Galaxy groups in photometric surveys

Looking back 11 billions years with the DETECTIF$_z$ group finder

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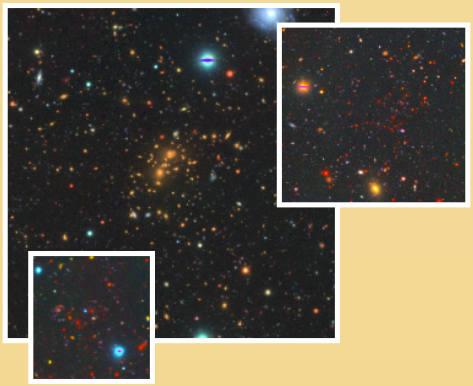
Sarron & Conselice 2021, MNRAS, 506, 2136

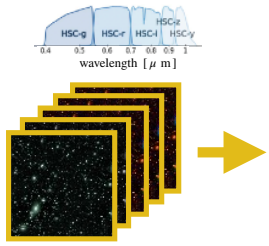


Abstract

- Large sample of galaxy groups and (proto-)cluster cores at $1 < z < 2.5$ (8 to 11 billions years ago) are crucial to understand galaxy cluster formation and suppression of galaxy star-formation (*quenching*) in the densest environments.
- Such samples can only be obtained using multiband photometric surveys combining optical and near-infrared (NIR) filters such as the upcoming *Euclid* space telescope survey.
- New group finder algorithm **DETECTIF$_z$** to detect galaxy groups in photometric data. Probabilistic framework to identify groups as stellar-mass over-densities. Pilot study on the deepest NIR fields available to date (REFINE).
- Galaxy **quenched fractions in groups than in the field up to** $z = 2.2$, the difference growing with decreasing redshift.

Multiband Photometric surveys

Credit: Princeton University/ HSC Project



Multiband observations

- Multiband observations allows to compute the *observed magnitudes* (luminosity) and *colours* of galaxies.
- These observables depend on galaxy intrinsic properties :
  - redshift (~distance)
  - stellar mass
  - star formation rate
  - etc.
- We can compute the posterior probability of intrinsic parameters given the data using Bayes theorem

$$p(\theta \,|\, \mathrm{data}) \propto p(\mathrm{data} \,|\, \theta) \times p(\theta)$$

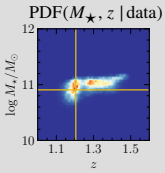


Fig 1 *Example of 2D joint posterior PDF. The yellow cross indicate the best fit point estimate*

- Most galaxy evolution study to date use only best-fit point estimate.

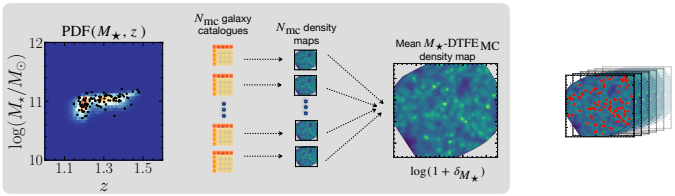
Challenge Use these multi-dimensional PDFs to study galaxy properties in galaxy clusters and groups

DETECTIF$_z$ *DElaunay TEsselation ClusTer IdentiFication with photo-z*

New galaxy group finder algorithm for photometric data :

- samples from the PDF($M_\star$, z)
- compute stellar-mass overdensity using Delaunay Tesselation

Workflow



Output: Group catalogue

Selection function on mock data

Mock datasets from cosmological simulations perturbed to look like the data

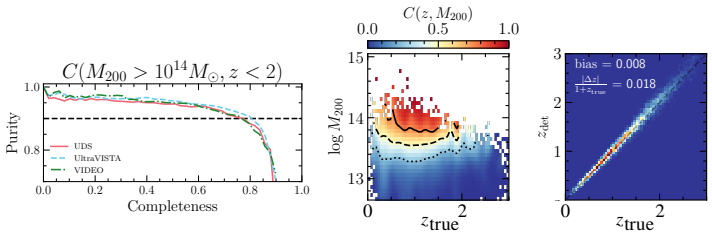


Fig 2 ***(left)*** *purity of the group sample (i.e. 1 - false detection rate) vs completeness for galaxy clusters at z < 2 for each of the survey fields of REFINE. The horizontal dashed line shows the 90% purity threshold.* ***(middle)*** *Completeness as a function of redshift and halo mass for a 90% pure sample. The solid, dashed and dotted lines shows the 90, 75 and 50% completeness thresholds.* ***(right)*** *DETECTIF$_z$ redshift estimate vs true redshift.*

Takeaway DETECTIF$_z$ has competitive performances on near-infrared photometric surveys. We are now exploring proto-cluster detection for *Euclid*-like data.

Example of scientific output : Galaxy quenched fractions

- **Context** In the local Universe, a large fraction of galaxies in clusters and groups are not forming stars anymore. The main physical mechanisms responsible for this shutdown of star formation (so called star formation *quenching*) are still debated.
- Insights can be gained by constraining the timescale on which quenching happened. This can be done by studying the fraction of *quenched* galaxies in galaxy groups up to high redshift (early in the age of the universe), a quantity so far badly constrained.

This is what we did in **Sarron & Conselice (2021)** using **DETECTIFz** on deep near-infrared data of the REFINE survey (UDS, COSMOS, CFHTLS-VIDEO)

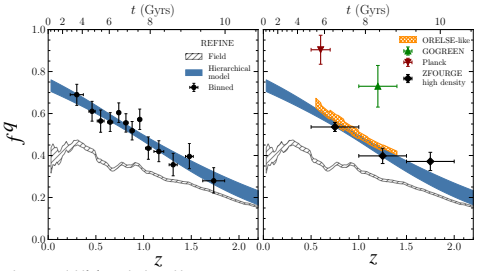


Fig 5. Quenched fraction vs redshift for galaxies with $10.25 < \log M_\star < 11$.
(left)*: Points with errorbars show the binned group quenched fraction. The shaded blue region displays our linear model hierarchical bayesian fit. The dashed region shows the field quenched fraction. Errorbars and shaded region display 68% confidence intervals.*
(right)*: Blue shaded and dashed regions from the left panel are reported and compared to values taken from the literature (ZFOURGE, ORELSE, Planck clusters, and GOGREEN clusters).*

Main result The quenched fraction is higher in groups than outside groups up to $z = 2.2$ (11 billions years ago)

Perspective Study the dependence on group mass (M_{200}), distance to the group center (r/r_{200}) in order to constrain quenching timescales

Summary and perspective

- DETECTIF$_z$ detects groups of galaxies up to high redshift in photometric data using a probabilistic framework. Successfully applied to the deepest near-infrared data available.
- Using DETECTIF$_z$ on larger datasets (HSC-SSP) and *Euclid*-like mock data we are investigating
  - → **Evolution of quenched fraction** with redshift? group mass? radial distance?
  - → **Large-scale environment** : proto-clusters ? Cosmic web filaments around our groups in COSMOS (Laigle et al. 2018) ?
  - → **Cluster mass assembly** and dynamics comparing X-ray *vs* optical/NIR properties

Bibliography
Laigle et al. 2018, MNRAS, 474, 5437
Mundy et al. 2017, MNRAS, 470, 3507
Sarron et al. 2021, MNRAS, 506, 2136