1996 - Film by Quentin Tarantino

Reconstructing the evolution of galaxies

Lucia Pozzetti

INAF – OAS - Bologna

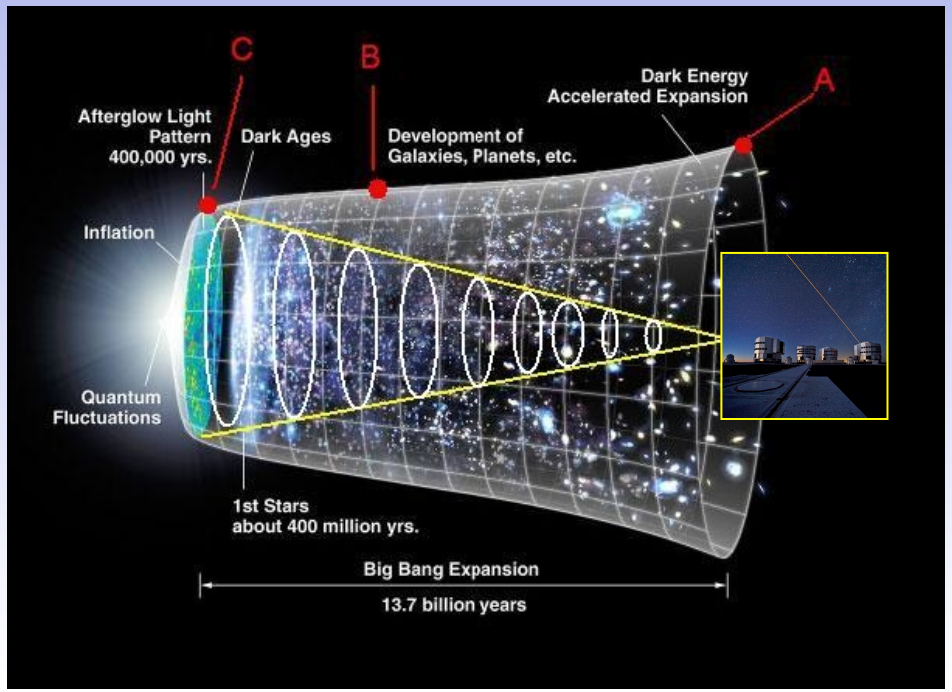
Giornate di Osservatorio, Bologna, 17-18/12/2018

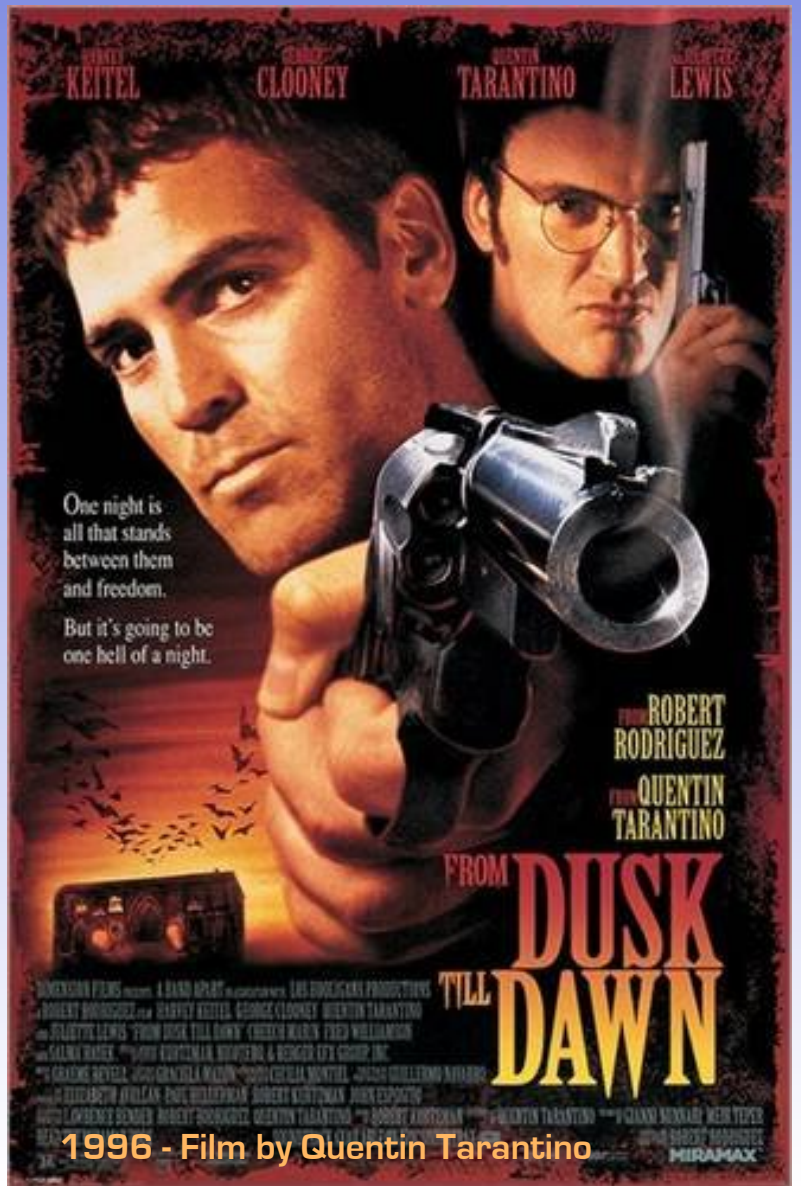
Reconstructing the evolution of galaxies

Studies about galaxy evolution, from the nearby to the high redshift Universe.

Involvement in present and future projects:

- Lookback time studies “From dusk till dawn”
- Archeological studies;
- Forecasts for future survey.





1996 - Film by Quentin Tarantino

Reconstructing the evolution of galaxies

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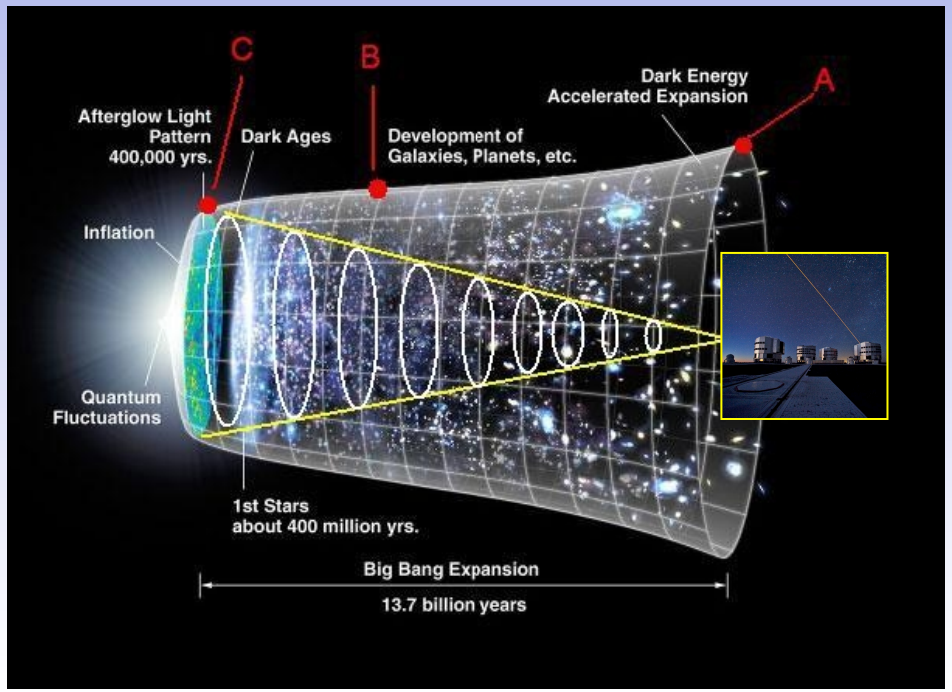


Past, Present, public and future spectroscopic projects

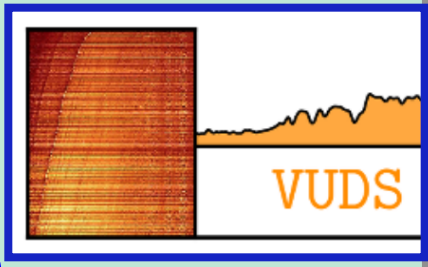
GMASS (~200 spectra @ z<1 & z>2)

zCOSMOS (20k spectra @ z<1)

VIPERS (100k spectra @ 0.5<z<1.2)

VUDS (10k spectra @ z>2)

VANDELS (2k spectra @ 1<z4)



SDSS + BOSS(high-R spectra @ z<0.5)

Lega-C (spectra z~1)

MUSE + MANGA (IFU)

WEAVE+STePs (high-R spectra @ 0.3<z<0.8)

MOONS (near-IR spectra 0.7<z<2)

Euclid (Halpha emitters 0.9<z<2.3)

SPICA+SAFARI (Far-IR)

Galaxy evolution reconstruction @ OASBo

- **Lookback time statistical studies: Mass Galaxy Assembly and Cosmic SFH** and the role of environment (zCOSMOS, Herschel, VUDS, VANDELS, WEAVE, MOONS, Euclid)
- **Archeological studies: Inferring Physical Properties from spectra**, (SDSS and BOSS, VANDELS, MOONS, Euclid stacked?).
- **Forecasts for future survey: Prediction and mocks** [WEAVE+STEPS, MOONS, Euclid, SPICA]

Researchers: S. Bardelli, M. Bolzonella. O. Cucciati, C. Gruppioni, M. Mignoli, L. Pozzetti, E. Vanzella, D. Vergani, E. Zucca (staff at INAF-OAS-Bo),

Associates: A. Cimatti (staff at UniBo) + G. Zamorani

Post docs/TD:, M. Talia (UNIBo), M. Moresco (UNIBo)

PhD Students: G. Girelli, (S. Quai, A. Citro)

Lookback time statistical studies: Stellar Mass Assembly History

COSMOS Cosmic Evolution Survey

GMASS

z-COSMOS 40'000 VLT redshifts for COSMOS

Galaxy Evolution is driven

by the mass and by the environment

through the quenching of SFGs into local ETGs

Several statistical studies from past dasets:

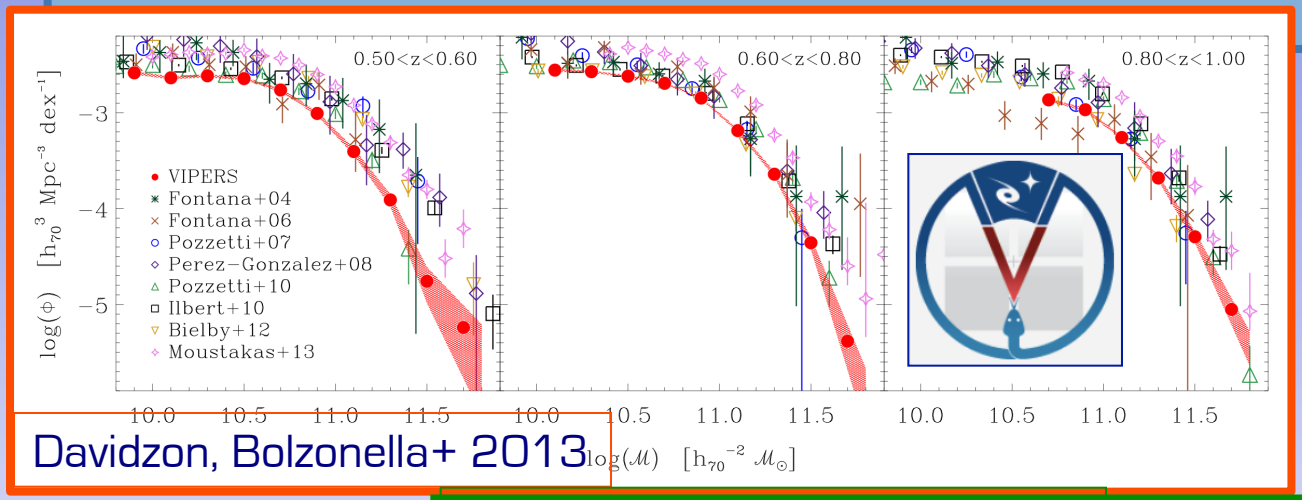
VVDS, GMASS, zCOSMOS,

Zucca + 2009,

Pozzetti+ 2010

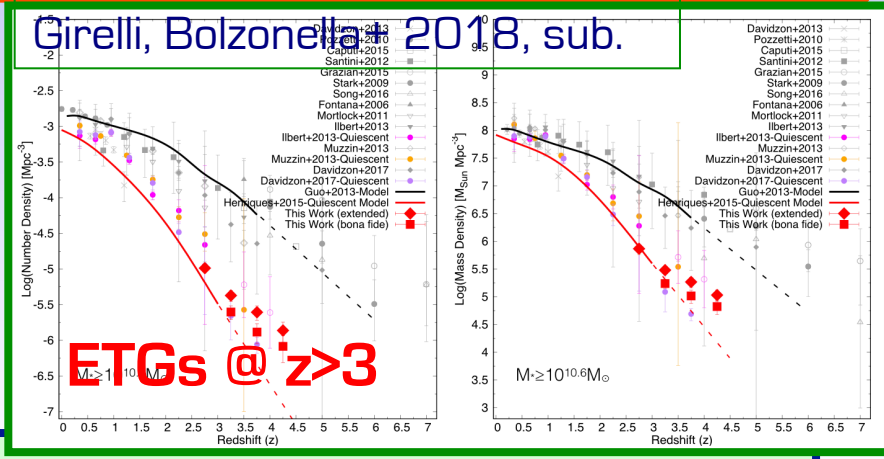
Bolzonella+ 2010

...



Davidzon, Bolzonella+ 2013

Girelli, Bolzonella+ 2018, sub.



downsizing scenario:

massive galaxies assembled their mass

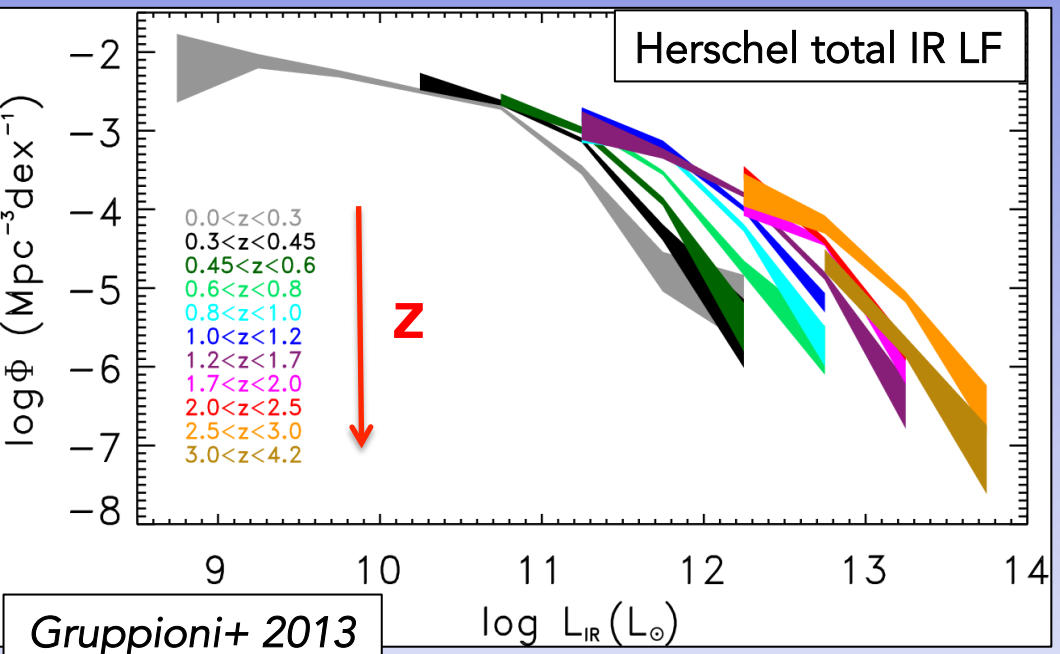
earlier and faster than low-mass galaxies

At odd with galaxy formation models

L.Pozzetti, M. Bolzonella, D. Vergani, O. Cucciati, E. Zucca, M. Mignoli @ OAS-Bo

Lookback time statistical studies: Galaxy evolution in the FAR-IR

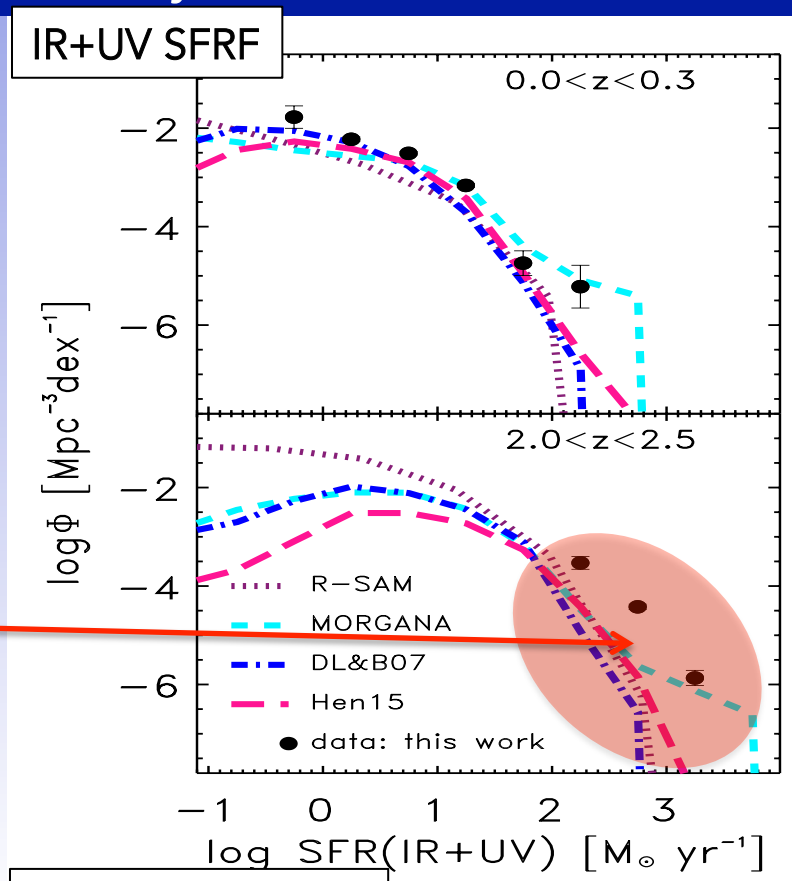
Herschel → strong evolution for the IR galaxy population: brighter at higher z



Gruppioni+ 2013

BUT: tension between IR Luminosity function / SFR function and SAMs:

the bright IR galaxies detected by Herschel at z>1.5-2



Gruppioni+ 2015

What are these "monsters" (SFR≥1000 $M_\odot$/yr)?

Most of them contain an AGN, though IR Luminosity dominated by SF → ALMA, JWST, SPICA

Extreme populations

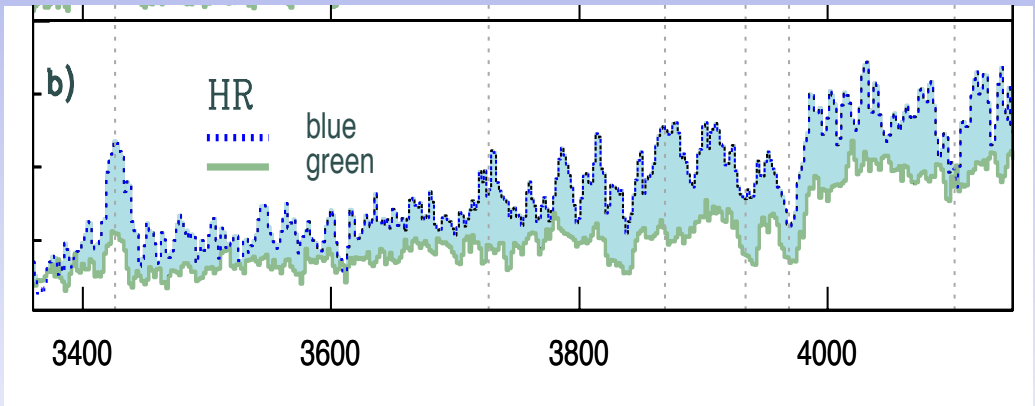
Search & characterization of peculiar populations focusing on SF quenching channels

Peculiar = Rare ≠ Irrelevant (but short phase)

only using huge, rich datasets

e.g., see on VIPERS AGN identified through the [NeV] emission line

A novel class of active (AGN) post-starburst galaxies in the blue cloud



Negative AGN feedback: is it more common than previously believed

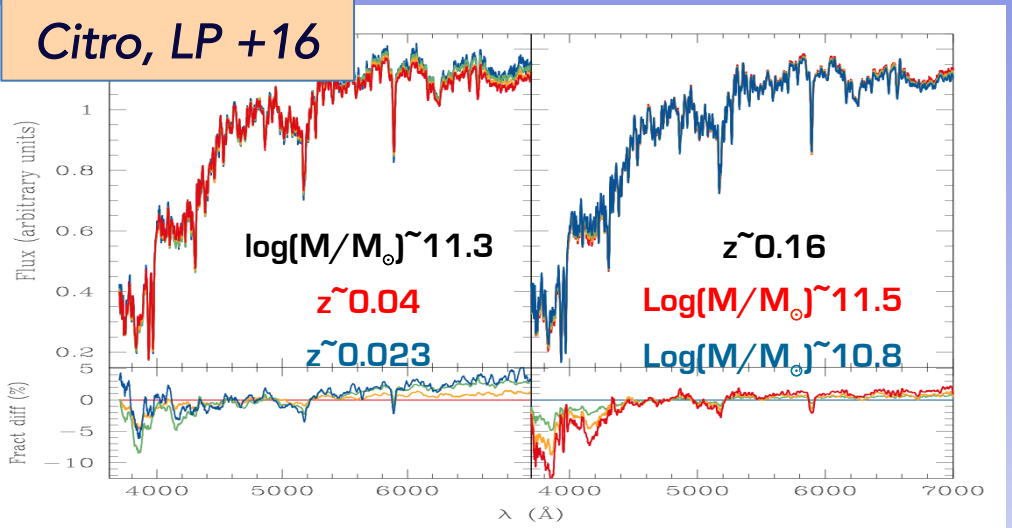
(Vergani et al. 2018, A&A in press)

D.Vergani, M. Bolzonella @ OAS-Bo

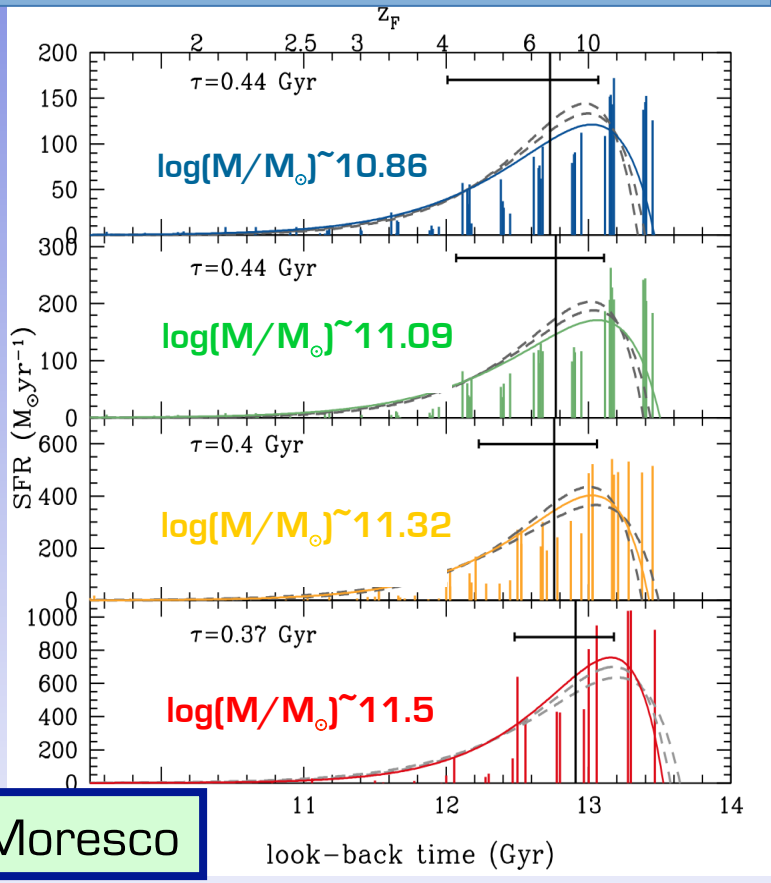
ETGs from an archeological approach

➔ *Inferring Ages, Metallicities, Dust, SFHs from high S/N spectra*

Citro, LP +16



~ 21500 SDSS DR4 ETGs @ z<0.3



➔*Ages increase with cosmic time & increase from the lowest to highest mass*

+

Metallicity does not evolve strongly

A. Citro, LP, Cimatti, Moresco

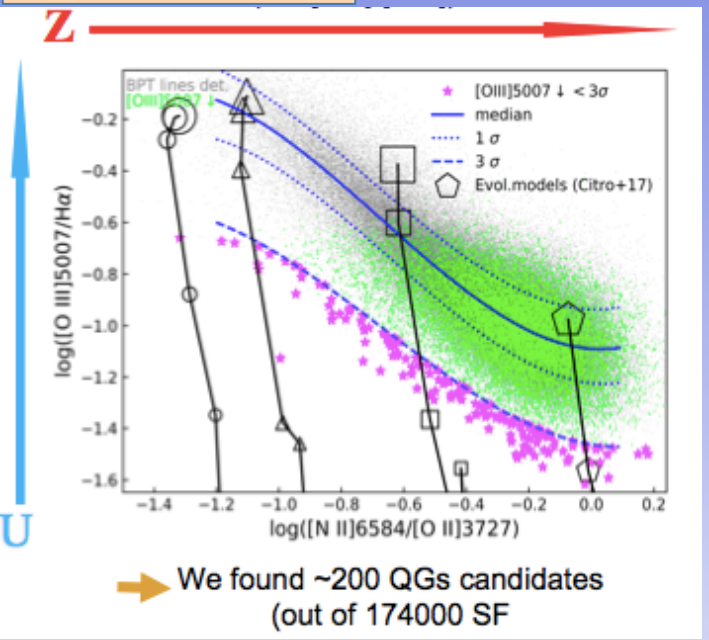
Delayed exponential SFH

More massive galaxies form stars earlier

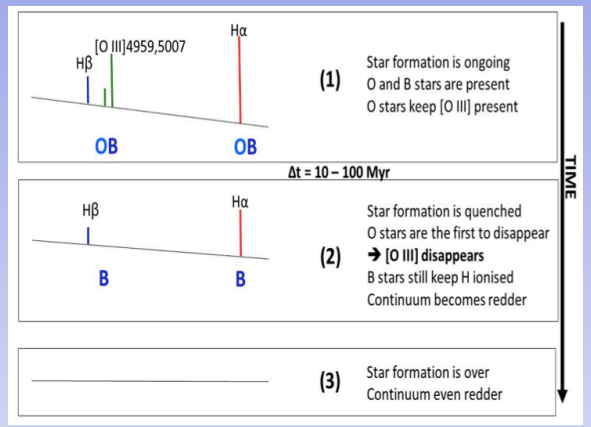
Selecting Galaxies just after the quenching of the SF

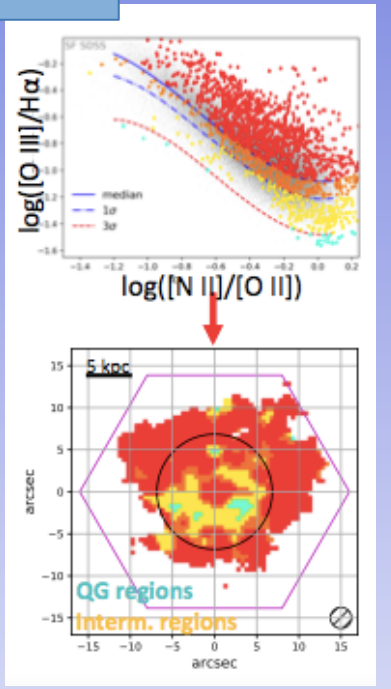
Quai, LP +18

➔ *Search for quenching galaxies (QGs)*



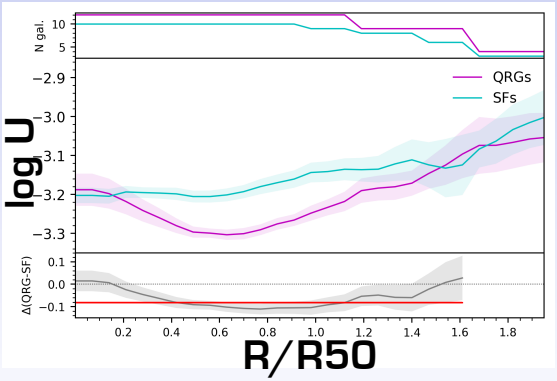
NEW METHOD: Selected in the SDSS-DR8 galaxies with **lowest [O III]/Hα ratio** (ionization indicator) for a given metallicity (i.e. [N II]/[O II]). Based on Cloudy models

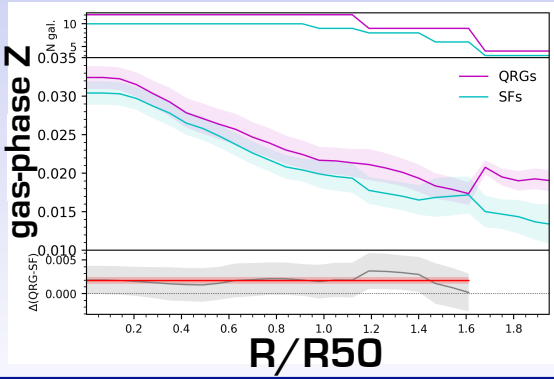




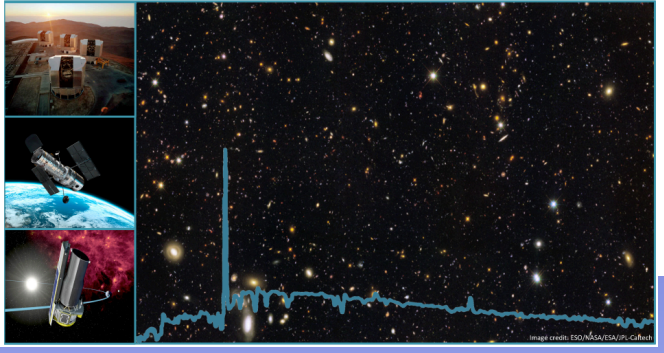
Quenching Galaxies Properties:

- **Blue colours**
- **Late-type morphology → no morphological transformation occurred yet**
- **Excess in high-dense environments**
- **quenching timescale τ_Q: 90Myr – 1.5Gyr, assuming a Tau model**





S. Quai, LP, A. Citro, Cimatti, Moresco



VANDELS

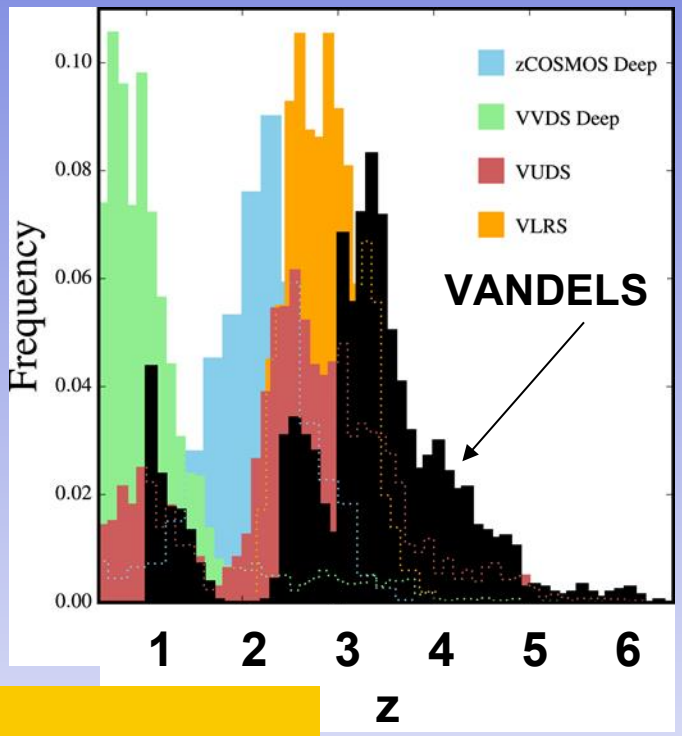
A deep VIMOS survey of the CANDELS UDS and CDFS fields

OAS Bo

ESO public spectroscopic survey

PIs: Laura Pentericci & Ross Mc Lure

- ✓ ~ 2500 high-z galaxies within CDFS and UKIDSS UDS (0.2 deg^2) → ***best available multi-wavelength data***
- ✓ ultra-deep (20-40-80h), medium resolution, optical spectra (0.48 μ m-1.0 μ m) with VIMOS @ VLT
- ✓ **up to 80 hours per target**



Not just a redshift survey!

Sufficient S/N and resolution to measure physical properties

Primary Targets

Star-forming galaxies at 2.4<z<5.5 (H_{AB}<24)

Passive galaxies at 1.0<z<2.5 (H_{AB}<22.5)

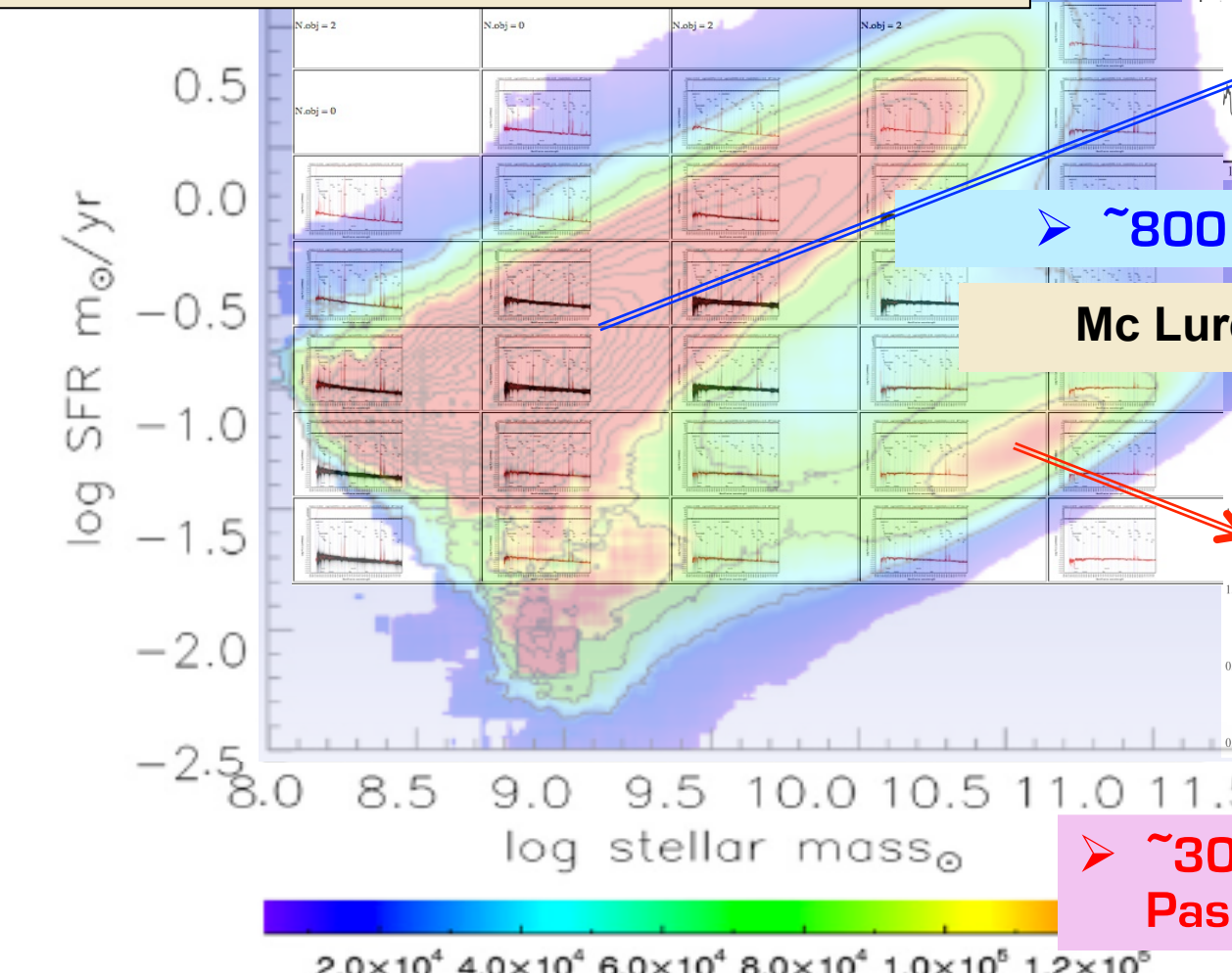
LP, Micol, Eros, Marco, Olga, Gianni involved @ OAS-Bo

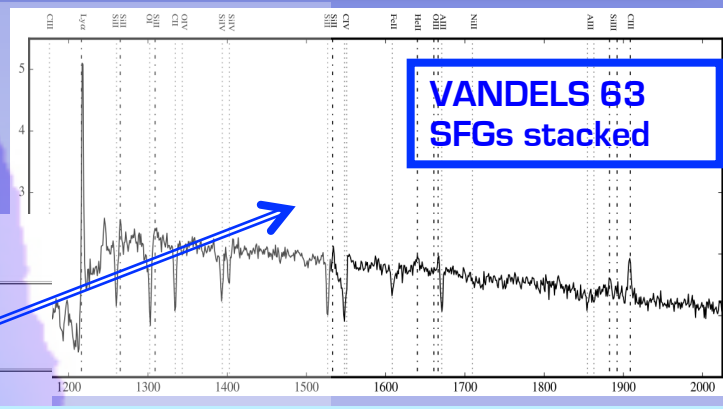
A.Cimatti, M. Brusa, M. Talia, M.Moresco, A. Citro @ UniBo

Primary Targets

Star-forming galaxies at $2.4<z<5.5$ ($H_{AB}<24$)

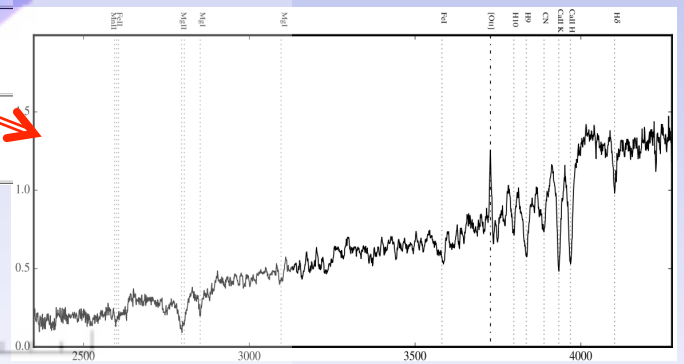
Passive galaxies at $1.0<z<2.5$ ($H_{AB}<22.5$)





➢ ~800 Star forming galaxies @ z>2

Mc Lure+ VANDELS team 2018



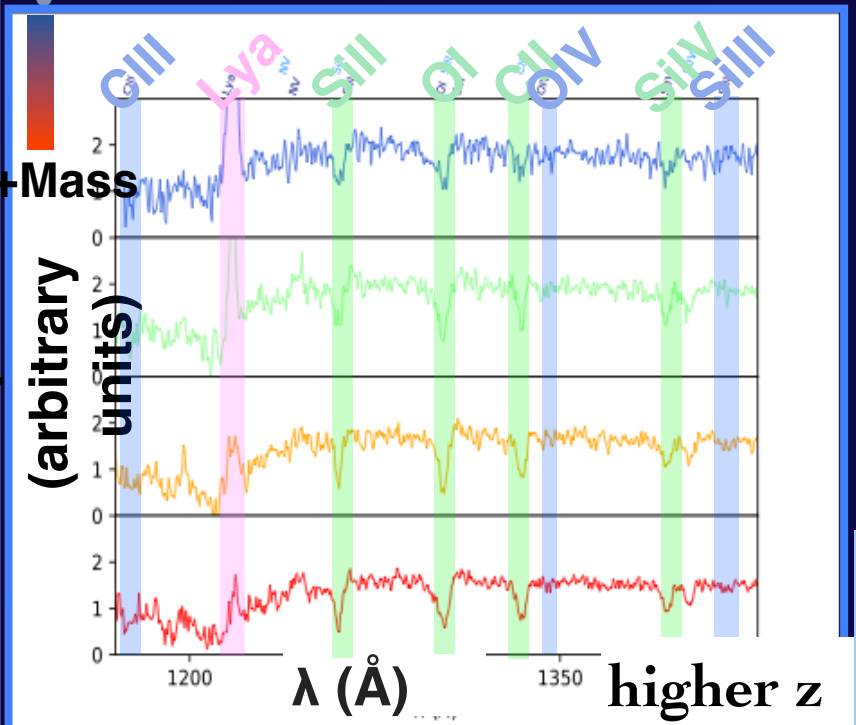
➢ ~300 Massive (>$10^{10.5}$ Msun) Passive galaxies @ $1.5<z<2.5$

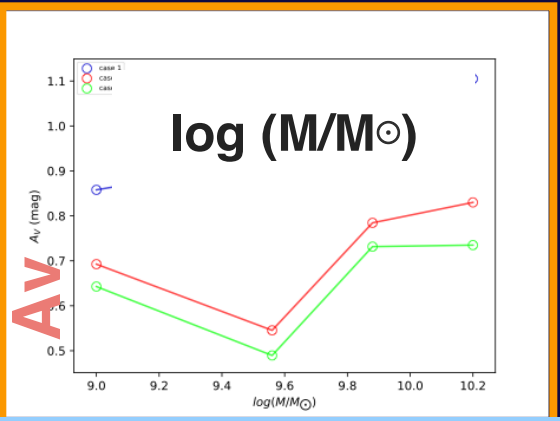
Annalisa Citro

VANDELS

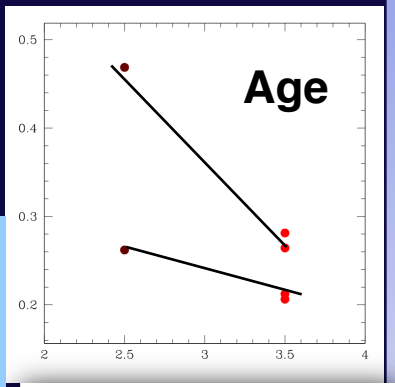
SF galaxies

Stacked Spectra

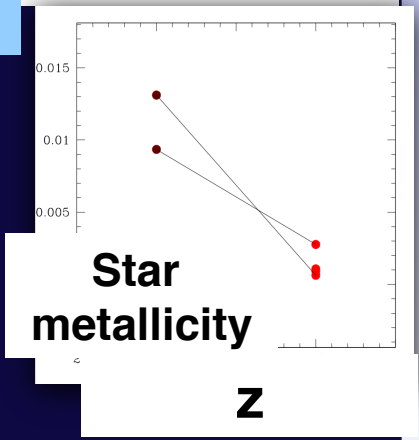


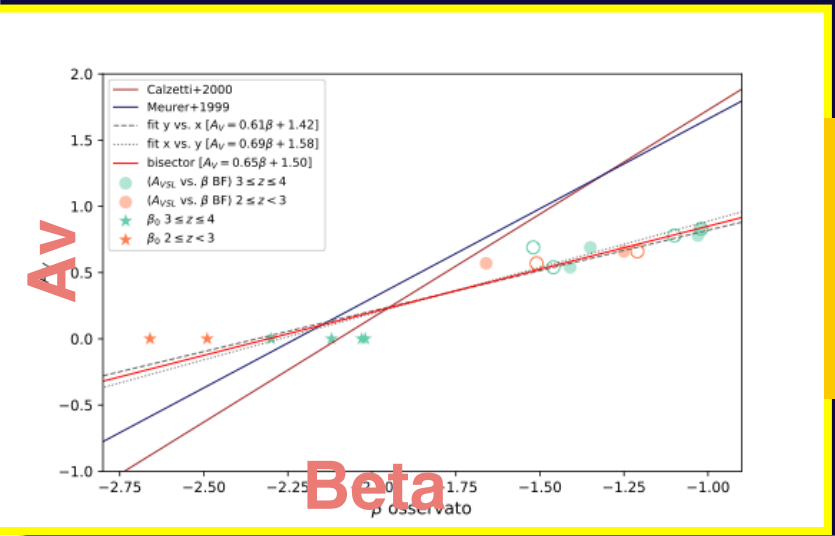


more massive galaxies have higher dust mass



age and stellar metallicity increase for decreasing redshift



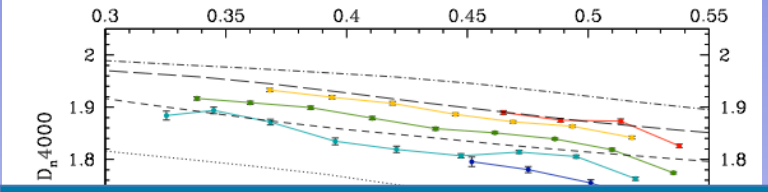


AV-beta: Flatter relation with respect to the ones by Calzetti et al. 2000 and Meurer et al. 1999

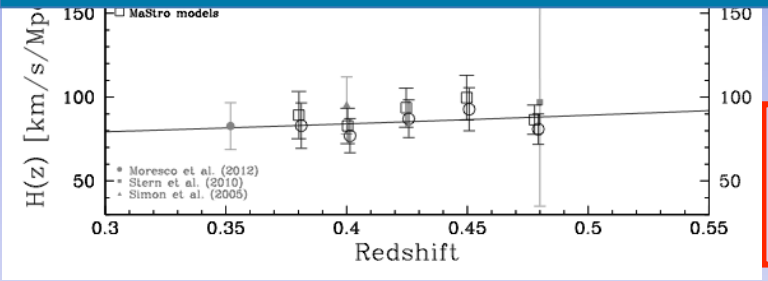
A.Citro,LP, Talia, Cimatti, Moresco

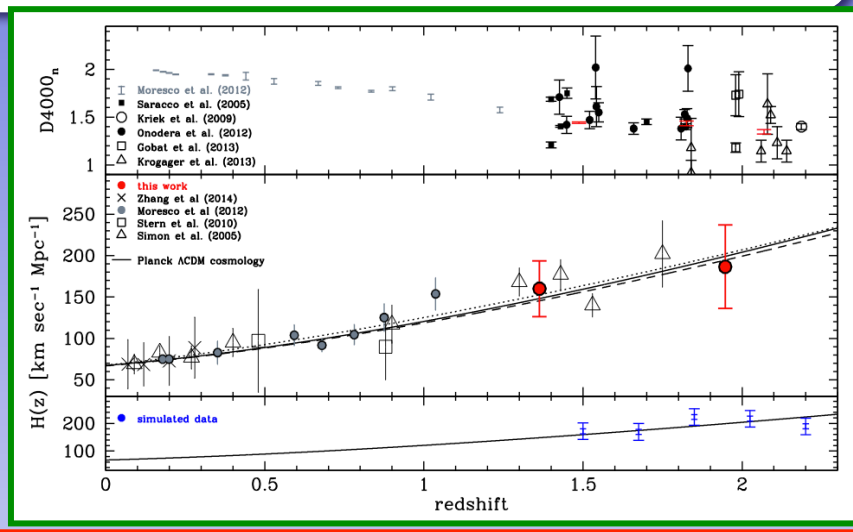
Cosmology with passive galaxies from SDSS to VANDELS

BOSS DR10 ETGs z=0



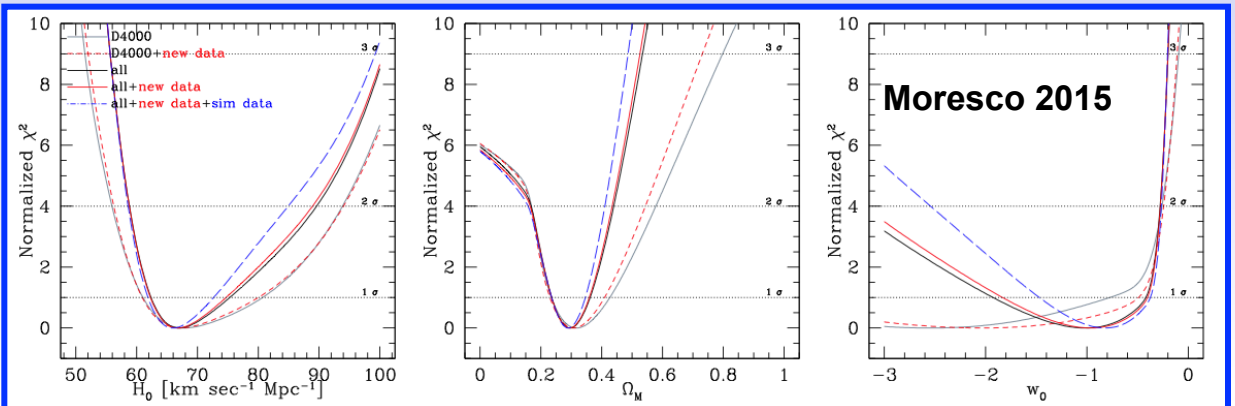
Evolution of Dn4000 vs. z





From ~30 to ~300 Massive (>$10^{10.5}$ Msun) Passive galaxies @ 1.5<z<2.5

H_0 Ω_m ω_0



H(z) constraint at z>1

People involved @ DIFA , M. **Moresco**, A. Cimatti

@ INAF-OASBo: L. Pozzetti

Stellar Population Survey (StePS)

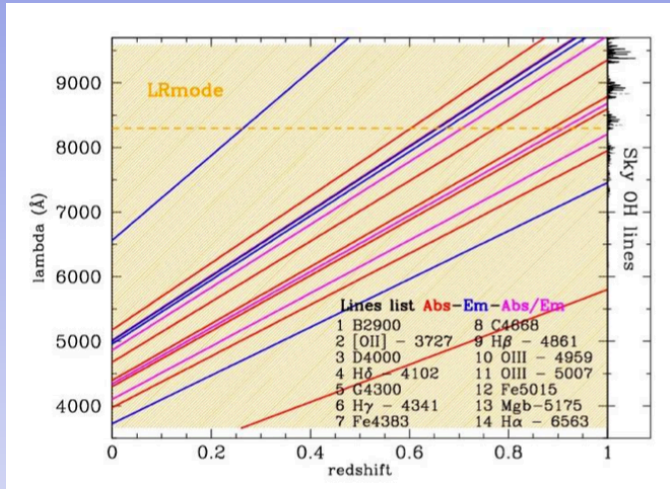
New High-Resolution optical spectograph @ WHT
1° light in 2019

Stellar Population Survey (StePS)

PI- B.Poggianti, A. Iovino

(survey definition by Iovino, Pozzetti, Bolzonella, Mercurio)

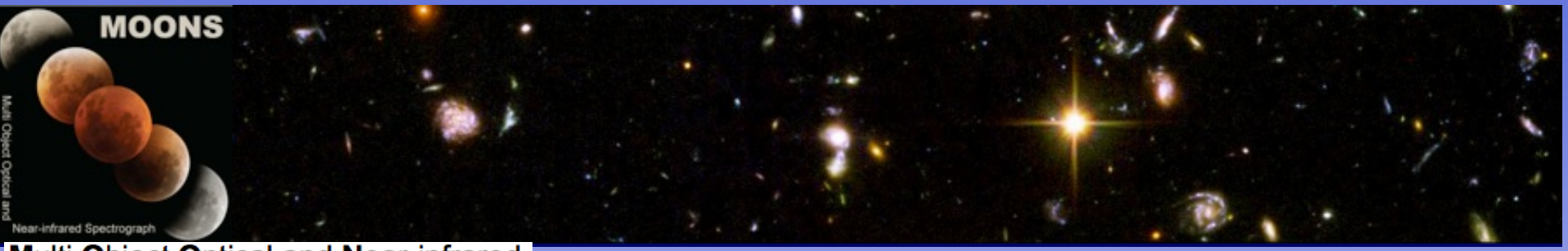
- *wide area of ~25 deg2 galaxy survey (I_{AB}<20.5)*
- *at intermediate redshifts (0.3<z<0.8) and Mass [i.e. log(M/Msun)>10.2,11.5]*
- *low **resolution grism (R~5000**, ~ 1Å resolution)*
- ***spectra with high S/N>15***
- *a total of ~35,000 spectra*



LP, Micol, Elena, Sandro, Olga Daniela involved @ OAS-Bo

Goals:

- *analysis of the stellar populations and of the emission line properties*
- *star formation histories*
- *provide gas kinematics and stellar velocity dispersions.*

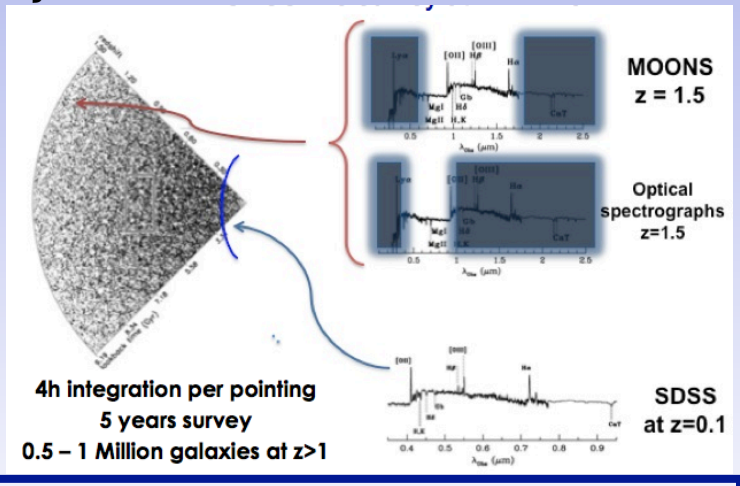


Multi Object Optical and Near-infrared Spectrograph for the VLT

PI: Michele Cirasuolo

The aim is to have MOONS operational by 2020-21.

- ✓ ~1000 fibers over a foV of ~500 square arcmin
- ✓ wavelength coverage is 0.6 μ m-1.8 μ m
- ✓ two resolution modes: medium (R~4,000-6,000) and high resolution (R~20,000)
- ➢ **An SDSS-like survey at z ≈ 1-1.5**



Extra-galactic survey: 200 nights→ 200k spectra /redshift

-Extragalactic WGs:

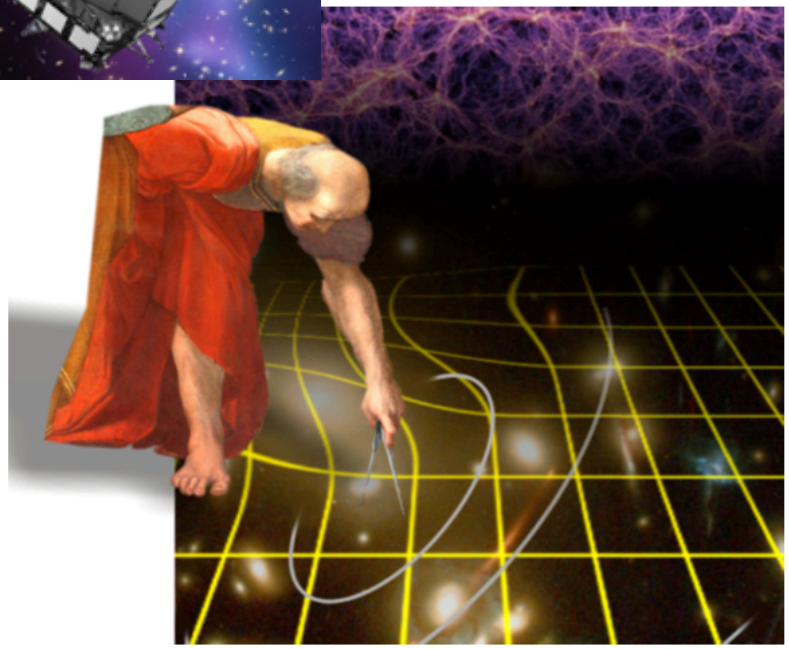
- - Emission line, SFGs (Mannucci/deputy Pozzetti)
- - Redshift/Spectral measurements (Pozzetti/Wild)

LPozzetti, E.Vanzella, G.Zamorani involved @ OAS-Bo

→ survey definition and forecasts

Euclid

Mapping the geometry of the dark Universe



ESA medium class space mission:

(launch by 2021-22)

PI. Mellier

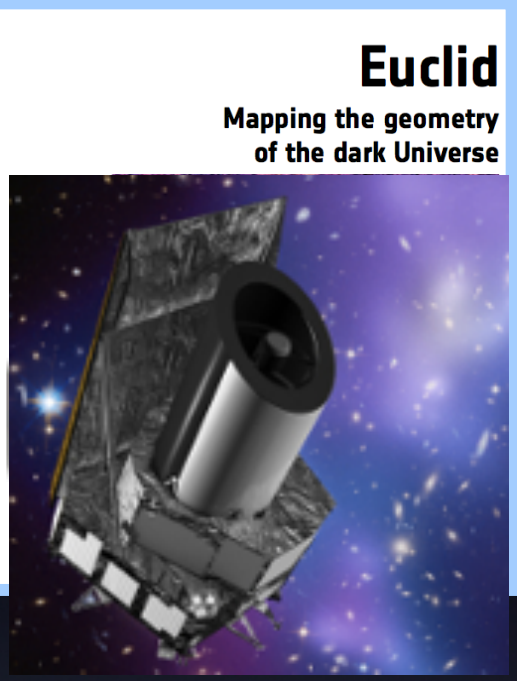
Board [Cimatti @ UniBo , Scaramella@ INAF-Rome, ...]

WIDE SURVEY: ~15,000 deg^2, VIS<24.5, + NISP (Y,J,H<24) photometric survey + NISP (H) slitless spectroscopy (>2e-16 erg/s/cm^2, Halpha @ 0.9<z<1.8)

DEEP SURVEY: ~40 deg2 @ 2 mag deeper

Goals of Euclid:

- Dark Energy probes (BAO, weak lensing and clusters)
- Galaxy evolution using ~2 Billions of gal. and ~50 millions of spectra



ESA medium class space mission:

(launch by 2021-22)

PI. Mellier

ScienceWGs[**Cimatti, Moscardini** @UniBo, **Meneghetti** @OAS-Bo ...)

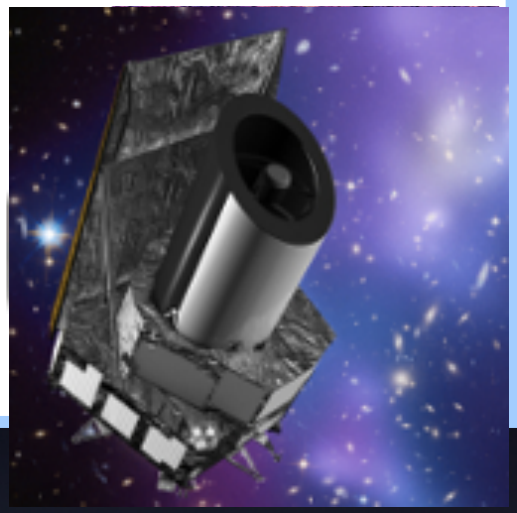
Galaxy Evolution In Euclid

@ OAS-Bo: S. Bardelli, M. Bolzonella. O. Cucciati, M. Mignoli, L. Pozzetti, E. Vanzella, D. Vergani, E. Zucca (staff at INAF-OAS-Bo), G. Zamorani + G.Girelli (PhD)

@ Uni-Bo: A. Cimatti, L. Moscardini, M. Moresco, M. Talia+

Euclid

Mapping the geometry of the dark Universe



ESA medium class space mission:

(launch by 2021-22)

PI. Mellier

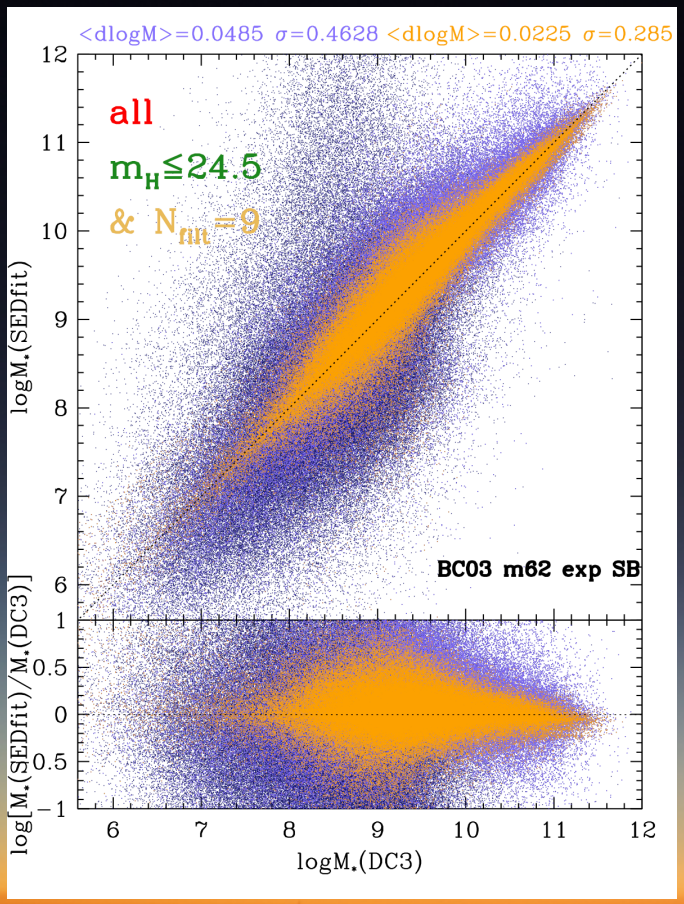
Galaxy evolution activities in Euclid:

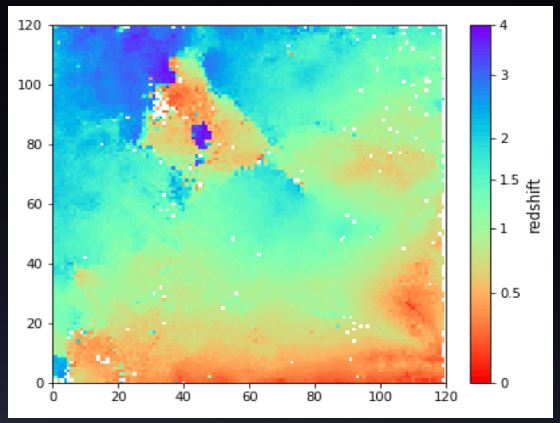
- ☑ **Physical Properties** of Galaxies from Photometry; [within Galaxy Evolution WG, and OU-PHZ for algorithm/pipeline] [**Pozzetti** WP lead]
- ☑ **Luminosity and Mass Function** (within Gal-WG+CG-WG and OU-LE3 for algorithm/pipeline) [**Zucca** WP+PF lead, **Bolzonella** PF lead, **Bardelli** Esternal data lead]
- ☑ **SFGs and ETGs** in GAL-WG [**Moresco** ETGs lead] and **blue grism science cases definition** [**Pozzetti** ETGs lead]
- ☑ **Forecast/mocks and SciencePerformanceVerification** (number density of Halpha emitters seen by NISP-Euclid + E2E simulations + mock implementation/validation} in particular for GC-WG cosmological probe [**Pozzetti** validation lead]
- ☑ **OU-SPE** for spectral measurements [**Moresco** WP5300 lead]

Euclid: Physical Parameters of galaxies

Testing SED fitting uncertainties:
stellar masses from simulated catalogues

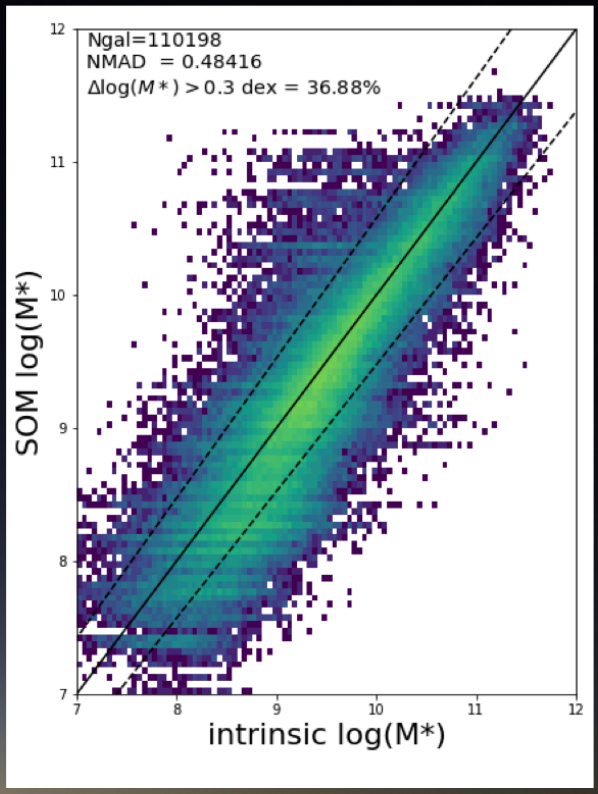
M. Bolzonella & L. Pozzetti (lead WP in GA-WG)





Self Organising Map method:
"routinely" used for photometric redshifts, starting implementation on physical parameters (by Iary Davidzon)

→ huge gain in computation time



Euclid: Empirical models of Halpha

Pozzetti et al. (2016)

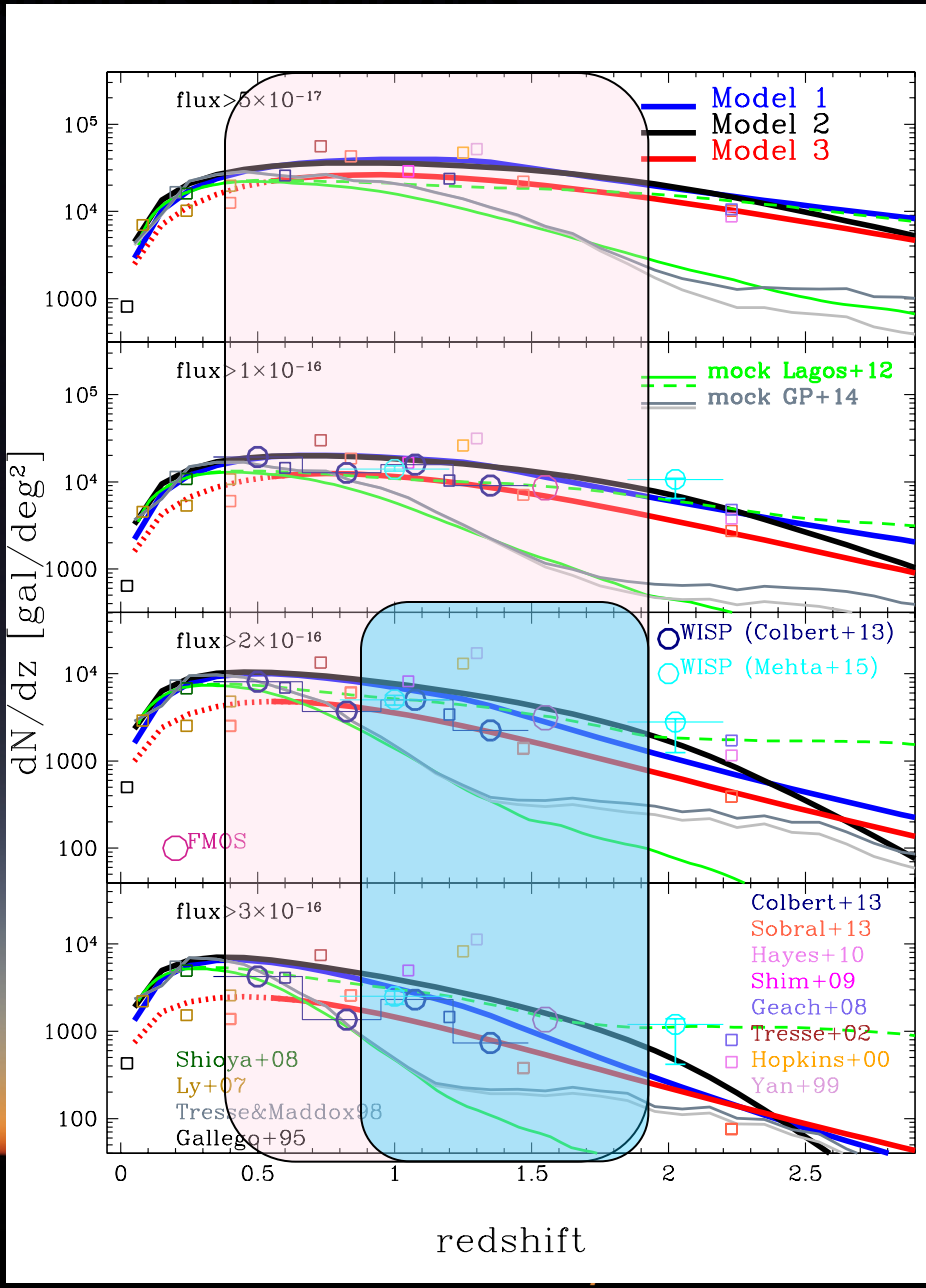
Predictions for Halpha emitters number densities at high-z:

Empirical models 1,2,3:

which cover the observed range.

SAMs do not reproduce them.

Models adopted for Forecast in Euclid and WFIRST and calibrate galaxy mocks



Euclid: Simulated mocks

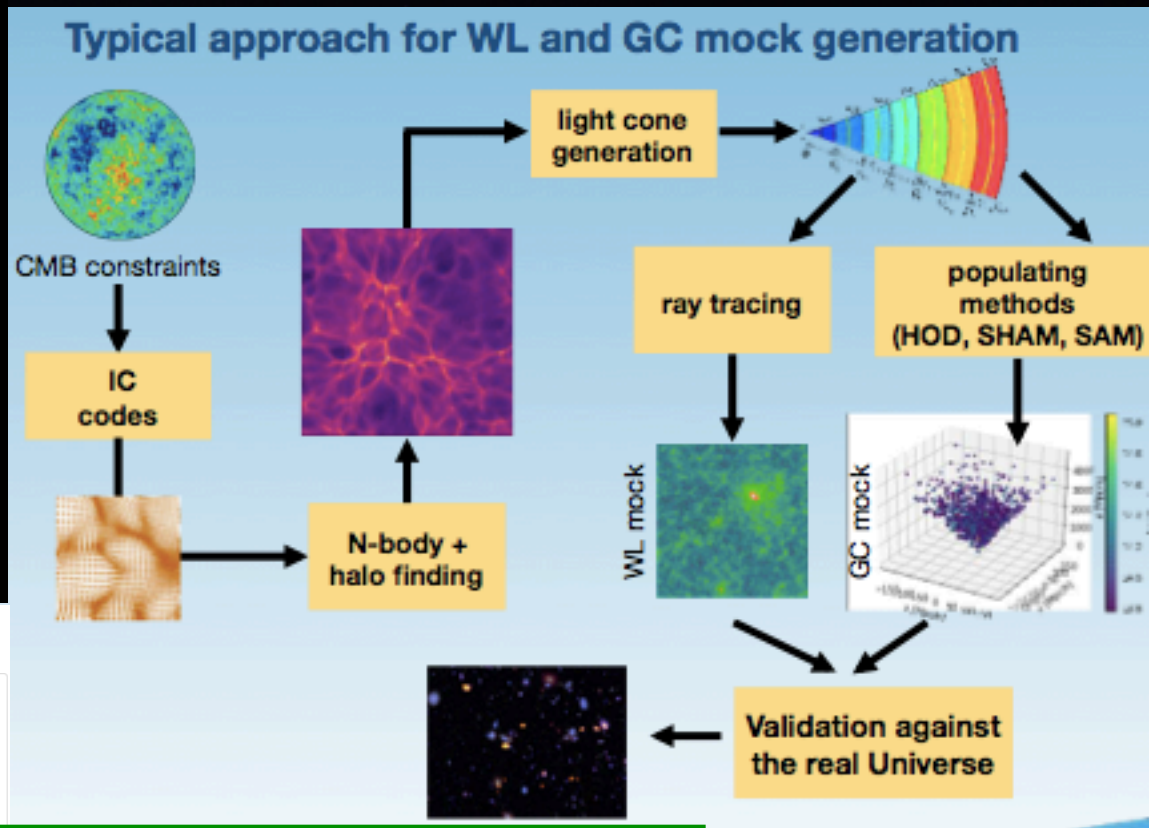
FLAGSHIP mock:

the largest simulated galaxy catalogue ever built

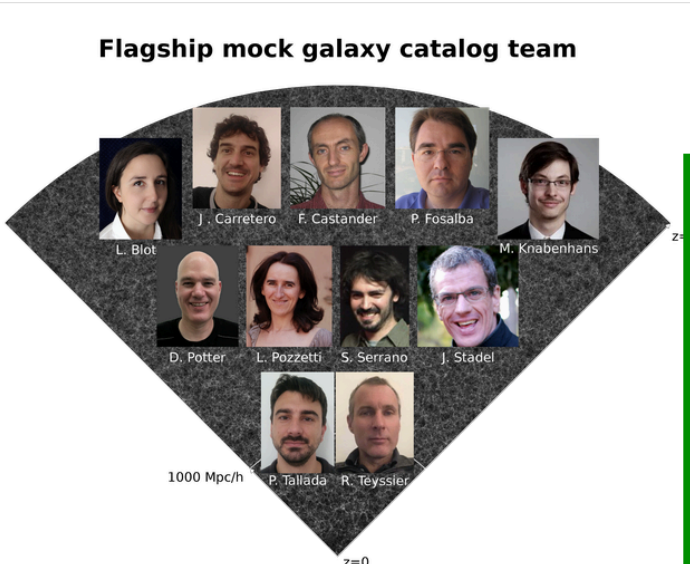
DM @ Univ. of Zürich

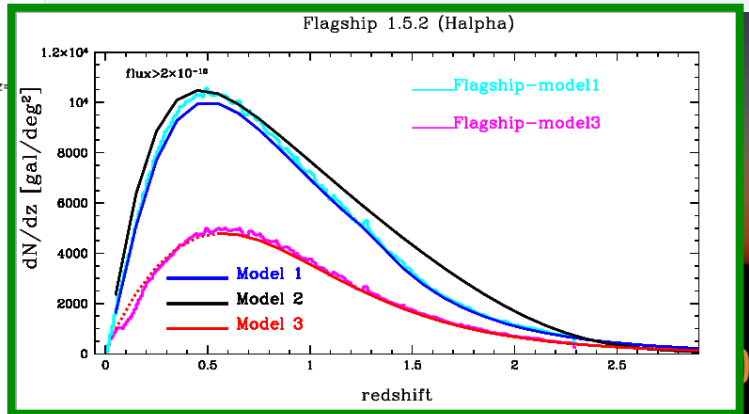
Galaxy @ Barcelona

Validation @ OAS-Bo



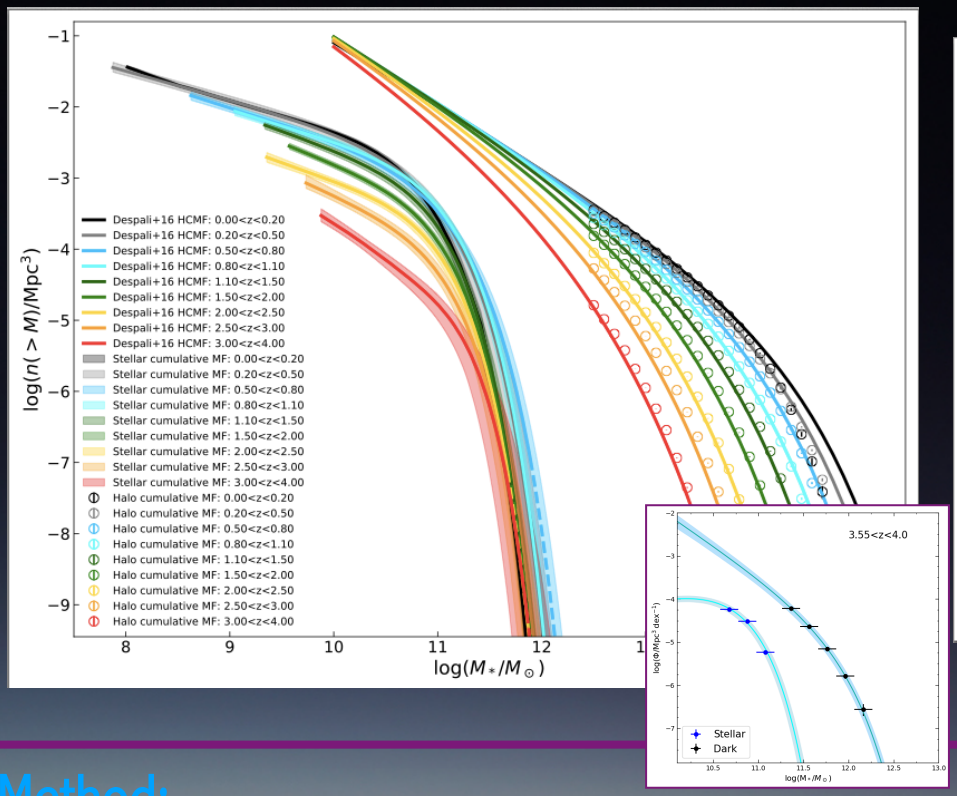
Euclid STAR Prize 2018 Team Award

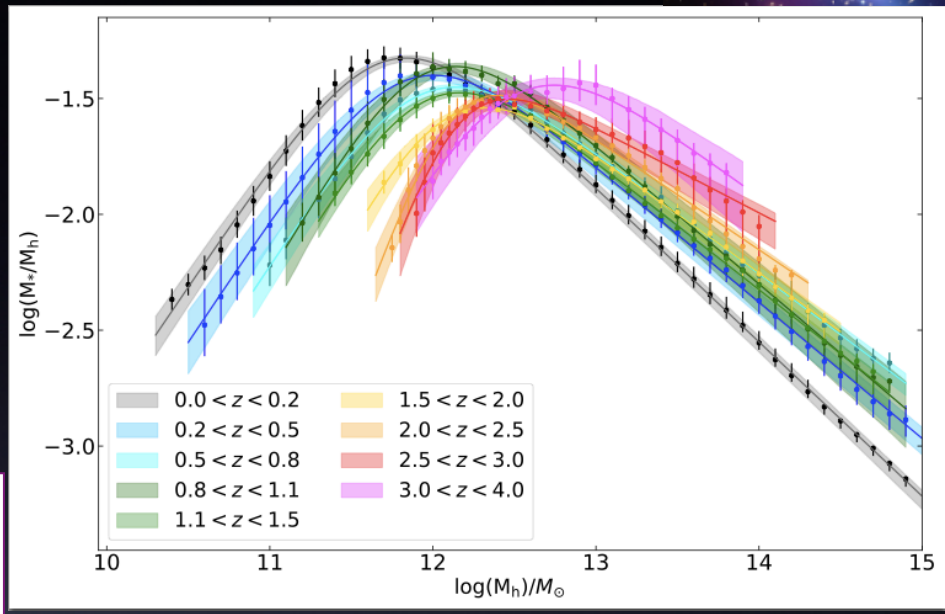




New SHAMs@ OAS-Bo

(G. Girelli, LP, M. Bolzonella, Giocoli, Baldi, +)





Method:

+ From Mhalo to Mstar using Stellar Mass Function-to-Halo Mass function vs. z
+ From Mstar to other properties using COSMOS+SXDF
+ Up to z~4-5

Reconstructing the evolution of galaxies

➢ HIGHLIGHTS

+ Stellar Mass Assembly History using best spectroscopic data up to z=1.5
+ Physical properties from high-S/N spectra (SDSS/VANDELS)
+ New method to select quenching & quenched galaxies (from SDSS to z>3)
+ Empirical models used for the calibration/validation of Euclid galaxy mocks

➢ FUTURE

+ Survey definition and forecasts for future spectroscopic surveys (WEAVE, MOONS, Euclid, SPICA+SAFARI)
+ Physical properties from high-S/N spectra [WEAVE/MOONS +**JWST**]
+ Definition and Implementation of algorithms (SPE, LF/MF) [Euclid/MOONS]
+ New SHAMs galaxy mocks

➢ CRITICALITIES:

- No Post-docs @OAS-Bo
- No "primo Ricercatore"/"Dirigenti di ricerca"
- Software developer missing

1996 - Film by Quentin Tarantino

Reconstructing the evolution of galaxies

Lucia Pozzetti
INAF – OAS - Bologna

THANKS

Giornate di Osservatorio, Bologna, 17-18/12/2018