Galaxy evolution in clusters: what is best to look at and where?

Stefano Andreon

INAF-Oss. Di Brera
stefano.andreon@brera.inaf.it

- 'galaxy evolution in clusters' : the key question is what is best to look at, how, and where on a 10 yr timescale? I only have a partial answer to this question, I need your input to complete it.

- Usual boundary conditions. What we want to do should largely rely on our forces (fixed money).
- General rule: everything is useful/interesting, something is however more useful/interesting that something else.
- I assume that we want priorities (which makes unhappy many peoples).
- "What I like most" is ill defined, there are about 100 "I".

INAF- documento di vision 2015-2024

nelle stelle in galassie. Qual é la storia di arricchimento chimico dell'universo? Come dipende dal tipo di galassia e dalla sua massa? Le galassie sono sistemi estremamente complessi e la gravitá é solo uno dei molti processi fisici che determinano la diversitá delle proprietá galattiche. Comprendere l'origine della varietá di morfologie galattiche, masse e storie stellari é una delle grandi sfide dei prossimi anni. Qual é l'origine della sequenza di Hubble? Quali meccanismi conducono alla formazione di galassie ellittiche, e di sferoidi in generale, e come si differenziano da quelli che danno origine a galassie con una componente di disco dominante, piú diffuse a tempi cosmici precedenti? Quanto importante é il ruolo dell'ambiente sui meccanismi di formazione delle galassie? Molte di queste domande richiedono grandi surveys di cielo, come abbiamo

similar text in the HST white book (<1980?) and HST & Beyond (Dressler et al. 1996).

Galaxy evolution does not have a fully-predictive physical model

We don't have a physical (ab initio) comprehensive model of galaxy evolution in which the only missing piece of information is the value of the model parameters. Therefore we cannot determine the parameters (or rule out a galaxy evolution model).

We replaced the physical galaxy evolution model with an empirical model based on observations (sometime guided by physics).

Adding a digit to the value of an empirical parameter is of limited interest, it does not rules out anything, and does not improve either our understanding of what's going on in galaxies and "continue to frustrate [us] … Observations of the critical epoch [hi-z] … is essential" Dressler et al. (1996, HST & Beyond report).

z<1 is somewhat known

At z<1 we are now consolidating (with a few exceptions) our already good (compared to hi-z) knowledge of galaxy evolution in clusters. A large number of surveys or facilities will provide on a very short time (and it is already providing, e.g. DES) an avalanche of data (photometry, spectro-photometry, spectroscopy) useful at z<1. The z<1 range is of outmost interest on a short timescale, with a few exceptions …

Exceptions:

when a completely new types of information become available such as:

- spatially resolved spectroscopy of passive, say, z=0.8 galaxies.

Also very useful as support of cluster studies at other wavelenghts, say, X-ray (Molendi presentation), SZ, Radio (Cassano presentation), etc., to calibrate the richness-mass relation (cf Biviano presentation), for example using weak-lensing masses (cf Meneghetti presentation), etc.: the emphasis is somewhat away from galaxy evolution in cluster.

To sum up, at z<1 the discovery space of galaxy evolution in clusters seems limited (the parameter space has been already explored) and is getting smaller on a very short timescale with some exceptions. Very useful as "service".

The partly unexplored evolution in hi-z clusters

Clusters at hi-z (say, $1.2<z<1.8$) are within the accessible range of current facilities (we are already study them, isn't? e.g. with VLT, HST, ALMA, JVLA, although at the frontiers of some of them), and soon-available facilities in the optical-NIR-MIR and radio (e.g. JWST, Euclid, SKA).

Progress in this field is slow because of the difficulty of collecting the relevant data (imagine to obtain velocity dispersion of quiescent galaxies at $z=1.5$-1.8).

The almost unknown evolution in z>2 clusters

We know almost nothing about galaxy evolution in very-hi z (z>>2) clusters, because no massive (or rich) cluster is known, only a few candidate proto-clusters are known.

Every galaxy evolutionary study performed on clusters at z>2 represent a significant increase in our knowledge.

Opinion: z>2 is the epoch of most of the size growth and mass assembly (also most of the star formation and probably enrichment of the ICM), when relations such as morphology-density, color (or metallicity)-mass, or velocity-dispersion vs size, etc., set (largely) in place.

Where, then?

Conclusion: on a 10 yr scale most promising is

a) searching very-hi z (z>>2) clusters or proto-clusters, and possibly study their galaxies.
b) studying evolution at high-z (z>1.5).

On a short time scale, don't forget z<1, in particular if you have a new parameter space to explore.

Cluster z>2 search: what available/need?

1) Euclid (in 2020), 15 k deg^2
2) NIR surveys, right now. Smaller solid angle, similar depth/deeper (e.g. VIDEO-VISTA). WFIRST (deeper, 2 k deg^2) on a longer timescale (but likely useful, but not needed for discovery)
3) photo-z or red-sequence overdensities + spec-z, follow-up of unusual populations (e.g. cold sub-millimeter Planck sources). What else?
5) for confirmation: z-machines: WFC3@HST, NIRSpec@JWST, KMOS@VLT, EMIR@CGT, CO-lines (NOEMA/ALMA?)

-Too far for SZ, X-ray (Athena will probably arrive too late for discovery, eRosita has too bad PSF). Any other mean? What about bent radio sources?

Detailed z>1.5 studies: what available/need?

A) (preferably) spatially resolved multi-band imaging
A1) JWST (2018), EELT (2024), HST, WFIRST (2025) (more depth and resolution than Euclid, 2020), but we are not in WFIRST.
A2) SF indicators, possibly minimally affected by dust. ALMA ? Can we go down to a very few Msol/yr over a decent (say 2'x2') fov, 1" resolution, at z~2.5 ? SKA (2018-2023)?
A3) AGN indicators. Athena (2028, resolution and effective area sufficient for low-activity galaxies at z>1.5?). What else? MIRI@JWST? spectral diagnostic plots?

B) spatially resolved spectroscopy (multi-object IFU-like) for dynamics, stellar population, and metallicity: quiescent galaxies are the most challenging to observe.
Very challanging on VLT (KMOS). More feasible with NIRSpec@JWST (2018)? KMOS-like spectroscopy with EELT (2024)?
C) what else really needed? what useful?

Summary:

WHERE:

a) a) searching very-hi z (z>>2) clusters, confirmed proto-clusters, and possibly study their galaxies

b) b) studying galaxy evolution in high-z (z>1.5) clusters.

HOW:

work in progress (see previous slides)

Thanks to Paolo Saracco & Mari Polletta for input.