Exploring the stellar population of nearby and high redshift galaxies with ELTs

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Introduction

To constrain models of formation and evolution of stellar systems we need to understand the history of their stellar population

→ reconstruct:
SFR(t) Star formation history
Z(t) Chemical evolution history

measure age and metallicity for all stellar populations in a galaxy

How stellar and galaxy formation and evolution depend on environment?
→ metal-poor vs. metal-rich systems
→ Isolated galaxies vs. groups vs. clusters

We need to look outside the Local Group

CMDs in the Local Universe

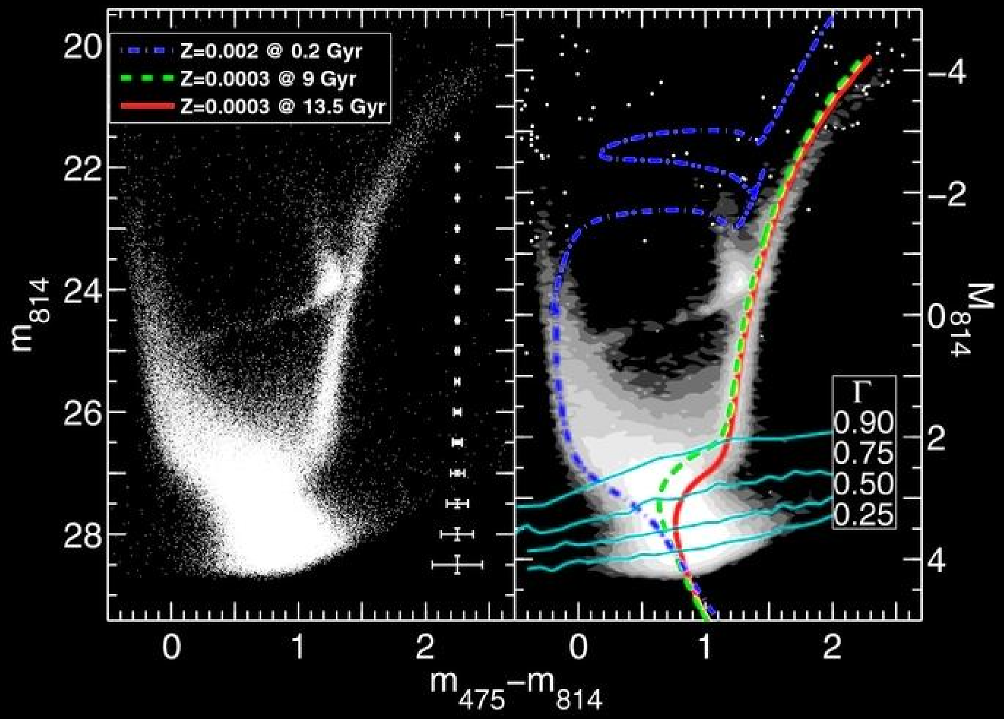
Resolved stellar photometry of MSTO stars is NOW possible only in the Local Group (d<1Mpc)

For more distant galaxies only evolved stellar populations can be detected

Beyond ~5Mpc : ages and metallicities from unresolved stellar populations

ACS@HST, ~8h each band

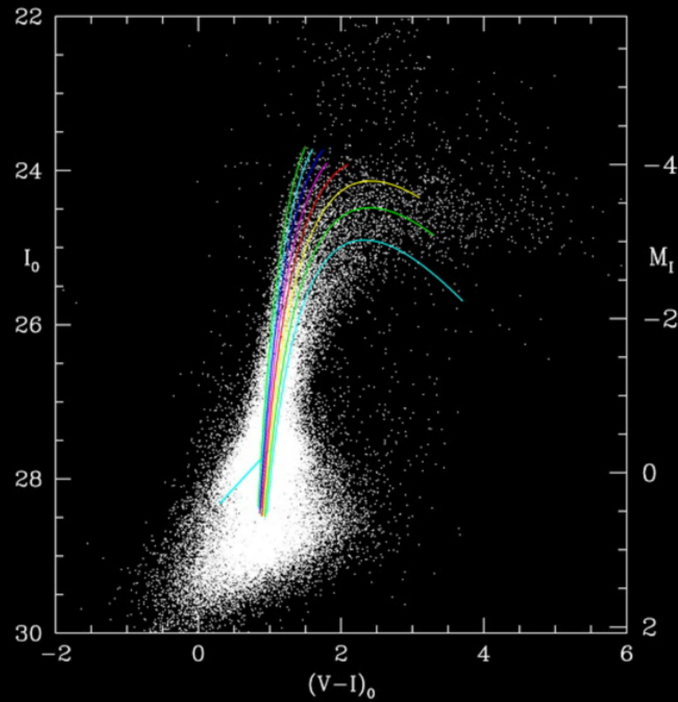
Skillman+2013



IC 1613: $(m-M)_0$=24.4 mag; d=0.7 Mpc

ACS@HST, ~8.5h each band

Rejkuba+2005



NGC 5128: $(m-M)_0$=27.9 mag; d=3.8 Mpc

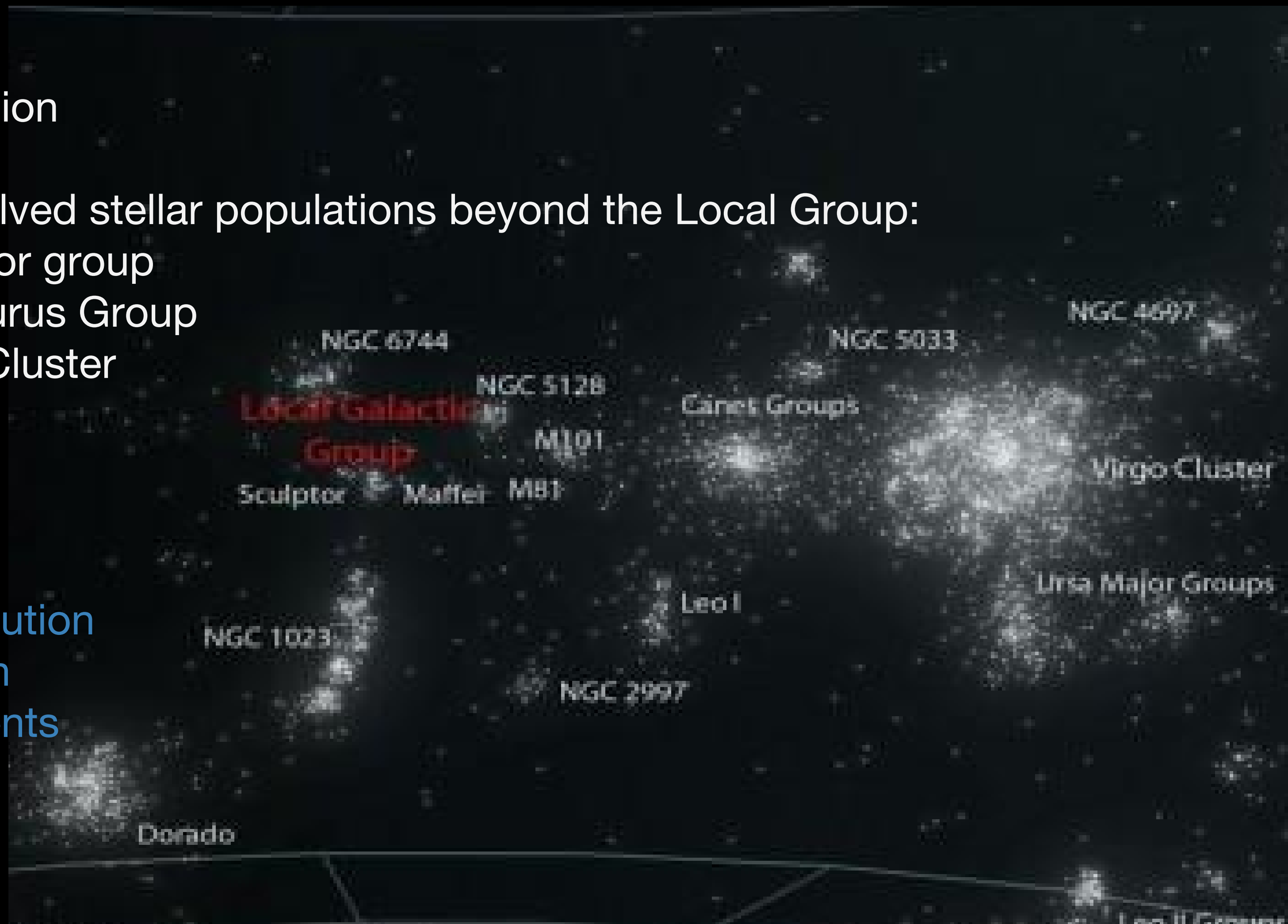
Beyond the limit

ELTs

→ sensitivity
→ spatial resolution

Photometry of resolved stellar populations beyond the Local Group:

→ Sculptor group
→ Centaurus Group
→ Virgo Cluster



Formation and evolution of stellar systems in different environments

Our project: science cases for E-ELT

Method

We simulated E-ELT observations adopting the specs of MICADO@E-ELT

Images are simulated using the Advanced Exposure Time Calculator http://aetc.oapd.inaf.it

Photometric measurements and analysis to asses the feasibility of the science cases

→ DAOphot, StarFinder, GalFIT

Cases

Greggio et al. 2012:

→ SFH in the center of the disk of a giant spiral in the Centaurus Group (4.6 Mpc)

→ SFH in the halo of giant ellipticals in the Virgo Cluster (18 Mpc)

Schreiber et al. 2014:

→ Metallicity gradients in Virgo ellipticals

Gullieuszik et al. 2014:

→ Nuclear Stars Clusters

Gullieuszik et al. in prep:

→ structural parameters and colour gradients in high z galaxies

Nuclear Star Clusters [Gullieuszik et al. 2014]

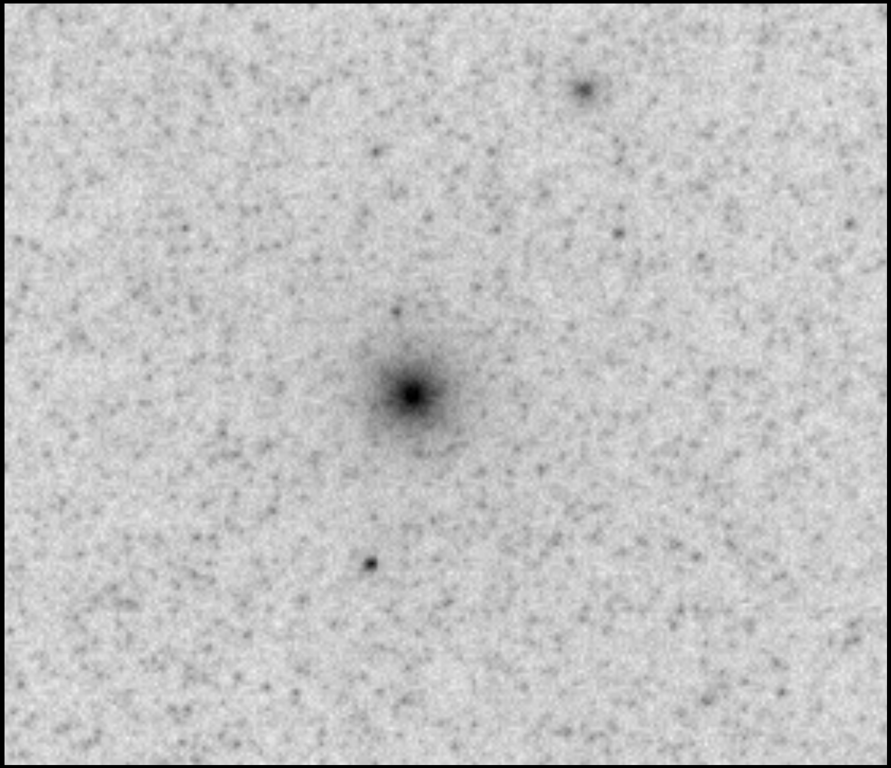
Compact objects (R ~ 2 - 4 parsec)

Massive and Bright (~3 mags brighter than galactic globular clusters)

Not resolved by HST

High spatial resolution is required

Perfect test-bed for ELTs performances



NGC300; d= 2.2 Mpc ; ACS@HST

Böker+2002

Found in ~70% of galaxies of all types

They follow the same scaling relations found for SMBH

Is there any relation between NSC and formation and evolution of SMBHs and galaxies?

We need to recover their SFHs

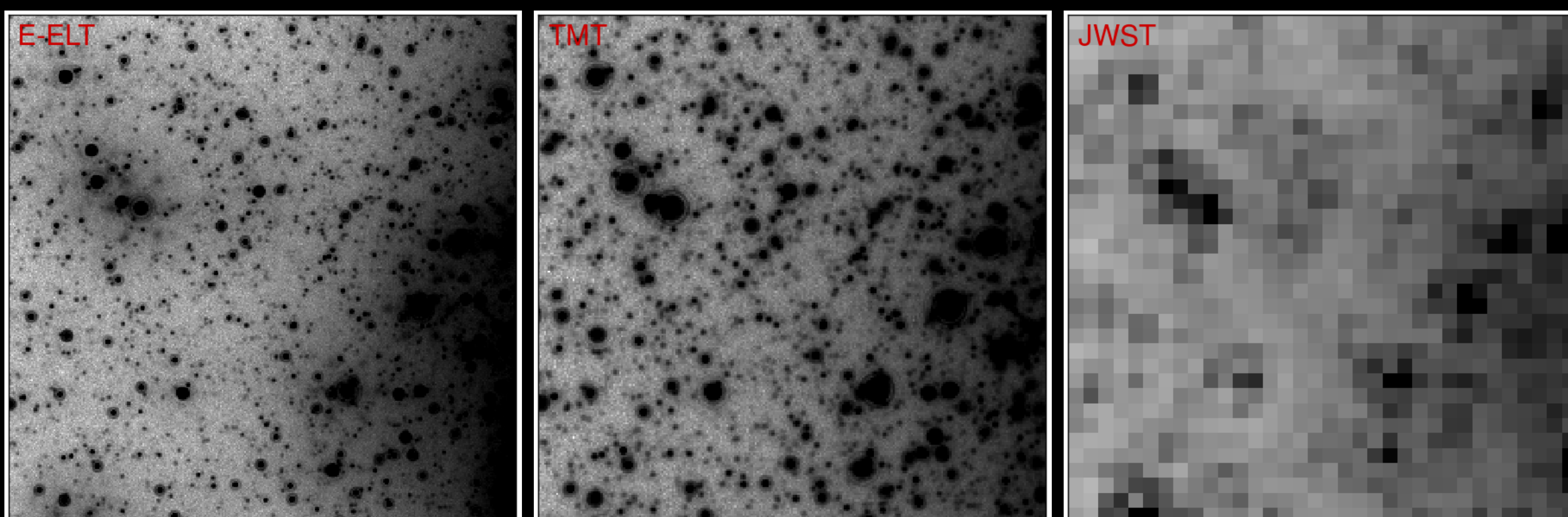
> resolved stellar photometry

Nuclear Star Clusters [Gullieuszik et al. 2014]

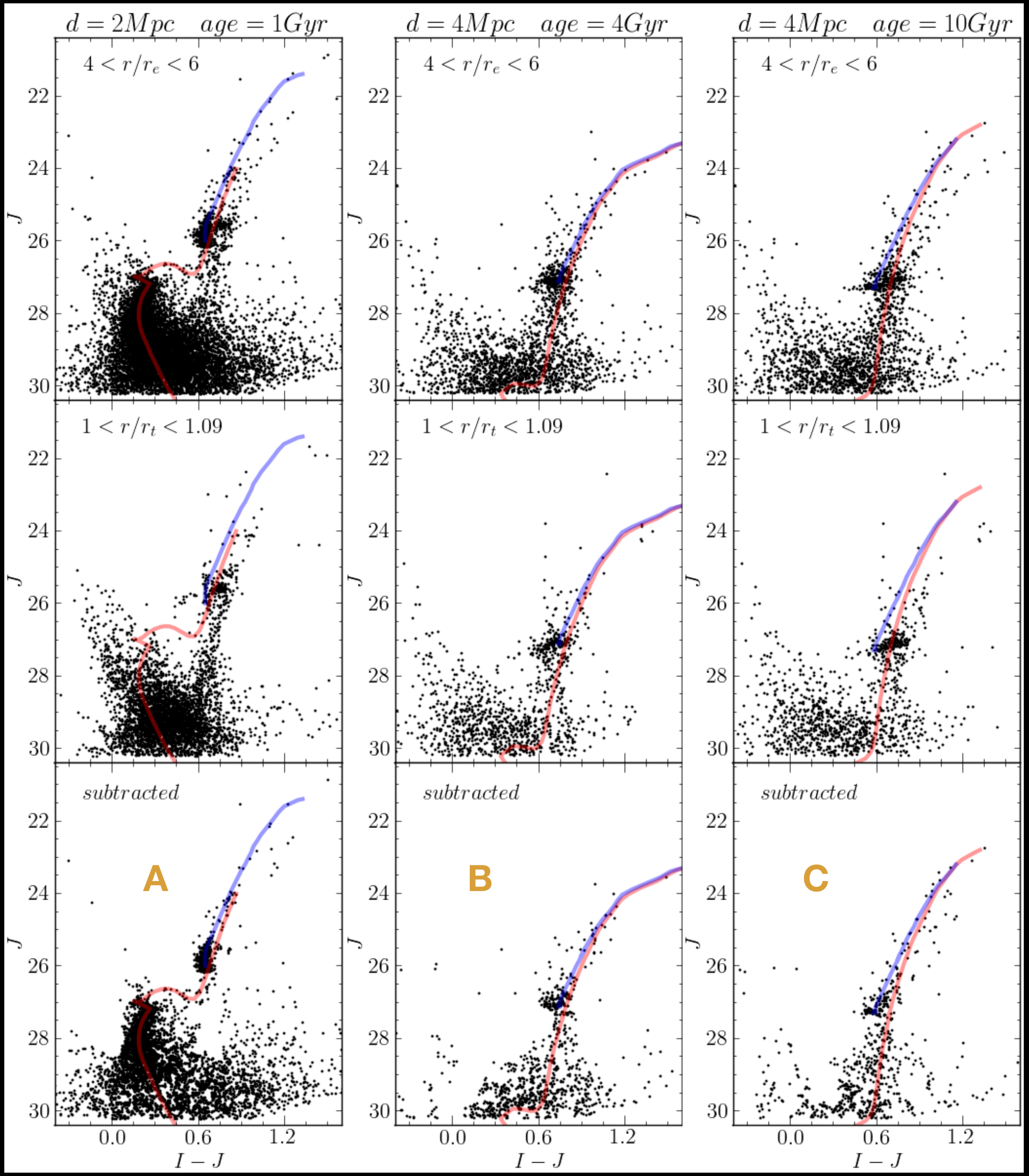
What stellar populations can be studied with ELTs?
> which MSTOs are detectable with an ELT?

We simulated NSCs using Simple Stellar Populations:
→ Ages: 1,4, 10 Gyr
→ Distance: 2, 4 Mpc
+ host galaxy stellar populations

- Photometry with Starfinder
- Analysis of photometric errors and completeness
- Statistical subtraction of foreground host galaxy
- detection of Main Sequence Turn off to asses the feasibility of SFH recovery
- feasibility with E-ELT, TMT (and JWST)



Nuclear Star Clusters [Gullieuszik et al. 2014]



In the central regions the crowding worsen the photometric accuracy

The outer region is dominated by the host galaxy

In the intermediate region the NSC populations are clearly visible.

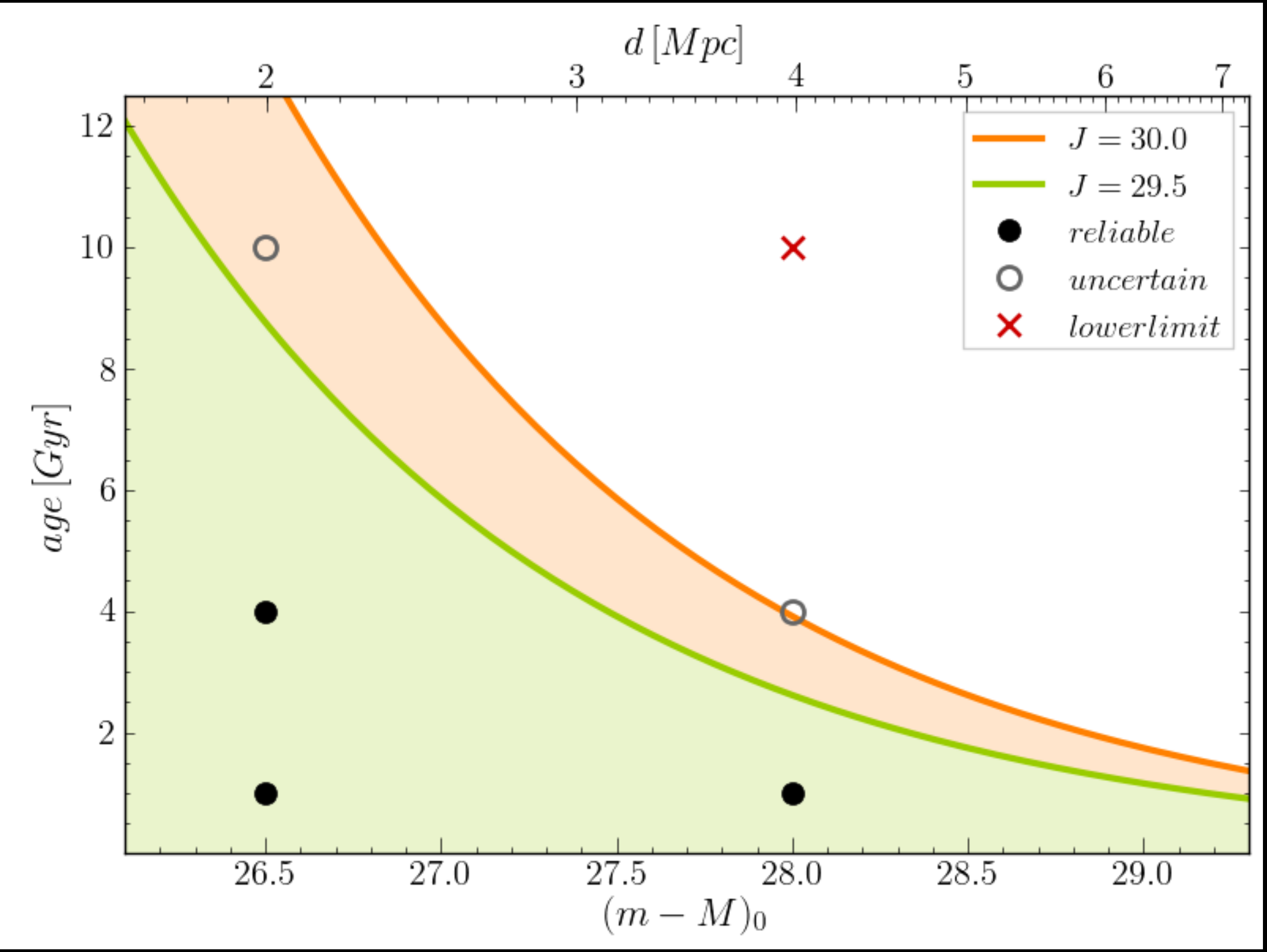
Statistical subtraction of the host galaxy stellar population

A: Detected:
Reliable age estimate

B: At detection limit:
Uncertain

C: Undetected
No age. Lower limit?

Nuclear Star Clusters [Gullieuszik et al. 2014]



MSTO magnitude calculated from Marigo+2008 stellar evolution models

Stellar population with MSTO magnitude:

Green: brighter than 80% completeness limit (J=29.5 mag)

Orange: brighter than 50% completeness limit (J=30.0 mag)

High-z galaxies. Intro

Galaxies @z~2 have Re smaller than a few Kpc

[at z~2 4 Kpc corresponds to ~0.5 arcsec]

they have Re ~ FWHM of HST

determination of structural parameters are strongly dependent on PSF deconvolutions

Populations gradients are more prominent in the inner regions.

>> higher spatial resolution

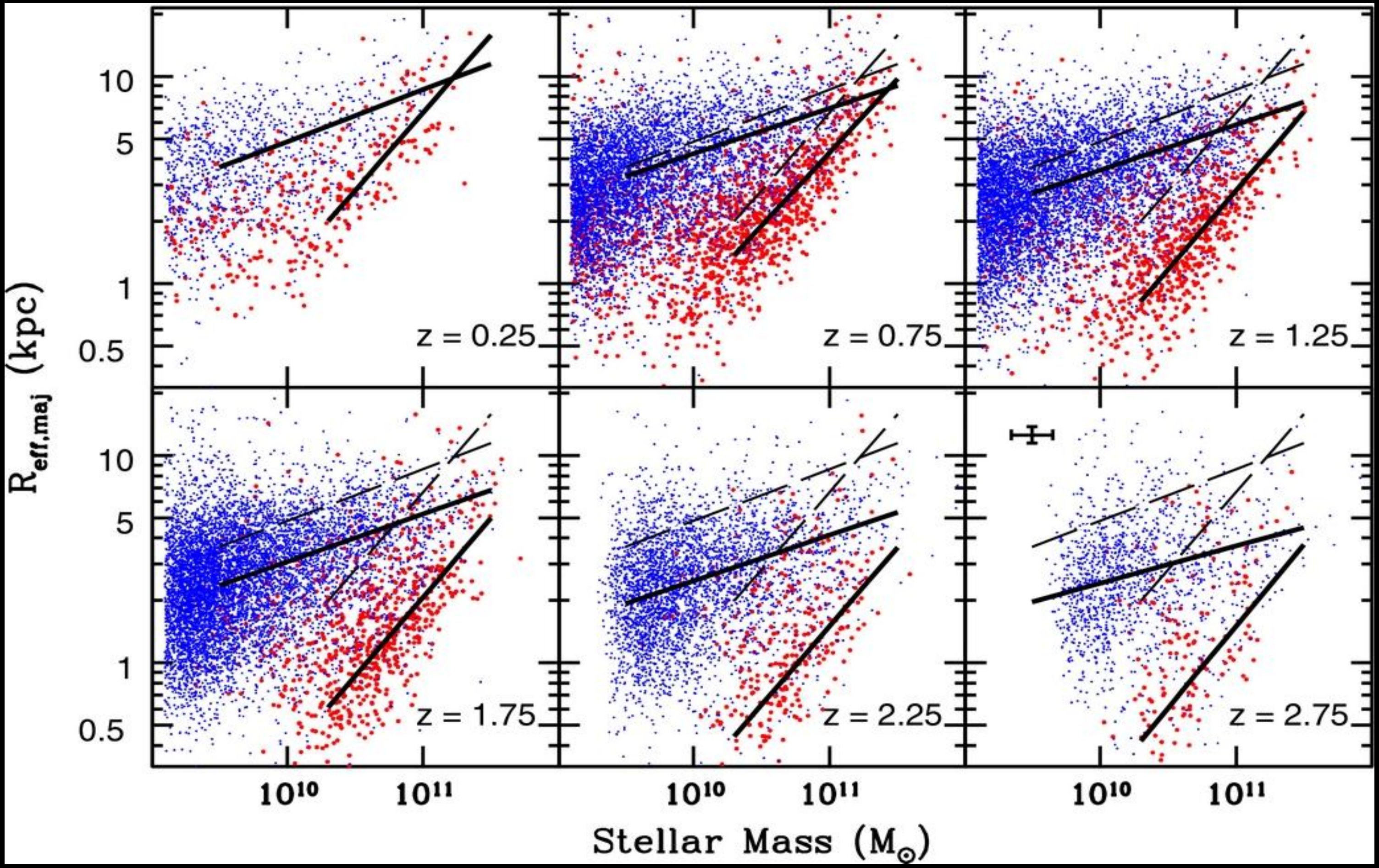
High-z galaxies

27 template galaxies:

9 mass : $10^9 < M/M_\odot < 10^{11}$

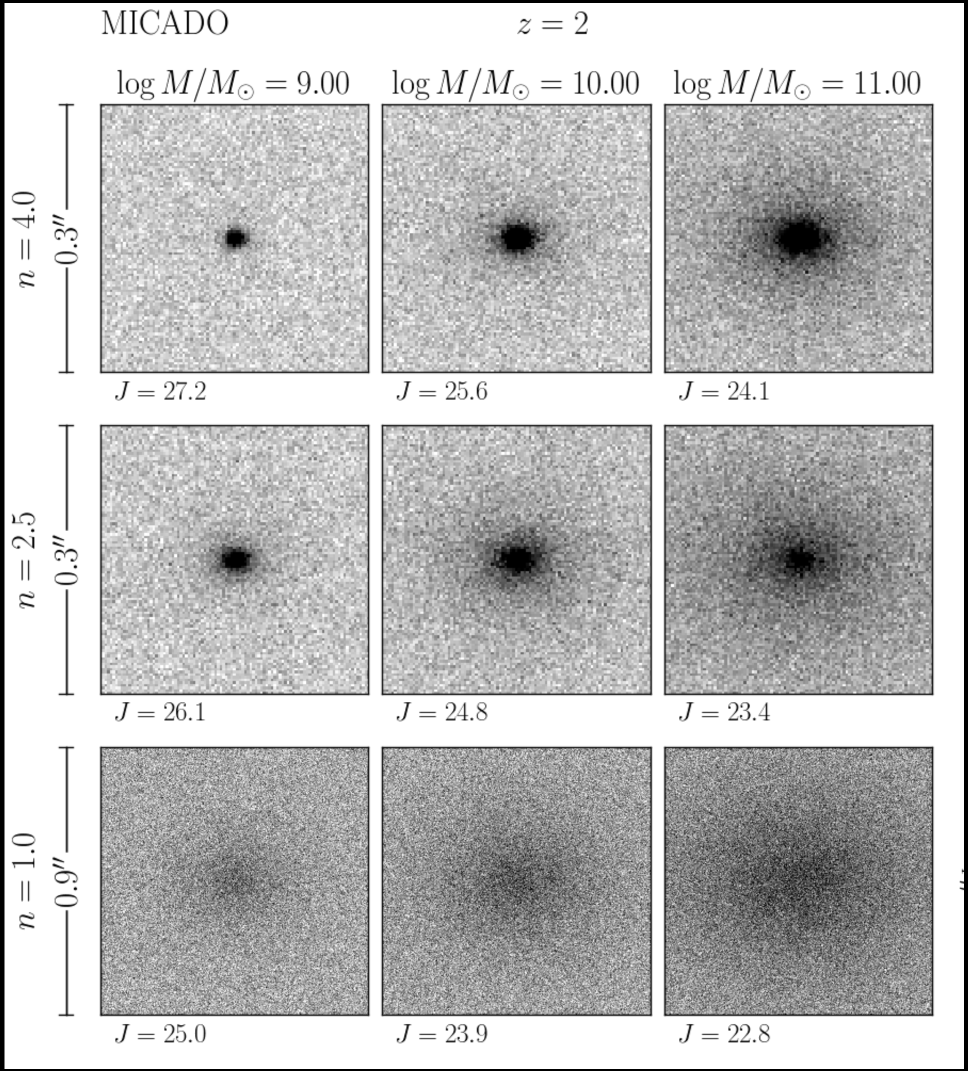
3 Sersic index : 1.0 (late-type), 2.5, 4.0 (early-type)

Magnitude, colour, Re from scaling relations obtained from observations of high-z galaxies



van der Wel+2014

High-z galaxies



- 2 set of simulations (z~2 and z~3)

  (U,V) -> J, H @ **z=2.2**

  -> H, K @ **z=3.3**

- 50 AETC simulations for each template galaxy 3h exptime with MICADO@E-ELT

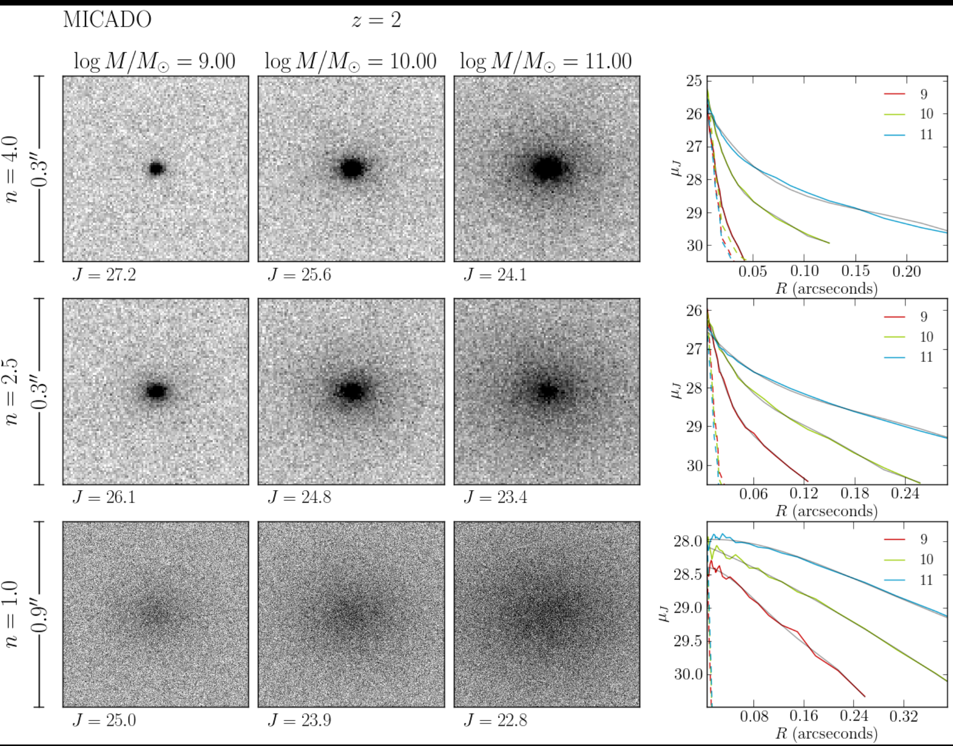
+ Sersic-fit with GALFIT
+ compare measured vs. input parameters and radial profile

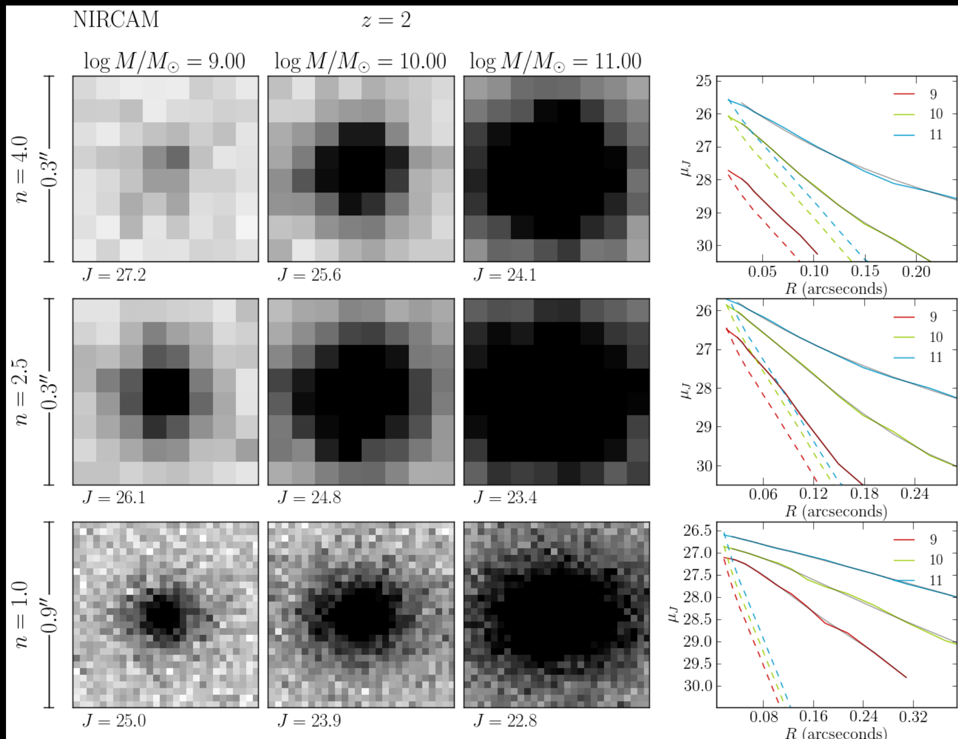
> Accuracy of GALFIT structural parameters

> Could we detect colour gradients?

>> what is the uncertainty in the recovered radial profile?

High-z galaxies: MICADO & JWST

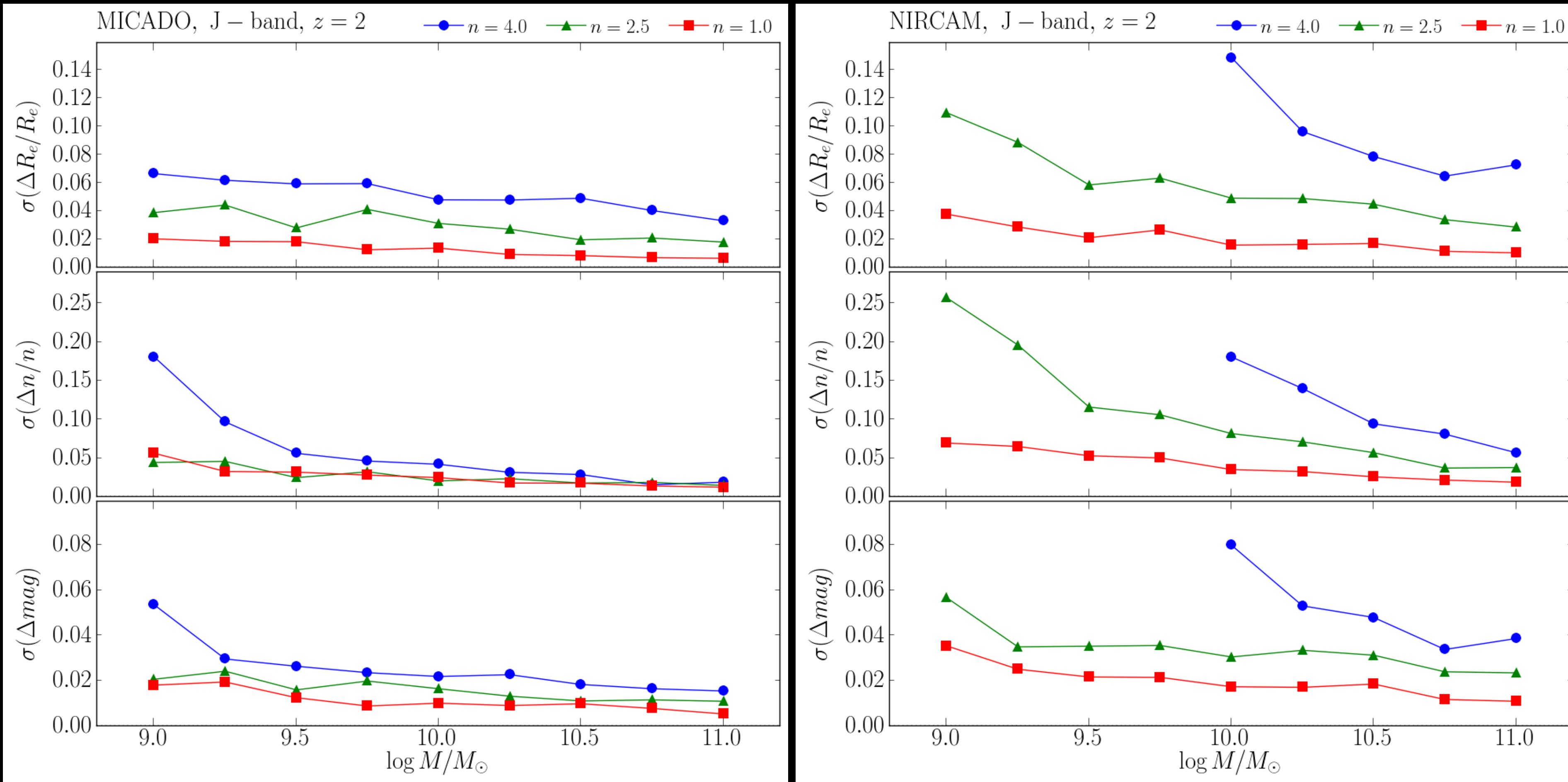




MICADO@E-ELT:
FoV: 53 arcsec
pixscale: 3 mas
PSF FWHM : 10 mas

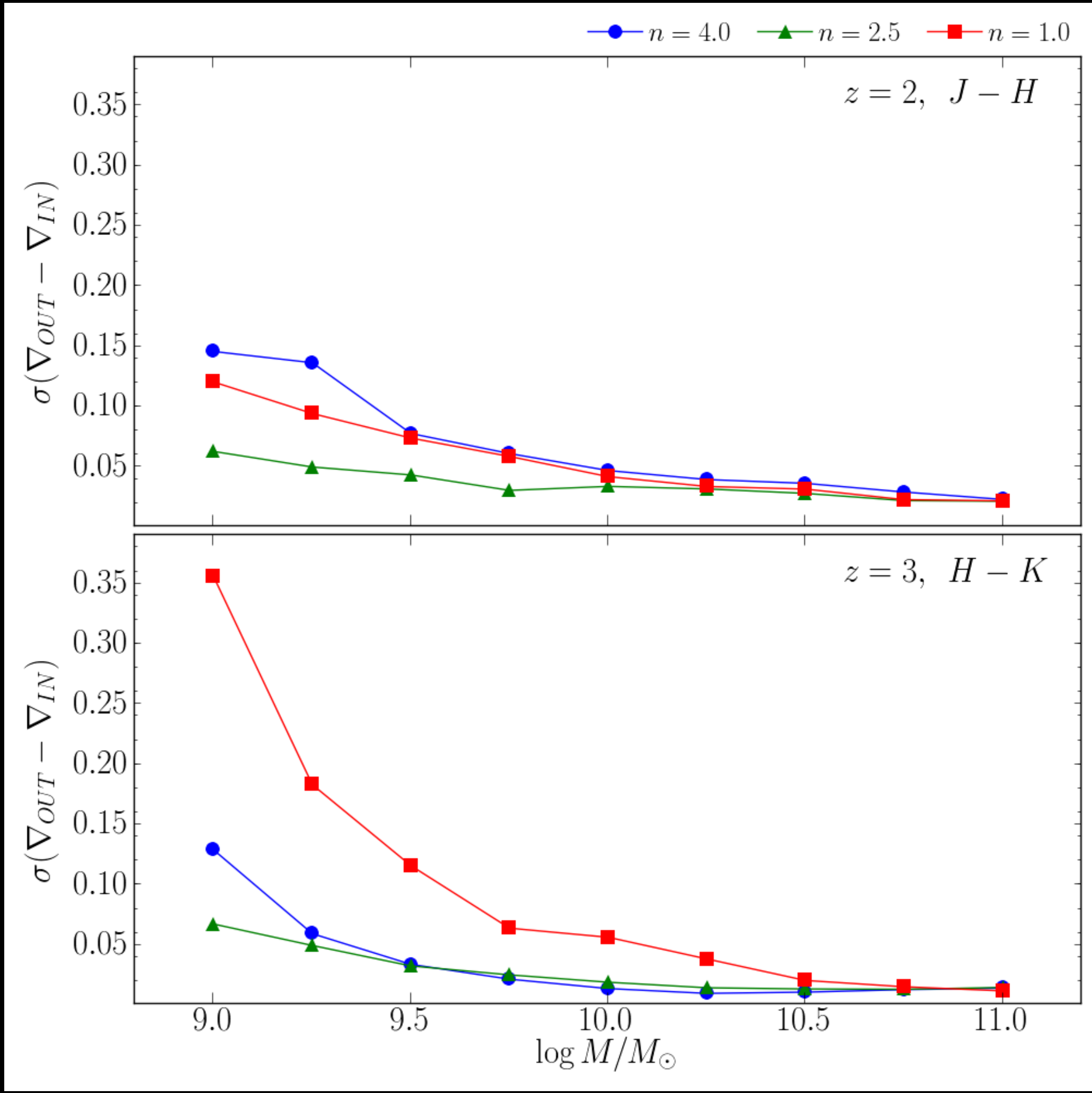
NIRCAM@JWST:
FoV: 53 arcsec
pixscale: 32 mas
PSF FWHM : 65 mas -> 6.5x wrt MICADO

High-z galaxies: structural parameters



MICADO@E-ELT:
negligible systematic effects.
accuracy of Re and n measurements ~5% for most galaxies.
~10% for the smallest (Re for galaxies of $10^9 M_\odot$ and n=4 is 6mas or 2 pixels)

High-z galaxies: colour gradients



The great accuracy achieved for the structural parameters allows to probe the color gradient of these galaxies with unprecedented reliability.

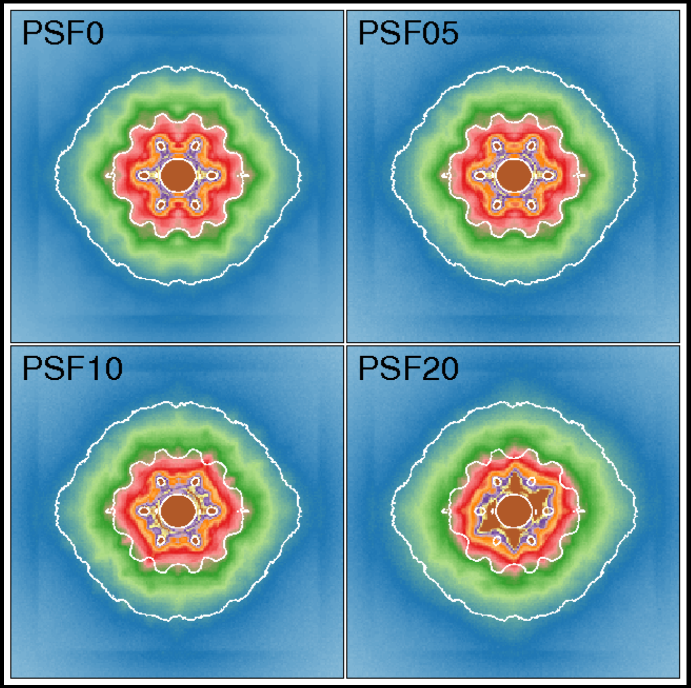
From SSP models:
U-V gradient of 0.1 mag:
>> 25% variation in age
>> 0.3 dex in metallicity

High-z galaxies: PSF variation

The Sersic models were convolved in GALFIT using the same PSF used to generate the simulated images.

>> in the real case it is not always possible to reconstruct exactly the PSF in the position of the target galaxy in the exact moment of the observations

High-z galaxies: PSF variation



To evaluate the effect of time and/or spatial variations of the PSF we used 3 different PSF as input model in GALFIT

PSF calculated for 5, 10 and 20 arcsec away from the center of MICADO FoV

systematic effect in Re and n ~5-10 % (20-30% for PSF20); 0.1 mag for magnitudes

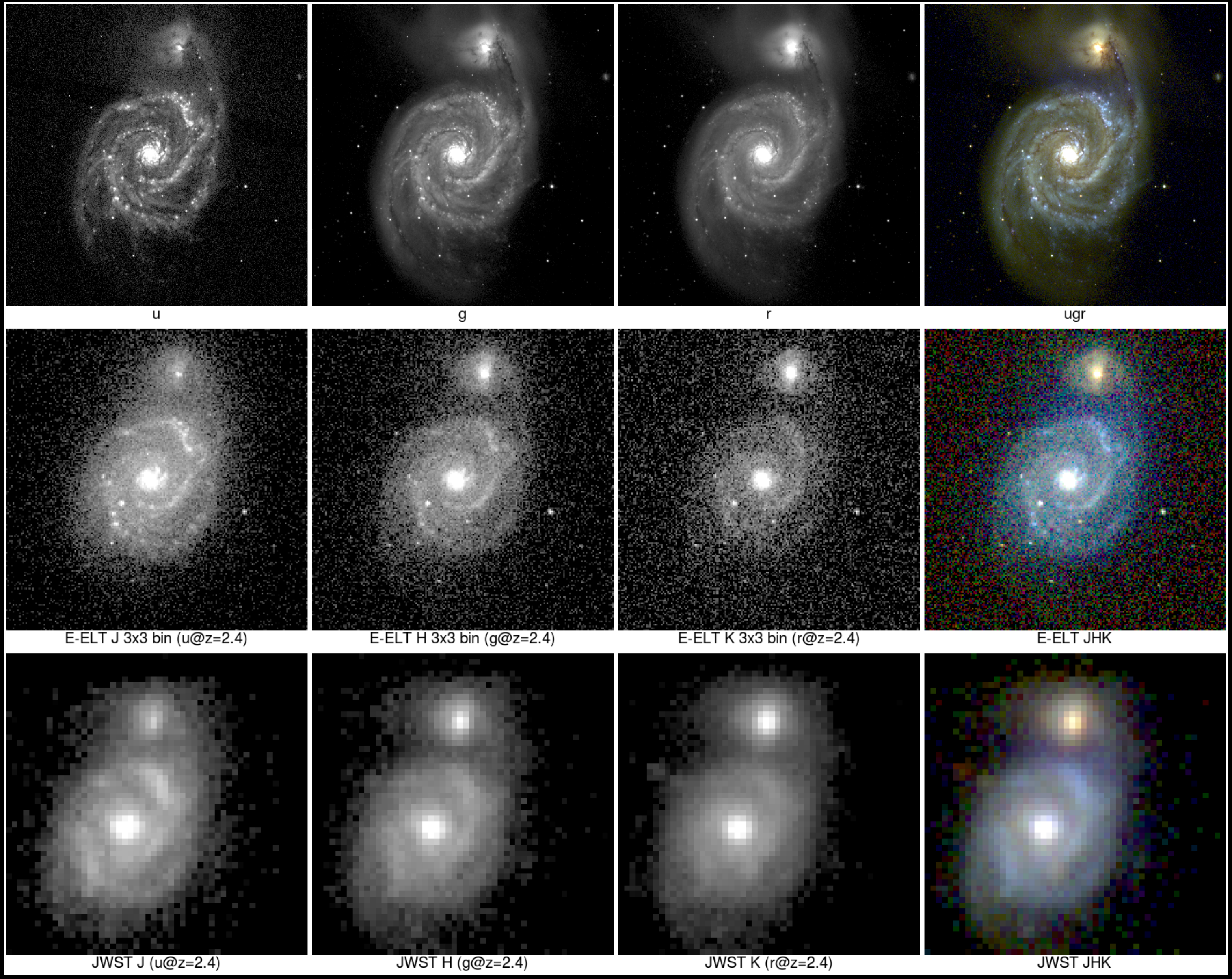
We conclude that for science cases aiming at measuring structural parameters of relatively large galaxies (Re ~ 40 mas) with accuracy of ~ 20%, PSF time and spatial variations would not be a critical issue. Particular care and/or dedicated observations would be instead required to perform extremely accurate measurements of very compact galaxies.

High-z galaxies

M51
SDSS

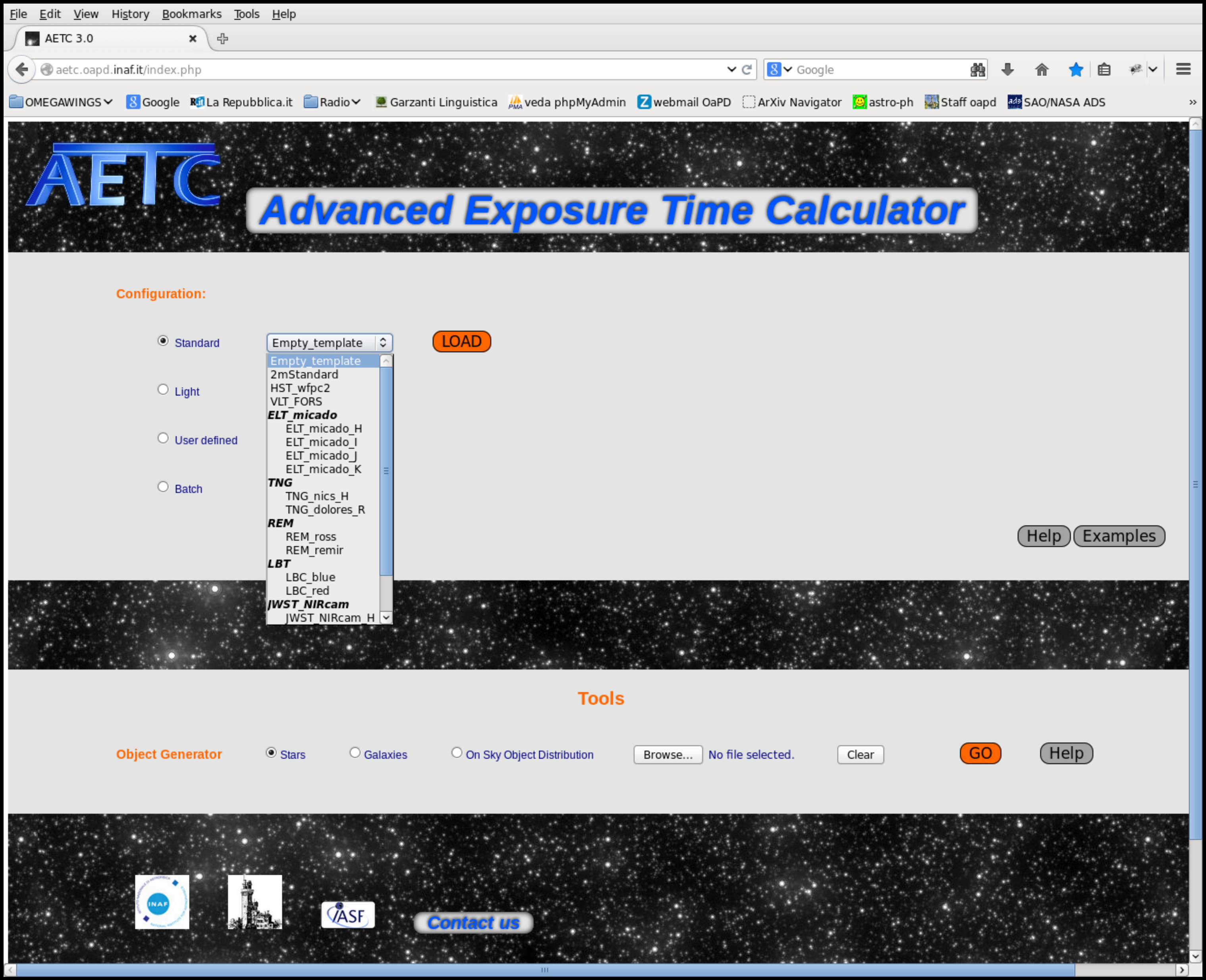
z=2.4
MICADO@E-ELT

z=2.4
NIRCam@JWST

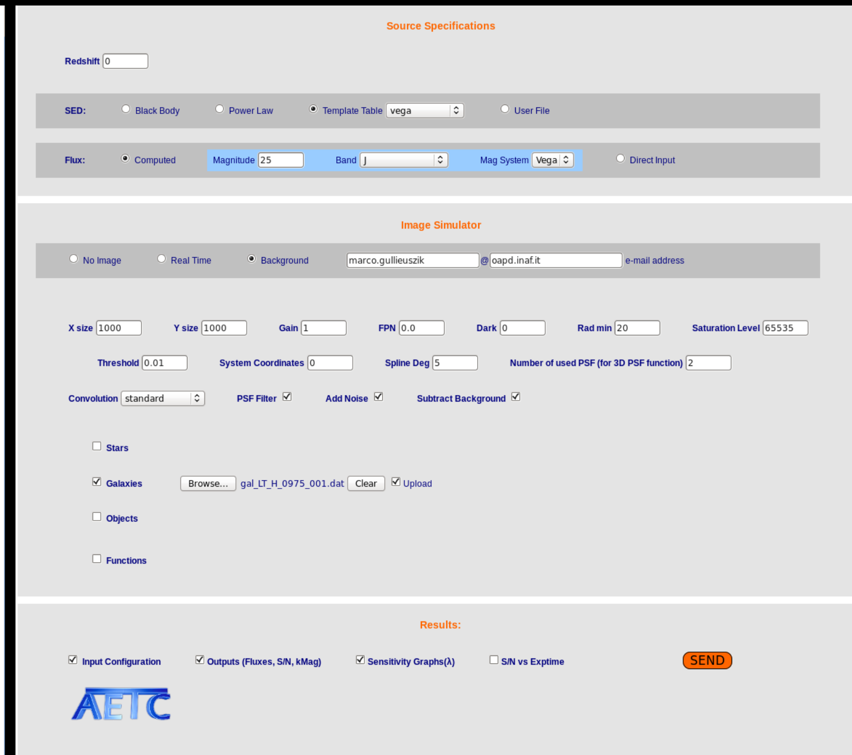


AETC

aetc.oapd.inaf.it



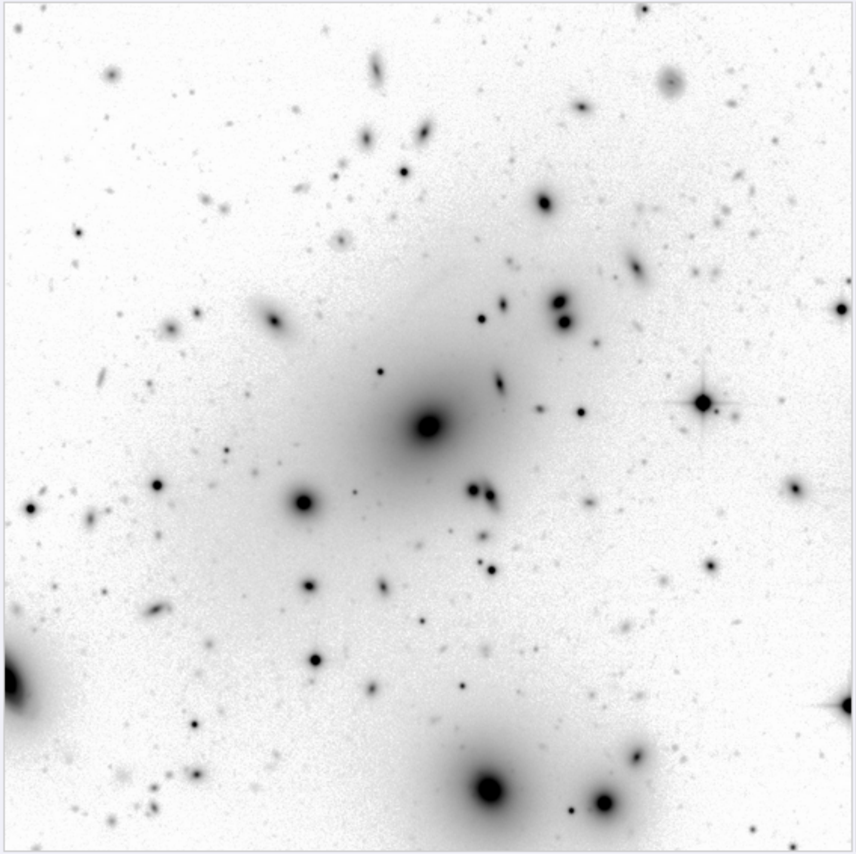
AETC



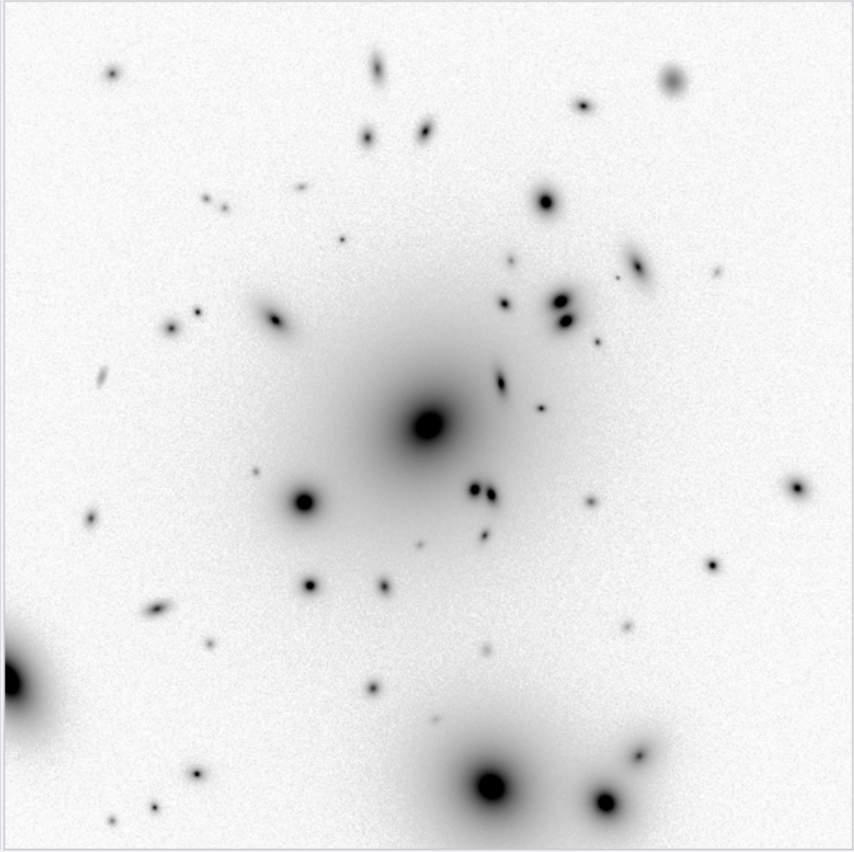
+ Graphic User Interface to manually set all parameters (telescope/camera, observing conditions, source, outputs)
+ batch mode to perform many simulations without the GUI

AETC

On the left panel below shows the central 1000x1000 pixels (5.5'x5.5') region of the WINGS V-band image taken with WFC@INT. The panel on the right shows the simulated image.
Click on the images to see the full-resolution version.
Note that we did not simulated the stars observed in the WINGS image and that the faintest galaxies are not included in the WINGS surface brightness catalog.



Observed



Simulated

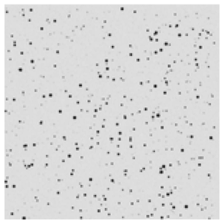
AETC

AETC documentation:

- HELP pages
- A set of examples

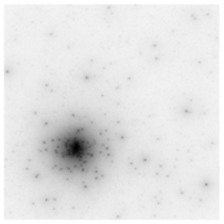
AETC - Example 1 : Star field with LBC@LBT

This basic example uses a simplified interface specialized for the red arm of the LBC camera mounted at LBT. In the example we show hot to simulate observations of a stellar field. The input star list is generated with the AETC Object Generator.



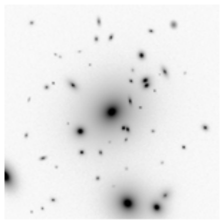
AETC - Example 2 : Star cluster with MICADO@E-ELT

In this example we consider a globular cluster. For this example we use the general interface, loading the configuration for MICADO@E-ELT. All parameters (telescope, camera, observatory) are initially pre-set, but the user can modify each of them.



AETC - Example 3 : Galaxies with custom instrument

This is the most general case. A new telescope+instrument+observing site is defined. In this example we simulate an observation of a the central region of a cluster of galaxies with the WFC camera mounted at the INT.

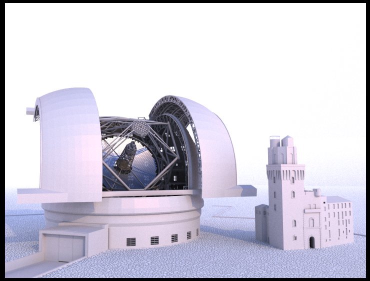


Summary

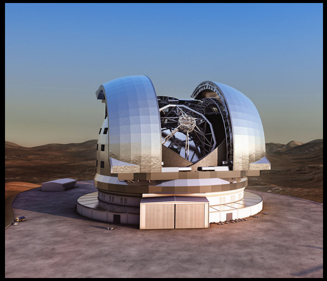
With (E-)ELT it will be possible to:

★ Recover SFH in galaxies at ~5 Mpc
★ Measure metallicity in the central regions of Virgo cluster ellipticals
★ Study stellar populations in NSCs
   ○ Old: up to 2Mpc
   ○ Intermediate-age: up to 3 Mpc
   ○ Young: up to 4 – (5?) Mpc

★ Measure the structural parameters (nSersic, Re, mag) of low-mass (~10^9 $M_\odot$) up to galaxies @z~3
★ Measure U-V colour gradients (~<0.1 dex) @z~3 for galaxies with M~$10^{10}M_\odot$
★ detect substructures (i.e. spiral arms/star forming regions) @z~2.5

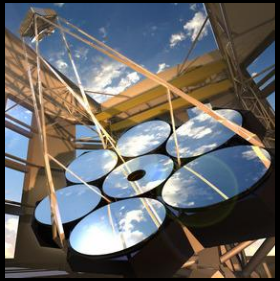


E-ELT @ Padova credit: M. Dima

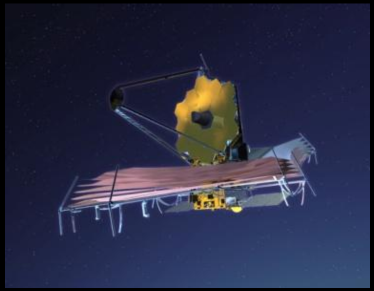


E-ELT @ Amazones

TMT @ Mauna Kea



E-ELT @ Las Campanas



JWST @ L2