SF2A 2019

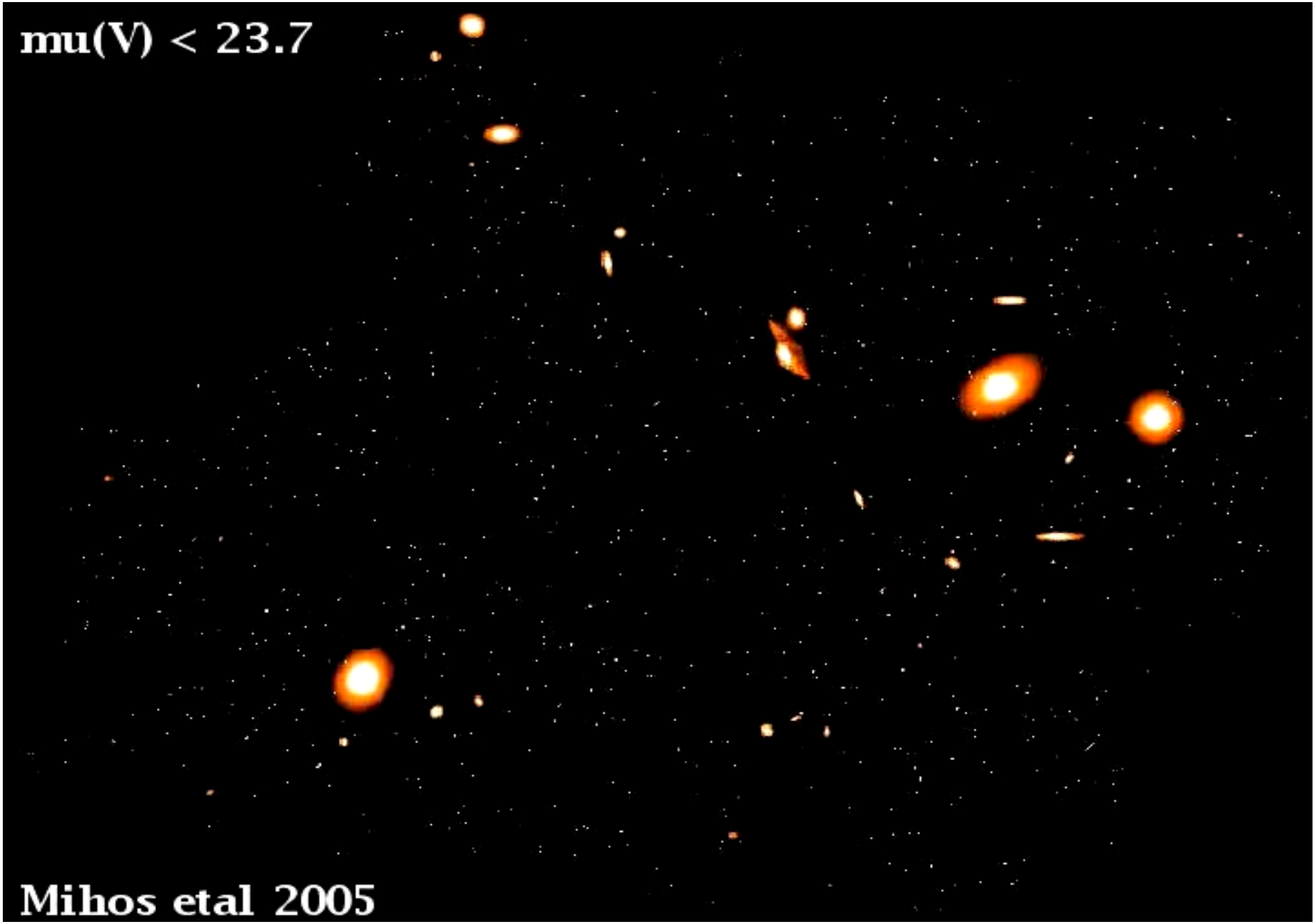
Detection of Intra-Cluster Diffuse Light: presenting DAWIS

PhD Student: **Amaël Ellien**

Supervisors: **Florence Durret, Christophe Adami (LAM)**

INSTITUT D'ASTROPHYSIQUE DE PARIS

Unité mixte de recherche 7095 CNRS - Sorbonne Université


mu(V) < 23.7
Mihos etal 2005

What is the Intra-Cluster Light (ICL)?

→ Galaxy clusters diffuse component in the optical wavelenghts (not X-rays or Radio !)

→ Detected for the first time by Zwicky in 1951

→ Very low surface brightness (μ>26.5 mag.arc^{-2} ; Mihos et al. 2005)

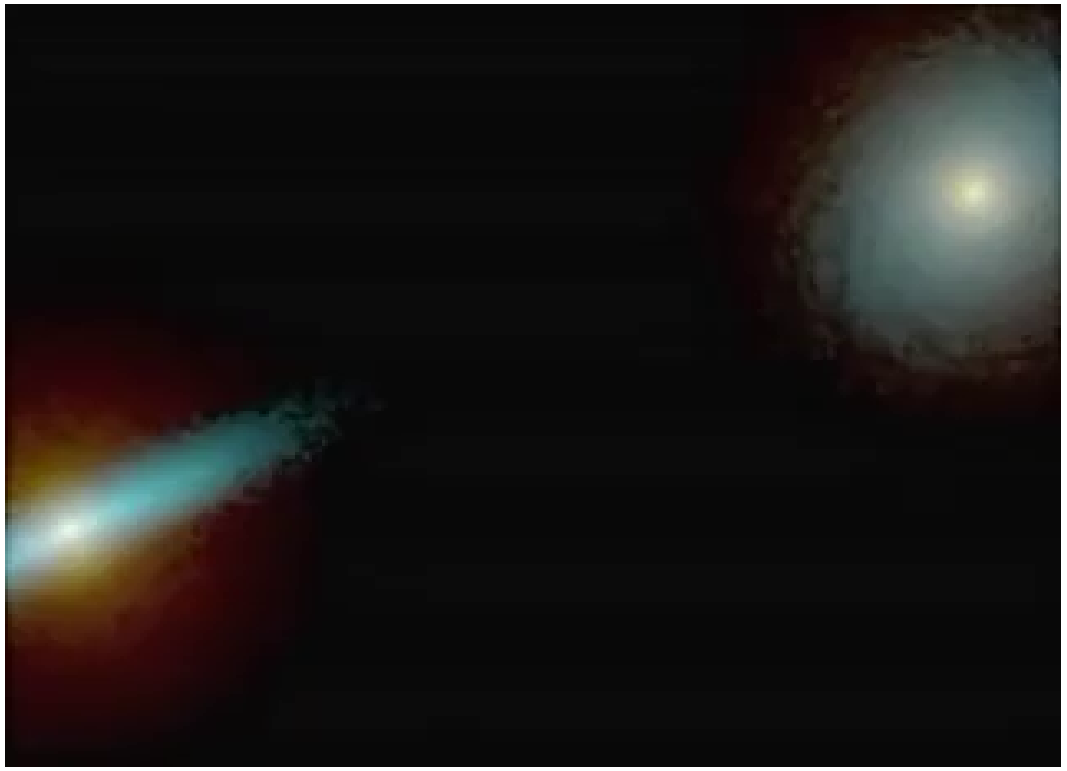
→ Composed of stars that are not related to any galaxy in particular

→ Embedded in the galaxy cluster gravitational potential

→ Form a smooth halo around the galaxy cluster center (~ few hundred kpc)

Scenario of ICL formation (The common one)

→ Stars stripped away from their home galaxy through gravitational interactions (mergers, tidal stripping); Merritt (1984)



Simulation By: Josh Barnes (University of Hawaii) and John Hibbard (National Radio Astronomy Observatory)

→ These stars are then mixed into the global gravitational potential of the galaxy cluster

→ Detecting and characterizing the ICL should give important information about the accretion history of the galaxy cluster

The theoretical point of vue (Cosmological Hydro and N-body simulations)

→ ICL produced by the more massive galaxies ($10^{10\text{-}11}$ $M_{\odot}$; Contini et al., 2014)

→ Metallicity of ICL is similar to the metallicity of cluster's galaxies (Contini et al., 2019)

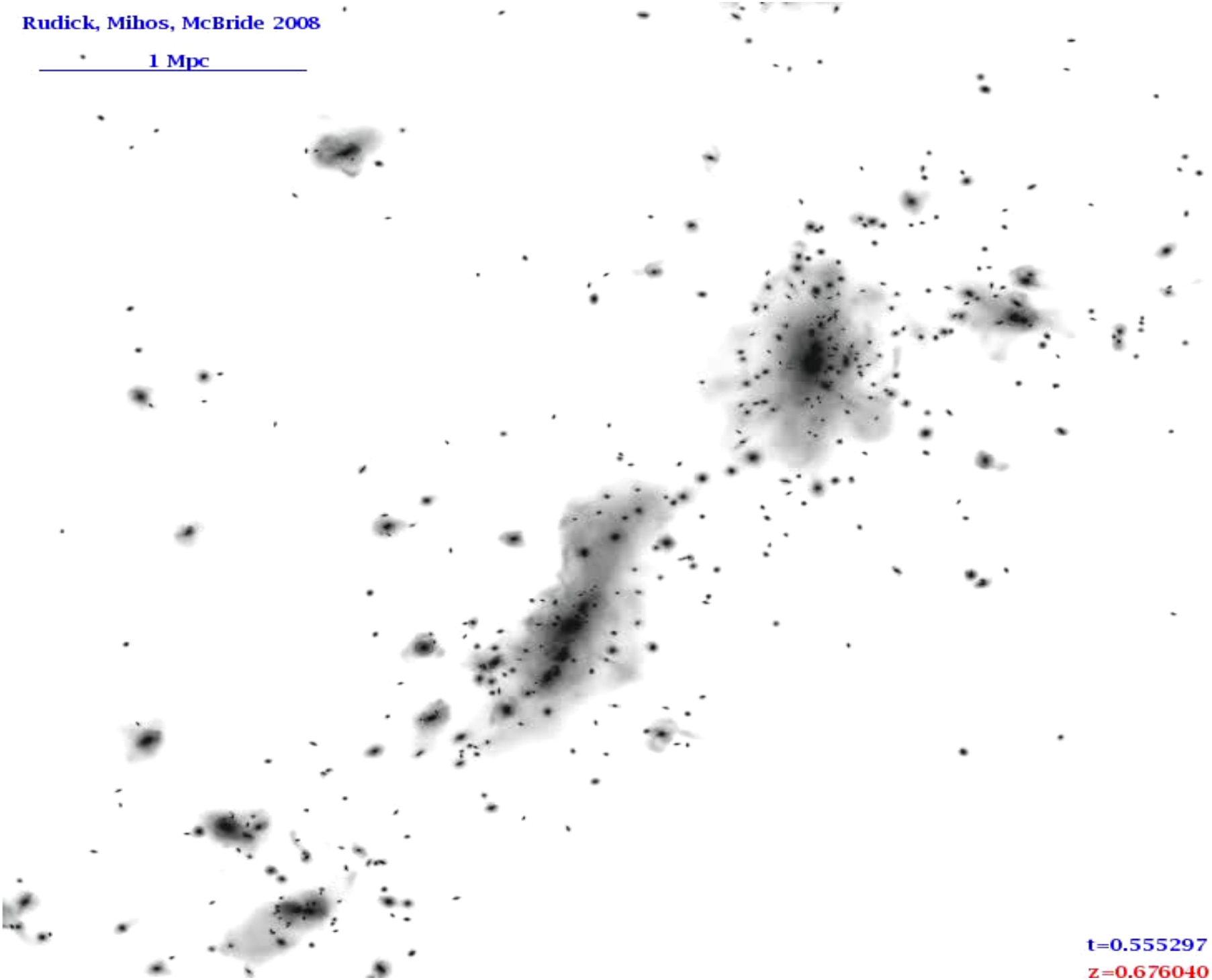
→ ICL forms at z<1-2 (Murante et al., 2007)

→ Massive galaxy clusters have more ICL (Murante et al., 2004)

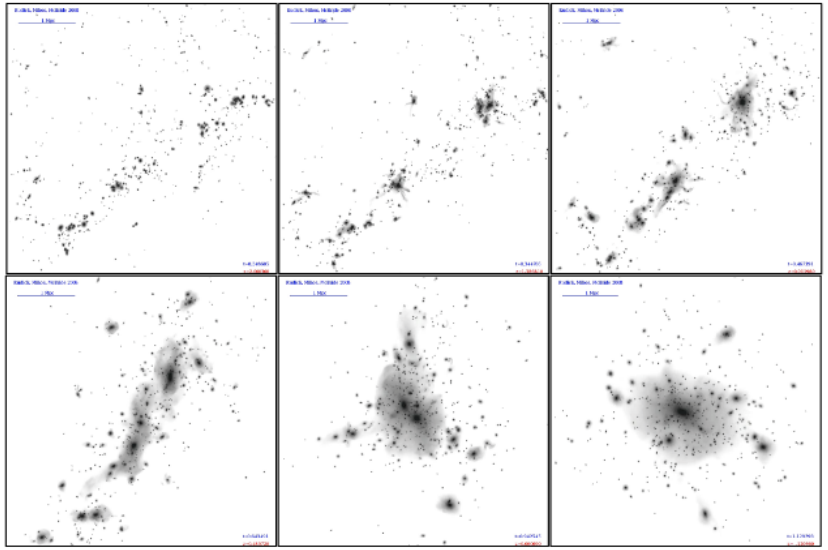
→ Fraction of ICL :

$$f_{ICL} = \frac{F_{ICL}}{F_{GAL} + F_{ICL}}$$

At z=0, the ICL emits around 10 to 40% of the total light of a galaxy cluster


Rudick, Mihos, McBride 2008
1 Mpc
t=0.555297
z=0.676040

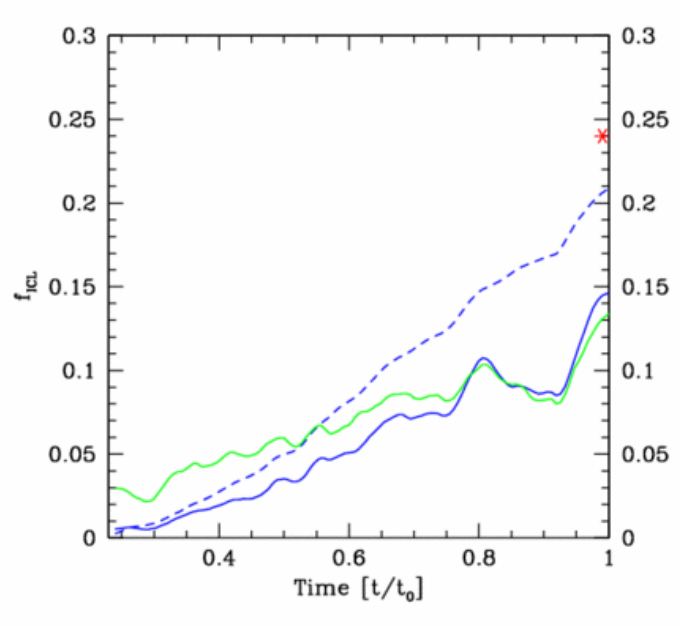
Multiple steps in the formation of Intra-Cluster Light (ICL)

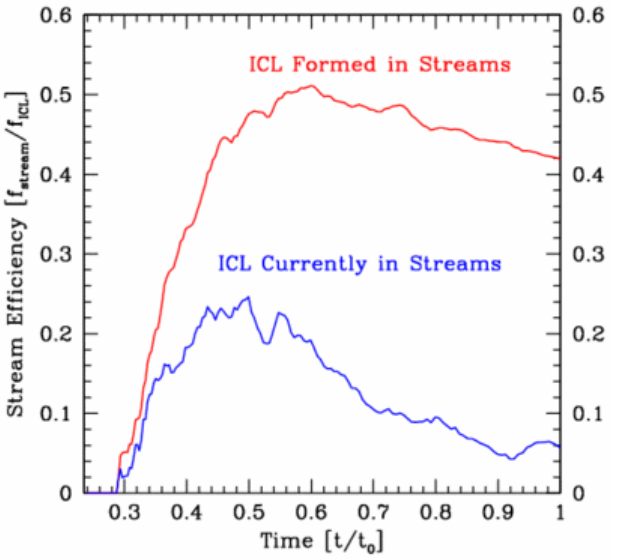


→ filamentary state

Rudick et al, 2009, 2011

→ relaxed state





→ Another conclusion of those studies : surface brightness thresholding is not very good to detect ICL !

Presenting DAWIS (Detection Algorithm using Wavelets fot Intra-cluster light Surveys)

→ Algorithm based on the wavelet theory – a first version was created by Da Rocha et al., 2005

→ Creation of a new version which is highly parallelized with most of the numerical work coded in Fortran and the rest in Python for flexibility

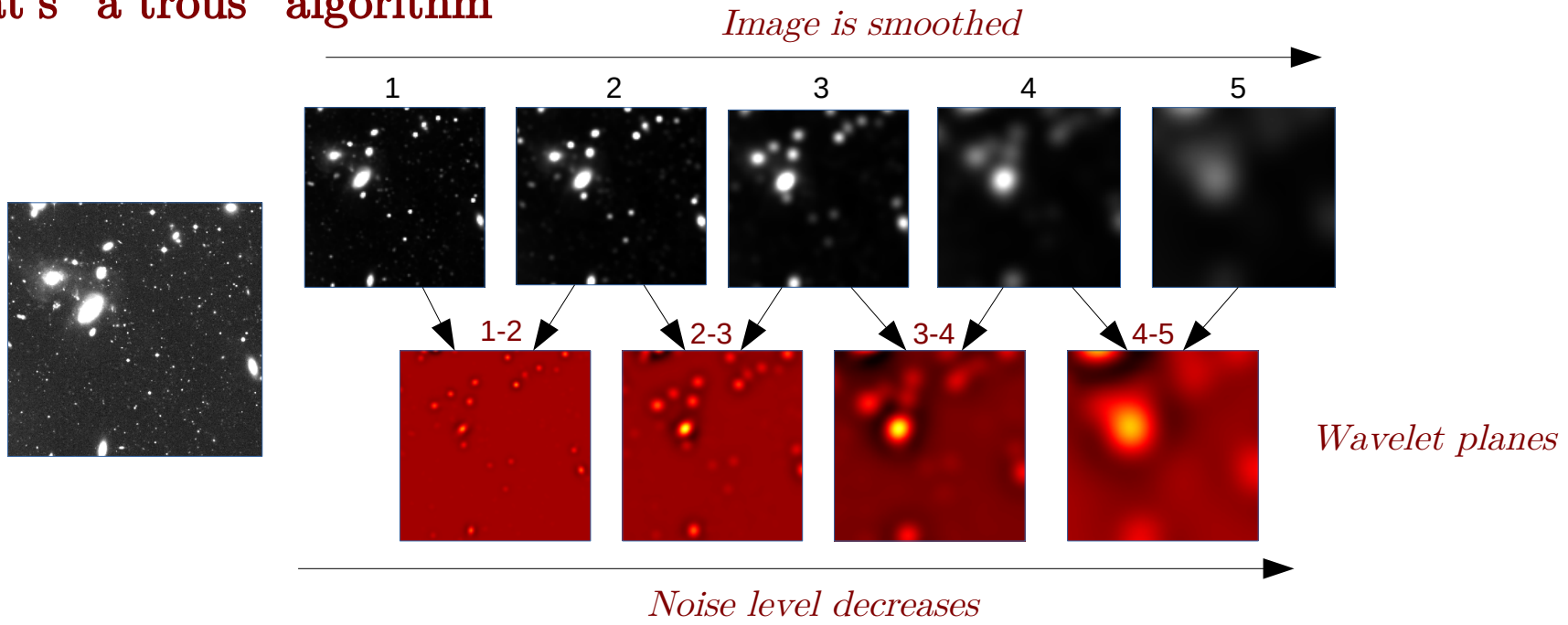
→ Very efficient to detect and model sources (galaxies) in astronomical images up to low surface brightness scales without the need for prior information

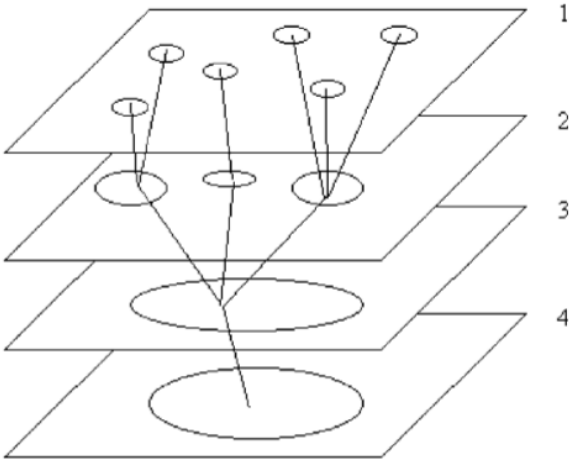
→ Subtract sources from image

→ ICL in residuals (hopefully)

DAWIS in a nutshell (1)

1 – Mallat's "à trous" algorithm





2 – Interscale trees

Thresholding → significant pixels grouped in regions

$$\Phi(x) \geq k\,\sigma_j$$

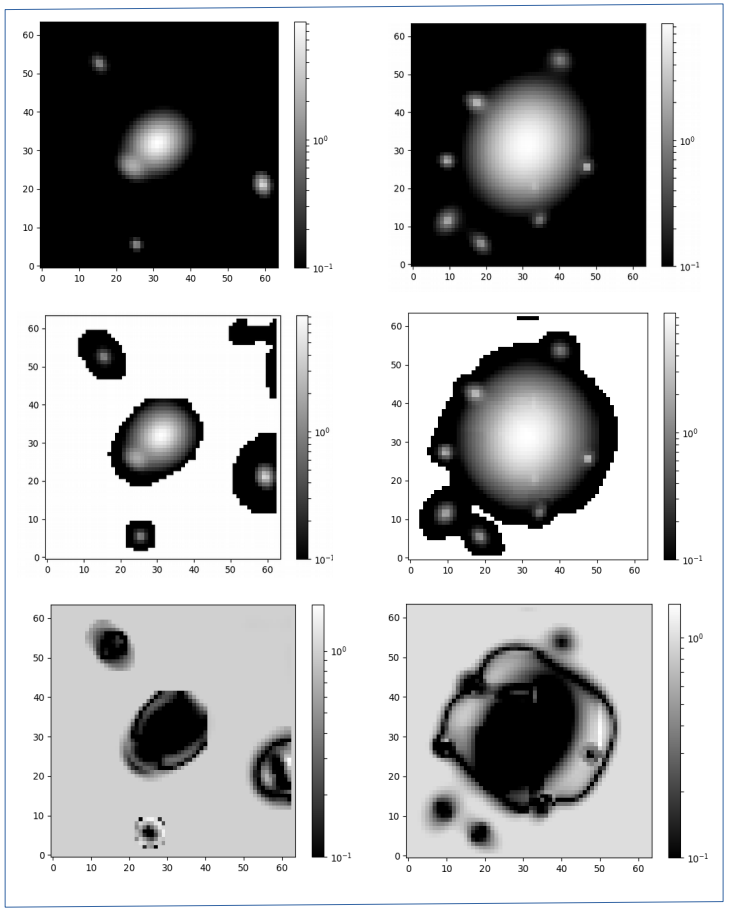
Linking → the regions linked into interscale trees

DAWIS in a nutshell (2)

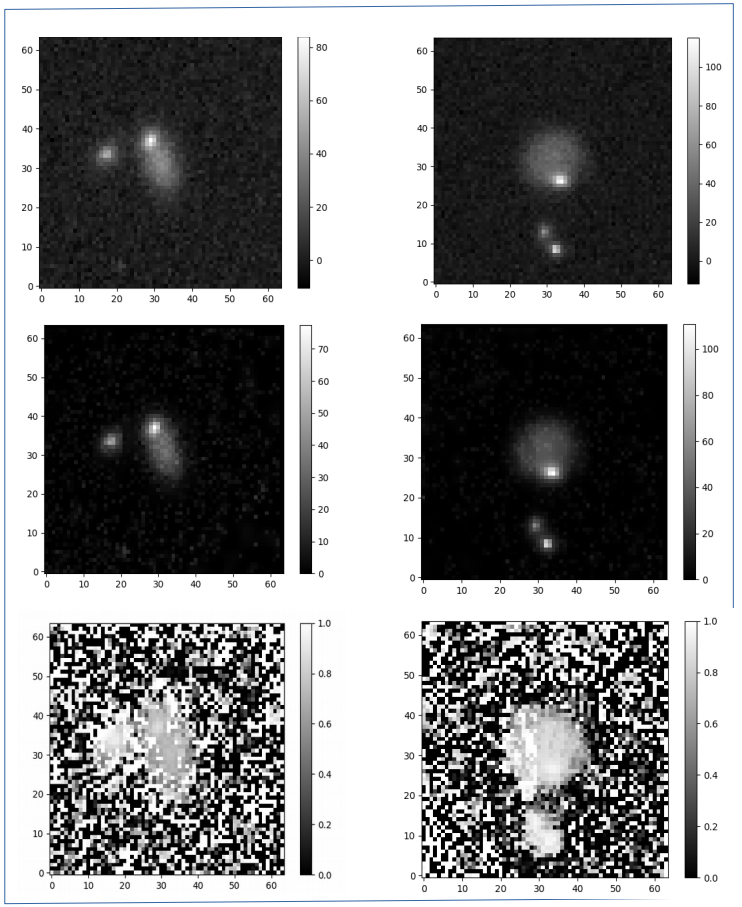
3 - Conjugate gradient algorithm (Stark et al., 1998)

→ Each object in an image is reconstructed separately and then the reconstructions are concatenated in a single reconstructed image

→ Tests on simulated galaxies :



Without noise



With noise

The case of MACSJ0717 in the Hubble Frontier Fields Survey (1)

Durret+ 2016

MACSJ0717: large galaxy cluster at redshift ~0.5 with a detected cosmic filament to the south-east.

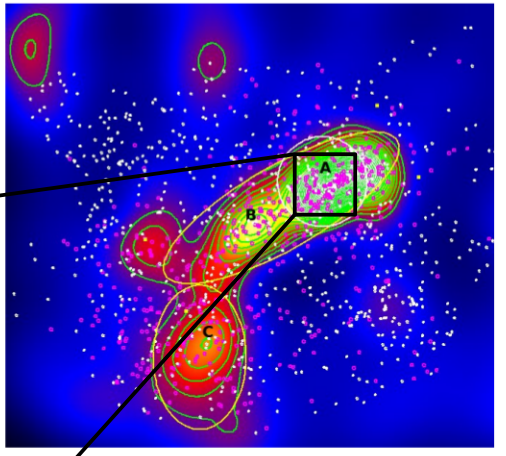
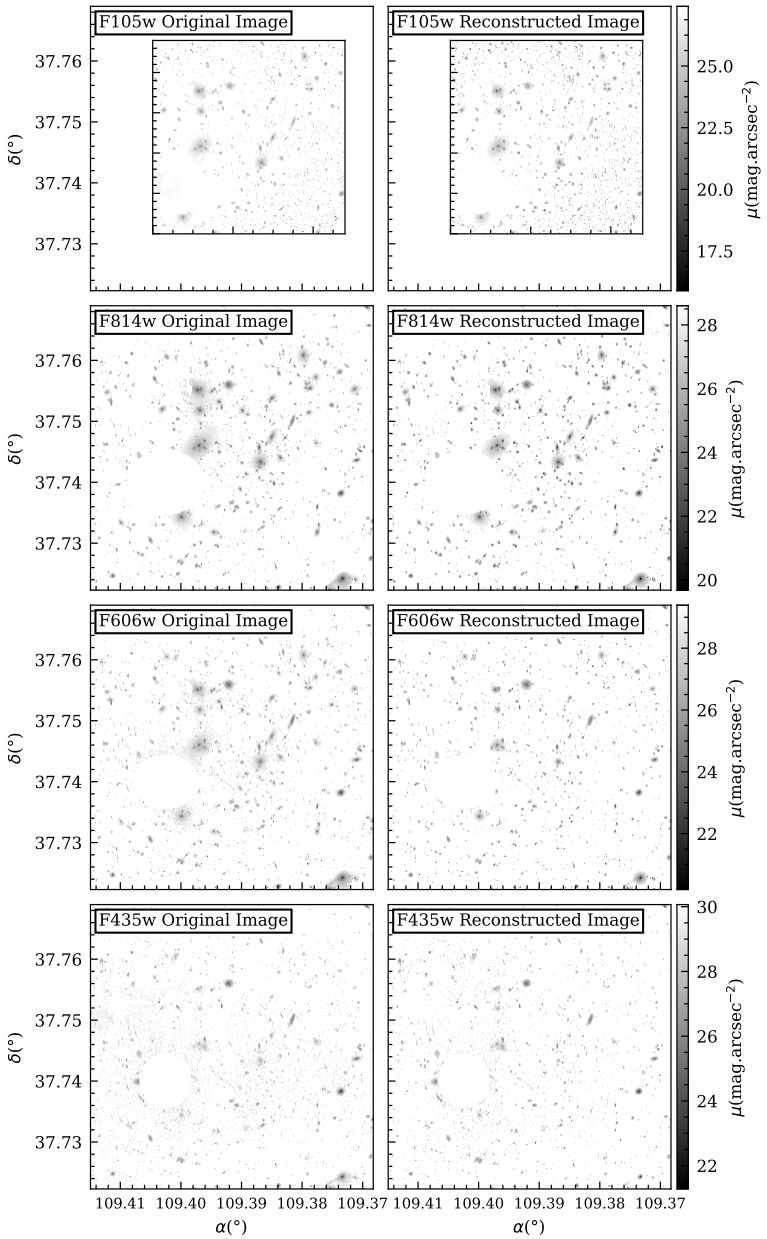
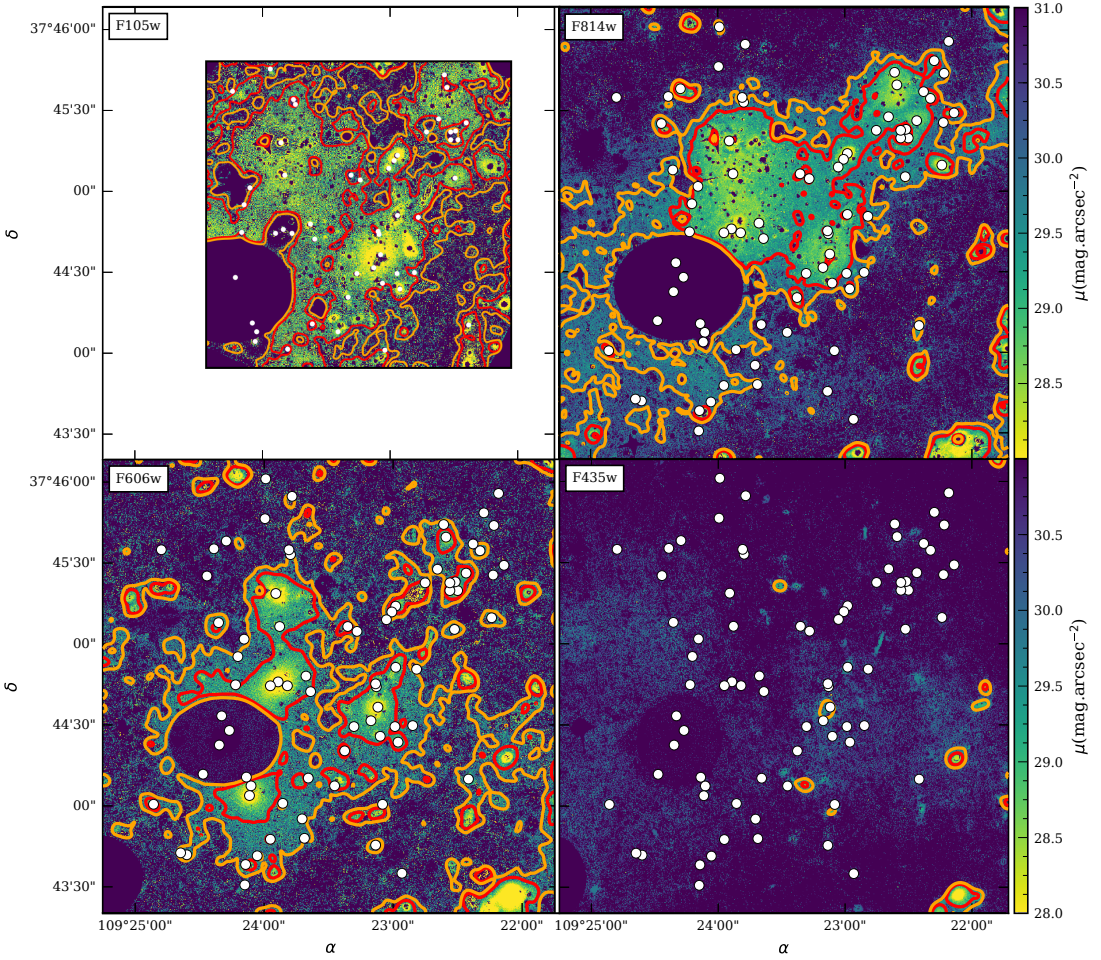


Fig. 5. Same as Fig. 3 for MACS J0717+3745 (z = 0.5458). The magenta points correspond to the galaxies with spectroscopic redshifts in the $0.53 < z < 0.565$ interval.

Hubble Frontier Fields: Very deep Hubble photometric survey in 6 bands (RGB image on the left).

The case of MACSJ0717 in the Hubble Frontier Fields Survey (2)



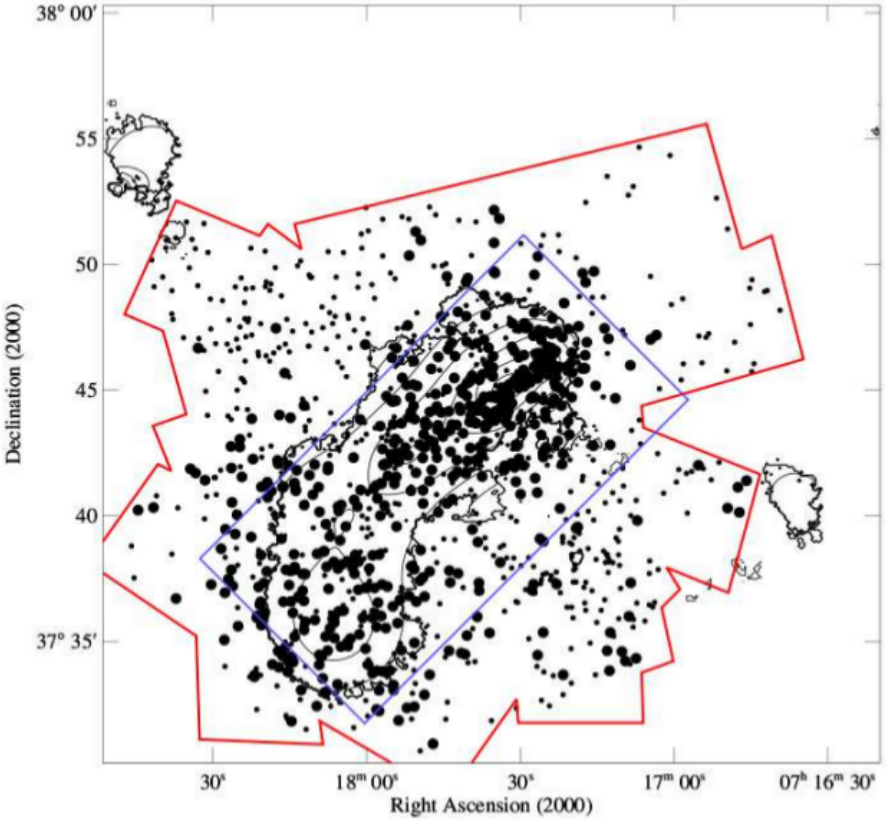


HFF	F435W	F606W	F814W	F105W
$3\sigma_{bkg}$ (mag.arcsec^{-2})	29.89	29.96	30.03	29.97
$5\sigma_{bkg}$ (mag.arcsec^{-2})	29.34	29.41	29.50	29.41
Radius (kpc)	275.3	562.5	421.5	FoV
f_{ICL}(%)	$2.48^{+0.19}_{-0.20}$	$24.43^{+3.37}_{-1.71}$	$16.10^{+1.03}_{-1.03}$	$13.22^{+1.76}_{-1.49}$

$$f_{ICL} = \frac{F_{ICL}}{F_{Gal} + F_{ICL}}$$

The case of MACSJ0717's filament

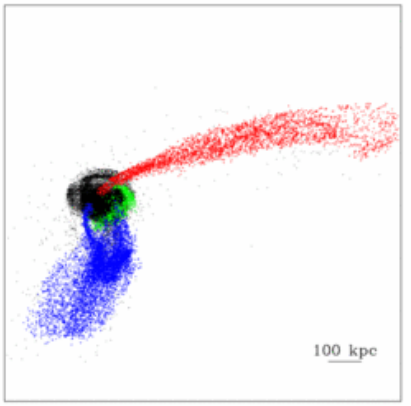
Jauzac+ 2012



Other HST mosaic for the filament (less deep).

No large diffuse contribution (what was expected)

→ looking for tidal streams



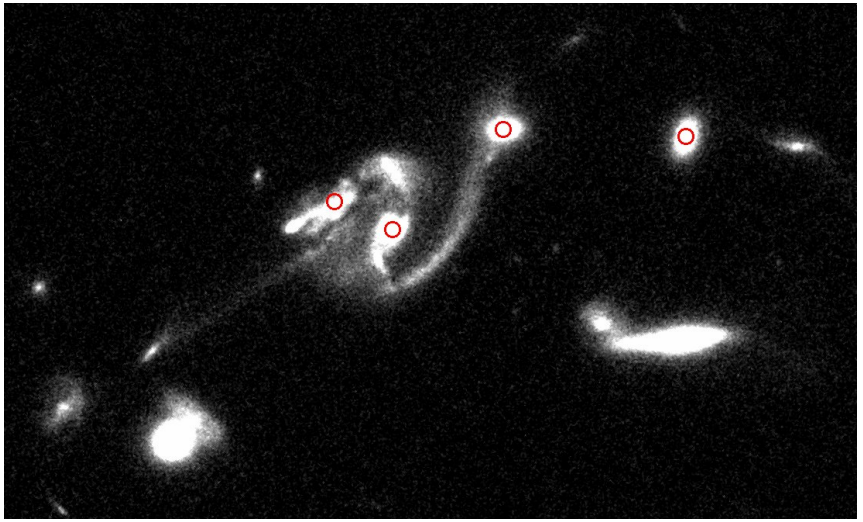
Rudick et al, 2009

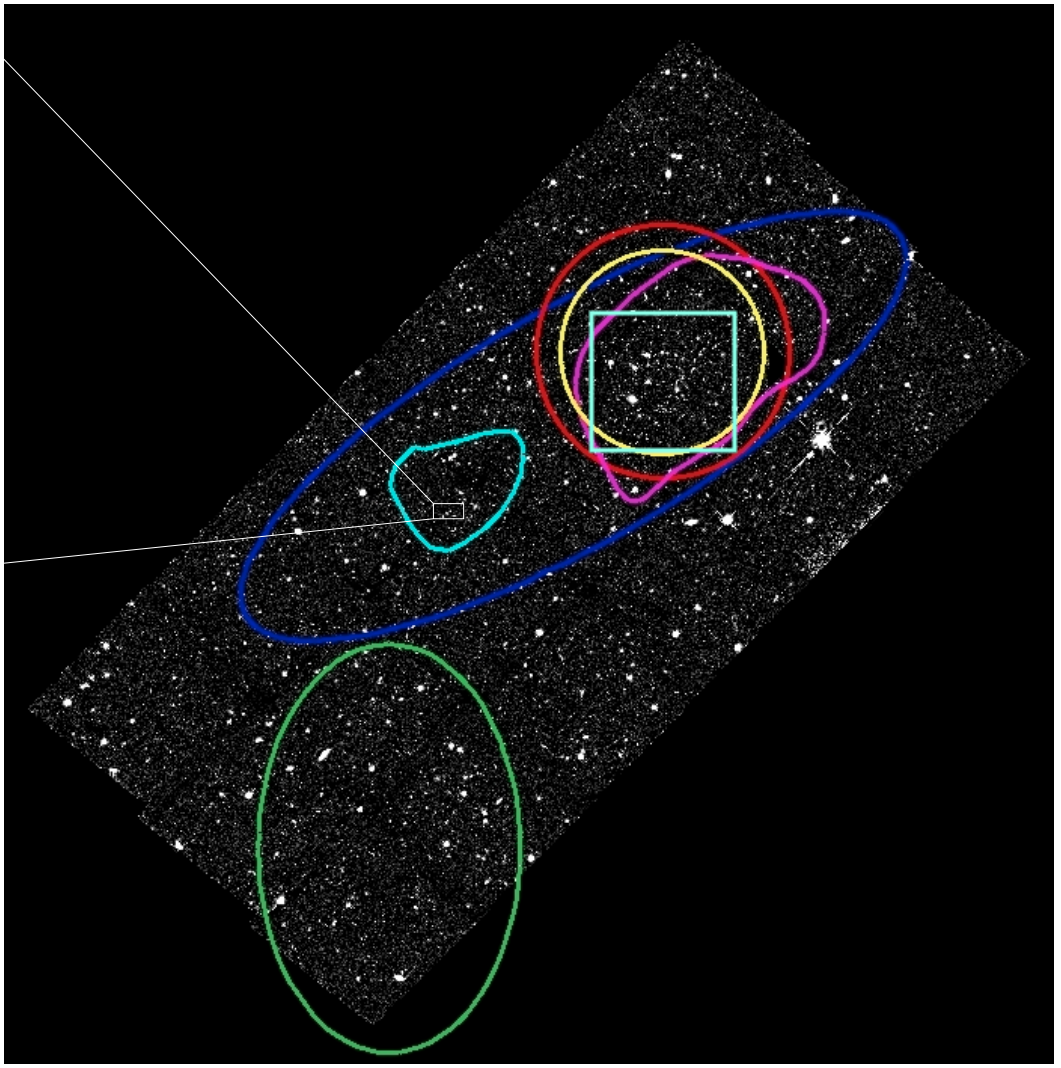
The complex case of MACS J0717.5+3745 and its extended filament: intra-cluster light, galaxy luminosity function, and galaxy morphology

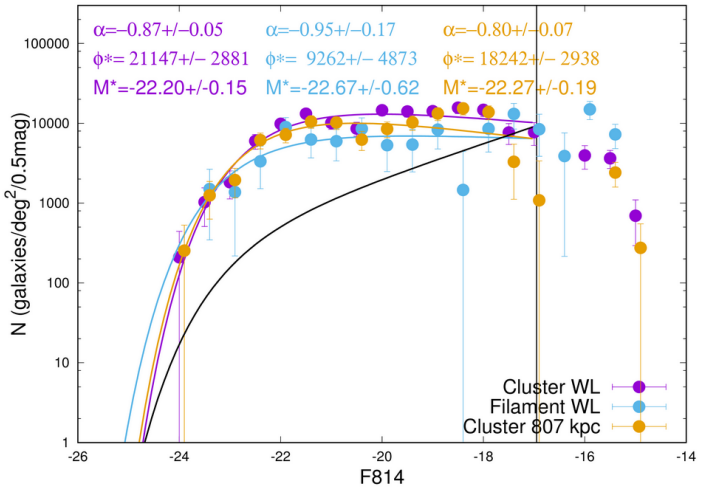
A. Ellien[1], F. Durret[1], C. Adami[2], N. Martinet[2], and C. Lobo[3,4]

A&A 2019 in minor revision

The case of MACSJ0717's filament







We can find strong tidal streams in the region demarcated by the WL (cyan) contours

→ Galaxy group ? (Galaxy Luminosity Function agrees)

What's next ?

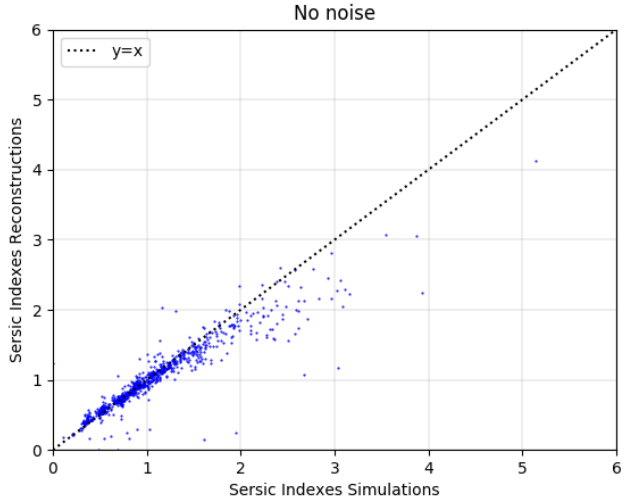
Pan-STARRS

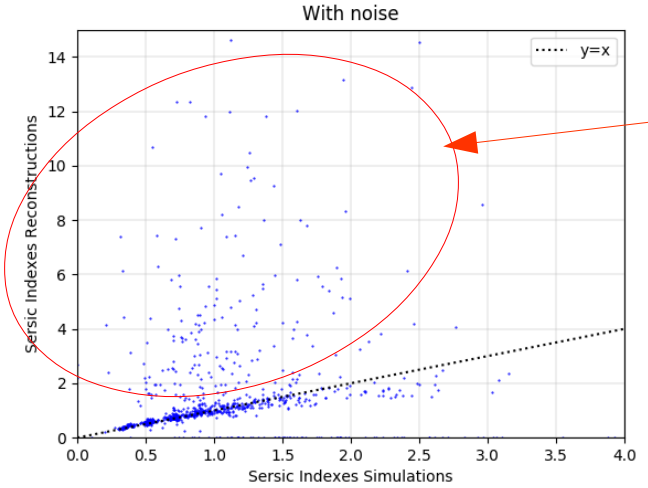
Elixir-LSB (J-C. Cuillandre)

THANK YOU

Is it working ?

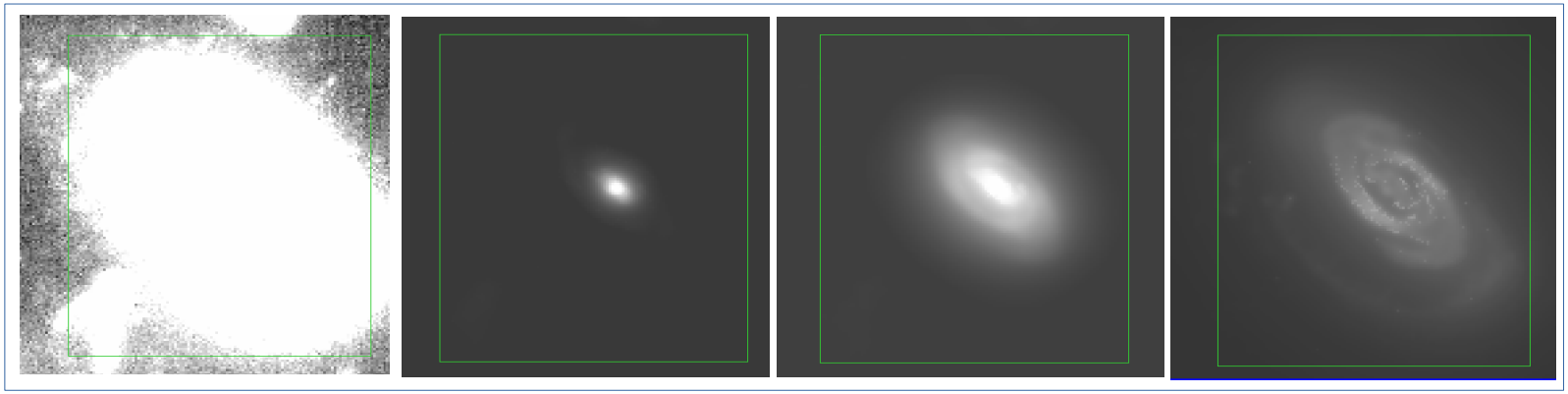
→ The reconstruction of an object does not have a single solution (some objects might be badly reconstructed)





Failures

→ There can be different usages of such algorithm (deblending, separating source's components, etc)



The case of MACSJ0717 in the Hubble Frontier Fields Survey (3)