Galaxy and cluster formation at $z \sim 2$

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DE LA RECHERCHE À L'INDUSTRIE





The interest of high-z clusters

Cosmology:

- growth of structure across cosmic time
- requires good statistics
- but constraints from unique objects

Environmental effects I:

- quenching of SF
- population segregation
- best at low to intermediate z

Environmental effects II:

- formation of the core population $(z_f > 2-3)$
- early ICM heating (non gravitational processes)
- co-evolution of cluster population & atmosphere







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Rosati+ 2002

Emergence of the red population



Co-eval ETG population up to $z\sim 2$





NASA/ESA

Spitler+ 2012

"proto-clusters" proto-clusters clusters Miley, G. & Overzier, R. Stanford+ 2012 -0 Ζ overdense Santos+ 2012 Ziemann+ 2012 Spitler+ 2012 NASA/ESA

ETG population BCG "dead" cluster characteristics core X-ray ICM

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Then: CI JI 449+0856, a "mature" X-ray detected cluster at z ~ 2 (Gobat et al. 2011)



- 20 σ overdensity of red galaxies (Y-K_s>2)
- with ETG morphologies (HST/NIC3)
- extended X-ray emission (7×10⁴³ erg/s)
- z-spec peak at z=2.07 (emission-line)

Initial dataset:

- BRIzYJHK_s Subaru imaging
- HST/NICMOS FI60W
- IRAC 3.6μ-8μ
- MIPS 24µ
- VLT/FORS2+VIMOS spectroscopy
- XMM + Chandra (80 ks each)

CIJI449+0856: the once and future mass



Extended X-ray emission at 3.5σ significance $L_X = (7\pm2) \times 10^{43} \text{ erg/s}$ $\Rightarrow M_{200} \sim 6 \times 10^{13} M_{\odot}, R_{200} \sim 0.4 \text{ Mpc}$

Would reach a mass at z=0 of $M_{tot,0} \sim 6 \times 10^{14} M_{\odot}$



Now: follow-up observations



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The Importance of Spectroscopic Follow-ups



Deepest WFC3 grism observations yet:

6.5 arcmin²
3 orientations
16 orbits of G141
2 orbits of F140W
(26.5 mag at 5σ, 1" aperture)



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G141





WFC3 grism redshifts



WFC3 grism redshifts



Grism spectra of red galaxies The Buried, the Bad and the Ugly



too faint

contaminated (2nd order)

blended

extracting red spectra an overdense region is still very challenging with WFC3 (continuum S/N, contamination from close neighbors, less compact, etc.)

The early early-type: a quiescent galaxy at z=3

Gobat et al., submitted to ApJL



Serendipitously discovered in the HST/WFC3 field

 $z = 2.993 \pm 0.015$

age ~ 0.7 Gyr logM $_{\star}$ = 11.08 ± 0.01 n = 1.8 ± 0.3

Grism spectra of red galaxies



0.04

0.02

0.00

5

10

15

20

Y (pix)

25

30

35

too faint

contaminated (2nd order)

blended

simultaneous fit of cross-dispersion profiles for each wavelength bin

- efficient deblending
- does not assume a contaminating spectrum

(thanks to C. Scarlata)







Redshift of the ETGs: $z = 1.99 \pm 0.01$ Biweight mean of the peak (including ETGs) : z = 1.995



Redshift of the ETGs: $z = 1.99 \pm 0.01$ Biweight mean of the peak (including ETGs) : z = 1.995CI J1449+0856: a X-ray detected cluster at $z \approx 2$









Large scale structure at z~2



Springel+ 2005

The z~2 cluster and z=2.07 z=2.07 "sheet" are separated by more than 100 Mpc (comoving)

 \Rightarrow not gravitationally bound

 $(t_{in} >> t_H)$

 $P_{align} > 0.3 \%$ (Poissonian case, assuming $5 \times 10^{13} + 10^{13}$ halos)

(likely a few % due to clustering)

AGN in CI J 1449+0856 (tentative)



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Star formation in CI J 1449+0856



 $SFR_{H\beta} = 10-30 M_{\odot}yr^{-1}$

(no line emitters in the core)

several 24 μ sources in the core: SFR_{24 μ} > 100 M_{\odot}yr⁻¹

but possibility of AGN contribution

 \Rightarrow PACS 100/160 μ observations

Star formation in CI J 1449+0856





Star formation in CI J 1449+0856



one PACS detection in the cluster:

the forming BCG at ~200 $M_{\odot}yr^{-1}$

Galaxy merging in the core the "proto-BCG"

4500 rame wavelength



tidal features

1000

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Galaxy merging in the core diffuse light



WFC3 1.4µ imaging reveals diffuse emission around core galaxies broad filter ⇒ likely continuum rather than line emission if stellar light, consistent with high merging activity

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Galaxy merging in the core

Salinas et al. 2011 diffuse CI JI 449+0856 scale at z = 2.07 (Mpc) -0.10 -0.05 0.05 0.10 G 5 arcsec 8.942 0.05 10 Gyr (Mpc) (6ep) 8.94(DEC (2.07 0.00 ? ъ -0.05 8.938 -0.10 222.308 222.312 222.310 222.306 RA (deg) WFC3 1.4µ imaging reveals diffuse (broad filter \Rightarrow likely continuum

if stellar light, consistent witl

ies

the CLASH team

Conclusions

CI JI 449+0856 is a "maturing" galaxy cluster at z=1.99:

- it has detectable X-ray emission and a central early-type galaxy population
- but it also hosts a high level of activity (star formation, merging and AGNs) apparently typical of structures at this epoch

The cluster environment is already established but the core galaxy population is still undergoing build-up

The earlier misidentification at z=2.07 is due to a combination of

- the observing strategy (slit spectroscopy)
- the large-scale structure of which CI J1449+0856 is part

