



GAZELLE

Galaxies Across z : Effects from Local and Large-scale Environment

Olga Cucciati (INAF-OAS)

Audizioni RSN1 – 19 May 2022

Origin and purpose



GAZELLE aims at studying how environment affects galaxy evolution based on analysis of extragalactic **spectroscopic redshift surveys, and on the comparison with galaxy evolution models.**

- **Continue to exploit already completed spectroscopic galaxy surveys** as VUDS and VIPERS:
 - exploit their uniqueness
 - VIPERS ($0.5 < z < 1.0$) large volume → rare galaxy populations like massive galaxies
 - VUDS ($z > 2$) depth and area → galaxy protoclusters [+ “bonus” survey ORELSE, see later]
- **Compare observations with galaxy evolution models**
 - GAEA
 - MamBo
- **Use models to link galaxy evolution from $z > 2$ (VUDS) to $z \sim 0.7$ (VIPERS)**

This project is the **heritage of the original VIPERS and VUDS teams** for what concerns galaxy evolution as a function of environment, and includes also a few new entries

Team in INAF



- **INAF: O. Cucciati**, U.Abbas, S.Bardelli, M.Bolzonella, A.Cappi, L.Cassarà, M.Castellano, R.Decarli, G.De Lucia, F.Fontanot, B.Garilli, B.Granett, A.Iovino, M.Magliocchetti, L.Pentericci, L.Pozzetti, D.Vergani, A.Zanichelli, E.Zucca
- **INAF Associates:** F.Marulli, P.Monaco, M.Talia, + 1 AdR starting in late 2022
- **Used to work in team**, and even more in THIS team (VIPERS, VUDS, and also VANDELS, MOONS, StePS, Euclid etc)
- Identified main expertise(s) for each member, among:
 - galaxy evolution
 - environment parameterization
 - cosmological models and models of galaxy formation and evolution
 - observational cosmology

→ all these fields are strongly connected to one another

→ fluid passage of information thanks to continuous cooperation in several surveys
- **Strong links with other “Schede”** : EuclIM2, GAEA, H2G, LSS@IASF-Milano, MOONS-VLT-0, VANDELS, WEAVE-ExtraGal

Team in INAF



INAF Personnel: 19 members

Roles:

- 19 permanent staff
- 0 TD/ADR/PhD

Institutes

- 8 OAS- Bologna
- 2 IASF-Milano
- 2 OA-Brera
- 2 OA-Roma
- 2 OA-Trieste
- 1 IAPS
- 1 IRA
- 1 OA-Torino

Real FTE/yr:

- 1.2 OAS
- 0.1 IAPS

Potential FTE/yr:

- 0.8 OAS
- 0.2 OA-Brera
- 0.2 OARoma
- 0.1 IAPS
- 0.1 OA-Trieste
- 0.1 OA-Torino

Extra FTE:

- 0.1 IASF-Milano
- 0.1 OA-Brera

INAF Associates: 3 members

Roles:

- 2 permanent staff
- 1 TD

Institutes

- 2 Univ. Bologna
- 1 Univ. Trieste

Real FTE/yr: 0

Potential FTE/yr:

- 0.1 Univ. Trieste

Extra FTE:

- 0.1 Univ. Bologna

+ 1 AdR (Univ.Bologna) from late 2022

→ about 0.8 real FTE on GAZELLE

Collaborating international team



- **International nature of VUDS and VIPERS**
 - collaboration with foreign colleagues
- In particular: environmental studies in VUDS carried on in collaboration with the survey **ORELSE (study of known clusters and their outskirts at $z \sim 1$)**, with PI from U.C.Davis and members in Davis and at Gemini
 - **link candidate protoclusters in VUDS with clusters in ORELSE**
 - survey C3VO: “Charting Cluster Construction with VUDS and ORELSE”
- Foreign members in C3VO work on both ORELSE and VUDS data, resulting in an **effective progress for the aims of GAZELLE**

Leadership in INAF



Most of GAZELLE's members covered and/or cover several roles of leadership, in INAF and in international teams

- Project and development of the VIMOS instrument
- Leadership in the development of the software for VIMOS data reduction
- Leadership in the development of semi-analytical models
- Leadership in the development of tools for environment parameterization
- Leadership in the development of tools for SED fitting
- (Co)PI/Leads in several “units” of several past and ongoing survey/projects (VIPERS, VANDELS, MOONS, EUCLID, StePS...)

Science/Technology



- **Products: only scientific (mostly publications)**
- **Past production (past ~10 years):**
 - VIPERS: 3 papers on galaxy evolution as a function of environment, 4 papers on density field reconstruction and void detection, several on galaxy clustering, bias and growth of structures
 - VUDS: 7 papers on protoclusters and environmental effects at $z > 2$, 2 papers on stellar mass / halo mass relation
 - ORELSE: 2 papers on cluster detection and halo mass function at $z = 1$ (O.Cucciati among the co-authors)
- **Acknowledgements:**
 - ESO press release on the proto-supercluster Hyperion, based on Cucciati+18 (<https://www.hq.eso.org/public/news/eso1833/>)
 - Invited talk at the congress “From galaxies to cosmology with deep spectroscopic surveys - A tribute to Olivier Le Fèvre”, July 2022
 - Invited summary talk at the congress “Extragalactic Spectroscopic Surveys: Past, Present and Future of Galaxy Evolution” (GALSPEC2021), remote, April 2021
- **Algorithms for environment parameterization:**
 - Density field reconstruction (Cucciati+14)
 - Identification of cosmic voids (Micheletti, Iovino+14)
 - Identification of clusters and protoclusters (Cucciati+18; Hung+20)
 - Identification of groups and clusters (Iovino, not yet published)
 - Identification of galaxy pairs (Cucciati, not yet published)

Results and perspectives



Aims: studying the environmental effects on galaxy evolution

- 1) in-situ and ex-situ stellar mass growth of galaxies
- 2) the time scales and environments that influence galaxy evolution;
- 3) the environmental history of galaxies

Methods:

- statistical analyses of large galaxy samples (VUDS, VIPERS)
- comparisons with models of galaxy evolution.

Exploit the unique characteristics of our data:

- very large volume in VIPERS
- depth and high specz sampling rate in VUDS

Results and perspectives (1)



Aims: studying the environmental effects on galaxy evolution

- 1) in-situ and ex-situ stellar mass growth of galaxies
- 2) the time scales and environments that influence galaxy evolution;
- 3) the environmental history of galaxies

Methods:

- statistical analyses of large galaxy samples (VUDS, VIPERS)
- comparisons with models of galaxy evolution.

Exploit the unique characteristics of our data:

- very large volume in VIPERS
- depth and high specz sampling rate in VUDS

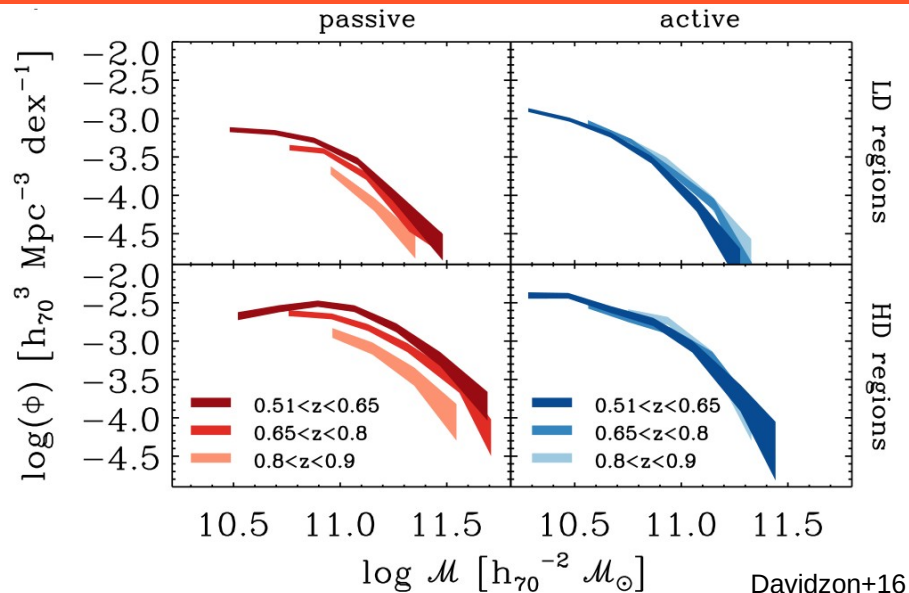
VIPERS

Previous studies in VIPERS:

- 1) Constrain for the first time the massive end of the galaxy stellar mass function (GSMF) in different environments and for different galaxy types (Davidzon+16).
- 2) Environment affects the SFR of massive galaxies (Cucciati+17), in contrast with previous studies on smaller samples (Peng+10).
- 3) Among massive galaxies the fraction of star forming galaxies is not negligible (Cucciati+17).

GAZELLE: study in more details the properties of such massive galaxies, with special focus on:

- 1) different environments (density field, cosmic voids, merger rate);
- 2) comparison of same galaxy population with model predictions;
- 3) use simulations to trace the environmental histories of these galaxies.



Results and perspectives (2)



Aims: studying the environmental effects on galaxy evolution

- 1) in-situ and ex-situ stellar mass growth of galaxies
- 2) the time scales and environments that influence galaxy evolution;
- 3) the environmental history of galaxies

Methods:

- statistical analyses of large galaxy samples (VUDS, VIPERS)
- comparisons with models of galaxy evolution.

Exploit the unique characteristics of our data:

- very large volume in VIPERS
- depth and high specz sampling rate in VUDS

VIPERS

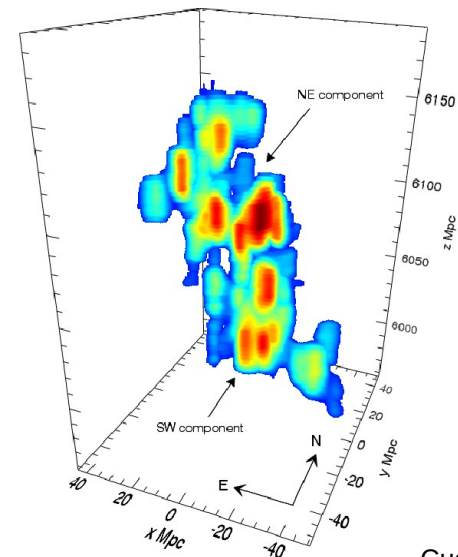
VUDS

Previous studies in VUDS:

- 1) Serendipitous detection of several proto-cluster candidates.
- 2) Detection of the Hyperion proto-supercluster.
- 3) Reversal of the SFR-density relation (Lemaux+22).

GAZELLE: study the onset of the environmental effects, and the co-evolution of galaxies and structures:

- 1) homogeneous detection of protoclusters;
- 2) characterization of Hyperion: intrinsic differences of seven individual structures spanning a factor of ~ 30 in total mass without the biases introduced by redshift and cosmic variance (MOSFIRE, SWIMS, HST, NOEMA, ALMA)
 - different galaxy populations
 - dynamical status of each peak
- 3) use simulations to
 - predict the fate of Hyperion at $z=0$
 - connect protoclusters in VUDS with clusters in ORELSE



Cucciati+18

Results and perspectives (3)



Aims: studying the environmental effects on galaxy evolution

- 1) in-situ and ex-situ stellar mass growth of galaxies
- 2) the time scales and environments that influence galaxy evolution;
- 3) the environmental history of galaxies

Methods:

- statistical analyses of large galaxy samples (VUDS, VIPERS)
- comparisons with models of galaxy evolution.

Exploit the unique characteristics of our data:

- very large volume in VIPERS
- depth and high specz sampling rate in VUDS

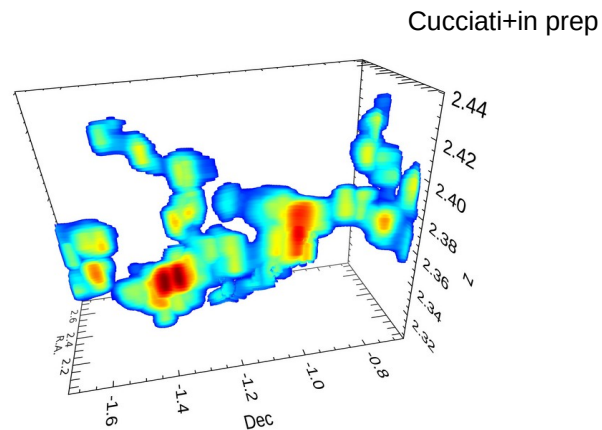
VIPERS

VUDS

GAEA

MamBo

The comparison of our results with model predictions represents an almost unexplored territory in the redshift range explored by GAZELLE ($z > 0.5$)



Volume (cMpc³)
Mass (Msun)
Max ext. (cMpc)

	HYPERION	GAEA
Volume (cMpc ³)	~10 ⁵	~10 ⁵
Mass (Msun)	~5x10 ¹⁵	~6x10 ¹⁵
Max ext. (cMpc)	60x60x150	69x103x151

Plan



Follow two main research lines:

- massive galaxies and their environments in VIPERS (density field, voids, mergers)
- detection and characterization of proto-clusters in VUDS with special focus on Hyperion

Complement the research with the use of simulations (GAEA, MamBo)

- comparison of galaxy properties as a function of environment
- study of environmental history of galaxies
- link high to low redshift

Time scales:

- 1 paper per year per person (but see “Criticalities”)
- Periodic wrap-up (in any form)

Foreseen/possible papers (≥ 10):

- Merger rate of massive galaxies at $z \sim 0.7$
- Galaxy properties in voids at $z \sim 0.7$ [Vergani et al., in prep]
- Galaxy conformity at $z \sim 0.7$
- Hyperion-like structures in simulated galaxy catalogues [Cucciati et al, in prep]
- Gas reservoirs in the massive galaxies in the most massive peak of Hyperion with NOEMA follow-up [new AdR]
- Hyperion and the supercluster SC1604 at $z=0.9$: progenitor and descendant?
- Galaxy populations from protoclusters at $z > 2$ (VUDS) to clusters at $z \sim 1$ (ORELSE)
- ... to high density peaks in VIPERS ($z \sim 0.7$)
- Galaxy evolution in the least dense regions, from VUDS to VIPERS
- Evolution of the stellar mass – halo mass relation based on our environment reconstruction
- ...

Funds



- **Past funds:** 0 k€
 - **Current confirmed funds:**
 - 2-yr AdR to work on protocusters, to begin in Fall 2022, cofunded by INAF and University of Bologna:
 - 6 k€ from “Ricerca di Base” INAF-OAS
 - 5 k€ from PRIN-INAFA 2019 (P.I. Viola Allevato)
 - ~56 k€ from University of Bologna (PRIN MIUR + ASI + RFO)
 - **Under evaluation:** 20 k€ from Mini-Grant INAF 2022
 - to fund some GAZELLE members on topics not covered by the AdR
- **TOTAL FROM INAF:** 11k€ confirmed + 20k€ under evaluation

Criticalities



1) Person power

Large number of members, but most with 0, 0.1, or 0.2 real or potential FTE/yr

→ “heritage” of the team organization in large surveys? Most of the work is done by PhD students and post-docs, while staff more often provide the team with intermediate products, and rarely have time to commit themselves to lead a project

→ in not-so-few cases, the lack of time for papers is the price to be paid to excel in “Leadership”

Only two persons (P.I. + 1) in this moment having time to lead a specific analysis within GAZELLE

Postdoc to join the team in Fall 2022: will take care of the study of protoclusters in VUDS, and namely of follow-up of the proto-supercluster Hyperion

→ other aspects of GAZELLE will not be covered

Degree and PhD thesis proposed several times at University of Bologna, without success (funding for the possible PhD thesis would have been granted by an agreement with INAF at large and also OAS specifically, based on an open call and not offered to GAZELLE in particular)

2) Funds

There is no dedicated funding for this project, a part to hire the above-mentioned postdoc, who will take care of only a small part of the analysis.

→ **proposed Mini-Grant to fund other aspect of the project** (mainly exploitation of VIPERS data and comparison with simulations for both VIPERS and VUDS results)