

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



LABORATORIO  
NAZIONALE  
**ADONI**  
OTTICA  
ADATTIVA

**Marco Gullieuszik**

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# The team

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# Our project: science cases for the E-ELT

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## Method

We simulated 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 assess the feasibility of the science cases  
→ DAOphot, StarFinder, GalFIT

## Cases

### Resolved Stellar populations:

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 up to 4-5 Mpc

### High-z galaxies:

Gullieuszik et al. submitted:

- structural parameters and morphology of high z galaxies

# AETC. <http://aetc.oapd.inaf.it>

ETC + Simulation of observations: stars, galaxies (Sersic profiles), templates

**AETC 3.0**

**Advanced Exposure Time Calculator**

**Configuration:**

- Standard
- Light
- User defined
- Batch

Empty\_template

LOAD

2mStandard  
HST\_wfpc2  
VLT\_FORIS  
**ELT\_micado**  
ELT\_micado\_H  
ELT\_micado\_I  
ELT\_micado\_J  
ELT\_micado\_K  
**TNG**  
TNG\_nics\_H  
TNG\_dolores\_R  
**REM**  
REM\_ross  
REM\_remir  
**LBT**  
LBC\_blue  
LBC\_red  
**JWST\_NIRcam**  
JWST\_NIRcam\_H  
JWST\_NIRcam\_I

Help Examples

**Tools**

**Object Generator**

- Stars
- Galaxies
- On Sky Object Distribution

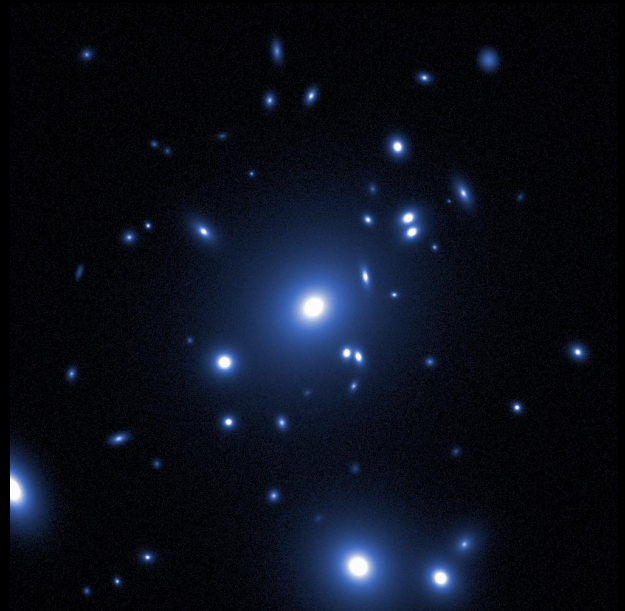
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INAF ASF [Contact us](#)

ETC + Simulation of observations: stars, galaxies (Sersic profiles), templates



Nuclear Star Cluster 4Mpc  
catalog of stars  
MICADO@E-ELT



galaxy cluster  $z=0.05$   
catalog of galaxies  
WFC@INT



M51-like galaxy  $z=2.4$   
template image  
MICADO@E-ELT

# AETC. Nuclear Star Clusters

Simulations of J-band observations of a Nuclear Star Cluster with



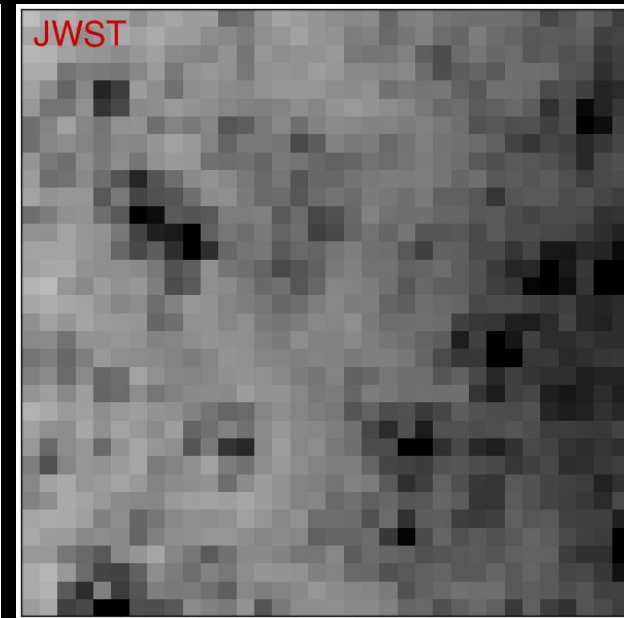
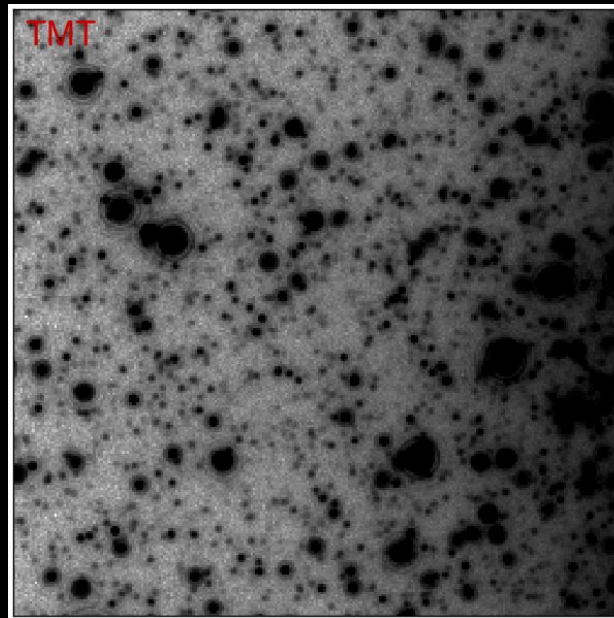
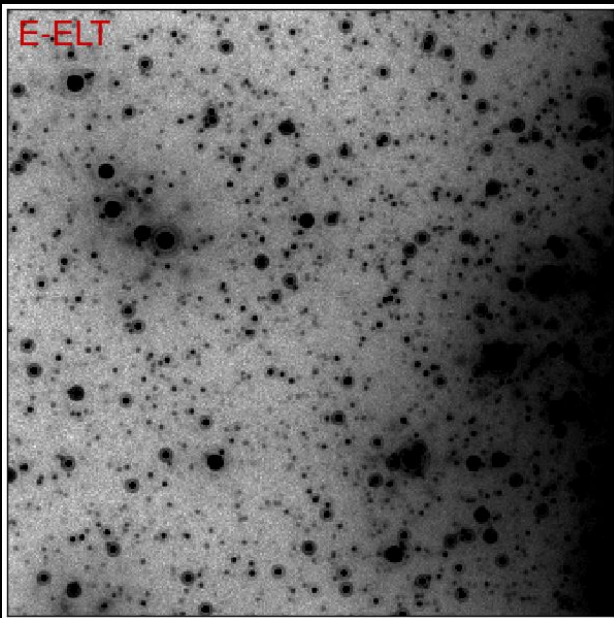
MICADO@E-ELT



IRIS@TMT



NIRC2@JWST

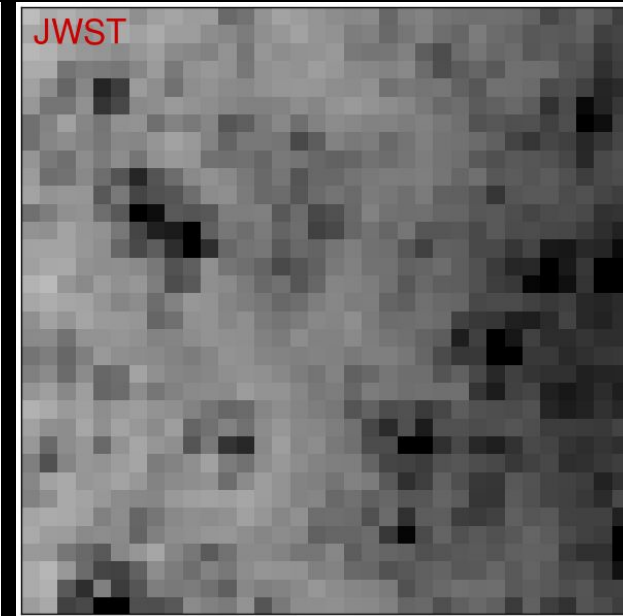
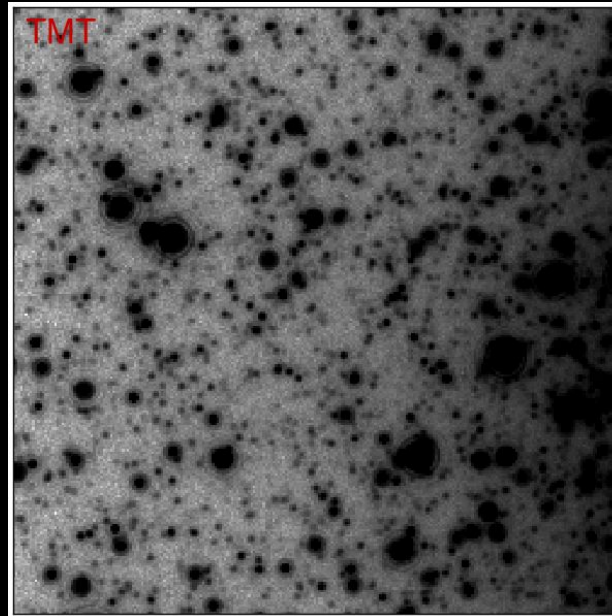
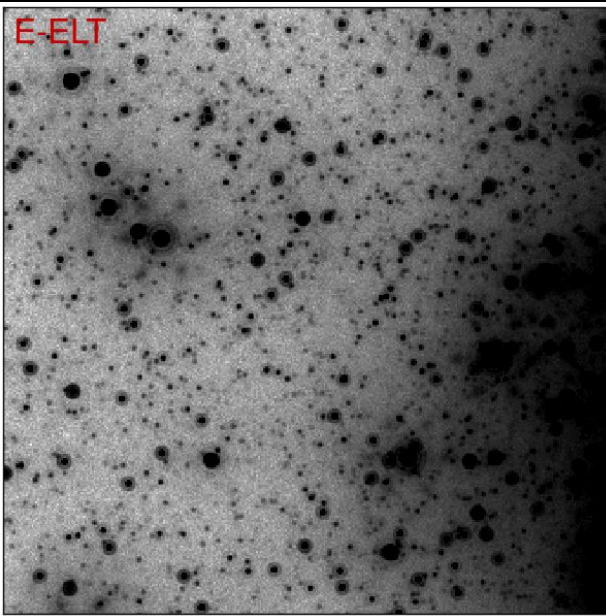


Gullieuszik et al. (2014)

# AETC. Nuclear Star Clusters



Primary mirror	39m	30m	6.5m
FoV	53" x 53"	17" x 17"	130" x 260"
pixel scale	3 mas/pixel	4 mas/pixel	32 mas/pixel
Resolution wrt MICADO	(10 mas @K-band)	x 1.4	x 6.5



Gullieuszik et al. (2014)

# High-z galaxies. Intro

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Key questions:

scaling relations for low mass galaxies at high-z

morphological evolution

Transition from early to late-type - Star formation quenching

size evolution (?)

colour gradients (?)

Galaxies @ $z \sim 2$  have  $R_e$  smaller than a few Kpc

[ e.g. at  $z \sim 2$  4 Kpc corresponds to  $\sim 0.5$  arcsec ]

they have  $R_e \sim$  FWHM of HST

determination of structural parameters are strongly dependent on PSF deconvolution

Populations gradients are more prominent in the inner regions.

Low mass galaxies are much smaller than HST FWHM

>> higher spatial resolution



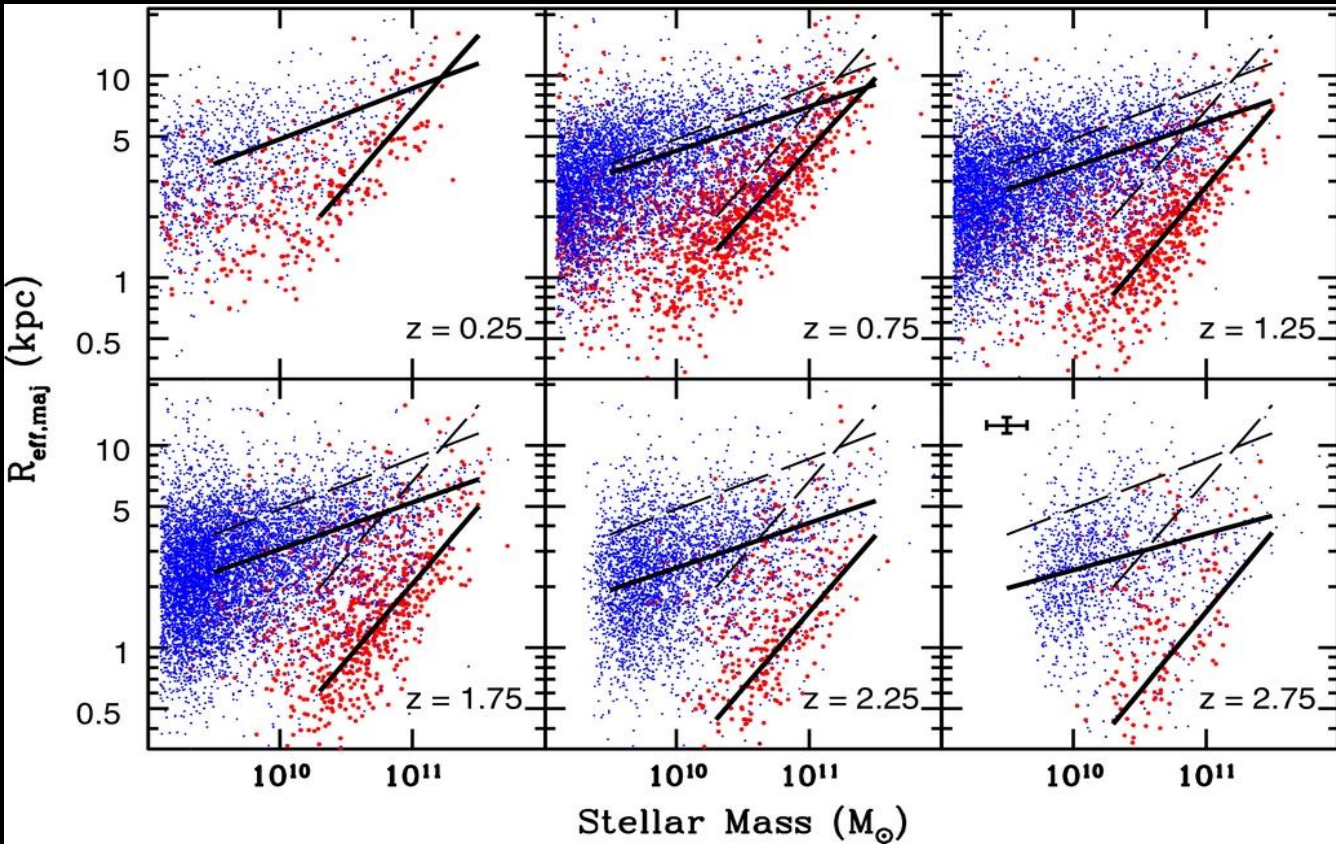
# High-z galaxies

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,  $R_e$  from scaling relations obtained from observations of high-z galaxies

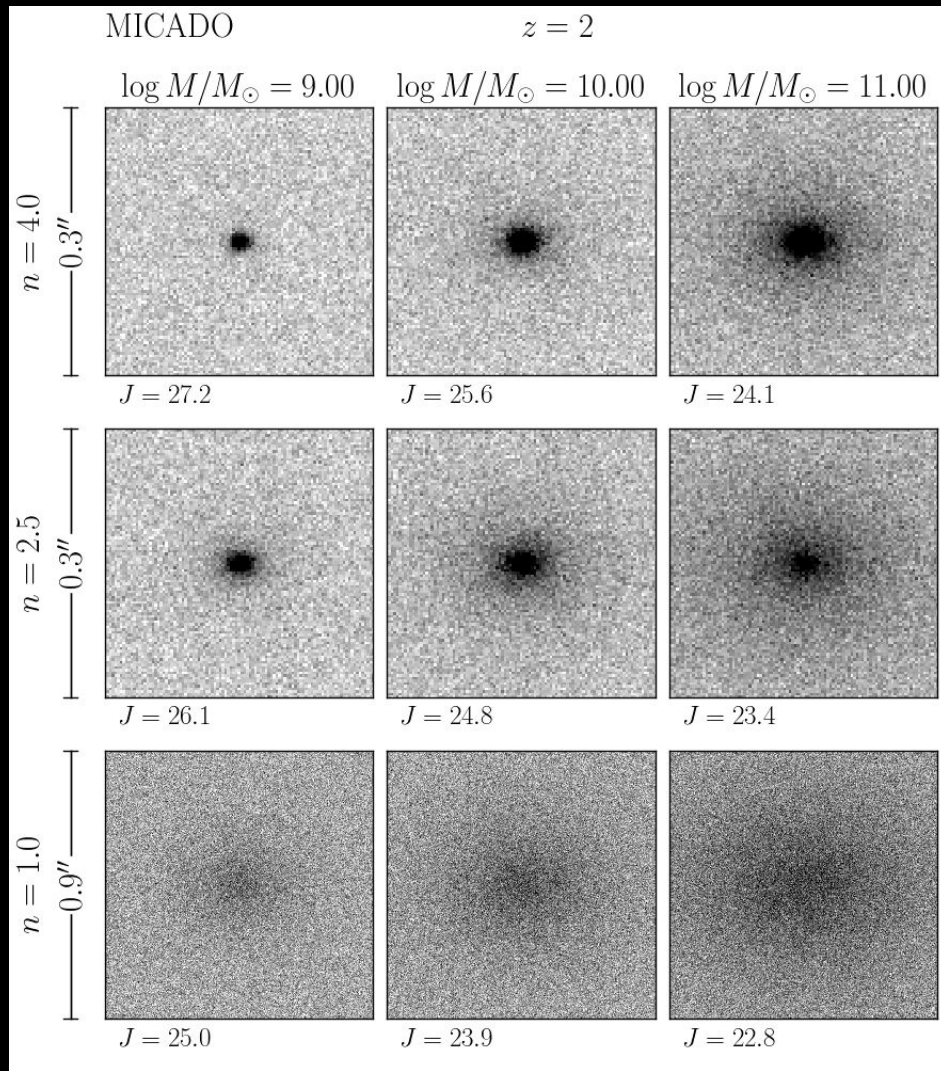


@z ~2  
 $10^{10} M_{\odot}$  early-type Galaxy

$R_e = 30 \text{ mas}$   
 $0.26 \text{ Kpc}$

van der Wel+2014

# High-z galaxies



- 2 set of simulations ( $z \sim 2$  and  $z \sim 3$ )

(U,V)  $\rightarrow$  J, H @  $z=2.2$

$\rightarrow$  H, K @  $z=3.3$

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

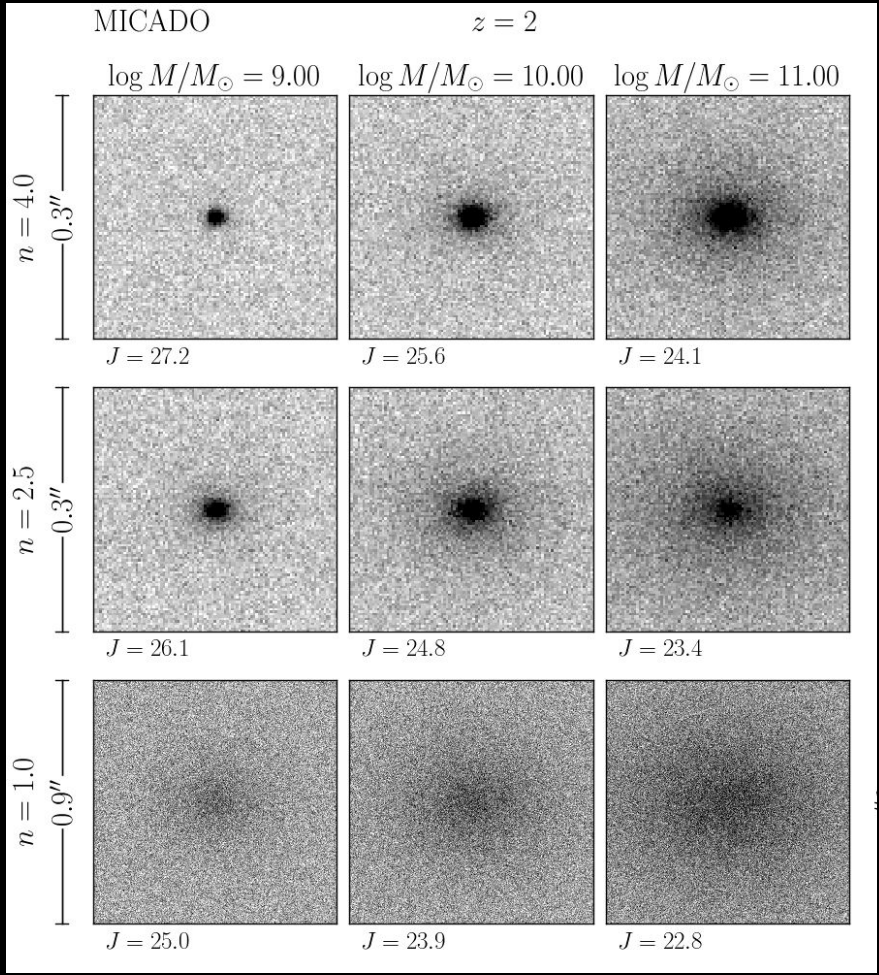
- + Sersic-fit with GALFIT
- + PSF model: simulated image of a bright star
- + compare measured vs. input parameters and radial profile

> Accuracy of GALFIT structural parameters

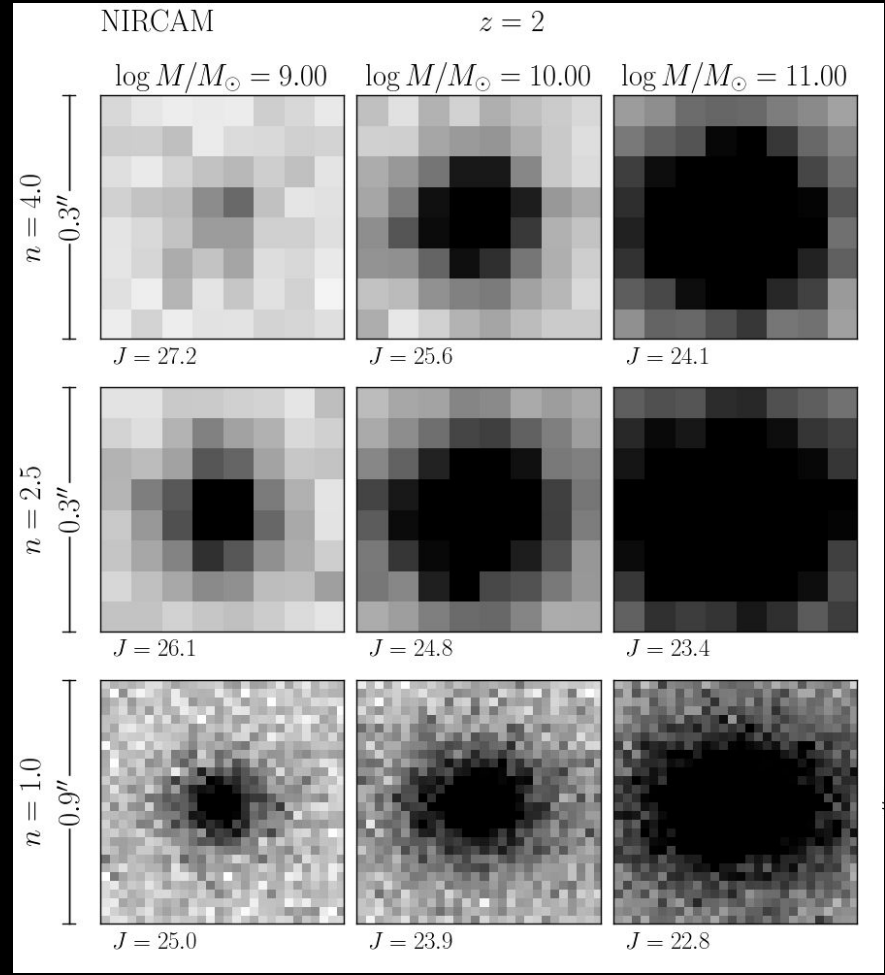
> Could we detect colour gradients?

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

# High-z galaxies: MICADO & JWST



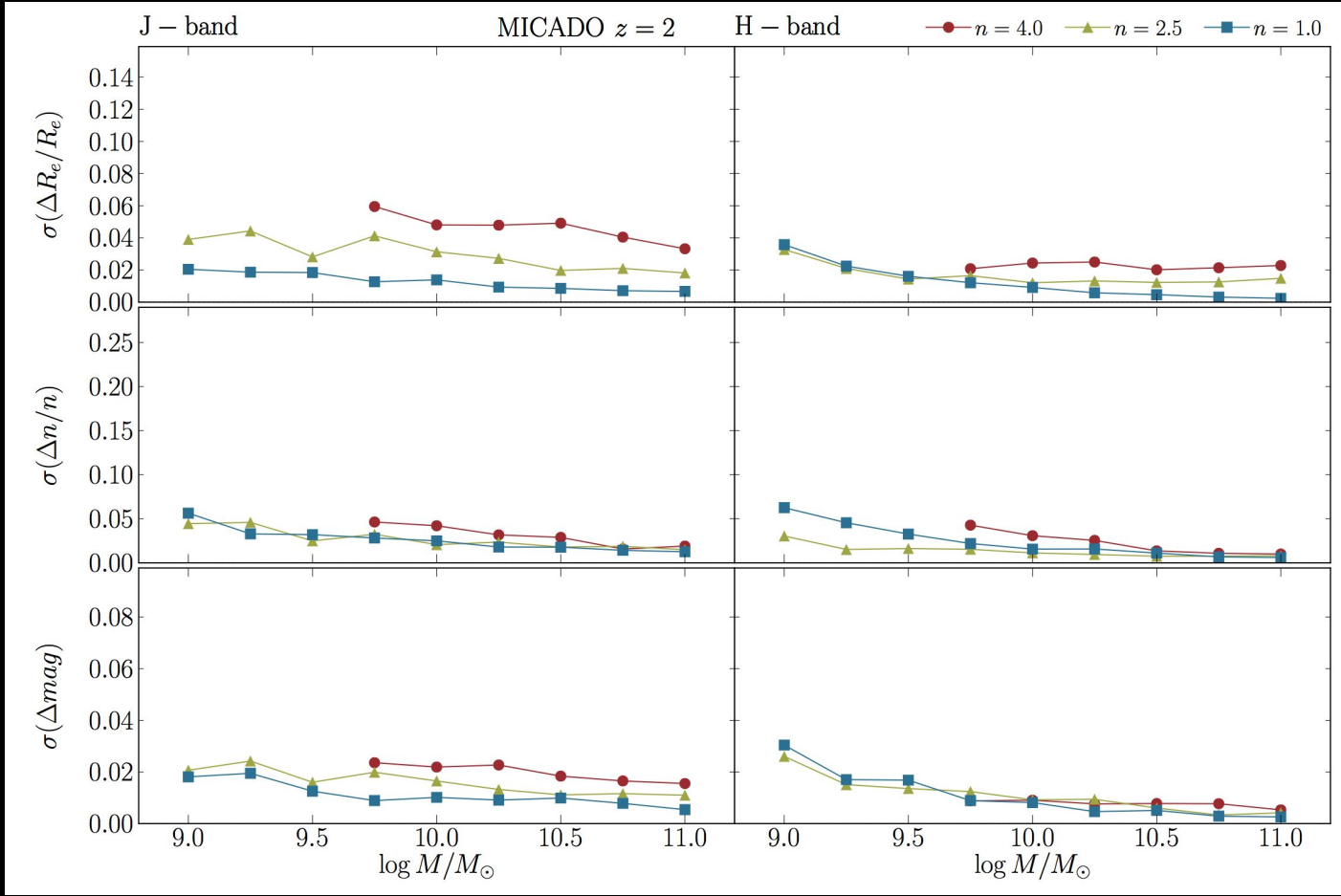
MICADO@E-ELT:  
 FoV: 53 arcsec  
 pixscale: 3 mas  
 PSF FWHM : 10 mas



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

# High-z galaxies: structural parameters

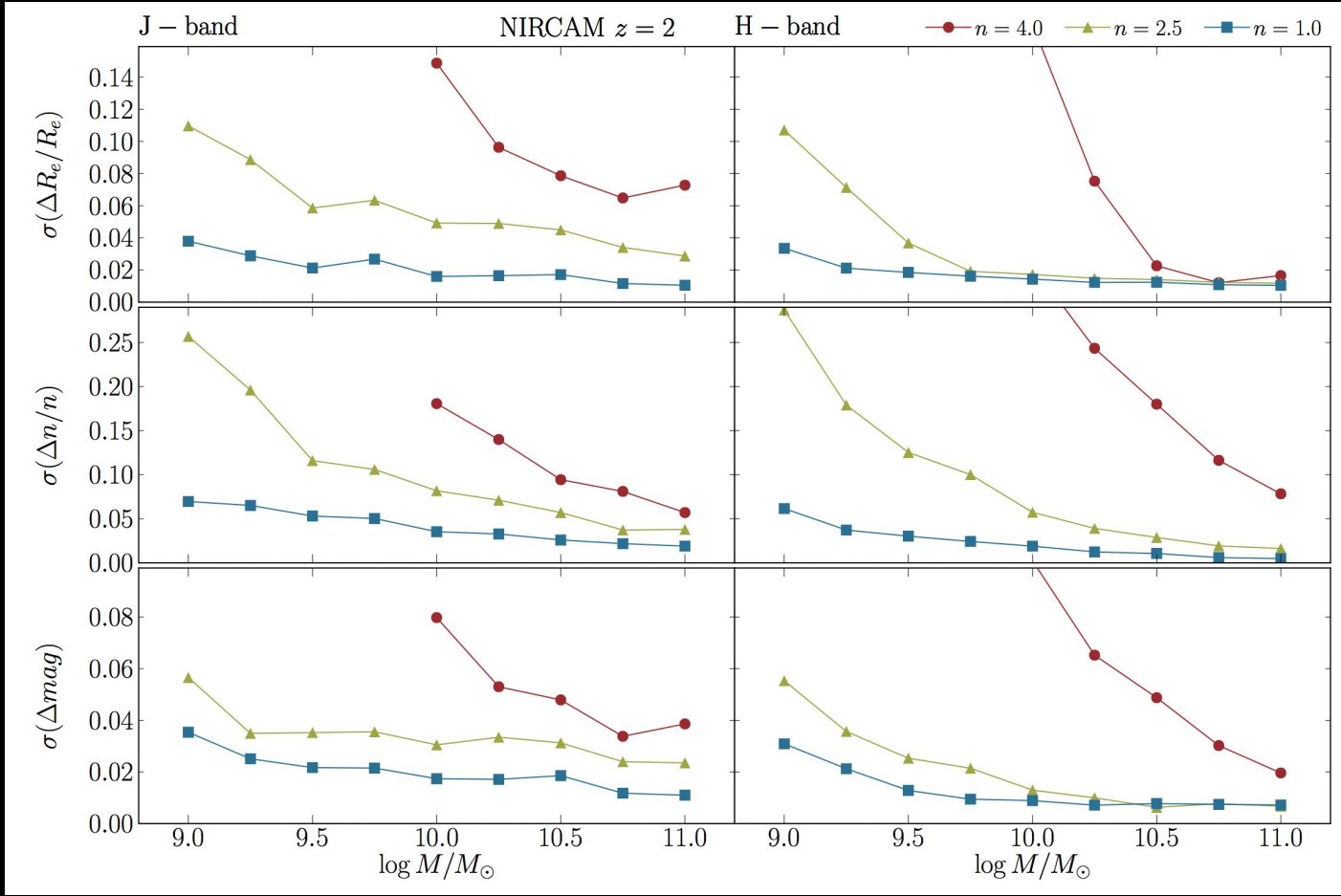
rms of 50 realizations of each template



**MICADO@E-ELT:**

negligible systematic effects for all galaxies but early type ones with  $M=10^9 M_\odot$ .  
 ( $R_e$  for galaxies of  $10^9 M_\odot$  and  $n=4$  is 6mas or 2 pixels)  
 accuracy of  $R_e$  and  $n$  measurements  $\sim 5\%$  for most galaxies.  
 $\sim 10\%$  for the smallest

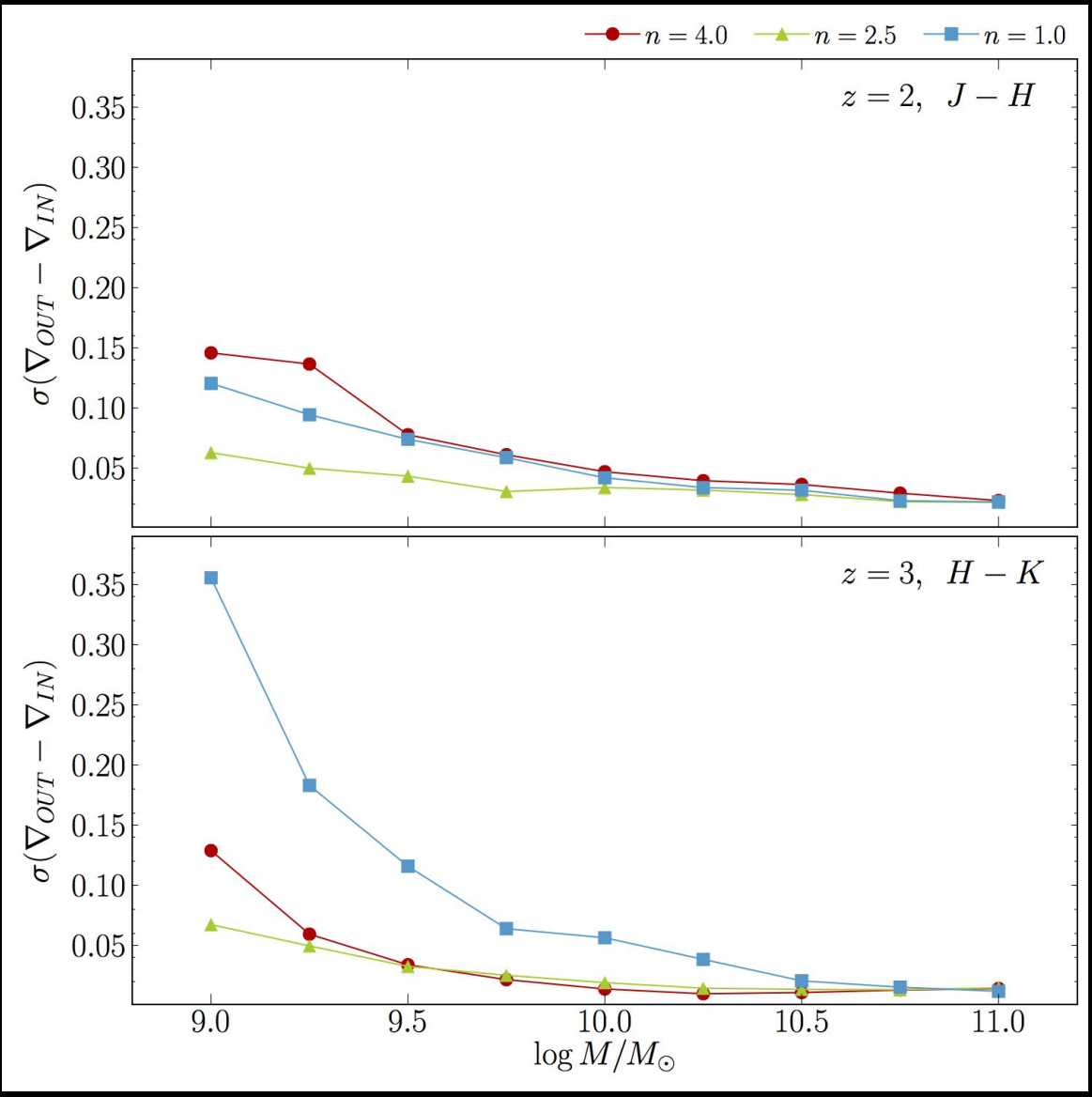
# High-z galaxies: structural parameters



## NIRCam@JWST

larger uncertainties wrt MICADO, in particular for early-type galaxies  
galaxies with  $M < 10^{10} M_\odot$  and  $n=4$  have  $R_e < 1$  pixel (32 mas)

# High-z galaxies: colour gradients

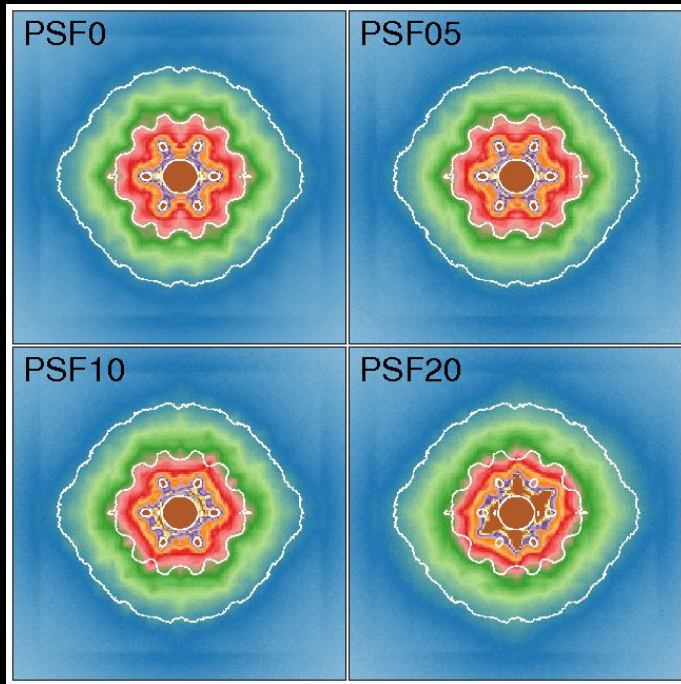


U-V rest frame  
 > J-H @ z~2  
 > H-K @ z~3

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



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

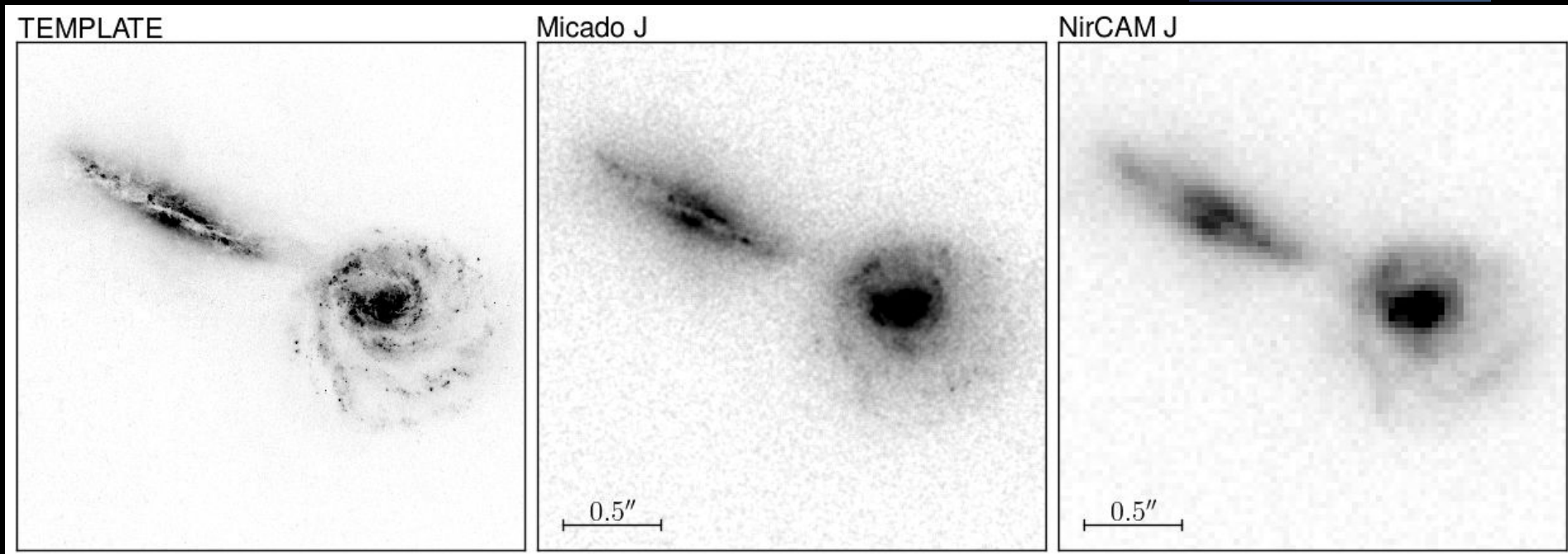
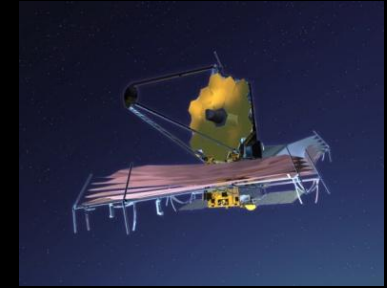
systematic effects in Re and n  $\sim$  5-10 % (20-30% for PSF20); 0.1 mag for magnitudes

## Results:

For measurements with an accuracy  $\sim$  20% in large galaxies (Re  $\sim$  40 mas) 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

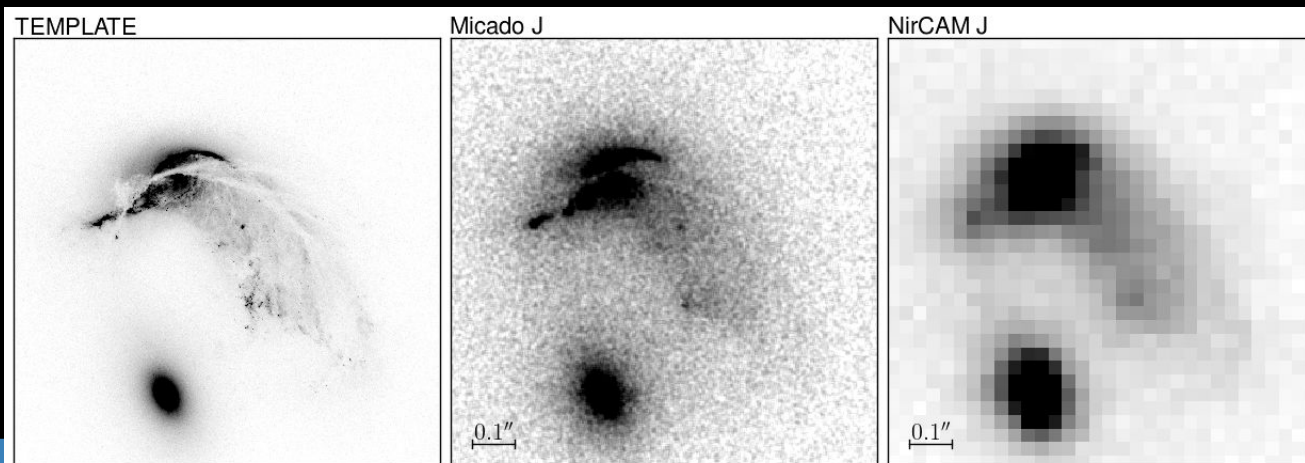
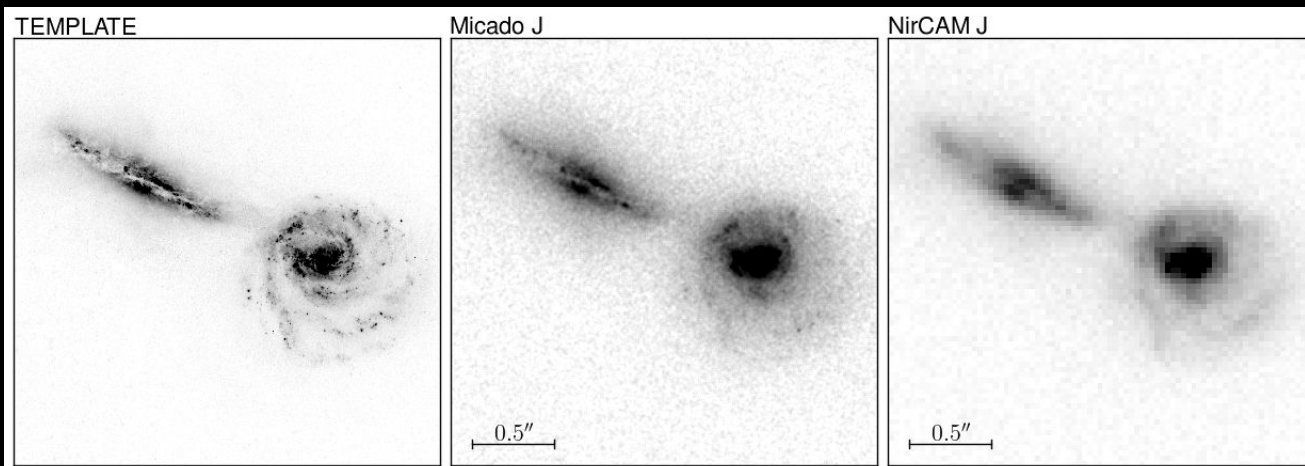
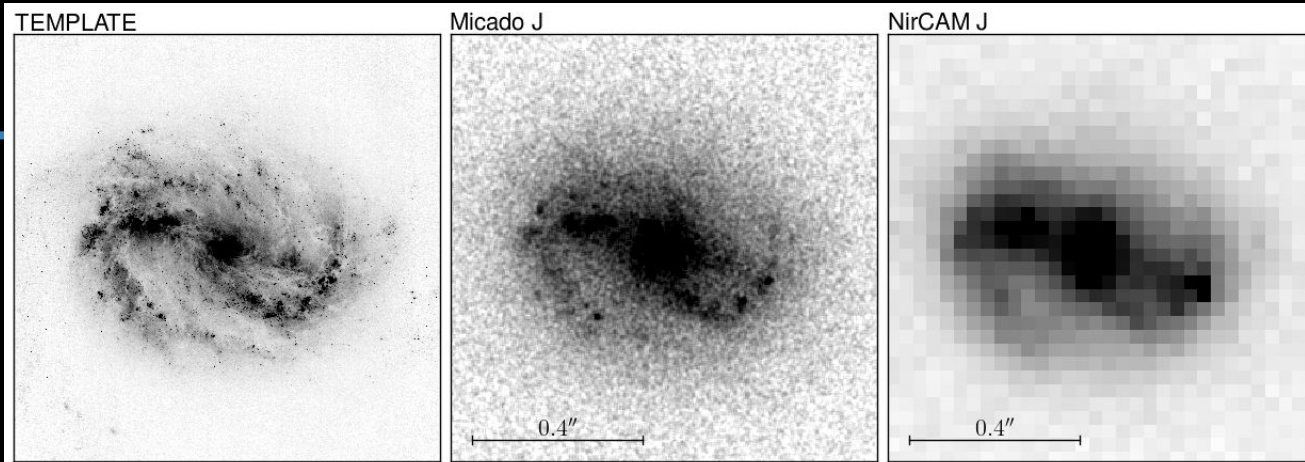


Template image @4350 Å  $\gg$  Jband @  $z \sim 2$

400 mas  $\gg$   $\sim 3.5$  Kpc

total magnitude (2 galaxies): J=22.5 mag





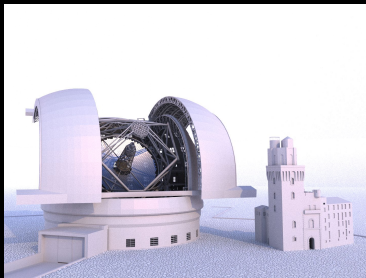
# Summary

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

- ★ Recover SFH in galaxies at  $\sim 5$  Mpc
- ★ Photometric metallicity in the central regions of Virgo cluster ellipticals
- ★ Study stellar populations in NSCs.

main-sequence turn off stars detection:

- Old: up to 2Mpc
  - Intermediate-age: up to 3 Mpc
  - Young: up to 4 – (5?) Mpc
- ★ Measure the structural parameters (nSersic,  $R_e$ , mag) of low-mass ( $\sim 10^9 M_\odot$ ) galaxies up to  $z \sim 3$
  - ★ Measure U-V colour gradients ( $\sim < 0.1$  dex)  $z \sim 3$  for galaxies with  $M \sim 10^{10} M_\odot$ .
  - ★ detect substructures (i.e. spiral arms, star forming regions)  $z \sim 3$



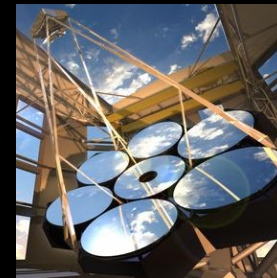
E-ELT @ Padova credit: M. Dima



E-ELT @ Cerro Armazones



TMT @ Mauna Kea



GMT @ Las Campanas



JWST @ L2