# Evolution of galaxies in the richest environments up to the highest redshifts

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## Context

Environment is known to play a role in galaxy evolution, however the extent of it is unclear, especially at high redshifts. Galaxy clusters, as the densest environments in the Universe, are essential to probe this effect.

In the local Universe, their core population is "red and dead" because of the known star formation-density relation – galaxies with quenched star formation tend to reside in dense environments.

Recent works (Quadri et al. 2011) have shown that this relation holds out to at least z~1. 8.
High redshift (z>1.5) clusters allow to observe this population when it was younger, even reaching a far enough epoch to observe a reversal of the star formation-density relation (Tran et al. 2010), thus providing a key test to estimate the impact of the environment on galaxy evolution.

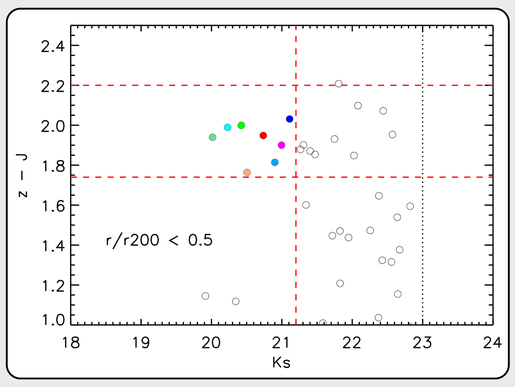
We here take advantage of JKCS 041 cluster ($z_{phot}$ ~ 2, Andreon et al. 2009) to study the star formation activity in high redshift clusters and also the Butcher-Oemler effect (Butcher & Oemler 1984), which states that clusters at higher redshift have a larger fraction of blue galaxies.

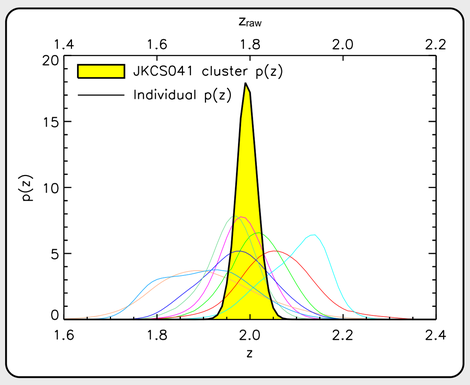
## JKCS 041: $z_{phot}$ ~ 2

**JKCS 041**:
CFHT/TERAPIX/WIRDS image
with Chandra X-ray image overlaid

**Data**
- CFHTLS (D1 field) optical: ***u*g'r'i'z'***
- WIRDS infrared: ***JHKs***

**JKCS 041 photometric redshift estimate**
- EAZY code
- Objects within 0.5*$r_{200}$ on the red-sequence

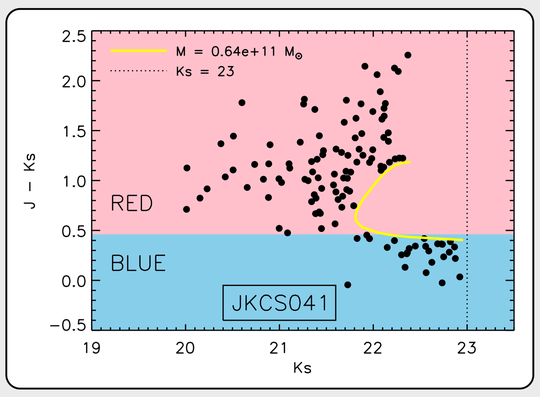



**Result**
All the 8 brightest objects of the red-sequence give a consistent $z_{phot}$ ~ 2.

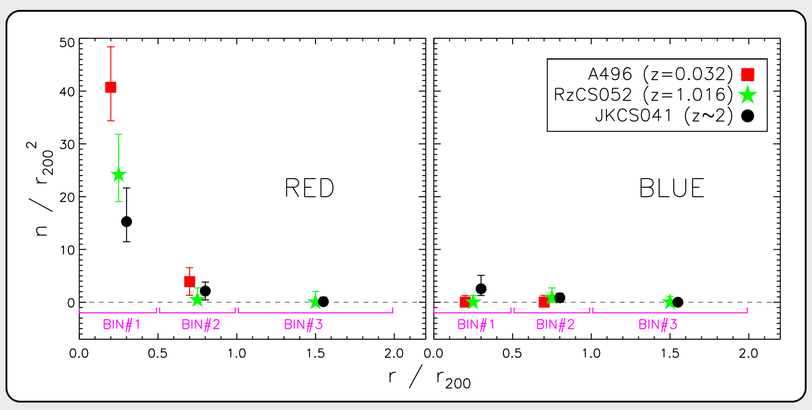
## Butcher-Oemler effect for 0 < z < 2

**Method: definition of a blue galaxy (Andreon et al. 2006)**
When comparing blue fraction $f_b$ at different redshifts, we want to probe the existence of an evolution of $f_b$ with redshift beyond the star aging with decreasing redshift. We use an evolving spectral template (with an exponentially declining star-formation history) in order to coherently separate blue galaxies from red galaxies.

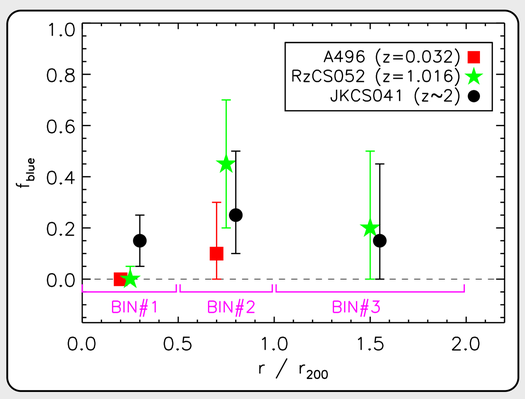



**Pre-Analysis**
- Stars removal
- Foreground sources removal through $z_{phot}$

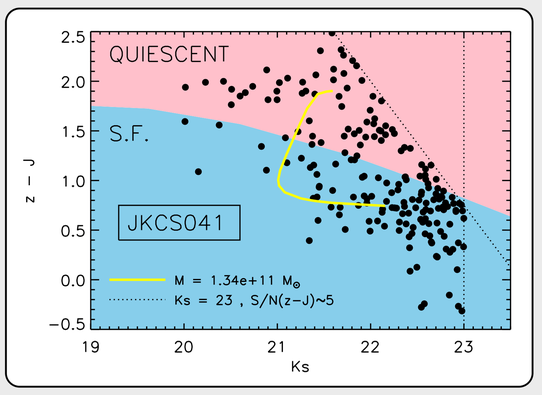
**Analysis**
- Two comparison clusters
  - A496 at z=0.032
  - RzCS052 at z=1.016
- Mass-selected sample
- Blue if bluer than a CB07 model with τ = 3. 7 Gyr (Andreon et al. 2006)
- Background statistical subtraction




**Result**
We do not observe any evidence of an evolution in the radial profile of the fraction of blue galaxy between z=2 and z=0, beyond star aging.
We remind that our work is limited to high mass galaxies (M > 0.64e11 $M_o$).




## JKCS 041 Star-Formation

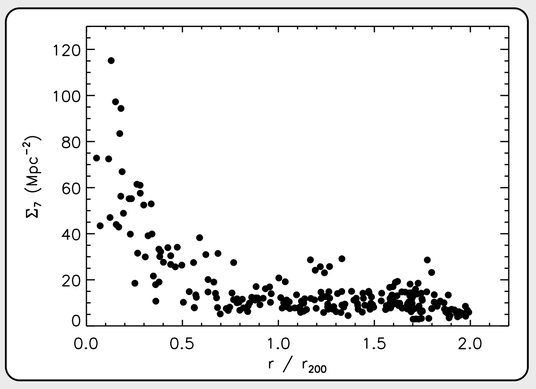


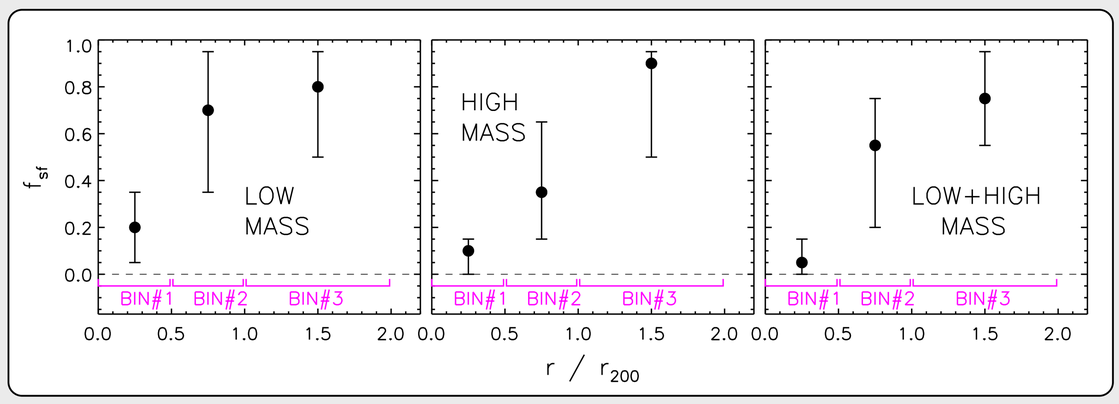

**Pre-Analysis**
- Stars removal
- Foreground sources removal through $z_{phot}$

**JKCS 041 star formation activity**
- Cut in S/N(*z-J*)~5
- Star-forming if bluer than CB07 models with SFR = 4 $M_o$/yr
- Background statistical subtraction

**JKCS 041 density profile**
- Cluster position defined by X-ray emission
- **$\Sigma_7$:** local density, estimated from the distance of the 7th nearest neighbor

➡ Density and cluster-centric distance run hand in hand




**Result**
Both our low-mass and high-mass subsamples show consistent and systematic increase of the fraction of star-forming galaxies with cluster-centric distance, hence with decreasing density.

## References


- Andreon et al. 2006, MNRAS, 365, 915
- Andreon et al. 2009, A&A, 507, 147
- Butcher et al. 1984, ApJ, 285, 426
- Quadri et al. 2011, arXiv:1104.1426
- Tran et al. 2010, ApJ, 719, L126


## Conclusion

- We confirm the high redshift nature $z_{phot}$ ~ 2 of JKCS 041 with a photometric redshift estimate based on 8 bands
- We do not observe any evidence for the Butcher-Oemler effect at 0<z<2, once accounted for the younger age of stellar populations at high redshift and for the higher star formation rate there
- In JKCS 041, the star formation-density relation is already in place: galaxies in the cluster core are quiescent