

Environmental effects on galaxies in clusters

OBSERVATIONS:

e.g. review of Poggianti 2005

- *galaxies properties are different in cluster and field environment
+ radial trend in clusters for color, SF (star formation), 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+ICL (bright cluster galaxy + intracluster light)
are typical of cluster environment

- *Inversion of the SF-density relation in clusters at $z \sim 1.5$??? 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.

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 decelerate the galaxy. The deceleration depends on the
galaxy mass and velocity $dv/dt \propto M \cdot \rho_{\text{DM}} / v^2$

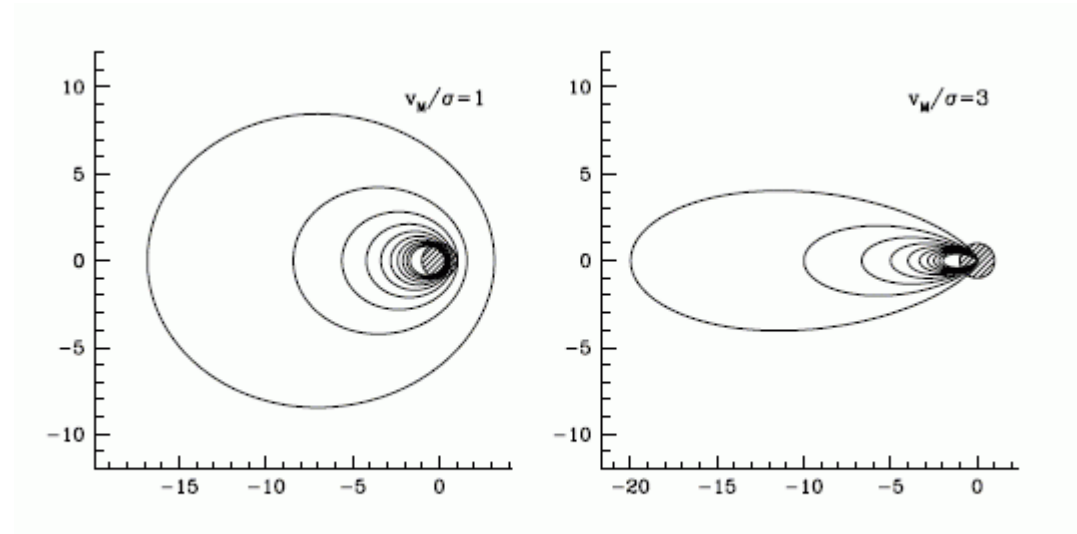


Figure 8.2 A mass M travels from left to right at speed v_M , through a homogeneous Maxwellian distribution of stars with one-dimensional dispersion σ . Deflection of the stars

Credit to Binney and Tremaine

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

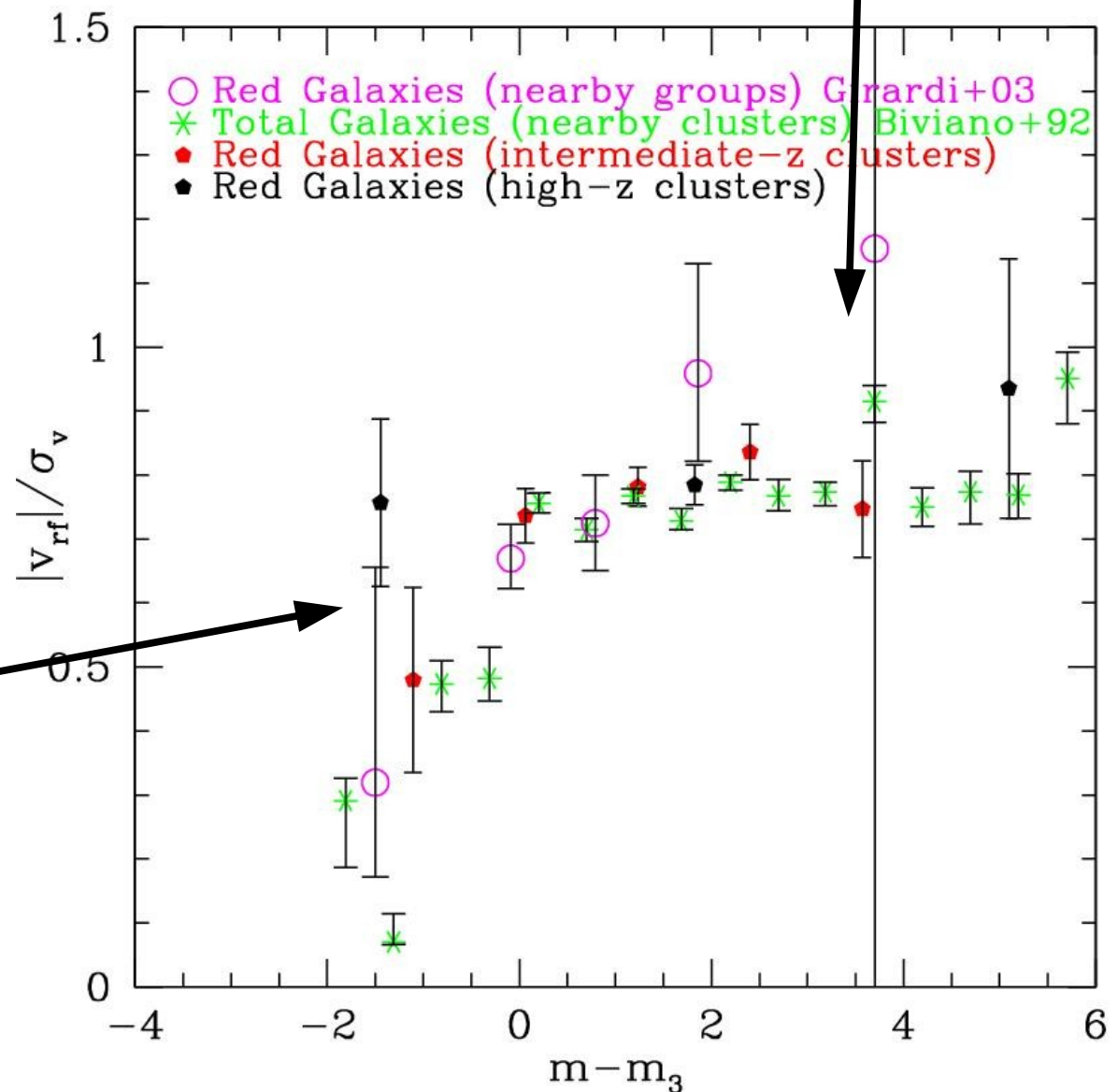
where

Luminosity segregation of galaxies in the velocity space

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

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

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



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GAL-CLUSTER

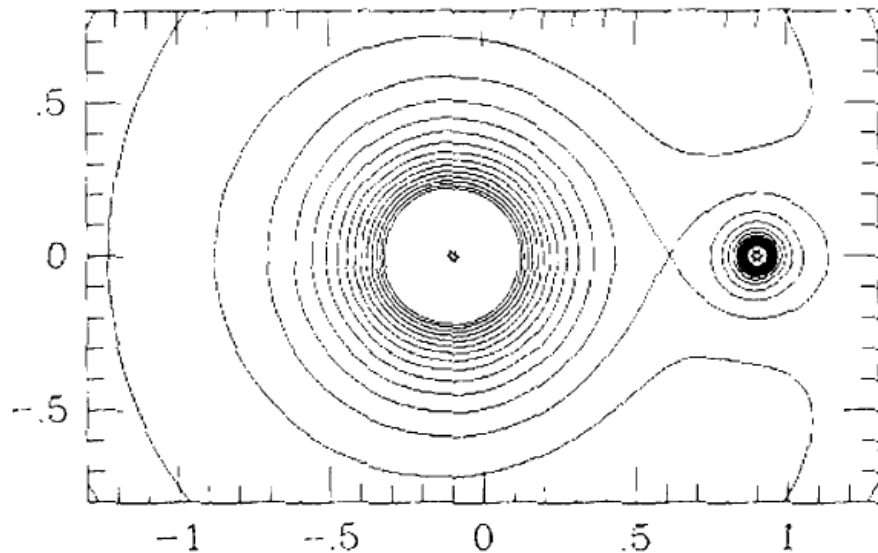


Figure 7-8. Contours of equal effective potential

The tidal radius.

In this way it is explained
The sharp boundary limit in the stellar
Ddistribution of globular
clusters in our Galaxy.

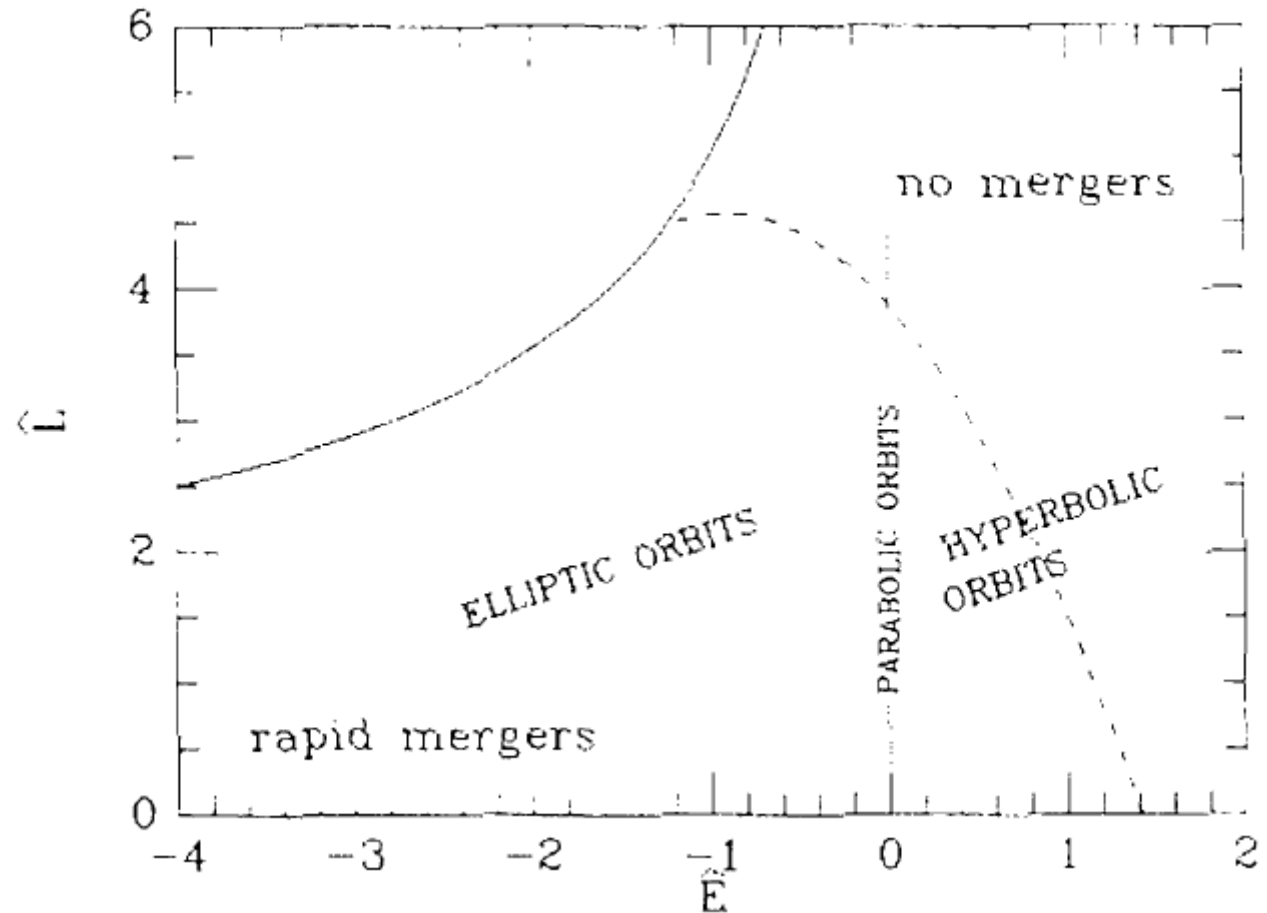
Credit to Binney & Tremaine

Environmental effects on galaxies in clusters

GAL-GAL

*Merger;

Small relative velocities of the encounter favors the galaxy merger.



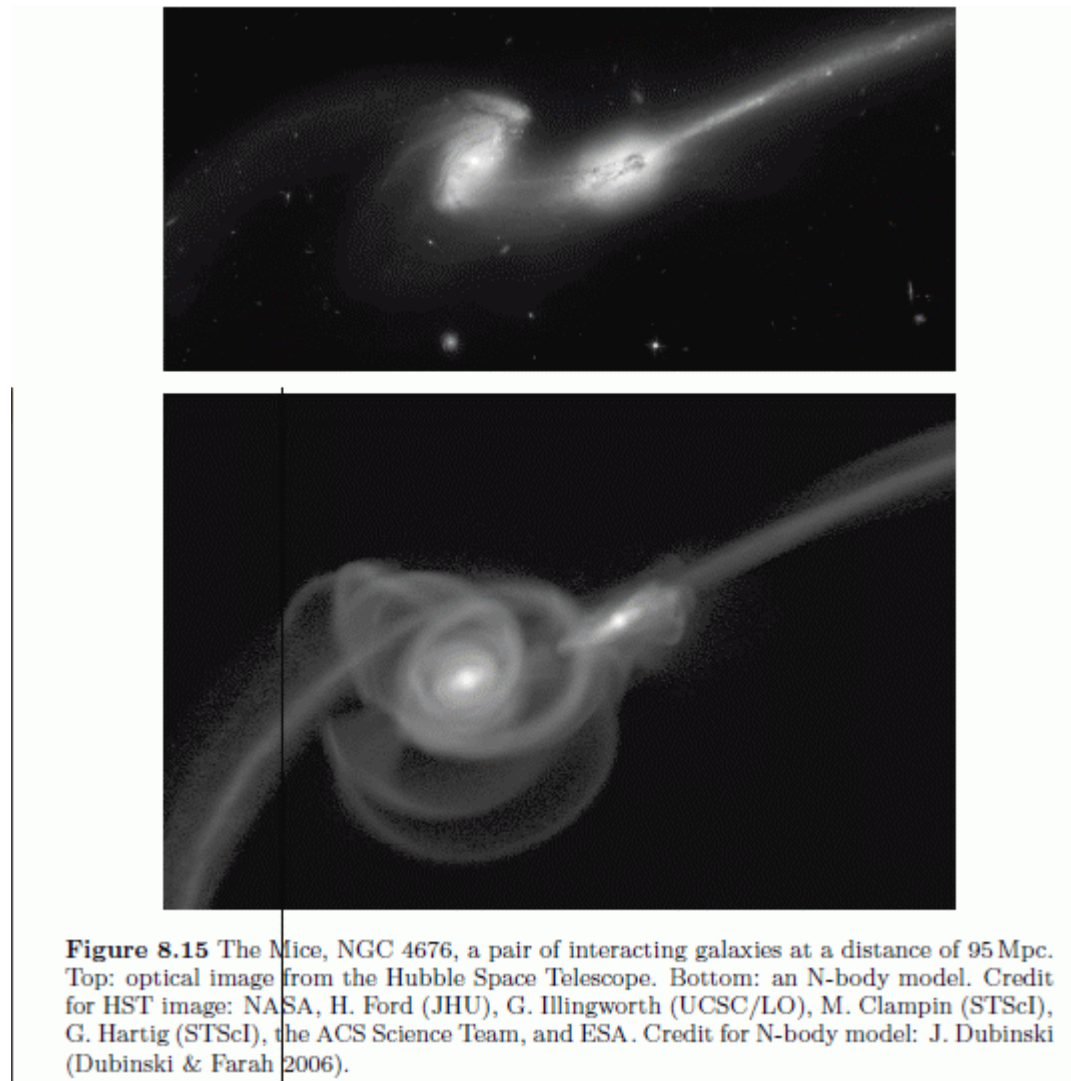
GAL-GAL

* Tidal stripping;

* Harassment defined as frequent high speed galaxy encounters within clusters.

Credit to Binney & Tremaine

Mergers from observations and N-body simulations.



Credit to Binney & Tremaine

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GAL-ICM

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

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

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

i.e. the fraction of stripped gas.

It is more efficient at the cluster center!

Proof: anemic spirals (i.e. no/little HI) and now the “jellyfish” galaxies, where this process seem trigger starburst.

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

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

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

Credit:

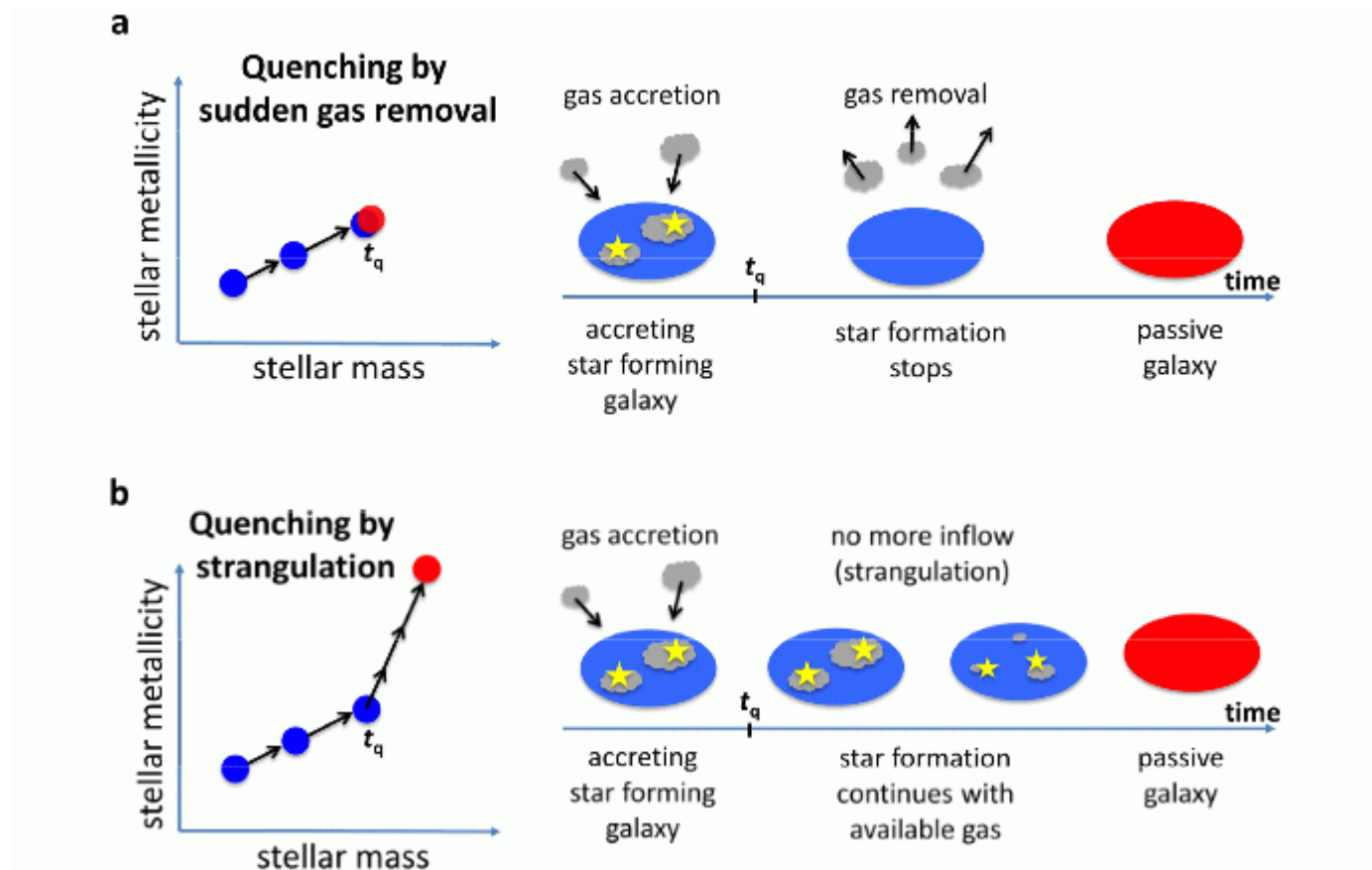
NASA, ESA, CXC

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



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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

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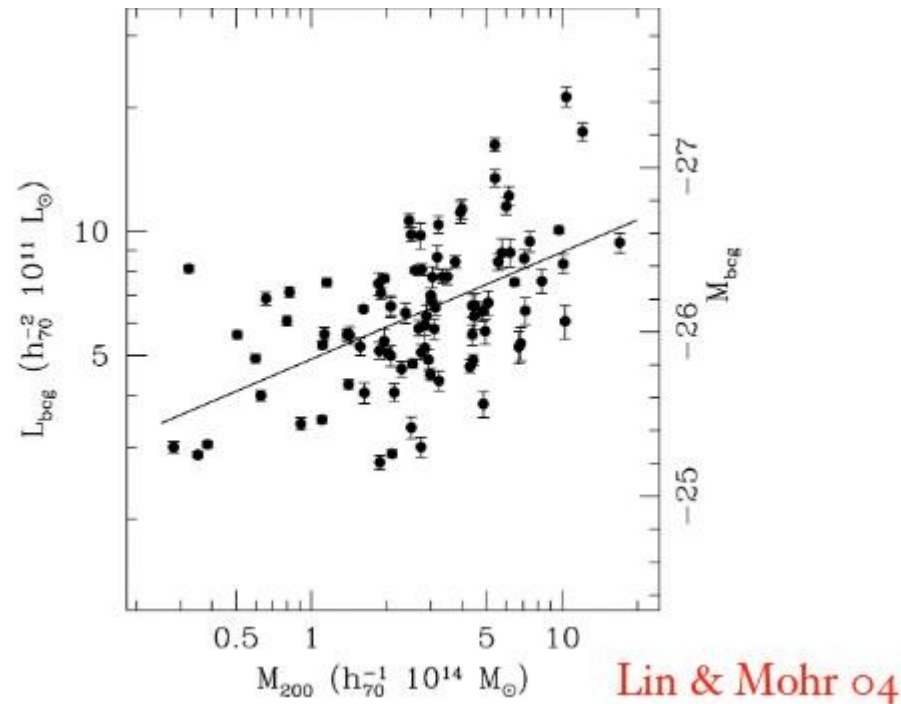
Formation of cD galaxies

*Cannibalization of galaxies slowed down by dynamical friction, that is debris cumulation.

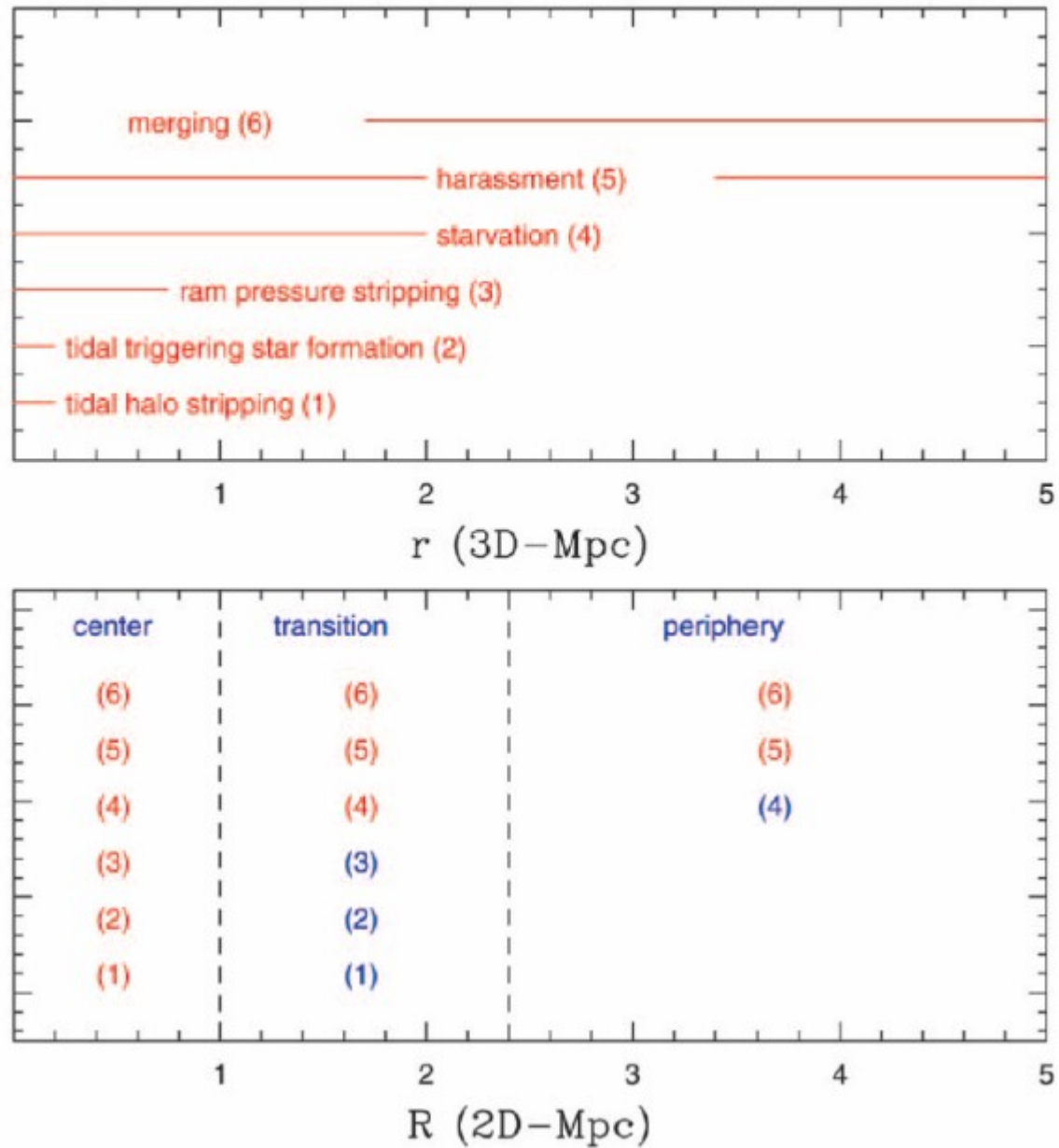
*Central position: it is not subjected to the tidal radius truncation.

*“Cooling flows”, ICM cools ($T_{\text{cooling}} \propto \rho_{\text{ICM}} T_{\text{ICM}}^{1/2}$), flows to the cluster center and accretes the central galaxy.

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



Comparison between different effects



Credit to Treu et al. 2003, ApJ