MAORY-MICADO @ E-ELT

A first look at the extragalactic scientific cases

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Outline of the talk

- Summary of the observing capabilities of MAORY-MICADO

- Some extragalactic scientific issues:
    - Search and structure of primordial galaxies (z>11)
    - Galaxy stellar mass growth and quenching: compact galaxies, spheroids and galaxy central regions.
    - From dual to binary SM Black Hole

MAORY+MICADO Reference numbers

IMAGING

- **53''x 53'' FoV, 4 mas/px** **MCAO-mode FWHM<0.02 arcsec**
- 16''x 16'' FoV, 1.5 mas/px
- I, z,Y, J, H, K filters + a set of narrow band filters
- 5σ **limiting mag.(AB) K=29.5, H=30.4, J=29.7** (5 hours exp)

SPECTROSCOPY

- Long-slit spectral resolution R=4000-8000
- slit orientation along the parallactic angle (slit width ~0.04)

KEY POINTS

- Unsurpassed angular resolution at near-IR wavelengths
- Depth

MAORY+MICADO Reference numbers

H_0=70 km s^{-1} Mpc^{-1}
Ω_m=0.3 Ω_Λ=0.7

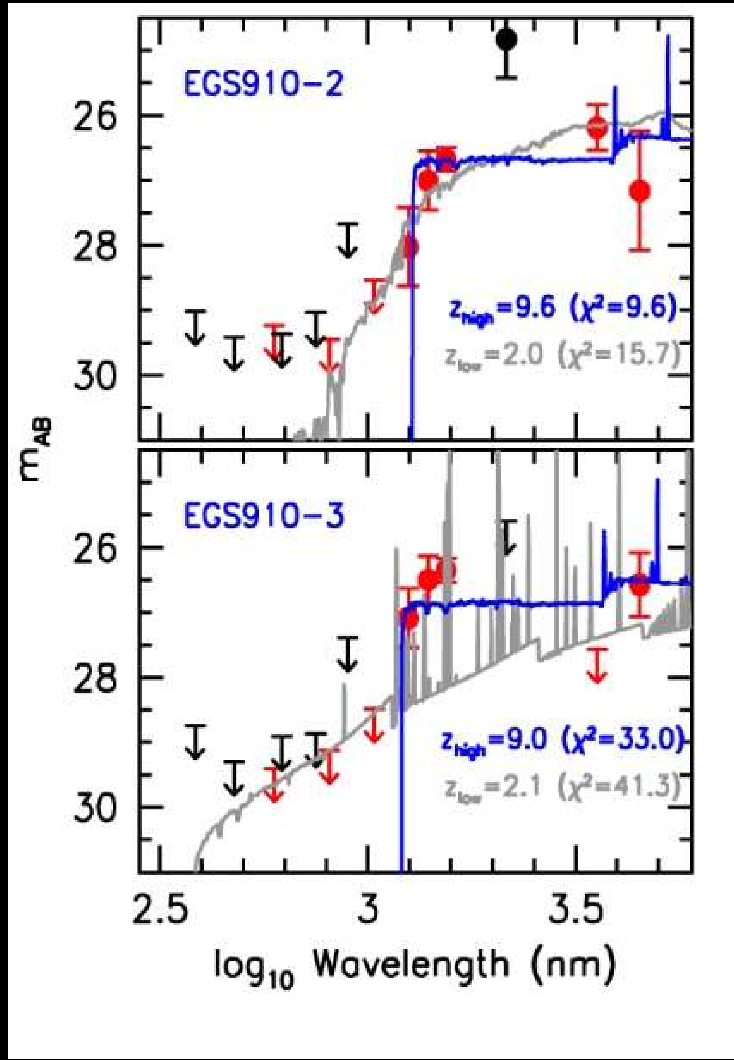
→ Seeing ~0.32'' at λ=2.2 μm, **S=0.6** (dl_FWHM=0.012 arcsec)
→ MCAO mode **~70%** of flux within **0.02 arcsec, 4 mas/pix**

Redshift	MCAO 0.02'' (5 pix)	JWST 0.064'' (2 pix)	HST 0.2'' (1.7 pix)
0.01	4 pc	13 pc	**40 pc**
0.05	20 pc	65 pc	**200 pc**
1.5	170 pc	540 pc	**1.7 kpc**
4	140 pc	442 pc	**1.4 kpc**
8	96 pc	310 pc	**1.0 kpc**
12	73 pc	234 pc	**730 pc**

- Giant molecular clouds (star forming regions) **~30-100 pc**
- AGN torus inner/outer diameter ~**few (>2) pc** up to hundreds pc
- From dual-to-binary AGN: **from ~1 kpc to ~1pc**
- Half-light diameter of densest galaxies ~**1 kpc**
- Half-light diameter of z=8-9 galaxies **~1 kpc**
- **Primordial galaxies z>11 ?**

Searching for primordial galaxies: LBGs at z>11

- Strong absorption of UV flux at λ_{rest}<1200 A (Ly-break) from intergalactic medium
- J,H drop-out, z >10,13
- Blue continuum at λ_{rest}>1200 A



Bouwens et al. 2016

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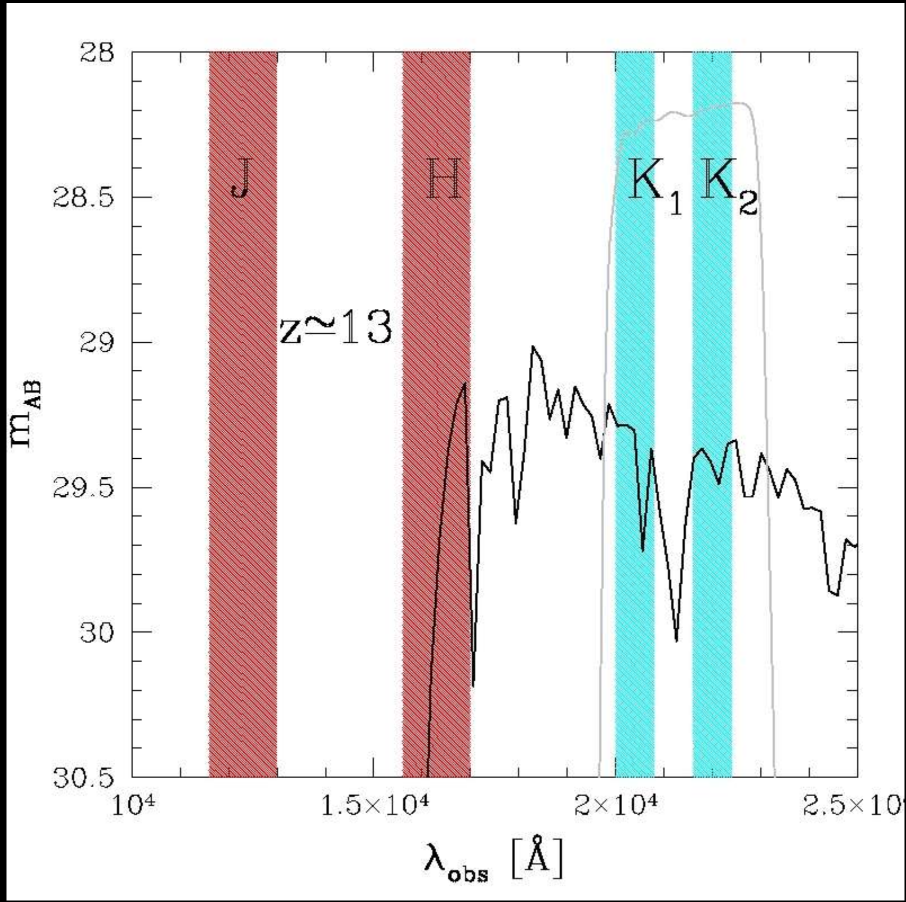


Color-color diagram
(J,H-K1) vs (K1-K2)
K1 and K2 dedicated filters

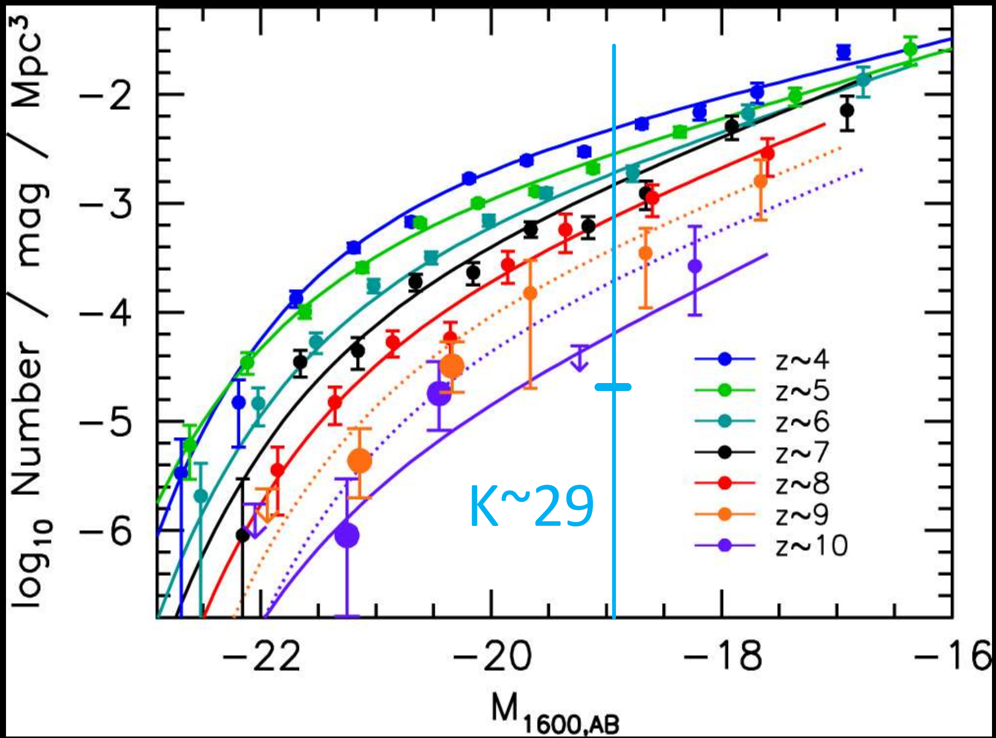
Searching for primordial galaxies: LBGs at z>11

Expected volume density at z>13
Φ_{gal}<5-25x10^{-5} Mpc^{-3}.

Surface density 12.5<z<15.5
0.1-0.5 gal/arcmin^2

	MAORY+MICADO	JWST
F.o.v	0.8 armin^2	9.4 arcmin^2

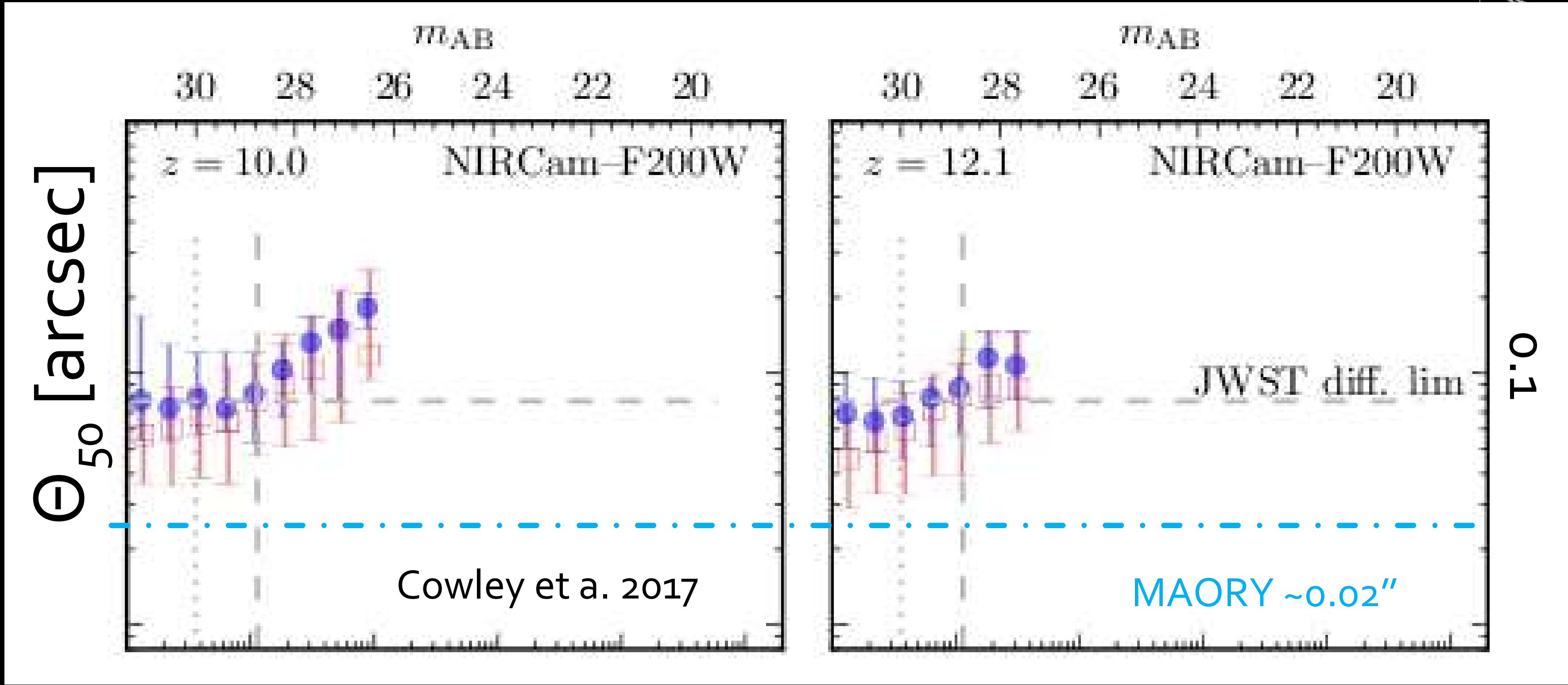
Comparable t_{exp} to reach K~29 (slightly better MAORY but not a factor 10)



Bouwens et al. 2016; Cowley et a. 2017

MAORY not very competitive *in searching* for primordial galaxies, but…

The structure of primordial galaxies

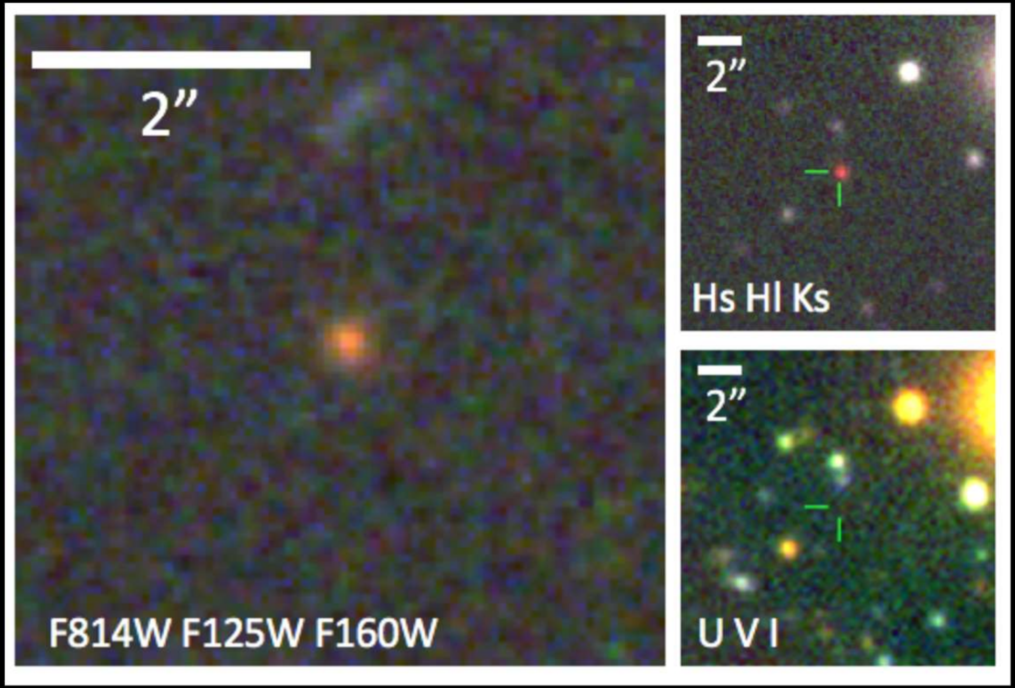


Size of galaxies at z>10-11 comparable to the FWHM of JWST
→ they will not be resolved by JWST

MAORY+MICADO the only instrument capable to study the structure (light profile) of primordial galaxies

Compact star forming galaxies and massive spheroids

How do spheroids assemble their stellar mass (>5x10^{10} Msun) and rapidly (<1 Gyr) quench their star formation ?



Massive spheroid

M>10^{11} Msun

R_e=0.5 kpc

High mass density Σ

z=3.7

age of the Universe 1.5 Gyr

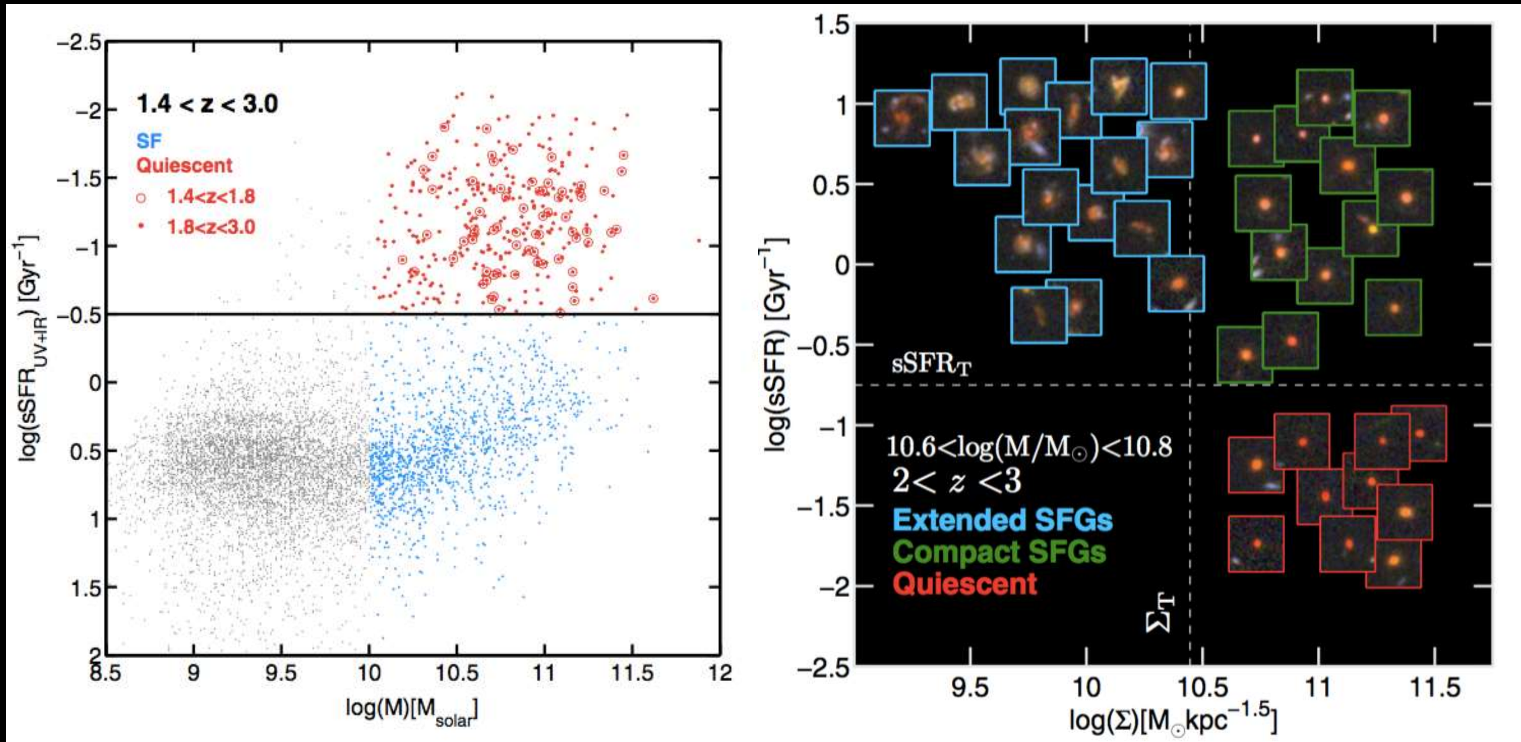
Glazebrook et al. 2017, Nature (arxiv.01702)

Who are the progenitors ?

What about their mass growth and quenching ?

Compact star forming galaxies and massive spheroids

A population of compact star-forming galaxies with properties different from those of large SF systems



Barro+13,14, van Dokkum+15

Are compact star-forming galaxies the progenitors of massive dense spheroids ?

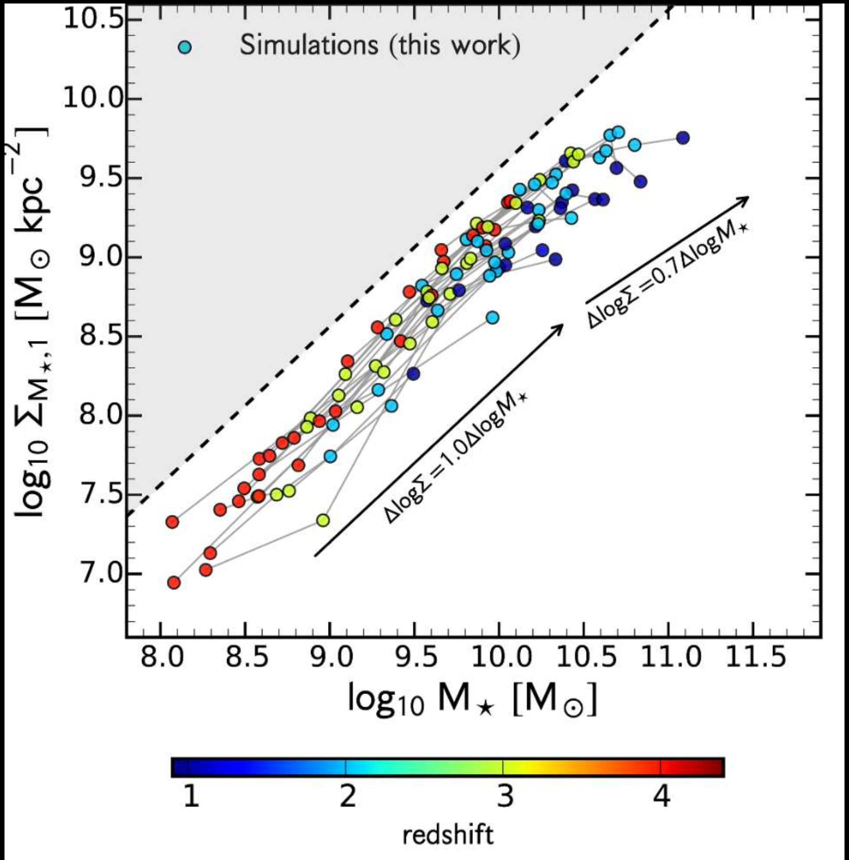
Mass growth, quenching and galaxy central regions

- What is that regulate mass growth and quenching in galaxies?
- What is the main process through which galaxies assemble their stellar mass? Internal star formation (in-situ) or accretion from external processes ?
- How does the quenching proceed ?

Models and observations seem to attribute a role to the galaxy central regions (<1kpc) in regulating mass growth and quenching.

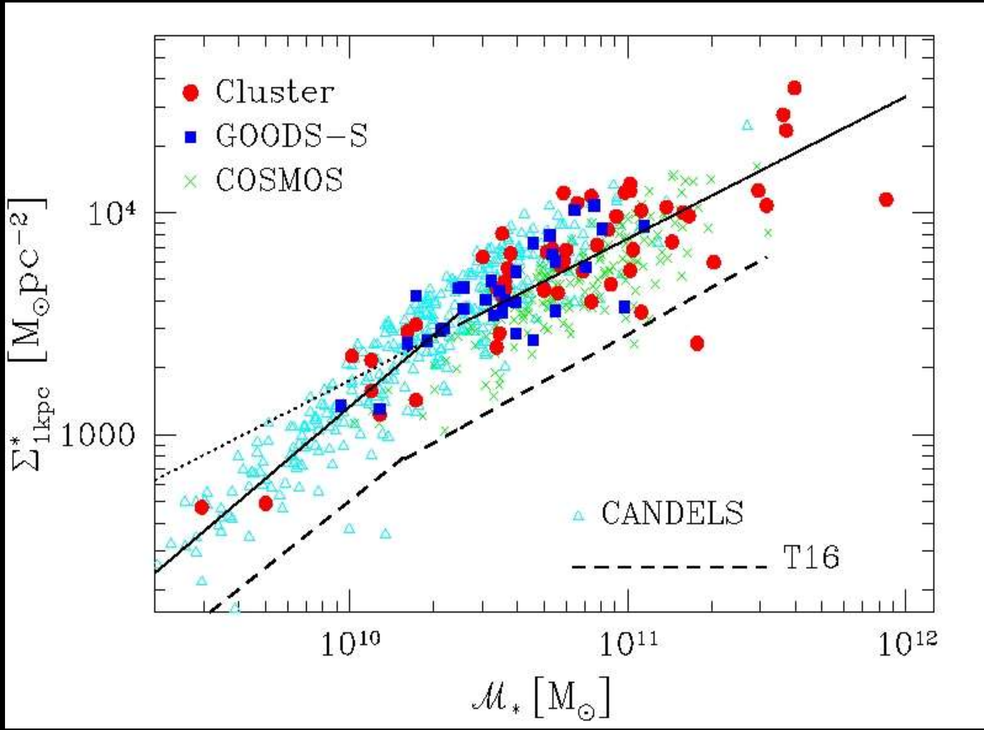
Mass growth, quenching and galaxy central regions

Central stellar mass density Σ_{1kpc} (<1kpc) < 0.1 arcsec at z>1



(Tacchella+16)

Early-type galaxies 1.2<z<1.5.



(Saracco+17)

Mass growth, quenching and galaxy central regions

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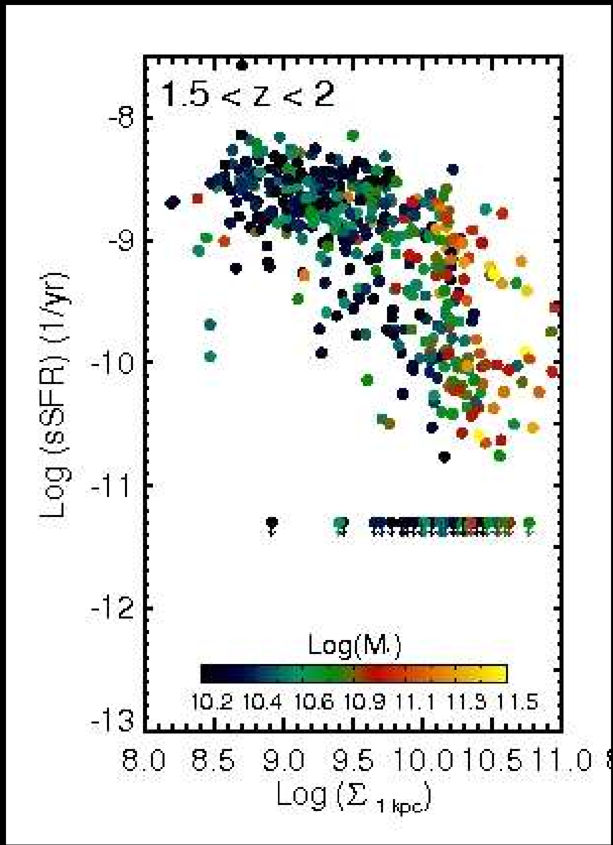
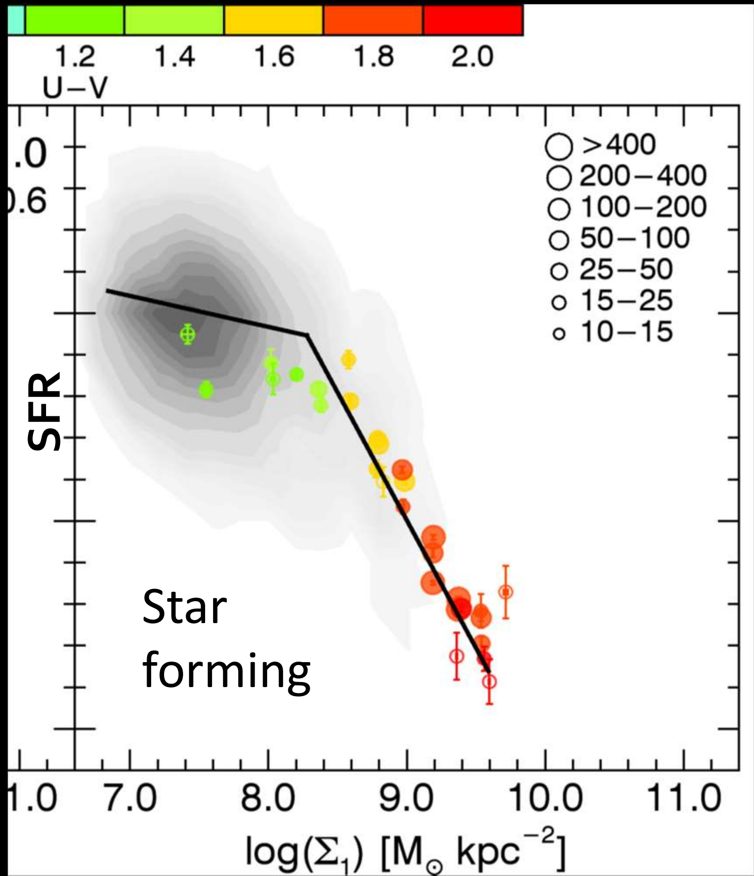


(Mosleh+17)



(Whitaker+17)

Causality not yet established, some underlying process?

Mass growth, quenching and galaxy central regions

MAORY-MICADO

Spatial resolution <150 pc (~0.02") at z>1.....

From J (λ_{rest}<4000 A at z~2) to K (λ_{rest}>6000 A)

Imaging

- Morphology and structure of SF and quiescent galaxies
- Color profiles: spatial distribution of the stellar populations.
- Narrow-band: spatial mapping of abs. features, stellar population properties (abs. features, e.g. Mgb 5173 A, D4000).

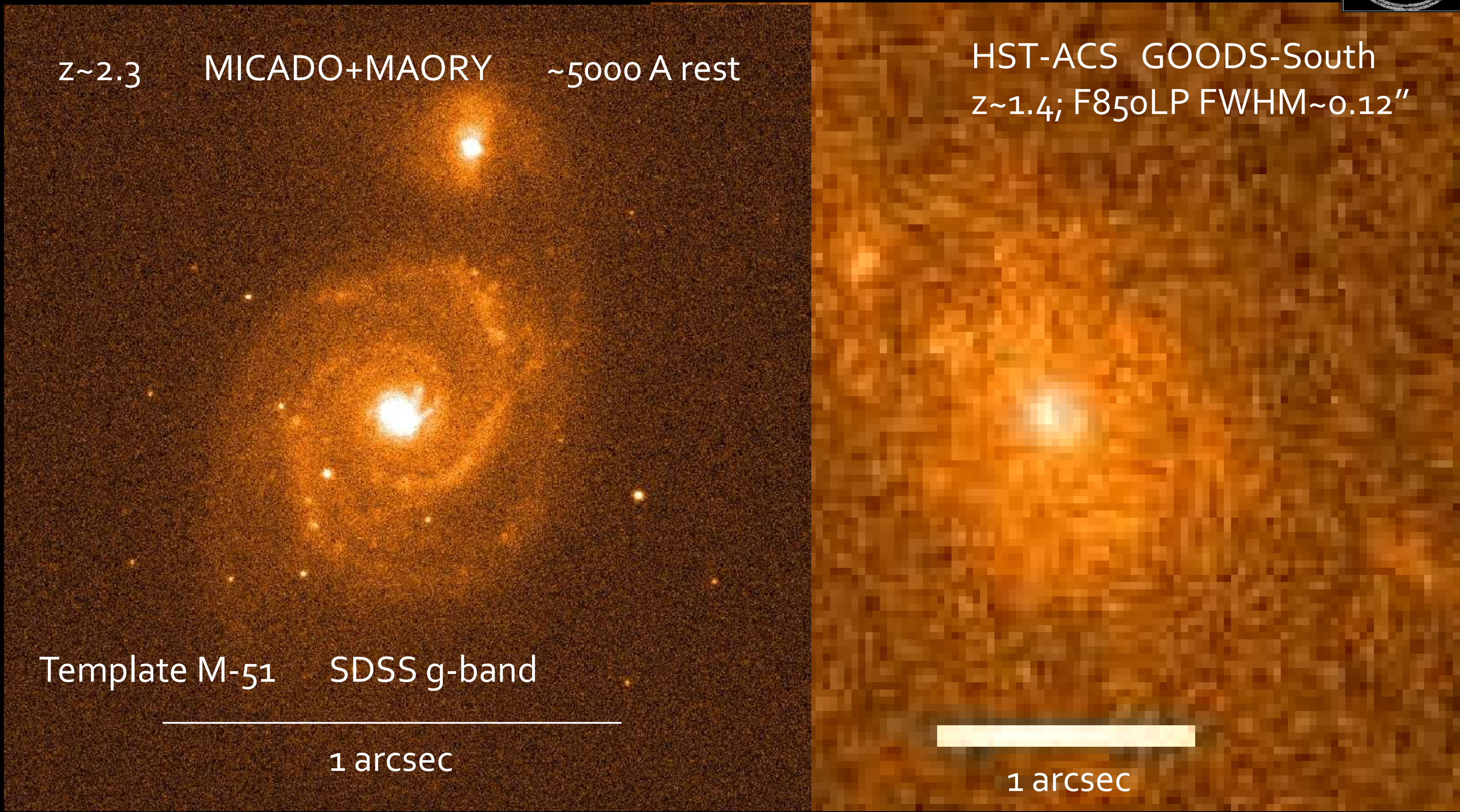
  Optimal targets: high-z proto-clusters/overdensities

  (tunable filter…unavailable!)

Spectroscopy

- Star formation history and chemical enrichment in the core of galaxies

The central regions of galaxies seen by MAORY



Advanced Exposure Time Calculator (AETC; Falomo et. al. 2011)

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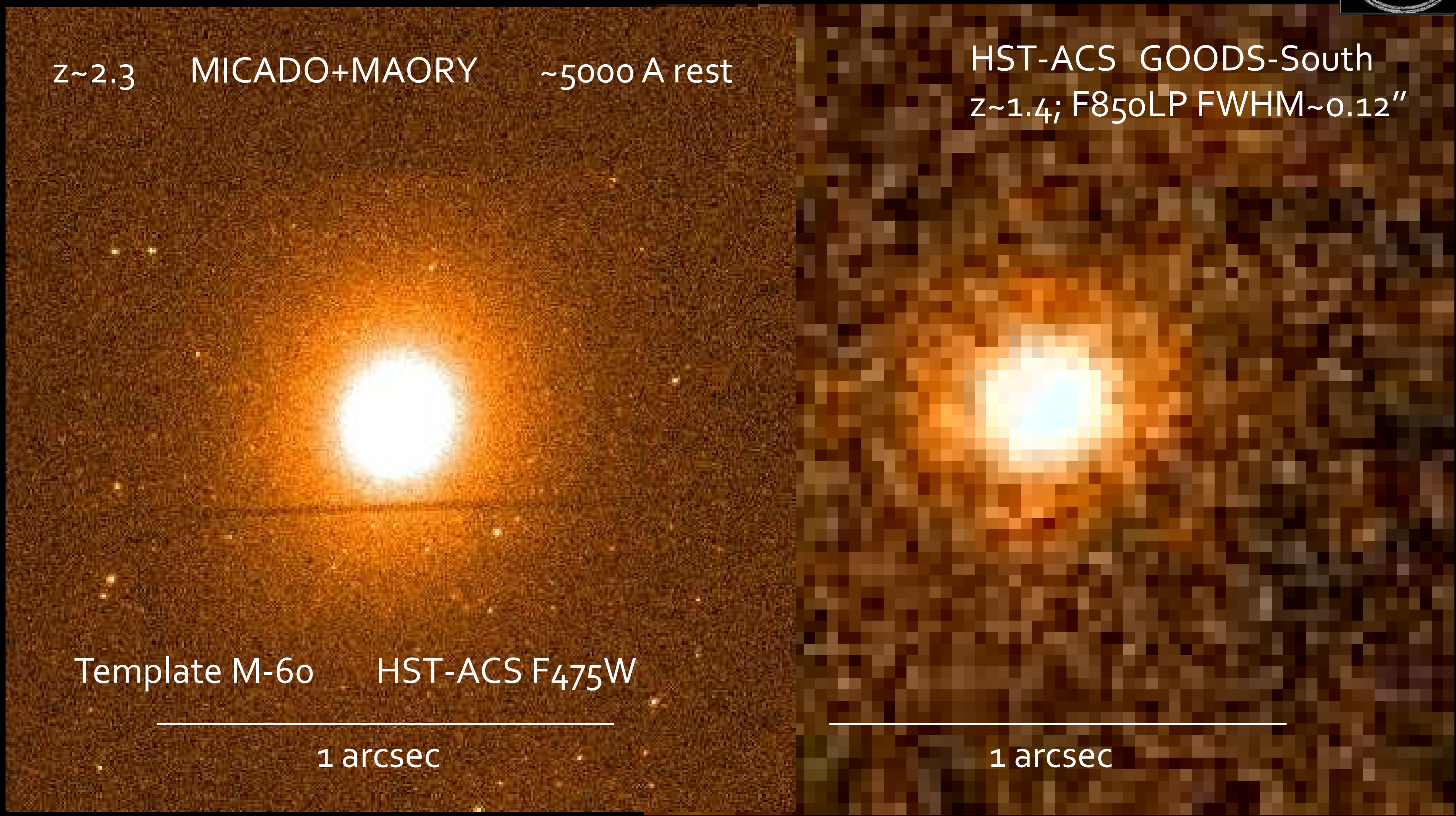


Advanced Exposure Time Calculator (AETC; Falomo et. al. 2011)

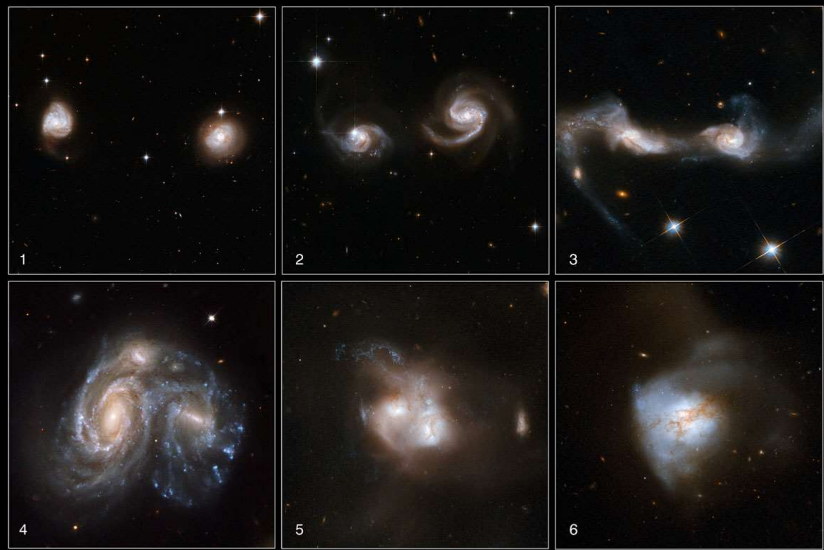
From Dual to Binary SMBH

Almost all galaxies with spheroids have SMBH in their cores

Dual and Binary SMBHs are
expected in a hierarchical Universe from mergers

Stages of gravitational interaction:

- Galaxy pairs (tens kpc separation)
- Dual SMBH (kpc scale separation)
- **Binary SMBH (pc separation)**
- **Coalescence (sub-pc separation)**
  GRAVITATIONAL WAVES

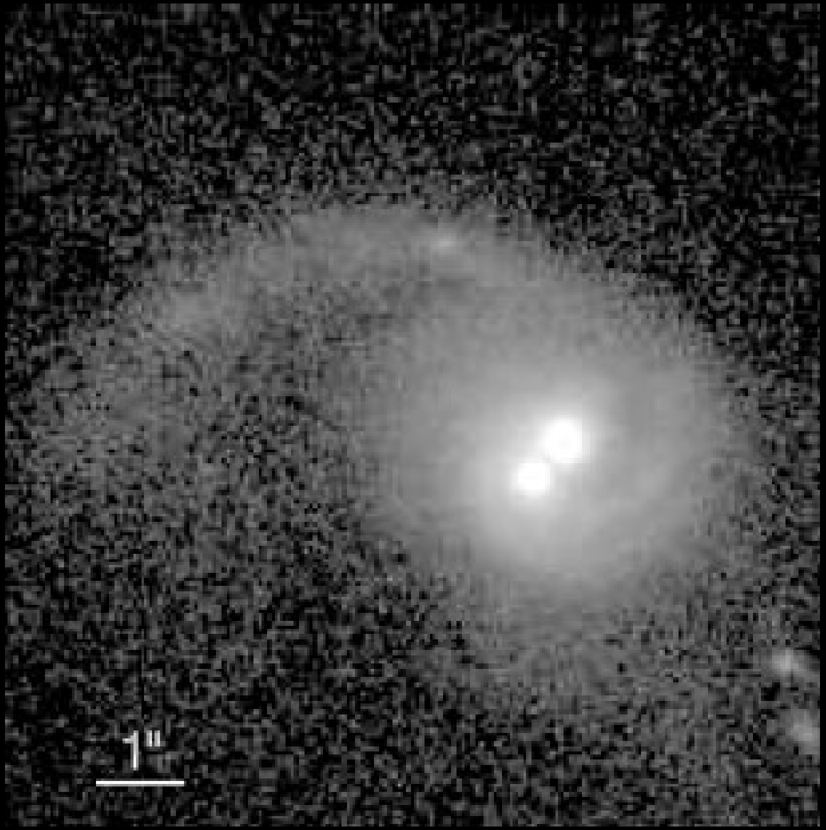


Encode crucial information about the assembly of galaxy bulges and SMBHs.

From the observational point of view

✓ High resolution imaging to resolve the two active nuclei

HST F814W ACS image of
J100043+020637
z=0.36
Two bright nuclei separated by
0,497” or 2.5 kpc



Comerford et al. 2009

What we observe…

- Thousands of known galaxy pairs.
- Dozens of dual SMBH at kpc separation
- A few definitive sup-kpc (three?) all at $z<0.06$

Huge gap between observed and expected numbers!

What we need …

- High sensitivity, high spatial resolution NIR images (less affected by absorption effects at least up to $z\sim3$)

MAORY-MICADO would allow to follow the merging phases almost up to the coalescence

Extragalactic scientific issues

- Structure of primordial galaxies
- Star forming regions/clumps in high-z galaxies
- The assembly of high redshift early-type galaxies.
- The central regions of high-z galaxies
- GCs detection in external galaxies and DM distribution.
- Dual to binary SM Black Holes in local and high-z Universe.
- Strong lensing with MAORY
- The early uiniverse with Gamma Ray Bursts
- …….

MAORY-MICADO will probe the Universe at unprecendented resolution.

Thank you!