Environmental imprints on galaxy chemical enrichment

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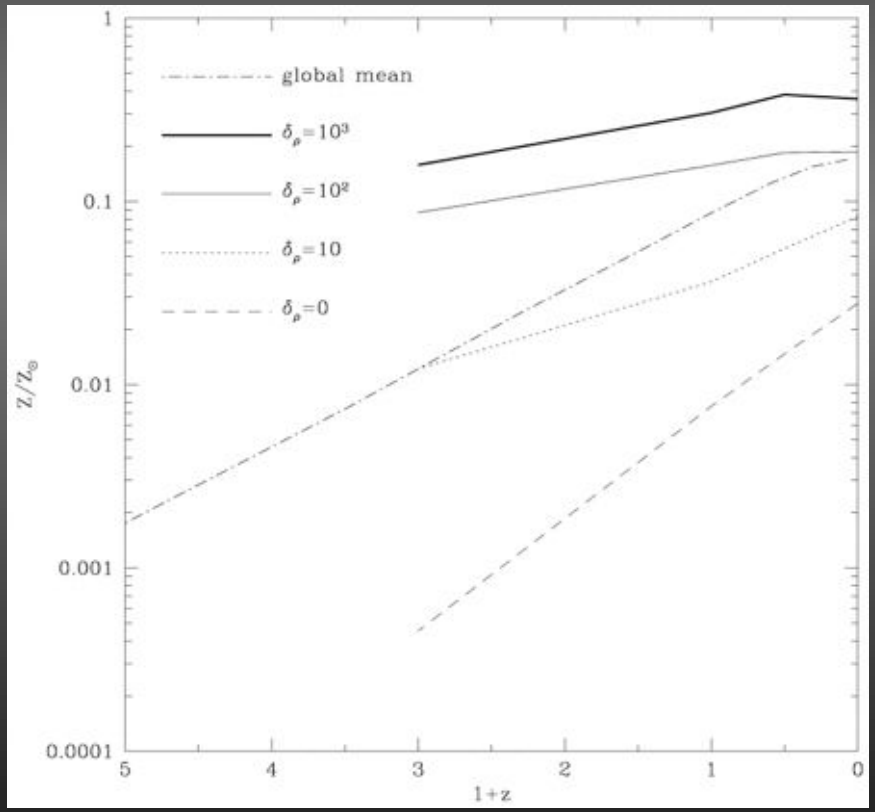
Estallidos

EVOLUTION OF THE METAL CONTENT OF THE UNIVERSE:

Contrary to “popular wisdom” metal content is not (**only)**
a function of the time & redshift vectors
it depends **on structure formation**
i.e. on *environment*

After Cen & Ostriker (1999) pioneering work



Galaxies in dense environments

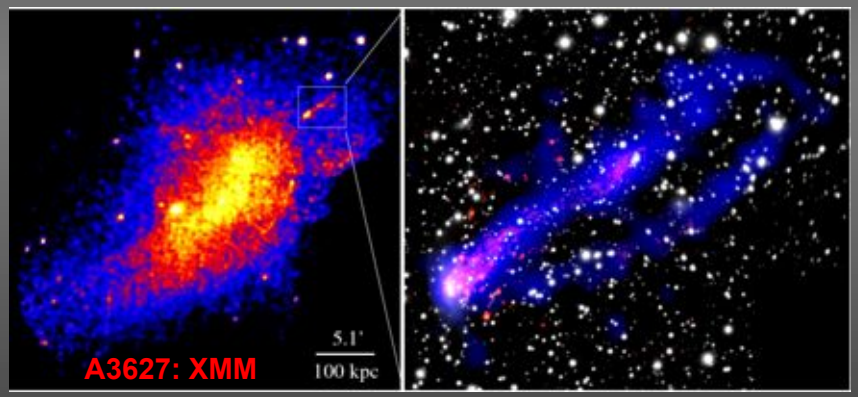
Several environmental processes can affect the evolution of cluster galaxies

I. Galaxy-ICM interactions ram-pressure stripping, thermal evaporation of the ISM, turbulent and viscous stripping of the ISM, pressure-triggered star-formation

II. Galaxy-Cluster Gravitational Potential interactions tidal compression of galactic gas, tidal truncation of the outer regions of a galaxy

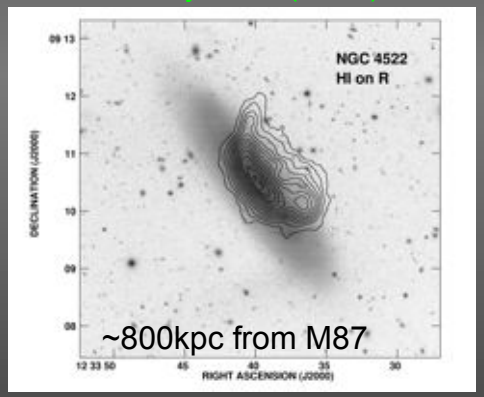
III. Galaxy-Galaxy interactions mergers, harassment

Ram-pressure stripping

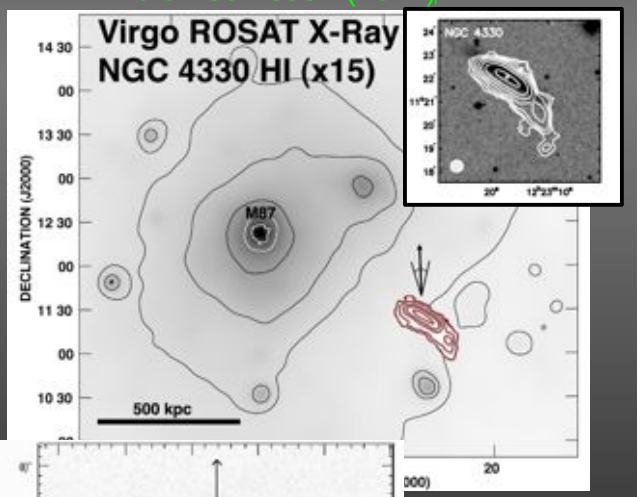


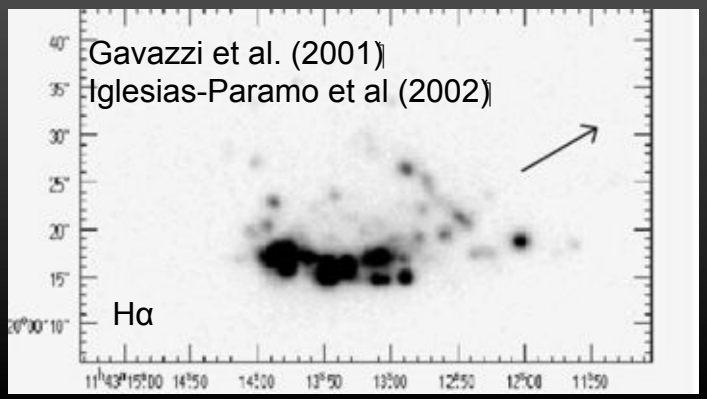
Sun et al. (2010)
XMM mosaic of A3627 one of the closest massive clusters (z=0.016)
Spectacular Xray(in blue)+Hα(in red) tail ~80 kpc in the galaxy ESO137-001
~280 kpc from the cluster center

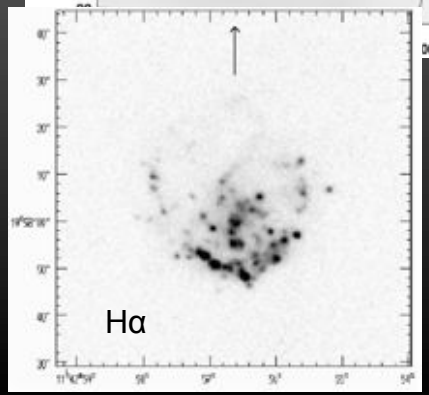
Kenney et al. (2004)



Abramson et al. (2011)

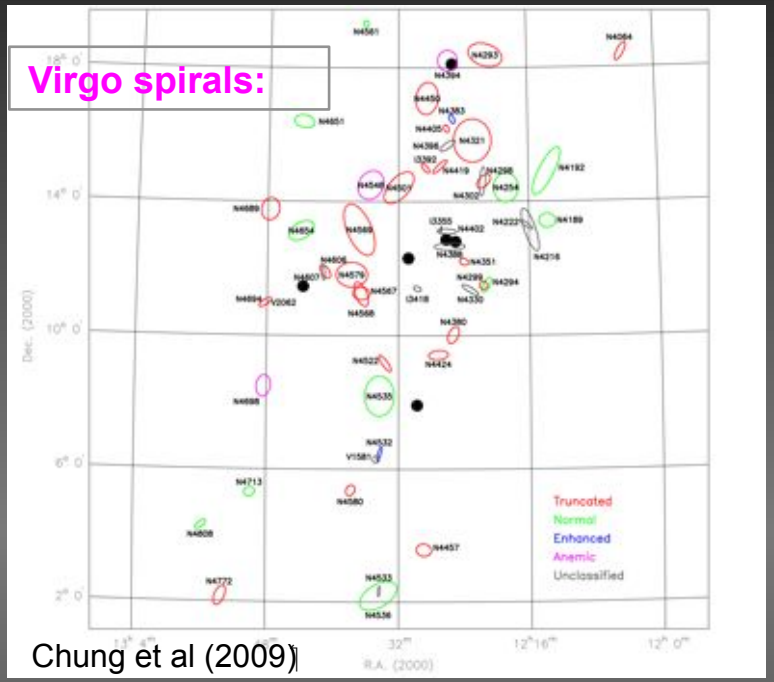




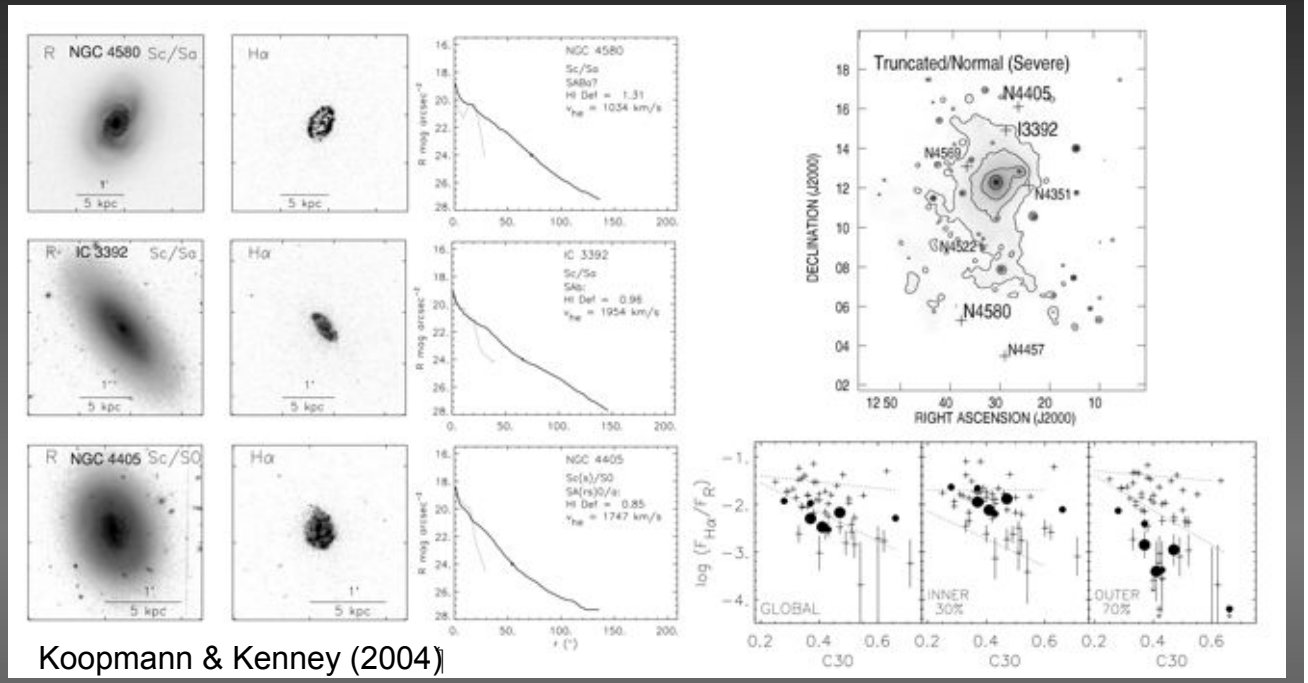


See also **Gavazzi et al (2001)**: 75 kpc trails of ionized gas behind two Irr galaxies in A1367

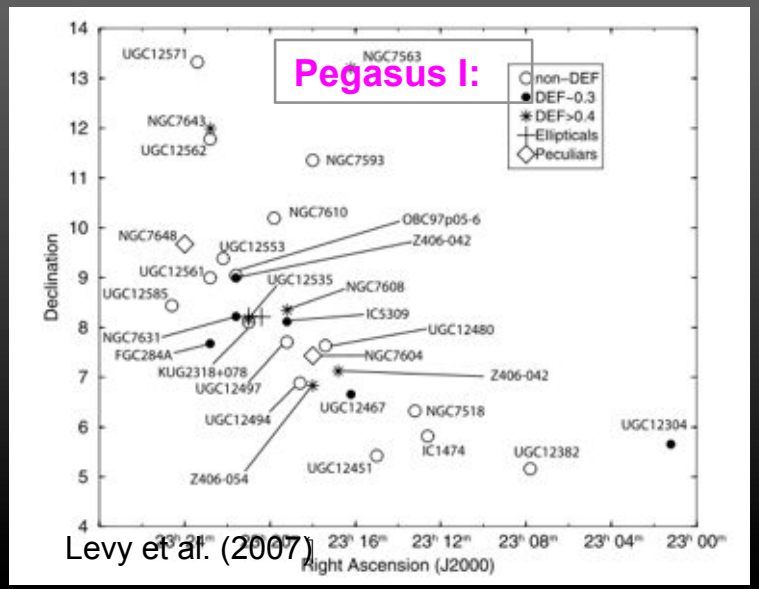
Effects of Environment: *Gas removal & SF truncation*



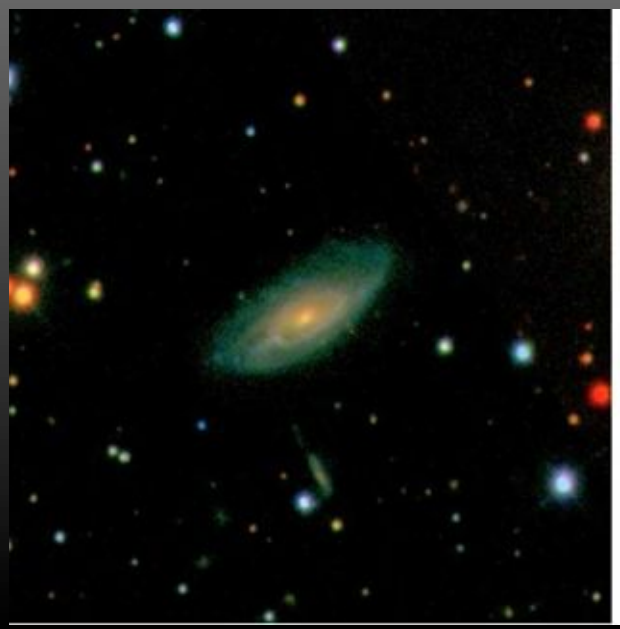
Chung et al (2009)

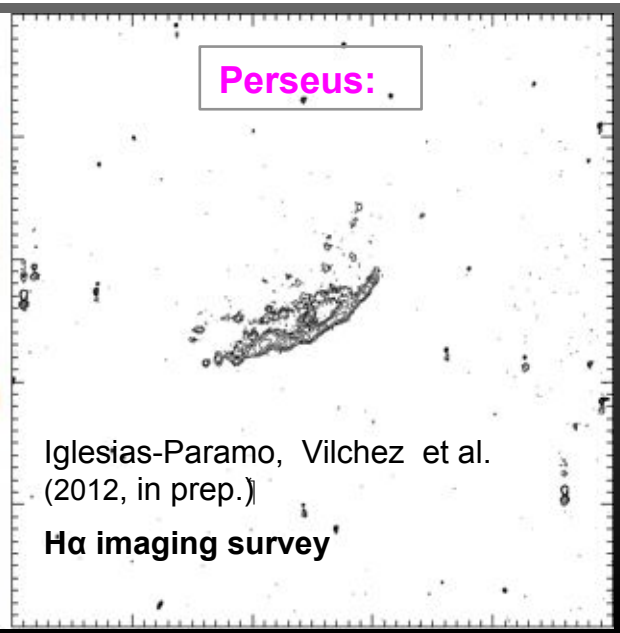


Koopmann & Kenney (2004)



Levy et al. (2007)





Iglesias-Paramo, Vilchez et al. (2012, in prep.)

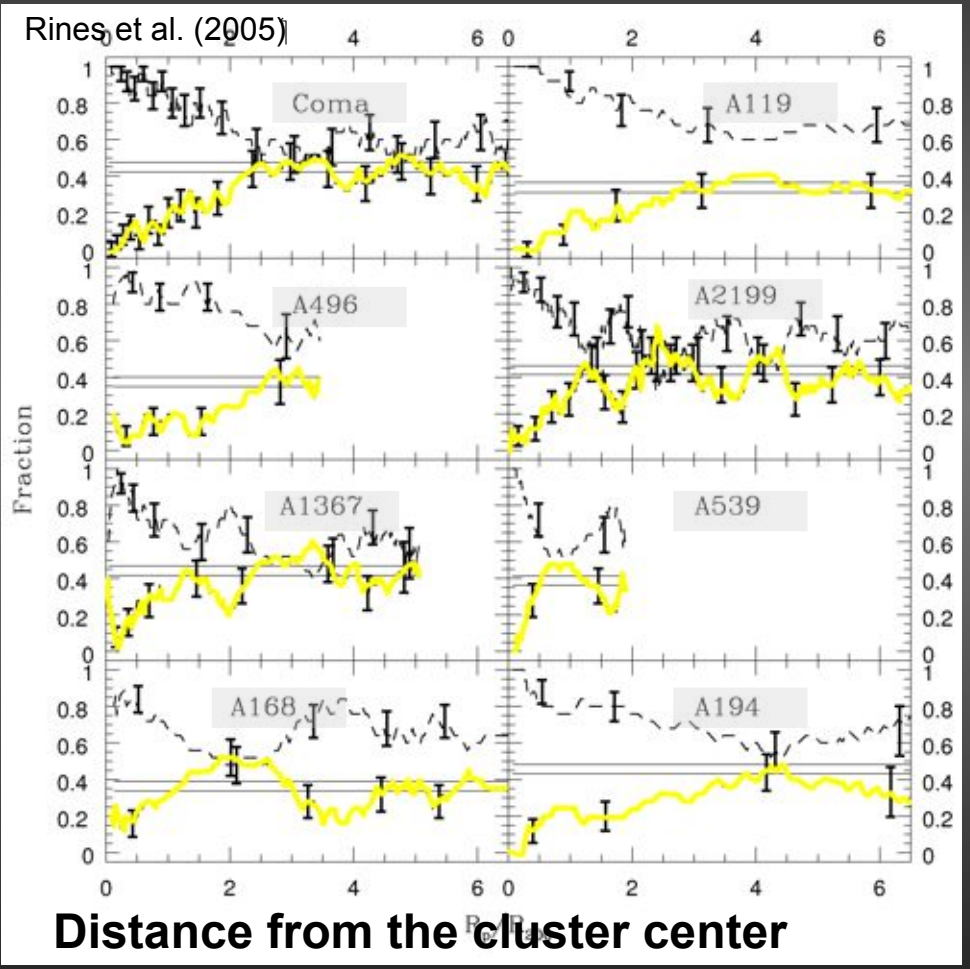
Hα imaging survey

SFH of galaxies in dense environments

CAIRNS: z<0.05

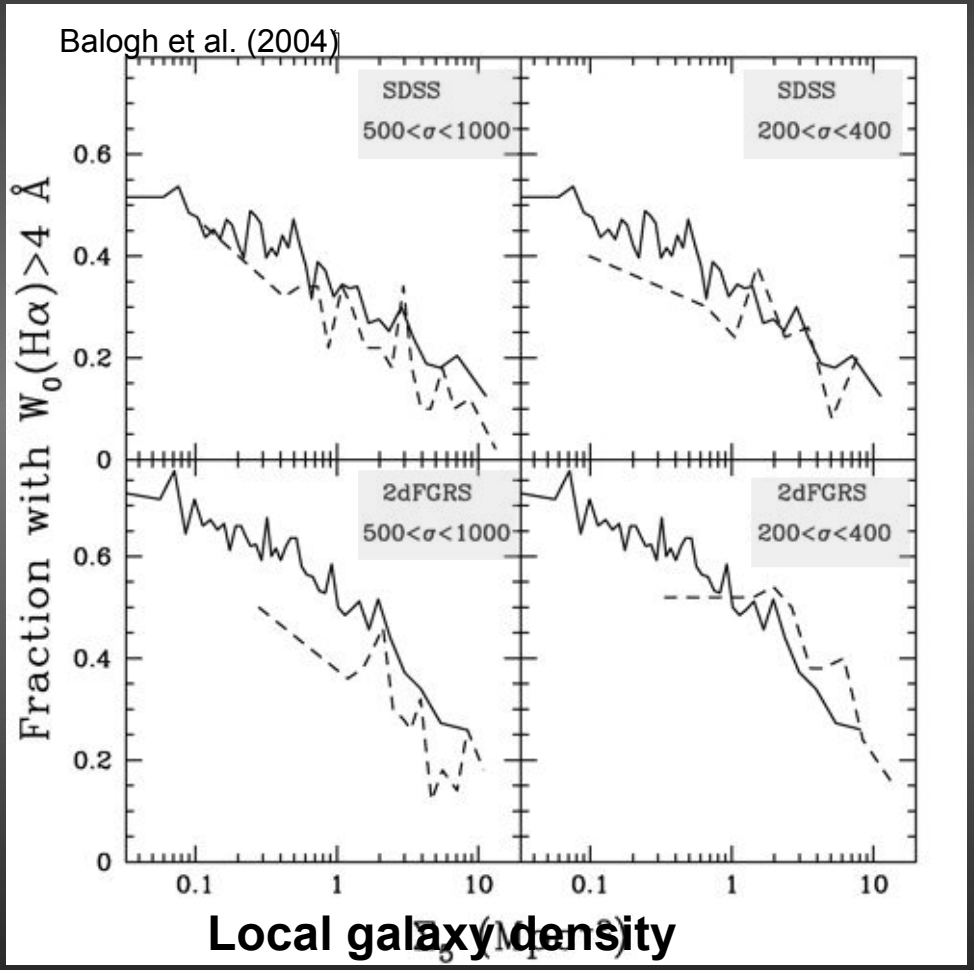
SDSS+2dF: 0.05<z<0.095

Rines et al. (2005)



Distance from the cluster center

Balogh et al. (2004)



Local galaxy density

M-Z relation in SFGs : Lequeux et al. (1979) -> Metallicity strongly correlated with galaxy mass …

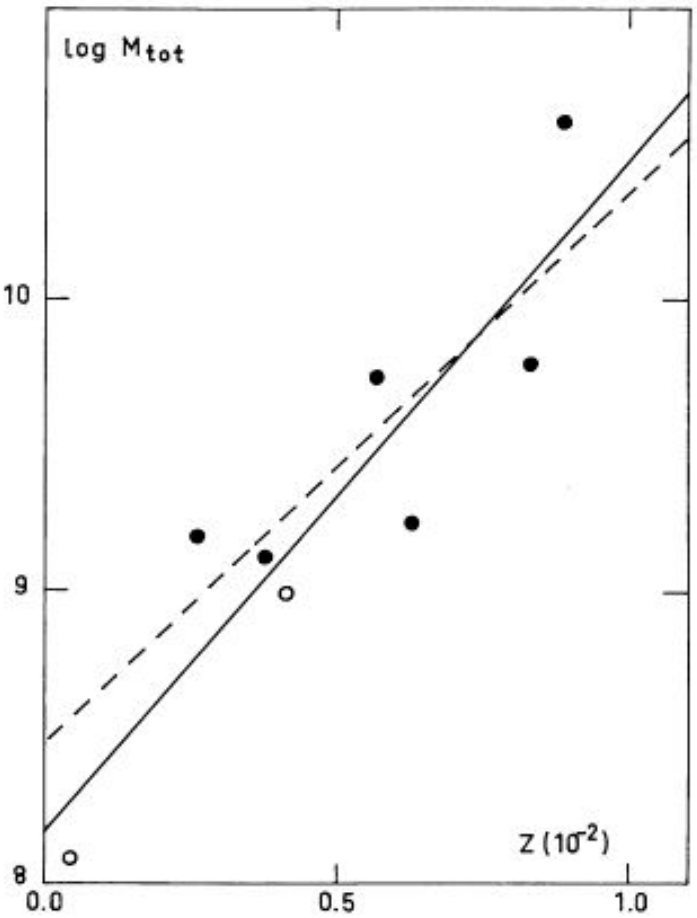


Fig. 4. Observed heavy element abundance, Z, versus total mass for the compact and irregular galaxies under consideration. Filled circles are objects with known mass; open circles are lower limits to the total mass for I Zw 18 and II Zw 40 (for which we adopted $9.9\ 10^8\ M_\odot$). *Solid line*, least-squares fit for all galaxies ($\log M_{tot} = 8.18 + 229\,Z$). *Dashed line*, least-squares fit for galaxies of known mass ($\log M_{tot} = 8.48 + 187\,Z$)

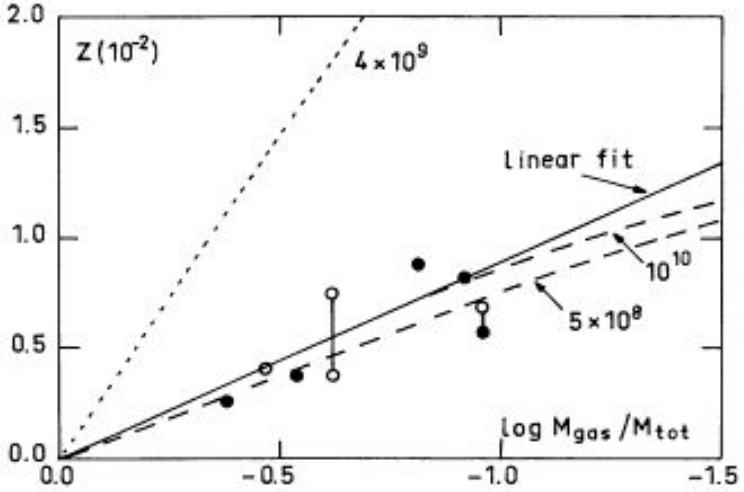


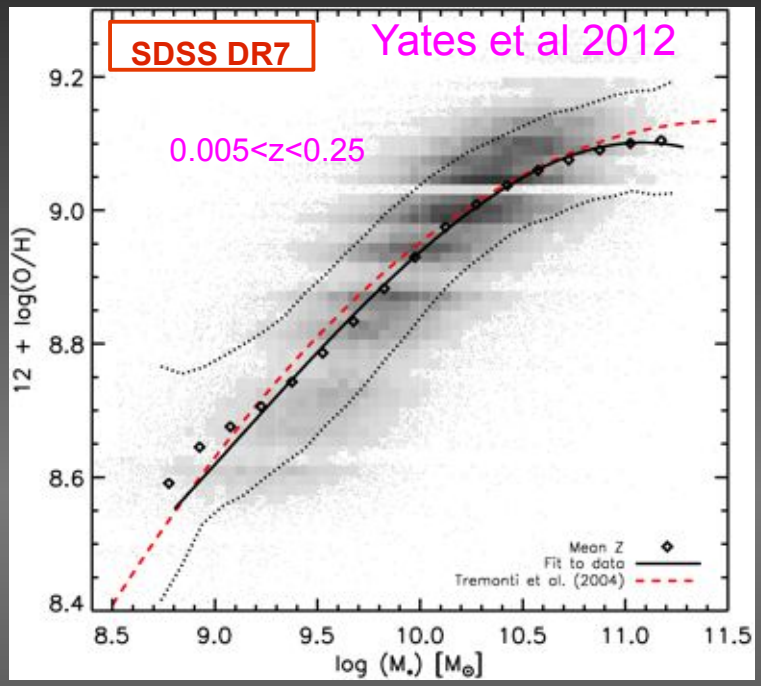
Fig. 5. Heavy element abundance versus gas mass to total mass ratio. *Solid line* is the least-squares fit to the observations $Z = -0.0003 + 0.0039 \ln (M_{tot}/M_{gas})$. *Dashed lines* are model calculations for extreme mass loss and different rates of star formation. *Dotted lines* is model calculation for no mass loss. For each model the characteristic time is indicated. Symbols as in Fig. 2 and 3

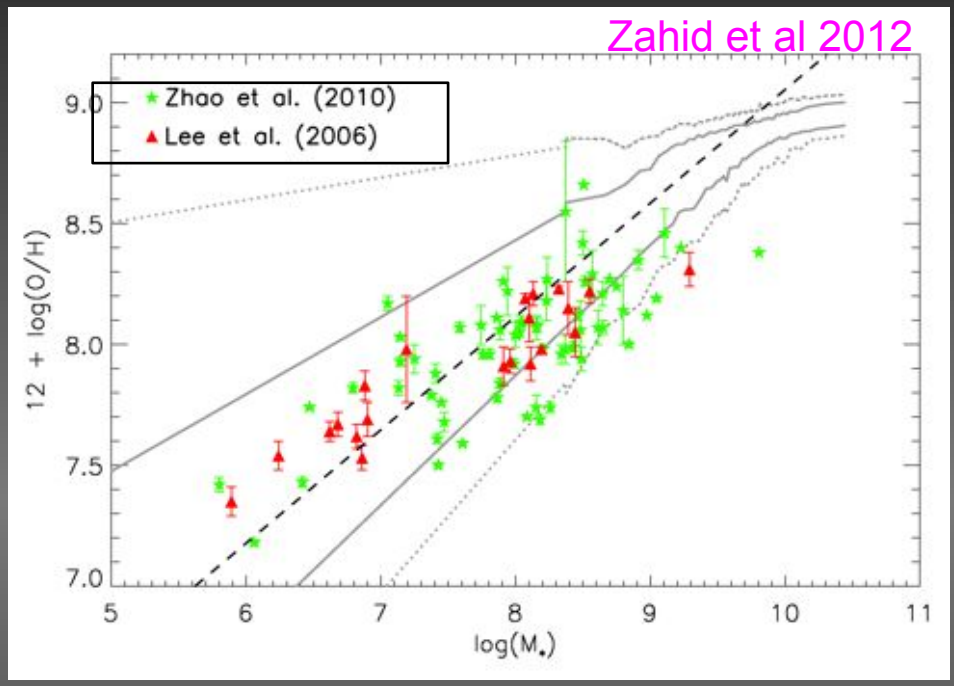
Table 6. Heavy element yields

p	
Observational	Theoretical
0.004 ± 0.001 [a]	0.004 [e]
0.004 [b]	0.013 [f]
0.003 [c]	$0.002 - 0.010$ [g]
0.005 ± 0.001 [d]	$0.011 - 0.034$ [h]
	> 0.015 [i]

a This work. For the irregular and blue compact galaxies in our

Galaxy Metal Content vs Mass





The MZR @ higher redshifts:

0.5<z<0.9: Savaglio et al (2005)
1.0<z<1.6: Shapley et al (2005), Epinat et al.(2009)
2.0<z<2.5: Erb et al. (2006), Lehnert et al. (2009)
3.0<z<4.0: Maiolino et al (2008), Mannucci et al. (2009)

Mass-Metallicity-SFR:
Mannucci et al (2010), Lara-Lopez et al (2010), Yates et al. (2012)

Which is the physical mechanism underlying the MZR?

Ejection of metal-enriched gas by momentum-driven gas outflows (Finlator & Dave 2008) or galactic winds (Spitoni et al 2010)

Variation of the IMF with mass (Koppen et al. 2007)

"Downsizing" (Brooks et al 2007, Calura et al 2009)

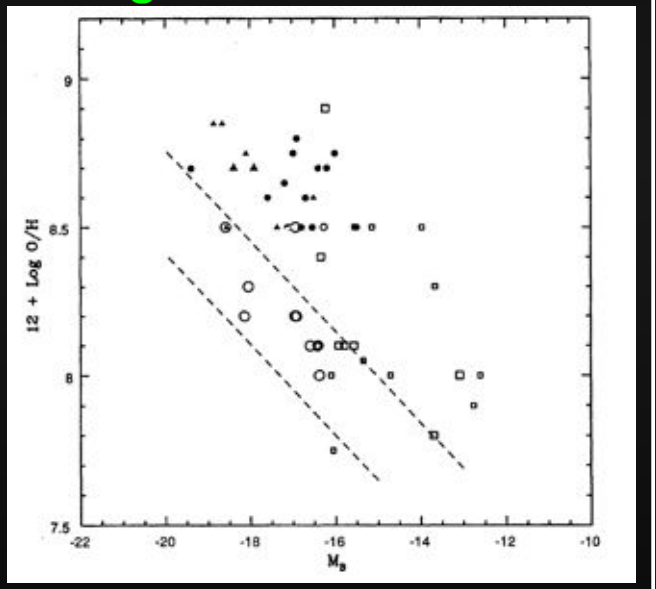
Inflows (smooth or via satellites) (Dalcanton et al 2004, Dave et al 2010)

Metallicity of SF galaxies in clusters

Several environmental processes can affect the SFH and the gas exchange between the galaxy and its environment, and as a consequence could alter the chemical evolution of cluster galaxies

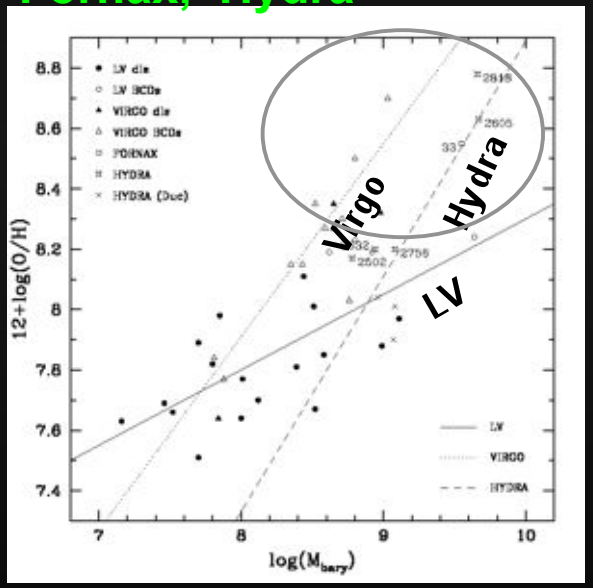
Could metallicity of cluster galaxies bear the imprint of the environment?

Virgo



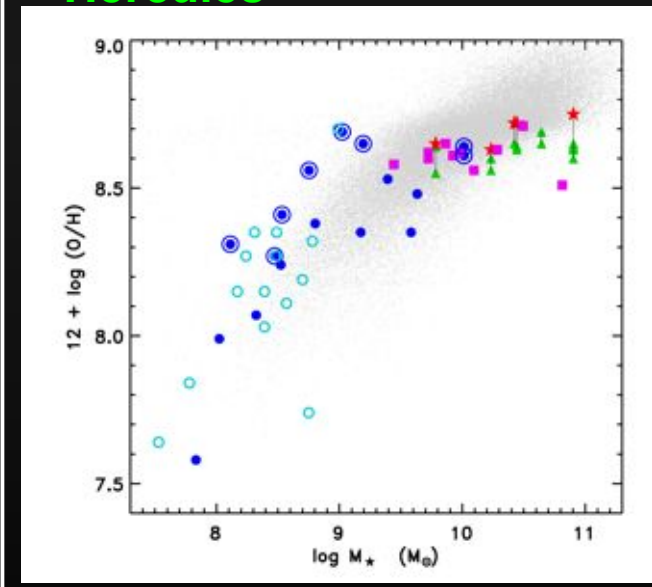
Vilchez 1995

Fornax, Hydra



Vaduvescu,Kehrig,Vilchez+2011

Hercules



Petropoulou et al. 2011

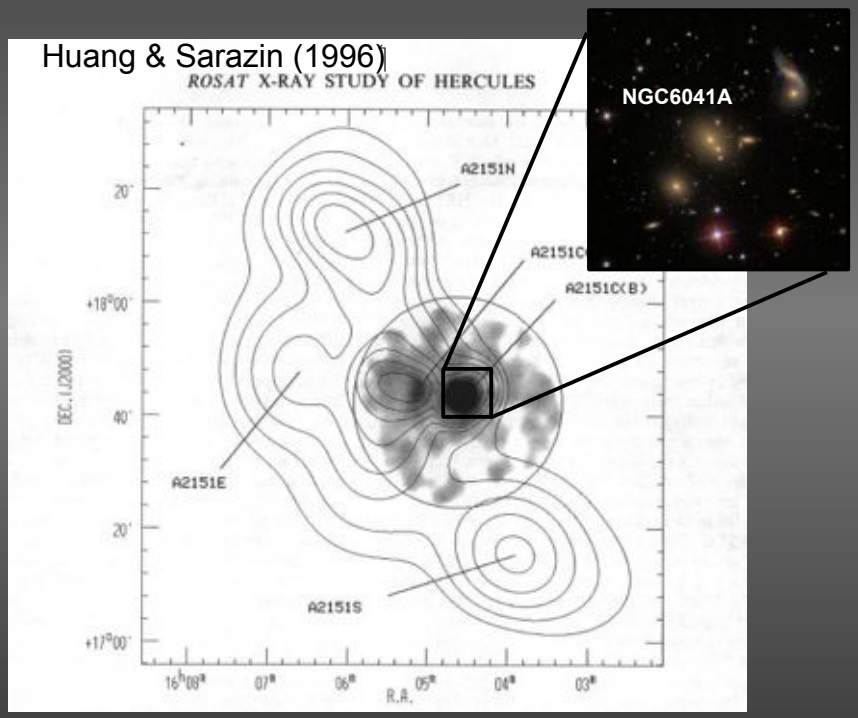
Spirals in Virgo (9): Skillman et al 1996 ; Henry et al 1992, 94, 96
Spirals in Pegasus I: Robertson et al 2012

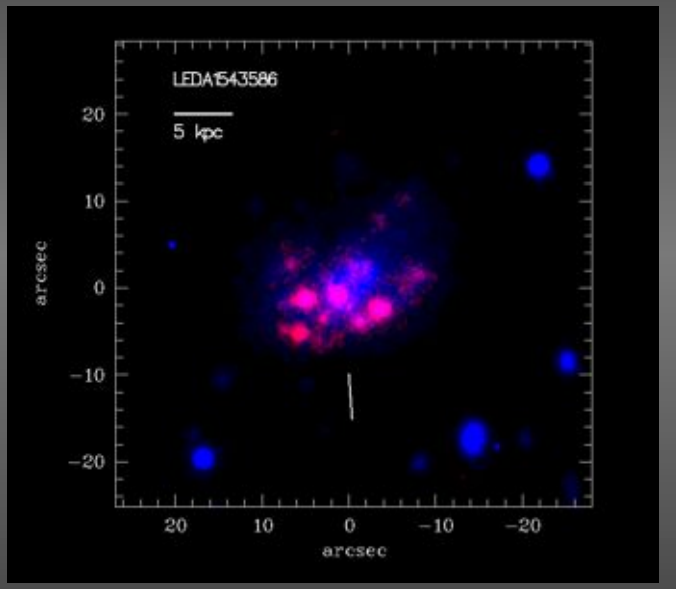
The Hercules cluster: *a benchmark*

α:16h05m15s **δ**: +17d44m55s **z**~0.036 σ_v~750km/s

Low-mass and low-metallicity galaxies show systematically $|\Delta V| > \sigma_V$ and disturbed Hα morphologies.

Huang & Sarazin (1996)





Red: Hα emission. Blue : r band image
(Petropoulou, Vilchez et al in prep.)

Bird et al. (1995): Central and eastern sub-clusters have recently undergone a merger event
Cedres et al. (2009): Hα survey: ~40 SF galaxies (-21<M_B<-16.5) in Hercules central region (<R_{200})
Petropoulou et al. (2011): Spectroscopic follow-up of SF galaxies

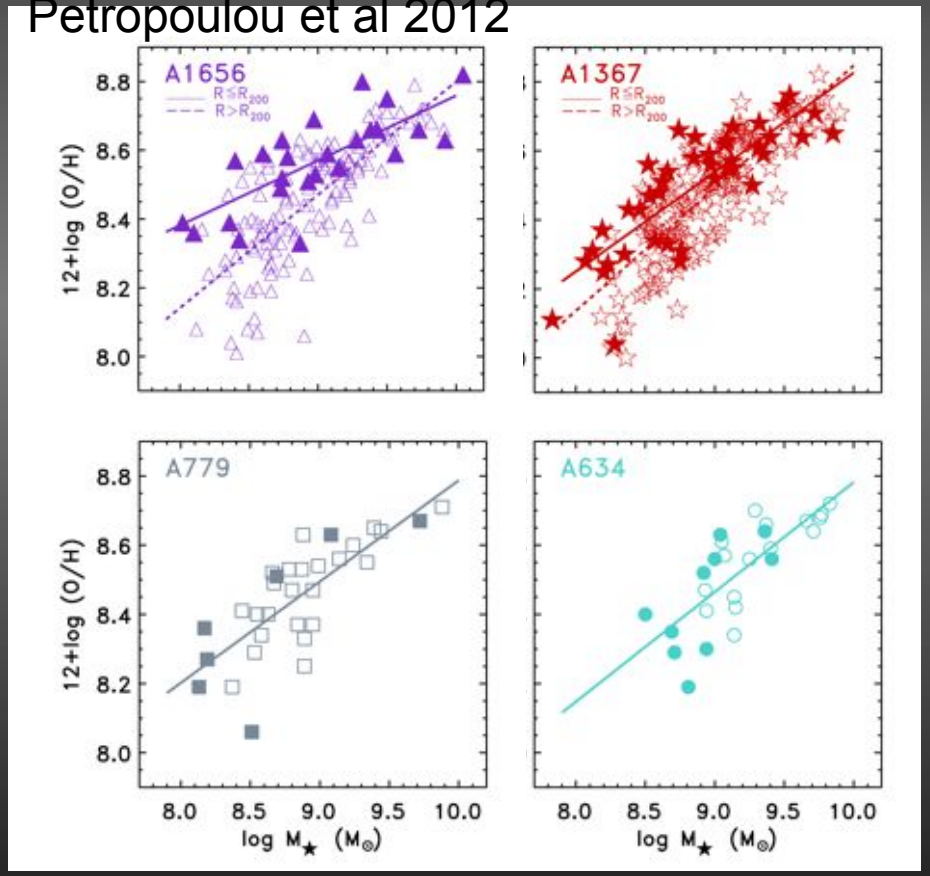
Low-mass galaxies in 4 nearby clusters:

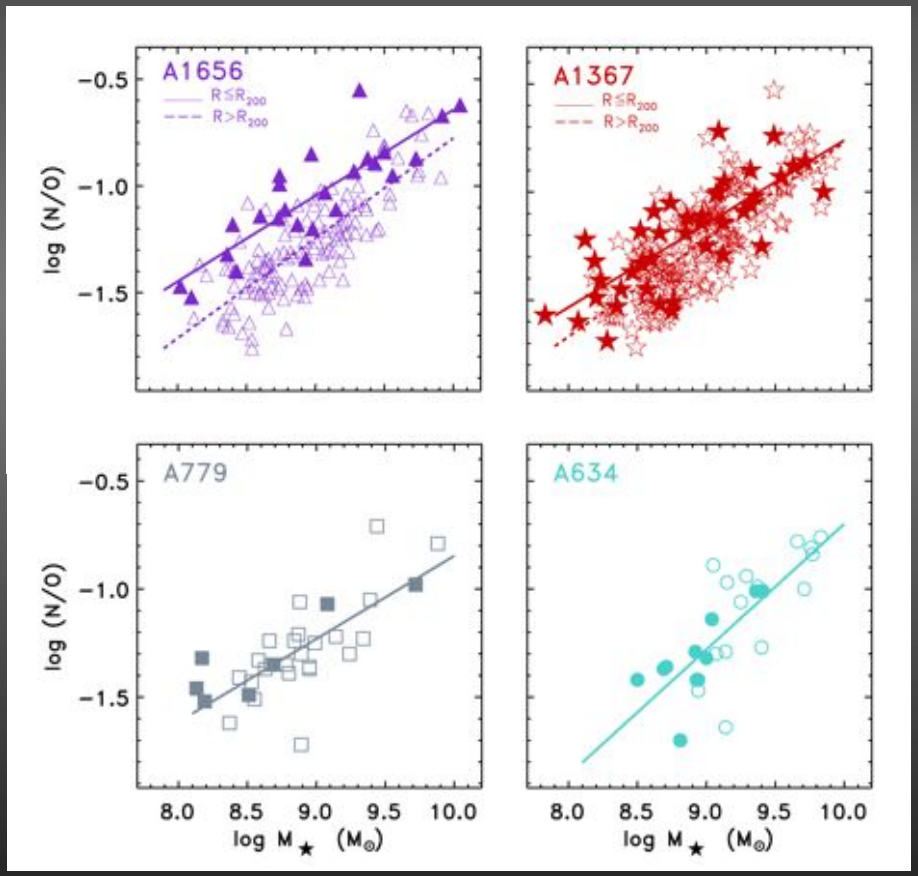
Coma, A1367, A779 & A634

Cluster sample: mass range:10^{13}-10^{15}, Distance ~100 Mpc

Spectroscopic data: SDSS DR8, corrected for stellar continuum

Petropoulou et al 2012



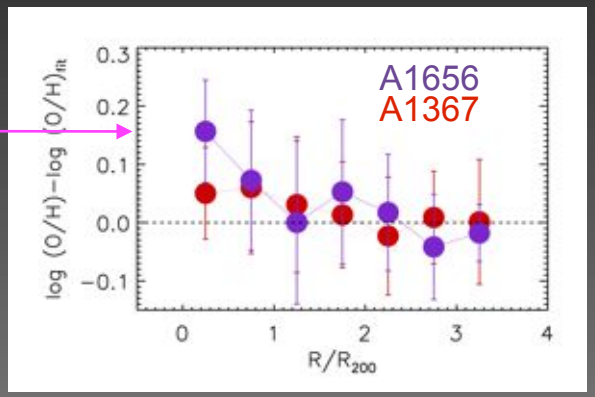


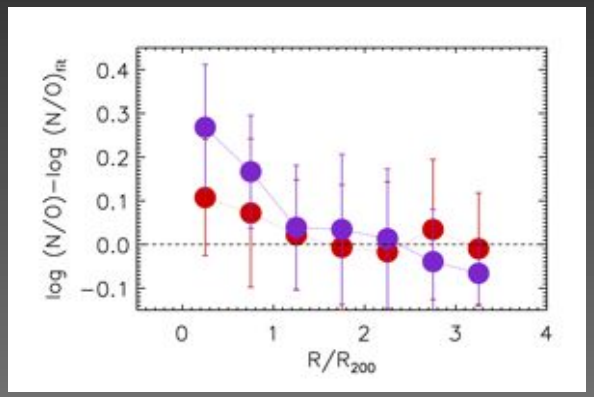
The mass … matters

Cluster membership or local density?

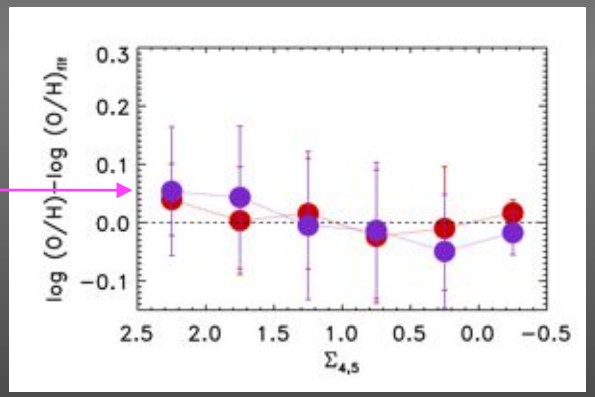
~0.15 dex

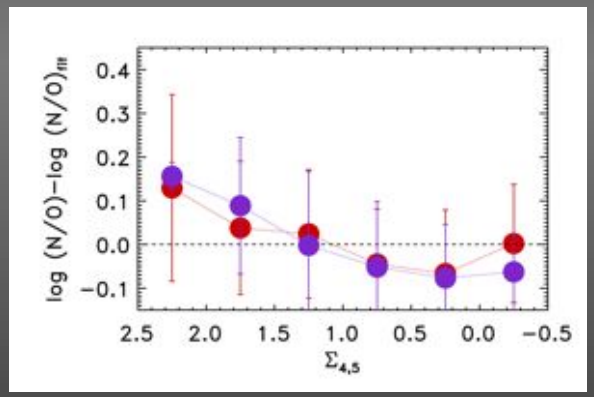
~0.05 dex





~0.3 dex

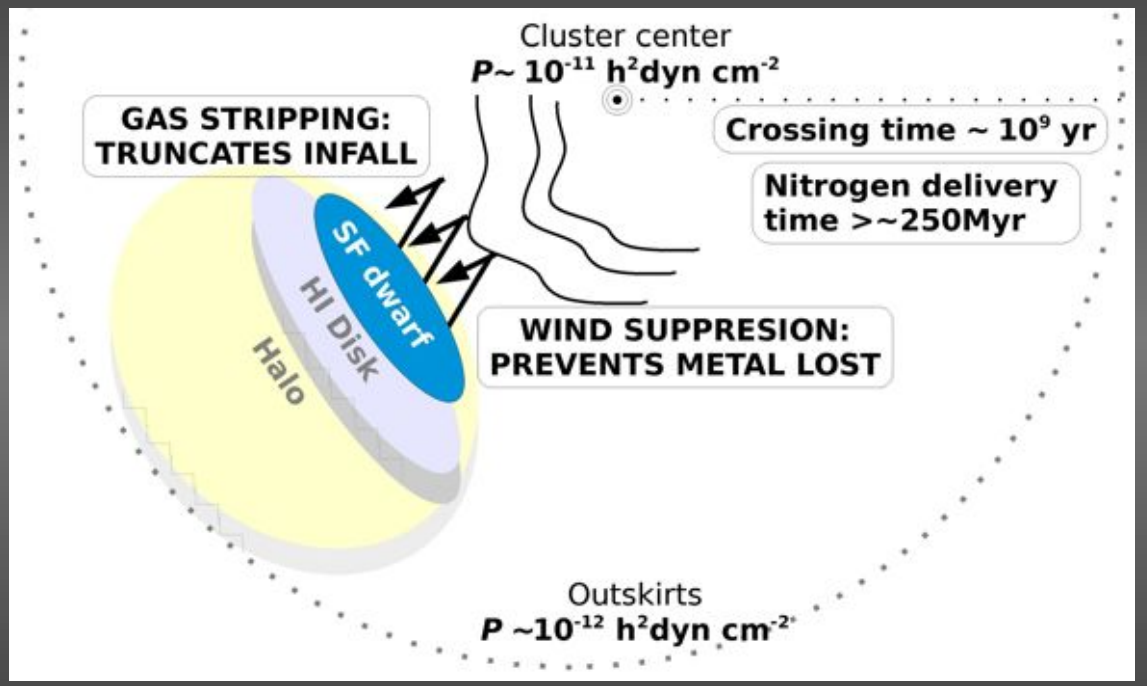




Left: The difference of the derived 12+log(O/H) of each galaxy with the 12+log(O/H)$_{fit}$ given by the bisector linear fit, as a function of the cluster centric radial distance (Up) and the local galaxy density (Down). Right: the same for N/O

The proposed scenario

In agreement with state-of-the-art hydrodynamic simulations that introduce an equilibrium model between inflows and momentum-driven gas outflows to describe galaxy chemical evolution (Dave et al. 2011, Finlantor & Dave 2008)



The enhanced metal enrichment could be produced by the combination of effects such as wind reaccretion, due to pressure confinement by the ICM, and the truncation of gas infall, as a result of RPS.

Thank you!