GALAXY CLUSTERS THROUGH PHOTOMETRY: from membership to star formation histories

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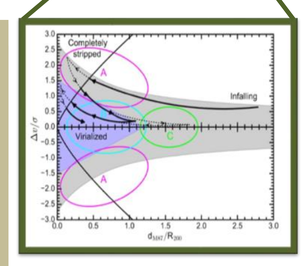
INTRODUCTION

Galaxy clusters are the most massive bounded systems in the Universe and continue to grow and accrete matter from the cosmic web. Determining the **mass distribution** in galaxy clusters provides essential information about cosmological parameters and the nature of dark matter as they are very sensitive to the underlying cosmological model through quantities such as mass-to-light ratio, X-ray luminosity function, spatial distribution or abundances. It also helps to study the **environmental processes** influencing galaxy evolution [1,2] and the intergalactic medium.

METHODS

X-ray emission	Weak lensing
Jeans equation	**Caustic technique**

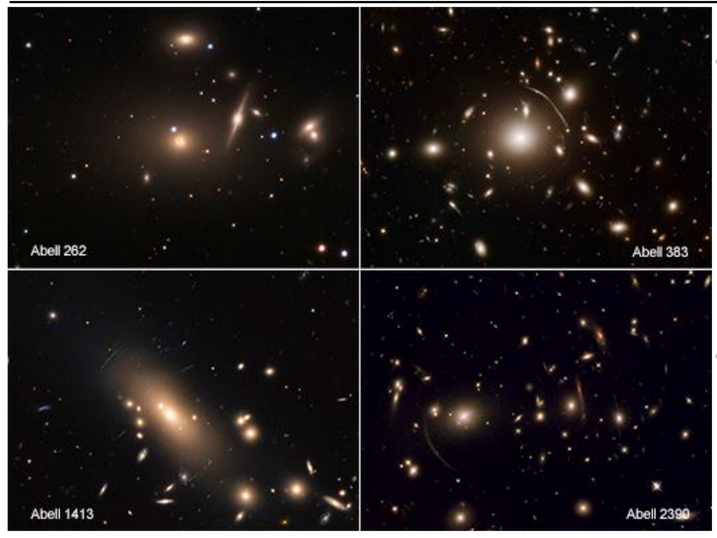
The **caustic technique** [3] takes **positions and velocities** of cluster **members** and projects them into a phase space of cluster-centric distances and radial velocities. The resulting **trumpet-shape** is the result of the increased velocities as galaxies are accelerated by the cluster, and the envelope, the **caustic**, shows the variation of the scape velocity with radius.

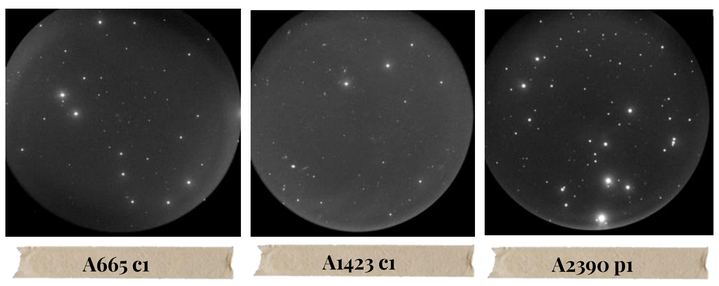


CATARSIS

CATARSIS is the new legacy survey for the **3.5m telescope** at the **Calar Alto Observatory**. It will observe a sample of **16 galaxy clusters** at redshifts $z \sim 0.15-0.23$ using the new **TARSIS** instrument (Tetra-ARmed-Super-IFU-Spectrograph), which has an 8 arcmin² field of view. The survey will map all objects within the clusters' virial radii, as well as foreground and background galaxies.

Achieving the objectives of the survey requires **precise spectrophotometric calibration**, detailed analysis of disk galaxy spiral morphologies, and measurements of sizes, ellipticities, and position angles. Additionally, the survey aims to **recover very low levels of residual star formation** and compare them with those observed in **cluster periphery** galaxies.





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OBJECTIVES

01 Getting photometry of CATARSIS clusters well beyond virial radius:
- Spectro-photometric calibration in the TARSIS wavelength range
- Spectral energy distribution (SED) fitting
- Physical properties of galaxies in clusters (morphology, stellar mass, star formation history...)

02 Mass profiles for a subsample of CATARSIS clusters:
- A2390: Euclid + weak lensing + intra-cluster light
- A2219: Euclid + Sunyaev Zeldovich

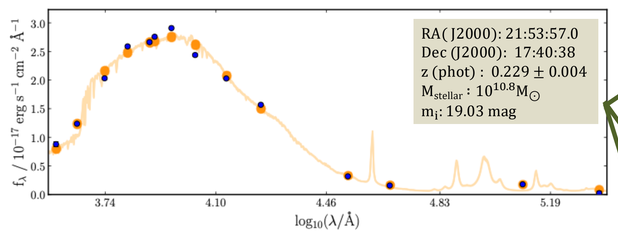
03 Develop a robust photometric membership criterion :
- Photometric redshift from SED-fitting + morphological parameters

Improve cluster membership

- Need for **spectroscopic** data on **blue, late-type** galaxies beyond the virial radius.
- Explore **scaling relations** [7, 8] and add **morphological information** to better identify blue or late-type members and separate from background galaxies.

Abell 2390

One of the CATARSIS clusters is **Abell 2390,** with 2×10^{15} M⊙ at **z = 0.228** recently observed in the Euclid ERO [4]. We have used **Euclid** data (**VIS, Y, J, H**), complemented by their pre-imaging deep photometry with **Suprime-Cam**, which provide six band optical coverage (**B, V, Rc, i, Ic, z'**), as well as **CFHT MegaCam u-band** imaging. This dataset has allowed us to derive photometric redshifts within the Euclid field of view through spectral energy distribution fitting using Bagpipes, selecting those compatible with being members of A2390 [6].



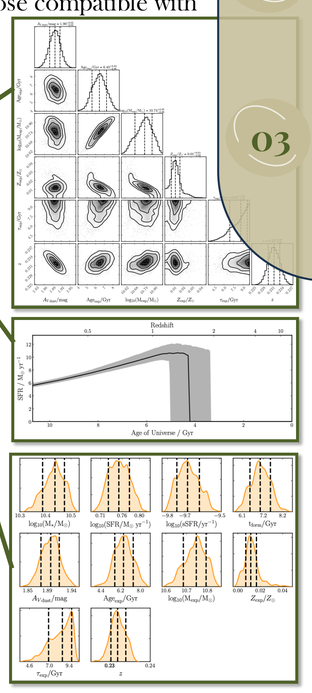
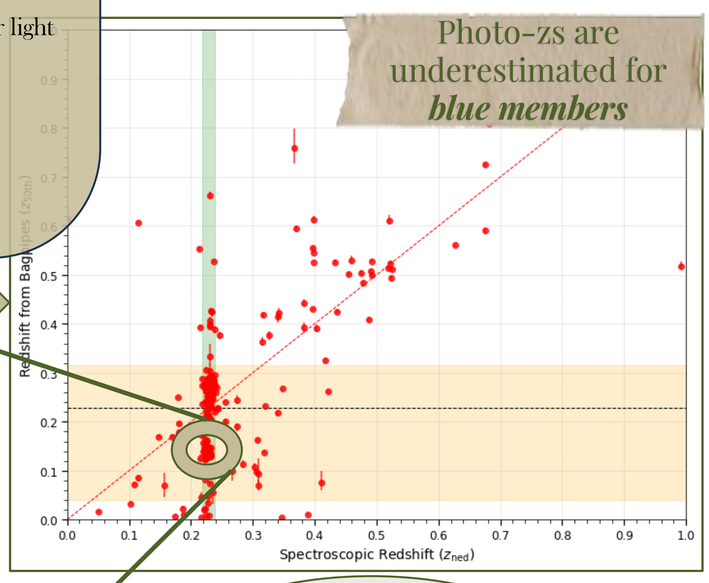
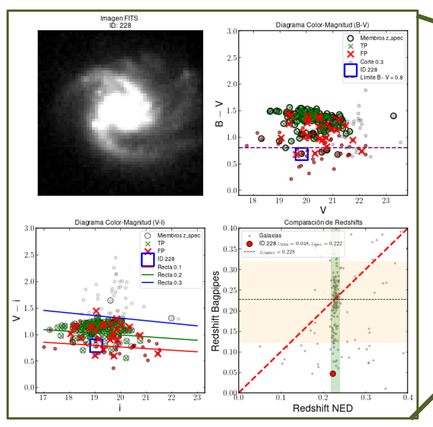


Photo-zs are underestimated for *blue members*

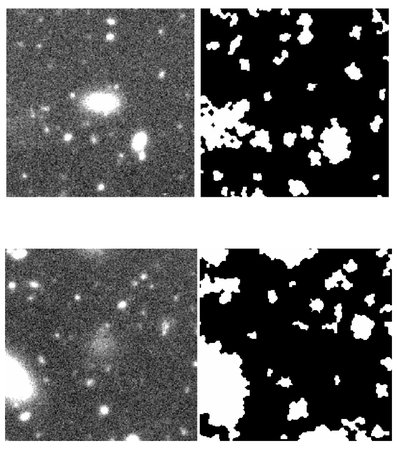




WHICH GALAXIES ARE CLUSTER MEMBERS?

INCORPORATING MORPHOLOGY

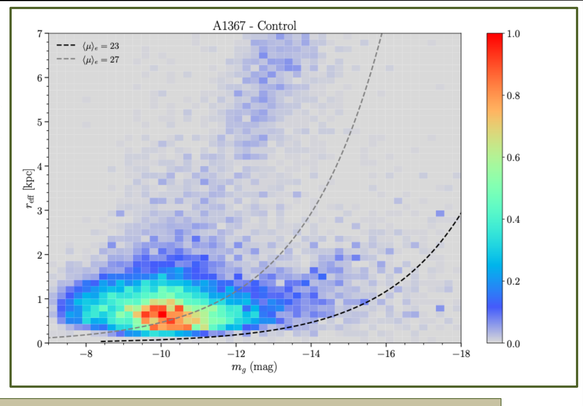
We take advantage of **deep Subaru/HSC imaging** [9, 10] **for eight nearby clusters** ($z \lesssim 0.05$), which provides high-resolution and high-sensitivity data to **better characterize the galaxies' structural and morphological properties** and integrate them into the membership framework. As part of this work, we are performing a systematic **morphological decomposition with GALFIT** [11] for all detected galaxies in these clusters through **NoiseChisel** [12], measuring structural parameters (e.g. effective radius, Sérsic index, ellipticity) to quantify environmental trends.



UDGs

Recent discovery of a significant population of galaxies with **large effective radii** and **low central surface brightness** mostly in cluster environments: $r_{eff} \geq 1.5$ kpc and $\mu_0 \geq 24$ mag /arcsec².

Particular attention is being given to **Ultra Diffuse Galaxies (UDGs)** as an extreme population of cluster galaxies. Their detection in the cluster regions, consistent with the expected surface-brightness limits, allows us to **assume cluster membership** and use them as benchmarks to test and calibrate the extended morphological membership framework.



- **Answer the question: do UDGs extend the size-luminosity relation as a low-luminosity tail? Or do they form a distinct population?** [13]
- This work is being developed in collaboration with international teams, with the goal of producing a public catalog of UDG candidates across the HSC cluster samples

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