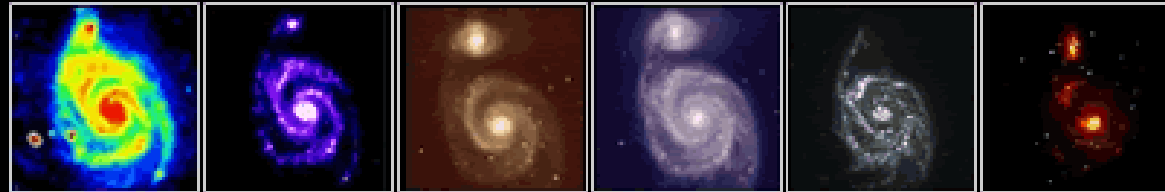




Galaxy Formation and Evolution in different environments

Alfonso Aragón-Salamanca

*School of Physics and Astronomy
University of Nottingham*



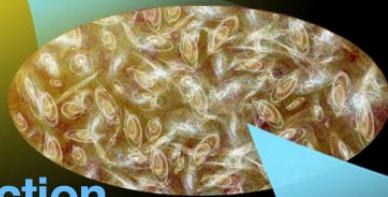
Overview:

- Galaxy formation in a cosmological context
- The effect of the environment
- Clusters as laboratories of galaxy evolution
- Summary



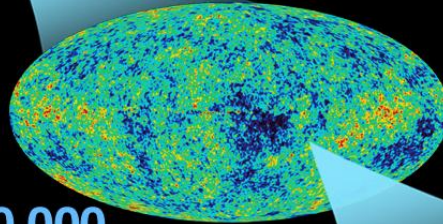
**DAWN
OF
TIME**

**tiny fraction
of a second**



inflation

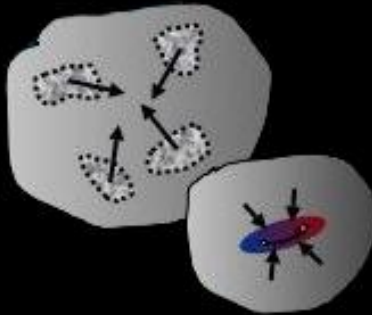
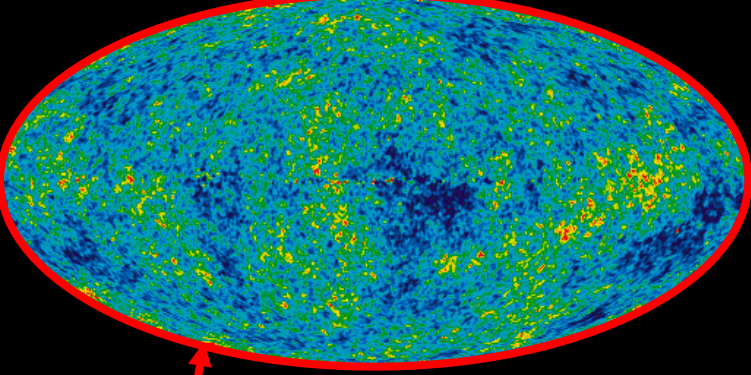
**380,000
years**



**13.7
billion
years**



A Theorist View of Galaxy Formation and Evolution



Growth of structure begins from initial dark matter distribution:

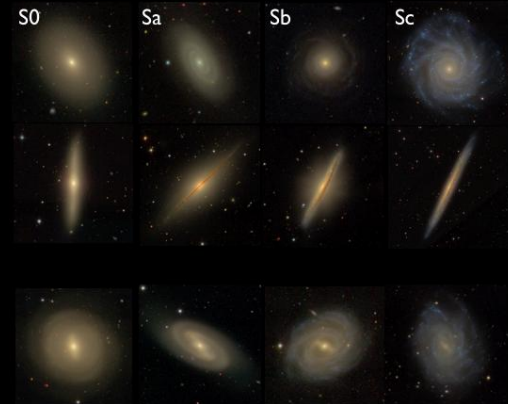
Cold-Dark-Matter Cosmogony



E0

E6

Irr

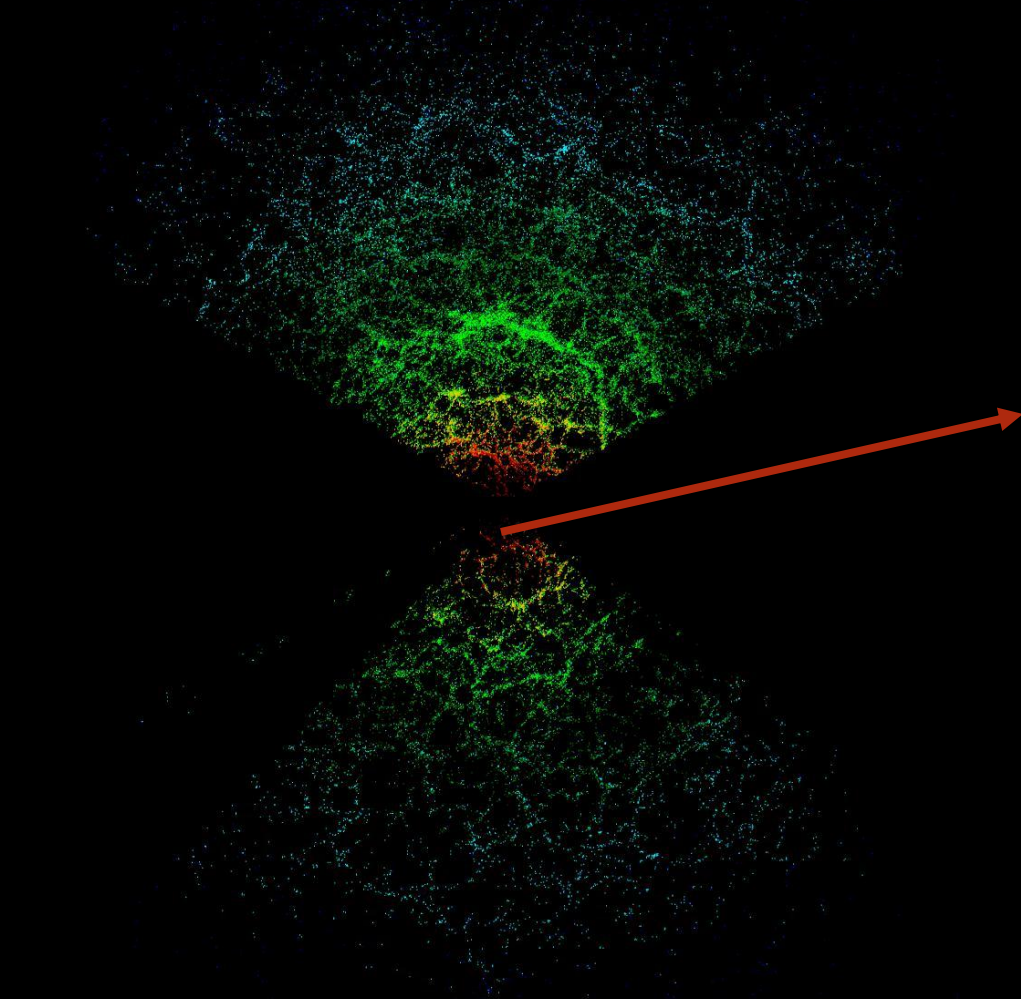
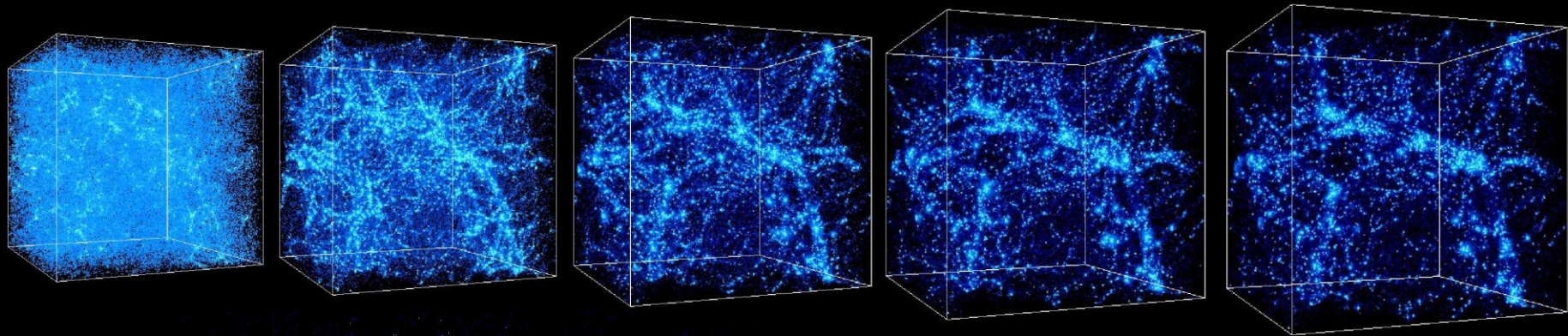


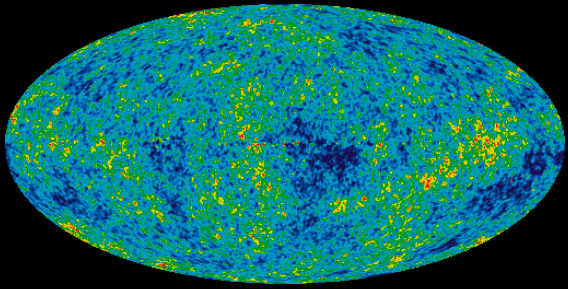
$z = 48.4$

$T = 0.05 \text{ Gyr}$

500 kpc

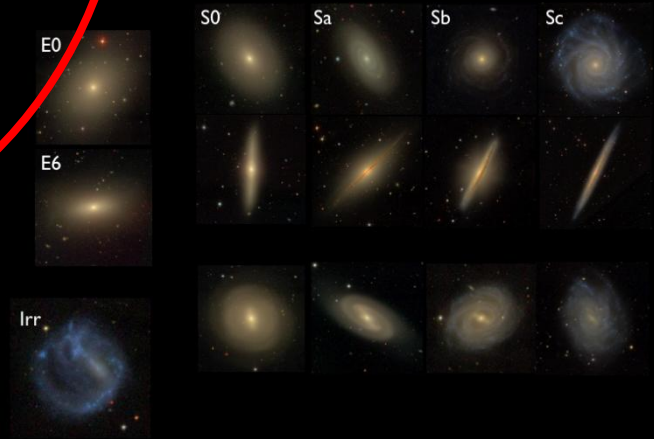
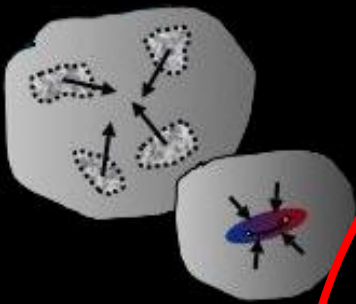
V. Springel et al. 2009

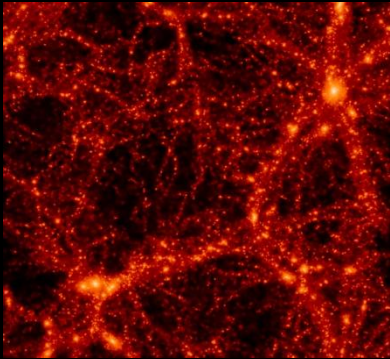
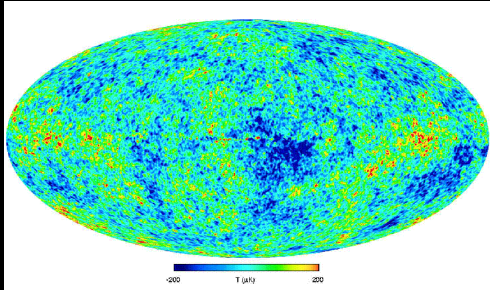




Complications
baryonic physics.

(Difficult to model)





Cosmological model
(Ω_m , Ω_Λ , h); dark matter

Primordial fluctuations
 $\delta\rho/\rho(\mathbf{M}, t)$

Dark matter halos
(N-body simulations)

Gas processes
(cooling, star formation, feedback)

Gasdynamic simulations

Semi-analytics

Formation and evolution of galaxies

Well established

Well understood

V Springel et al.

Galaxy Formation: gas-dynamic simulations

$z = 20.0$

dark matter density

gas density

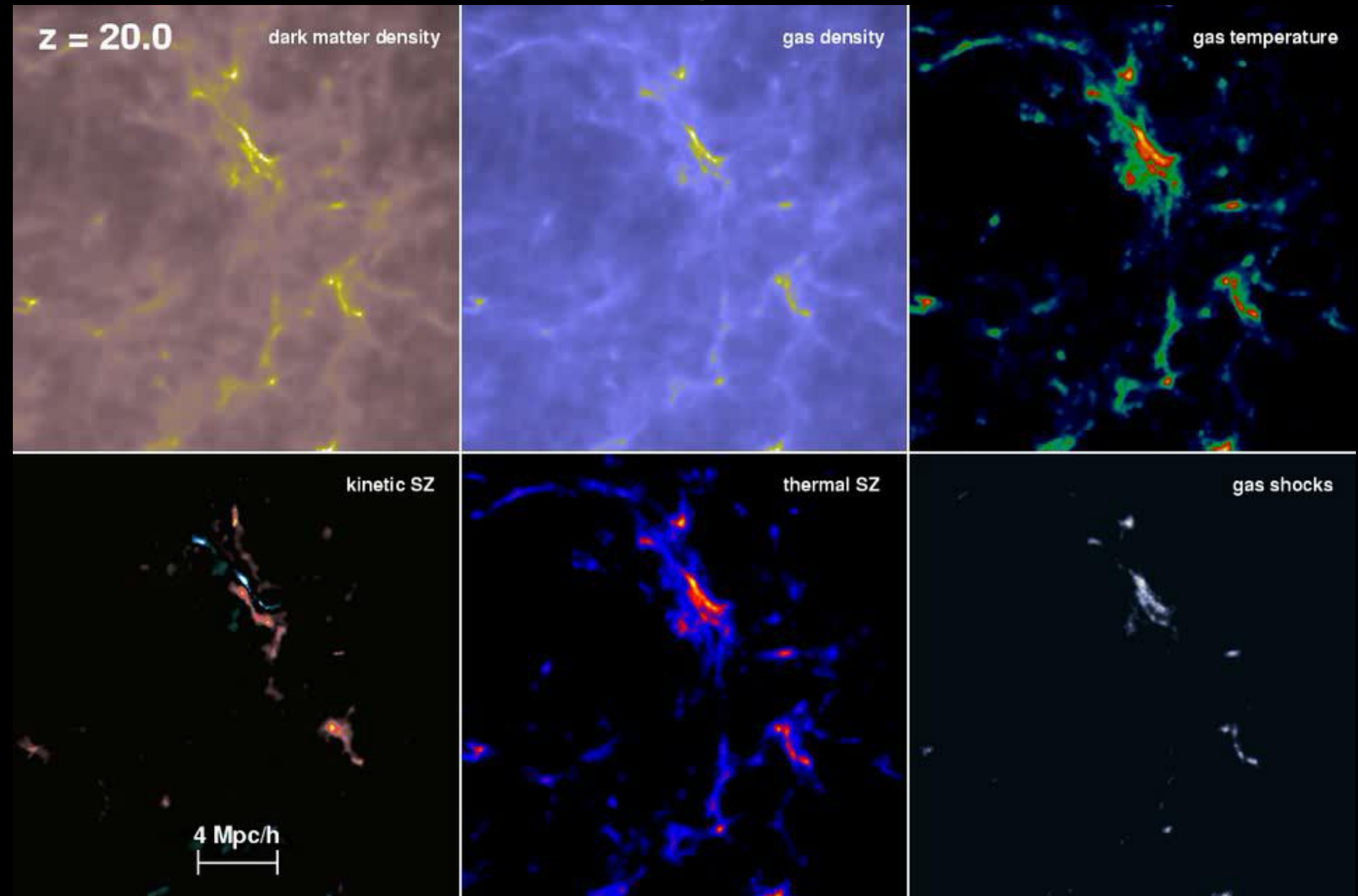
gas temperature

kinetic SZ

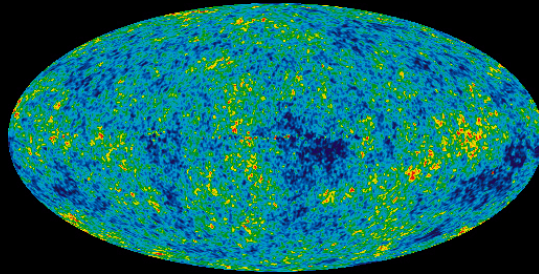
thermal SZ

gas shocks

4 Mpc/h



HIERARCHICAL GALAXY FORMATION

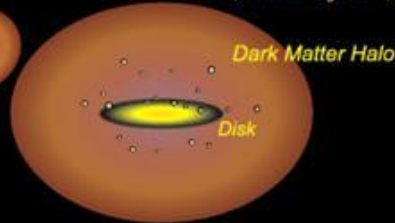


1. Small mass fluctuations (such as those revealed by the all-sky map, shown at left, obtained by the COBE satellite) are relics of the Big Bang. These are the "seeds" of galaxy formation.

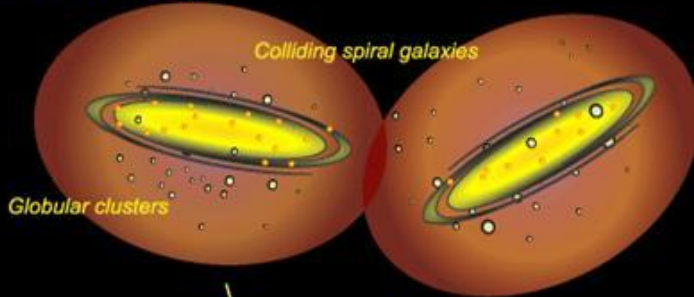
2. Invisible dark matter halos (shown in brown below) collapse from the ambient background, tracing the initial mass fluctuations.



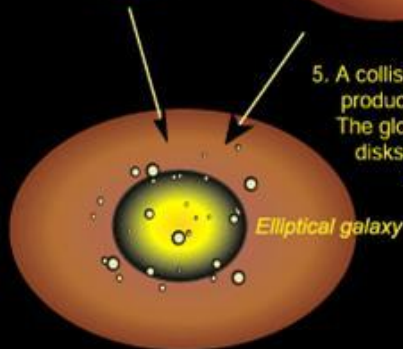
3. Primordial gas condenses within the dark matter halos. Some stars form during the collapse, and collect into globular clusters. Most of the gas collects into disks (shown in yellow).



4. Stars form in the disk, gradually building up a spiral galaxy.



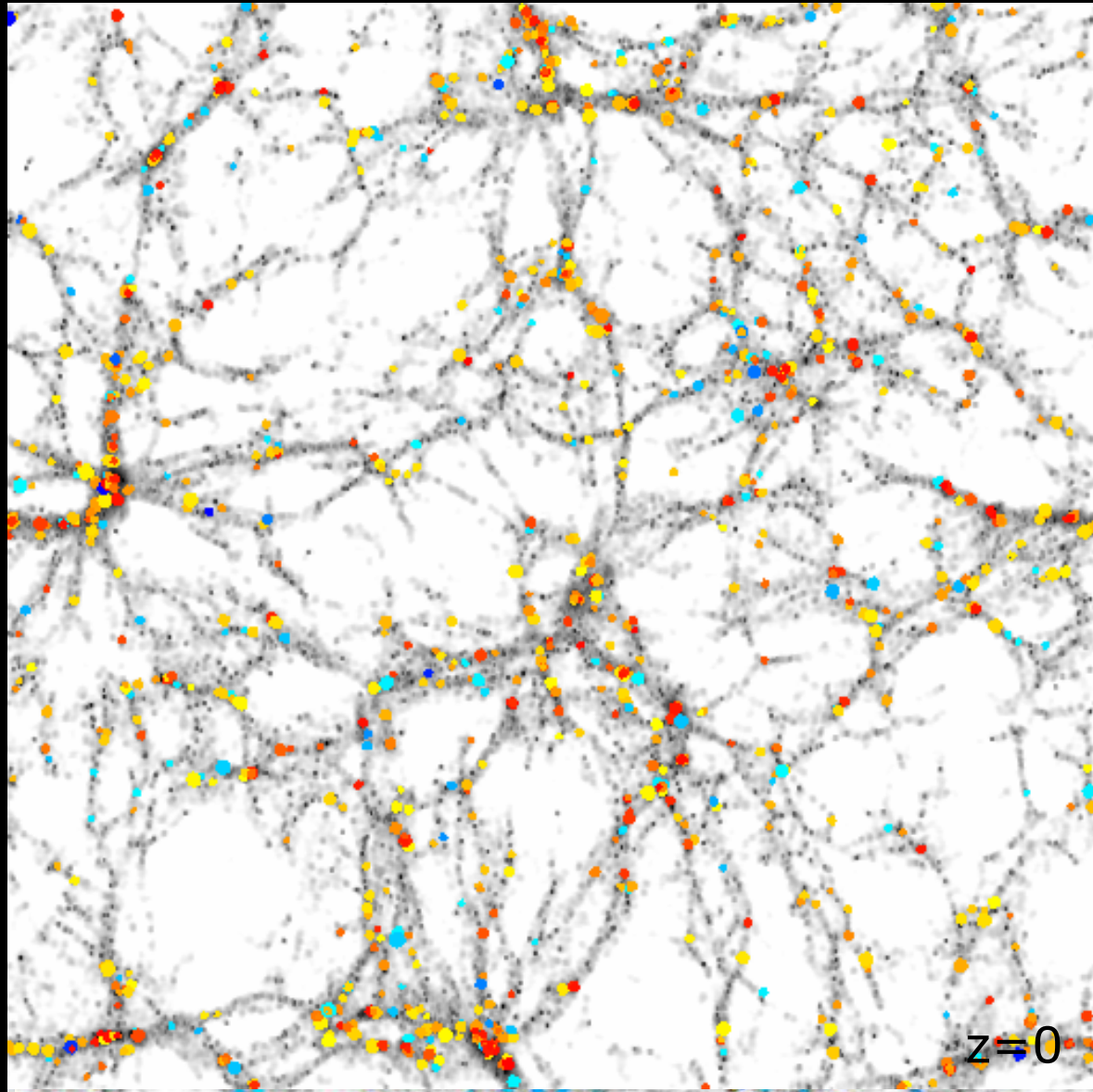
5. A collision of two (or more) disks produces an elliptical galaxy. The globular clusters from the disks are preserved in the transformation.



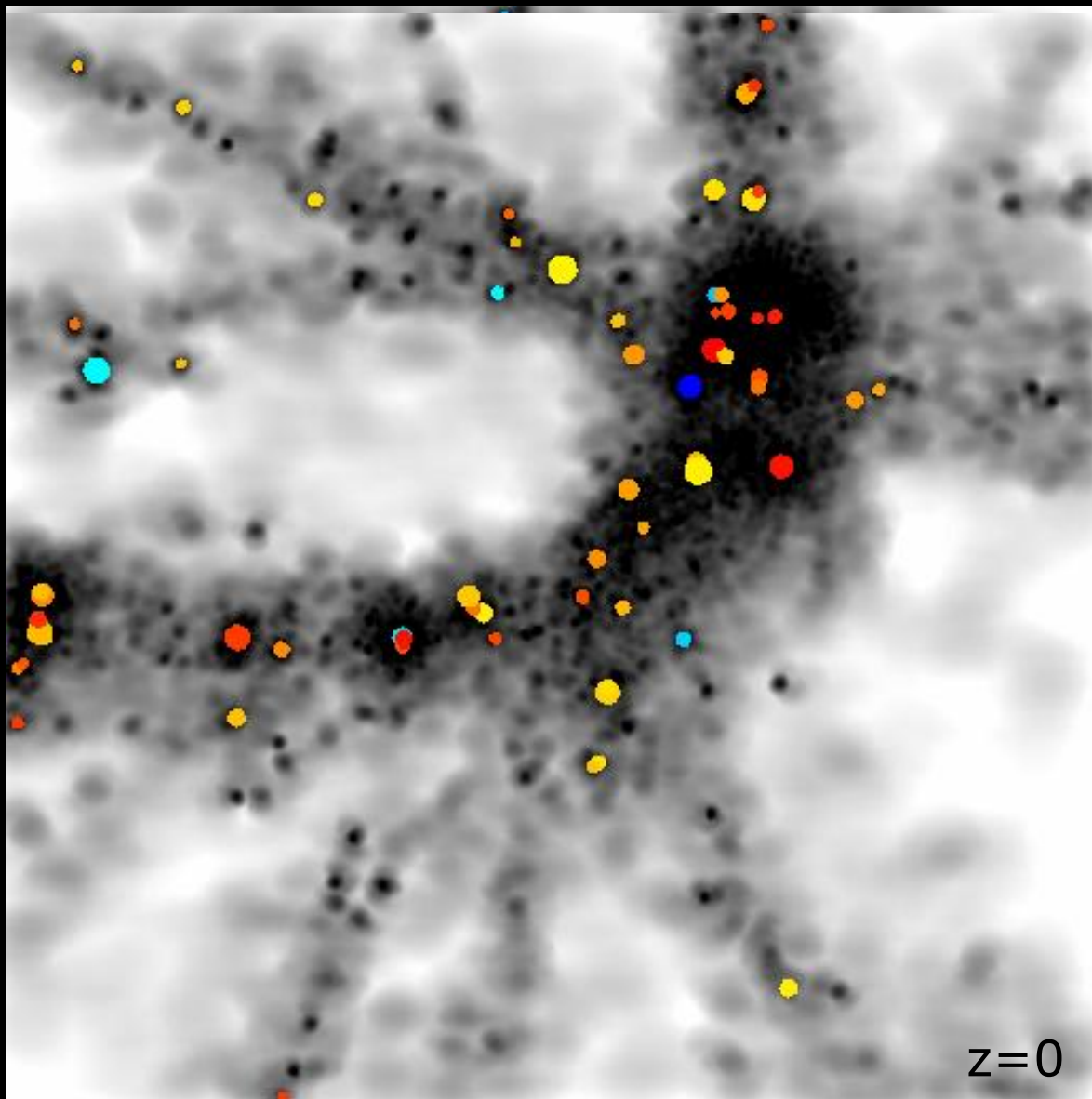
Galaxy Formation: Semi-analy models

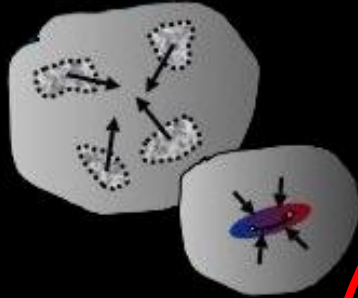
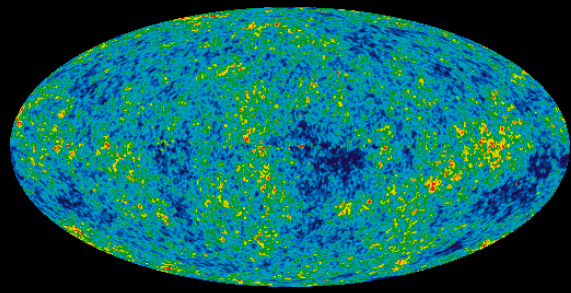
Kauffmann et al.
Cole, Baugh et al.

Galaxy Formation: Semi-analytic models



Galaxy Formation in clusters: Semi-analytic models





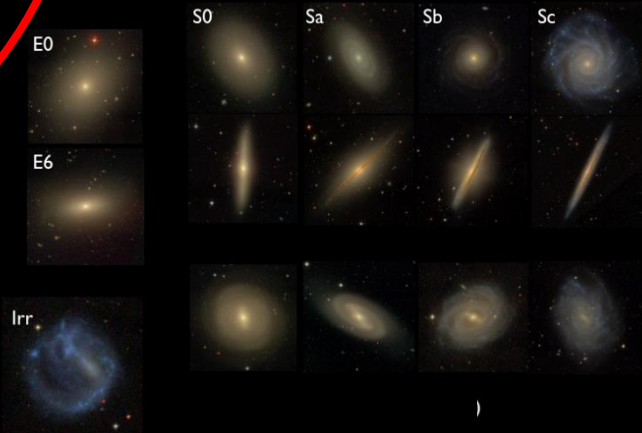
Complications and inconsistencies from baryonic physics.

(Difficult to model)

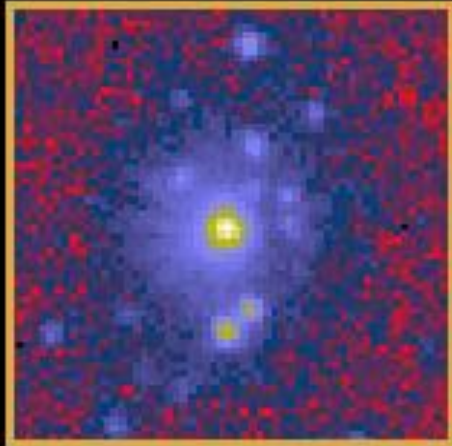


Want to observe fundamental properties comparable to models:

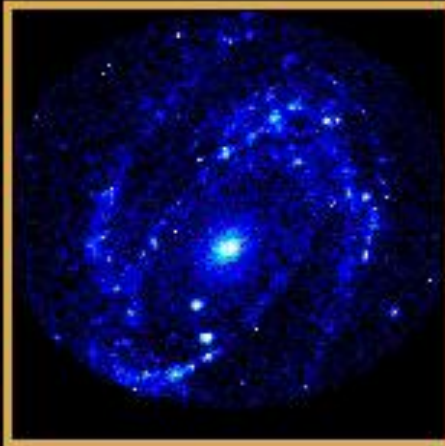
- Stellar Masses
- Star formation rates
- Morphologies



Multi-wavelength Observations



X-Ray: ROSAT



Ultraviolet: ASTRO-1



Visible: DSS



Visible: R. Gendler



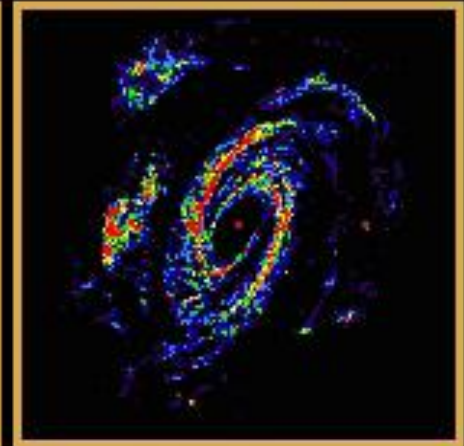
Near-Infrared: Spitzer



Mid-Infrared: Spitzer

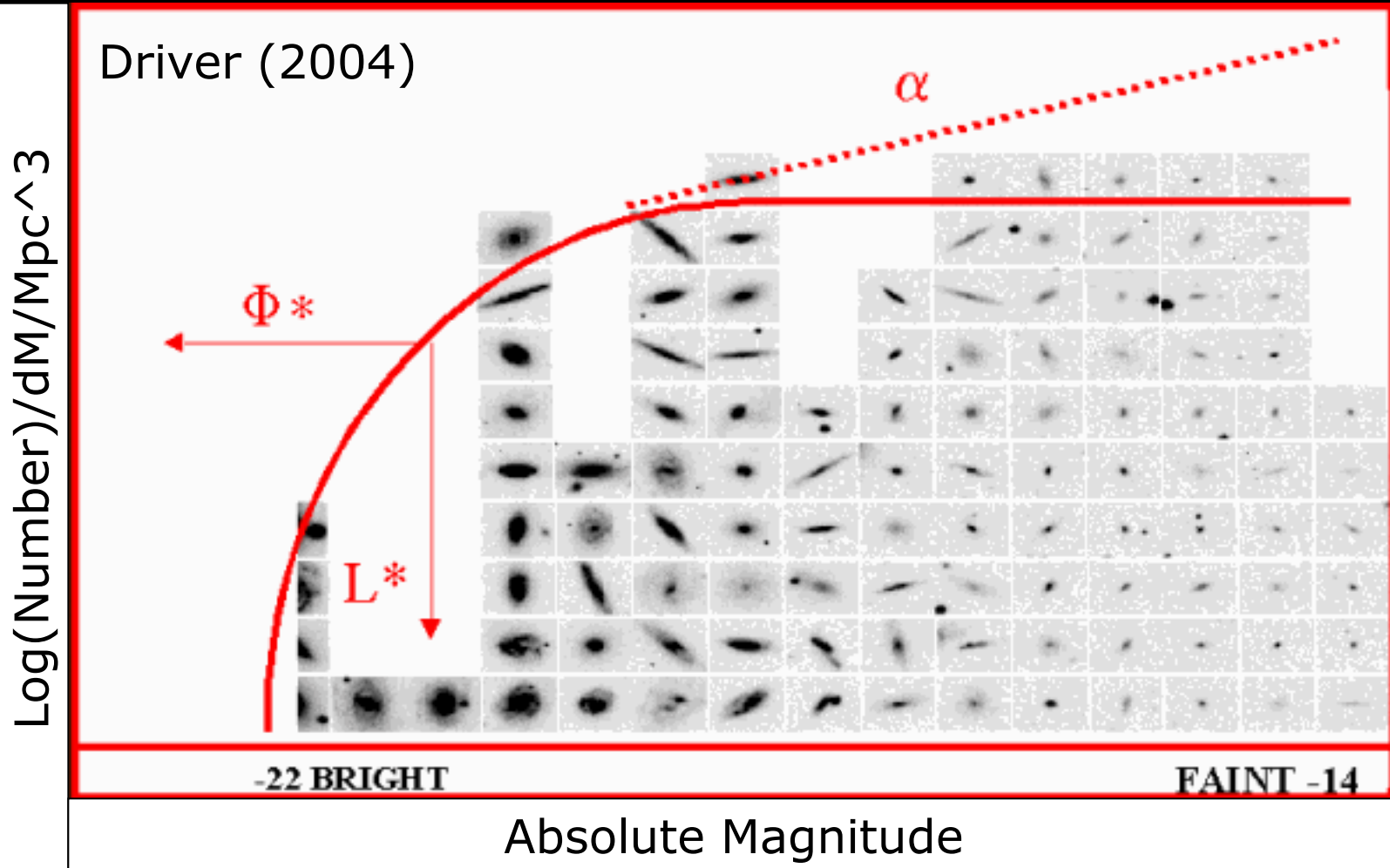


Far-Infrared: Spitzer



Radio: VLA

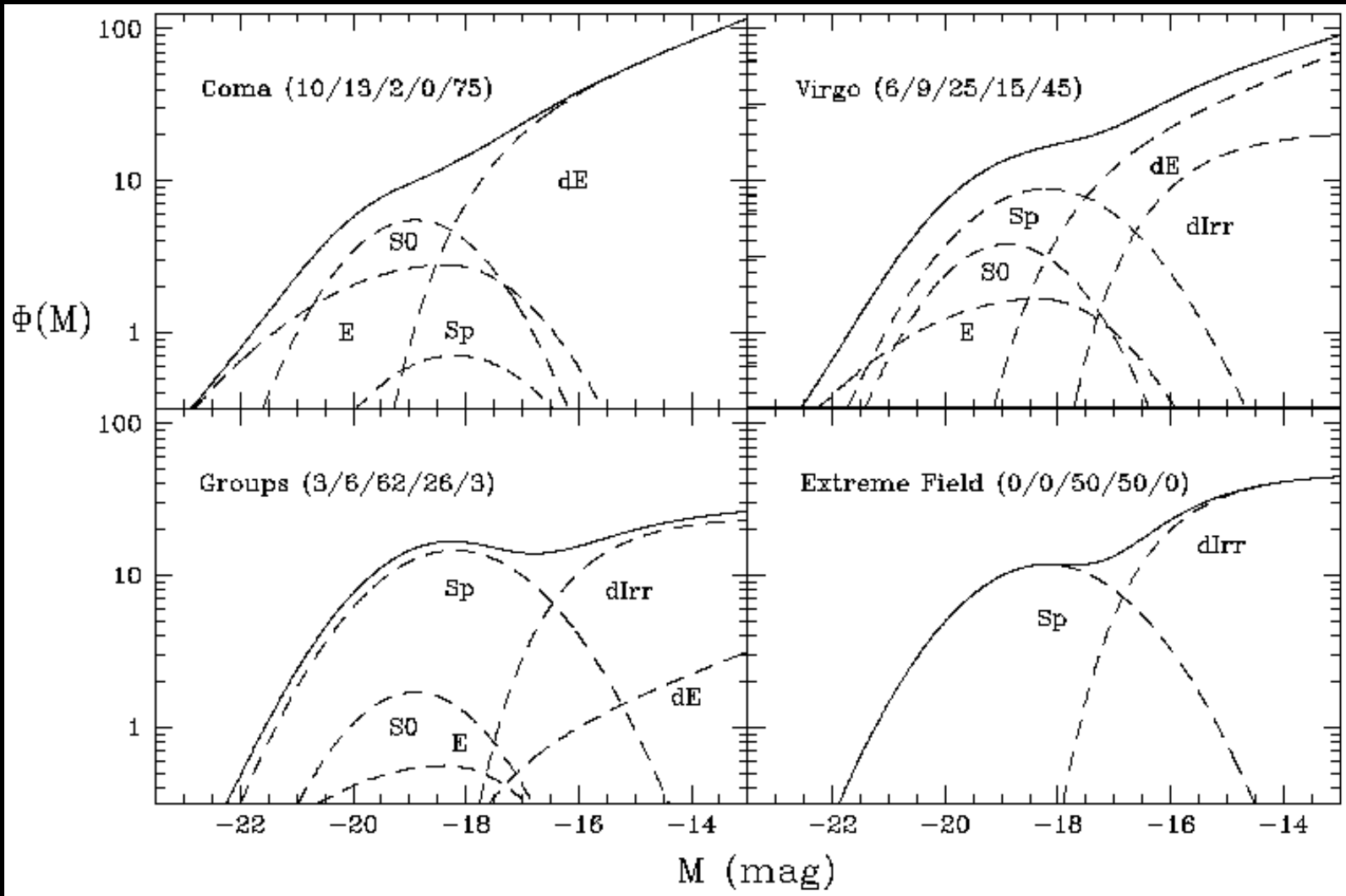
Luminosity Function



Schechter function:

$$\phi(L)dL = \phi^* \left(\frac{L}{L^*} \right)^\alpha \exp\left(-\frac{L}{L^*}\right) \frac{dL}{L^*}$$

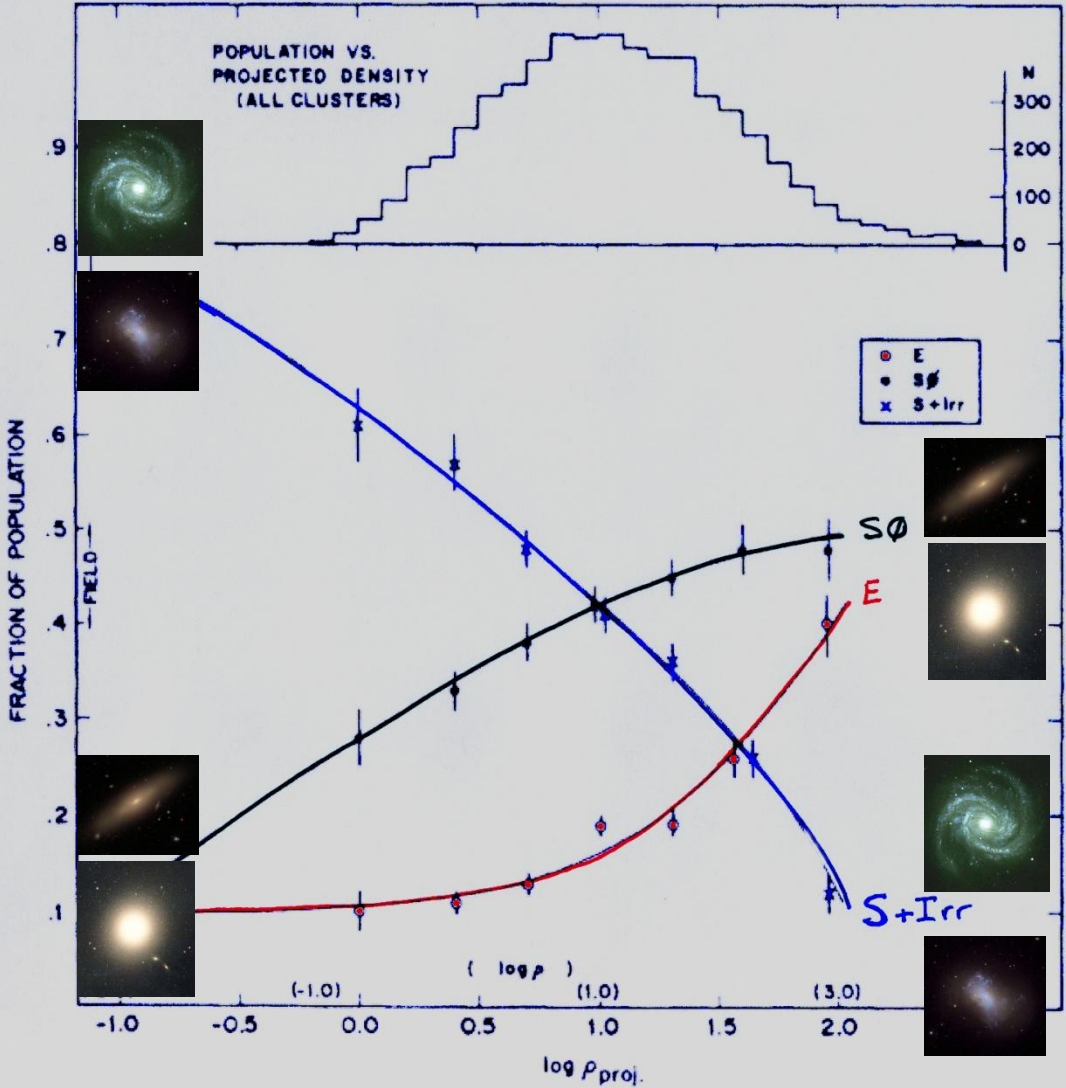
Luminosity Functions at $z \sim 0$



Jerjen & Tammann (1997)

Sandage, Binggeli, & Tammann (1985)

Morphology-Density Relation at $z \sim 0$

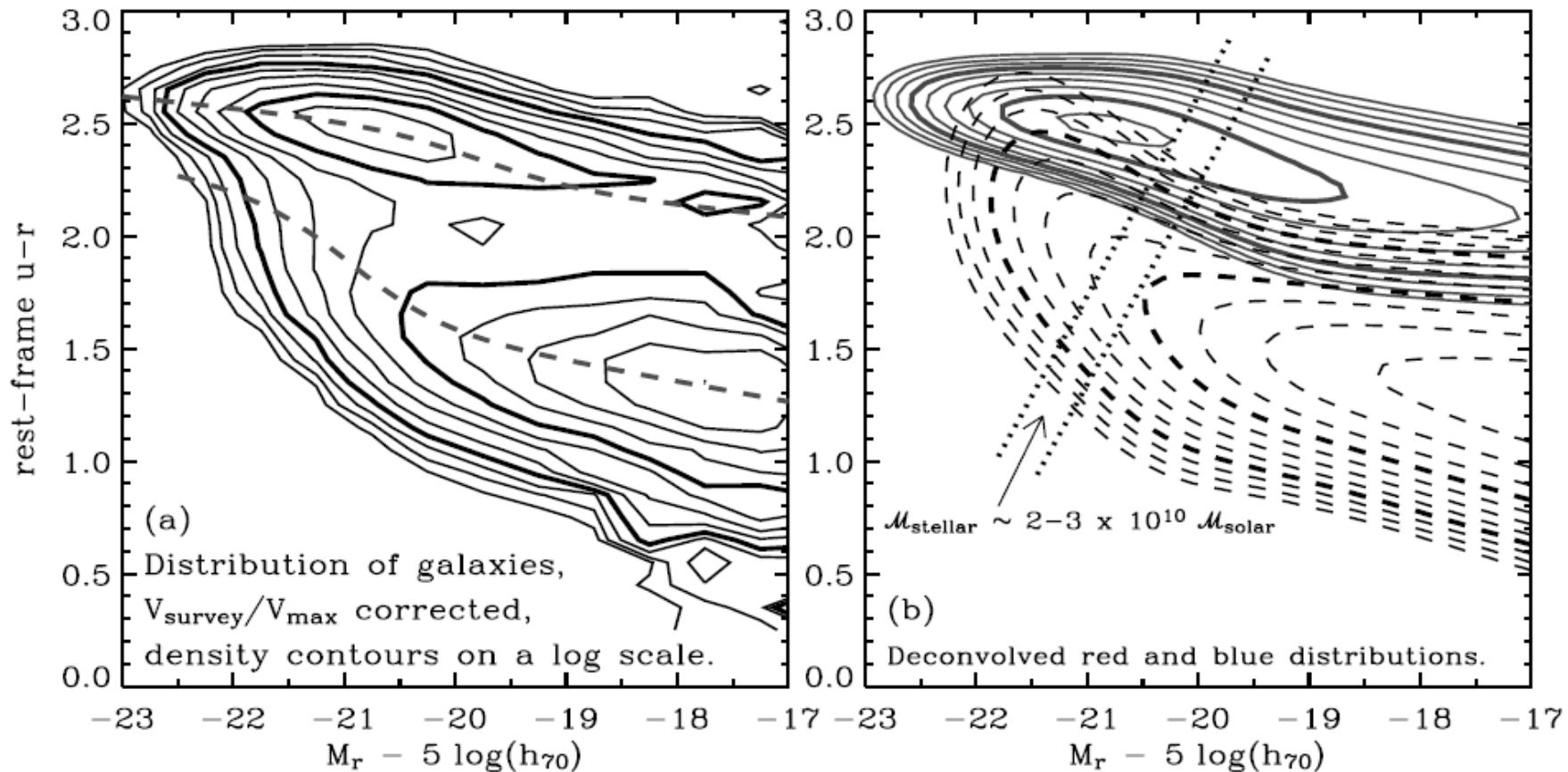


Hubble & Humason (1931)

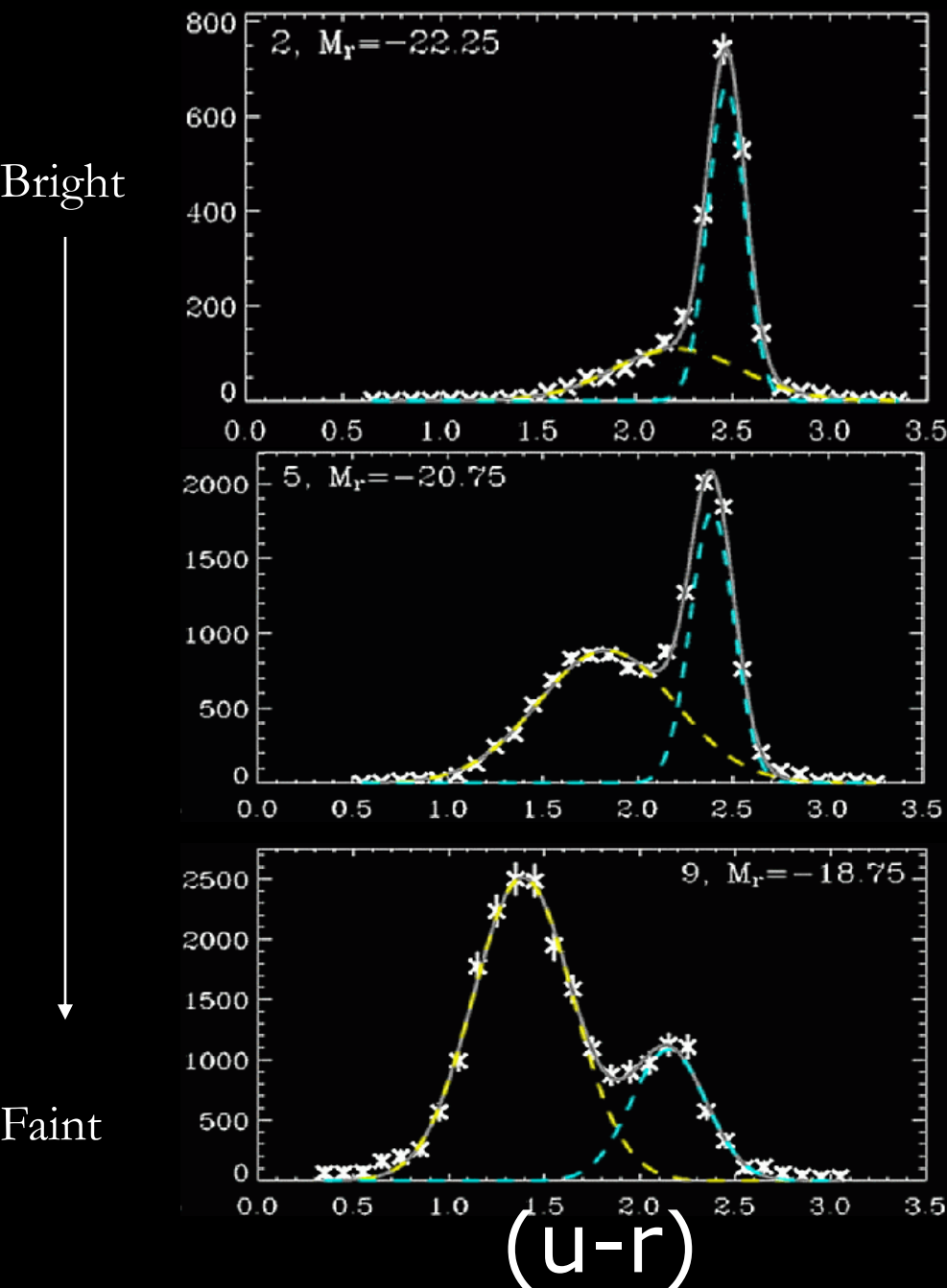
Dressler (1980)

Density

Very large photometric & spectroscopic datasets at $z \sim 0$: SDSS



Very large photometric & spectroscopic datasets at $z \sim 0$: SDSS

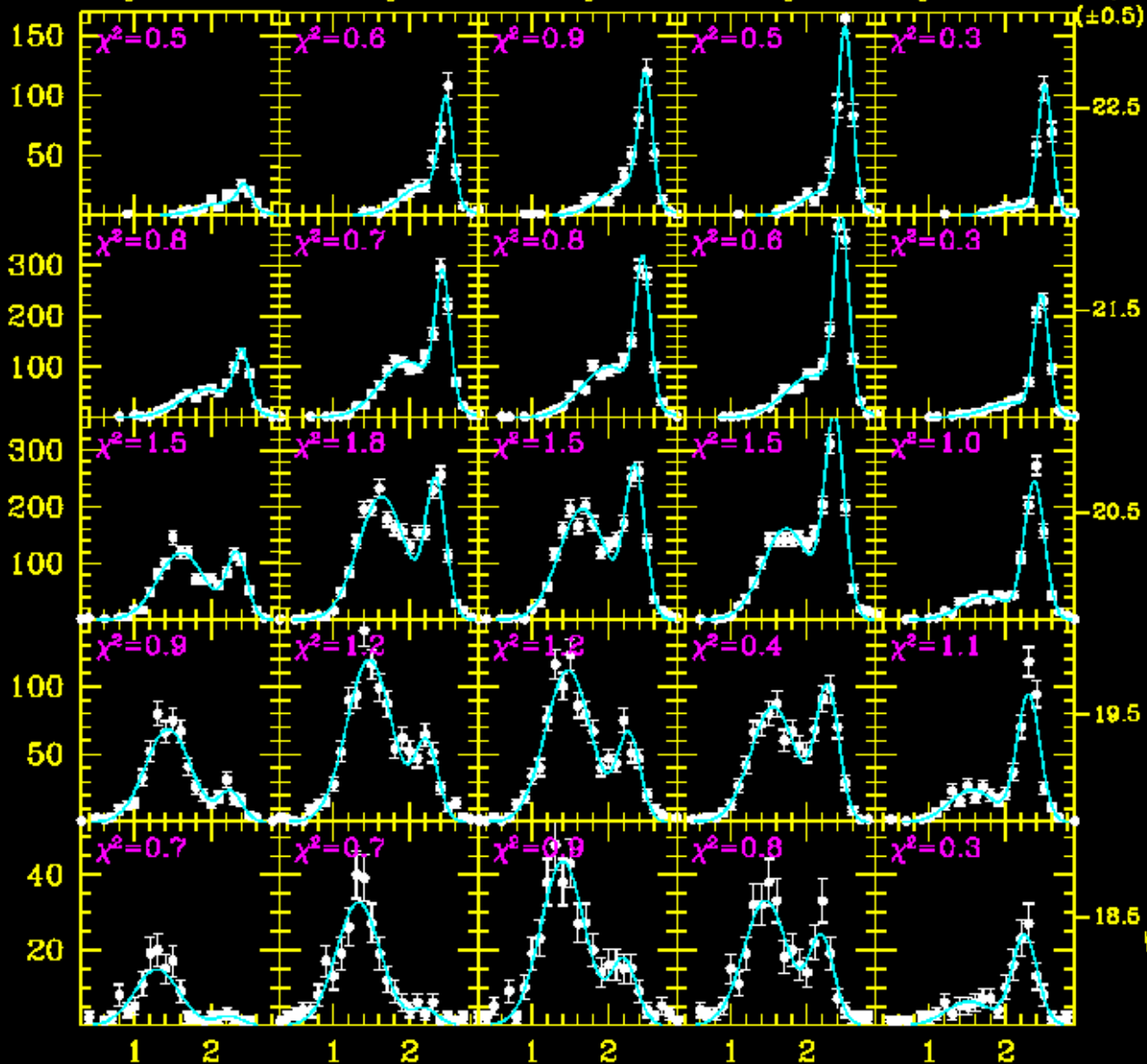


Baldry et al. 2004

Number of galaxies per 0.1 mag bin

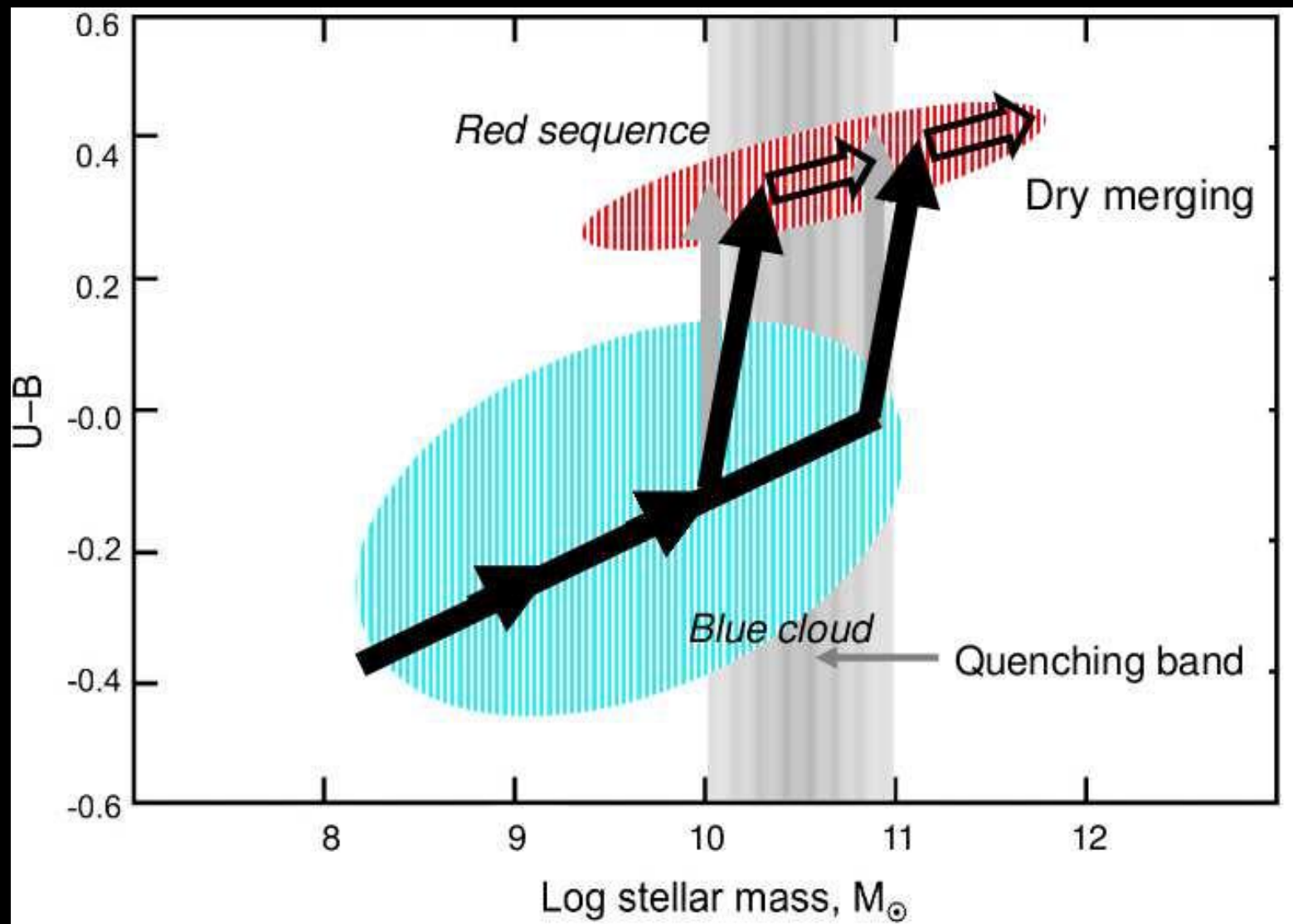
Increasing Density

$\Sigma_0 < 0.2$ $0.2 < \Sigma_0 < 0.5$ $0.5 < \Sigma_0 < 1.4$ $1.4 < \Sigma_0 < 6.5$ $\Sigma_0 > 6.5$ M_r



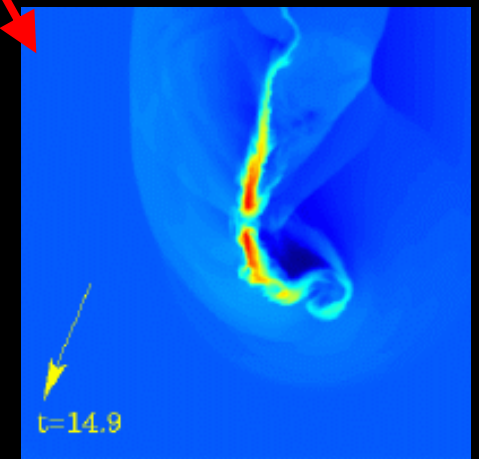
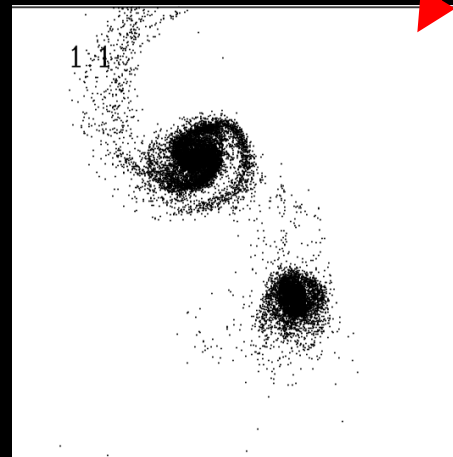
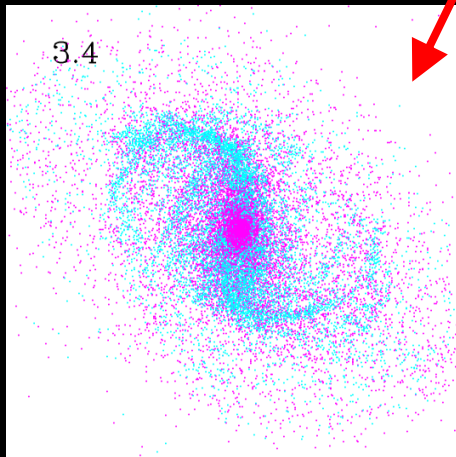
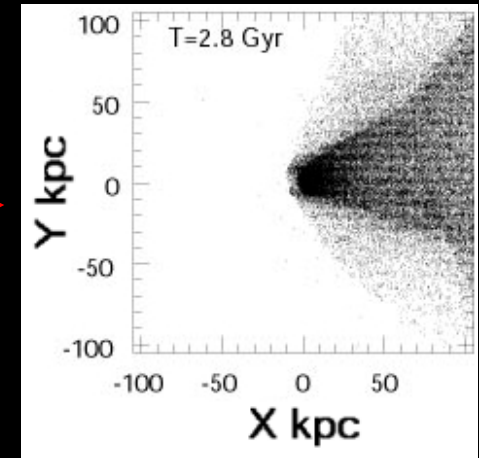
Very large photometric & spectroscopic datasets at $z \sim 0$: SDSS

Balogh et al. 2004

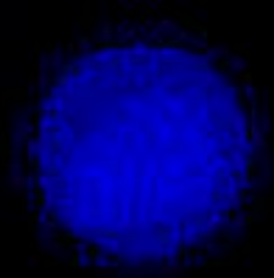


Clusters as Laboratories of Galaxy Evolution

- Physical processes:
 - ram-pressure stripping
 - of gas halo (Bekki et al. 2002)
 - of disk gas (Quilis et al. 2000)
 - galaxy-galaxy interactions
 - harassment (Moore et al. 1998)
 - mergers (Bekki 1998)
 - cluster tidal field (Bekki 1999)
 - &cetera

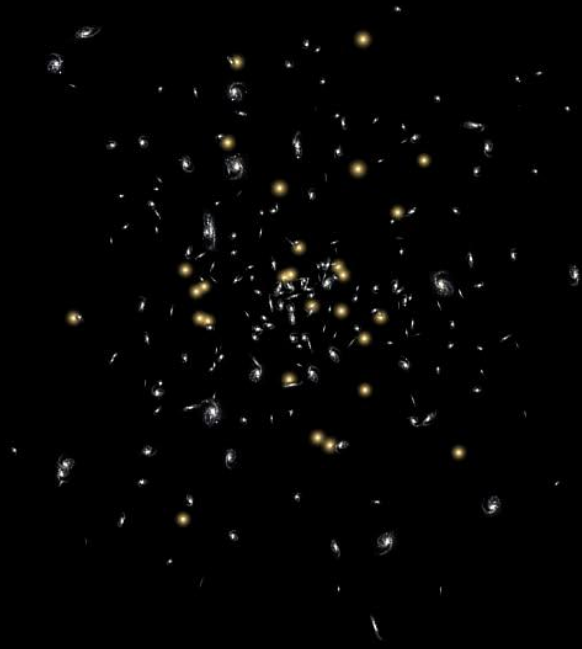


$z=49.000$



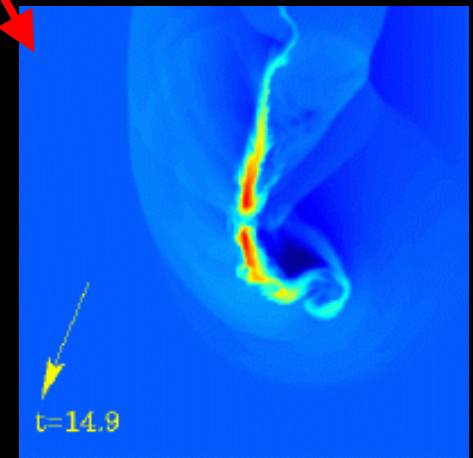
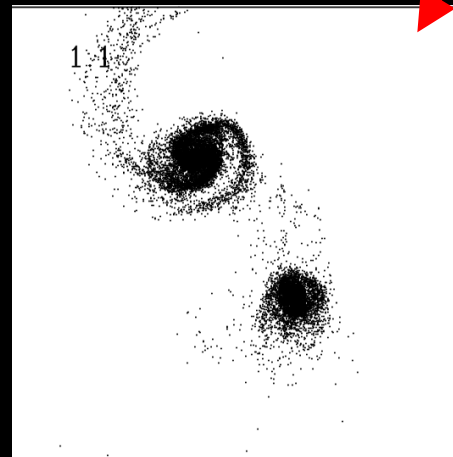
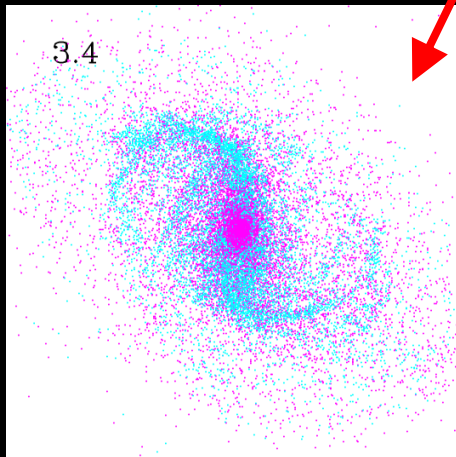
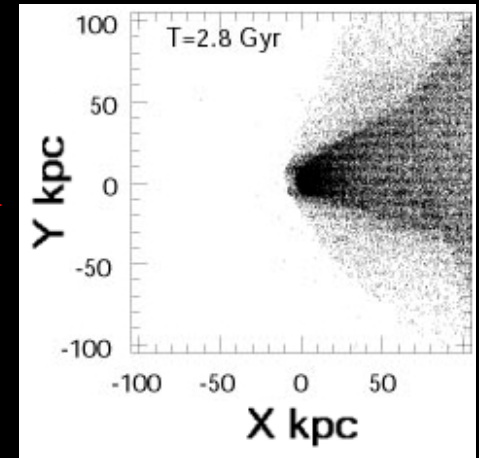
B. Moore

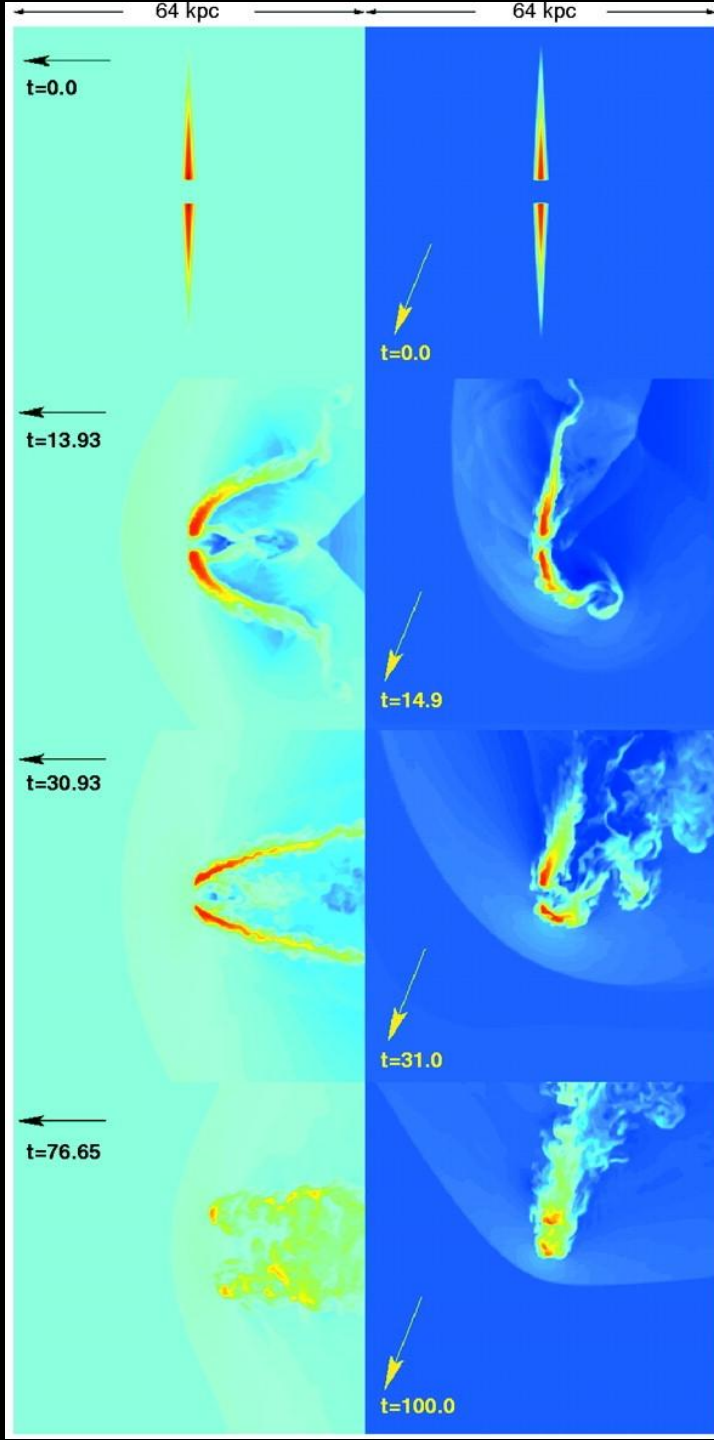
Cardiff Numerical Simulations Group (2009)



Clusters as Laboratories of Galaxy Evolution

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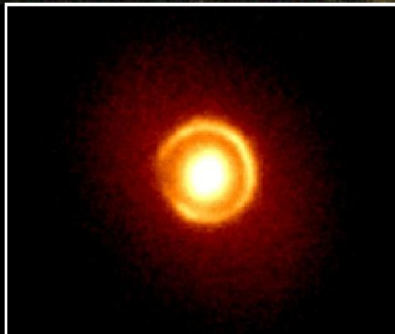
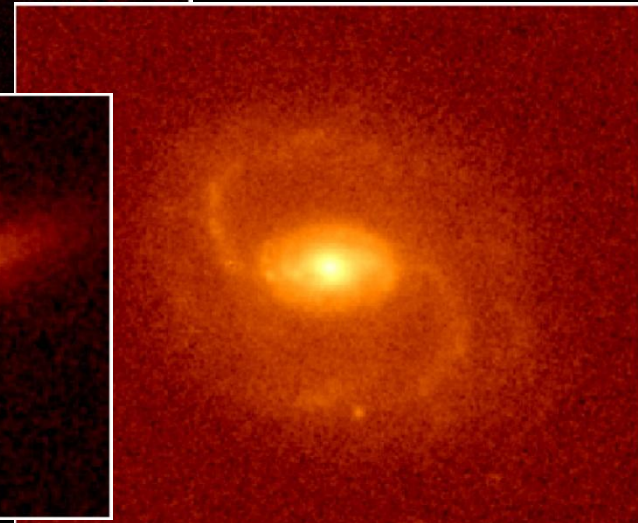
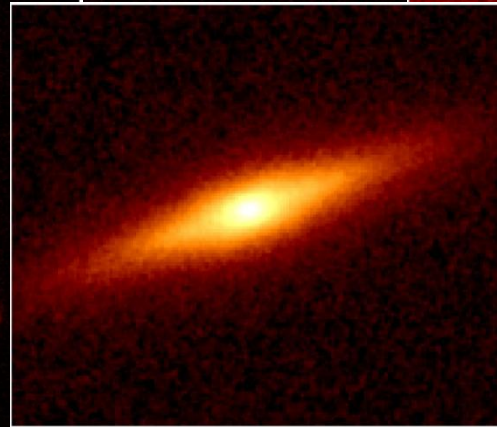
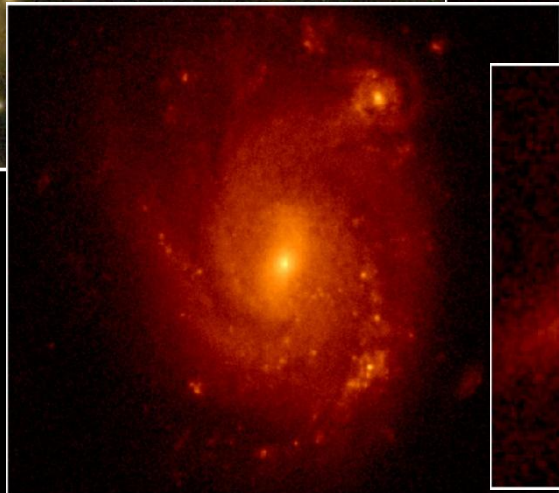
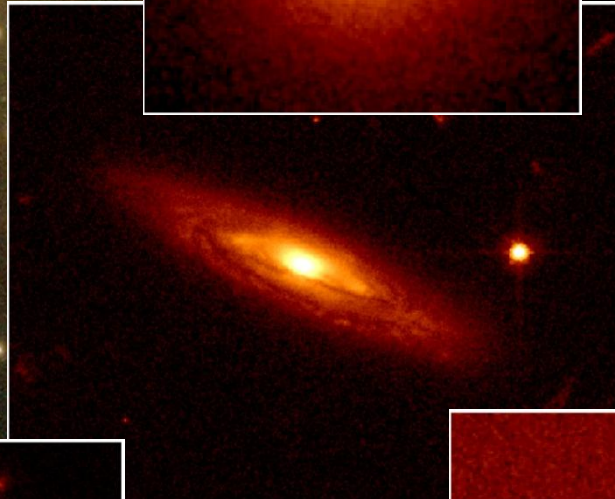
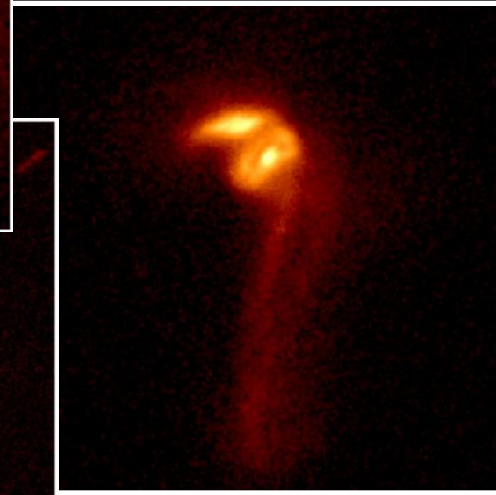
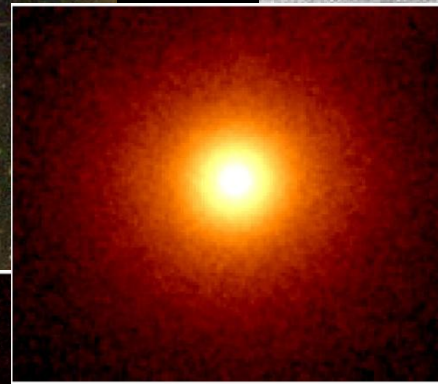
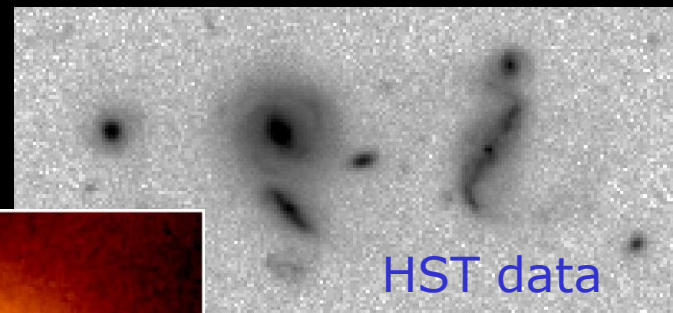
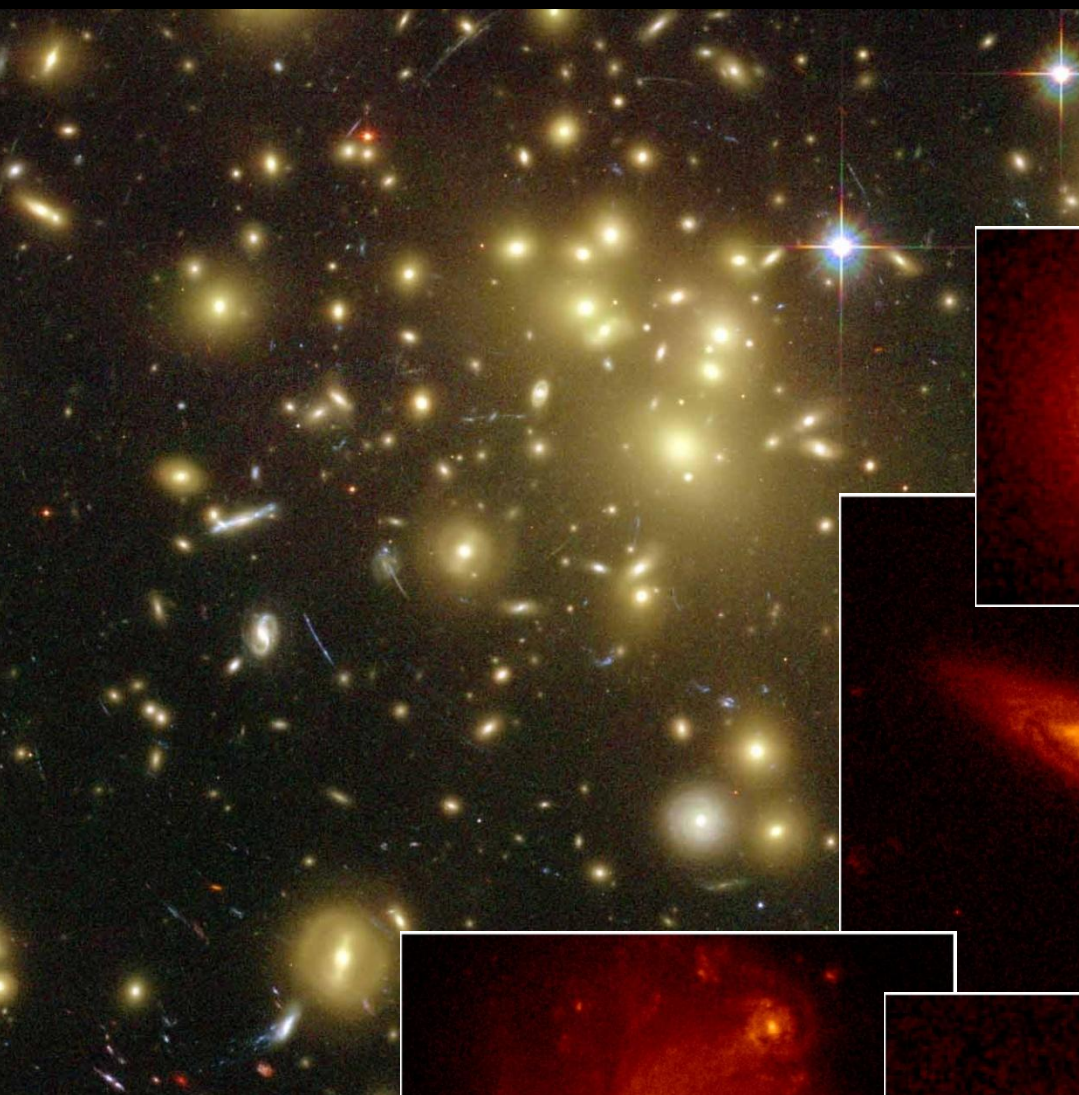


Ram Pressure:

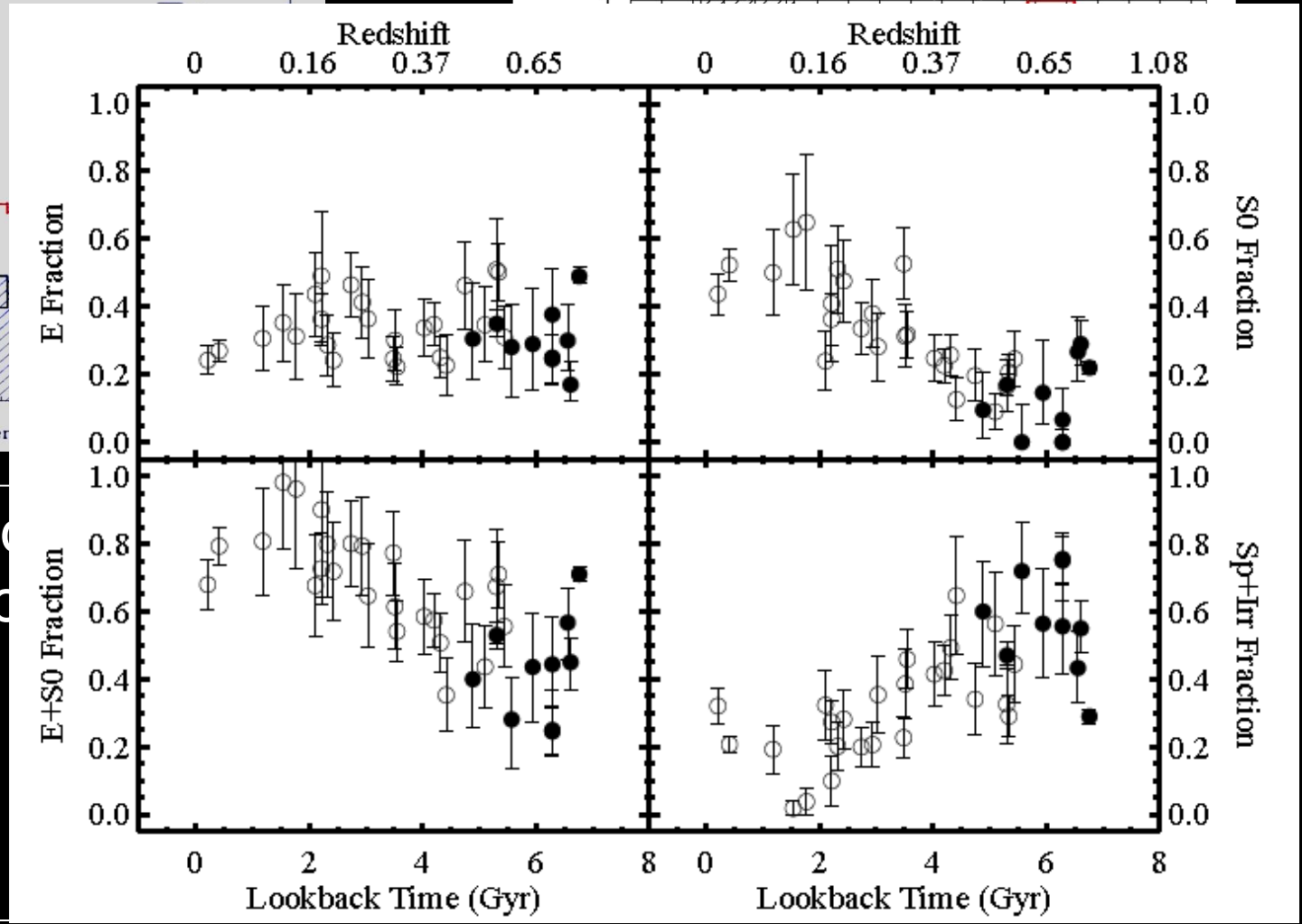
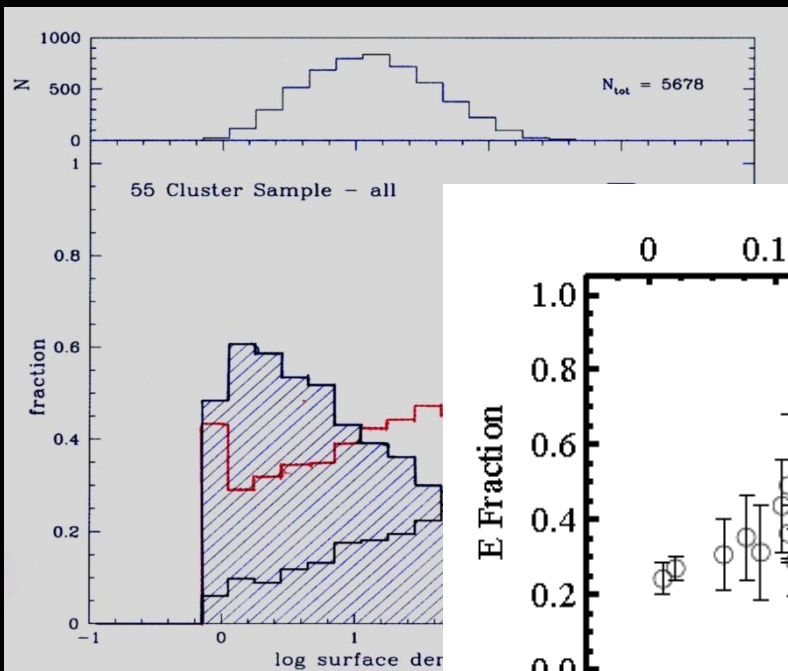
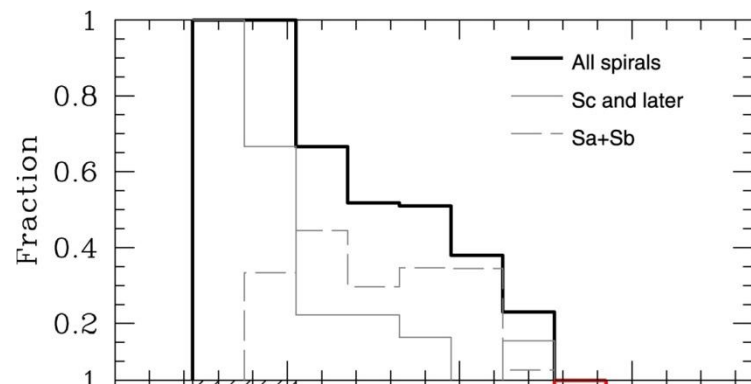
Gas disk interacting with hot intracluster medium

Cardiff Numerical Simulations Group (2009)

Quilis, Moore & Bower (2000)



Dressler et al. (1997)
 Desai et al. (2007)
 Poggianti et al. (2008)



Morphology
 relation

Summary

- Galaxy formation and evolution need to be studied in a cosmological context – galaxies do not form or live in isolation.
- The environment plays a very important rôle in the development of galaxies and their morphology.
- Clusters of galaxies are excellent laboratories to study environmental effects.