Metallicity of SF Galaxies in Extreme Density Environments

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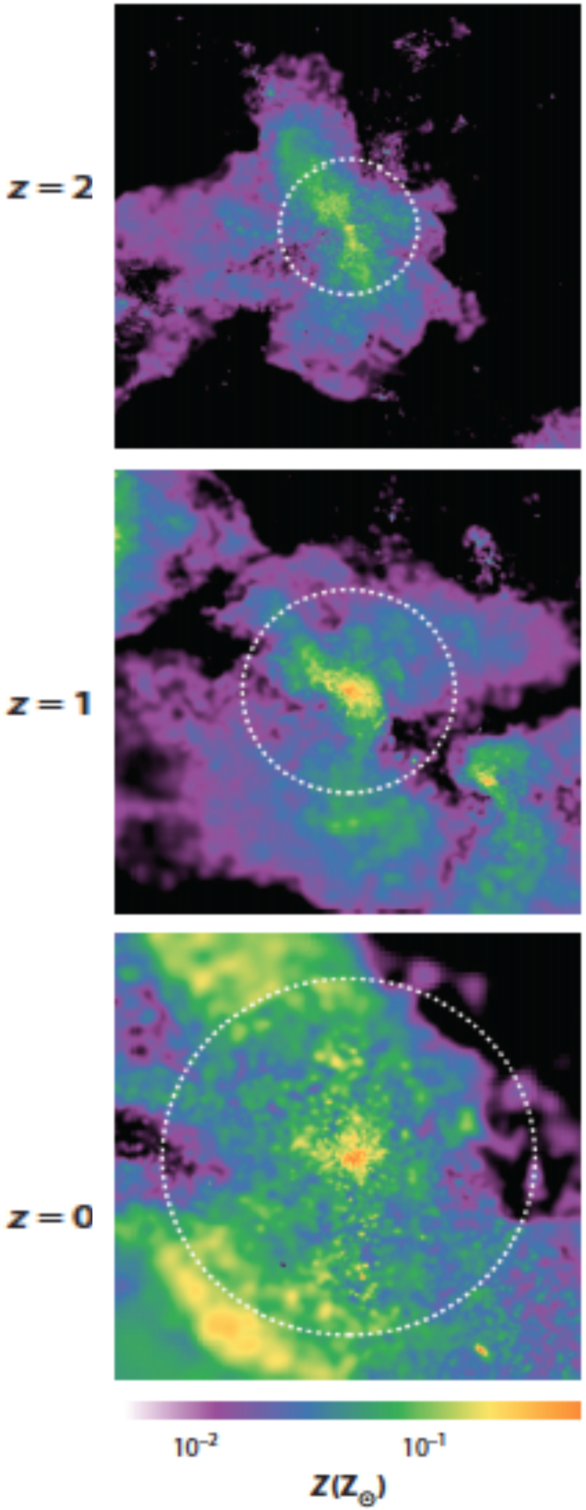
…

ESTALLIDOS

ELGS KICC, CAMBRIDGE 2017

simulated views (from EAGLE; adapted from Schaye et al. 2015 and Oppenheimer et al. 2016) of the CGM



single galaxy with $M_\star = 2.5 \times 10^{10}\ M_\odot$ at $z = 0$

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ANNUAL REVIEWS

The Astrophysical Journal, 772:119 (19pp), 2013 August 1 Lilly et al.

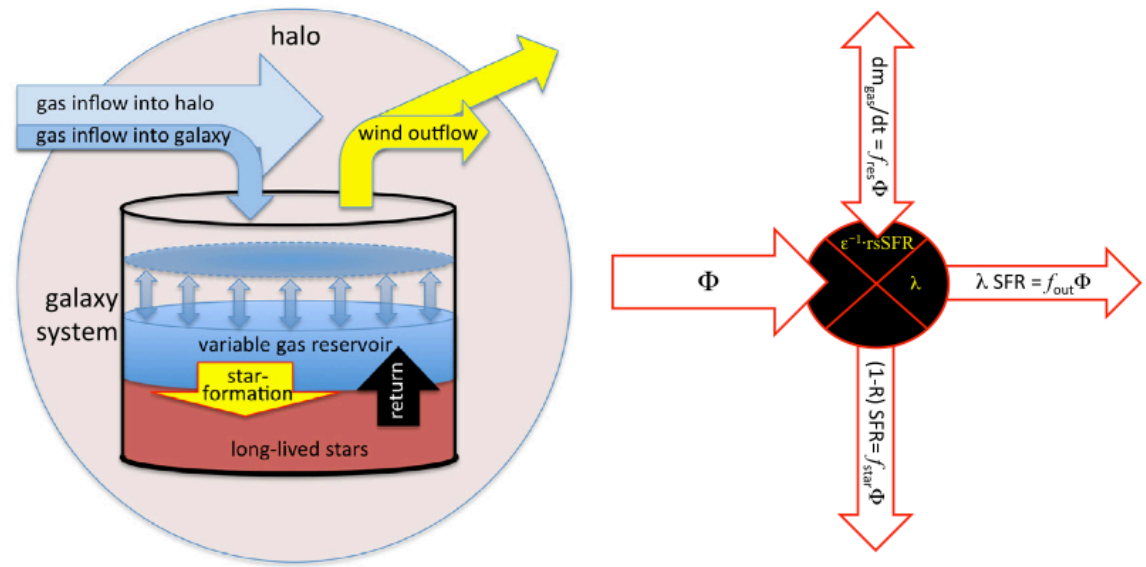


Figure 2. Illustration of the gas-regulated model, in which the SFR is regulated by the mass of gas in a reservoir within the galaxy. Gas flows in to the halo, some fraction f_{gal} of which also flows into the galaxy system at a rate Φ and adds to the gas reservoir. Stars continuously form out of the reservoir at a rate that is assumed to be proportional to the mass of gas, characterized by a star formation efficiency ε or gas consumption timescale τ_{gas}. A fraction of the stellar mass is immediately returned to the reservoir, along with newly produced metals. Finally, some gas may be expelled from the system, and possibly from the halo, by a wind Ψ that is assumed to be proportional to the SFR. The mass of gas in the reservoir is free to vary and this regulates the star formation. The picture on the right shows, in schematic form, the net flows through the system. The division of the incoming flow Φ into three streams is determined by ε, λ, and the sSFR, which are assumed to vary on timescales that are longer than the time the gas spends in the system. The duration that the gas is in the system is given by the gas consumption timescale τ_{gas}.

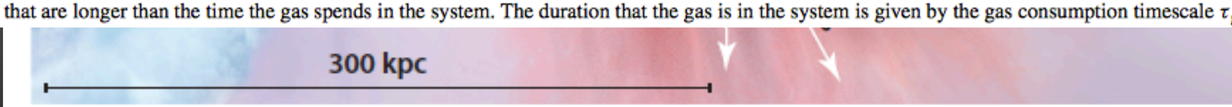


Figure 1

A diagram of the CGM. The galaxy's red central bulge and blue gaseous disk are fed by filamentary accretion from the IGM (*blue*). Outflows emerge from the disk in pink and orange, whereas gas that was previously ejected is recycling. The diffuse gas halo in varying tones of purple includes gas that is likely contributed by all these sources and mixed together over time. Refer to **Supplemental Figure 1** for an alternate version of the figure, which illustrates the different observing techniques we discuss in Section 3. Abbreviations: CGM, circumgalactic medium; IGM, intergalactic medium.

redshift

Figure 14. Mean metallicity of the Universe (in solar

dot) metallicity of the IGM as probed by O VI absorption in the Lyα forest (Aguirre et al. 2008); (*black pentagon*) metallicity of the IGM as probed by C IV absorption (Simcoe 2011); (*magenta rectangle*) metallicity of the IGM as probed by C IV and C II

SF in galaxies in dense environments

Environmental processes can affect the evolution of SF galaxies in clusters

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

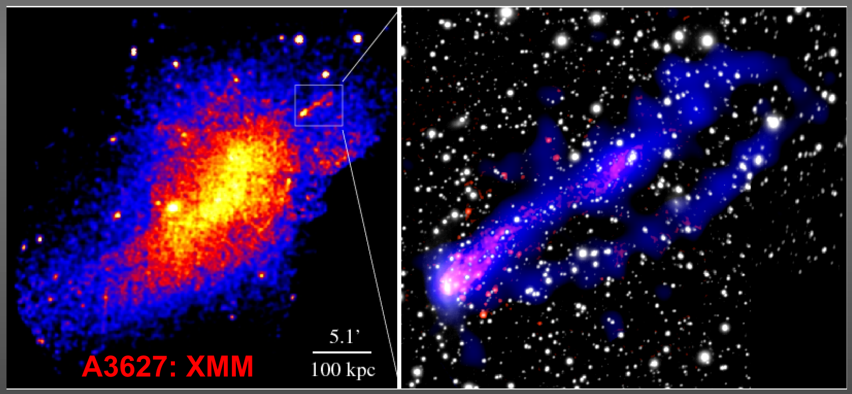
II. Galaxy-Cluster Gravitational Potential interactions tidal compression of galactic gas, tidal truncation of the outer regions of a galaxy (Inter-galactic light, PNs Virgo/Coma)

III. Galaxy-Galaxy interactions mergers (Tissera's models), harassment (Moore+)

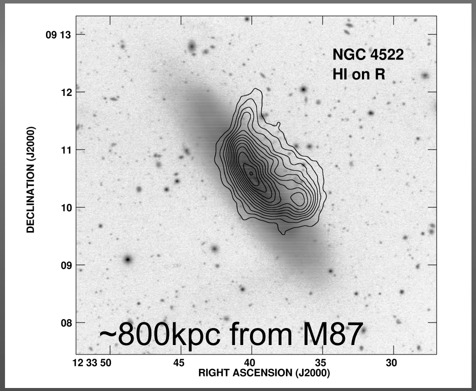
IV. Starvation/strangulation halo gas reservoir lost. Larson (1980); Balogh (80); Peng et al (2015)

Ram-pressure stripping

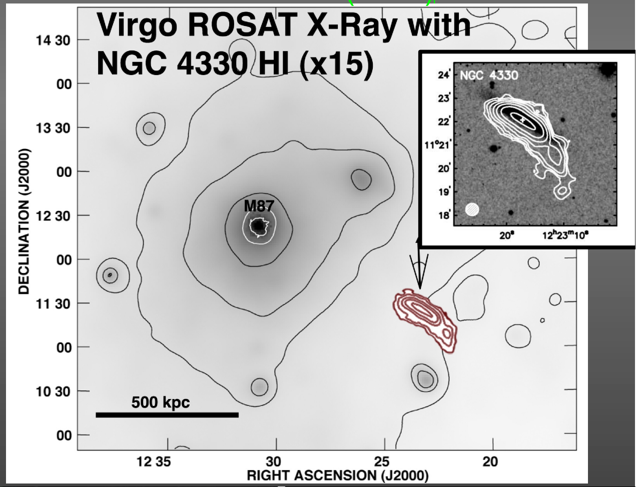
review in e.g. Treu+ 2003



Kenney et al. (2004)



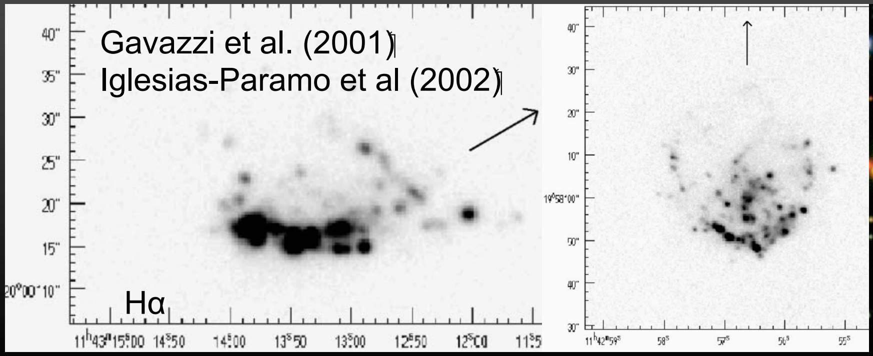
Abramson et al. (2011)

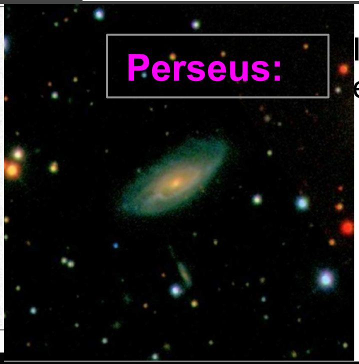


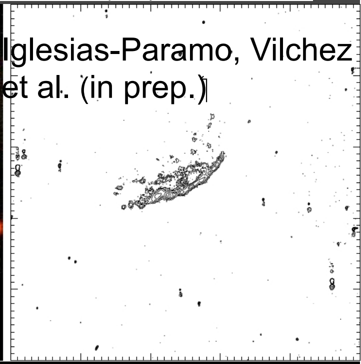
Sun et al. (2010)
XMM mosaic of A3627 one of the closest massive clusters (z=0.016)
Spectacular Xray(in blue)+Hα(in red) tail ~80 kpc in the galaxy ESO137-001
~280 kpc from the cluster center

Also **Gavazzi et al (2001)**: 75 kpc trails of ionized gas behind two Irr galaxies in A1367
Gavazzi et al (2017).

Boselli and Gavazzi (PASP 2006)



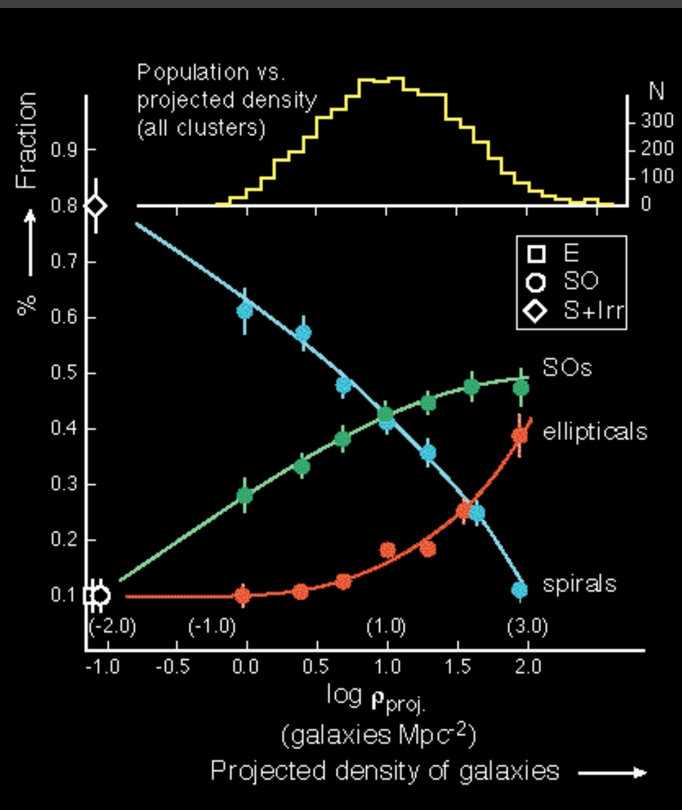




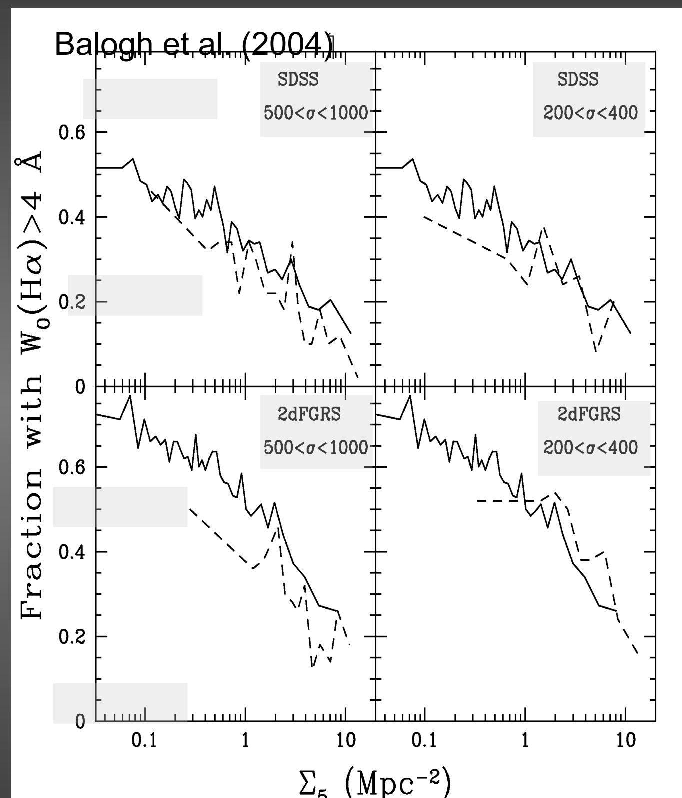
Morphology-density & SF-density Relations

*Observing the **nearby** universe*

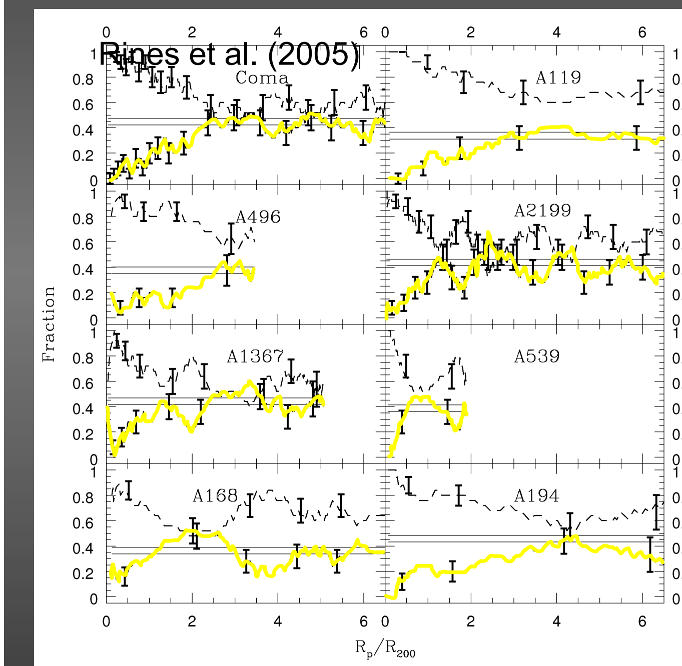
Dressler (1980)



SDSS+2dF: 0.05<z<0.095



CAIRNS: z<0.05



Local galaxy density

Distance to the cluster center

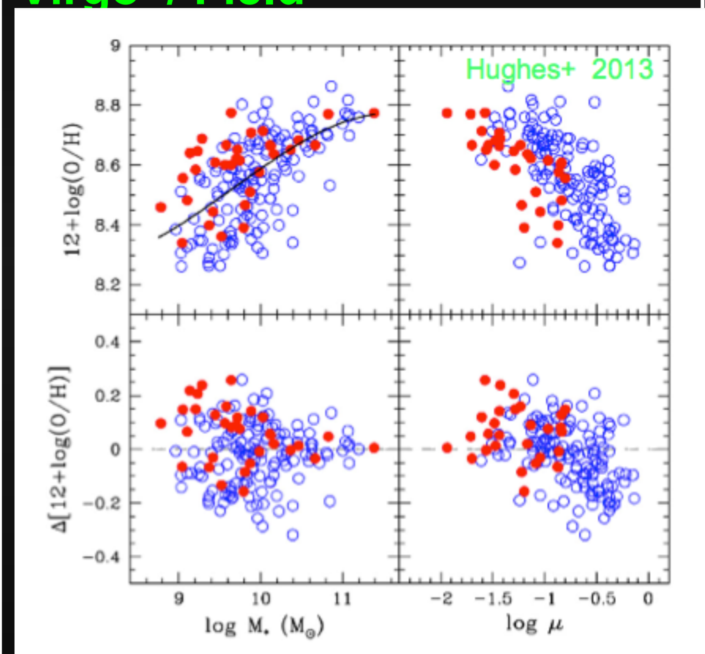
@ HIGH Z: CHANGE -> high SF associated to higher density of galaxies
Emission line Surveys (e.g Elbaz+ z ≥ 1: HIZELS Cochrane+ 2017; Sobral +)

Mass-SF-Environment: *Metallicity of galaxies in* ***clusters***

Environmental processes affect gas exchange with CG Medium/environment
=> effect on SFH & chemical evolution of cluster galaxies

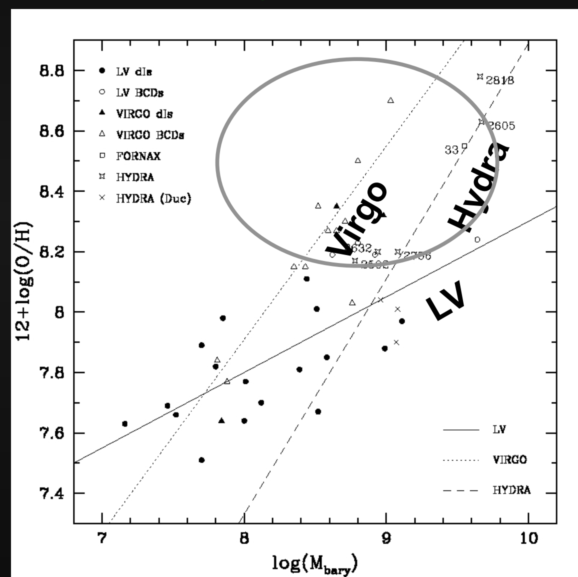
Imprint of cluster environment on metallicity ?

Virgo / Field



Vilchez 1995; 2003

Fornax, Hydra



Vaduvescu+ 2004
Vaduvescu,Kehrig,Vilchez+2011

Hercules

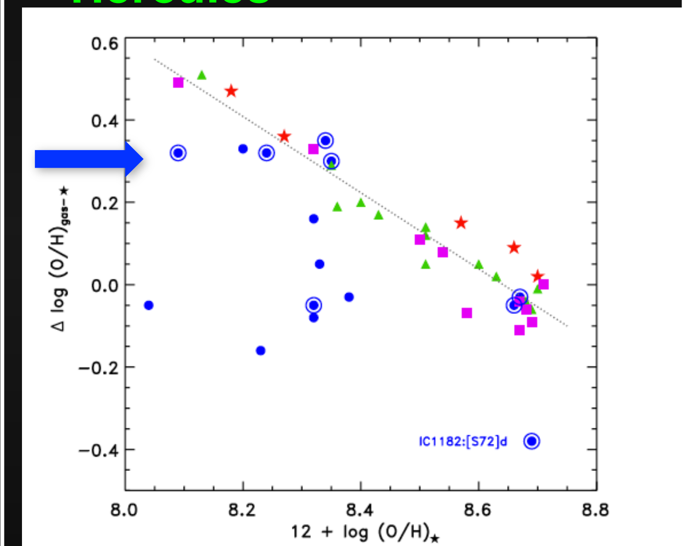


Figure 16. Difference between gas-phase and stellar oxygen abundances vs. stellar oxygen abundance $12+\log(O/H)_\star$ derived from the STARLIGHT mass-weighted stellar metallicity $Z_{\star,m}$ (colors and symbols as in Figure 11).

Petropoulou, Vilchez et al. 2011, 12
Petropoulou+ 2017 (HSC in prep)

Virgo / Field: Skillman et al 1996 ; Henry et al 1992, 94, 96; Telles & Terlevich 95; Hughes+ 2014
Spirals in Pegasus I: Robertson et al 2012

IMPORTANT AMOUNT OF WORK EXPLORING M-Z(-SFR) VERSUS ENVIRONMENT:

e.g. Mouhcine 2007; Cooper et al 2008; Ellison et al 2009; Petropoulou et al. 2011, 2012; Hughes et al 2015; Pilyugin et al . 2017; Petropoulou et al. 2017 (Hercules Supercluster)

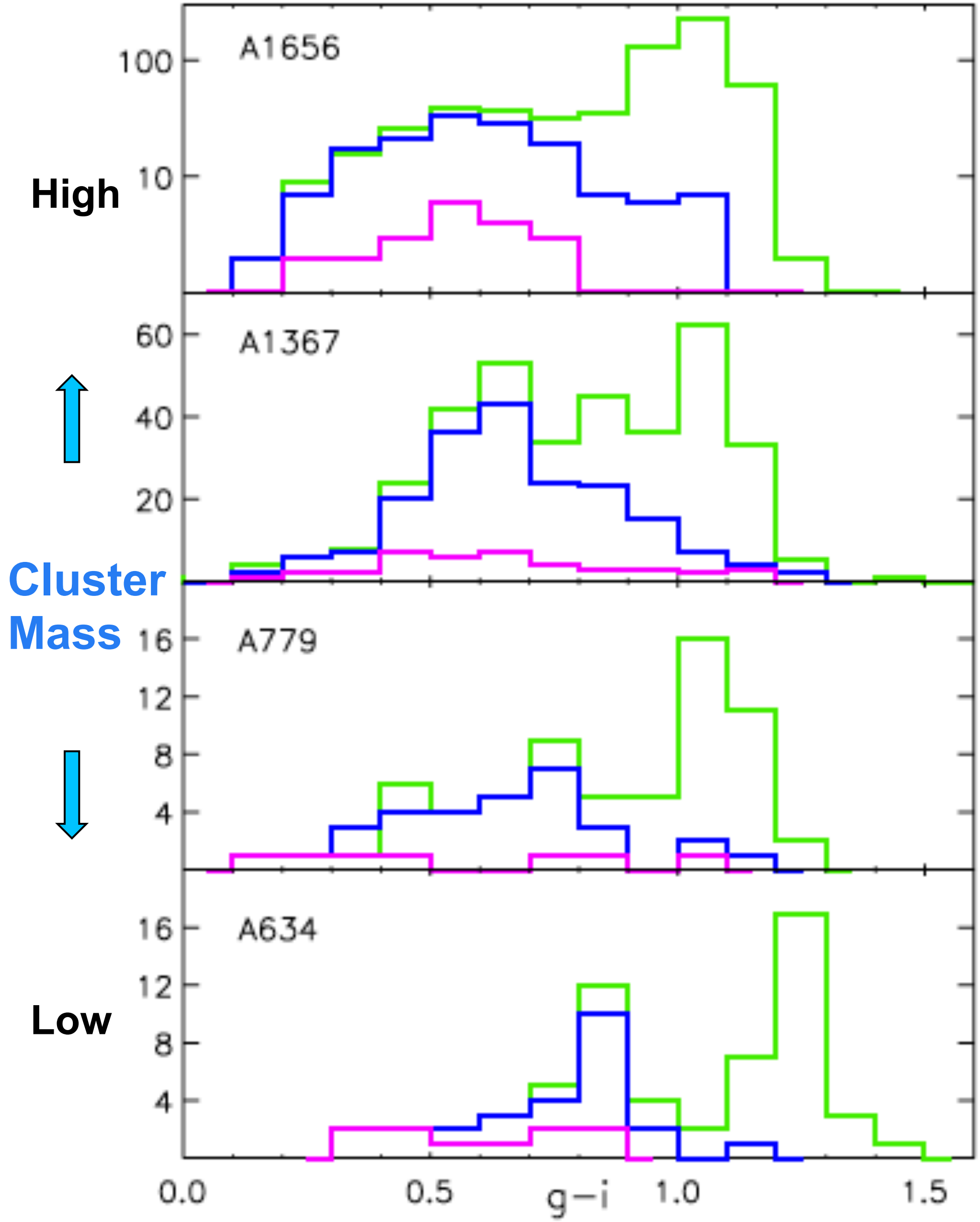
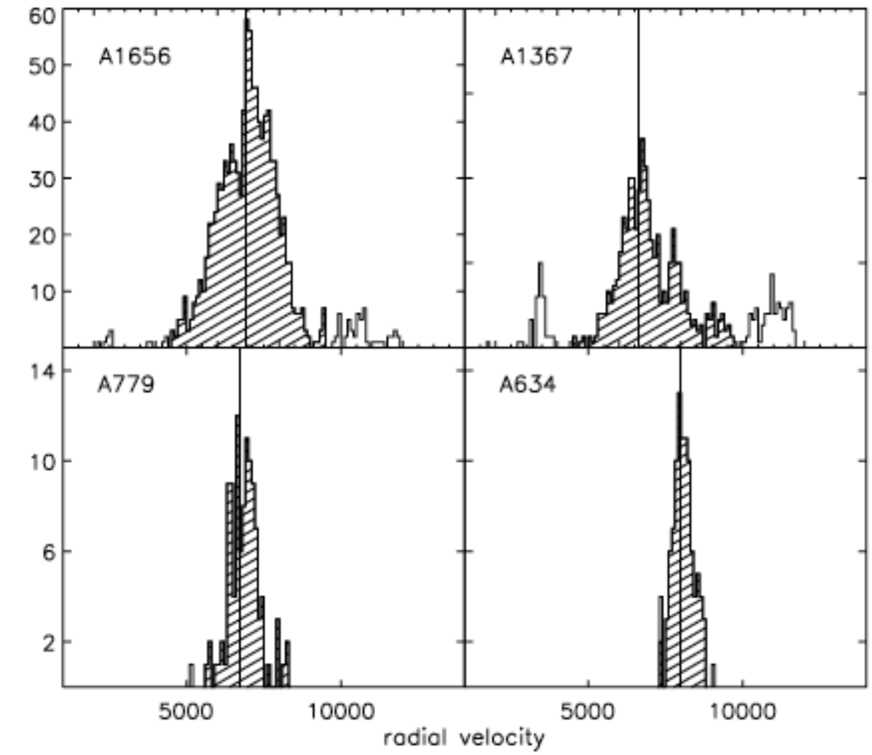


Figure 2. Color $g - i$ histogram of dwarf galaxies (green line), SF dwarf galaxies (blue line), and SF dwarf galaxies to $R \leqslant R_{200}$ (magenta line) for our clusters' sample. Logarithmic scale is used for A1656. No correction has been performed for the galactic extinction, and the shift observed for A634 toward redder colors is consistent with the slightly higher galactic extinction suffered by this cluster.

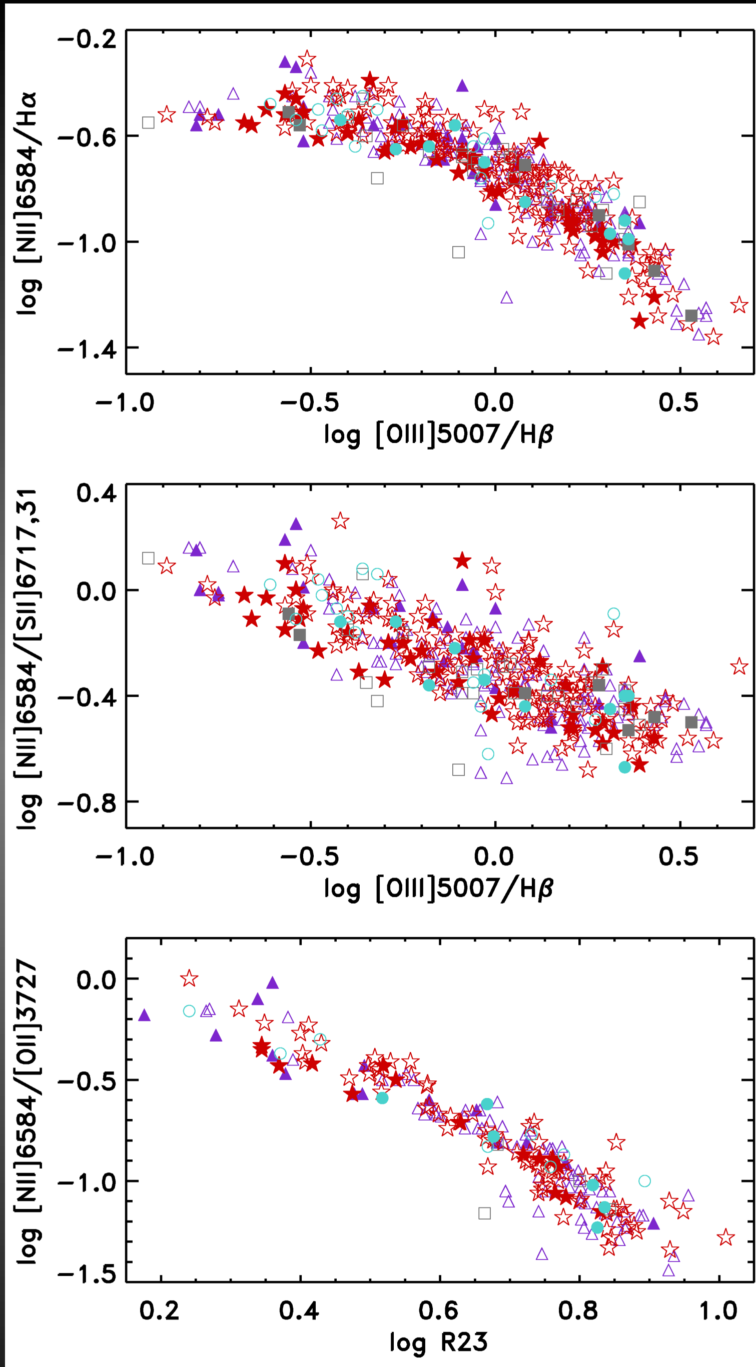


y histogram for all galaxies with SDSS-DR8 spectroscopic data within $3R_{200}$ from the center of each cluster. The velocit
nts the mean cluster radial velocity as given in NED (Coma: $cz = 6930$ km s^{-1}; A1367: $cz = 6600$ km s^{-1}; A779: 6
ed region indicates the adopted velocity range at $\pm 3\sigma_v$ around the mean cluster velocity.

Galaxy Sample:

4 nearby clusters

SF Dwarfs



ALL galaxies cover the whole range in excitation conditions, no matter where they are located, i.e. within or outside the Virial radius of each cluster

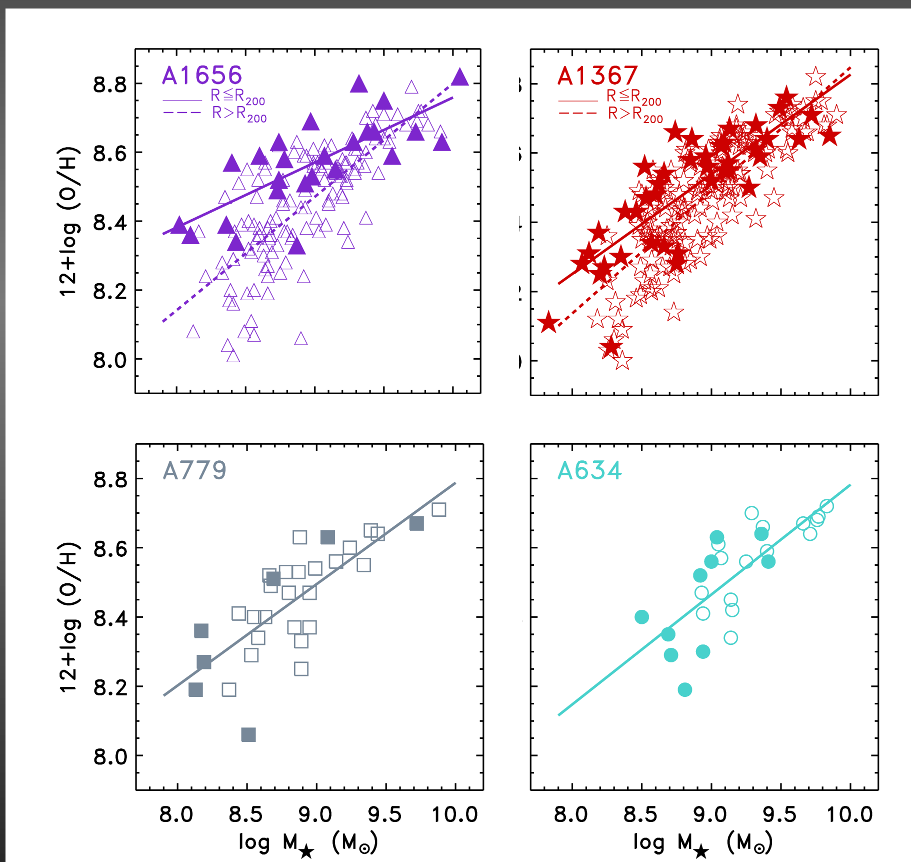
Cluster core: filled symbols

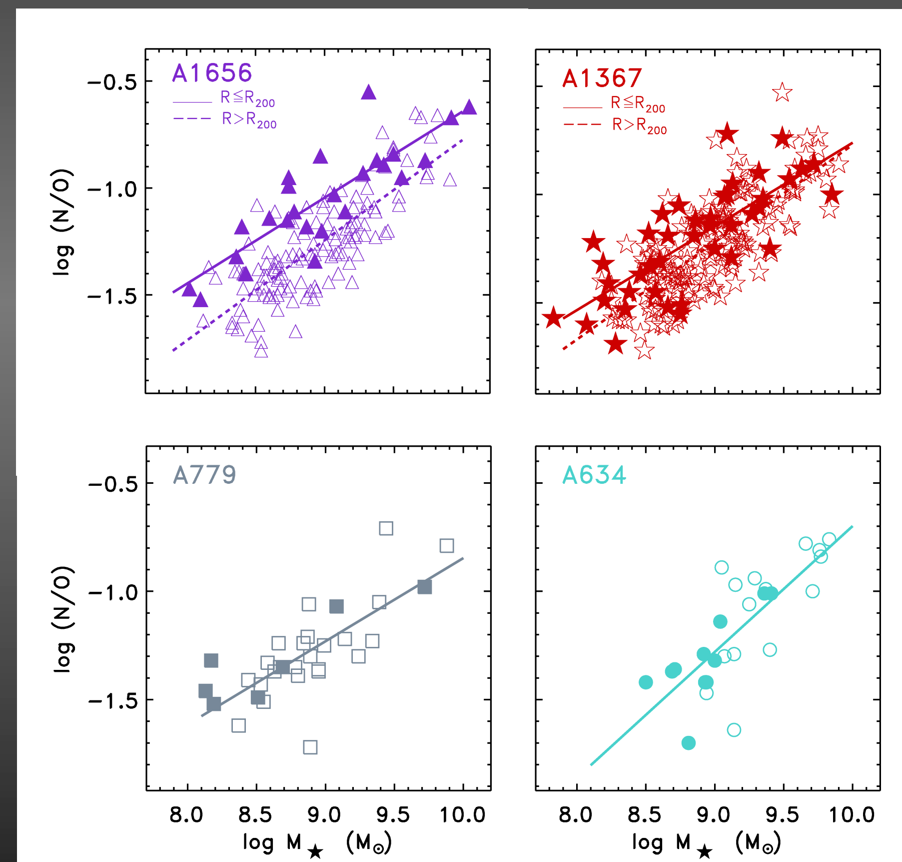
SF Dwarf galaxies in 4 nearby clusters:

Coma, A1367, A779 & A634

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

Spectroscopic data: SDSS **corrected for underlying stellar continuum**





Cluster mass … matters

Petropoulou et al 2012 ApJ; HSC 2017 (in prep)

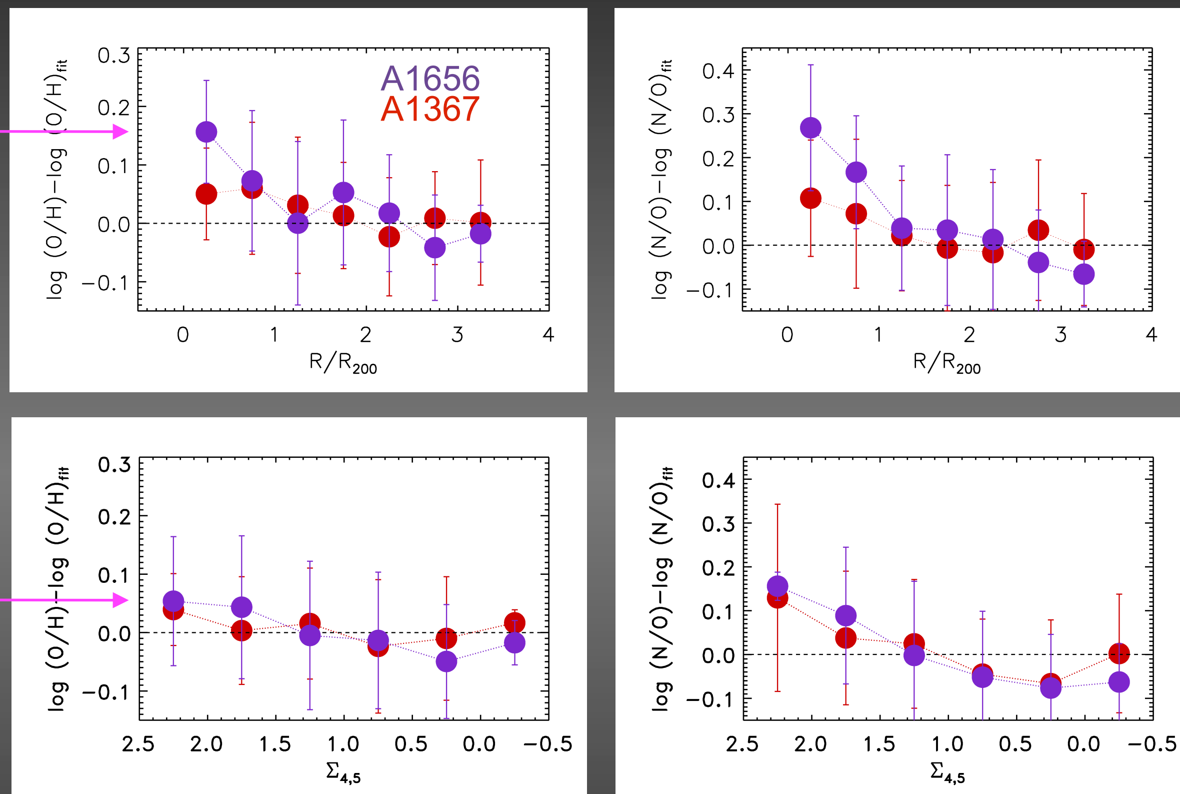
Cluster membership or local density?

Distance from the cluster center

~0.15 dex

~0.3 dex

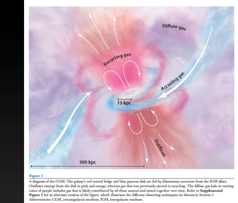
~0.05 dex

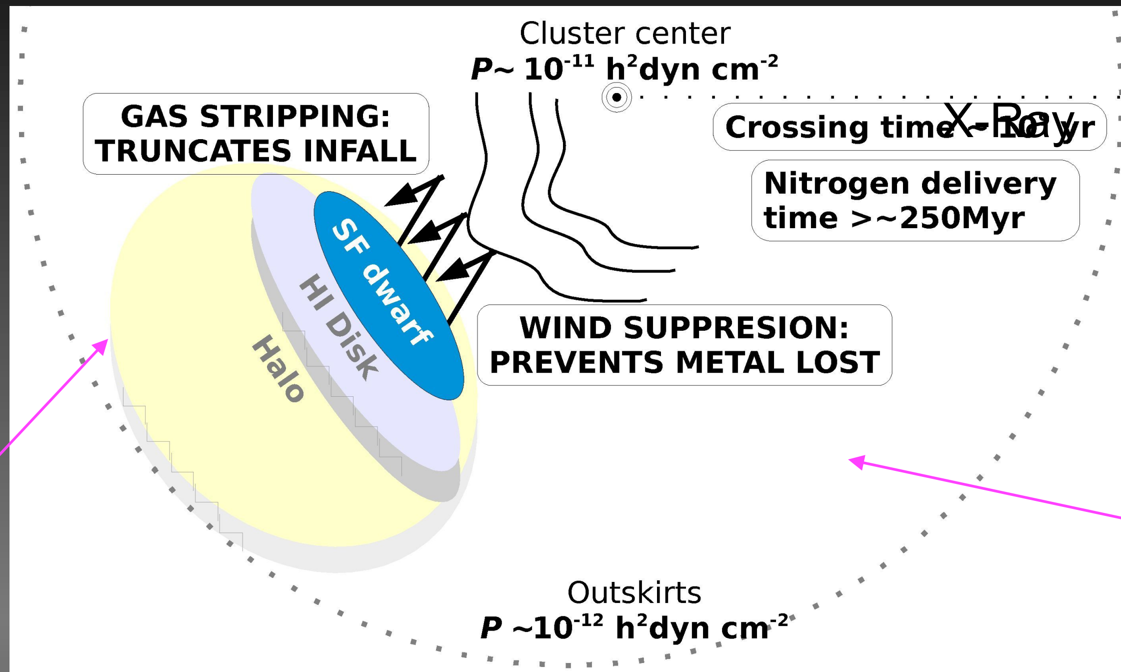


Local galaxy density

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

A proposed scenario





Enhanced metallicity could be produced by a combination of effects: the gal. wind reaccretion, due to pressure confinement by the ICM, plus the truncation of gas reservoir infall as a result of RPS.
SF (stripped) dwarfs and satellite galaxies (Petropoulou+ 2011, 12; Pasquali+ 2010, 12) <=> more metal rich

Current hydrodynamic simulations (Bahe et al 2017; EAGLE) propose: i) stripping of metal poor (galaxy) gas & ii) suppression of metal poor inflow + recycling.
Metallicity-environment density correlation expected following Genel (2016; ILLUSTRIS):
(1/3) satellites dwarfs have lower SFR and older ages in dense environments, and
(2/3) a higher concentration of the star-forming disks of satellite galaxies => bias SFR-weighted metallicities toward their inner, more metal-rich parts (see Gupta et al. 2017)
This **work is consistent with model predictions by Dave et al. (2011), Finlantor & Dave (2008)**

take home points: metallicity & environment @ z≈0

i.- M-Z versus general galaxy density <=> Moderate-small absolute effect (0.05 – 0.15 dex) on the avg M-Z relation (SDSS; Ellison 09; Cooper+; Pilyugin+ 2017; Wu et al 2017 z=0..8; other data at high/cluster density: Vilchez+ 2003; Hughes+ 2013)

ii**.- Some environmental effects detected:**

a) M-Z outliers (≥ 0.2-0.3 dex) e.g. Tidal Dwarfs; *Preprocessing* SF infalling galaxies / satellites / RPS SFGs (Massive clusters) metal enriched w.r.t. centrals or avg M-Z @M_* (Pasquali+ 2010; 2012; Petropoulou 2011; 2012; Vilchez+ 2003; Gupta+ 2017). A feature expected in C.H. simulations (EAGLE Bahe+ 2017; IllUSTRIS Genel 2016).

b) the turnover mass in the M-Z "universal" parameterization anti-correlates with local density (Wu+ 2017; see de Rossi+ 2017)

CAVEATS: SDSS spectra needed corrections for limited aperture coverage; see CALIFA empirical aperture Abundance and Halpha SFR empirical corrections - curves of growth (Duarte-Puertas+ 2017 A&A; Iglesias-Paramo+ 2015 ApJ) . Highest galaxy densities (clusters cores) not well sampled in SDSS studies.


Thank you!