Environmental effects on galaxies in clusters

e.g. review of Poggianti 2005

OBSERVATIONS:

*galaxies properties are different in cluster and field environment
+ radial trend in clusters for color, SF (star rormation), morphology.

* → Quenching star formation in galaxies: SF galaxies → passive.

* In clusters at medium z, many more SF galaxies:
the so-called Butcher-Oemler effect;

*Many more lenticulars (S0) at z=0 than at intermediate z.

*cD or BCG+intracluster light – ICL are typical of cluster environment

*Inversion of the SF-density relation in clusters at z~1.5??? e.g., Santos+14

Environmental effects on galaxies in clusters

GAL-CLUSTER DM

Dynamical friction (Chandrasekhar) when a massive particle moves in a sea of small mass particles.

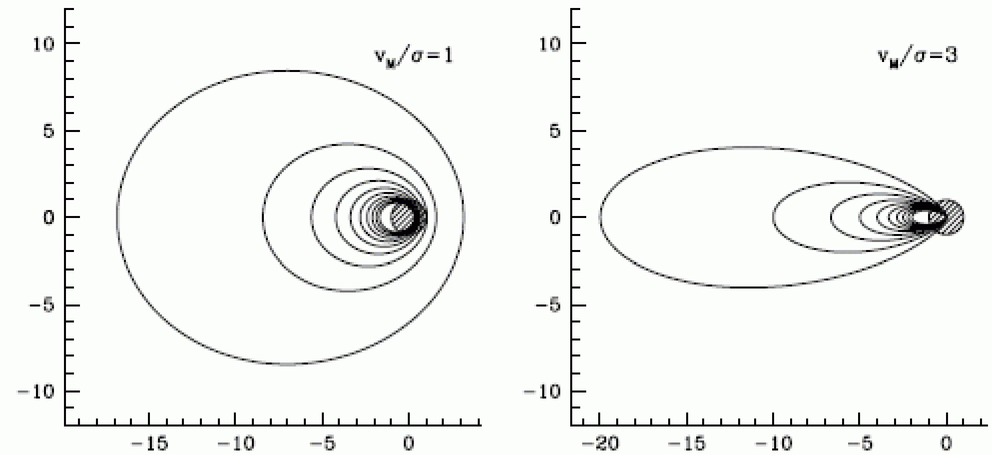


Figure 8.2 A mass M travels from left to right at speed v_M, through a homogeneous Maxwellian distribution of stars with one-dimensional dispersion σ. Deflection of the stars

Example:
a galaxy moves in a sea of DM particles. There is the formation of
An overdensity of particles in the back of the galaxy...
The DM particles decelerates the galaxy. The deceleration depends on the Gaxy mass and velocity dv/dt $\propto$ M*rho$_{DM}$/v^2

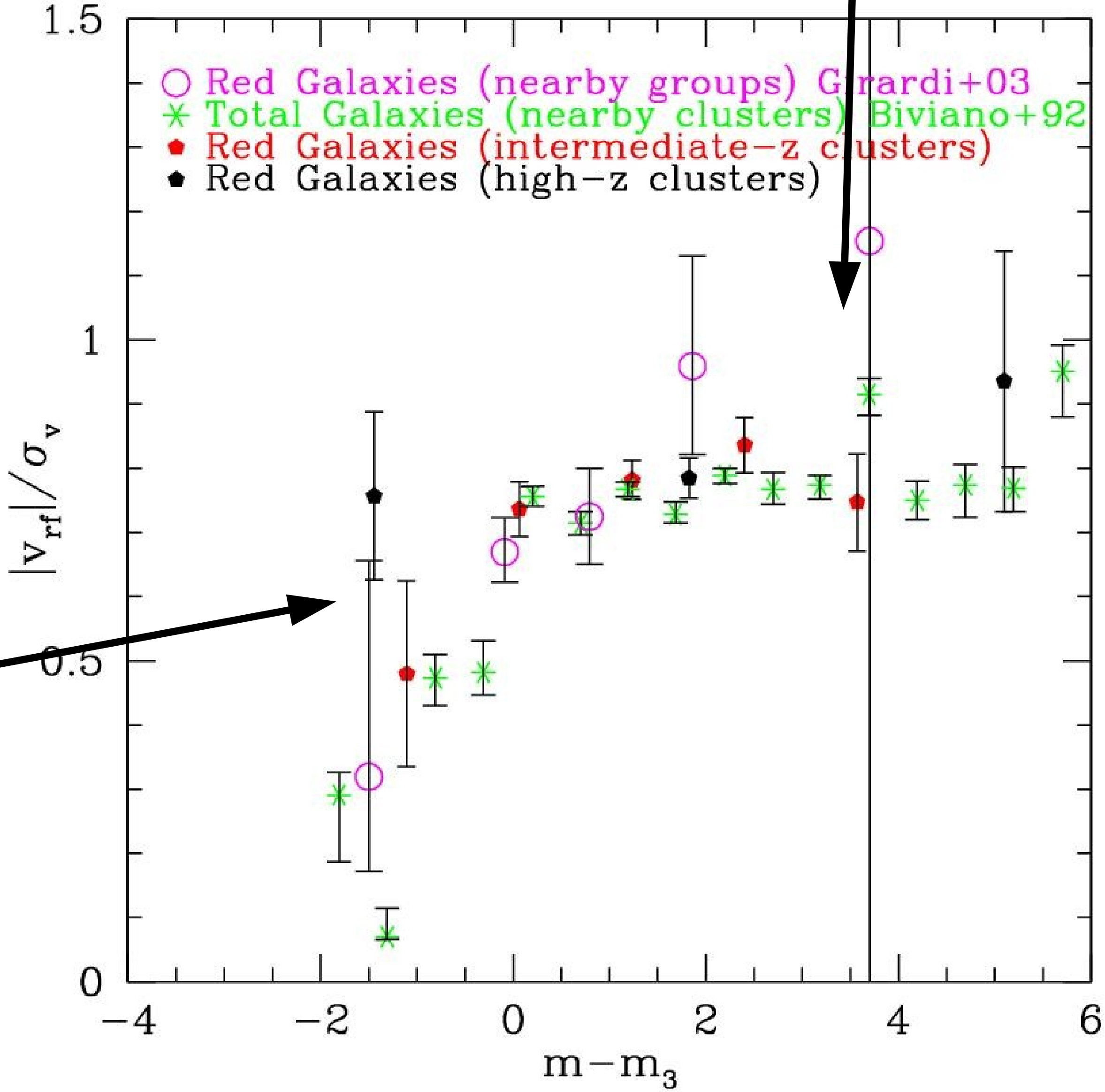
$$\mathbf{f}_{dyn} = M\frac{d\mathbf{v}_M}{dt} = -\frac{4\pi \mathrm{Ln}(\Lambda) G^2 M^2 \rho}{v_M^3}\left[\mathrm{erf}(X) - \frac{2X}{\sqrt{\pi}}e^{-X^2}\right]\mathbf{v}_M$$

where

Luminosity segregation of galaxies in the velocity space

Most galaxies are in a state of velocity equipartition, in agreement with theory of the violent relaxation.

(Biviano 1992; MG+03...; Barsanti's thesis 2016 in prep.)



Luminous (massive) gals are slowed down by... dynamical friction?

Environmental effects on galaxies in clusters

GAL-CLUSTER

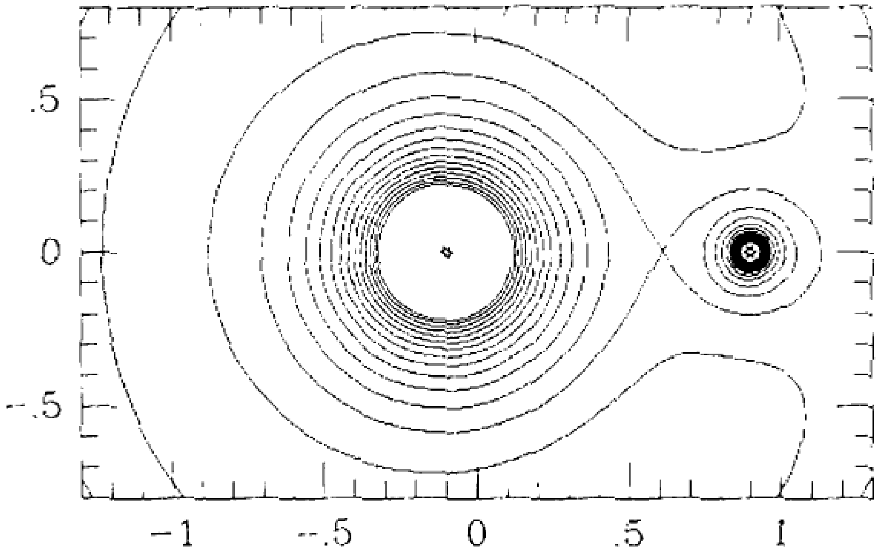


Figure 7-8. *Contours of* equal effective potential

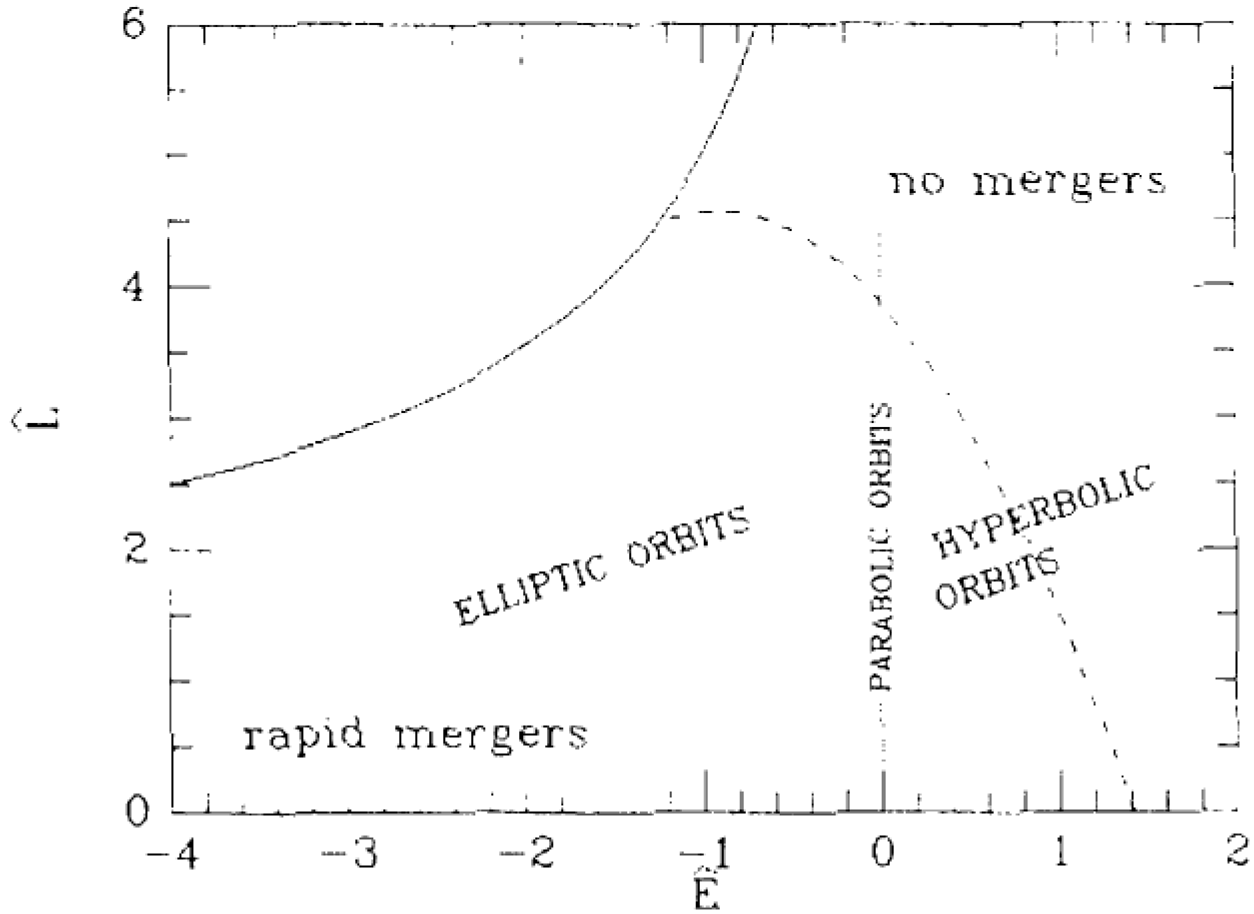
Roche Lobe theory and
The tidal radius.

Credit to Binney & Tremaine

Environmental effects on galaxies in clusters

GAL-GAL
*Merger;

Small relative velocities of the encounter favors the galaxy merger.



Credit to Binney & Tremaine

GAL-GAL
* Tidal stripping;
* Harassment defined as frequent high speed galaxy encounters within clusters.

Mergers from observations and N-body simulations.

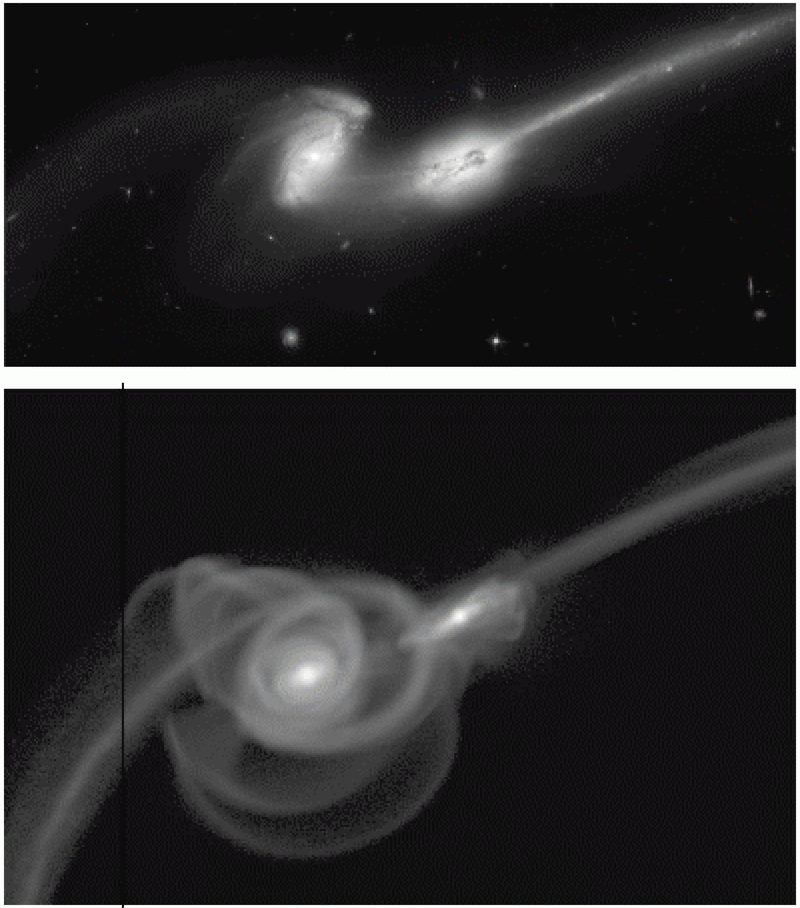


Figure 8.15 The Mice, NGC 4676, a pair of interacting galaxies at a distance of 95 Mpc. Top: optical image from the Hubble Space Telescope. Bottom: an N-body model. Credit for HST image: NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA. Credit for N-body model: J. Dubinski (Dubinski & Farah 2006).

Credit to Binney & Tremaine

Environmental effects on galaxies in clusters

GAL-ICM

*Ram pressure (Gunn & Gott 1972): a galaxy in motion with velocity v within the ICM. Pressure is propoportional to the density of ICM

$P \propto \rho_{ICM}\, v^2$

$F_{press} > F_{grav} \rightarrow \rho_{ICM}\, v^2 \pi R_{gal}^{\ 2} > GfM^2/R_{gal}^{\ 2}$, where $f=M_{gas}/M$

i.e. the fraction of stripped gas.

It is more efficient ad the cluster center!

Proof: anemic spirals (i.e. no/little HI) and now the "jellyfish" galaxies, this process can also trigger starbust.

*Stripping for evaporation (also in the case that galaxy is at rest, due to $T_{ICM} = 7$ keV $= 10^8$ K $\gg T_{gal} = 1$ keV

$dM_{evap}/dt \propto T_{ICM}^{\ 5/2}$

*Stripping for turbulence and viscosity $dM_{t,v} \sim 0.3\, dM_{evap}/dt$

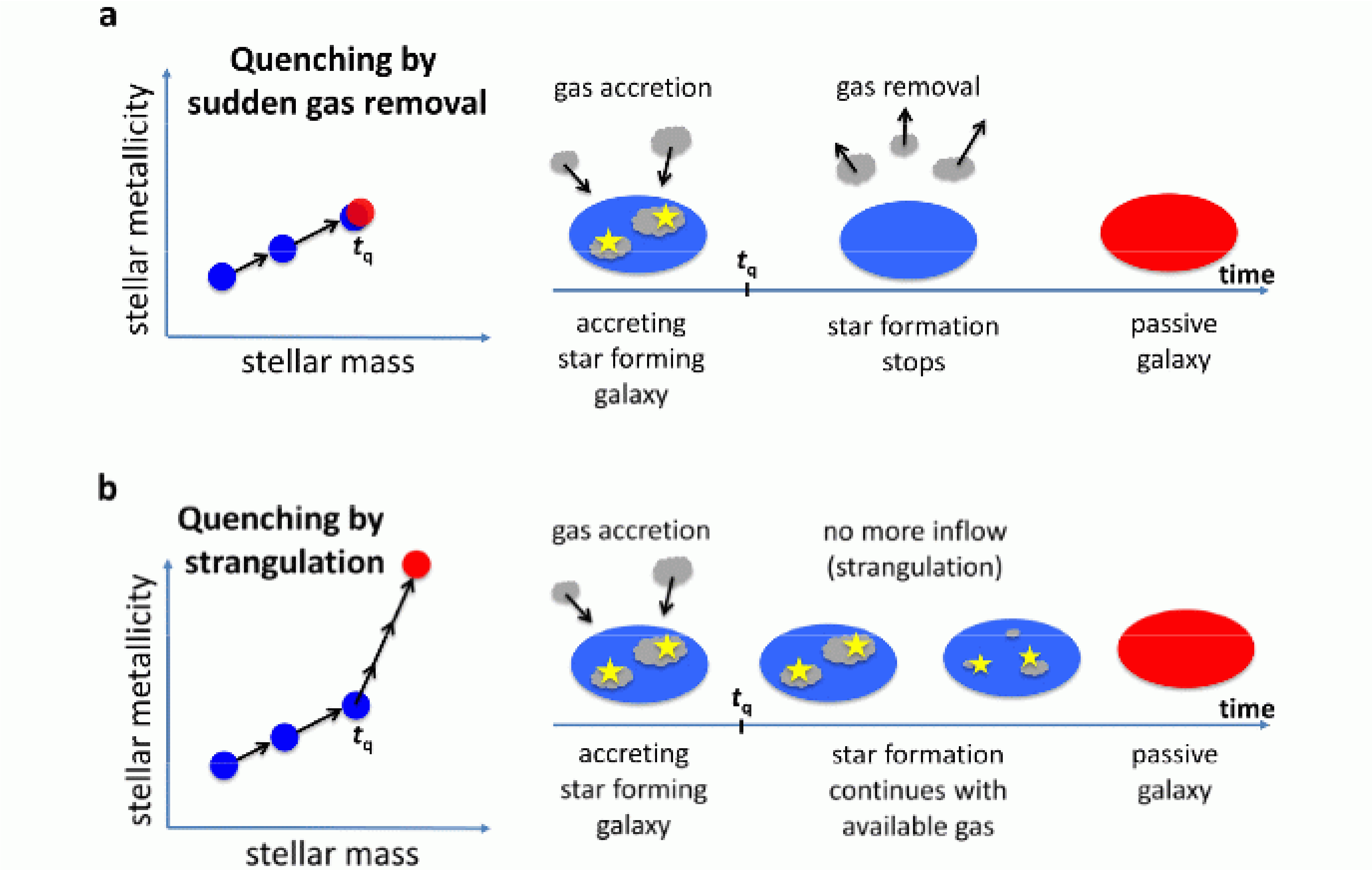
Credit:

NASA, ESA, CXC

Example of
Jellyfish galaxy
(i.e. stripped of the gas)
in the
NORMA
CLUSTER

Environmental effects on galaxies in clusters

RECENTLY Strangulation (the supply of gas is halted) seems the better according to the study of Peng, Maiolino, Cochran Nature 2015
The question is still discussed!



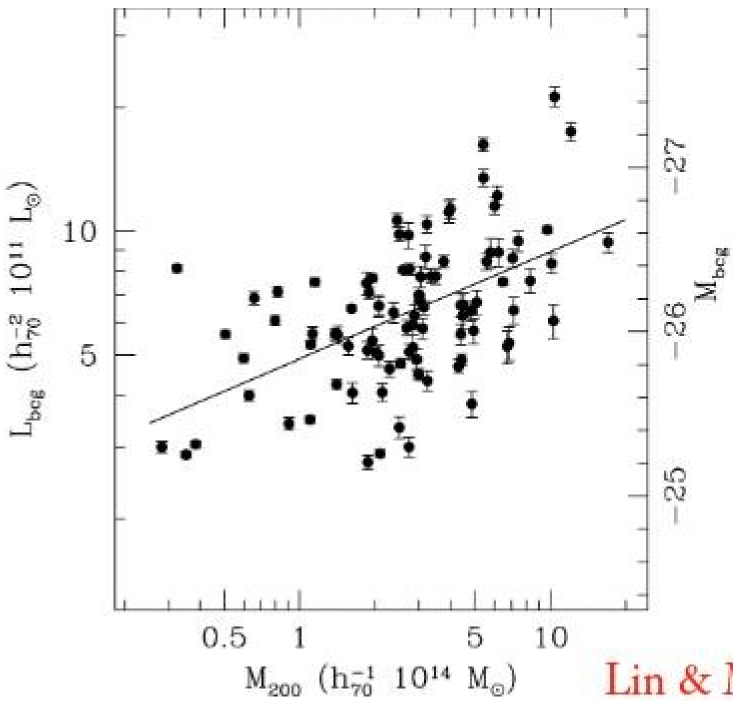
Credit to Pen et al. 2015, Nature

Environmental effects on galaxies in clusters

Formation of cD galaxies

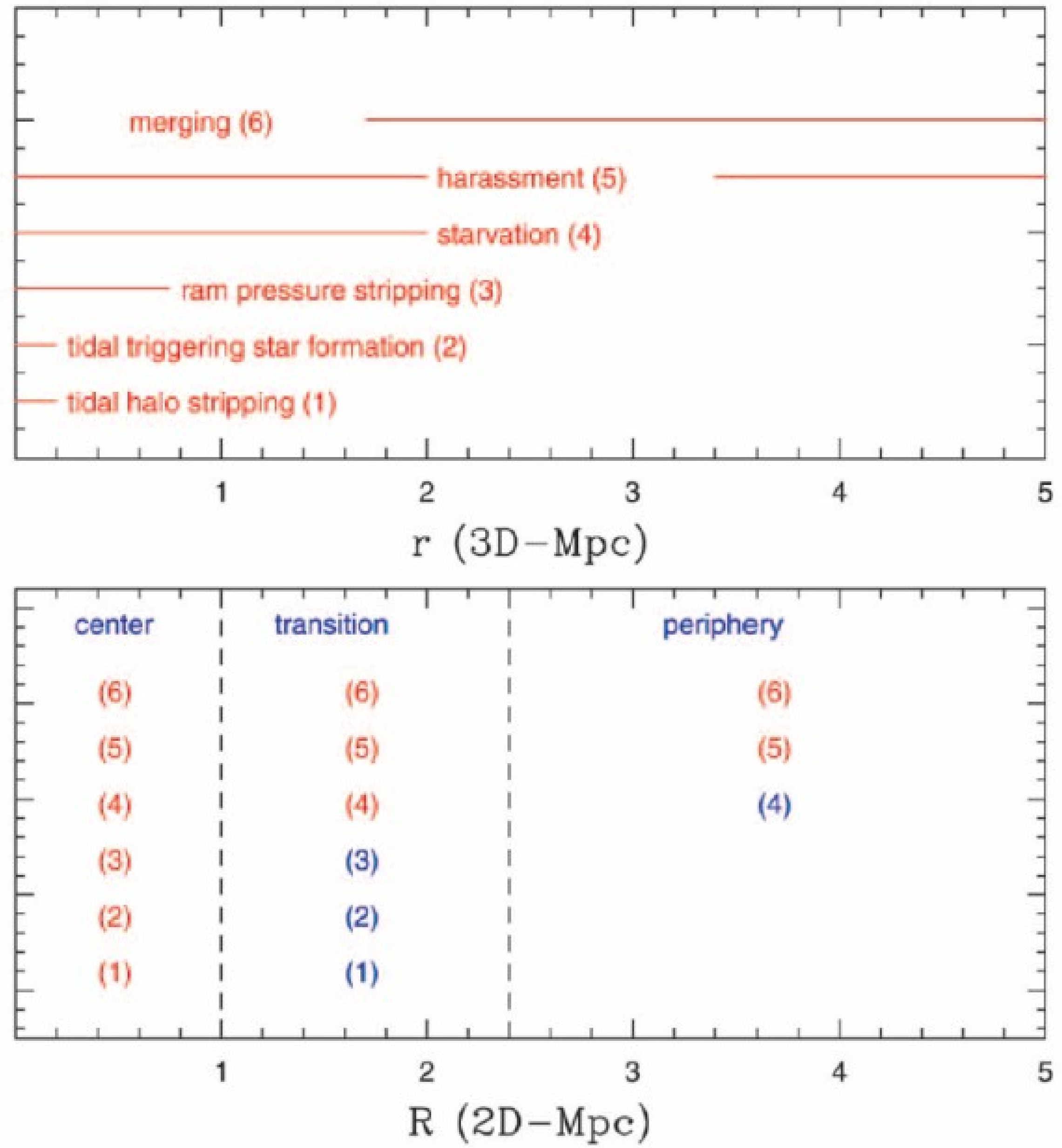
*Cannibalization of galaxies slowed down by dynamical friction, that is debris cumulation.
*Central position: it is non subjected to the tidal radius troncation.
*"Cooling flows", $T_{cooling} \propto \rho_{ICM} \; T_{ICM}^{1/2}$

BCGs Brightest cluster members grow as the cluster grow. M_{200} is the cluster mass.



Lin & Mohr 04

Comparison between different effects



Credit to Treu et al. 2003, ApJ