Environment matters: low metallicities and enhanced sSFRs in star-forming galaxies in an X-ray detected cluster at z=2

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(ApJ, 801, 132)

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IGM@50, Abbazia di Spineto, June 10th 2015

Valentino et al. 2015

Nature vs nurture: a (still) interesting story to tell

- How important is the environment in shaping galaxy properties (and quenching)?

Density →

Known density trends at z=0: red, massive, early-type, and passive galaxies generally reside in the core of (virialized, X-ray emitting) clusters

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Nature vs nurture: a (still) interesting story to tell

- Do we observe a relation between surrounding density and galaxy metal content at $z=0$?

"We find that at a given stellar mass, **there is a strong dependence of metallicity on over-density for star-forming satellites** (i.e. all galaxies members of groups/clusters which are not centrals). […] Instead, **for star-forming centrals no correlation is found**." (Peng & Maiolino, 2014)

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Instead
Maiolin

"We find that there is **a strong relationship** between metallicity and environment such that **more metal-rich galaxies favour regions of higher overdensity**." (Cooper et al. 2008)

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"We find that there is a strong relationship between metallicity

"Taken together, these results show that **galaxies in clusters are, on average, slightly more metal rich than the field, but that this effect is driven by local overdensity** and not simply cluster membership." (Ellison et al. 2009)

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drive
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"Although **some cluster galaxies are gas-deficient objects, statistically the stellar-mass metallicity relation is nearly invariant to the environment**, in agreement with recent studies." (Hughes et al. 2013)

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"Considering environments ranging from voids […] to the periphery of galaxy clusters […] **we find no dependence of the relationship between galaxy stellar mass and gas-phase oxygen abundance,** along with its associated scatter, on local galaxy density." (Mouhcine et al. 2007)

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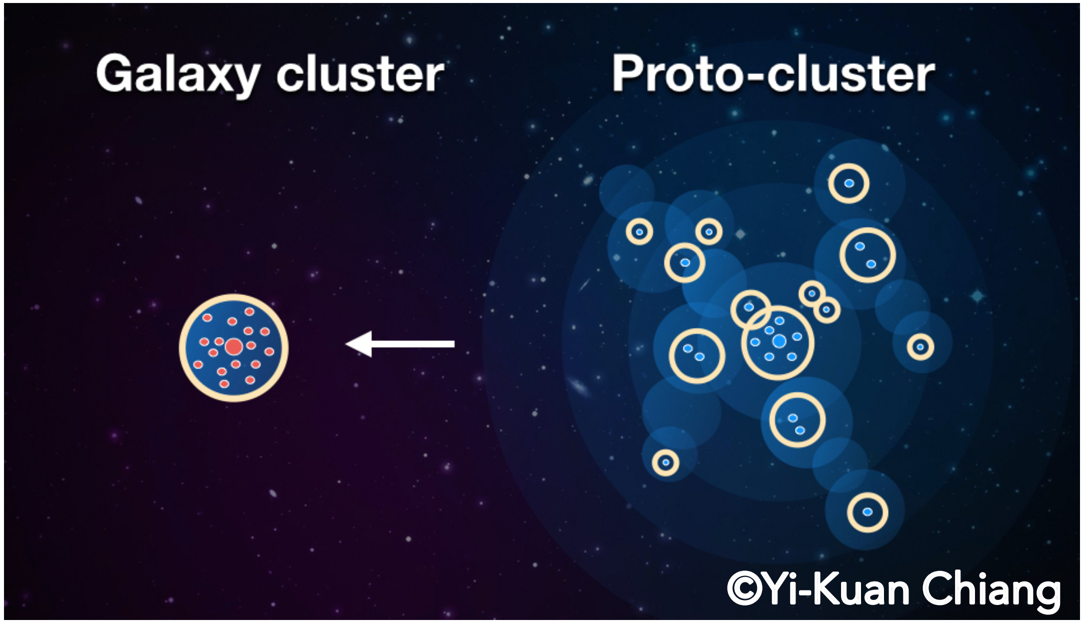
Nature vs nurture: a (still) interesting story to tell

- What about the high-redshift Universe (z>1.5-2)?

- Estimating metallicities becomes challenging
- We approach an epoch where structures were **instrinsically different**



Contradictory results at high redshift (Kulas et al. 2013, Shimakawa et al. 2015 **vs** Kacprzak et al. 2015).

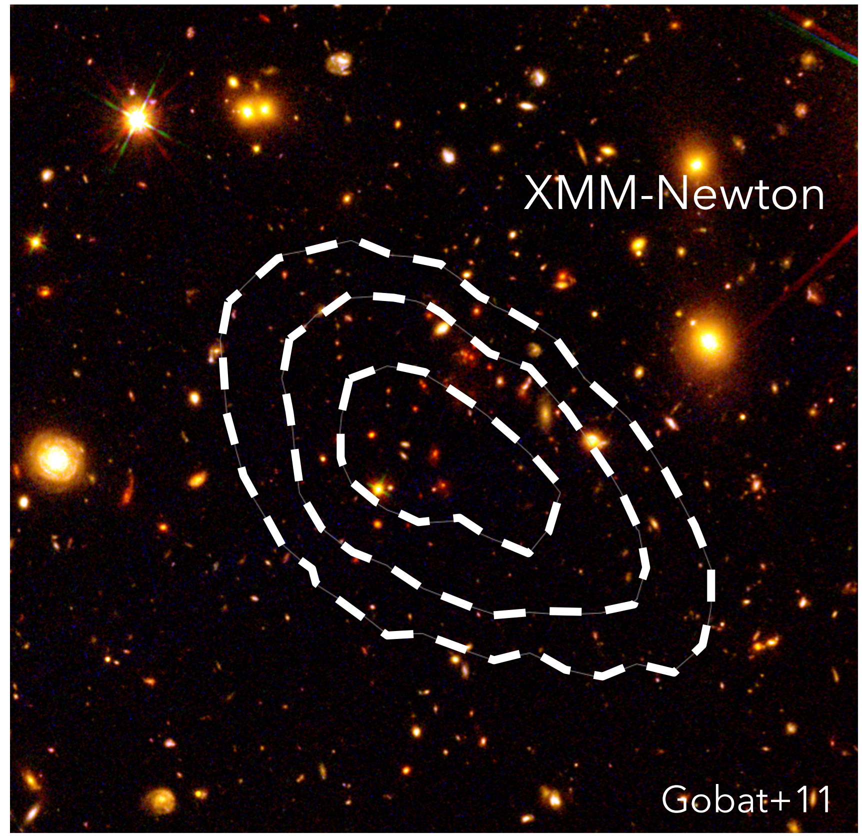
Valentino et al. 2015

The remarkable case of CL J1449+0856 at z=1.99

A **relatively evolved cluster** (red, massive, quiescent galaxies in the core, extended X-ray emission), which hosts **a significant fraction of active galaxies** (Gobat et al. 2011, 2013, Strazzullo et al. 2013).

Extensively followed-up:

- 13-band photometry (**SED modelling**)
- HST/WFC3 slitless spectroscopy ([O II], Hβ, [O III] at z~2)
- **Subaru/MOIRCS HK spectroscopy of star-forming galaxies**



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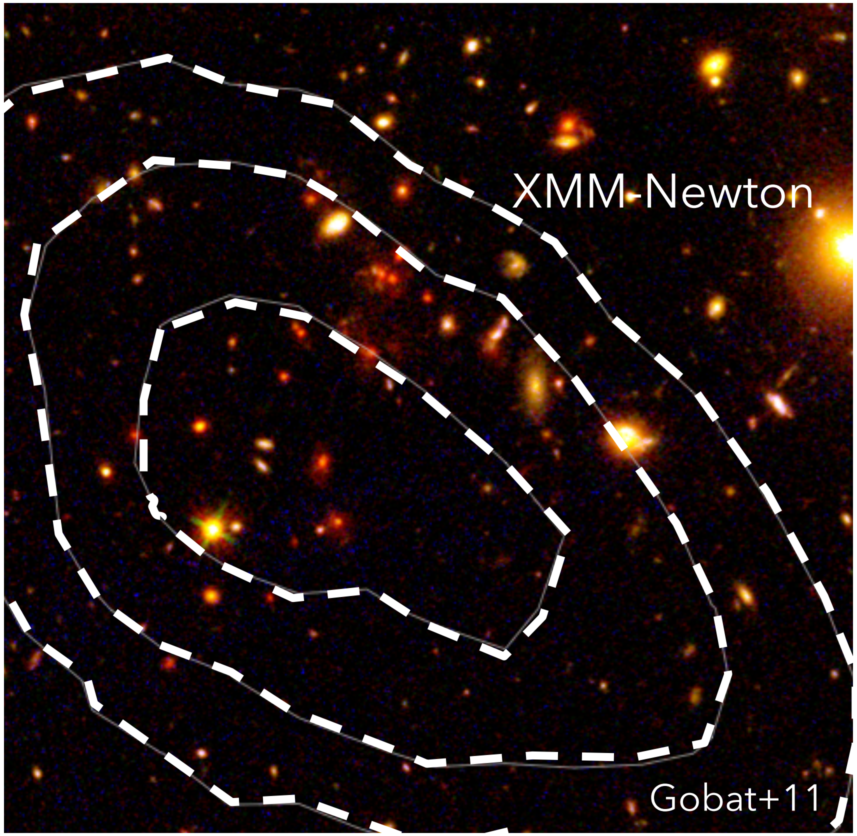

Valentino et al. 2015

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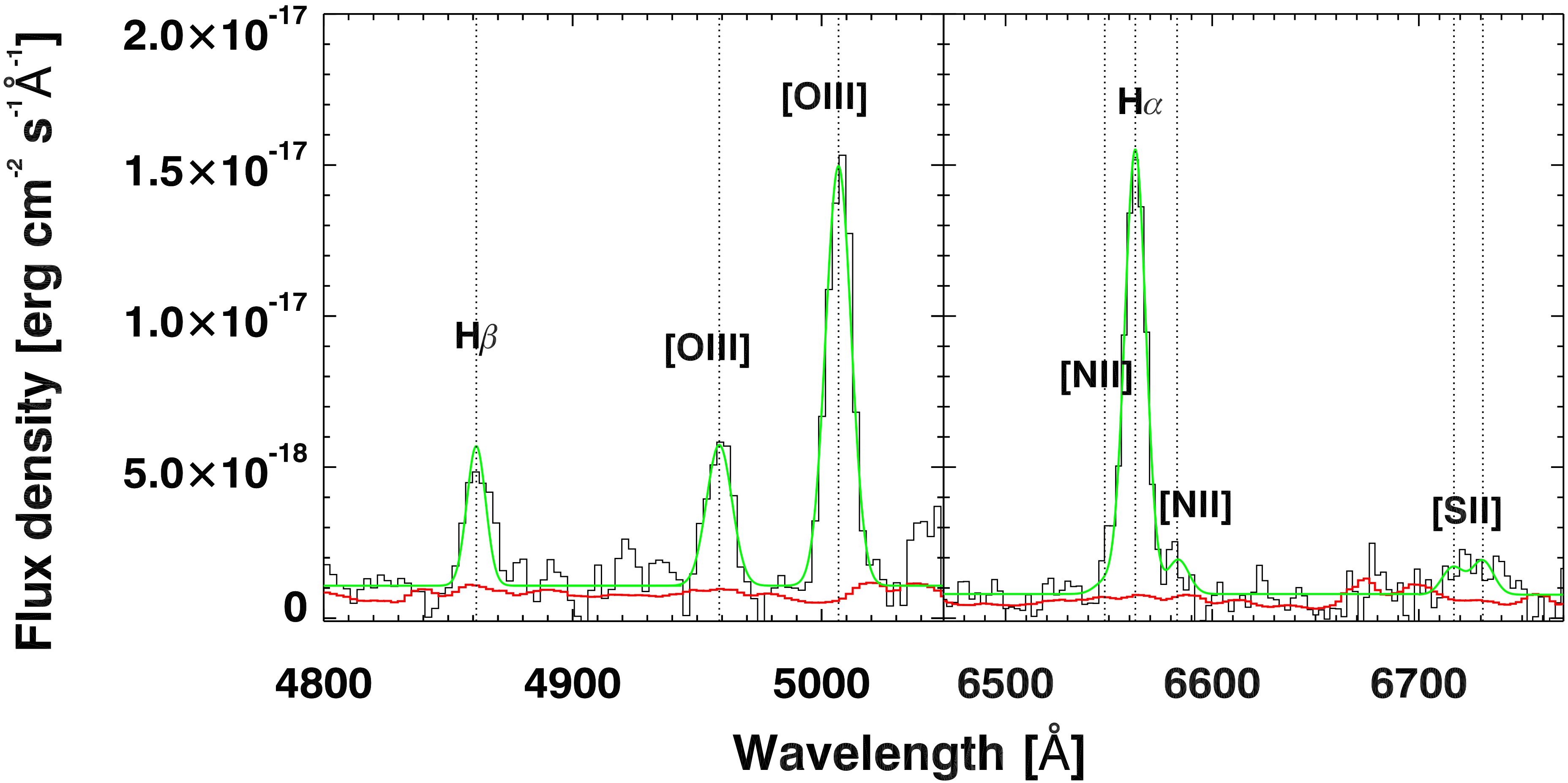
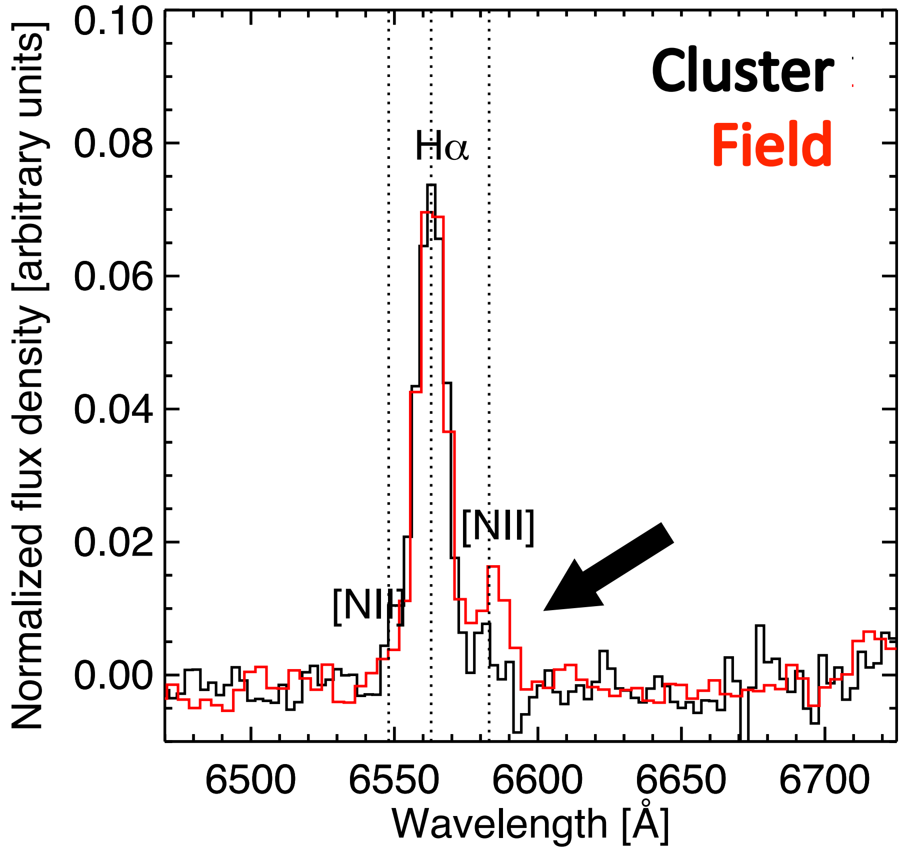


Valentino et al. 2015

Observing an environmental signature

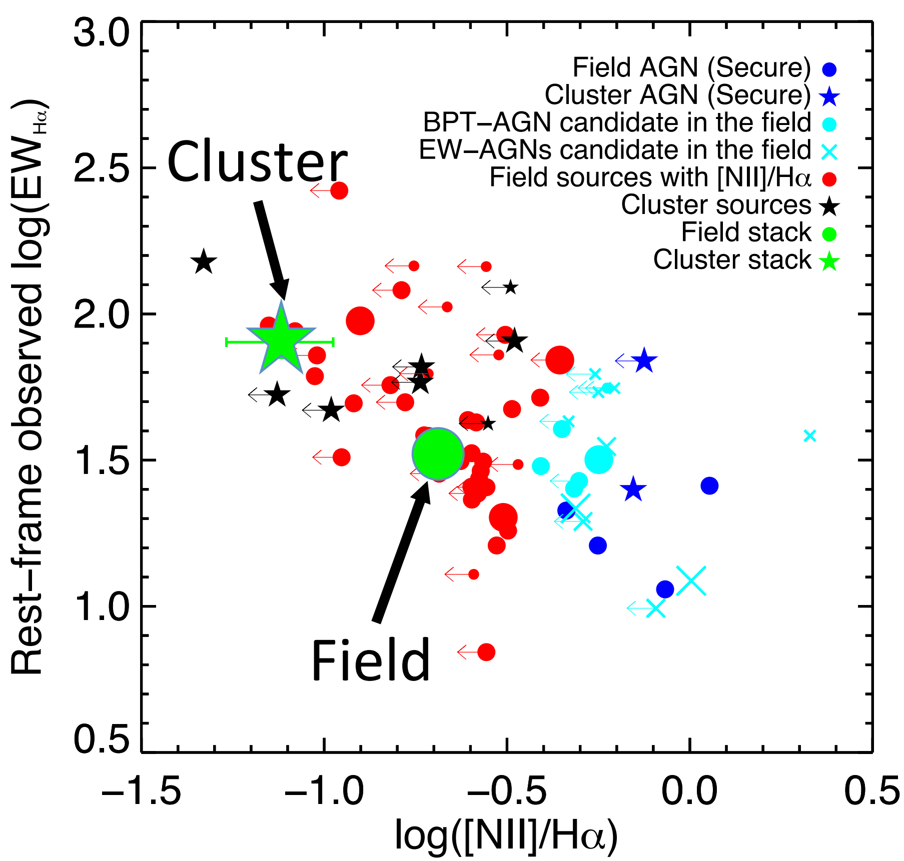
We detect a **≈4σ significant lower [N II]/Hα ratio in the cluster stacked sample** than in the mass-matched field sample (while [O III]/Hβ is compatible between the two).



Valentino et al. 2015

Observing an environmental signature

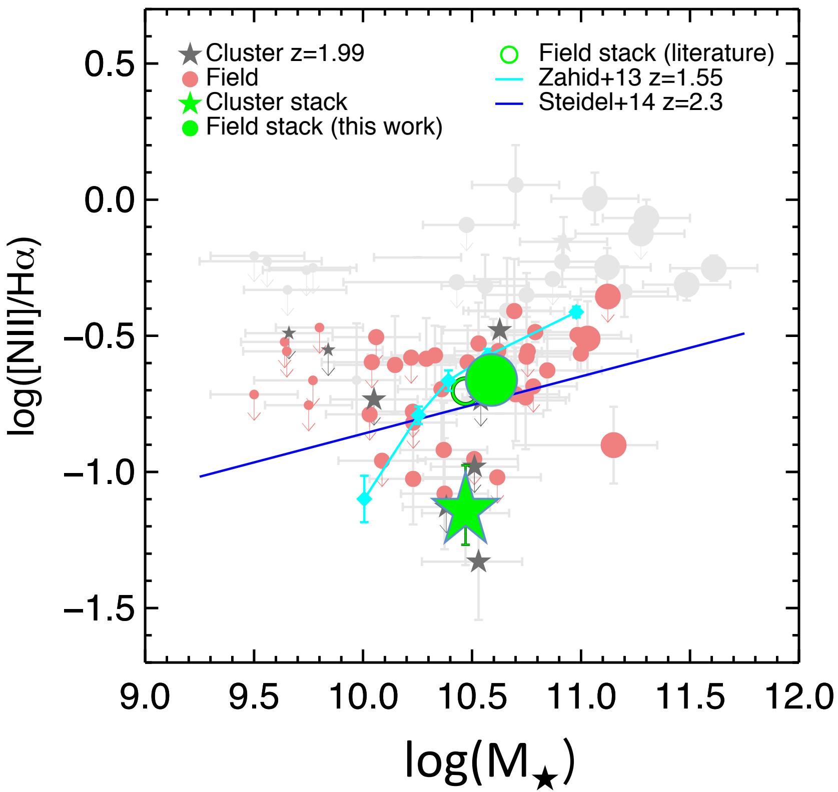
We detect a **≈4.7σ significant higher observed EW(Hα) in the cluster stacked sample** than in the mass-matched field sample.



Gaining physical insight

We can convert [N II]/Hα in **gas-phase oxygen abundance 12+log(O/H)** by means of a proper calibration (e.g., Pettini & Pagel 2004, Steidel et al. 2014).

$$12+\log(O/H) = a + b\times\log([N\ II]/H\alpha)$$

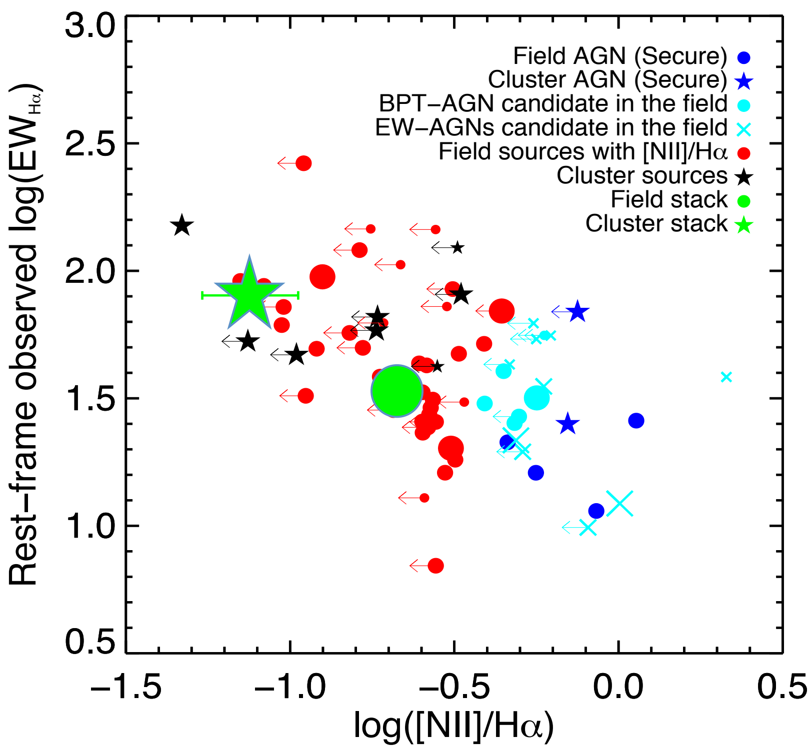


Thus, star-forming galaxies in CL J1449+0856 are on average more metal poor than mass-matched field counterparts (by ≈0.09-0.25 dex, according to the calibration or indicator used)

Gaining physical insight

We can interpret the higher EW(Hα) as **a proxy for the sSFR.**

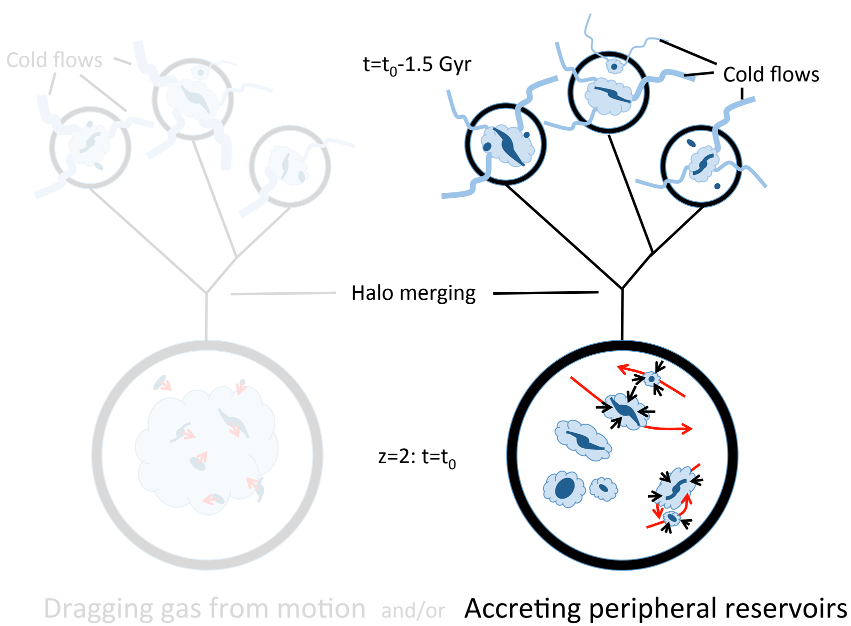
$$EW(H\alpha) \approx sSFR \times 10^{0.4E(B-V)*k(H\alpha)*(1/f-1)}$$

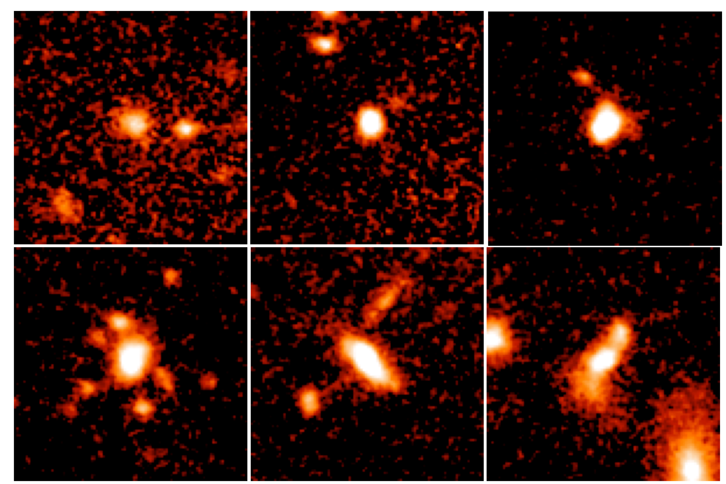


Thus, star-forming galaxies in CL J1449+0856 have higher sSFRs (the significance of this result depends on the adopted reddening correction)

A speculative picture of the situation

We ascribe lower metallicities in cluster star-forming galaxies to **the accretion of pristine gas** from the surroundings, facilitated by the **“gravitational focusing effect”** (Martig & Bournaud 2007):





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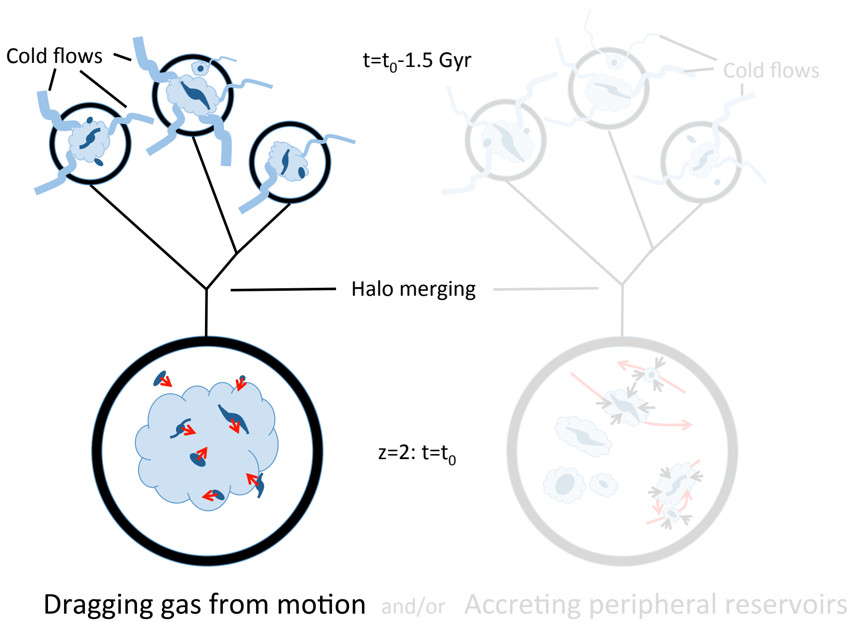
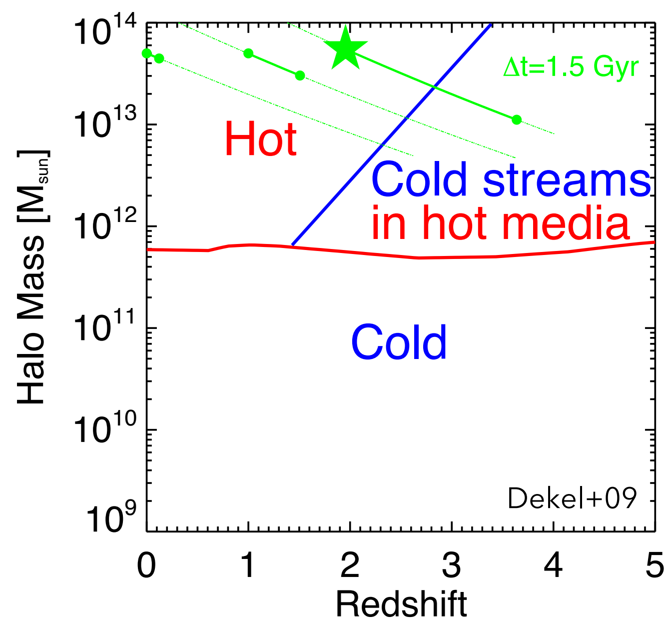




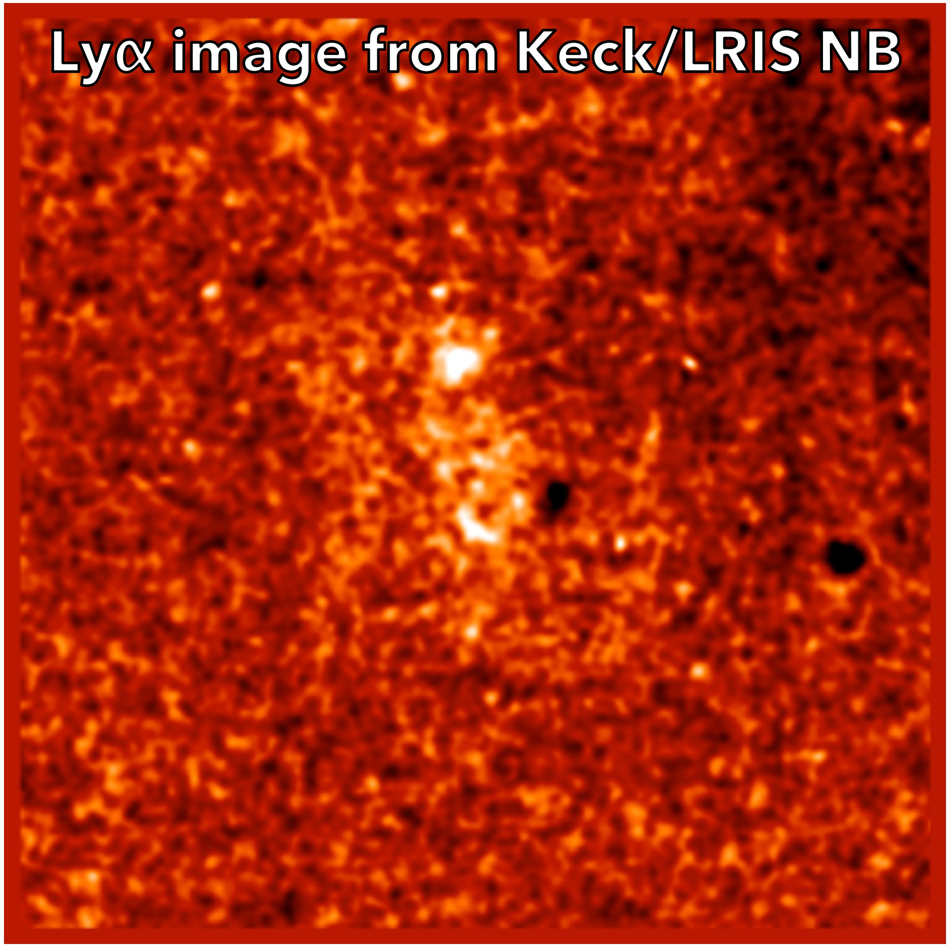
Valentino et al. in prep.

A giant Lyα nebula in the core

"Warm" diffuse gas (>100 kpc, T ≈ 10^{4-5} °K), possibly ionized by a hard X-ray AGN.

"Hot" extended atmosphere detected both by XMM-Newton and Chandra (T ≈ 10^7 °K, ~1.5 keV)

- Complex two-phase intracluster medium already at high-z. How do the two phases interact?
- The high-z analog of Extended Emission Line Regions (Fu & Stockton 2006, 2007)?
- Physics characterization still ongoing, but:
  - M_{ion}~10^9-10^{11} $M_\odot$ (depending on the filling factor)
  - n_{el} ~ 5-10^{-2} cm^{-3}



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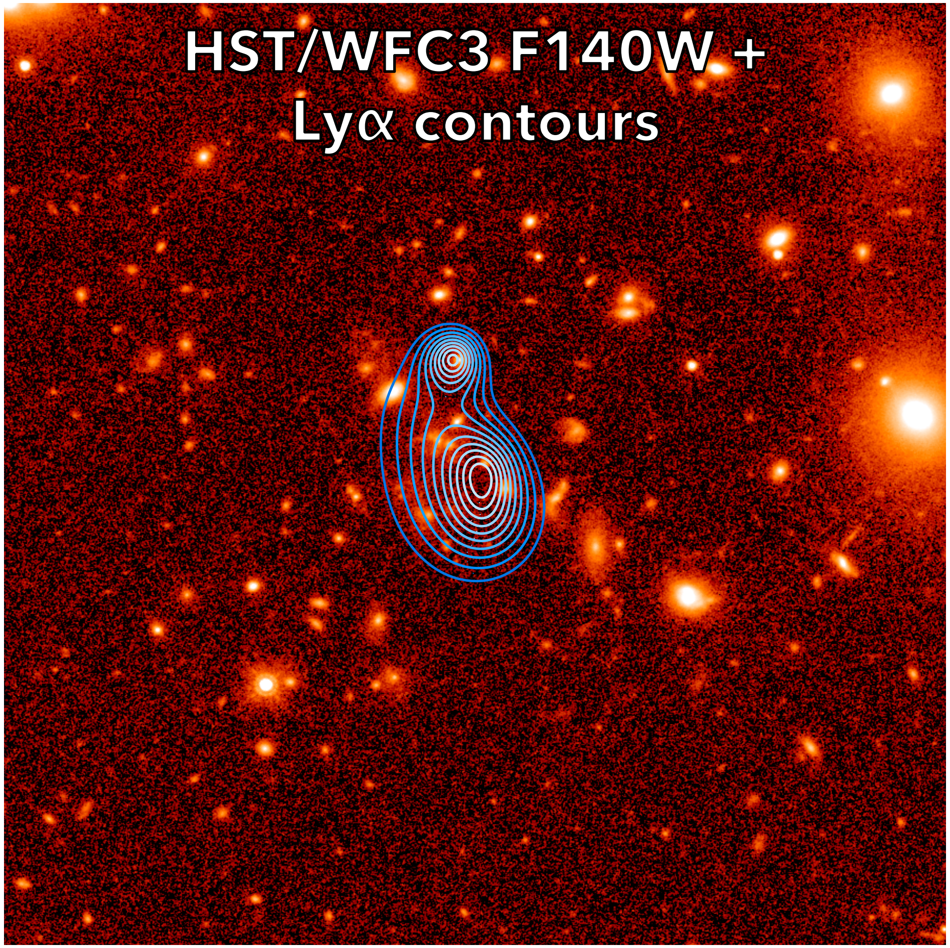

What does the future hold for us?

- Look for **signatures of enhanced gas fractions** in cluster galaxies and census of total star-formation rate in the core

  > ALMA continuum at 850μm (completed) and CO[3-2] (ongoing?) observations (PI: Strazzullo)

- Observed 7.5h KMOS proposal P95A:

  > Full census of SFR with a unique tracer (Hα)

  > Emission line maps to trace **metallicity gradients**

A powerful tool to test gas accretion and metal enrichment scenarios

Summary

- Subaru/MOIRCS follow-up of cluster SFGs in CL J1449+0856 at *z*=1.99
- **Lower gas-phase metallicity, higher sSFR in cluster SFGs**
- We ascribe these effects to the **accretion of pristine gas** on cluster scales and/or due to mergers, both facilitated by the gravitational focusing effect

Further details in Valentino et al. 2015 (ApJ, 801, 132)

- Keck/LRIS NB imaging revealed a giant Lyα nebula in the cluster core: a large warm gas reservoir(?)