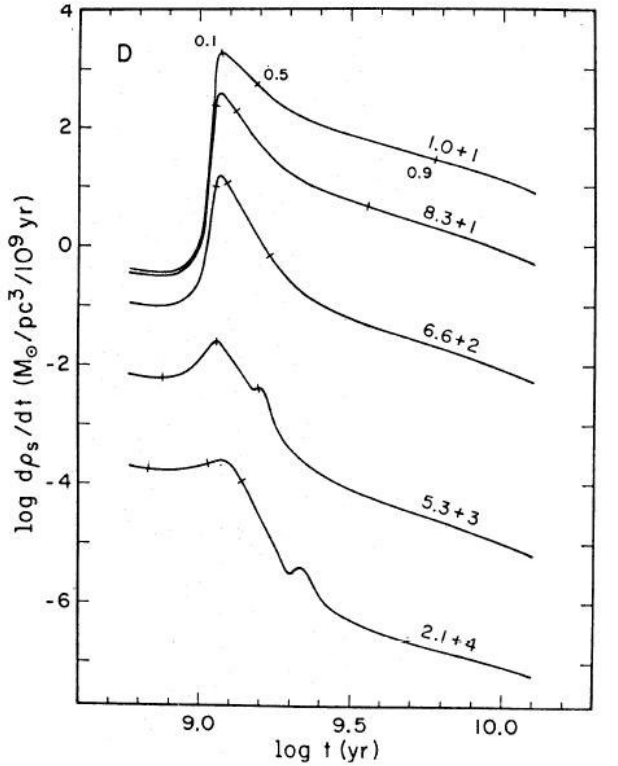
A very rapid starburst and gas outflow due to the BH terminates star formation abruptly, which yields a red galaxy (old stars) at $z = 0$.

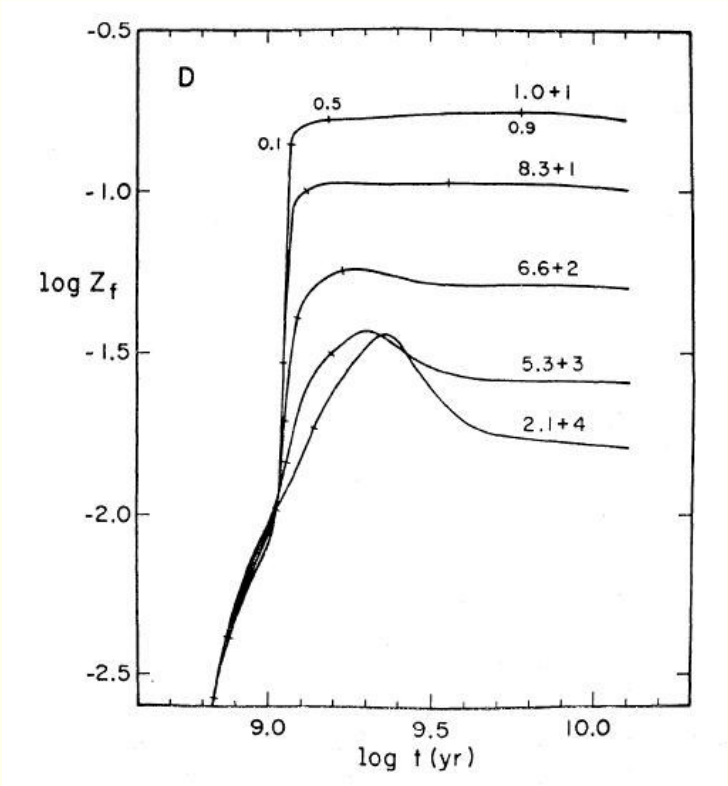


Larson (1974)

Different approach: monolithical collapse of a spherically symmetric system (no mergers involved). Only **gas** and **stars** are considered, no DM.

The simulation by Larson is able to reproduce the low gas fraction (which was also observationally determined in ellipticals) and the abundance gradient toward the center of his modeled galaxies.





Conclusions

- Elliptical galaxies form through major mergers of disky progenitors

  (minor mergers trigger bar instabilities in spiral galaxies)
- Fast gas accretion during merger process destroys disks and (perhaps with help of AGN) forms an elliptical galaxy.
- Smooth gas accretion in merging processes leads to formation of disks.