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Oh no!
I'm already
in trouble

We'll
marinate you...

...before cooking
obviously!!!

The Pre-processing Scenario Across Cosmic Time:
The mass assembly history at different scales

Does the M_{vir} drive the IntraClusterLight?

ICL vs Environment

Higher M_{VIR} \rightarrow more ICL ??

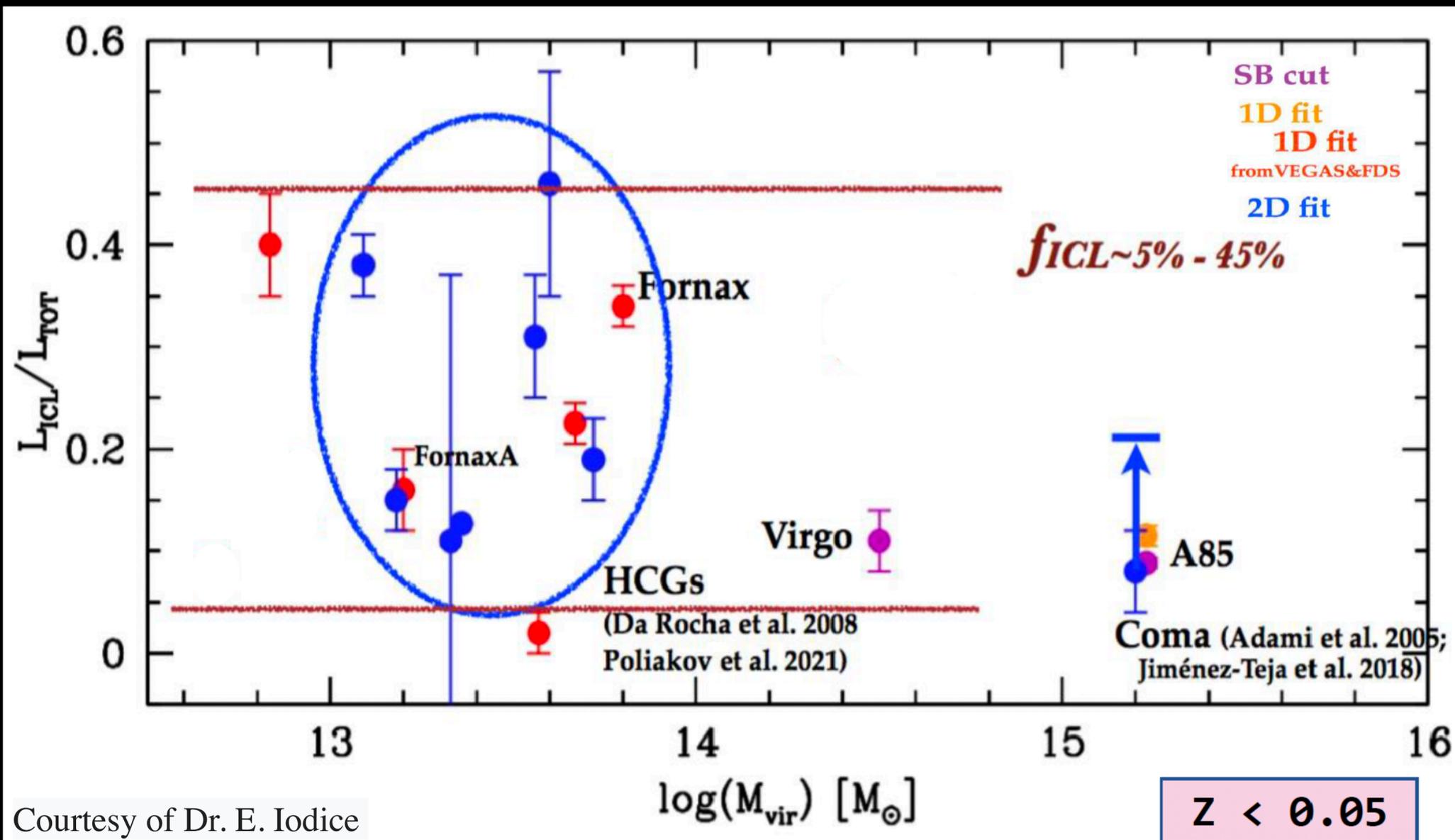
Ragusa et al. 2021
Ragusa et al. 2022
Ragusa et al. 2023



ROSSELLA RAGUSA, INAF FELLOW
In collaboration with : E. Iodice, M. Spavone, M. Paolillo et al.

The state of the art at the beginning...

Observations vs Theoretical predictions



IN THE LOCAL UNIVERSE
($Z < 0.05$)...

- *Non-homogeneous sample*
- *Few points to draw definitive conclusions*

Courtesy of Dr. E. Iodice

In the end....

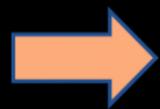
*Statistically significant
and homogeneous sample*

*50% of the points
from VEGAS*

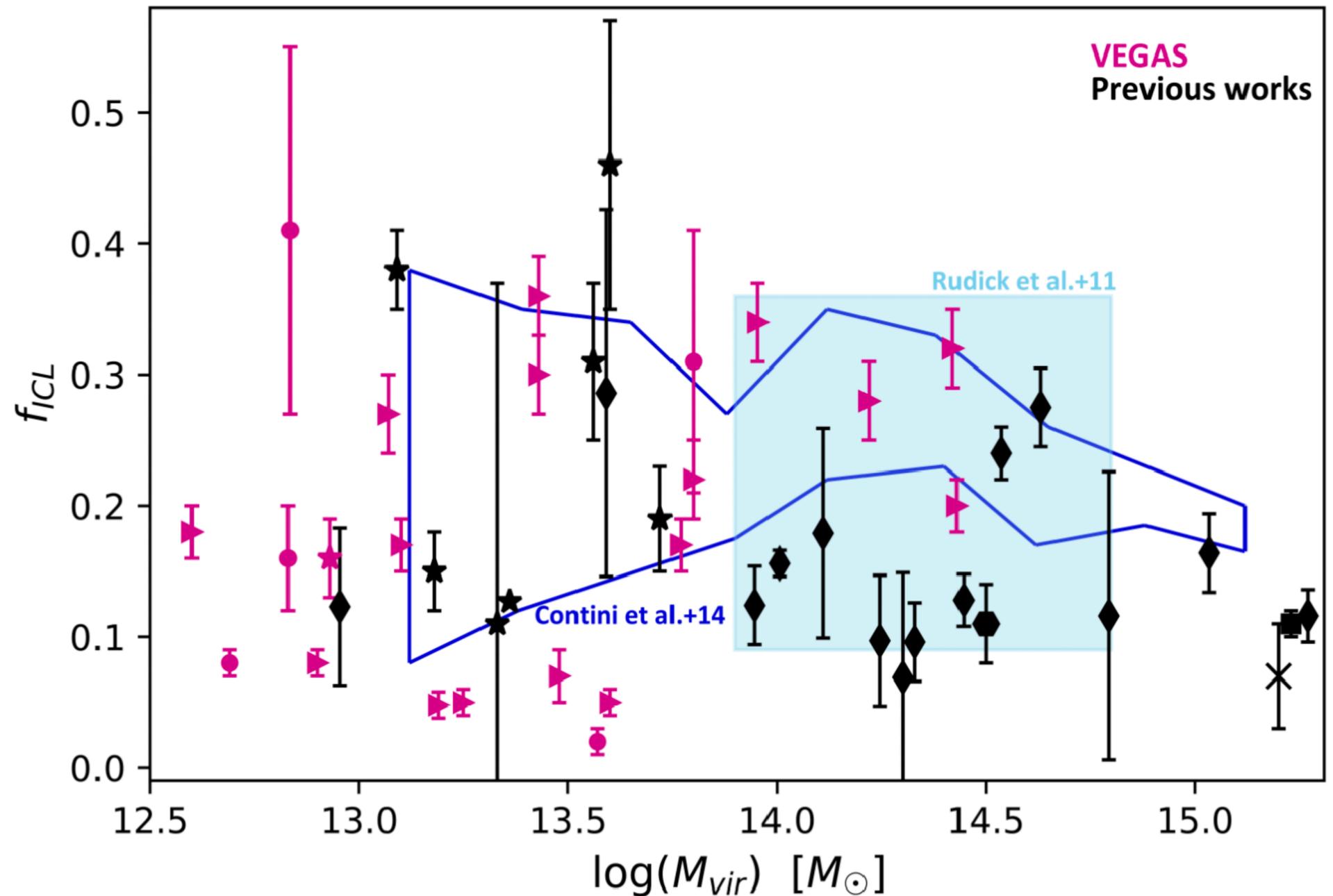
*In agreement with several
theoretical predictions*



No trend exists!!



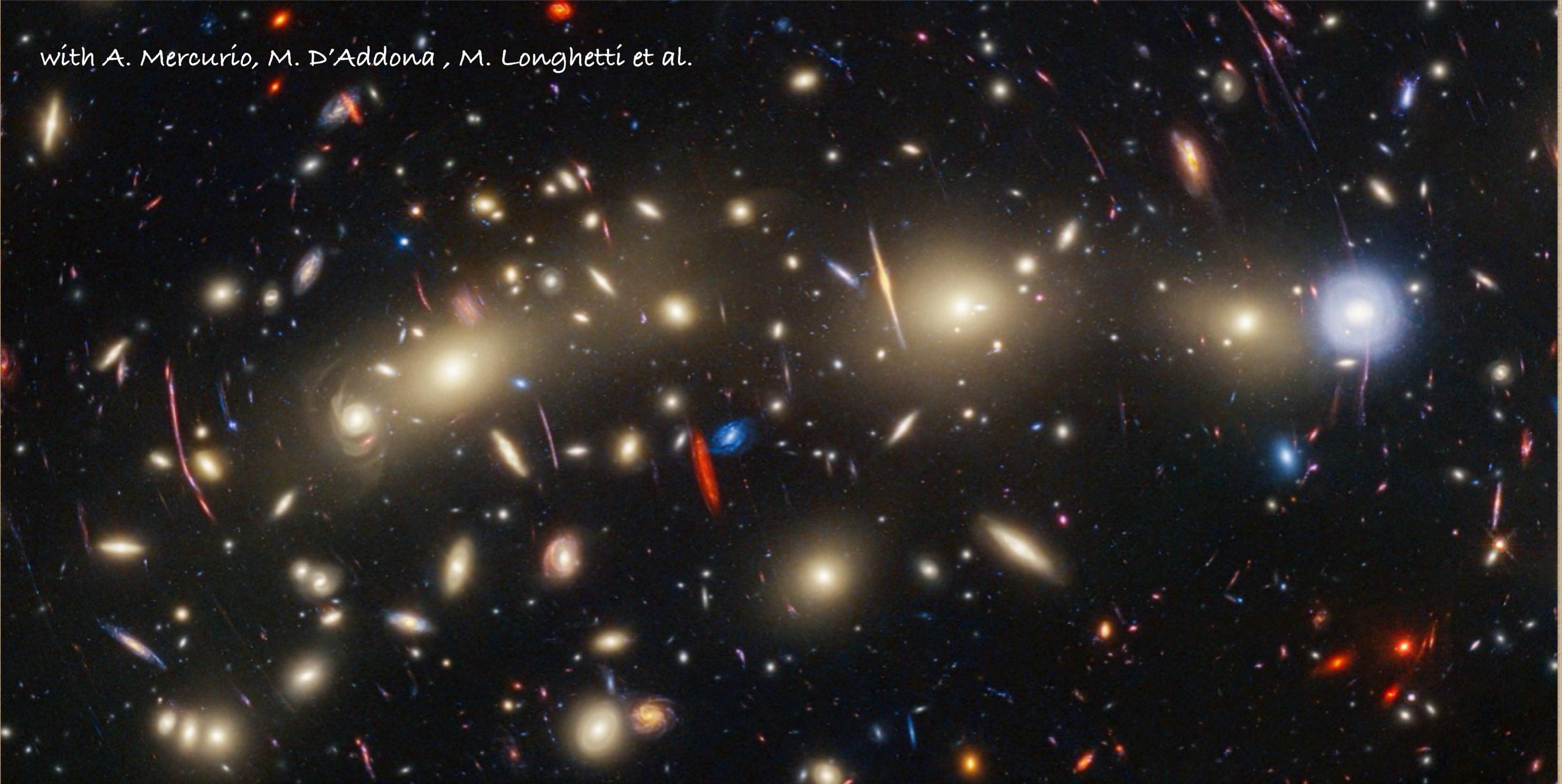
Very Large Scatter



*different concentrations of the haloes,
different mass assembly history..*

Ragusa et al. 2021
Ragusa et al. 2022
Ragusa et al. 2023

with A. Mercurio, M. D'Addona, M. Longhetti et al.



Across MACS J0416 by using AAOMEGA spectrograph

Galaxies at the edges

Studying the outskirts of massive galaxy clusters at intermediate z

$$M = 0.88 \times 10^{15} M_{\odot}$$

$$L_x \sim 10^{45} \text{ erg s}^{-1}$$

$$z = 0.3977$$

Why ??

$R > 2R_{200}$
limited to the low z

impact of hierarchical cluster assembly on galaxy evolution

**GALAXIES
VS
ENVIRONMENT**

Gas inflows \longrightarrow SF

High T e ρ \longrightarrow quenching



Credit: X-ray: NASA/CXC/SAO/G. Ogreaan et al.; Optical: NASA/STScI; Radio: NRAO/AUI/NSF

What does MACS J0416 look like?

VST-GAME
(ugri bands)

P.I. A. Mercurio



G-CAV
(JHKs bands)

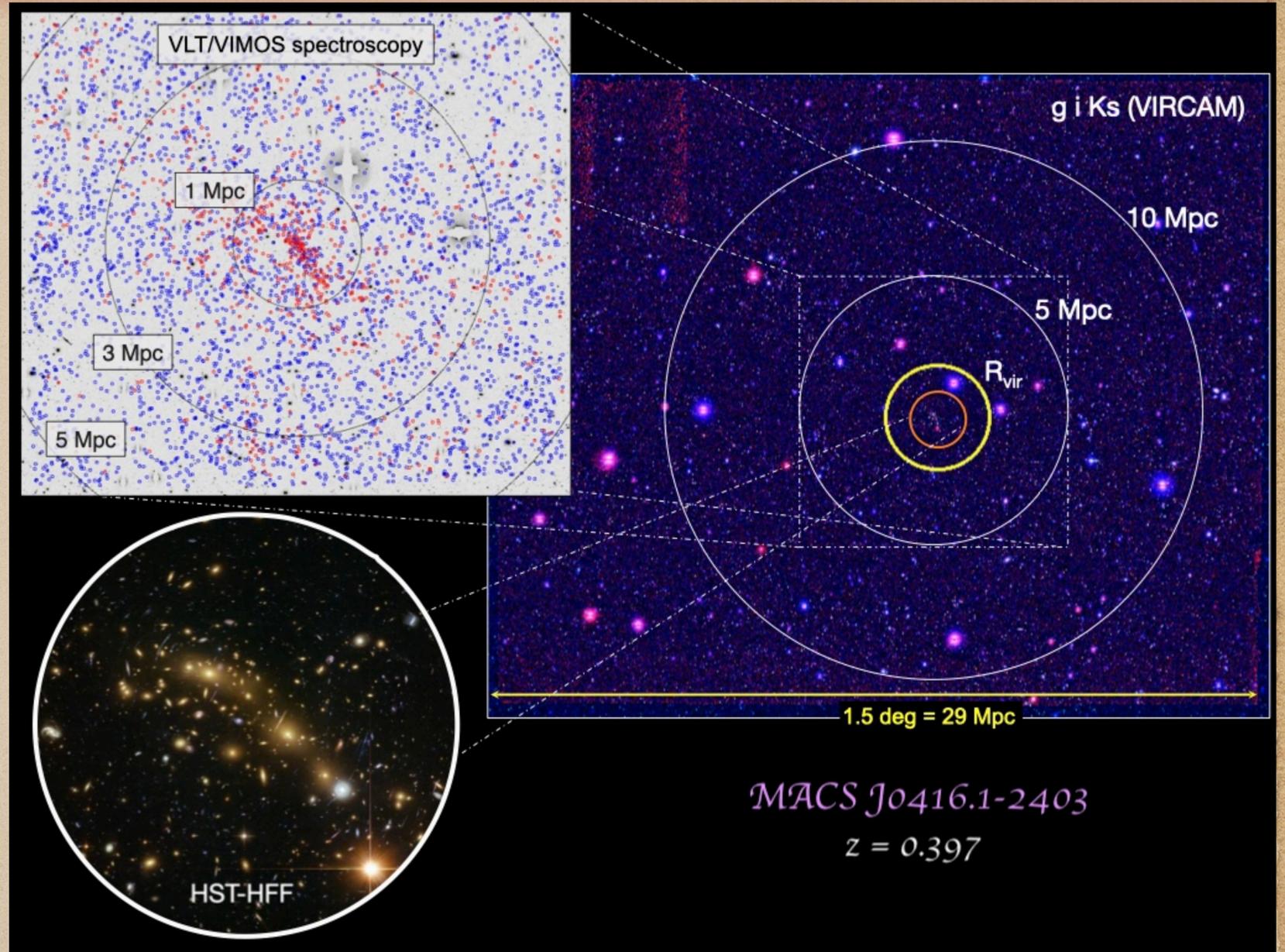
P.I. M. Nonino

→ z_{phot}



CLASH-VLT

To calibrate z_{phot}



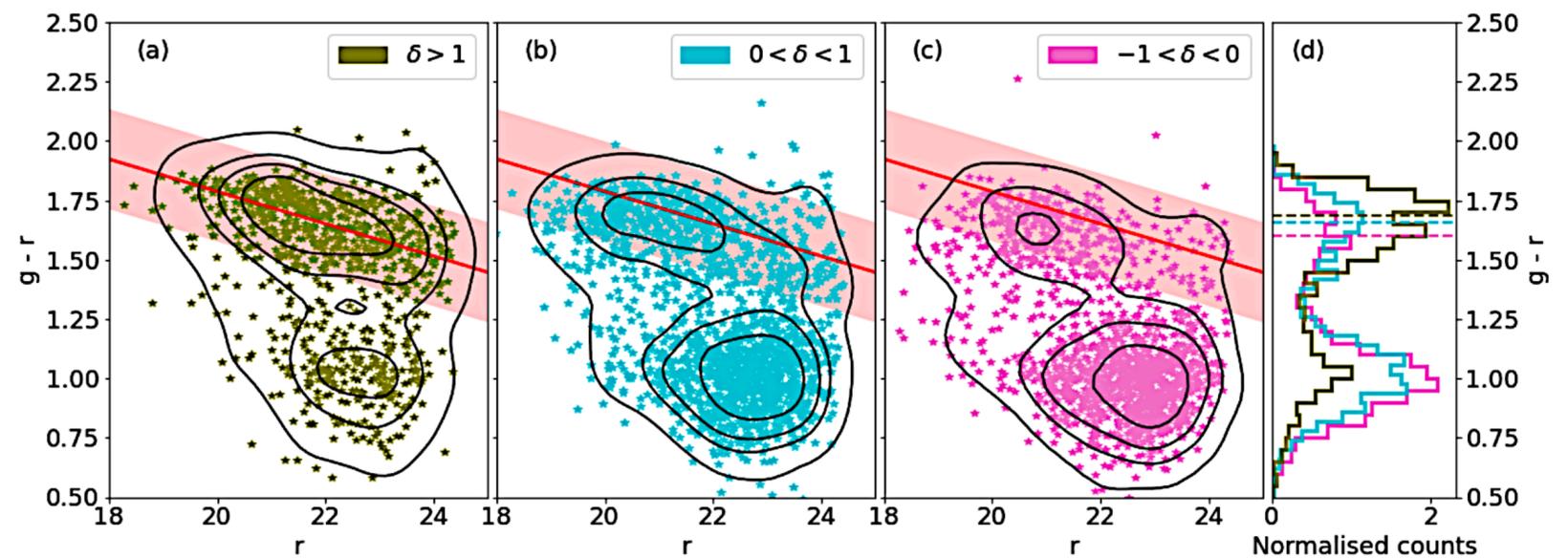
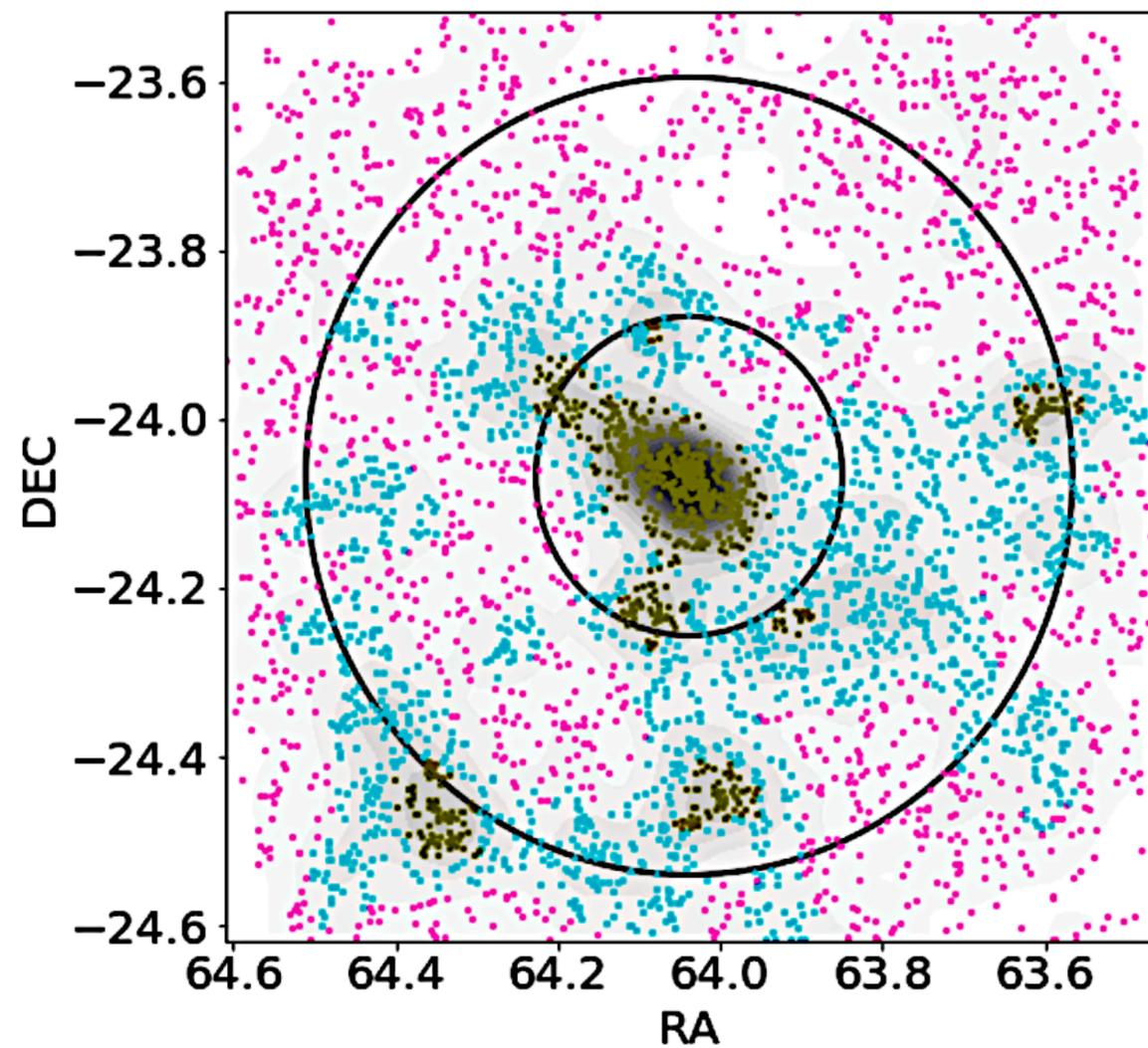
AAOMEGA

data for a spectroscopic follow up, up to 5.5 R₂₀₀ (10 Mpc)

What does MACS J0416 look like?

Studying the density in the cluster.... (up to $5.5R_{200}$)

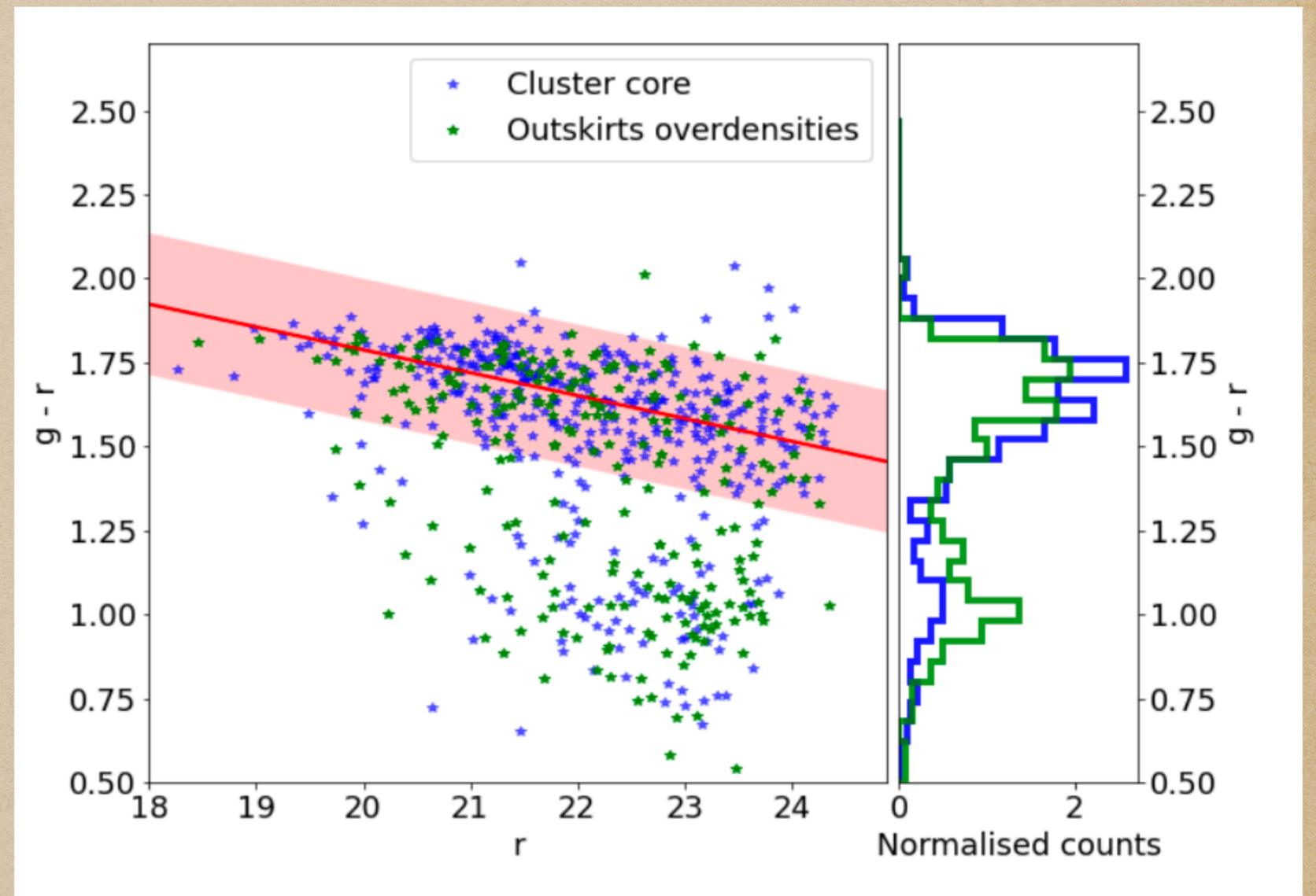
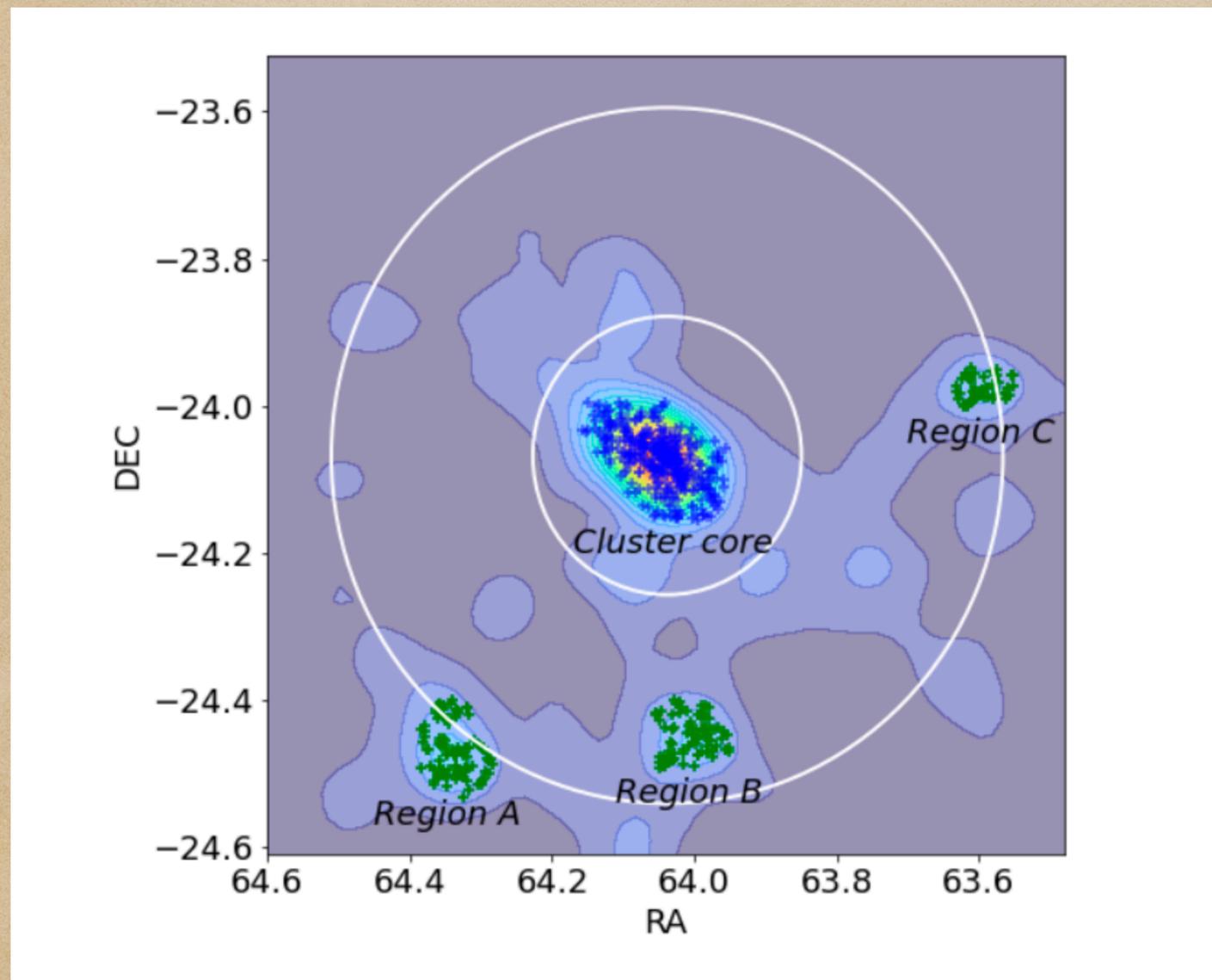
Different properties of the galaxies in the different cluster density



Estrada et al, +23

What does MACS J0416 look like?

Three photometric overdensities in the outskirts \rightarrow Similar colors of the inner part



Are we actually tracing the PRE-PROCESSING ?????

AA OMEGA Spectrograph for the outer regions of MACS J0416

OPTICON PROPOSAL 21B/008

(PI A. Mercurio)

Observations : 2 nights

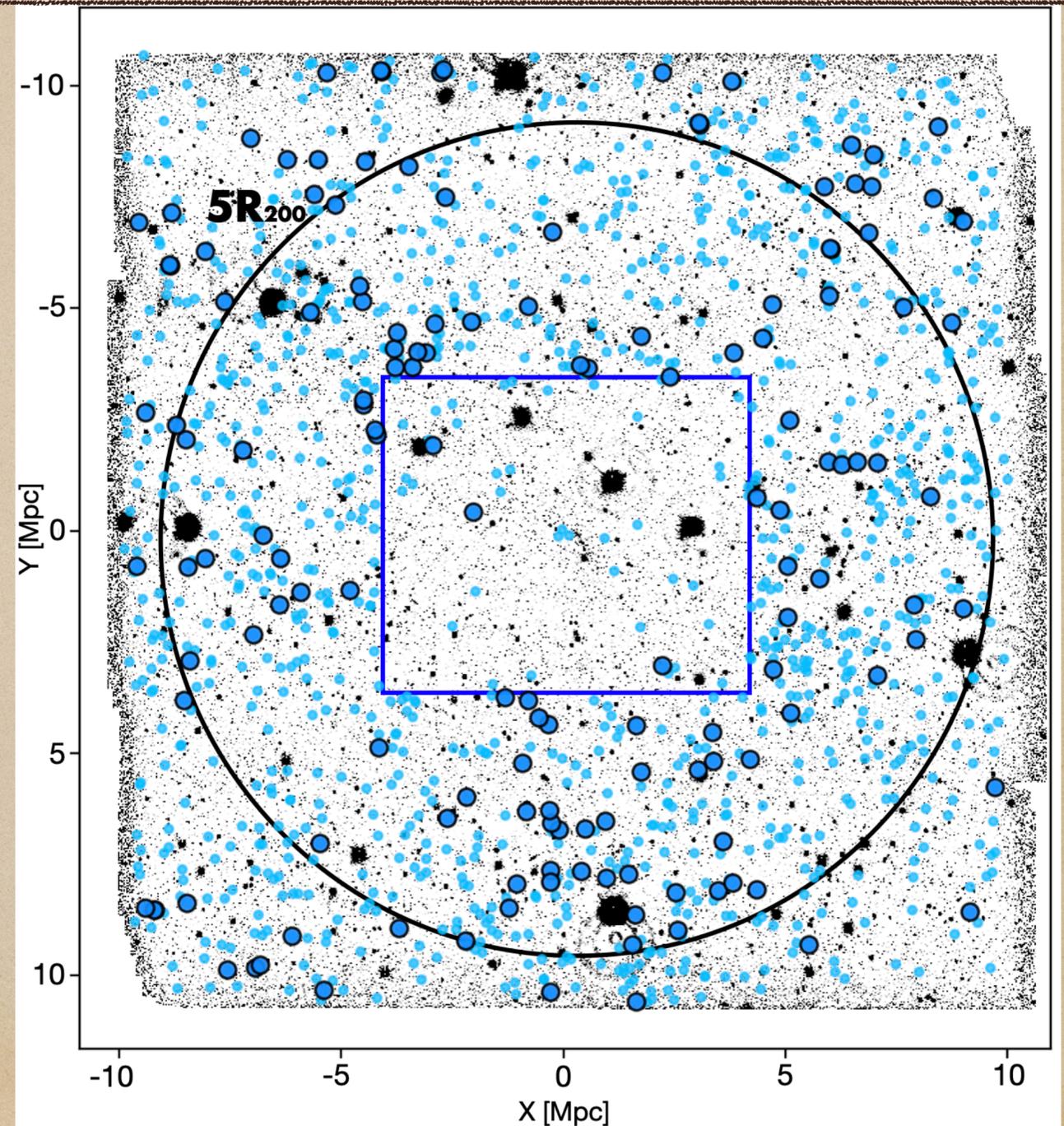
Redrock & Redmost



Z spec for ~ 1236 sources
up to $5.5 R_{vir}$ ($1 R_{vir} = 1.82$ Mpc)

$V < 21.5$ mag and $S/N > 5$ per Å

VST i-band image covering 1 deg^2 (~ 20 Mpc), with measured AA Omega (cyan) over the redshift range $z = [0.02 - 6.2]$. The filled blue circles represent the 148 fiducial members of MACS0416.

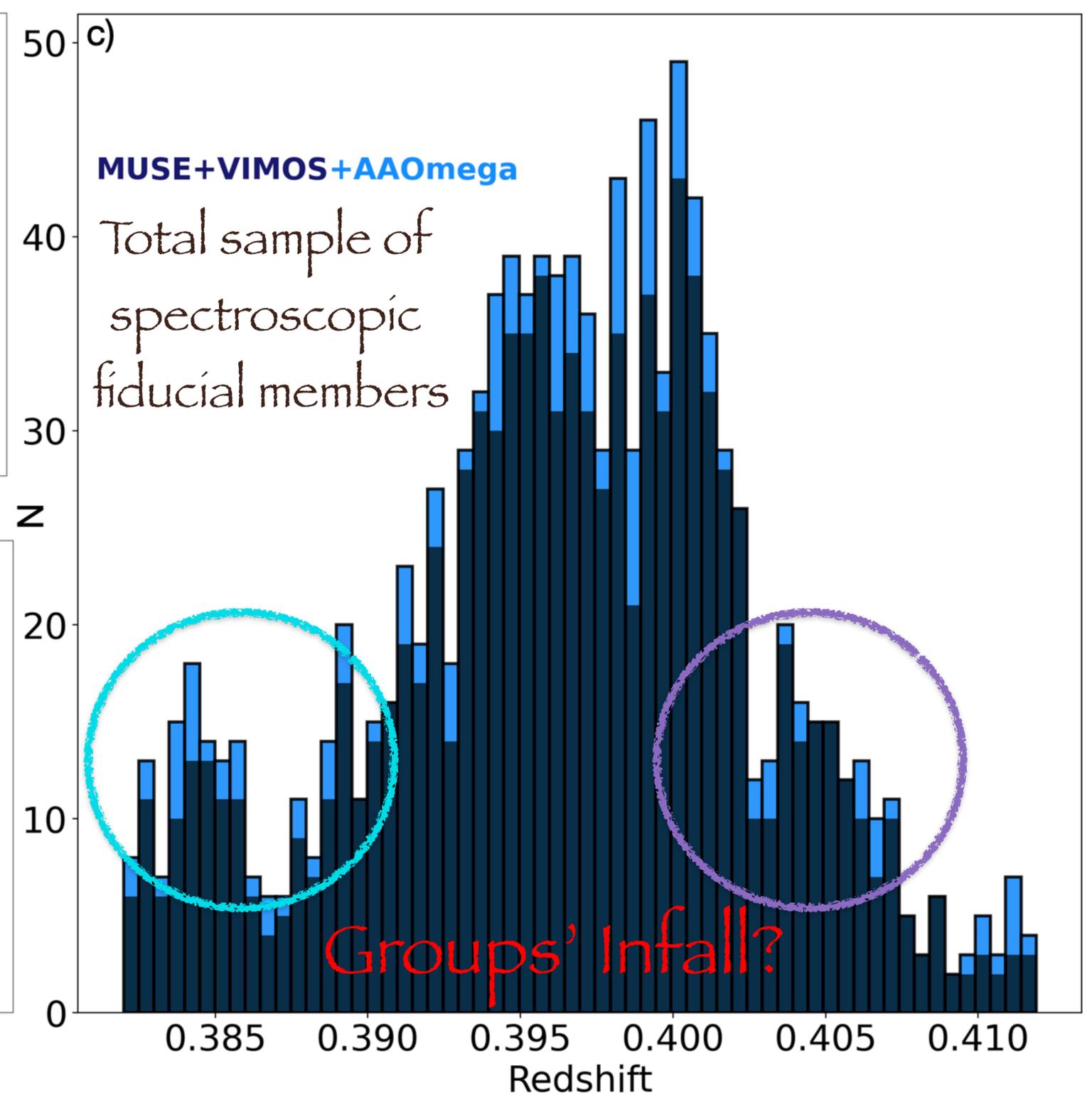
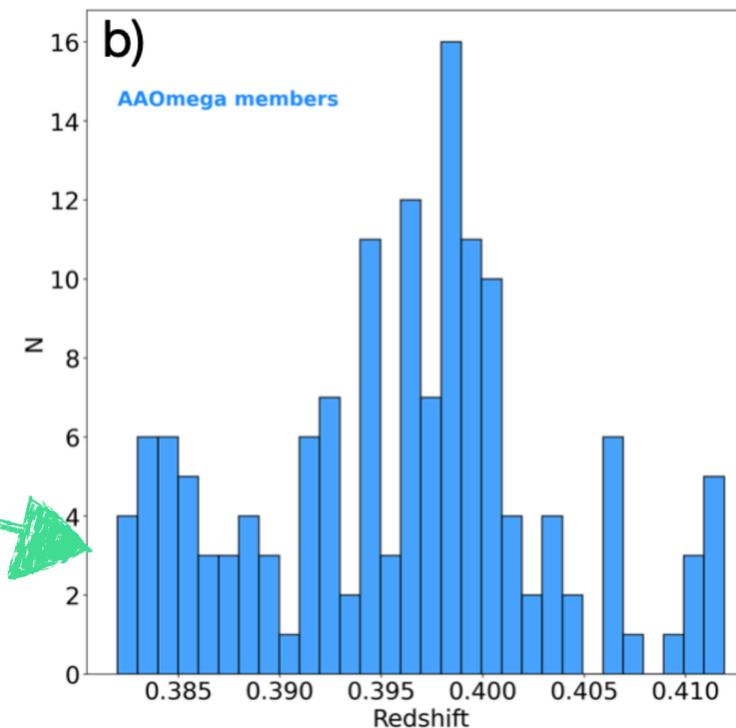
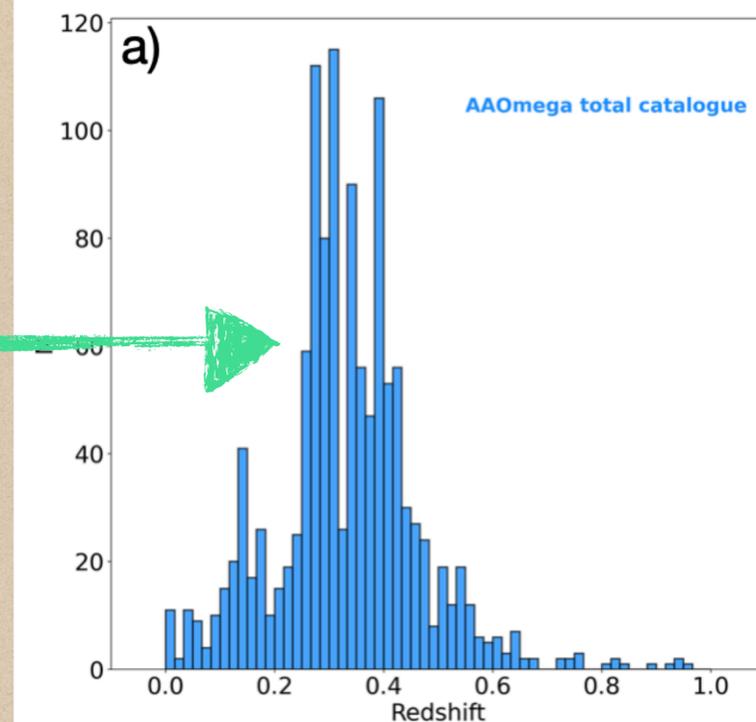


AA Omega Spectrograph for the outer regions of MACS J0416

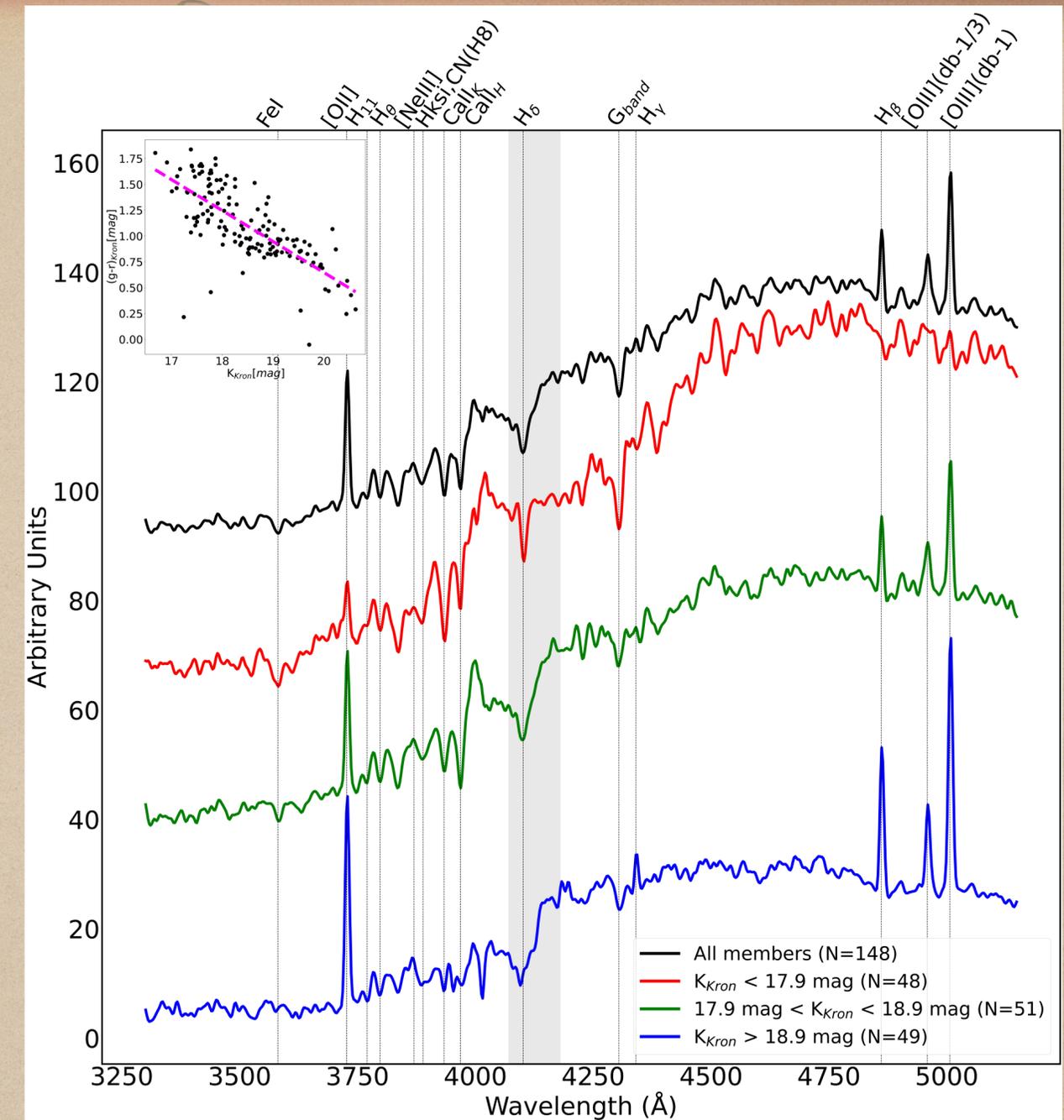
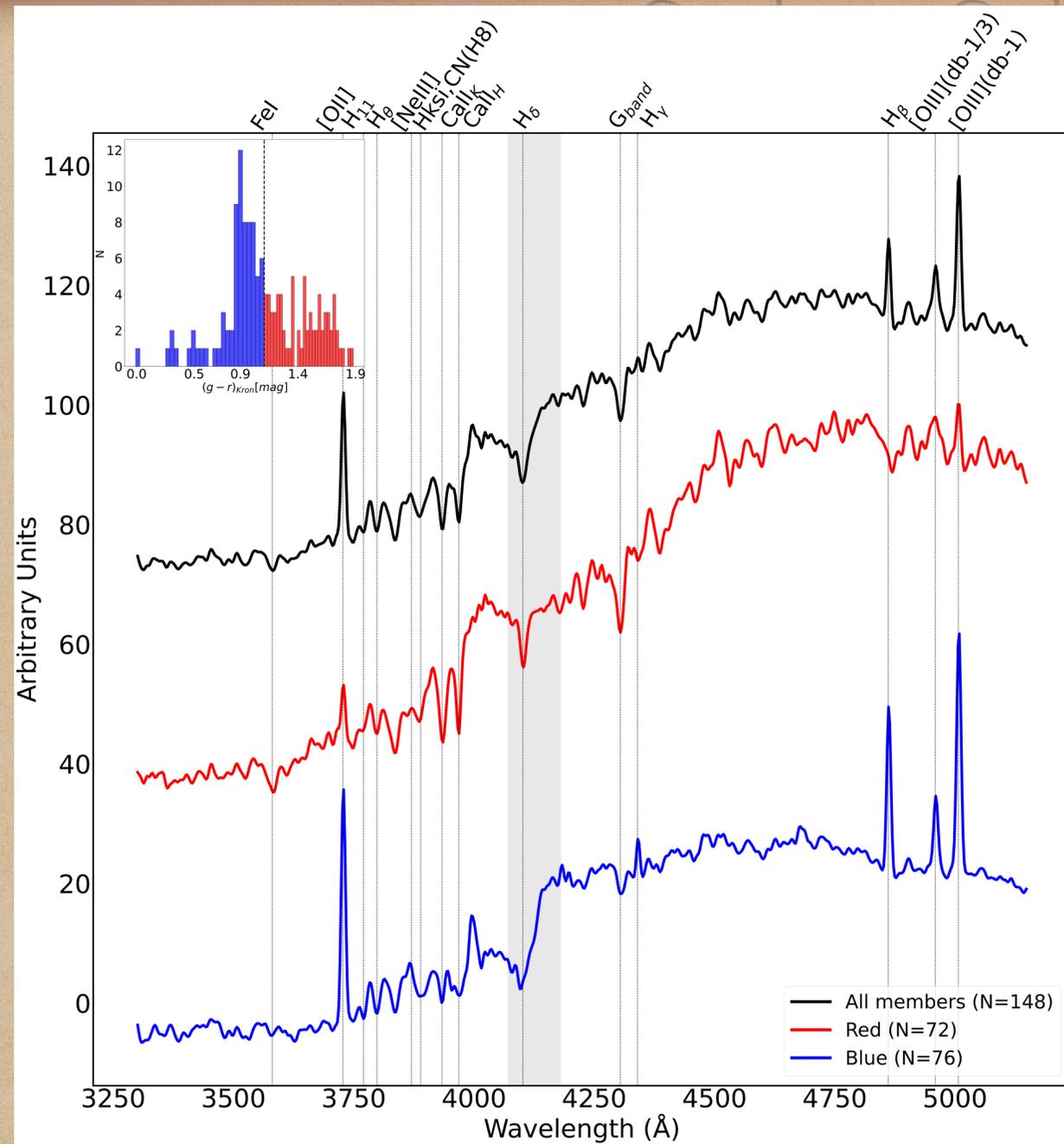
1236 new & unique objects

Zooming into...

148 spectroscopic cluster members from AAOmega observations



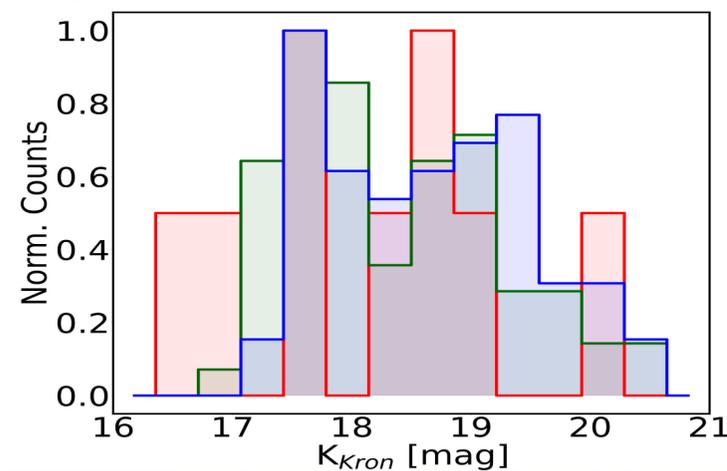
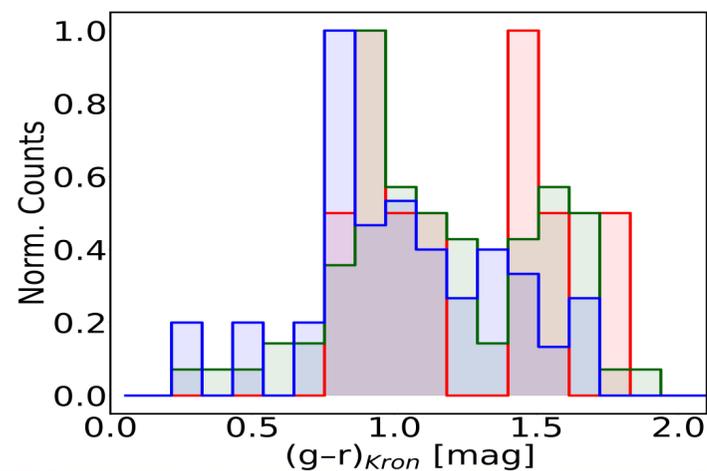
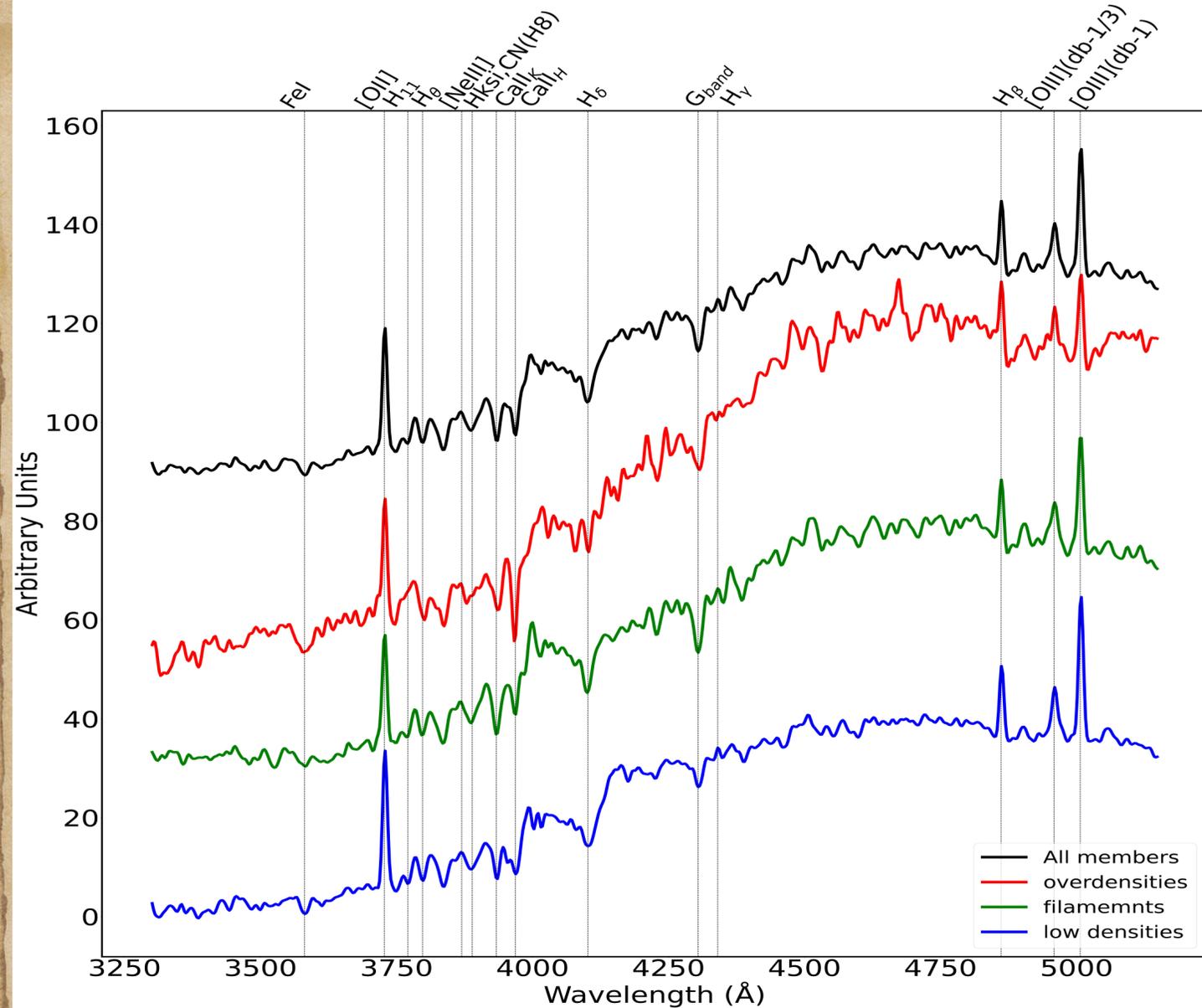
AA Omega Spectrograph for the outer regions of MACS J0416



Average spectral properties of our AA Omega sample as a function of color.

Average spectral properties of our AA Omega sample as a function of stellar mass.

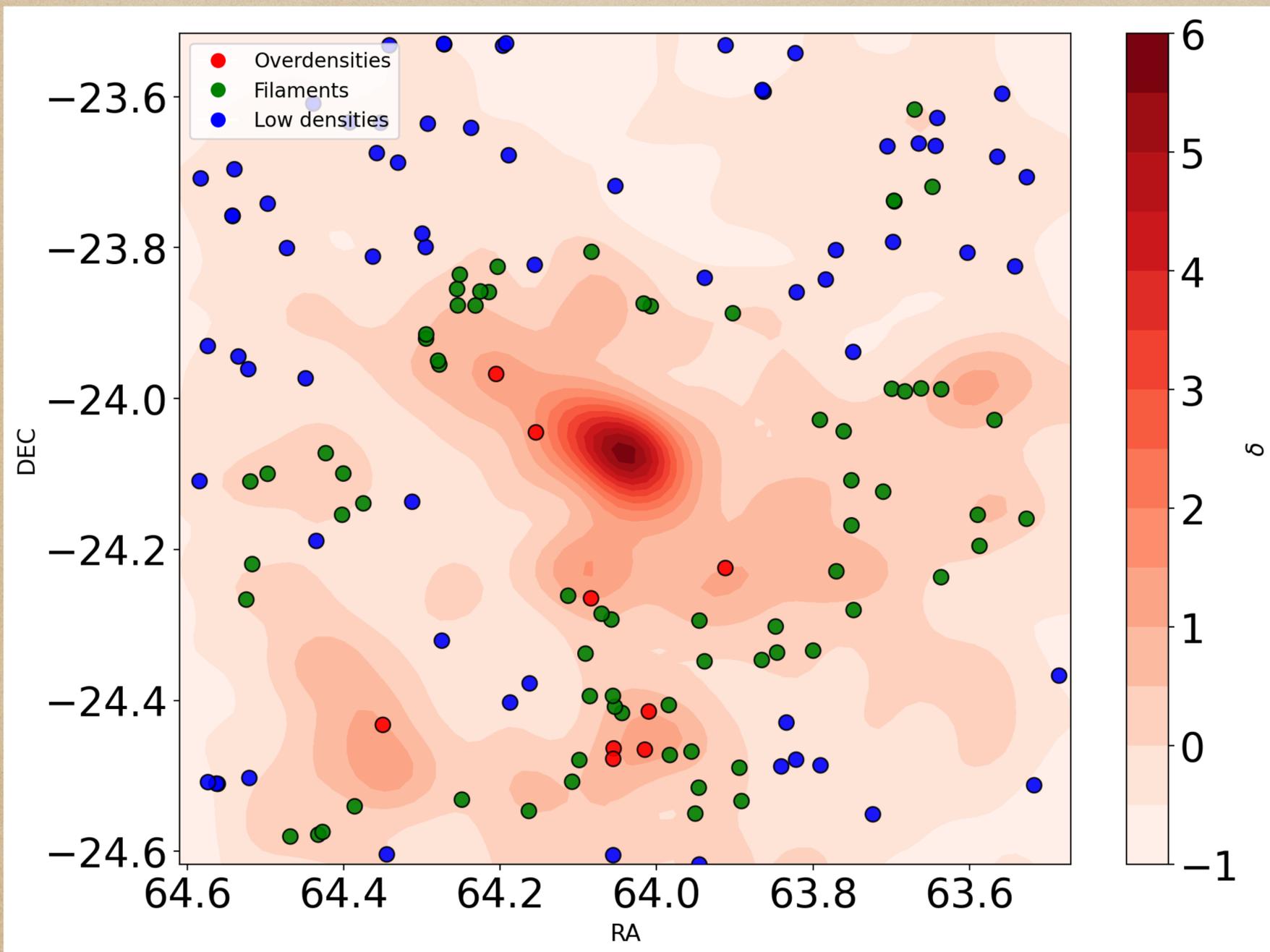
AA Omega Spectrograph for the outer regions of MACS J0416



Average spectral properties of our sample as a function of the local environment. The entire sample was divided into three subclasses based on the three bins of density δ : overdensities, filamentary regions, and low densities.

AGAIN: groups' infall??

AA Omega Spectrograph for the outer regions of MACS J0416



81 members out to 148 (~ 60%)
found in the overdensity
regions (clumps plus
filamentary regions)



PRE-PROCESSING scenario
as a fundamental role

Take home messages & the future...

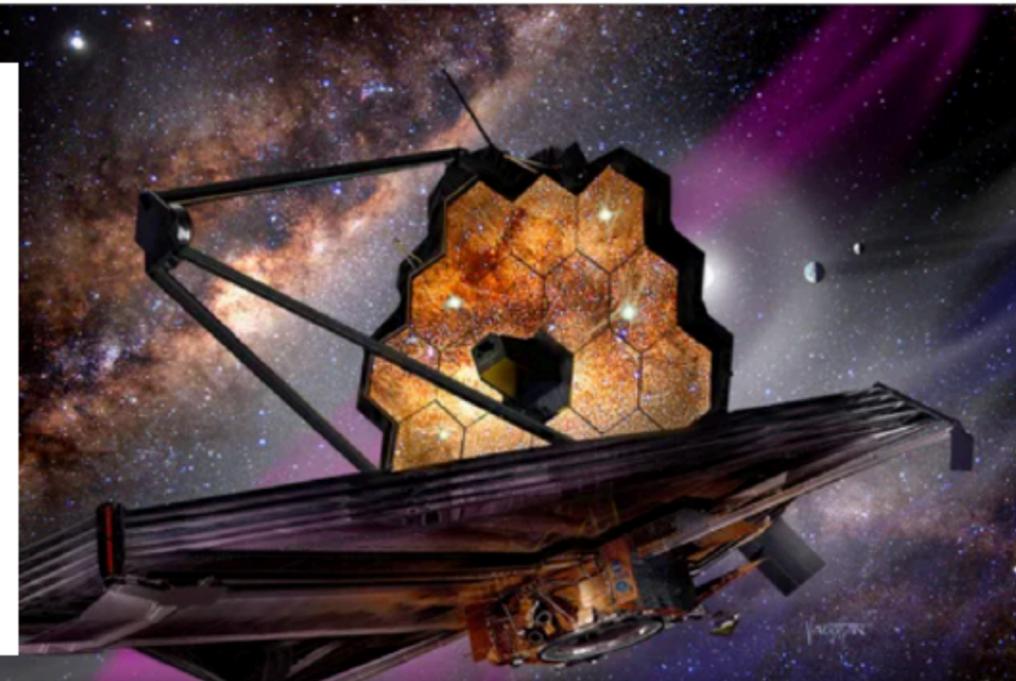
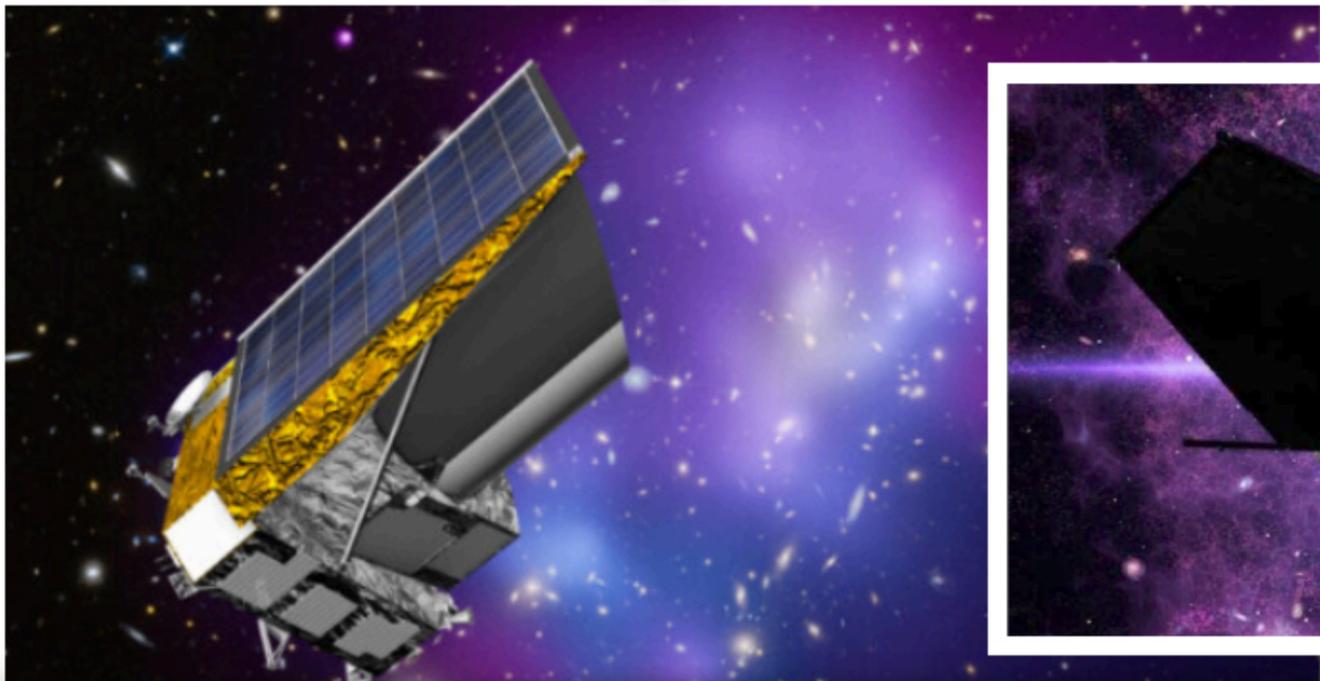
- ◆ 1236 new spectra up to $5.5 R_{vir}$ \rightarrow 148 new spectroscopic members;
 - ◆ Qualitative trends with color, mass and density;
 - ◆ Clear correlations between the environment and galaxy properties;
 - ◆ 81 galaxies associated with both overdensities and filamentary regions;
-
- ◆ SFHs, dynamical analysis, mass assembly history...;
 - ◆ More targets to analyze (another OPTICON proposal won but AAOmega out of work)!!

All research involves some elements of risk. There is no guarantee that the universe will conform to our arrangements.

THANKS FOR
THE ATTENTION

PREPROCESSING SCENARIO AS A MAIN CHANNEL IN SHAPING MASS ASSEMBLY IN MASSIVE GALAXY CLUSTERS

The -imminent- Future



MORE AND MORE IS COMING.....

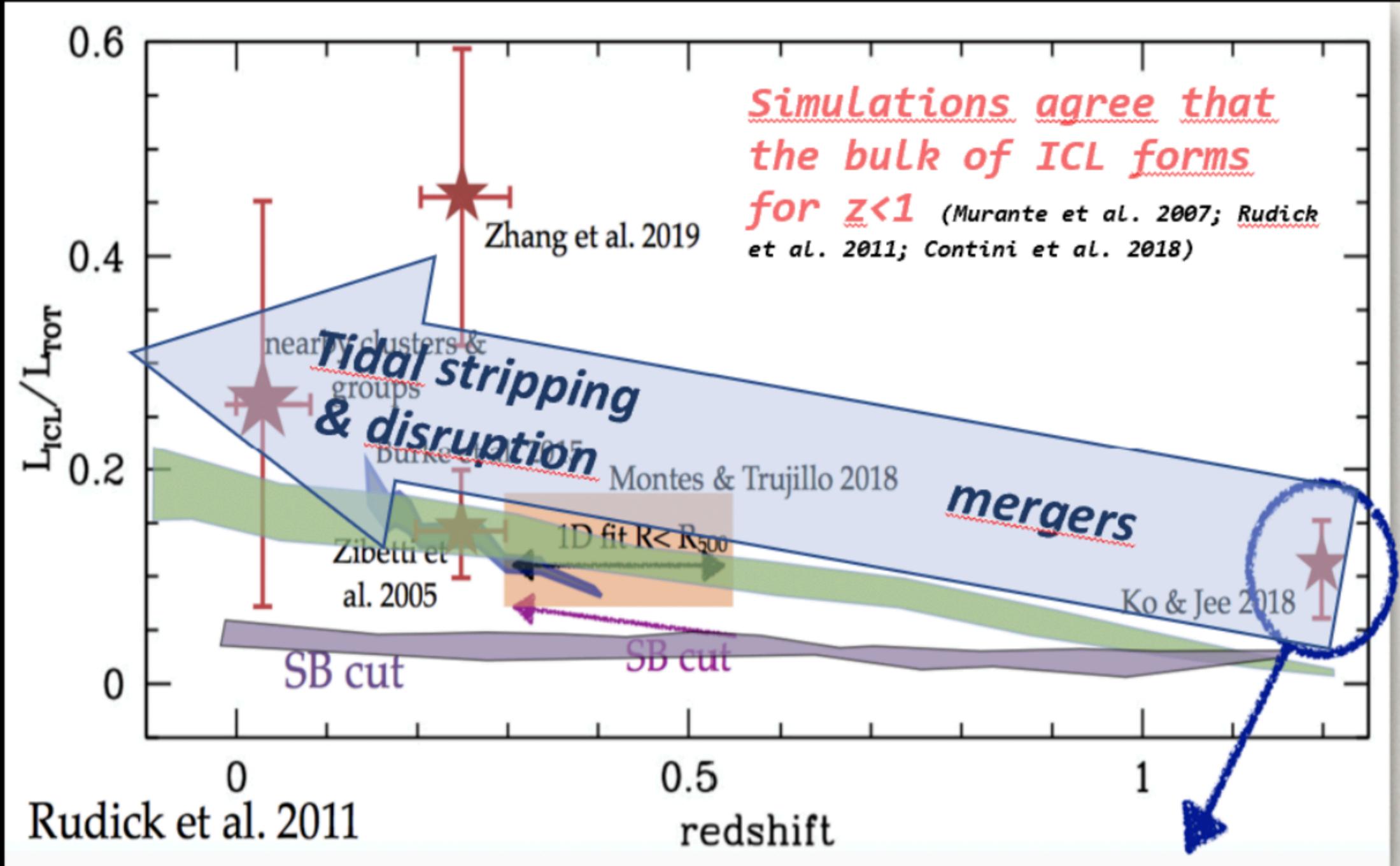


ICL with HST at $z=1.24$

$$F_{\text{icl}} = 15\%$$



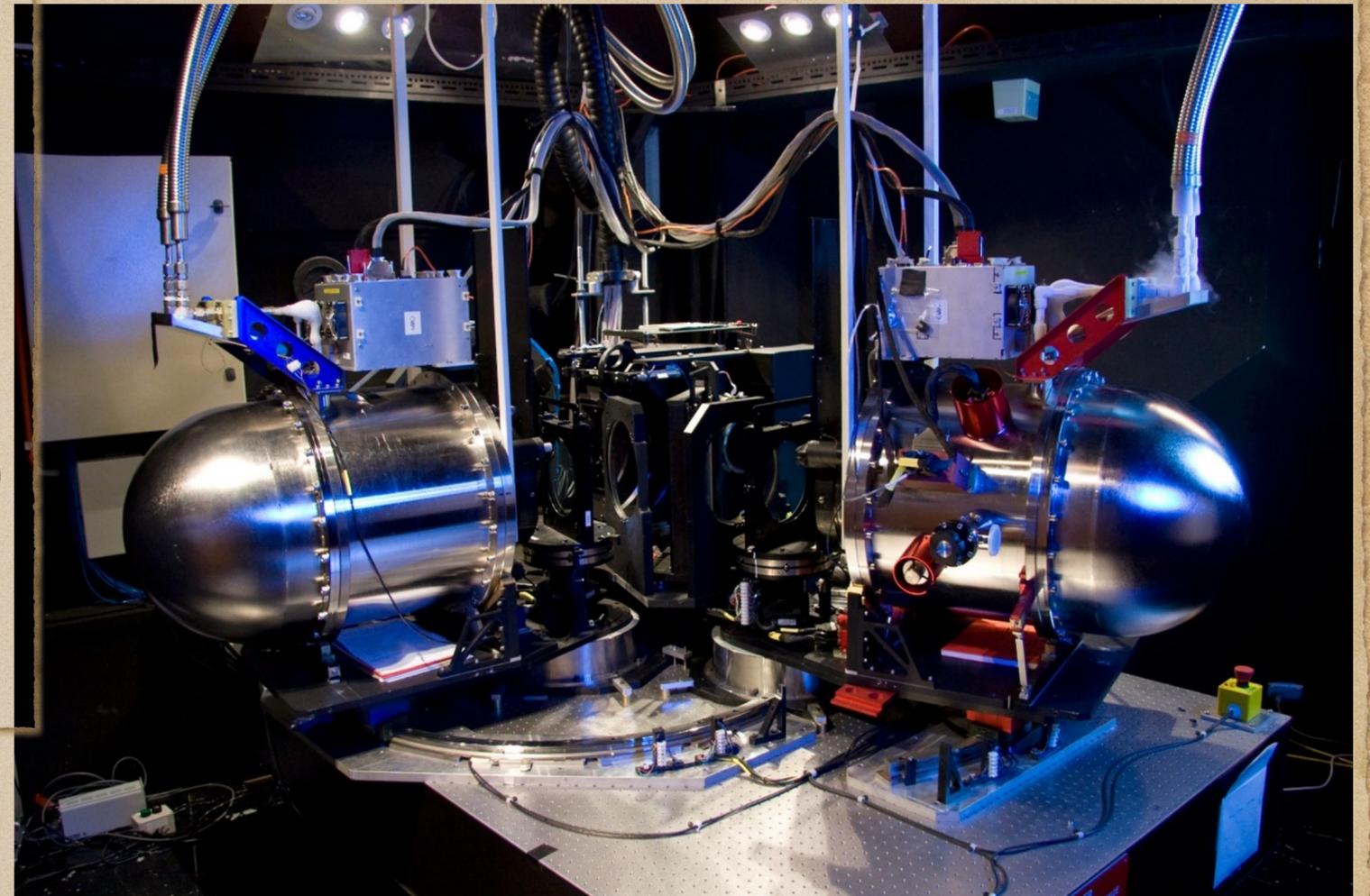
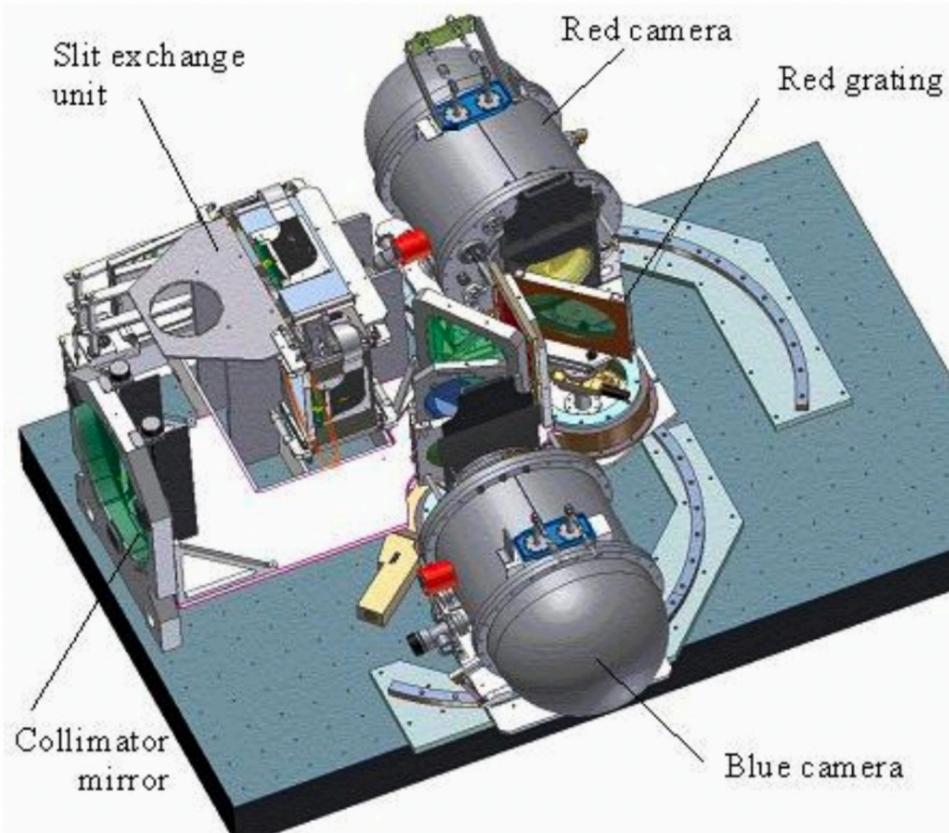
TOO MUCH???



OUTLIER

AAOMEGA spectrograph

- Mounted on Anglo-Australian Telescope
- Dual-beam Spectrograph:
Blue and Red arms (370nm - 850nm)
- 392 fibers on prime-focus focal plate (2dF)



- FOV: 2 degrees diameter
- on-sky aperture of 2"/fiber

2dFdr for AAOMEGA Spectrograph

2dFdr for AAOMEGA Spectrograph

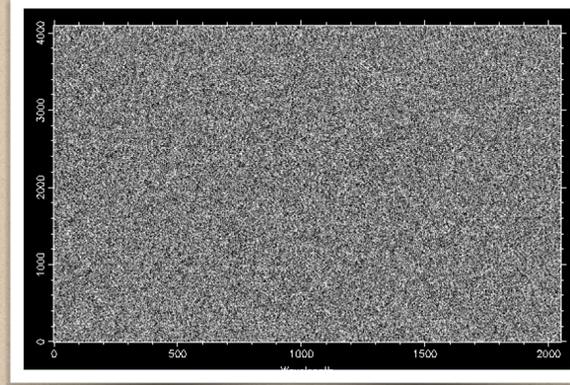
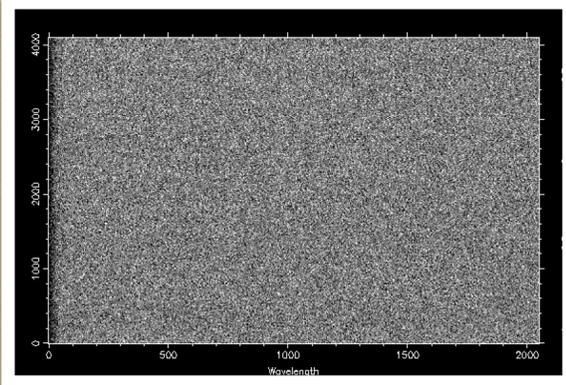
Graphical Interface

3. SKY SUBTRACTION

2. FLAT FIELDS

already present in the Science Folder

1. STEP: BIAS & DARK REDUCTION



4. COMBINED in each CCD

5. FINAL COMBINED (Join of the 2 CCDs)

Instrument: AAOMEGA-2DF
CCD1 02nov1_

/Users/rossellaragusa/Desktop/FINAL_REDUCTION/NIGHT1_FIELD1/CCD1

Data Files | General | Extract | Calib | Sky | Combine | Plots | RnD

Data Files	Class	Status
▷ 02nov10045.fits	MFARC	Reduced
▷ 02nov10046.fits	MFFFF	Reduced
▷ 02nov10048.fits	MFOBJECT	Reduced
▷ 02nov10049.fits	MFOBJECT	Reduced
▷ 02nov10050.fits	MFOBJECT	Reduced
▷ 02nov10051.fits	MFOBJECT	Reduced
▷ 02nov10052.fits	MFOBJECT	Reduced
▷ 02nov10053.fits	MFOBJECT	Reduced
BIAScombined.fits	BIASRED	Combined
DARKcombined.fits	DARKRED	Combined
02nov1_combined.fits	MFSOBJECT	Combined

Automatic Processing of Unreduced

Start Auto Reduction | Stop Auto Reduction

What does MACS J0416 look like?

Deep and wide
photometric data

What do we need?

Spectroscopic
data

...MACS J0416...

...and...

X-ray & radio data

HST:

CLASH survey (Postman et al.12)

Hubble Frontier Fields (Lotz et al.17)

JWST:

CANUCS survey (Willott et al.22)

VLT Survey Telescope (VST):

VST-GAME (A. Mercurio)

VISTA G-CAV (M. Nonino)

VIMOS:

CLASH-VLT (Rosati et al.14)

~800 cluster members
< $2R_{200}$

MUSE: (Caminha et al +17)

in the inner 2 arcsec^2

GLASS (P.I.: T. Treu)

What does MACS J0416 look like?

SO FAR...

known mainly for its strong lensing features

$$\theta_E > 0.35'' \quad z=2$$

$$M = 0.88 \times 10^{15} M_\odot$$

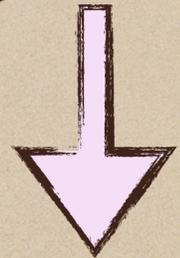
$$L_X \sim 10^{45} \text{ erg s}^{-1}$$

$$z = 0.397$$

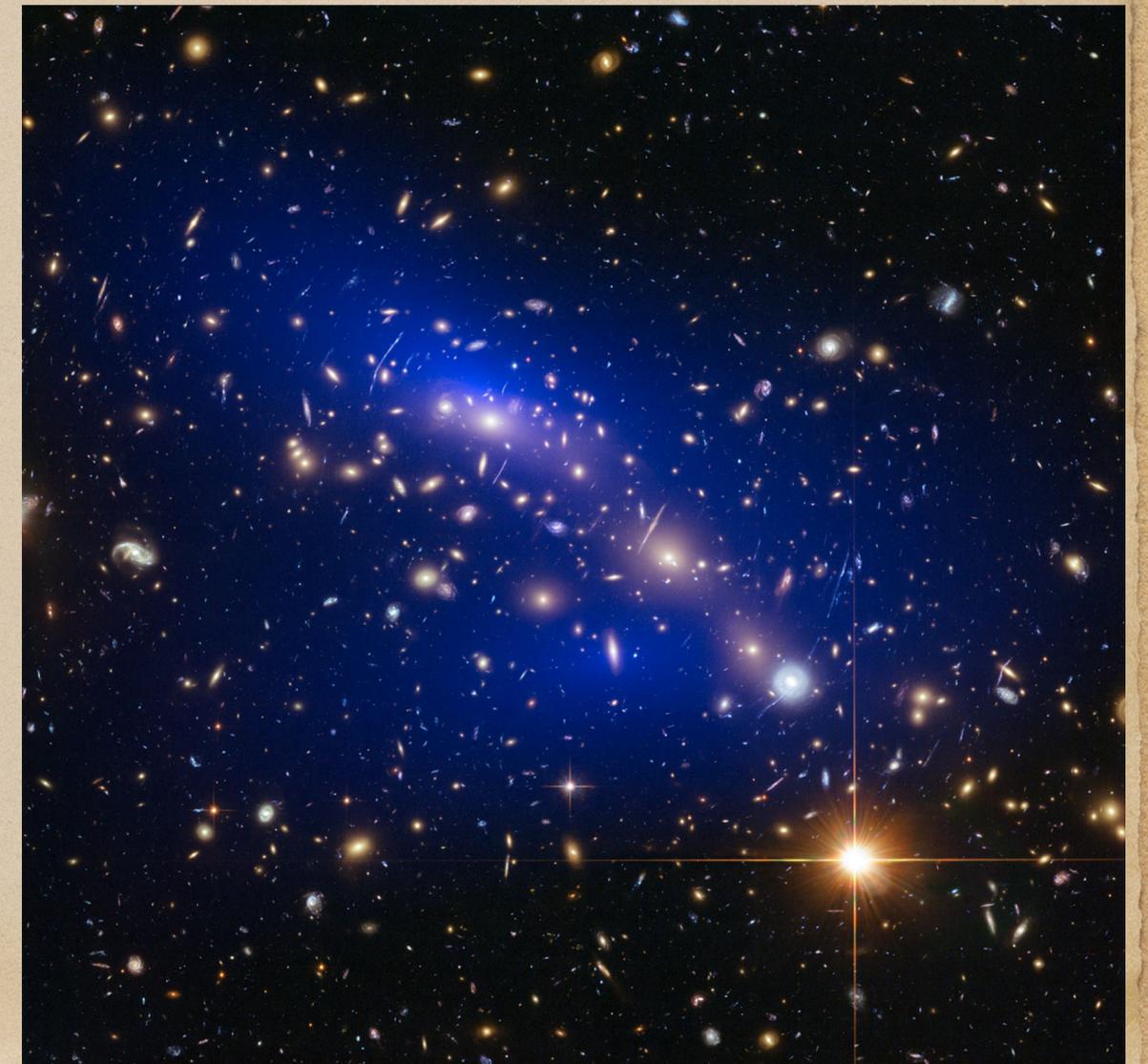
but also because of

Complex dynamical structure

Elongated morphology with 2 main sub-structures

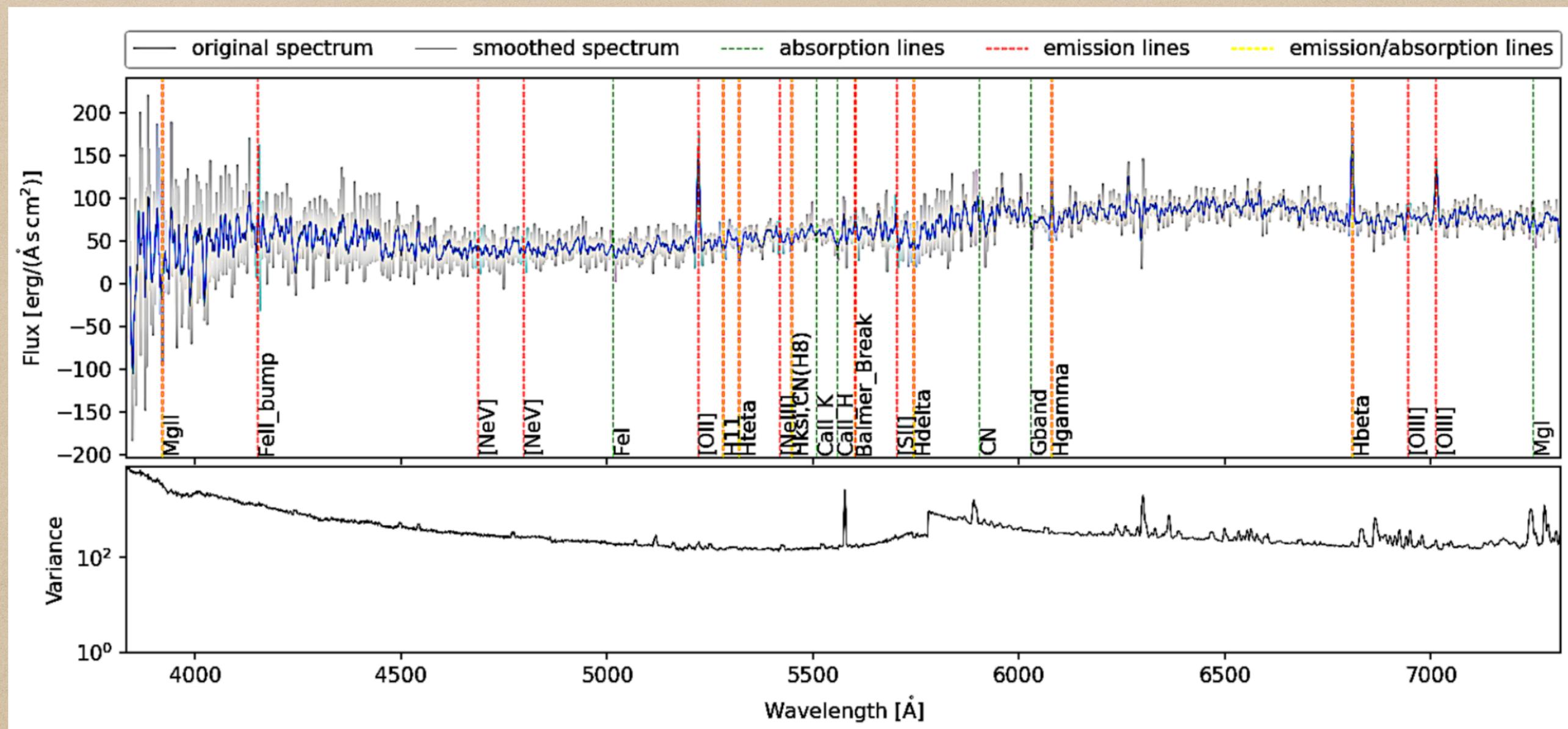


Pre-collisional phase



AA OMEGA Spectrograph for the outer regions of MACS J0416

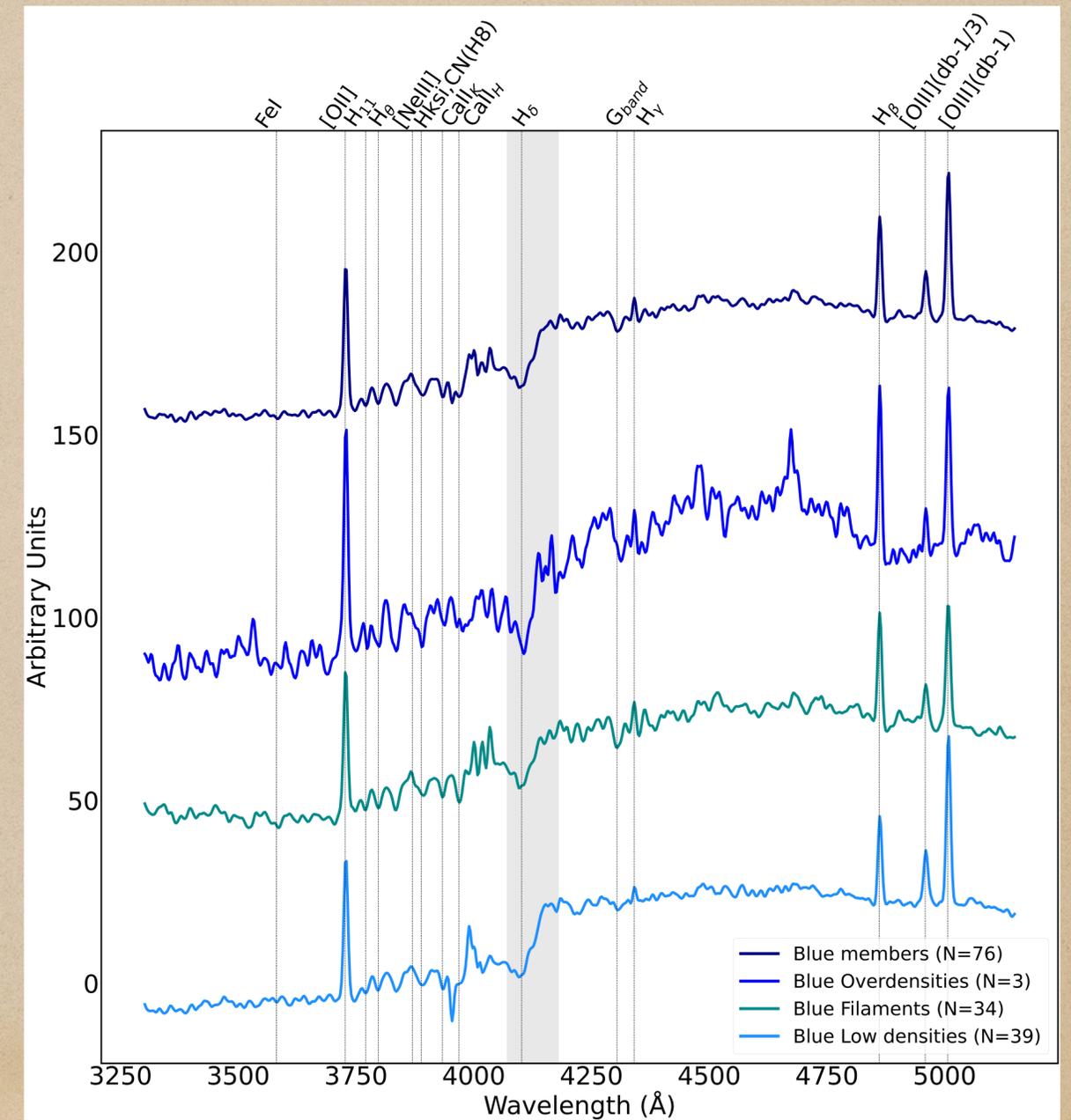
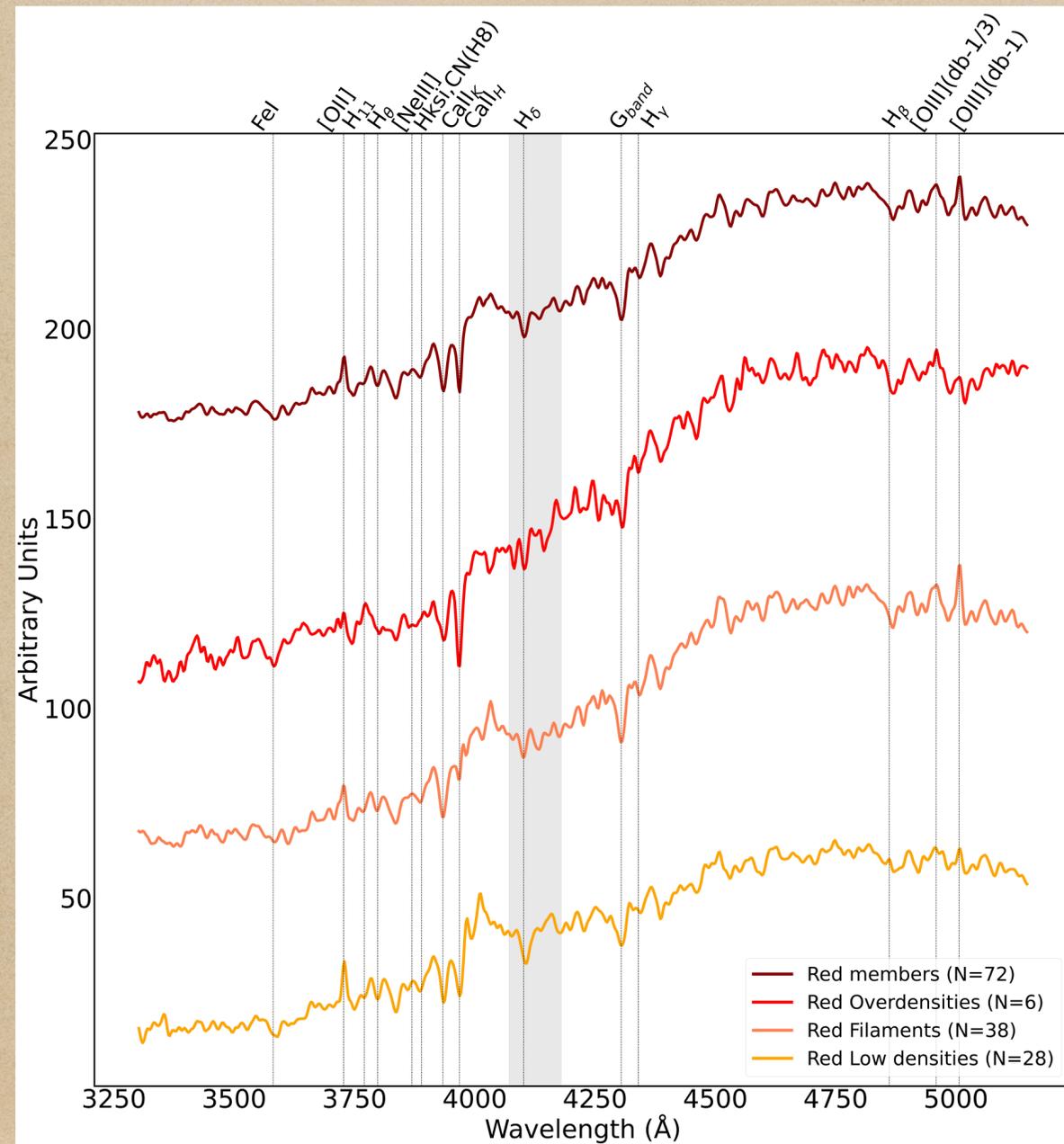
Example of one of the MACSJ0416 members spectra \rightarrow z measured with redrock



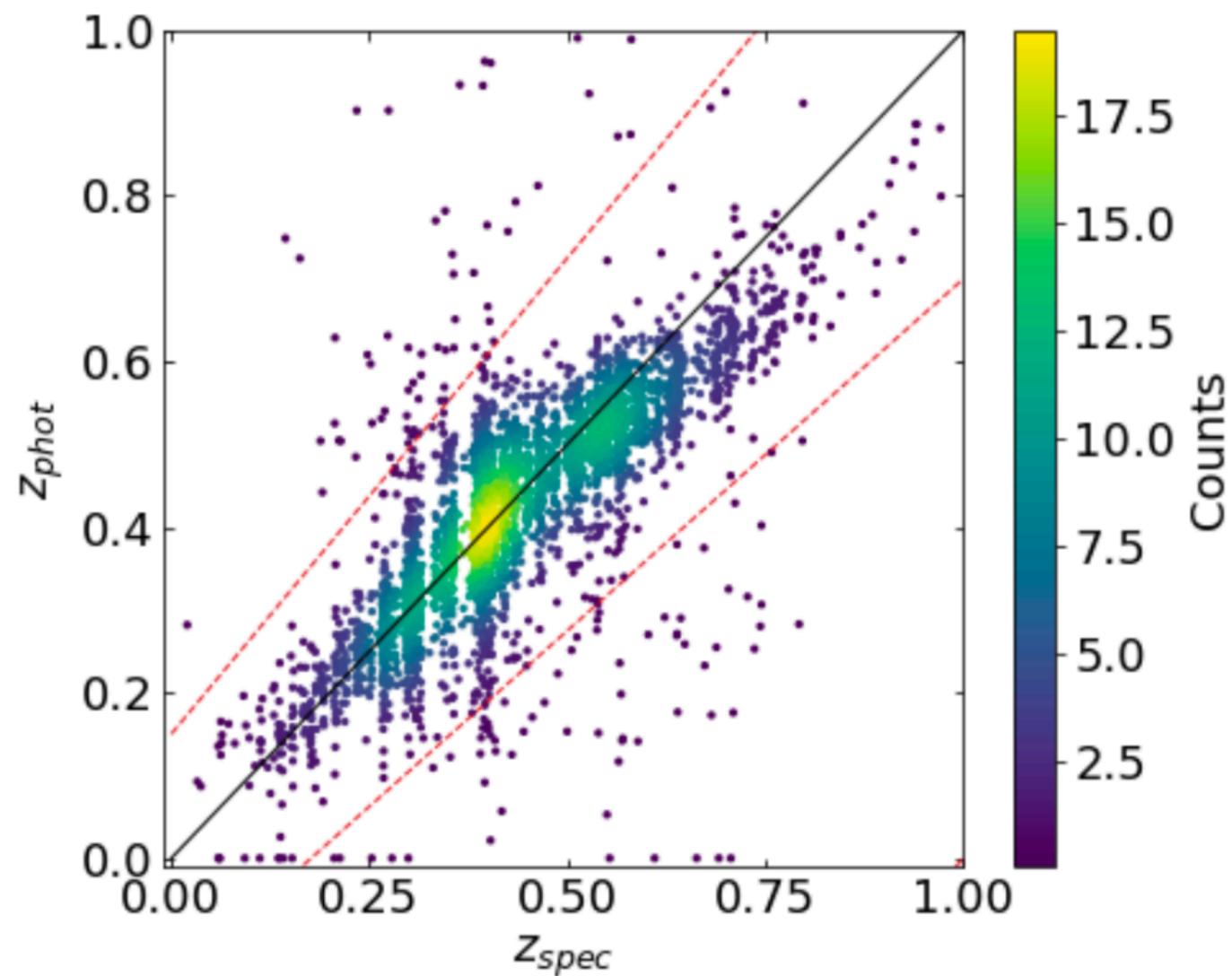
AA OMEGA Spectrograph for the outer regions of MACS J0416

Average spectral properties of our sample of red galaxies a function of the local environment.

Average spectral properties of our sample of blue galaxies a function of the local environment.

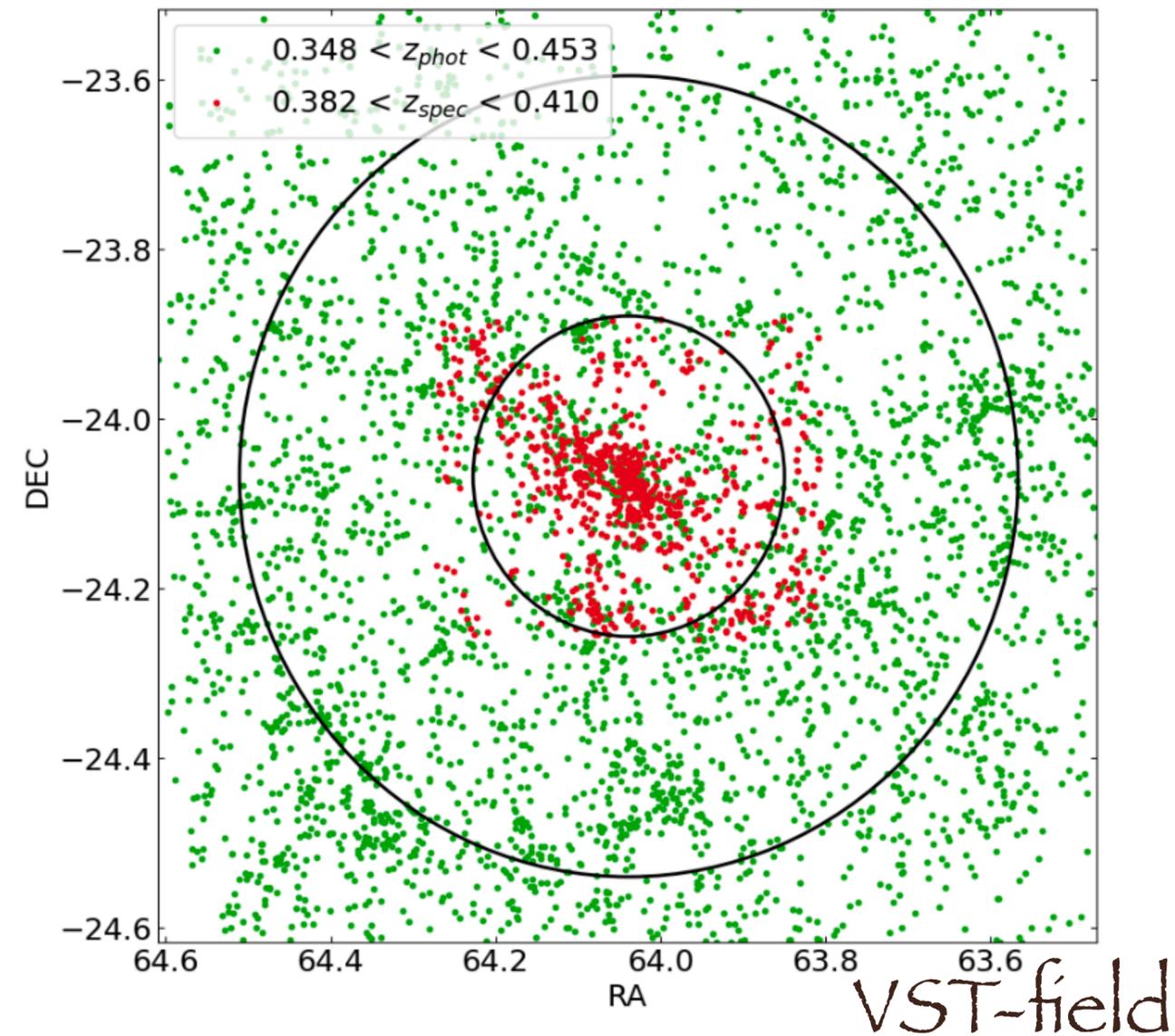


What does MACS J0416 look like?



Calibration between phot e spec z

Estrada et al, +23



In red (and up to 4 Mpc) the spec. members
In green (and up to 10 Mpc) the 4067 phot.
members with $m_r < 24.4$ mag