

LABYRINTH

THE LARGE SCALE STRUCTURE OF THE UNIVERSE

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ON BEHALF OF

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UniBo-DIFA: A. Cimatti, L. Moscardini, F. Marulli, M. Moresco

ENVIRONMENT IN (SPECTROSCOPIC) EXTRAGALACTIC SAMPLES

Scientific goals:

- 1) Cosmology (clustering, halo mass function ...)
- 2) Galaxy evolution (SF quenching, morphological transformations...)

Guidelines:

- 1) Use galaxies as tracers
- 2) Use spec-z whenever you have them!
- 3) Focus on all environments, from empty to crowded regions



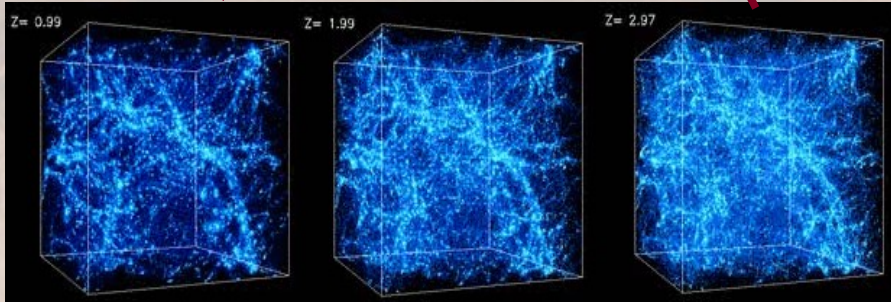
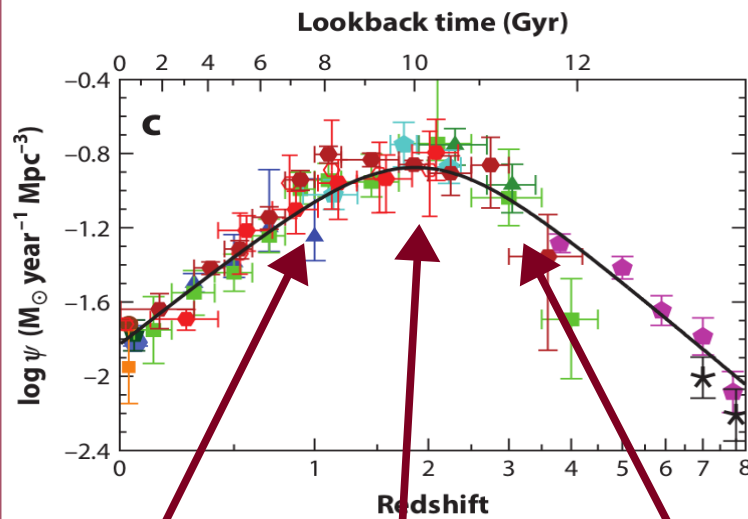
SCIENTIFIC AIMS

1) Galaxy evolution

→ how environment affects galaxy properties

→ focus on average properties of galaxy populations

Cosmic Star Formation Rate Density



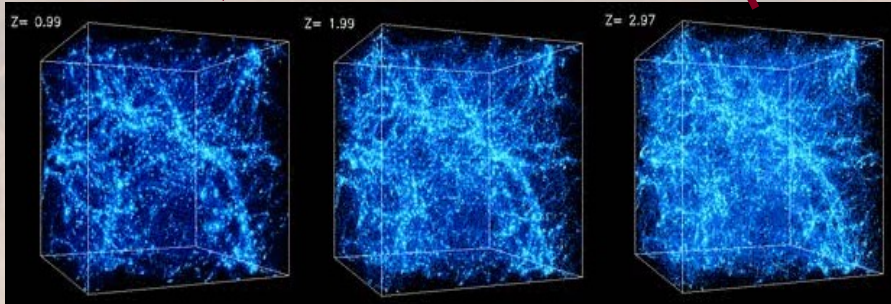
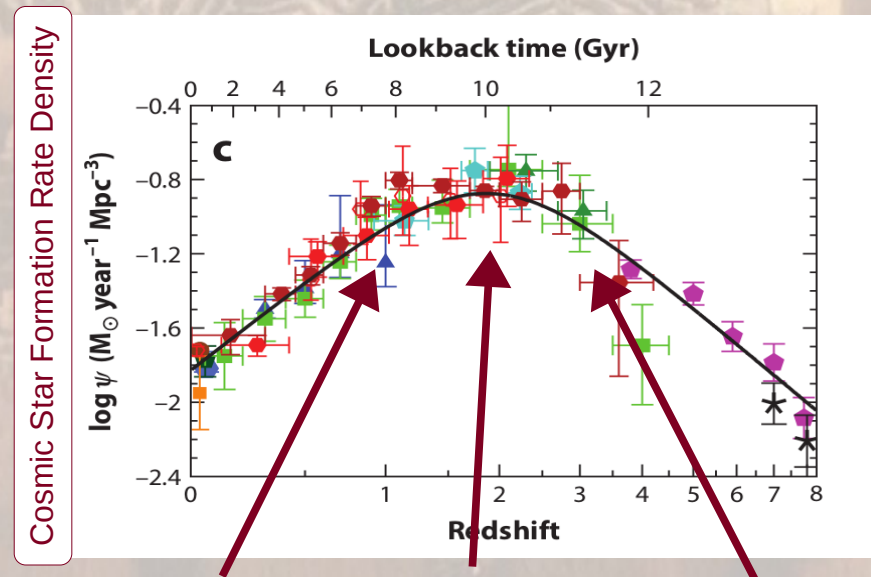
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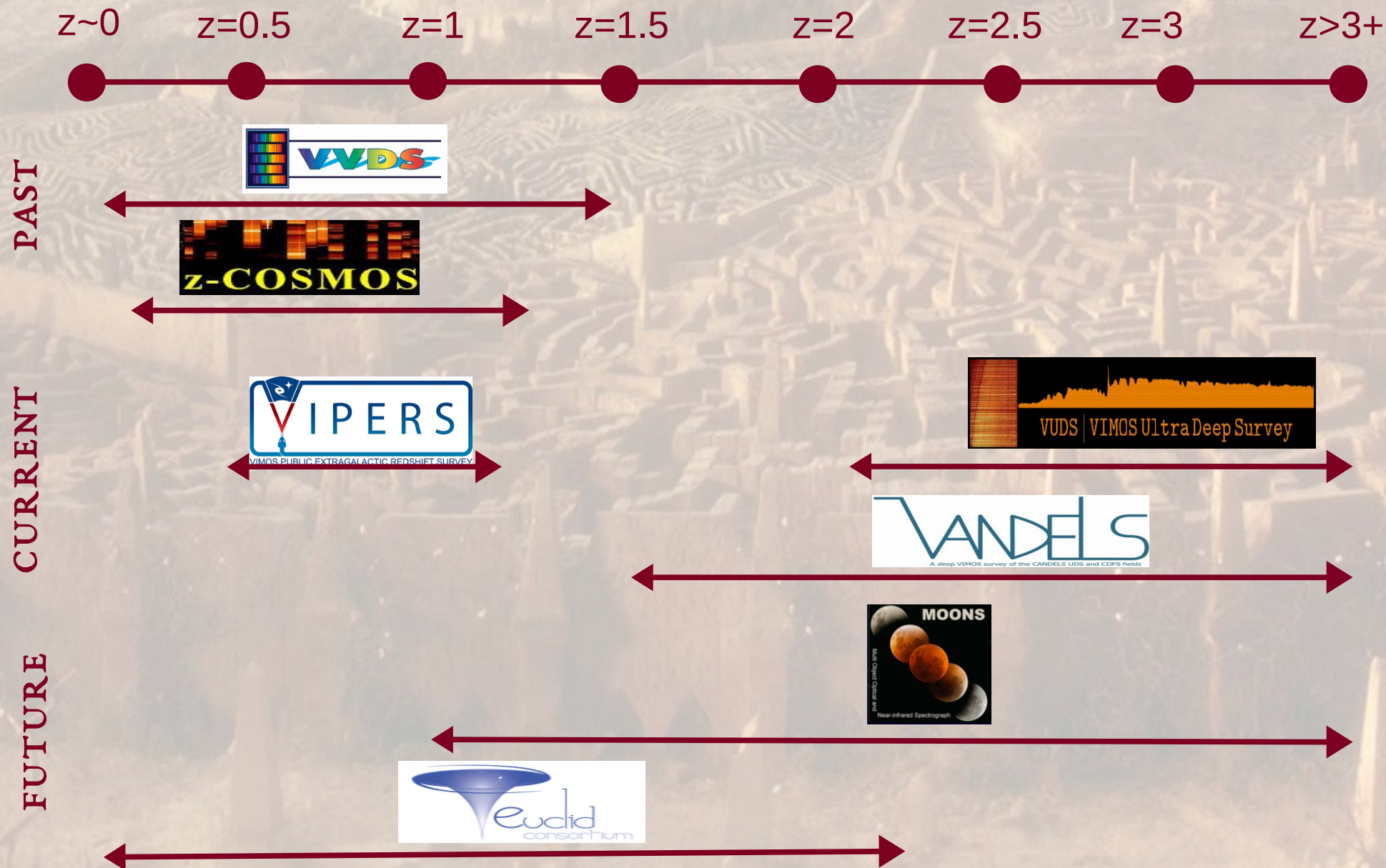
- how environment affects galaxy properties
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2) Cosmology

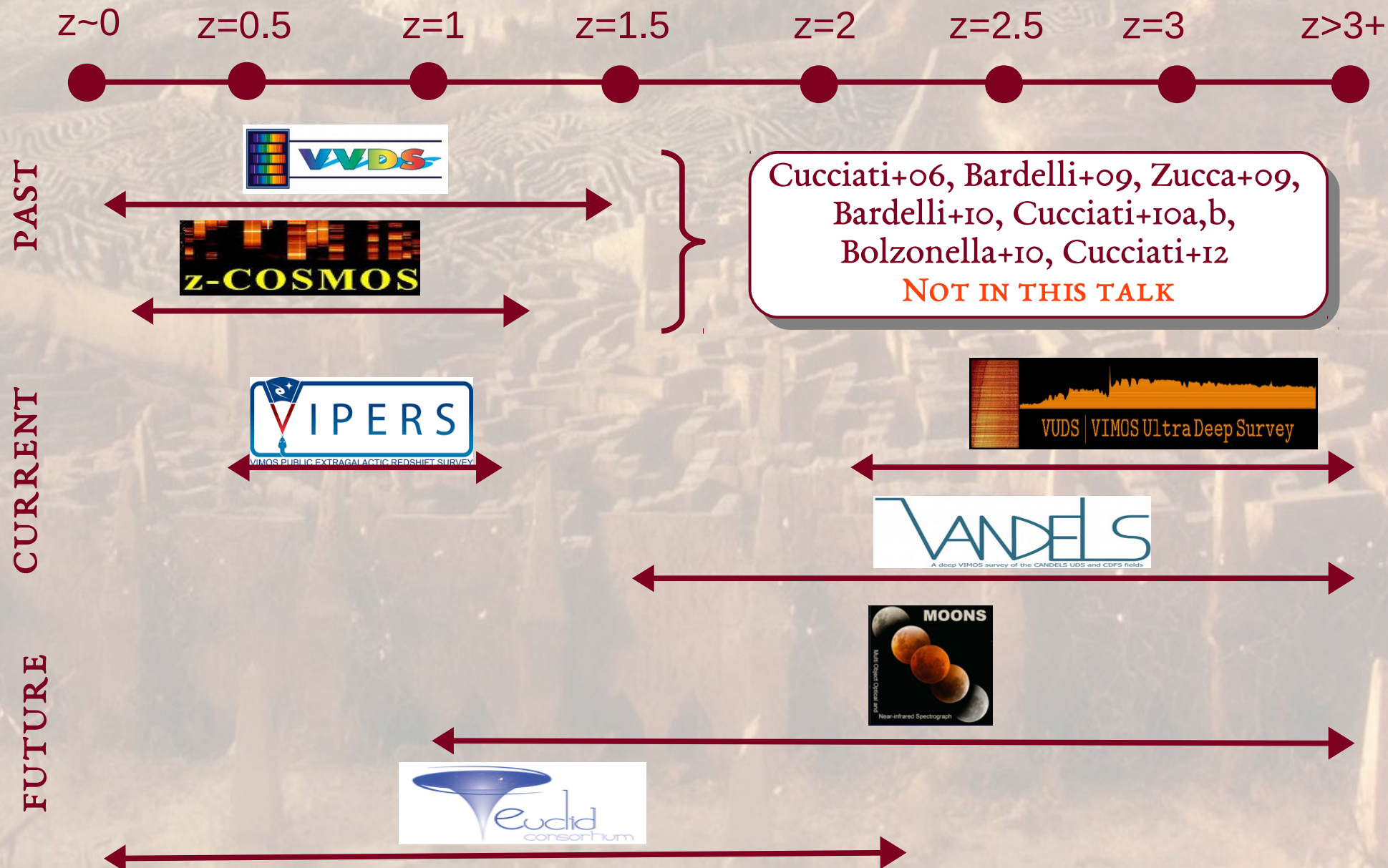
- cosmological parameters from galaxy clustering, halo mass function, etc.
- currently, clustering studies less represented in our group, but see eg the work by Alberto on “Hierarchical scaling and bias” (Capri+15)
- cosmology with galaxy clusters is one of the aim of Euclid



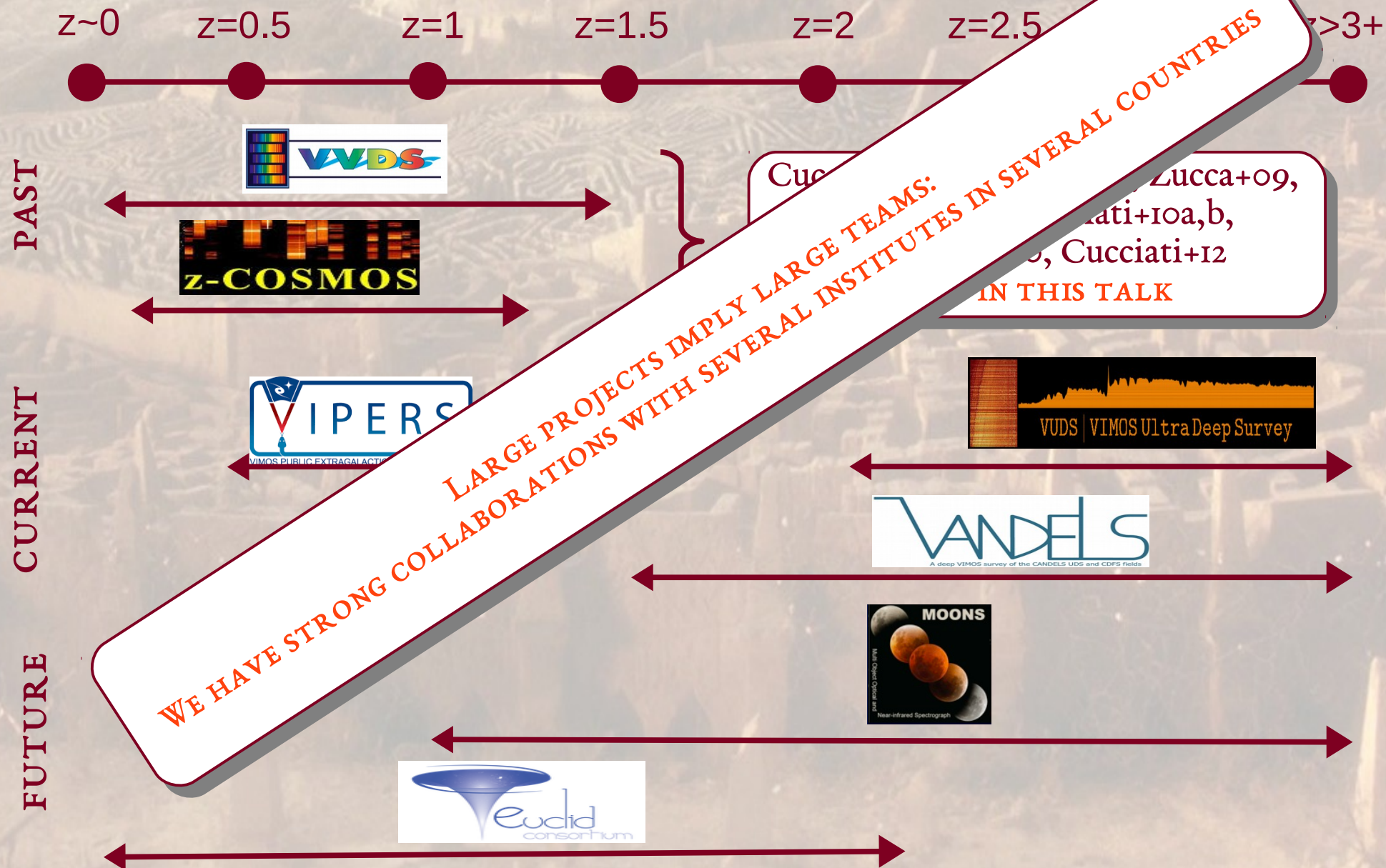
ENVIRONMENT IN (SPECTROSCOPIC) EXTRAGALACTIC SAMPLES



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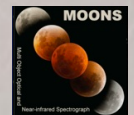
ENVIRONMENT IN (SPECTROSCOPIC) EXTRAGALACTIC SAMPLES



ENVIRONMENT IN (SPECTROSCOPIC) EXTRAGALACTIC SAMPLES

Not all projects have been designed for environmental studies, but you can always find a reason to study environment:

- **LARGE (NOT NECESSARILY DEEP) SURVEYS:** how environment acts on rare galaxy populations, like e.g. very massive galaxies
- **DEEP SURVEYS (EVEN IF IN SMALL FIELDS):** high- z study on the on-set of environmental effects on galaxy evolution
- **HIGH RESOLUTION AND/OR S/N SURVEYS:** detailed study of physical properties (metallicity...) to disentangle between different quenching mechanisms



→ APPROACHES ARE SO DIFFERENT THAT EVERY TIME YOU NEED TO **ADAPT YOUR TOOLS** TO THE SURVEY CHARACTERISTICS, OR EVEN TO **DEVISE BRAND-NEW METHODS**.

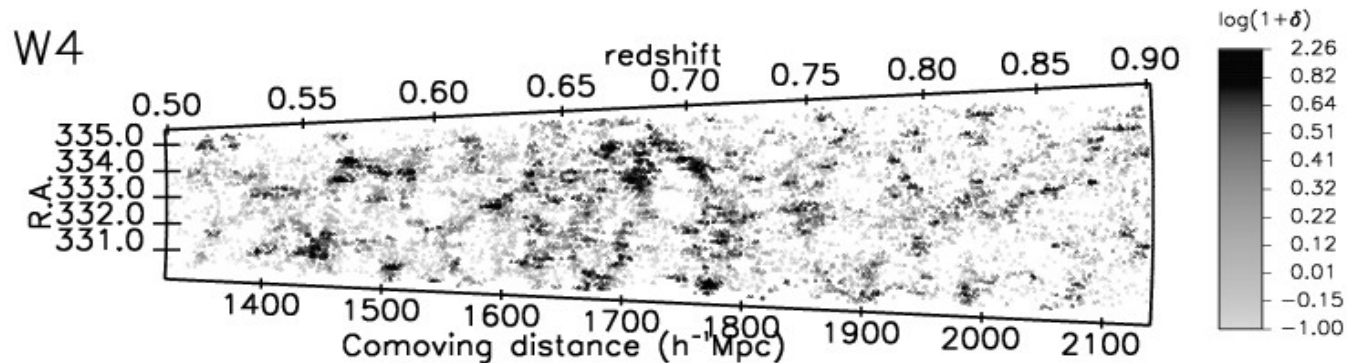
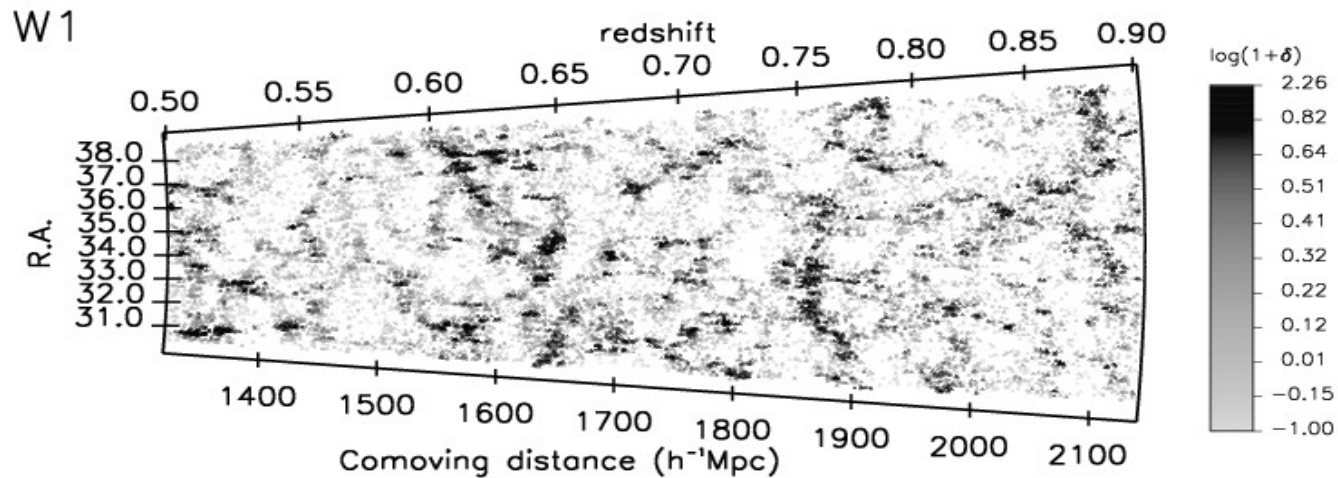


LARGE SURVEY AT $0.5 < z < 1.2$

- * RARE GALAXY POPULATIONS**
- * RICH STATISTICS OF "NORMAL" GALAXIES**
- * REDUCED EFFECTS FROM COSMIC VARIANCE**

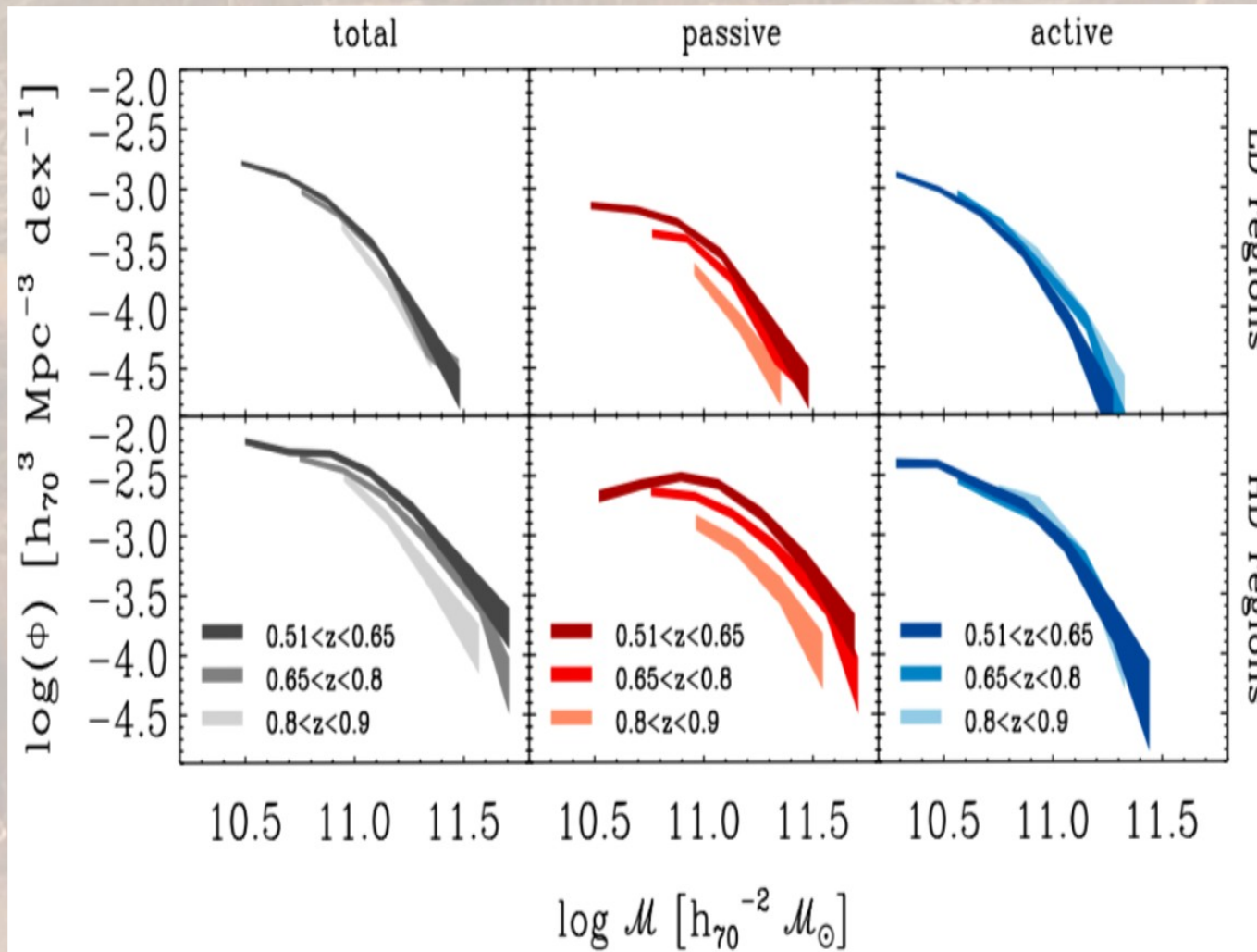


42 members in the project core team, 4 from OAS
→ Micol Bolzonella coordinator of the science related to “Galaxy evolution”



GALAXY STELLAR MASS FUNCTION PER ENVIRONMENT

(DAVIDZON, CUCCIATI, BOLZONELLA ET AL. 2016)



- **Different shape** in low and high densities

- **Evident evolution in high densities**, nearly constant in low densities

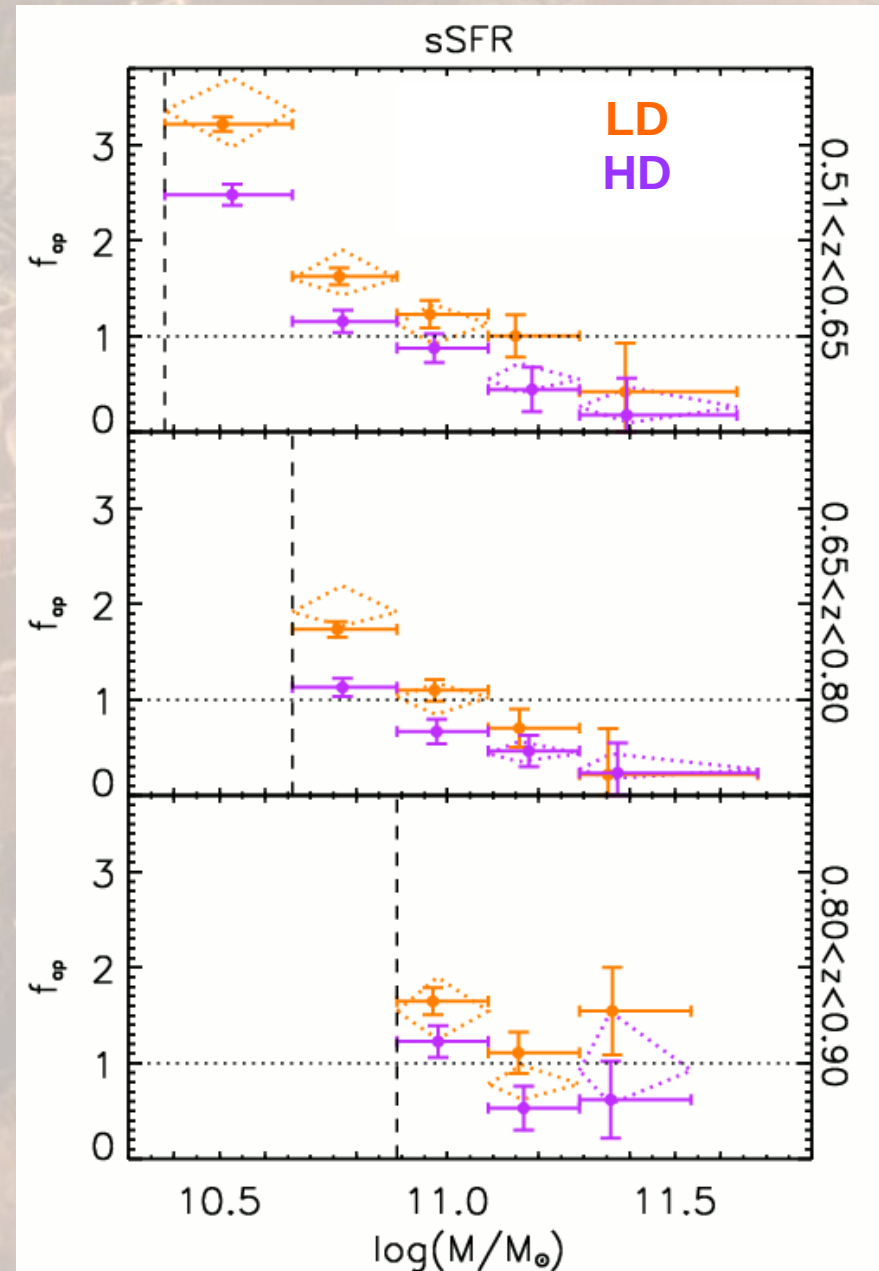
- In the high density regions a significant **contribution from dry mergers is needed** to explain the passive GSMF evolution

FRACTION OF ACTIVE OVER PASSIVE GALAXIES AS A FUNCTION OF ENVIRONMENT

(CUCCIATI, DAVIDZON, BOLZONELLA ET AL., 2017)

* The fraction of star forming galaxies depends on environment **at any mass**

→ this holds also for **very massive galaxies** (unexplored before VIPERS)



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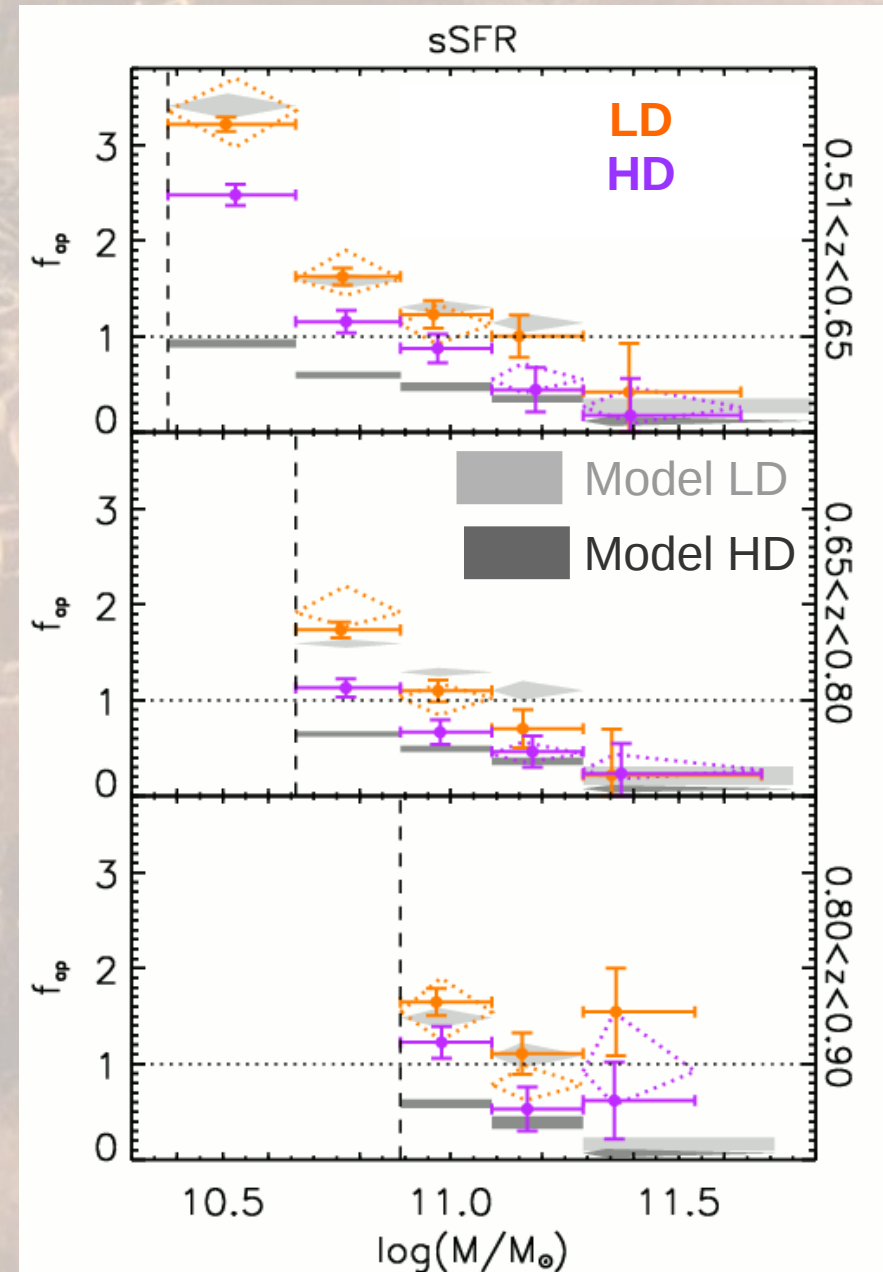
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* Comparison with semi-analytical models of De Lucia & Blaizot 2007

Toy model to reach agreement:

- 1) need to **remove “old” satellites**
- 2) need **slower quenching** for “**young**” satellites

→ help to understand galaxy evolution in high-density environments





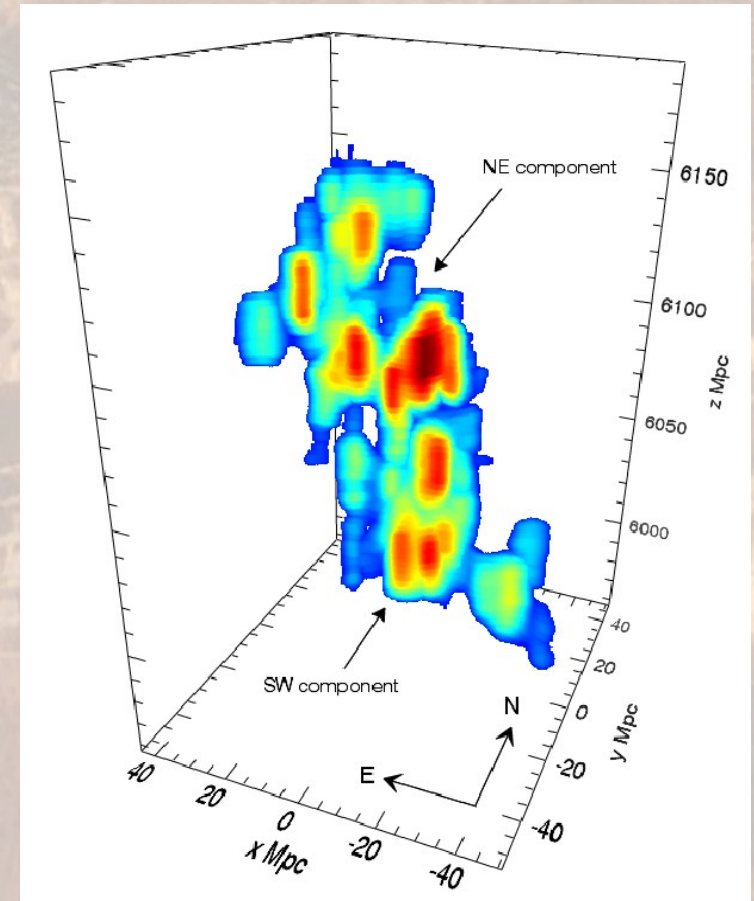
DEEP SURVEY AT $z > 2$

- * ENVIRONMENTAL EFFECTS ON THEIR ON-SET
- * SYSTEMATIC BLIND SEARCH OF PROTO-CLUSTERS



PROTO-CLUSTERS AND GLOBAL ENVIRONMENT AT $Z > 2$

- 1) Serendipitous discoveries of proto-clusters (Cucciati, Zamorani et al 2014)
- 2) Systematic search for proto-cluster candidates at $2 < z < 5$ (in prep)
 - ~50 proto-structures in 1 deg² over $2 < z < 4.6$
- 3) Detailed analysis of peculiar candidates (Cucciati+18)
 - **study of environmental effects** during structure formation
 - **check Λ CDM validity** with proto-clusters counts and very massive structures (e.g. HYPERION)



HYPERION PROTO-SUPERCLUSTER

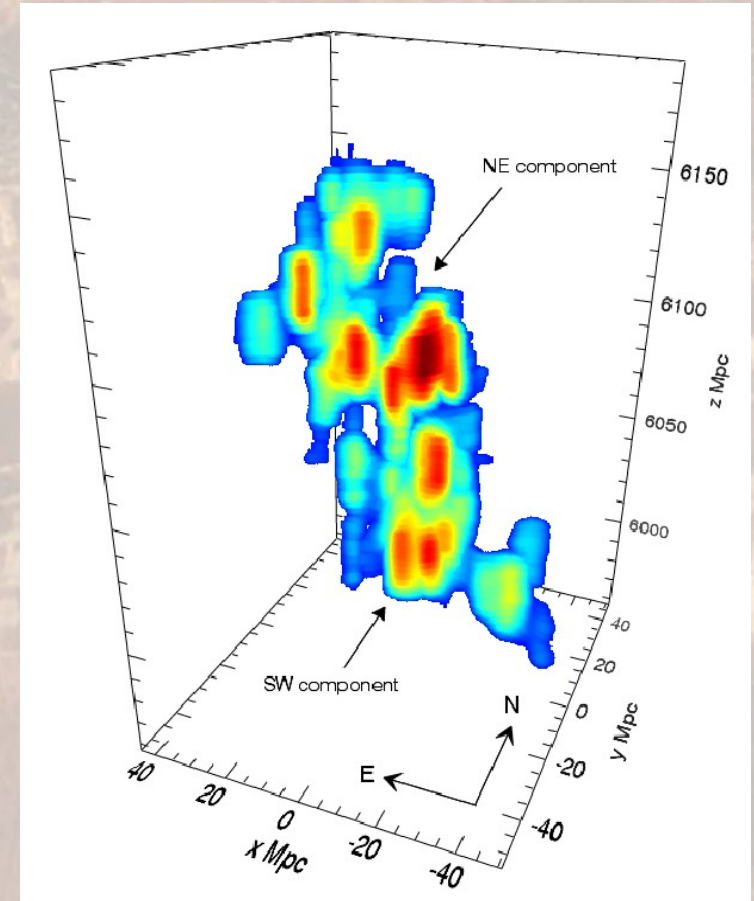
$z=2.45$

$M_{\text{TOT}} = 5 \times 10^{15} M_{\text{SUN}}$
(HIGHLIGHTS OF A&A)



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SIMILAR PROJECT TO BE PERFORMED IN VANDELS
(O. CUCCIATI LEADS THE “ENVIRONMENT WG”)





LARGE AND DEEP SURVEY(S) AT $0 < z < 2$

- * UNPRECEDENTED RICH SAMPLE OF GALAXIES AND CLUSTERS AT INTERMEDIATE AND HIGH REDSHIFT
- * RICH SAMPLE OF RARE GALAXY POPULATIONS
- * COSMIC VARIANCE EFFECTS DRASTICALLY REDUCED

OAS PARTICIPATION IN ENVIRONMENT-RELATED TOPICS



* Leadership

- M.Bolzonella and E.Zucca: leads of “LF-CL” PF in OU-LE₃ “Clusters”
- M.Bolzonella: co-lead of “MF-CL” PF in OU-LE₃ “Clusters”
- S.Bardelli: co-lead of “Validation” WP in SWG “Clusters of galaxies”

* Active Participation in:

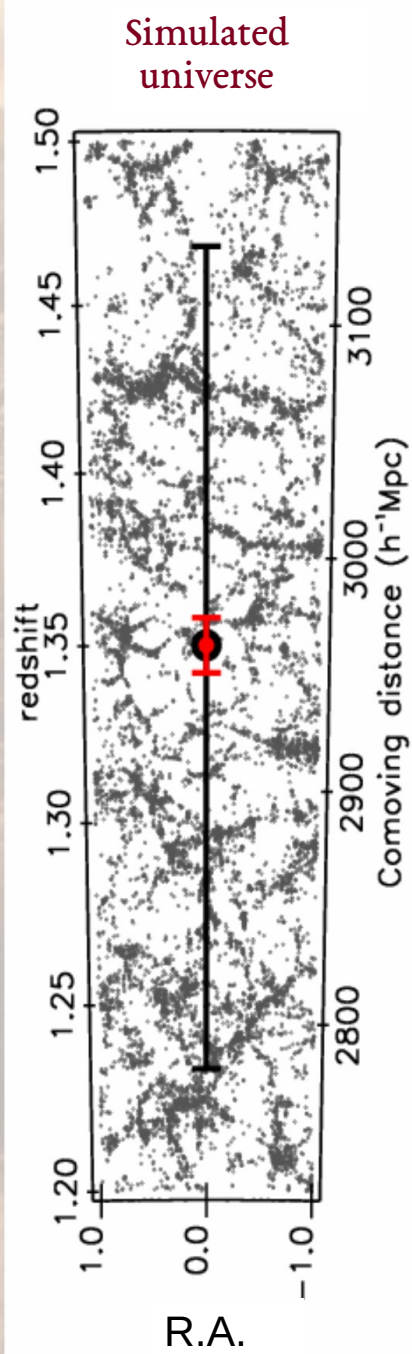
SWG “Clusters of Galaxies”

SWG “Clustering”

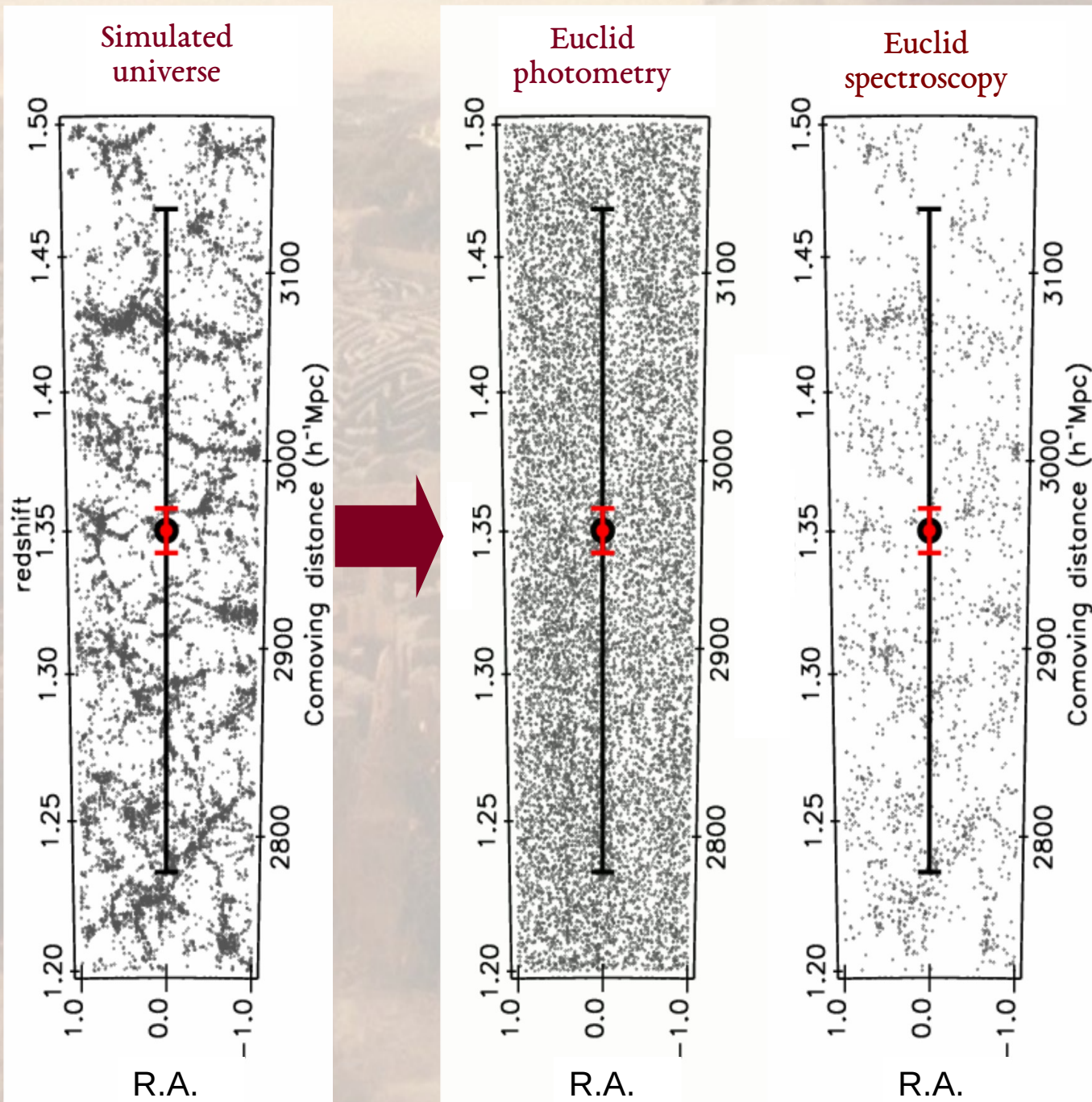
SWG “Galaxy and AGN Evolution”

OU-LE₃ “Clusters”

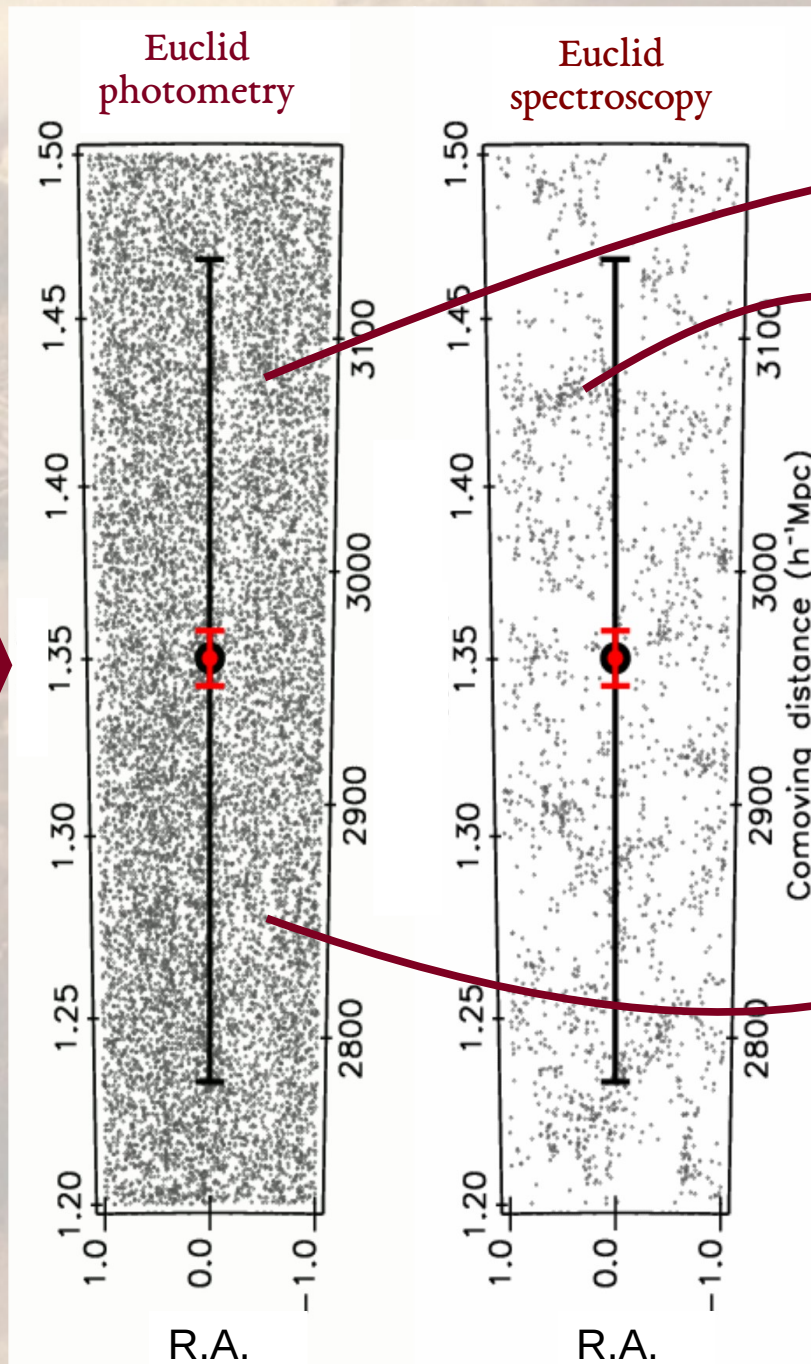
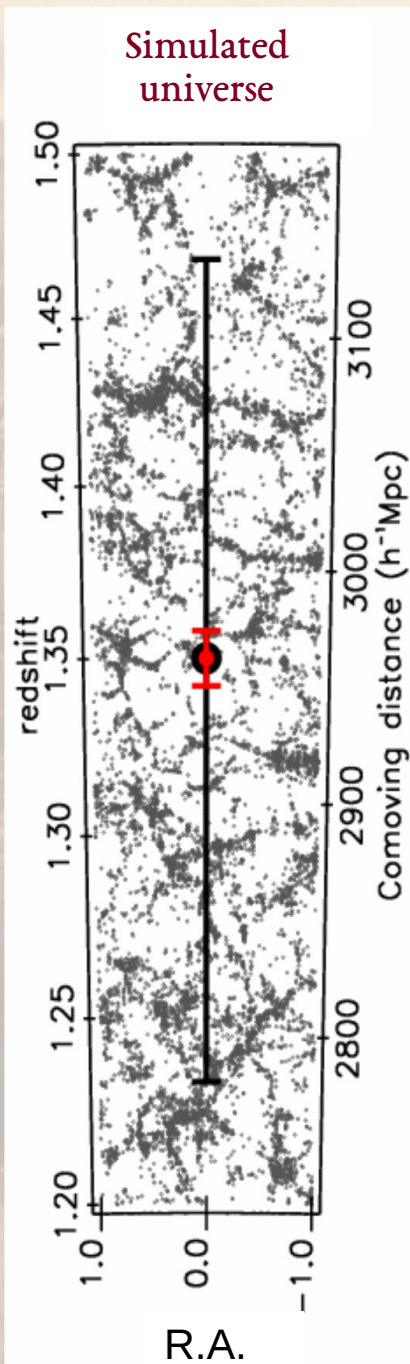
ENVIRONMENT PARAMETERIZATION



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ENVIRONMENT PARAMETERIZATION



1) DENSITY field
RECONSTRUCTION

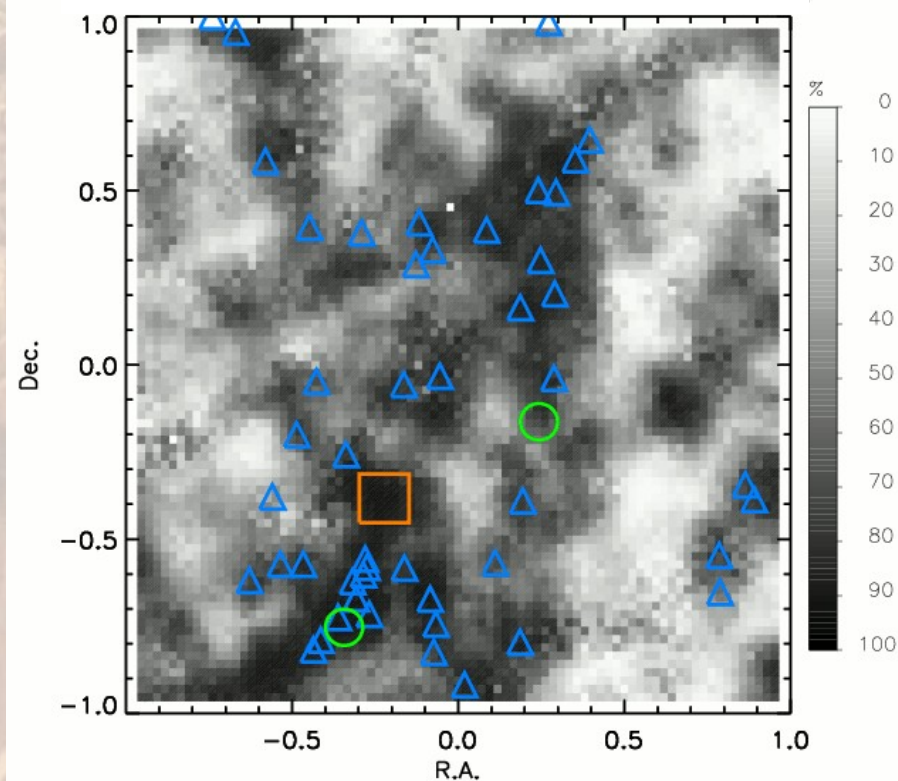
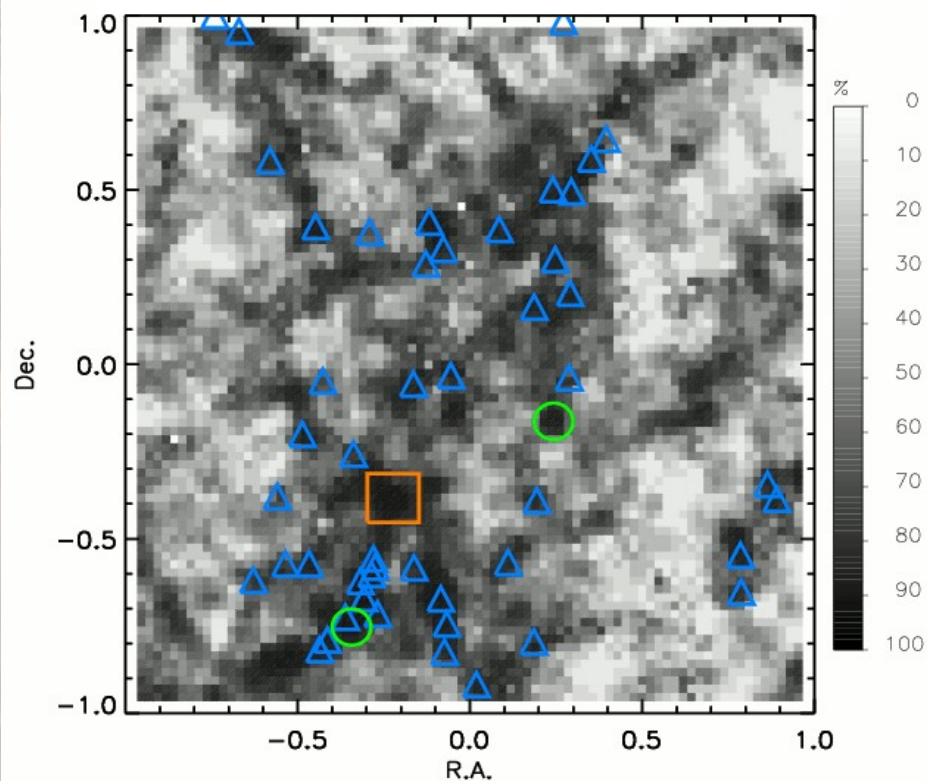
2) IDENTIFICATION OF
GALAXY CLUSTERS

I) ENVIRONMENT PARAMETERIZATION IN THE EUCLID DEEP SURVEY

(CUCCIATI, MARULLI, CIMATTI ET AL., 2016)

Simulated Universe at $z=1.6$
Density computed on 2 Mpc scales

EUCLID-LIKE (z phot + z spec)
Density computed on 2 Mpc scales

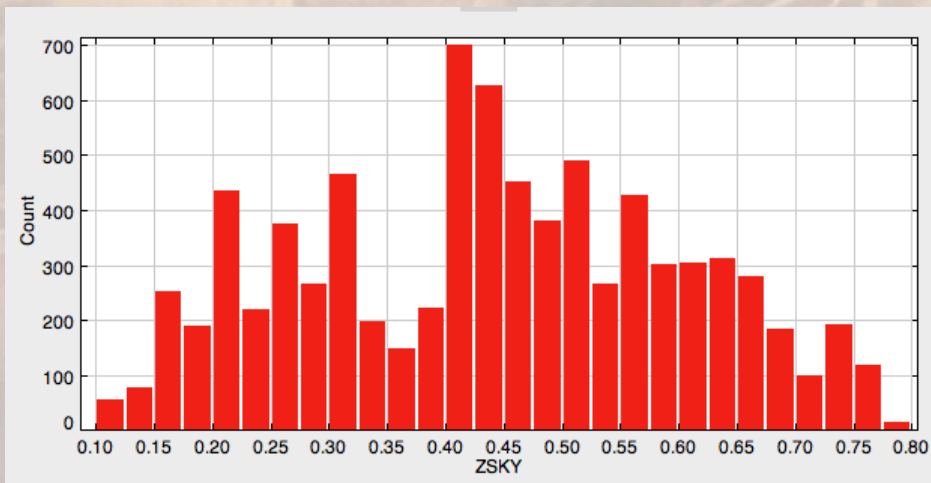


2) CLUSTERS DETECTION: PREPARATION TO EUCLID AND THE CODE “AMICO”



The VST-Kilo Degree Survey:
map of 1500 square degree in u,g,r,I

Aims: 1) astrophysics and cosmology
2) as training set for Euclid



7988 clusters in 377 deg²
in the range 0.10 < z < 0.8

Cluster Finder “AMICO”
Linear optimal matched filter

$$A(\vec{\theta}_c, z_c) = \alpha^{-1}(z_c) \sum_{i=1}^{N_{gal}} \frac{C(z_c; \vec{\theta}_i - \vec{\theta}_c, m_i) p_i(z_c)}{N(m_i, z_c)} - B(z_c) .$$

A = measure of cluster abundance

C = Cluster Model

N = Background galaxies

p(z) = photometric redshift PDF

Bellagamba et al., 2011

Bellagamba, Roncarelli et al., 2018



2) CLUSTERS DETECTION: PREPARATION TO EUCLID AND THE CODE “AMICO”



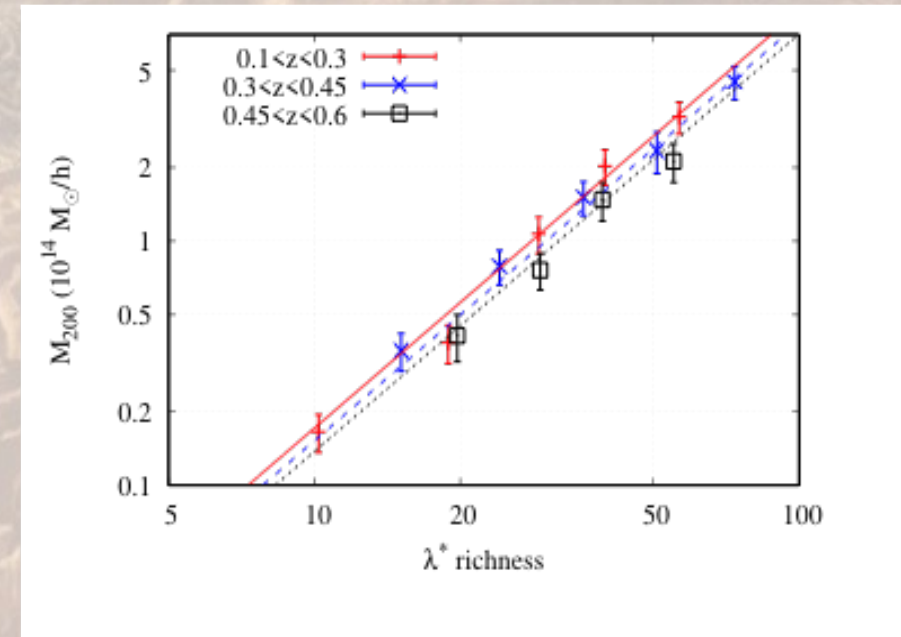
Latest features of “AMICO”:

1) **mass-richness calibration** using weak lensing

→ Bellagamba, Sereno, Roncarelli...Bardelli,
Moscardini et al, 2018, in press

2) **new method to handle the selection function**
of the detected clusters

→ Maturi, Bellagamba, ... Roncarelli, Sereno, ...
Bardelli et al, 2019, in press



* **REQUIREMENTS:** ROBUST ESTIMATION OF NUMBER COUNTS,
SELECTION FUNCTION AND SCALING RELATION

* **AMICO HAS BEEN SELECTED AS THE MAIN OFFICIAL ALGORITHM**
FOR CLUSTER DETECTION IN EUCLID, AFTER 5 “CHALLENGES”

→ ADAM...BELLAGAMBA...CAPPI...RONCARELLI..BARDELLI... ET AL.,
2019, TO BE SUBMITTED

HIGHLIGHTS



- * First assessment of environmental effects on massive galaxies at $0.5 < z < 1$.
- * Hyperion proto-supercluster most massive coherent structure at $z=2.5$
- * Code “AMICO” selected as the official Euclid cluster finder
- * ...

FUTURE



- * Environment parameterisation:
 - Exploitation of the Euclid Surveys
 - MOONS: study of environment at $1 < z < 2$, at the peak of the cosmic SFRD
 - ... wait for a large FoV MOS @ E-ELT!
- * Link environment to physical processes: analysis of gas reservoirs (recent/future facilities from sub-mm to radio)
- * Interpret the global picture with the comparison with simulations of DM and galaxy evolution (e.g. INAF-OATs)



CRITICALITIES



- * The design of a survey for environmental studies is very difficult: ideally, would need very high spectroscopic sampling rate, which is too much time-consuming



- * Not enough manpower: many environment-related topic still to be performed on current surveys, but we already need to think of future facilities



- * Half of the team for Cluster detection in Euclid has been lost for the expiration of contracts (“anni Gelmini”)

→ one of the postdocs was heavily co-funded by INAF-OAS