

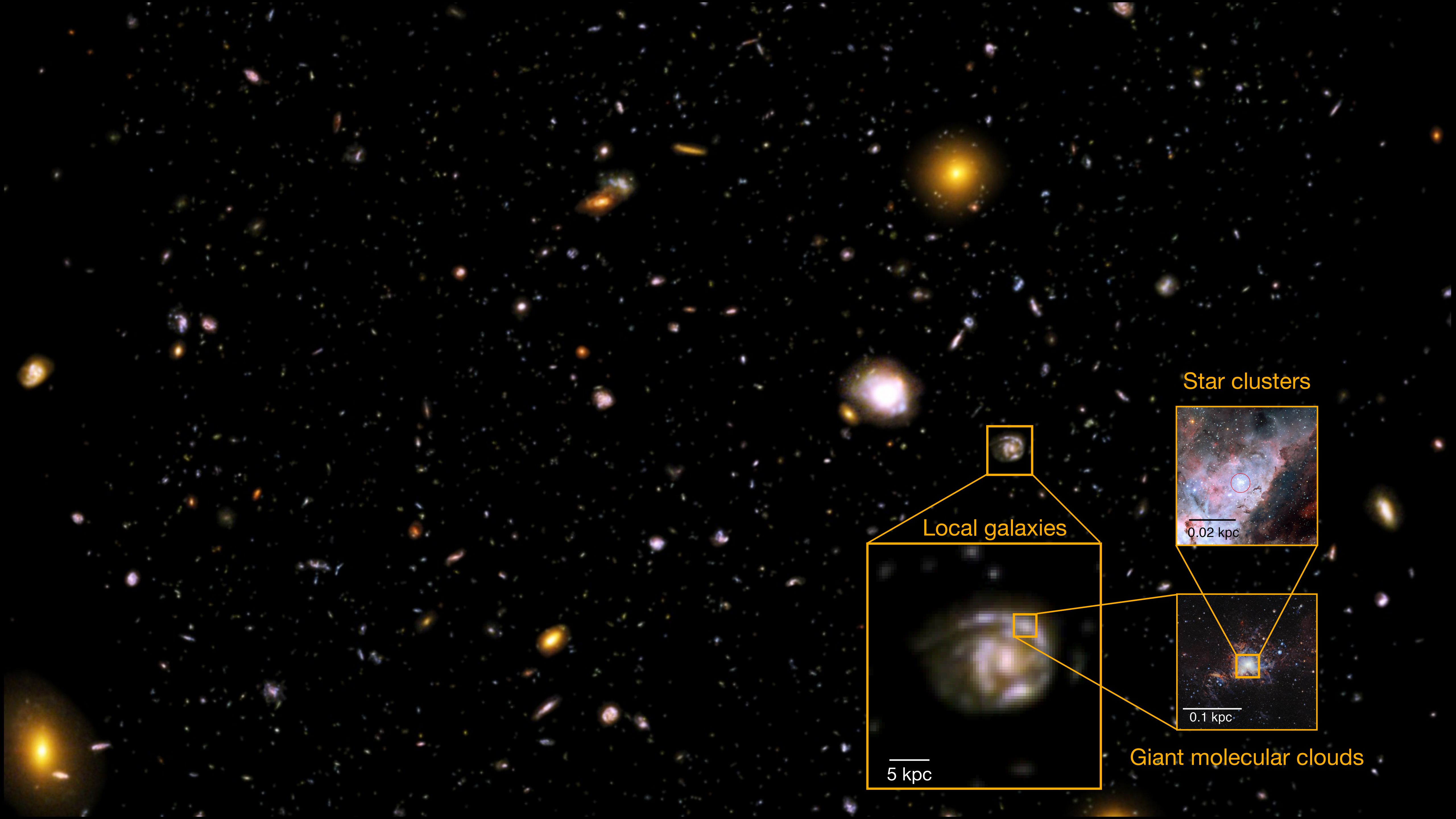


Opening a new window on high redshift star formation with the ELT

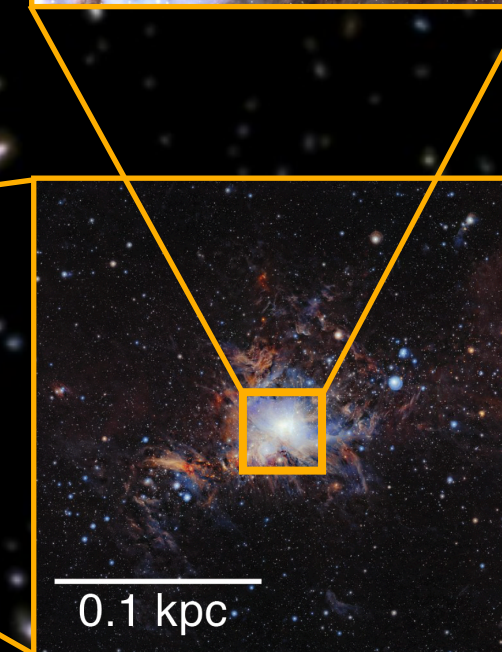
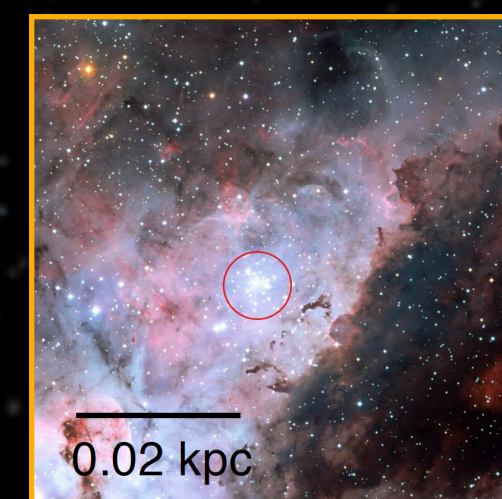
Anita Zanella

with E. Vanzella, P. Bergamini, R. Marai, A. Taranto, F. Annibali, M. Messa, A. Bolamperti et al.

anita.zanella@inaf.it

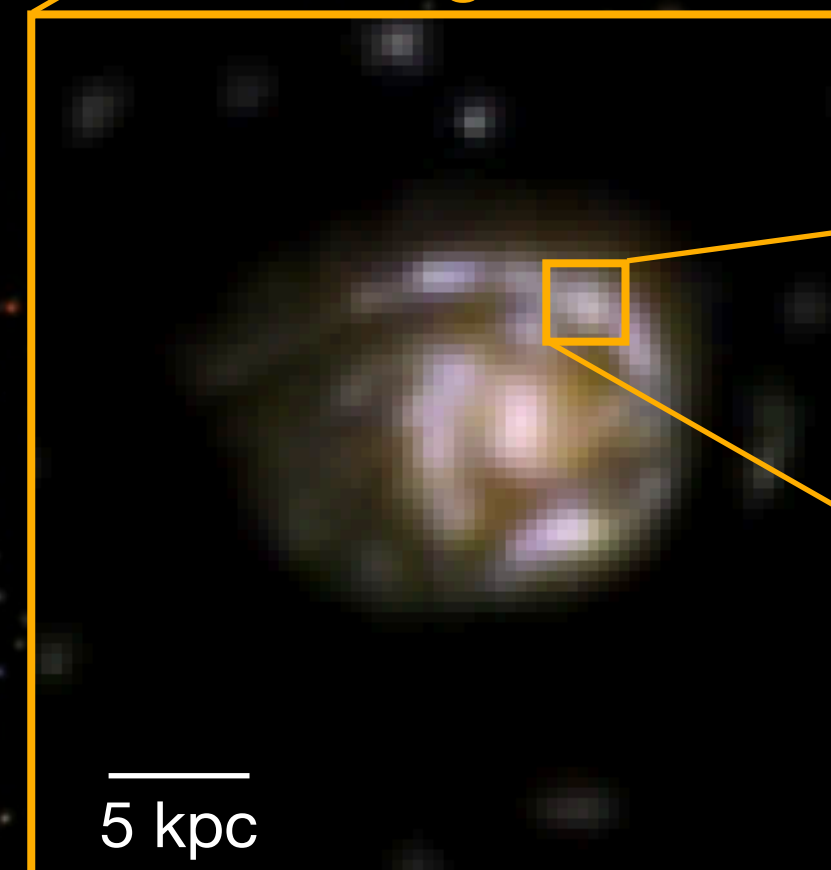


Star clusters

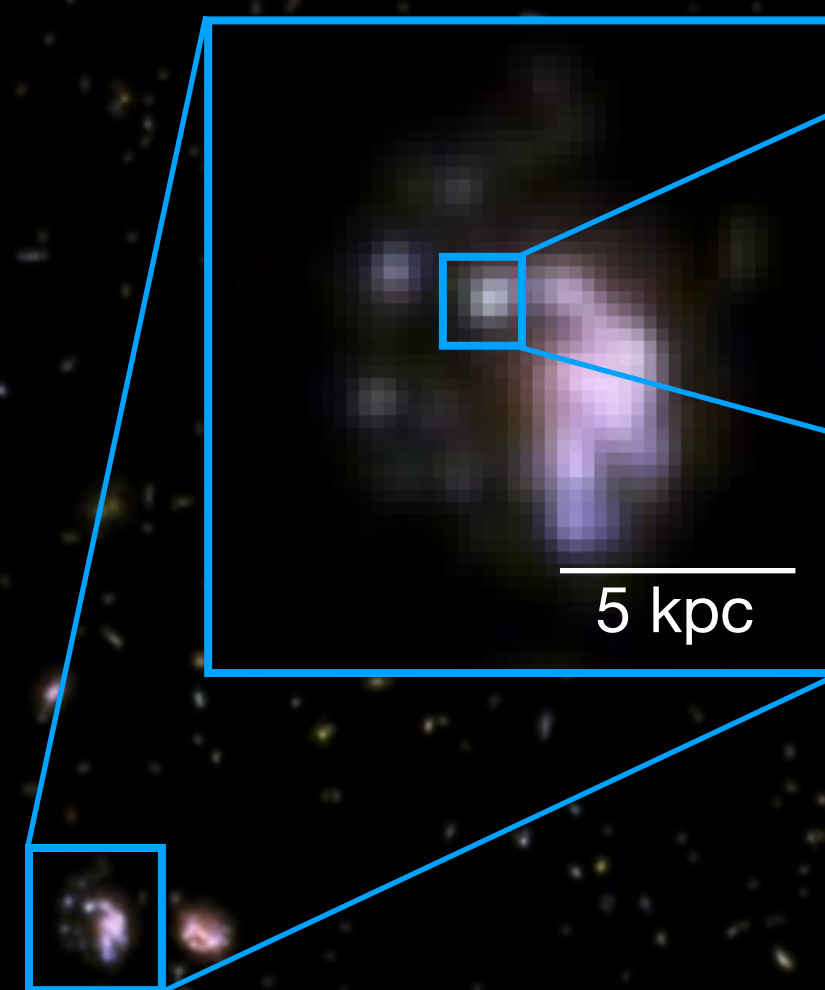


Giant molecular clouds

Local galaxies

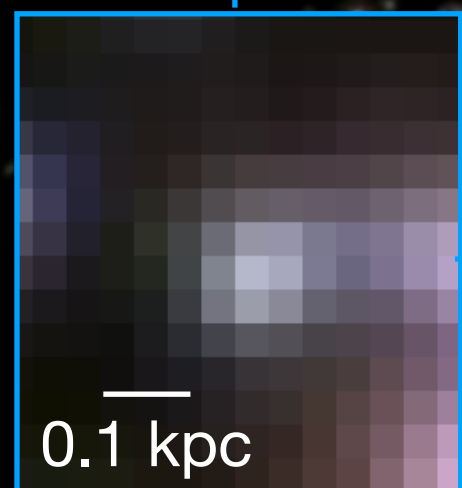


High-redshift galaxies



Giant
molecular
clouds?

Alma 2040?

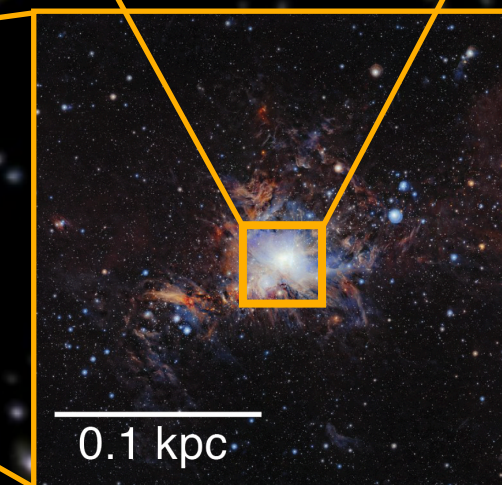
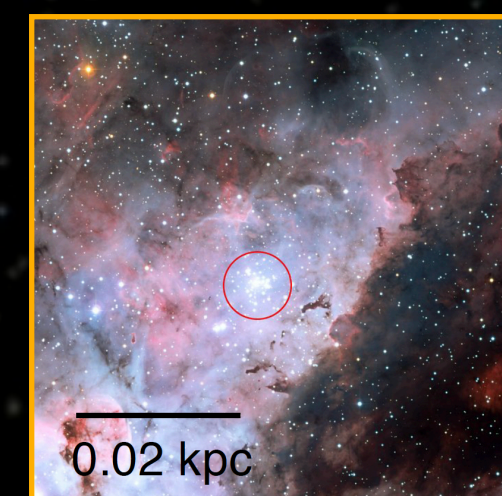


ELT/
MICADO,
HARMONI
VLT/MAVIS

Star complexes/clumps

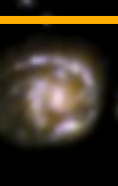


Star clusters



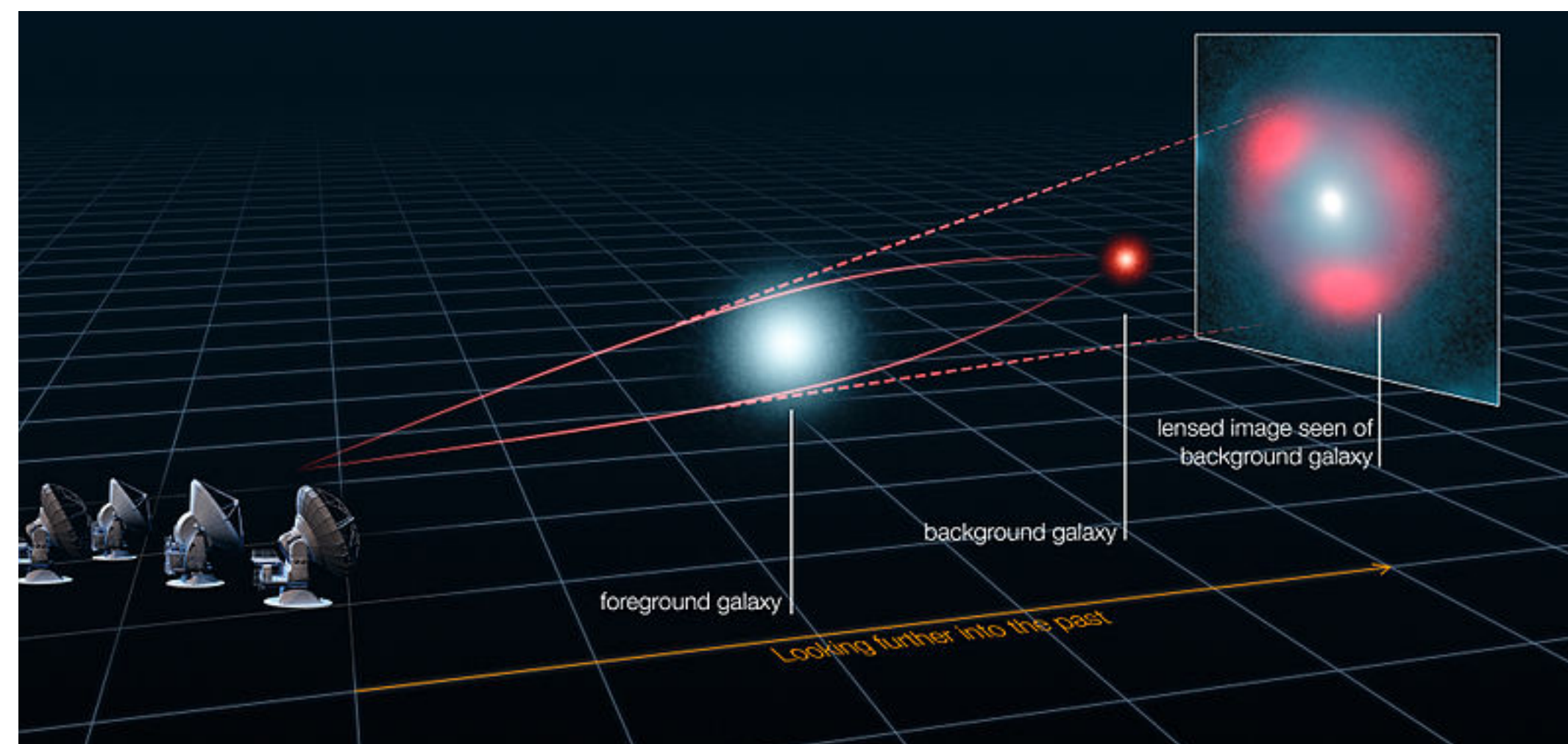
Giant molecular clouds

Local galaxies





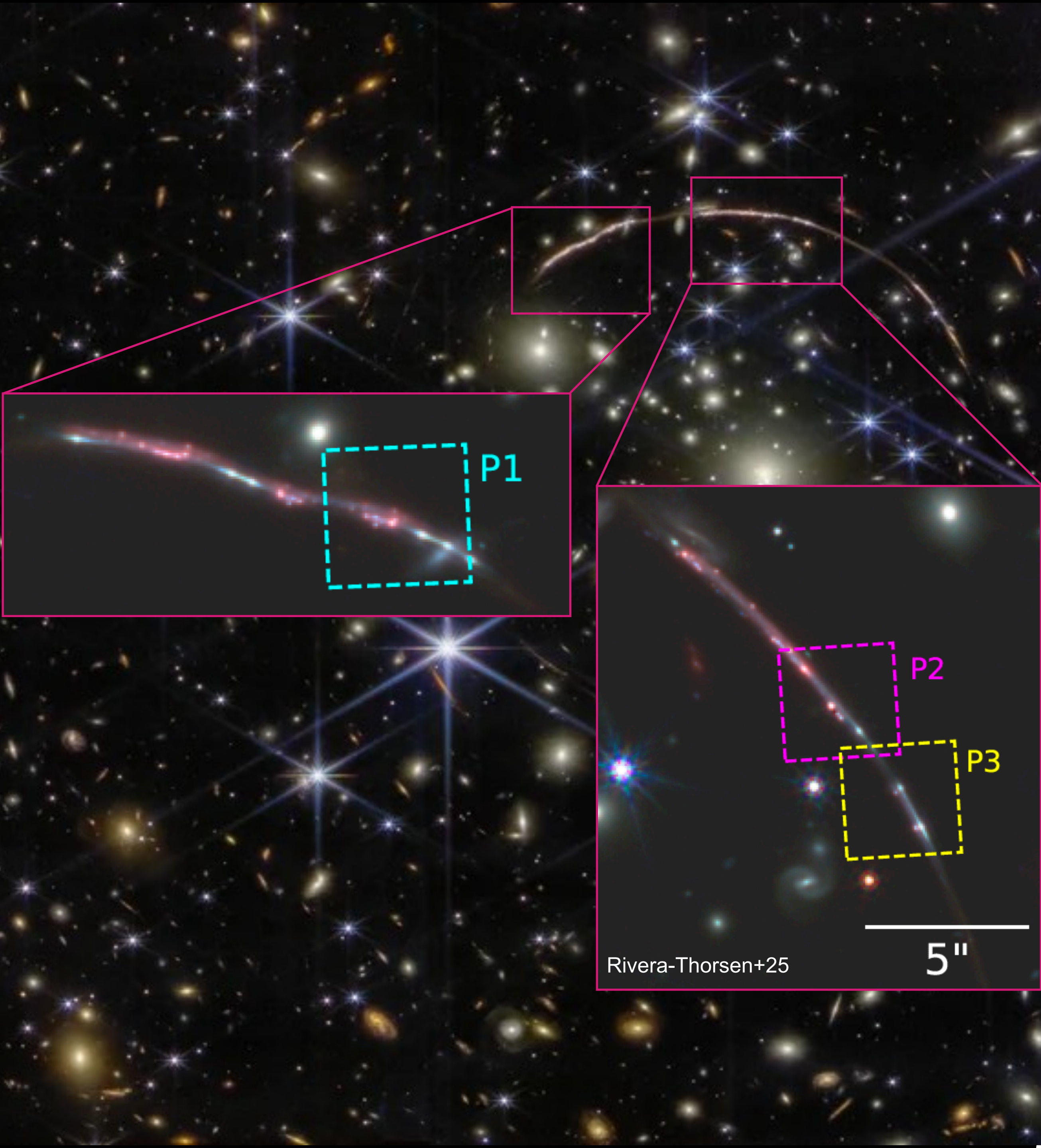
Lensing shows that clumps have sub-structure



Strong lensing is like a cosmic telescope:

- magnifies sources
- increases spatial resolution

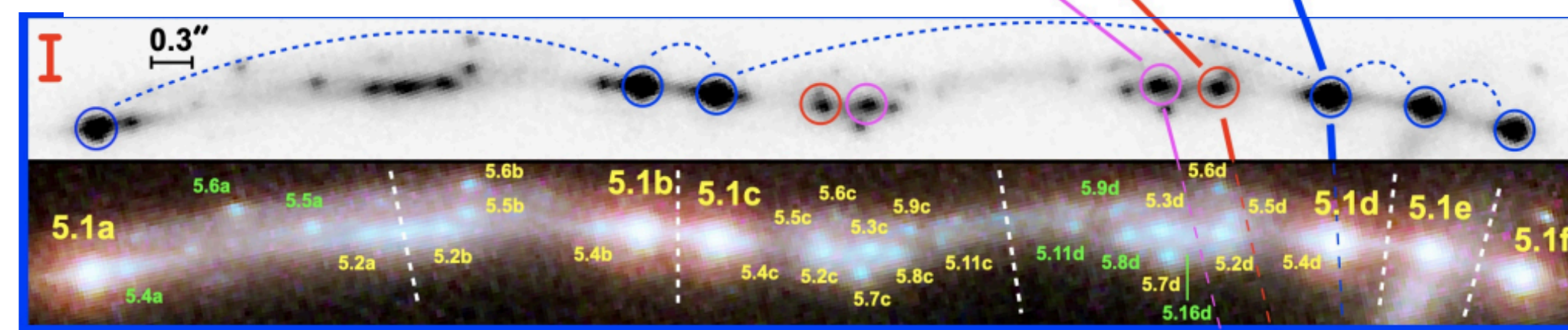
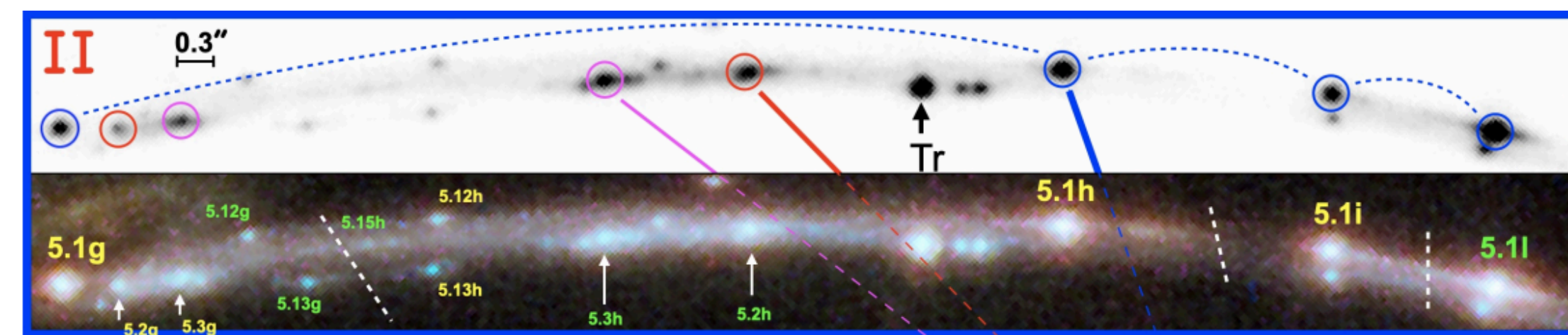
it allows to spatially resolve galaxies down to the smallest scales and faintest structures



Lensing shows that clumps have sub-structure

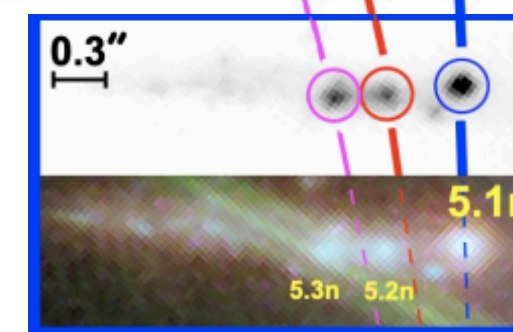
When resolution increases,
clumps are on average smaller

FWHM ~ 7 pc
 $\mu > 50$

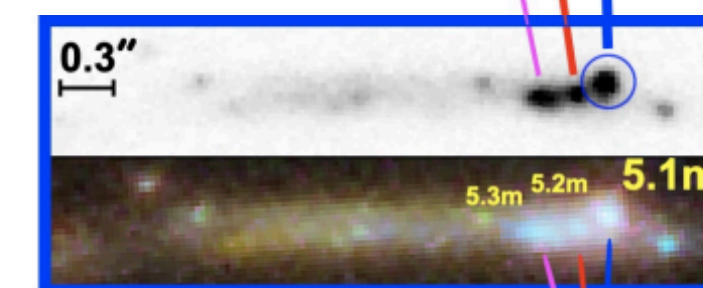


FWHM ~ 19 pc

FWHM ~ 35 pc

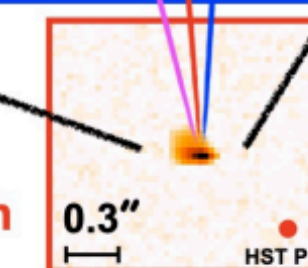


FWHM ~ 70 pc



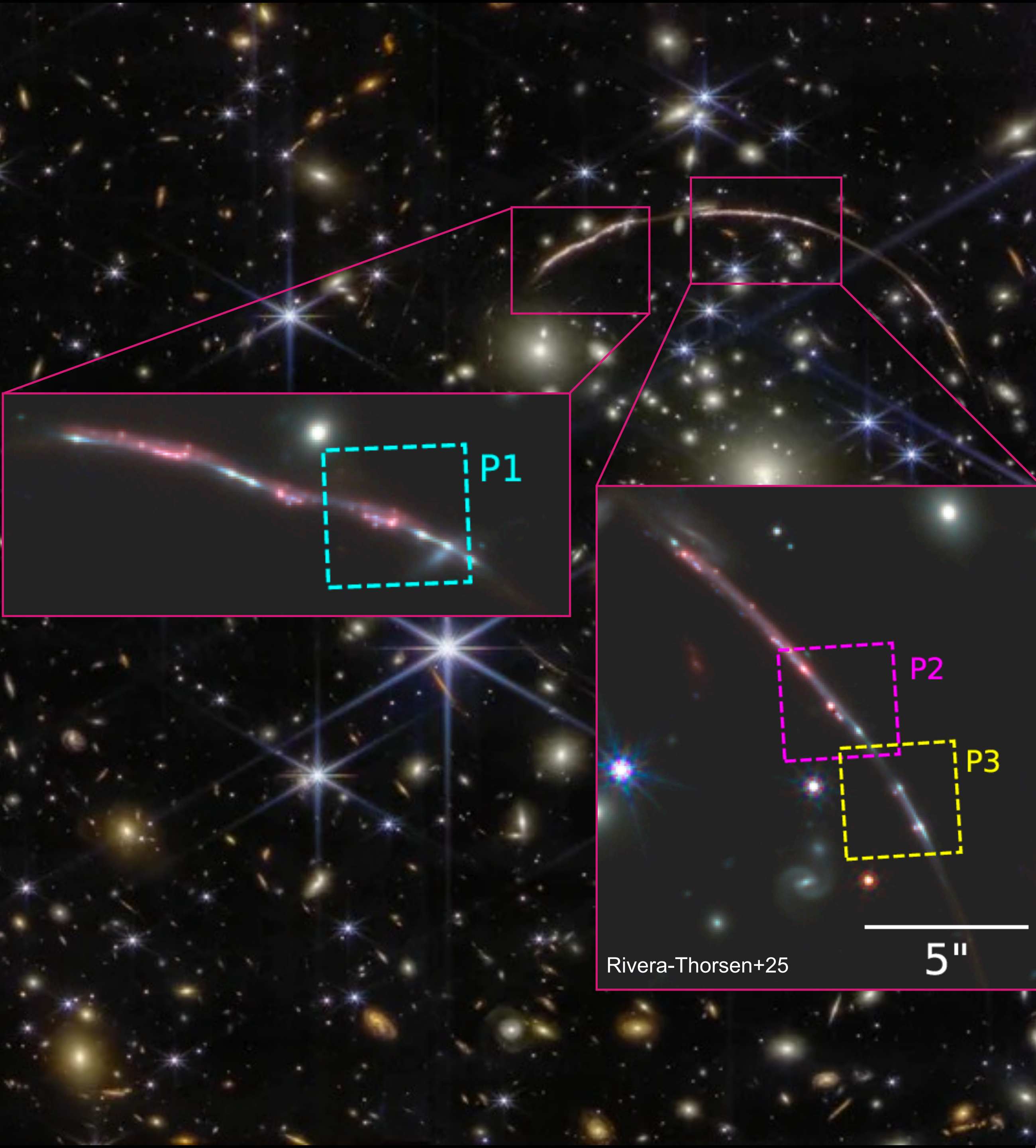
FWHM ~ 820 pc
 $\mu = 1$

Source plane
Reconstruction



Increasing magnification

Vanzella+22, but also
Vanzella+17, +21, Cava+18



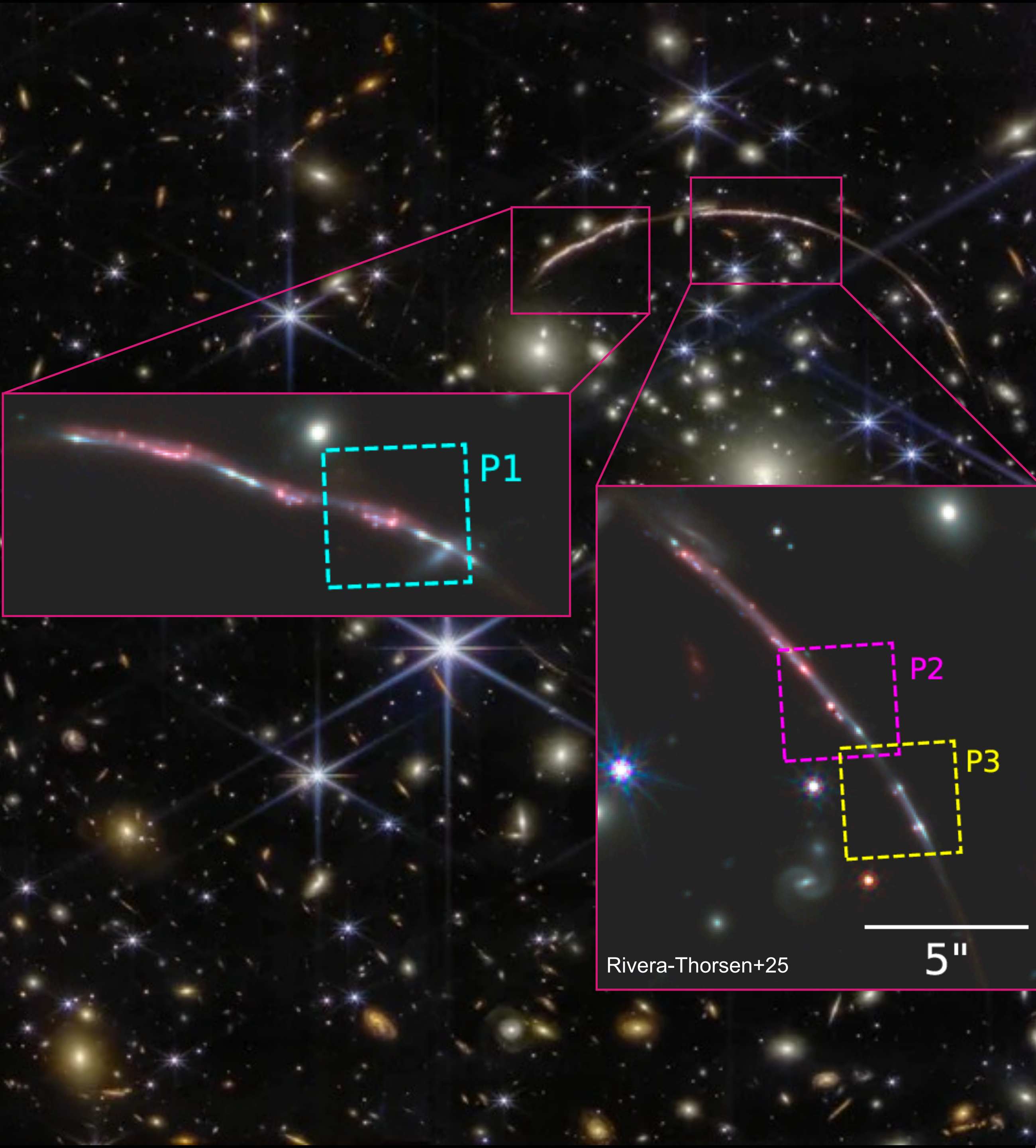
Open questions

What are the properties of high- z star clusters?
Could they be the progenitors of local GCs?

How do they contribute to the star formation activity of the host?

Are they the sites of (extremely) metal-poor star formation at high redshift?

What are the properties of their birth clouds?



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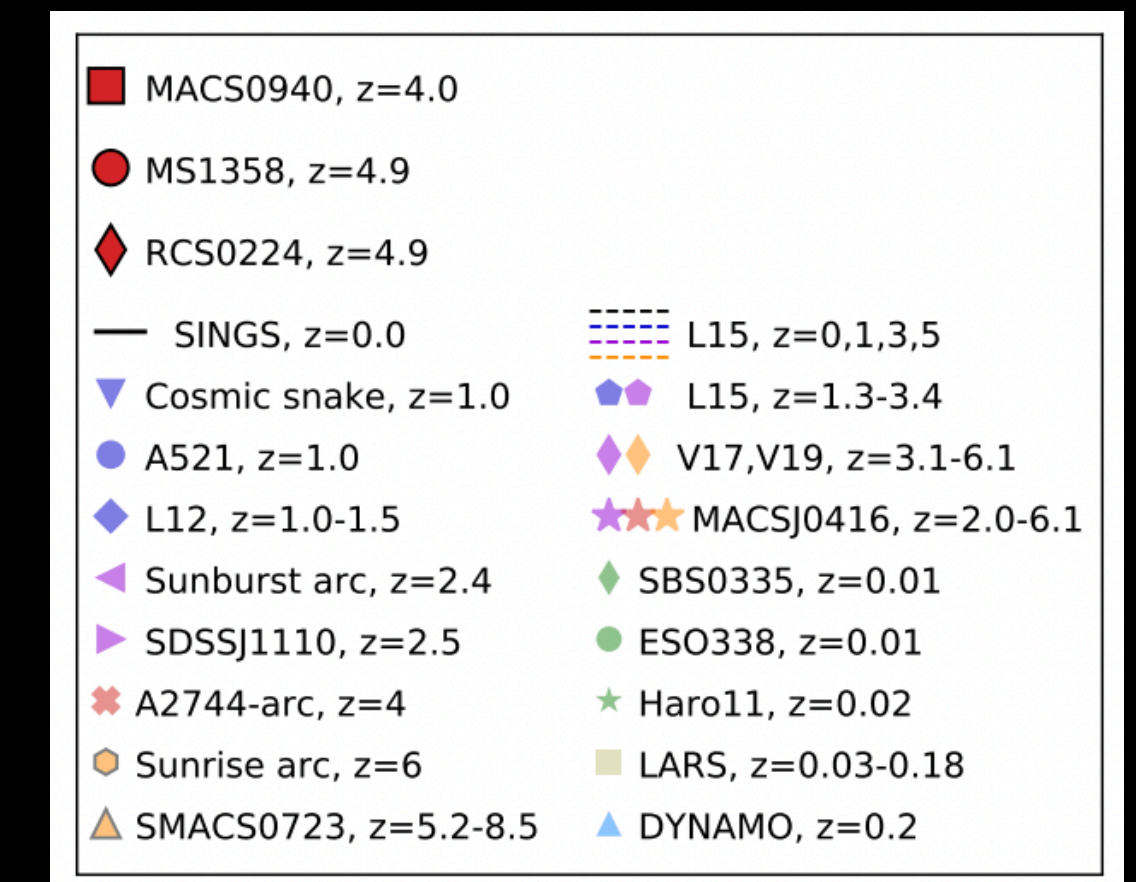
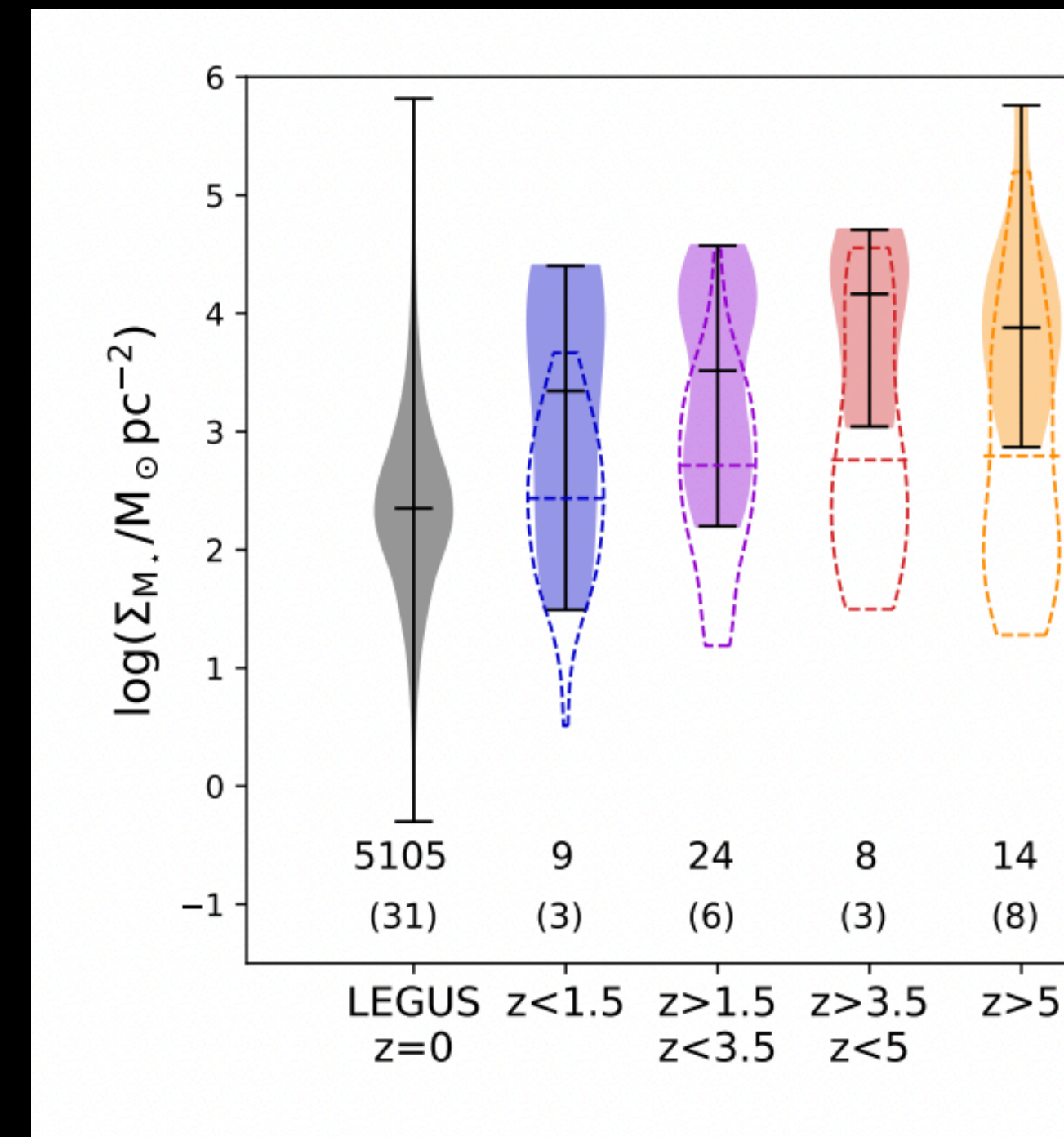
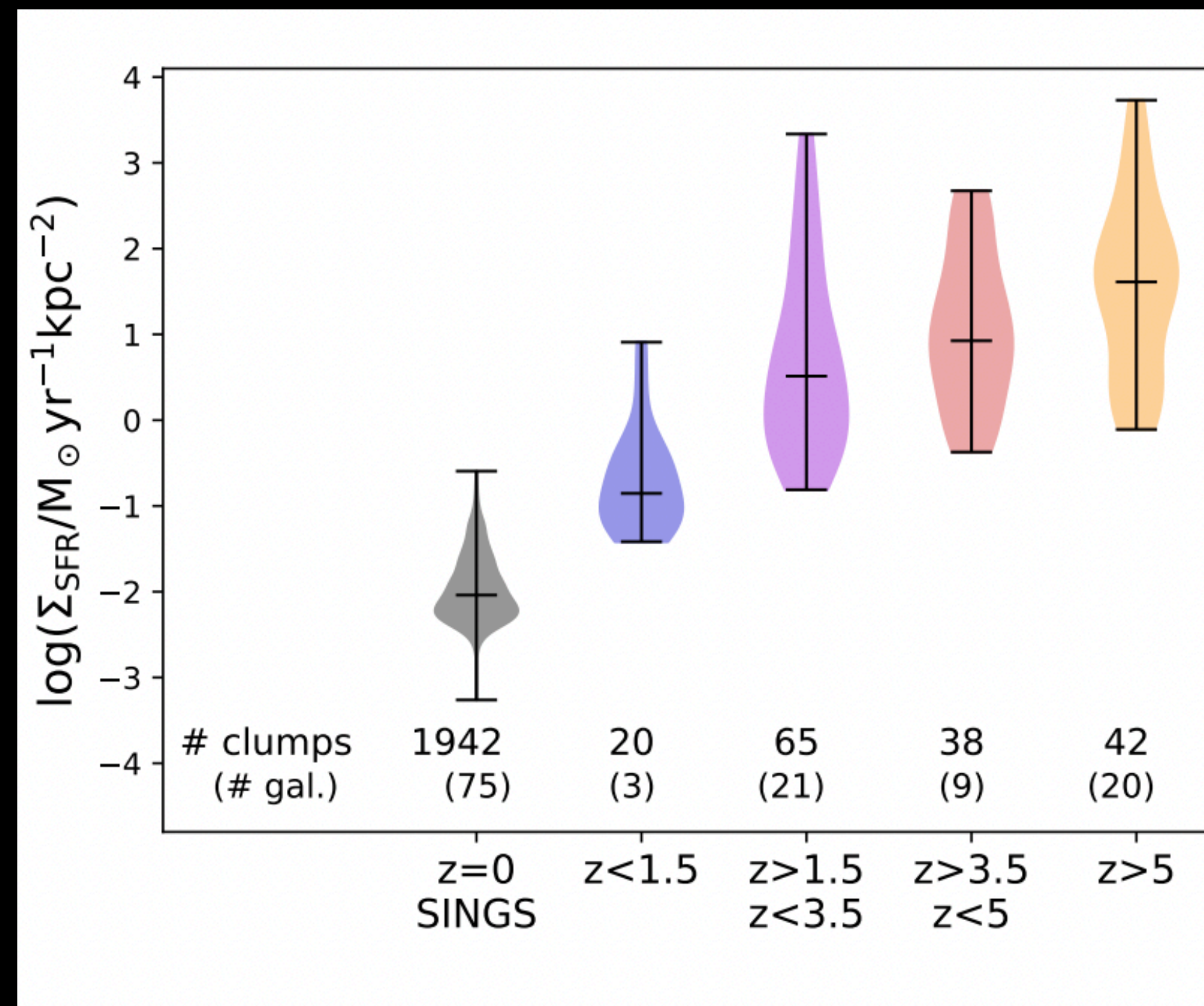


Determining their sizes is crucial

ELT, in synergy with VLT/MAVIS
and ALMA (incl. ALMA2040), will be the key player

Determining clumps' size is key

Understand if the properties of clumps/star clusters evolve with redshift
(Σ_{SFR} , Σ_{Mstar} , ...)

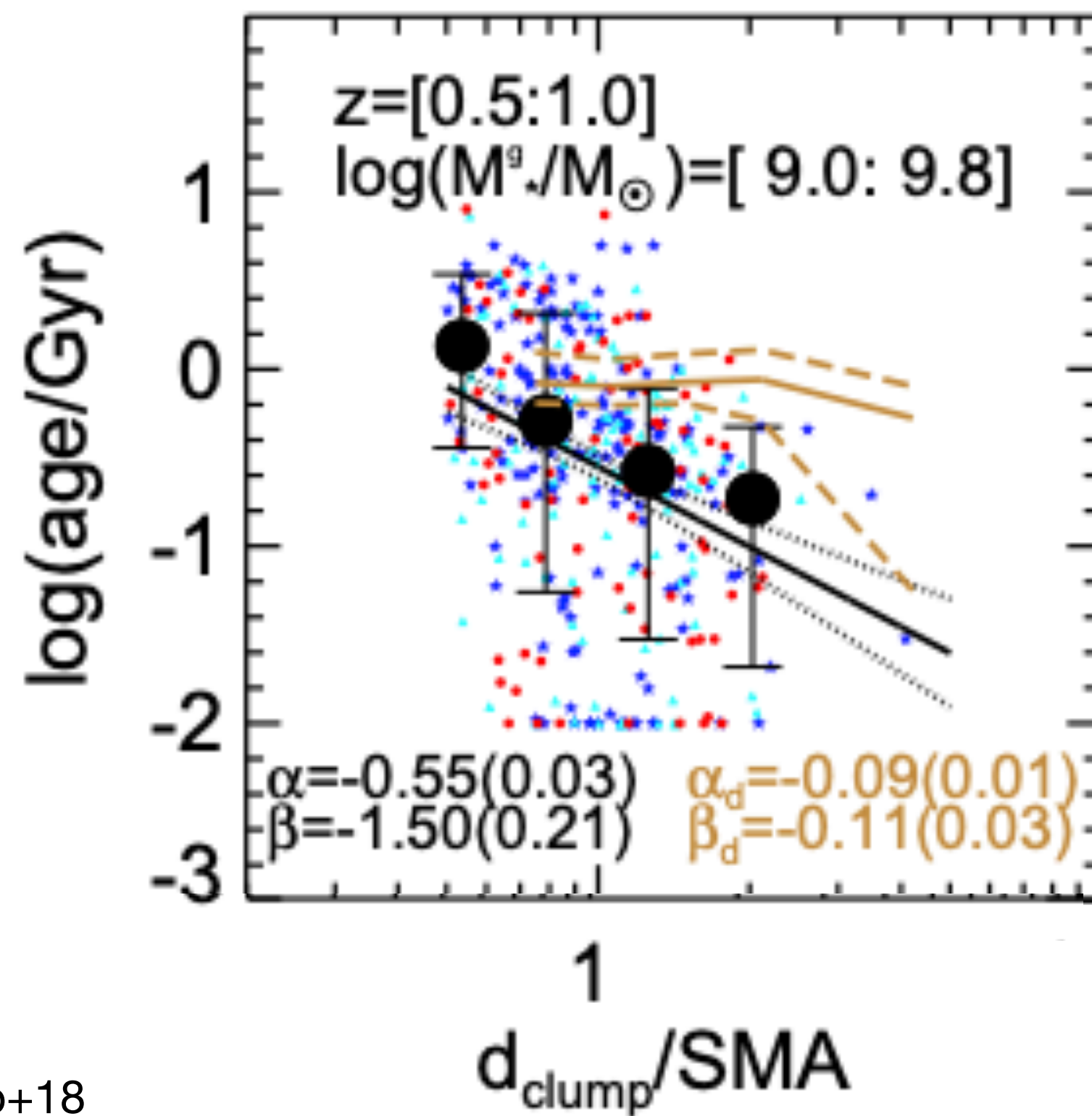


Messa et al. 2024

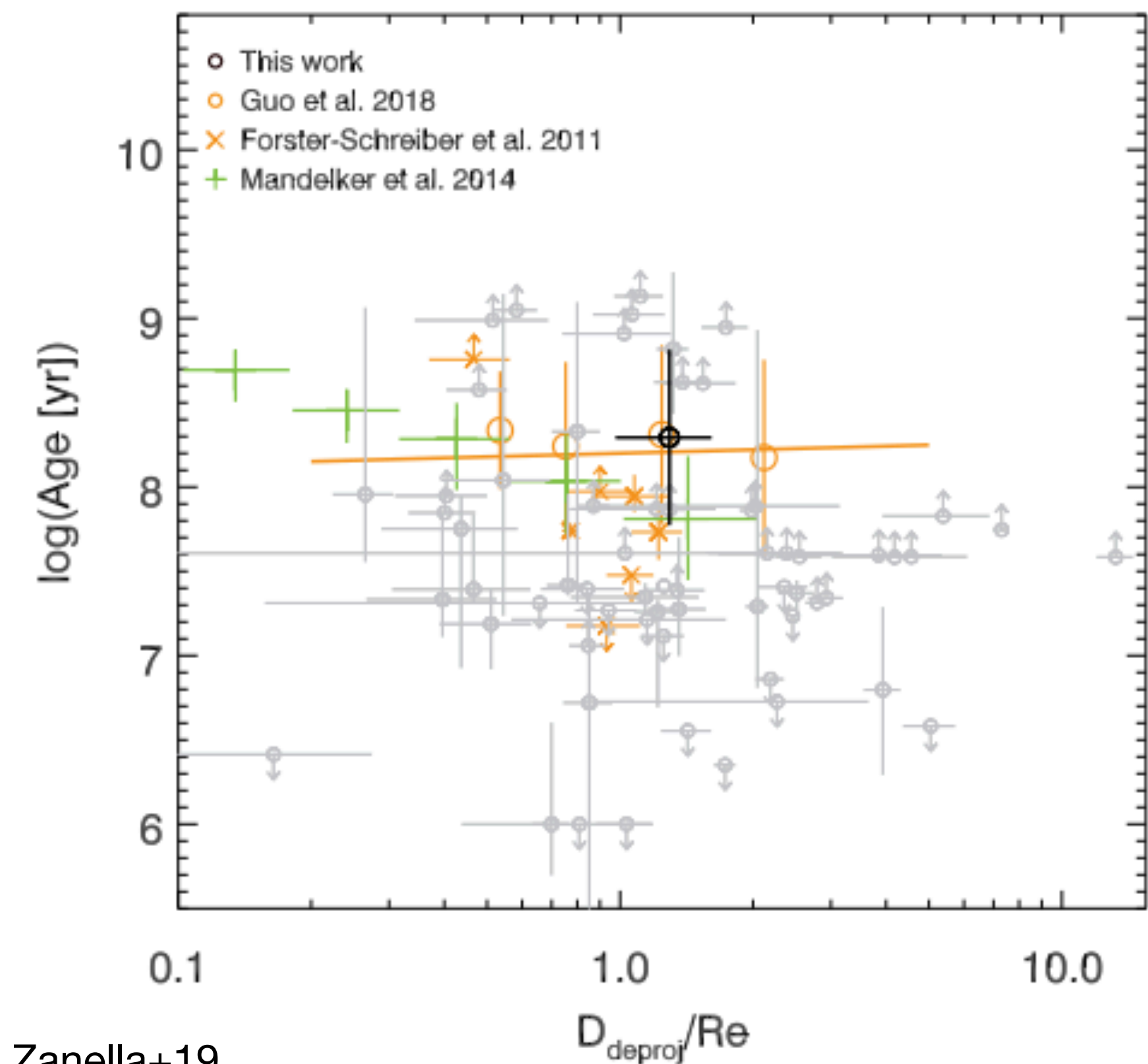
On average, the stellar density of clumps increases at higher redshift $\rightarrow$ the conditions for star formation evolve over time

Determining clumps' size is key

Understand clumps' role in galaxy evolution
(e.g., bulge formation, disk thickening, ...)



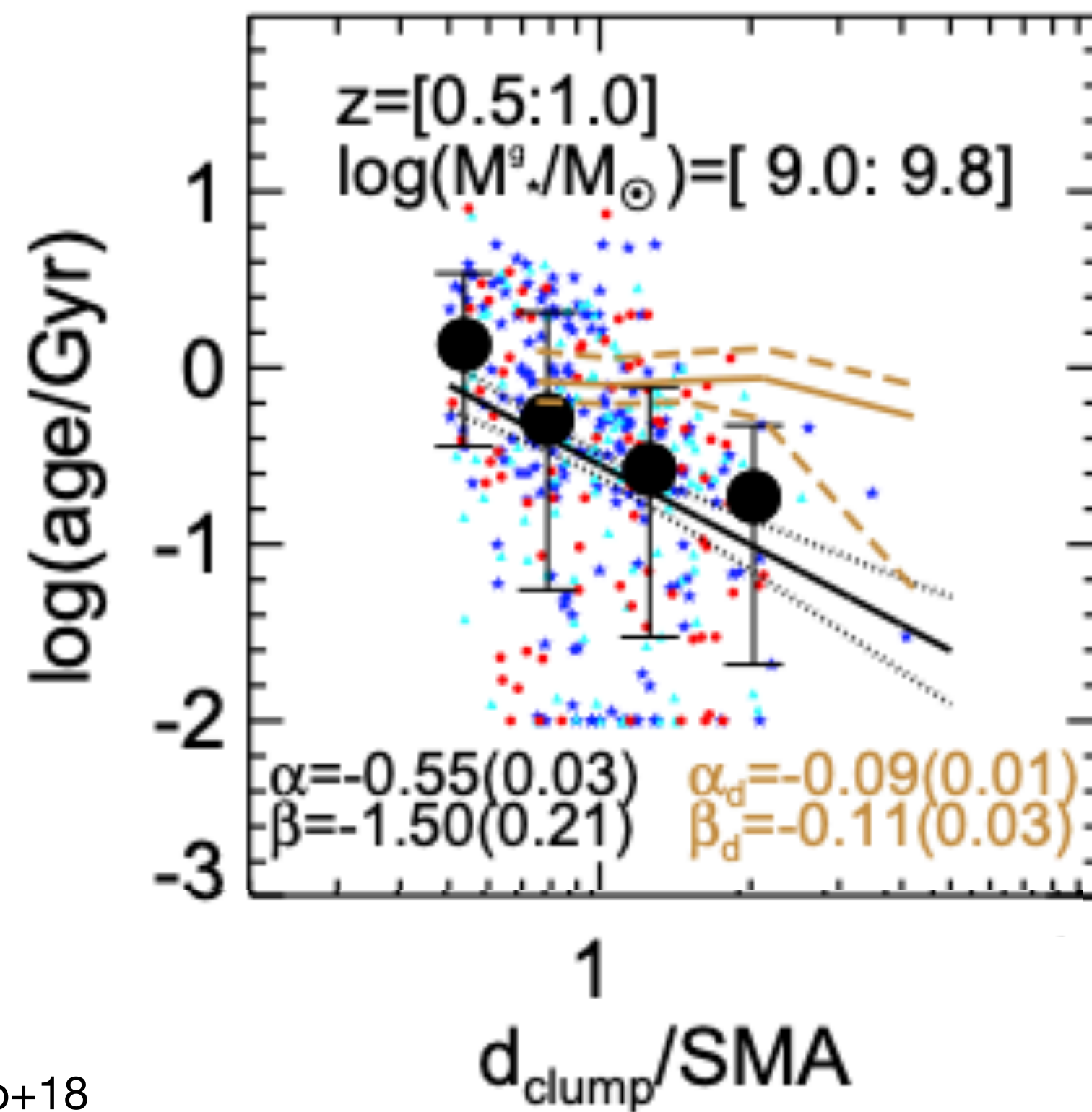
Guo+18



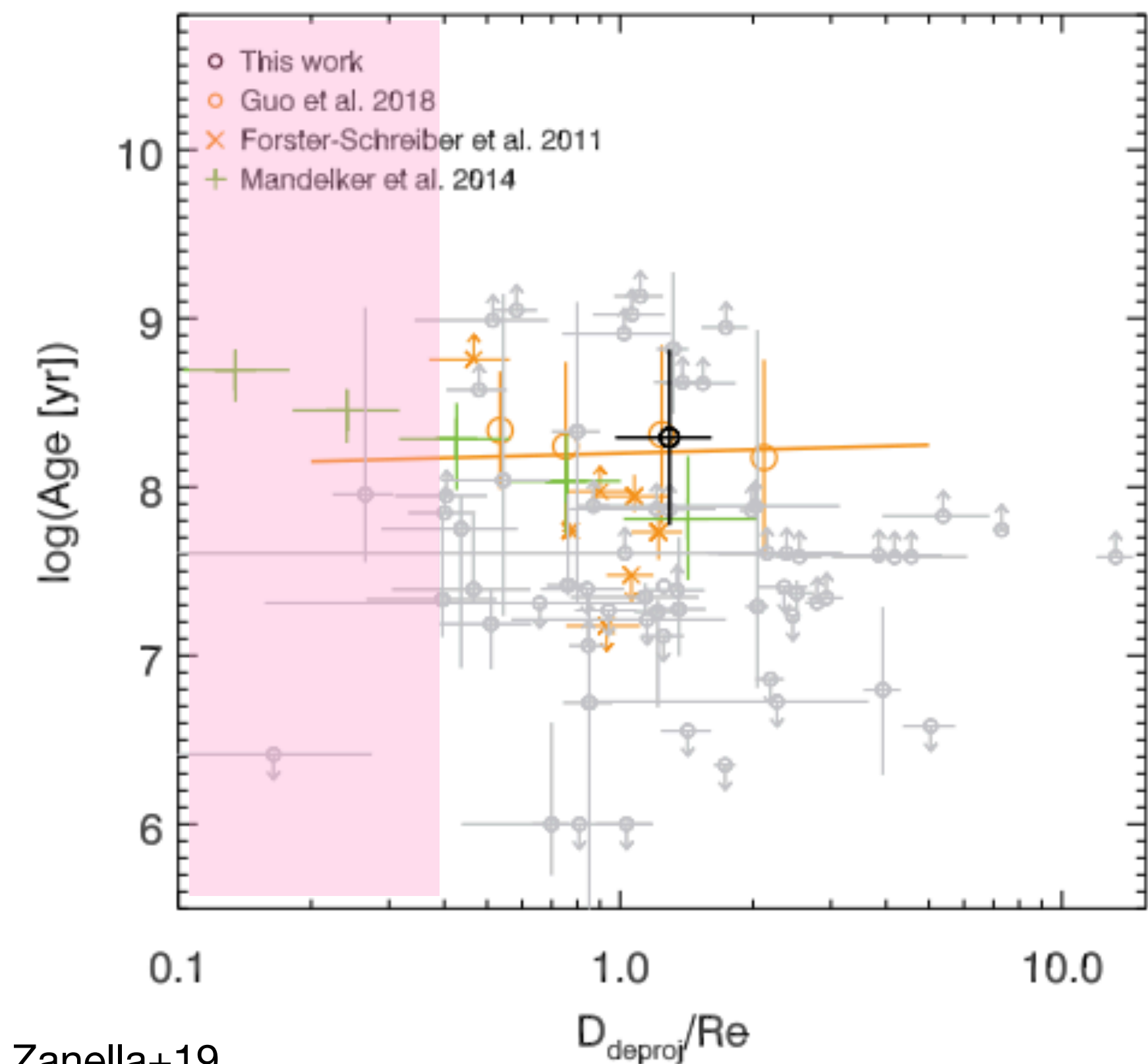
Zanella+19

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Guo+18

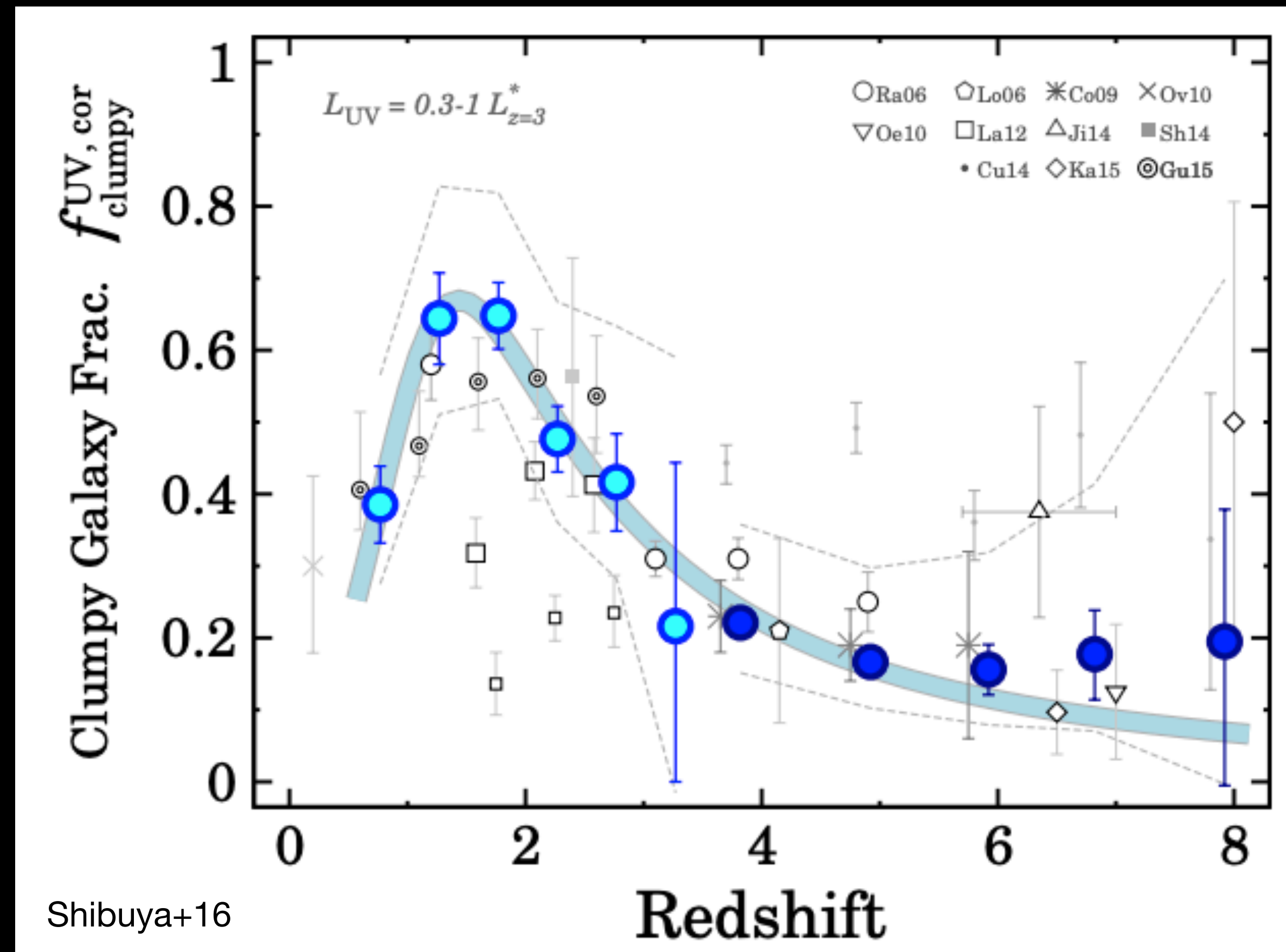


Zanella+19

Understand if clumps inward migration contributes to the morphological and structural evolution of the host galaxy

Determining clumps' size is key

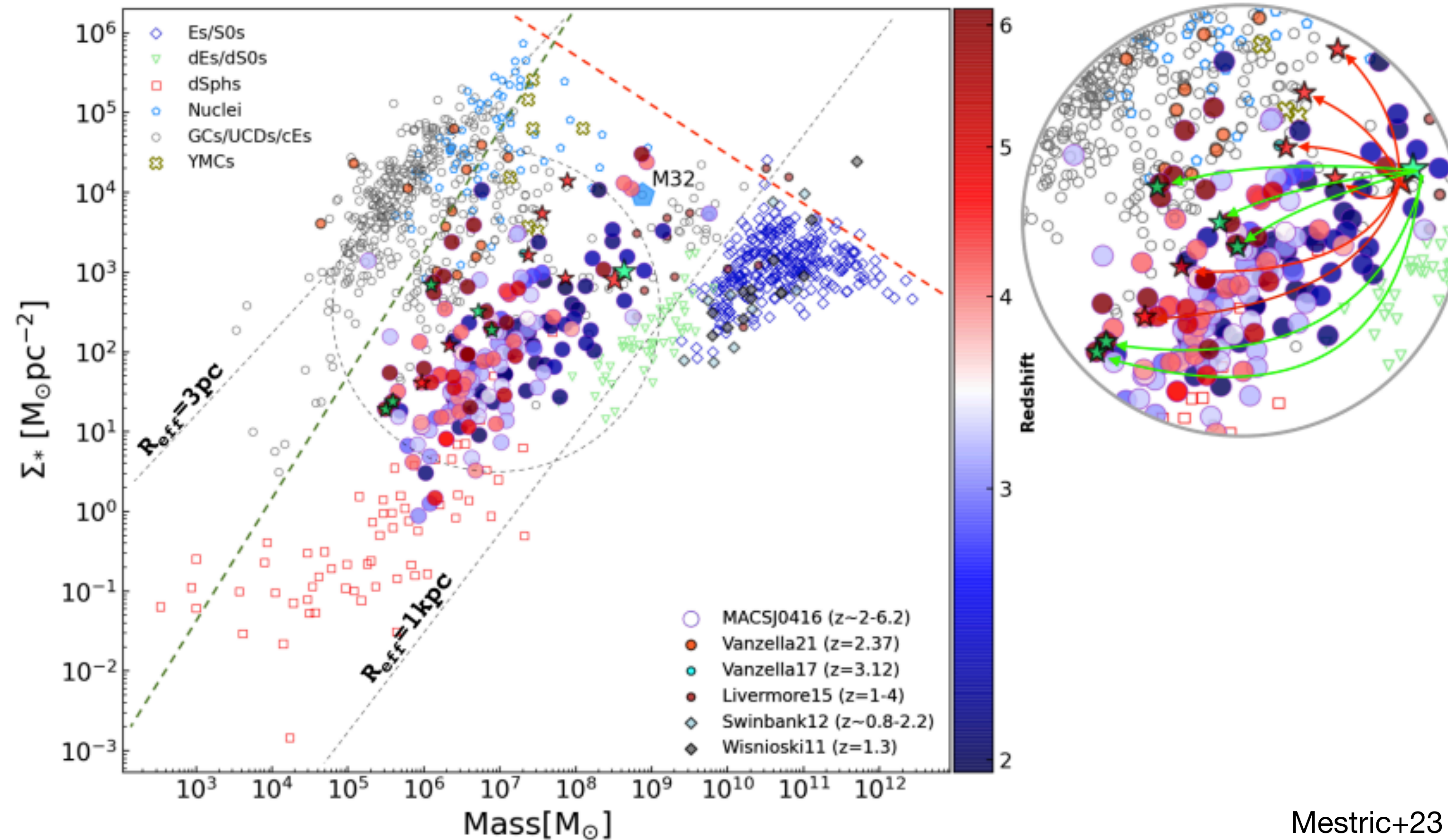
Identify clumps up to the epoch of reionization
and understand their origin



Clarify the number density of clumps, as a function of redshift → deblending is crucial

Determining clumps' size is key

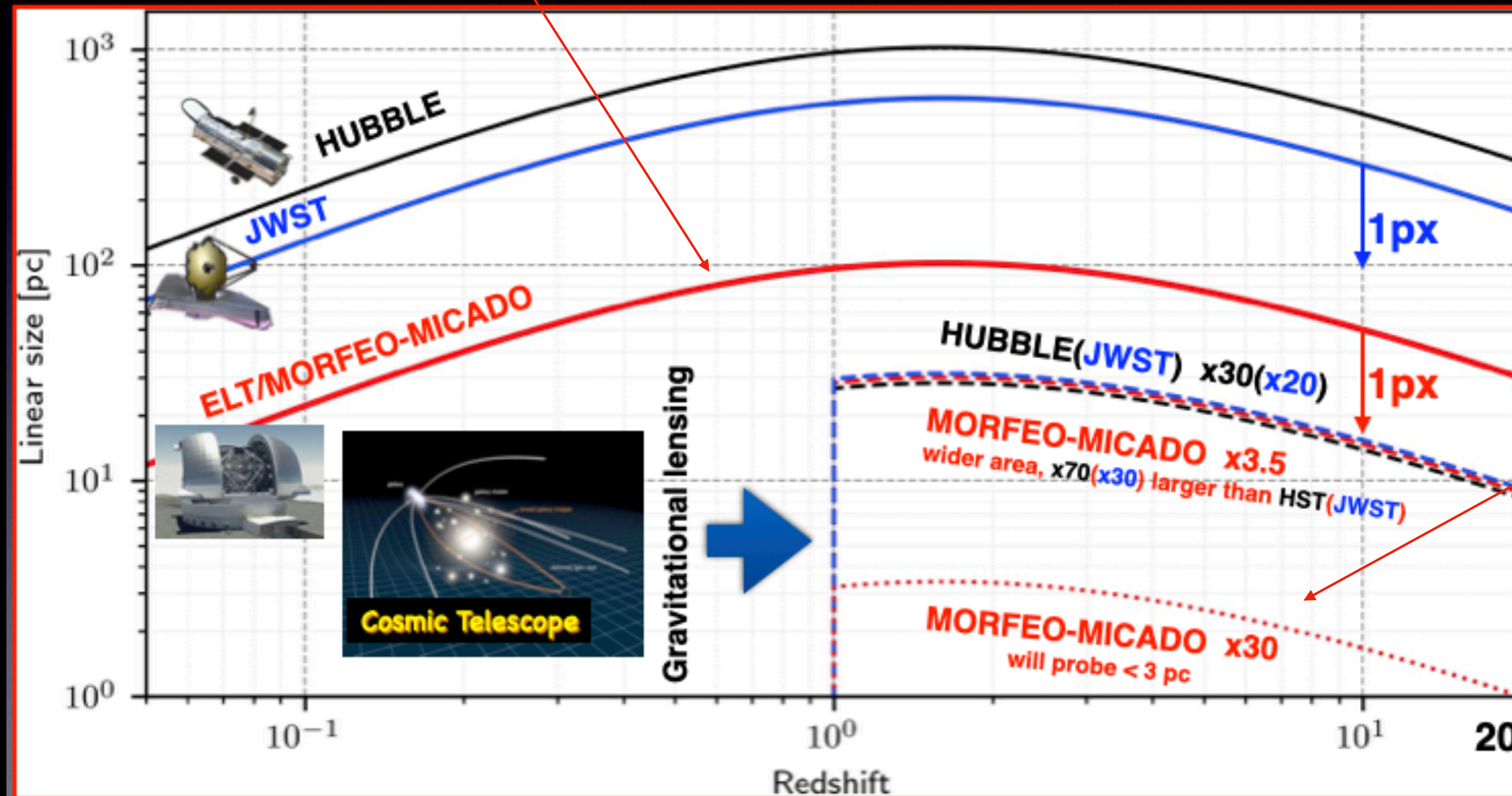
Understand if clumps can be the progenitors of local globular clusters



Accurate stellar mass density determinations are fundamental

The future MORFEO and MICADO on the Extremely Large Telescope

tens of pc in blank fields



Courtesy: E. Vanzella

The future MORFEO and MICADO on the Extremely Large Telescope

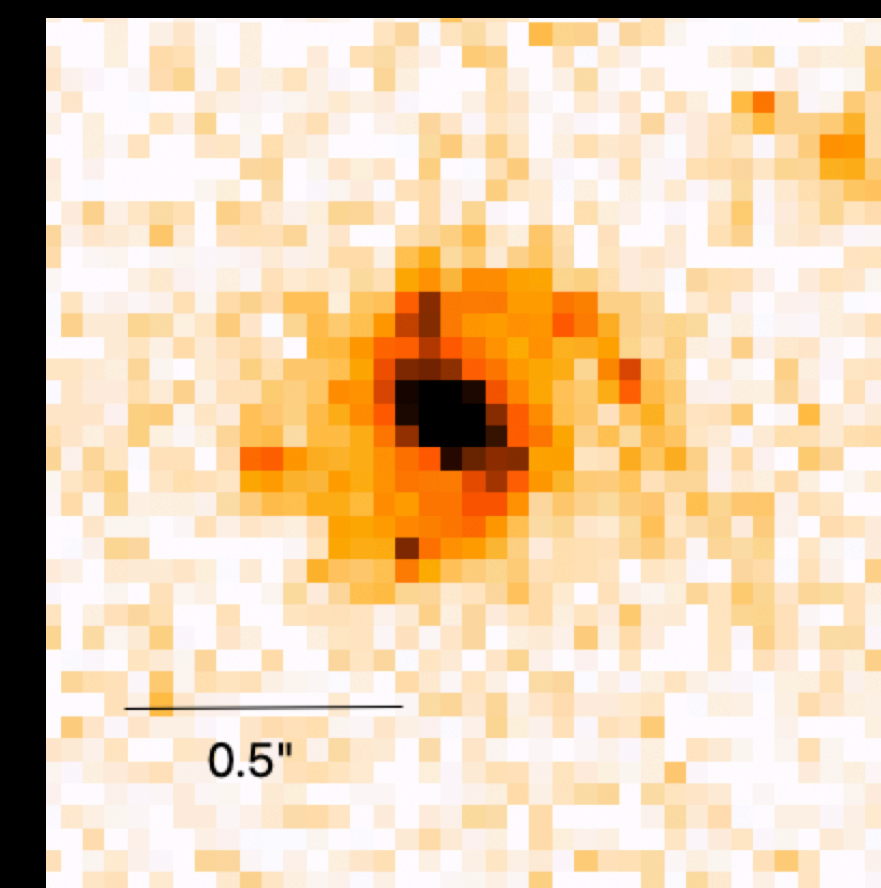
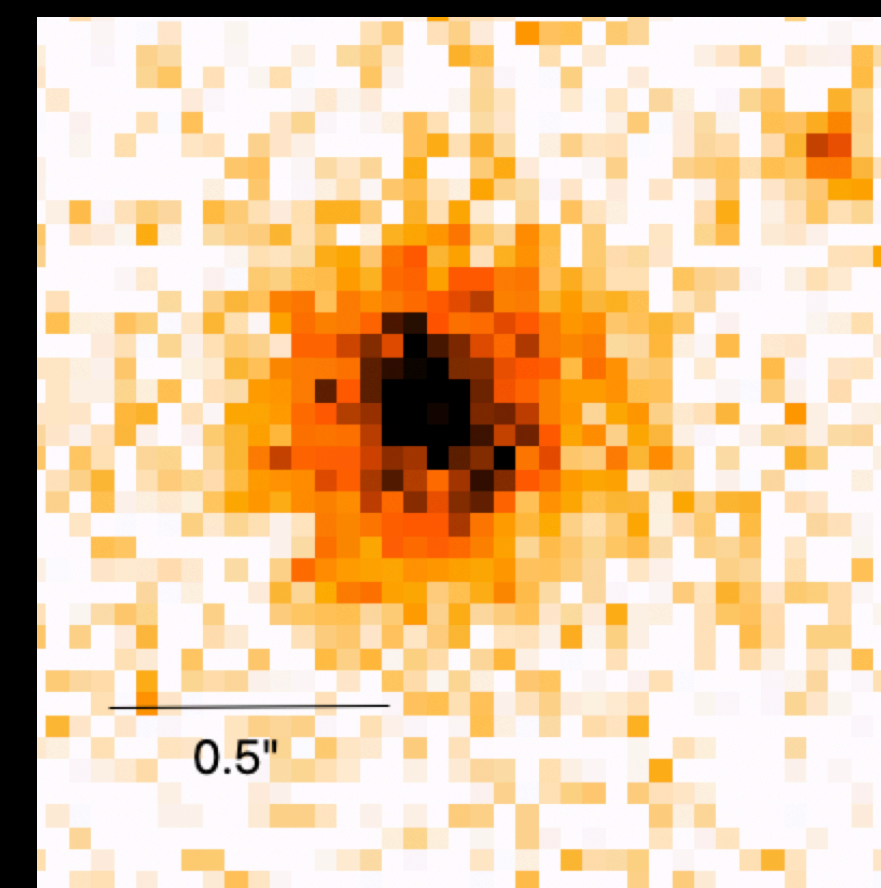
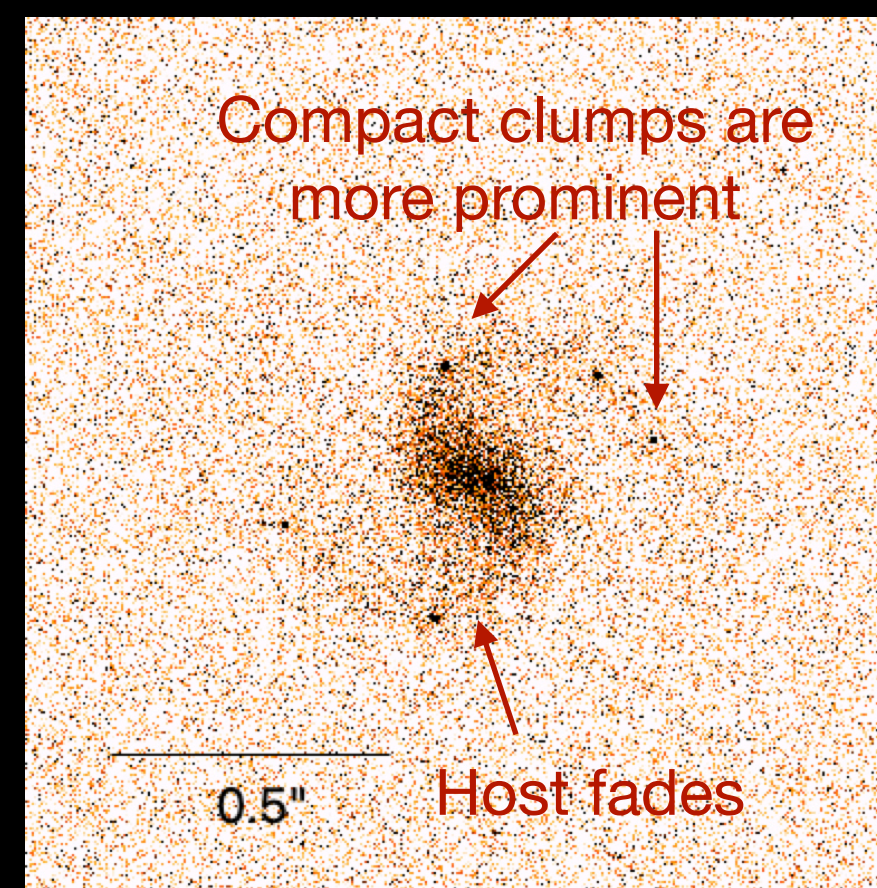
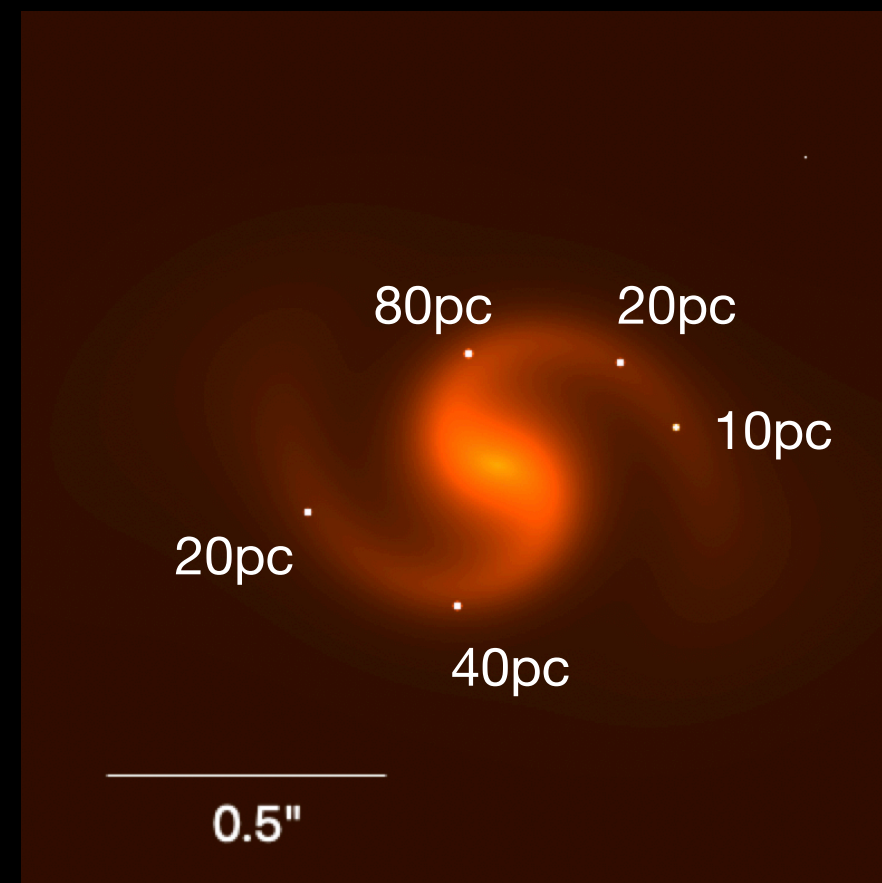
Model

ELT/MORFEO H band

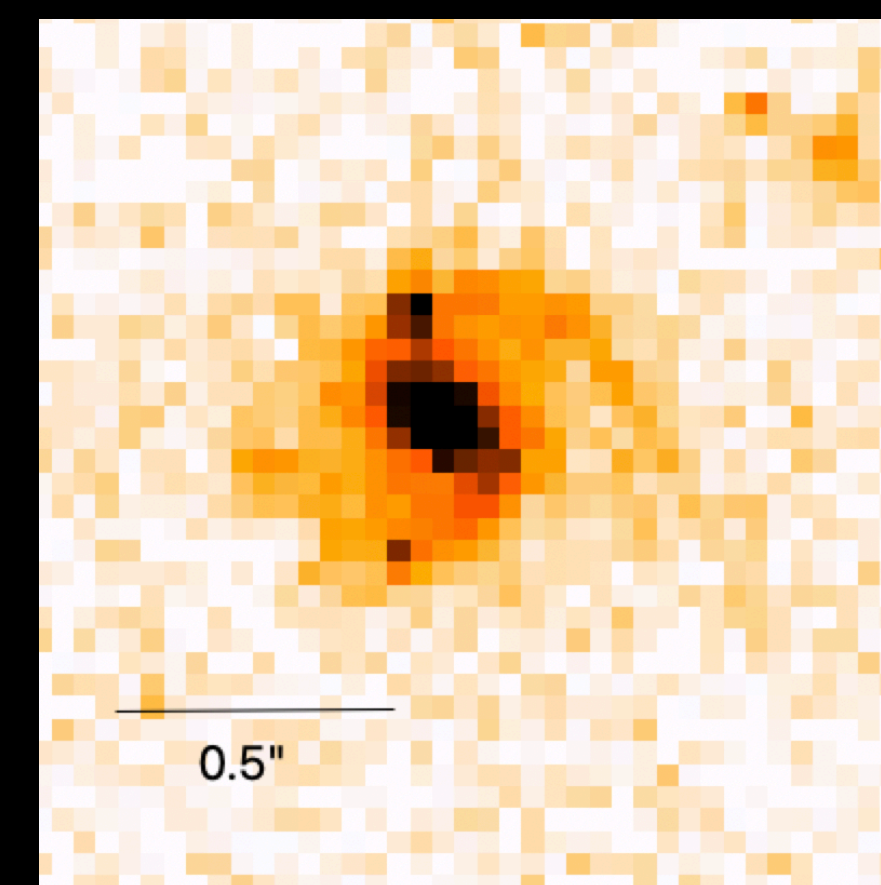
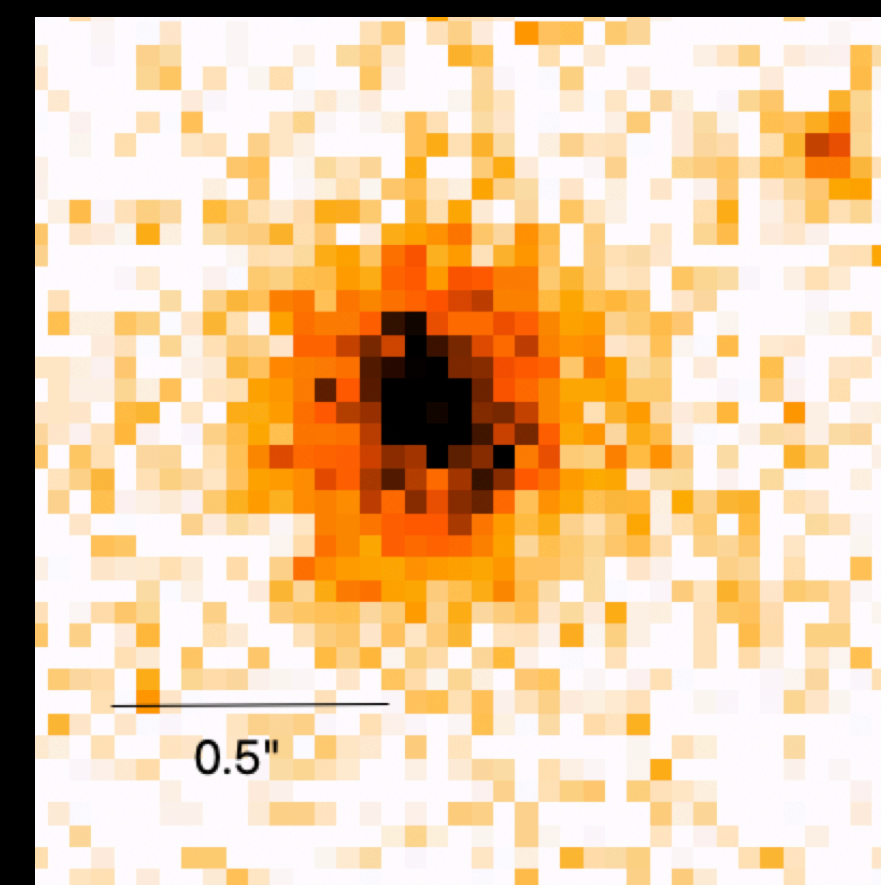
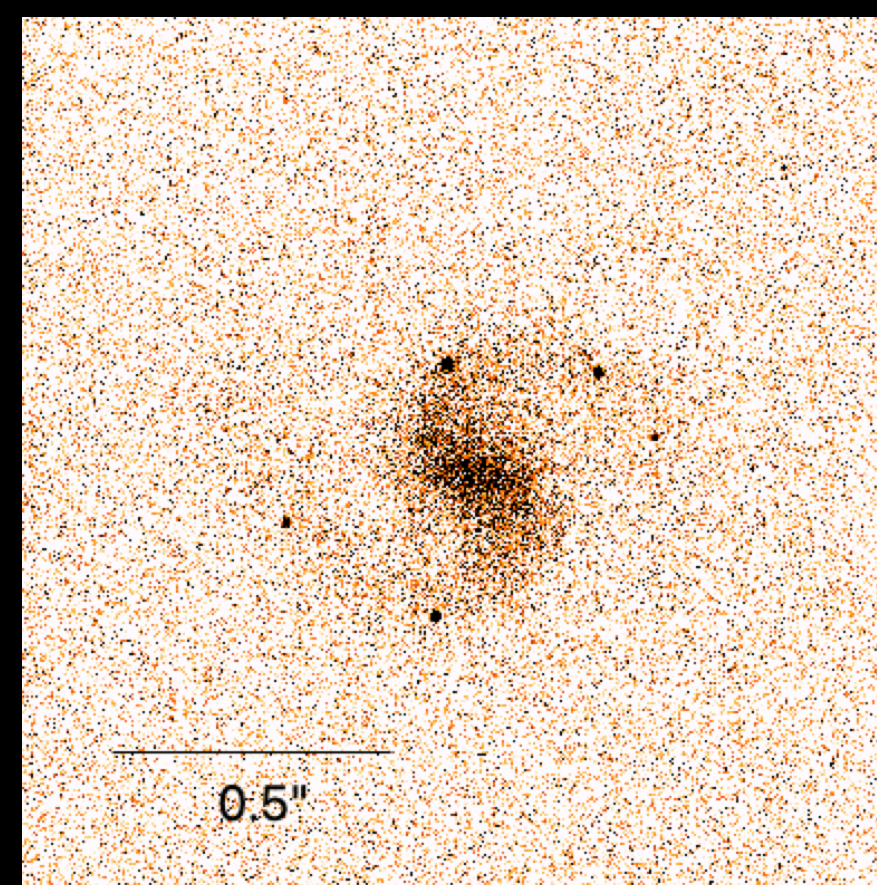
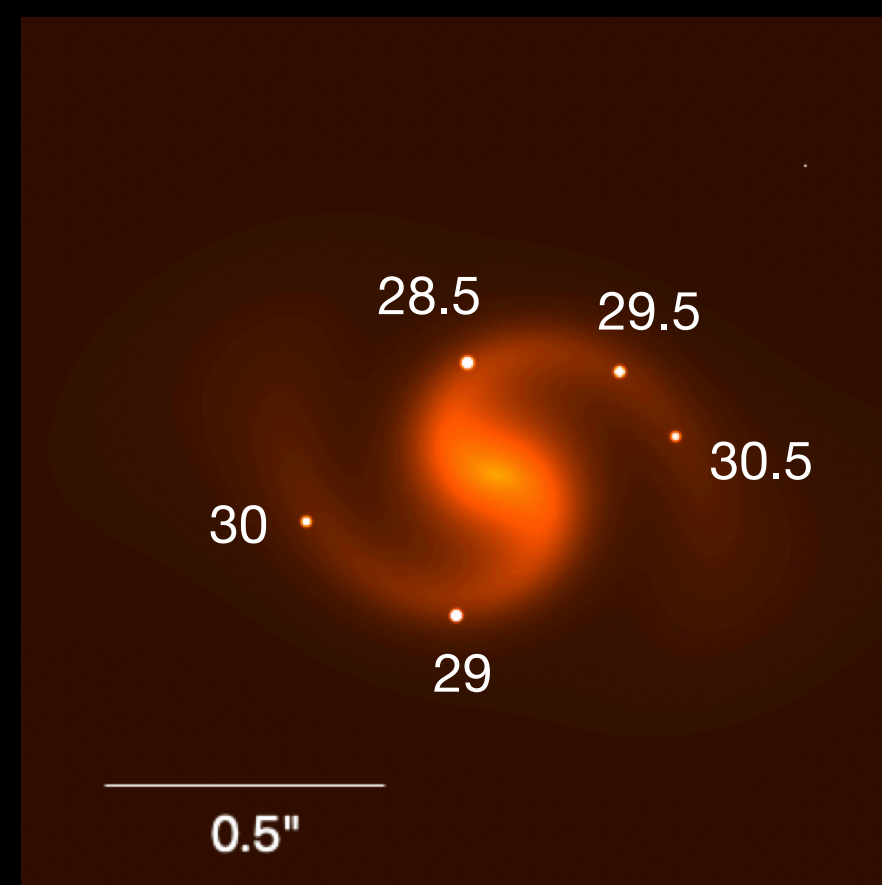
HST F160W

JWST F150W

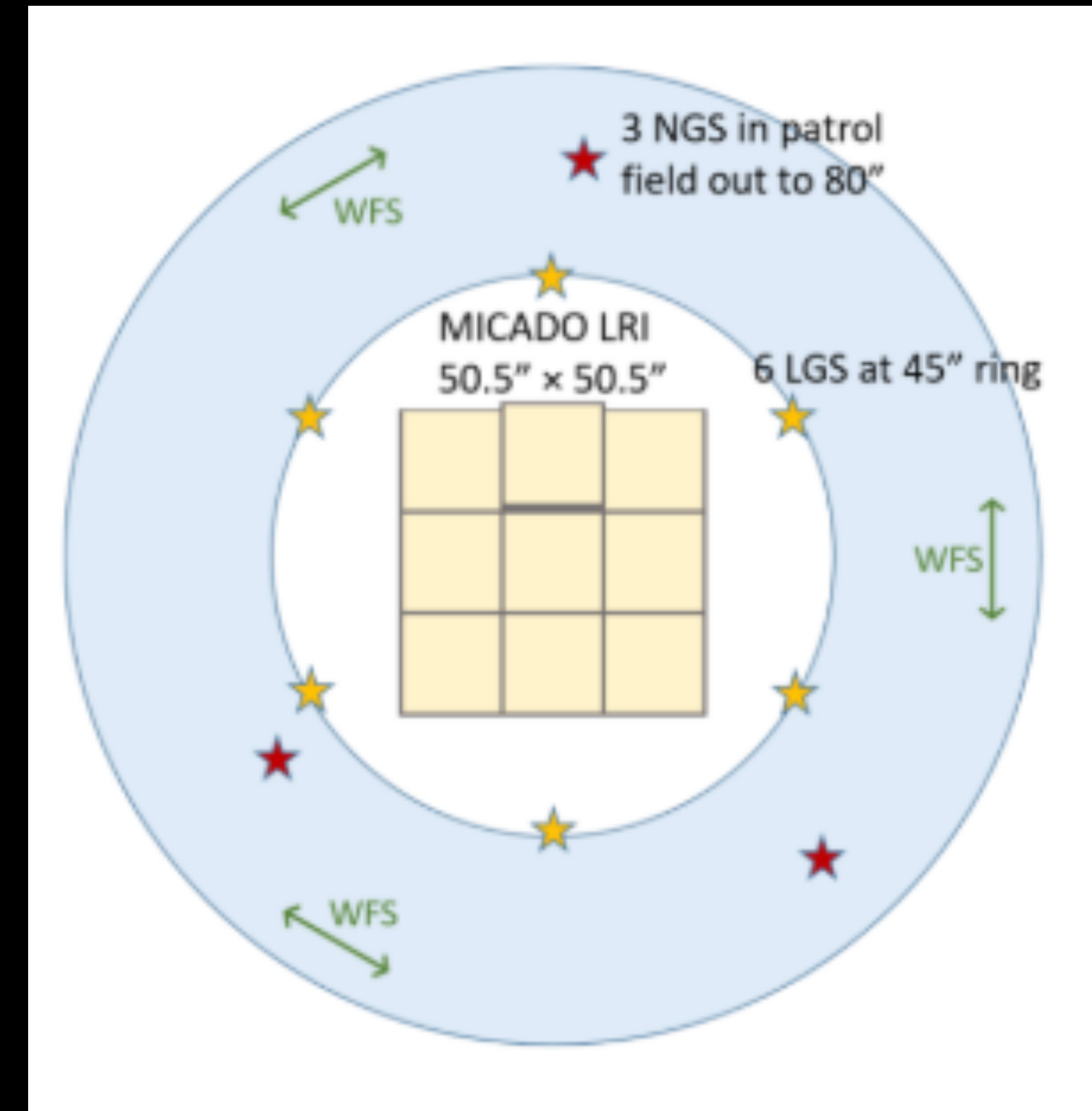
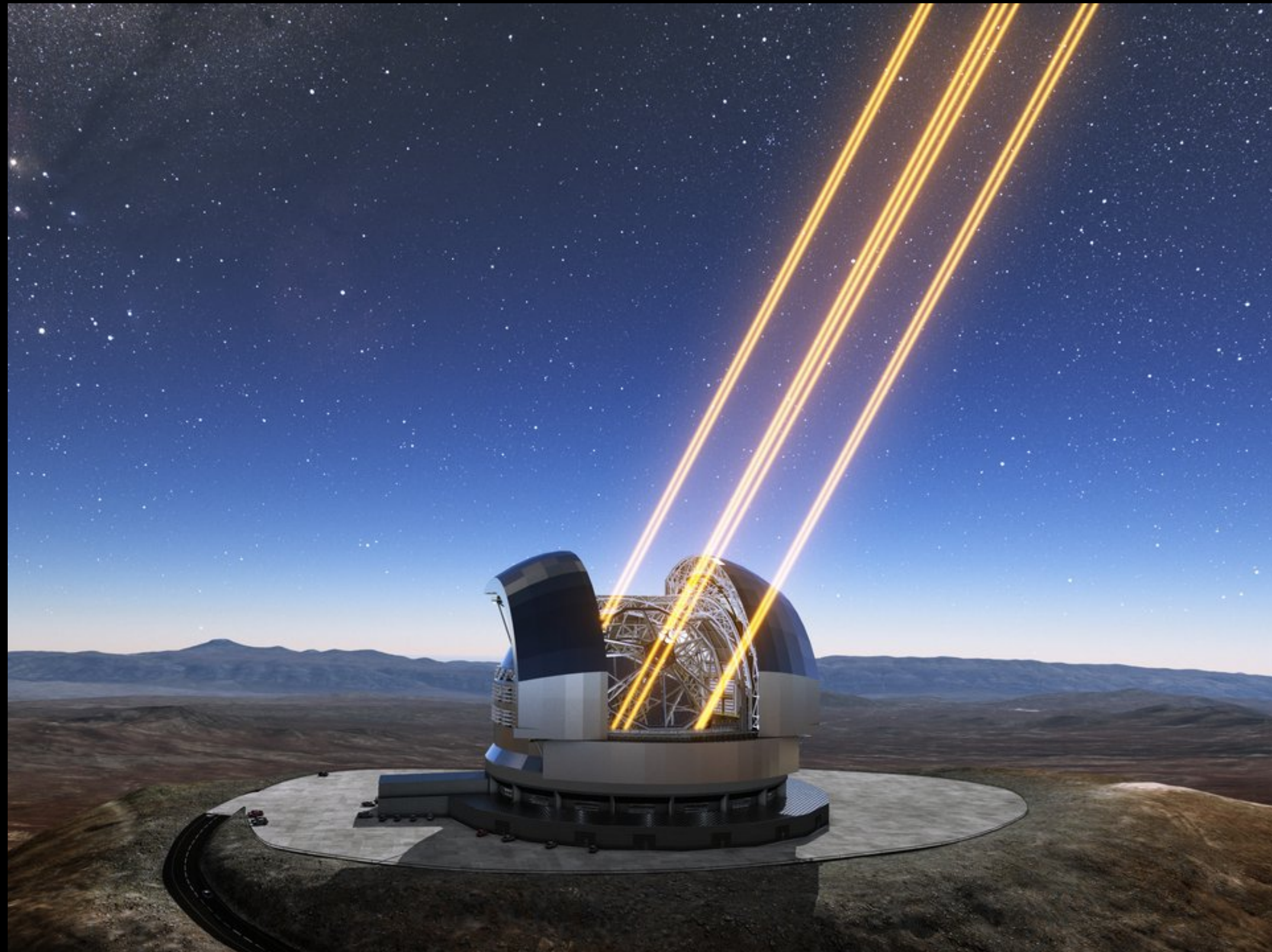
Fix mag = 29 AB



Fix Re = 40 pc



The future MORFEO and MICADO on the Extremely Large Telescope

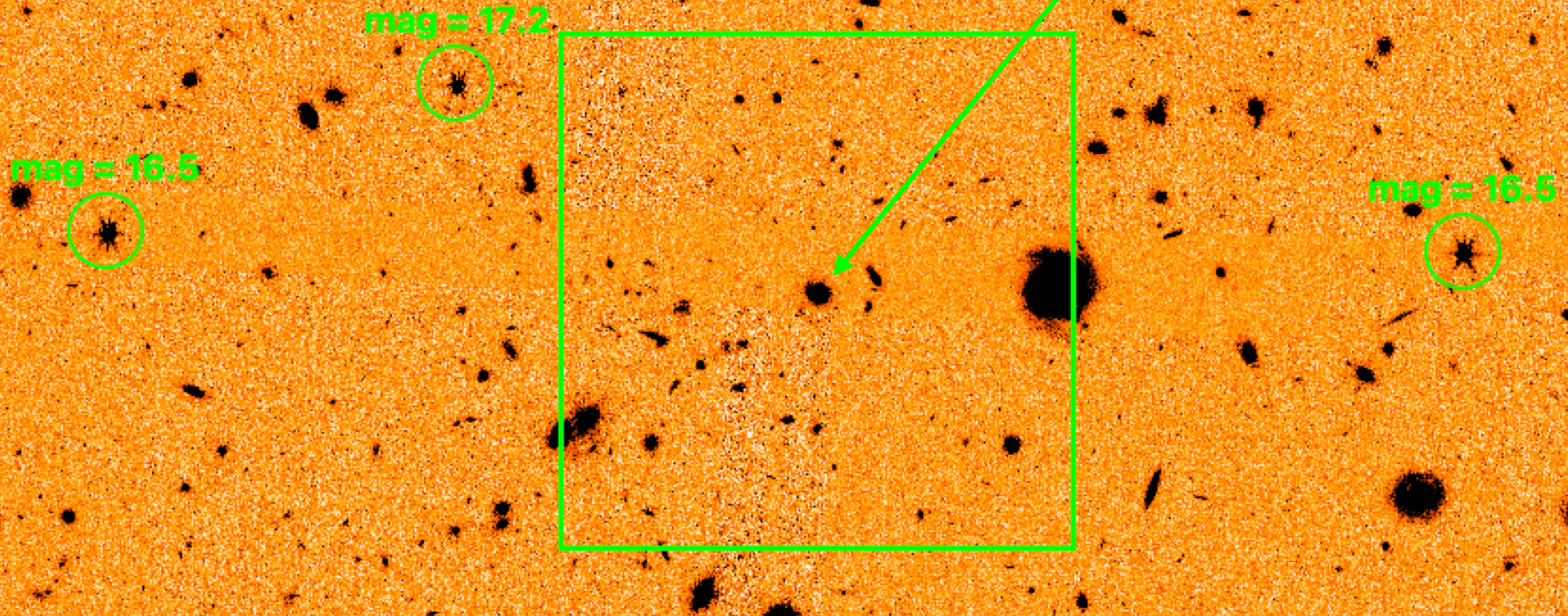


However, three natural guide stars (NGS) with $10 < H < 21$ are needed for optimal MORFEO performances

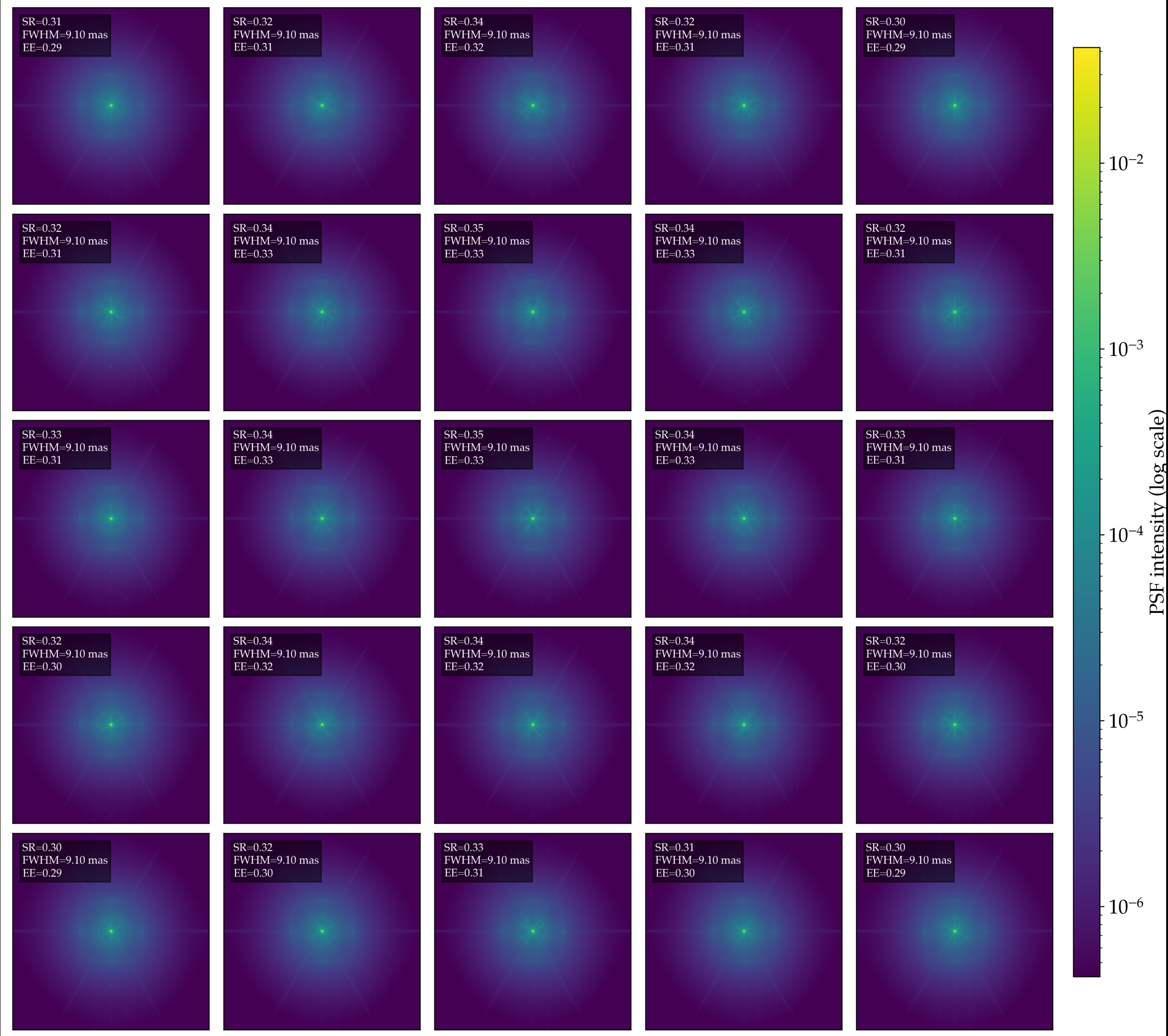
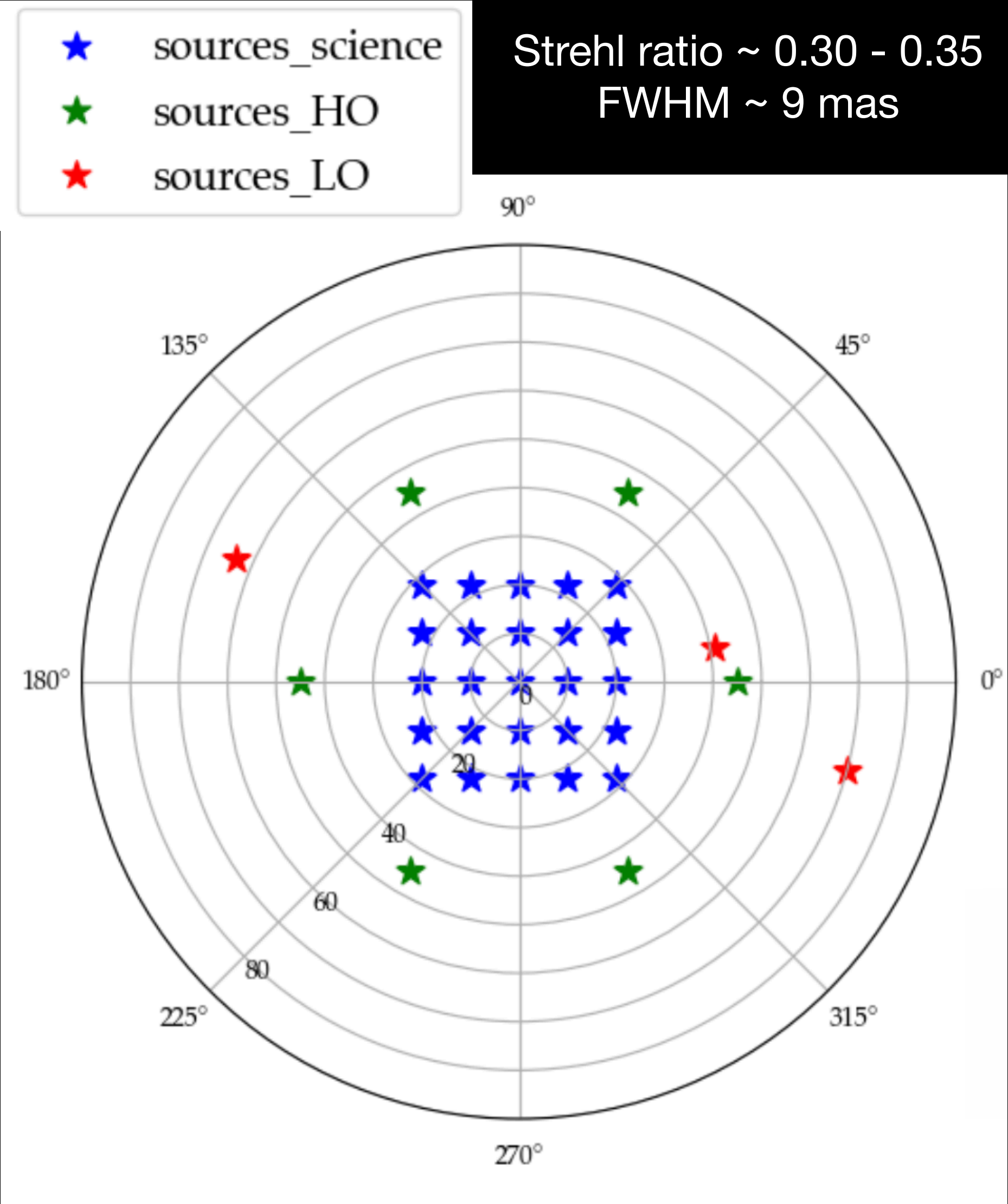
PSF variation across the field of view

The case of the COSMOS field

$z \sim 2$ target from the CONDOR
ALMA large program



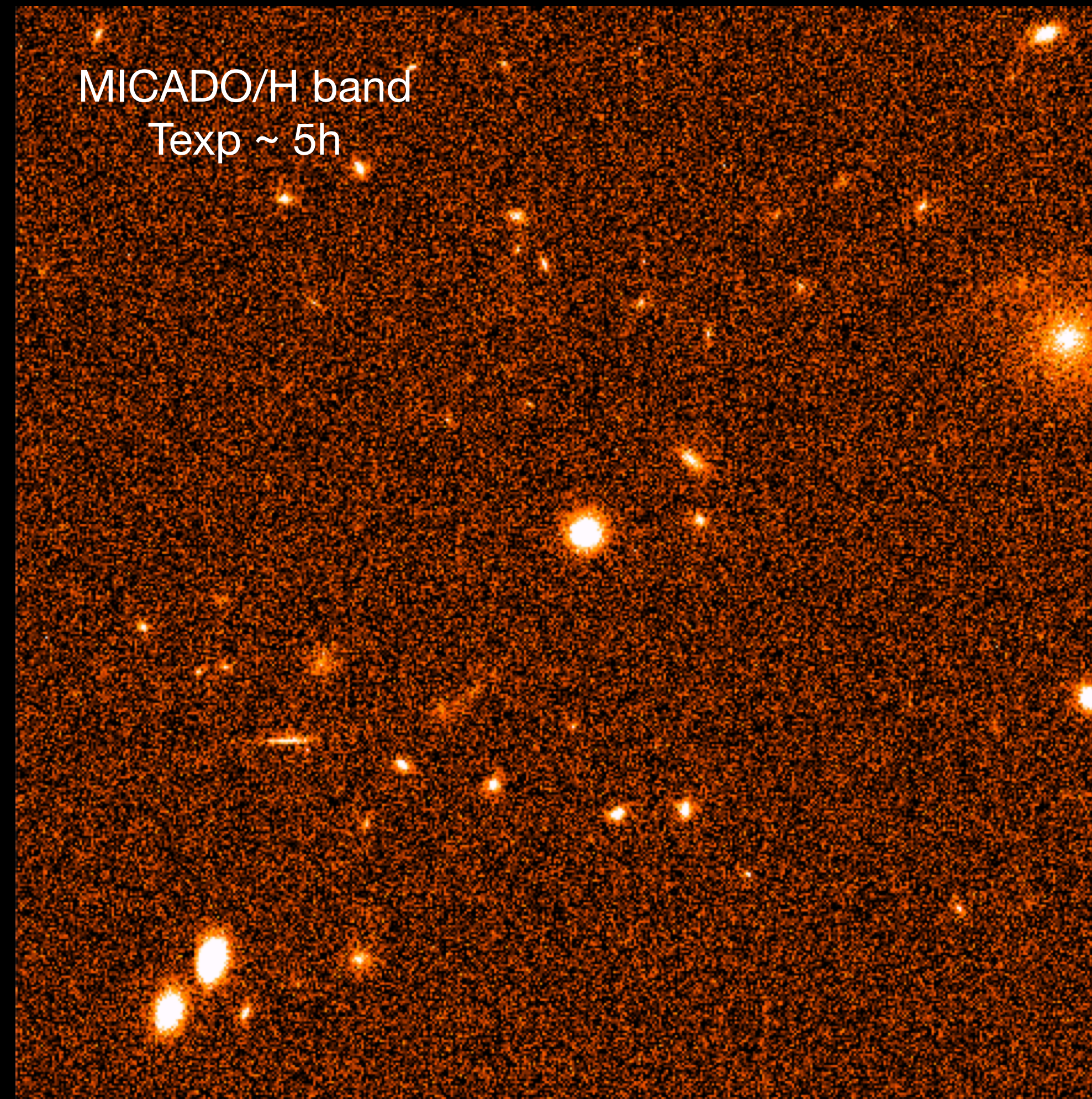
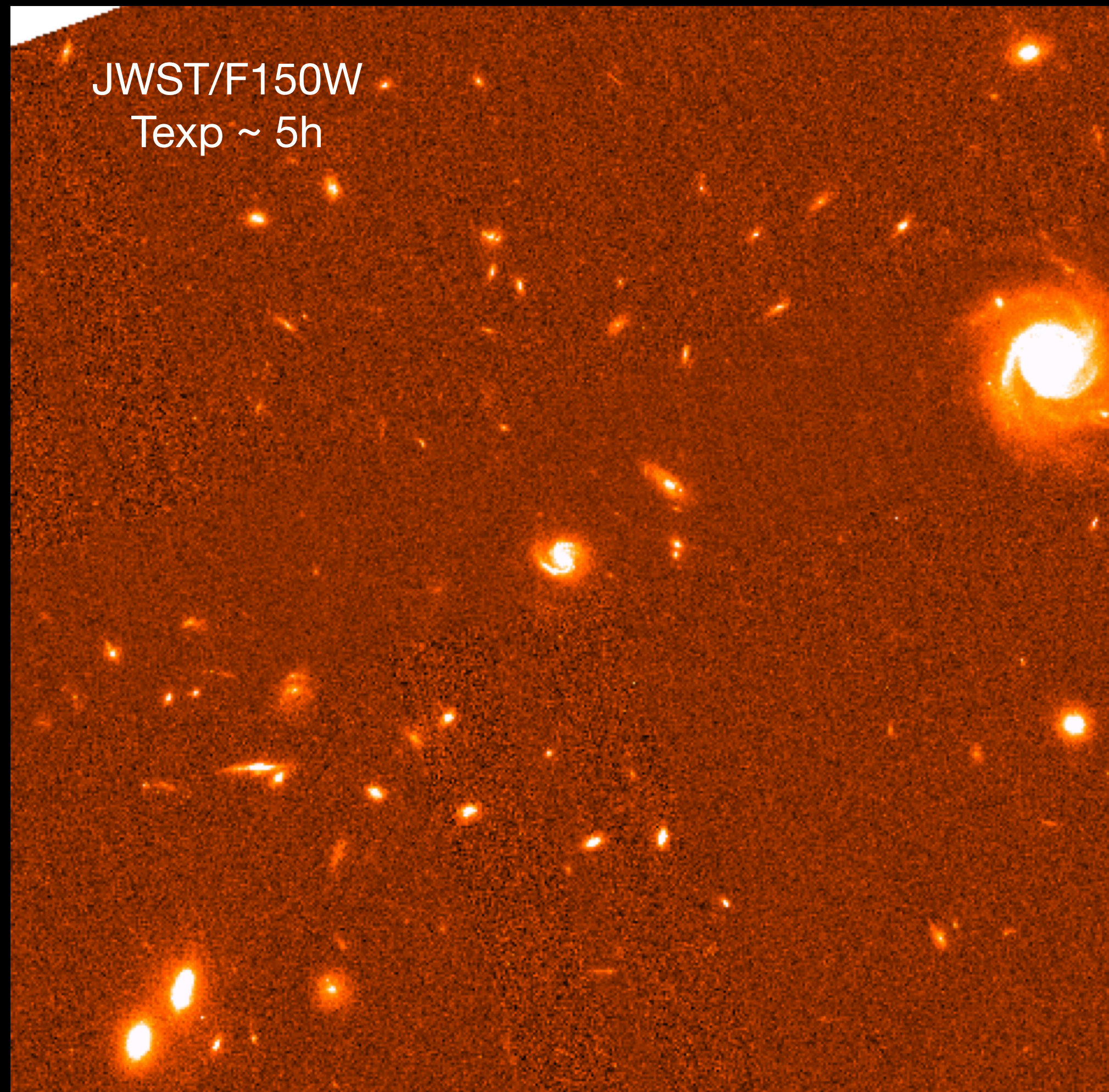
PSF variation across the field of view



PSFs generated with TipTop

PSF variation across the field of view

The entire MICADO FoV: 50" x 50"

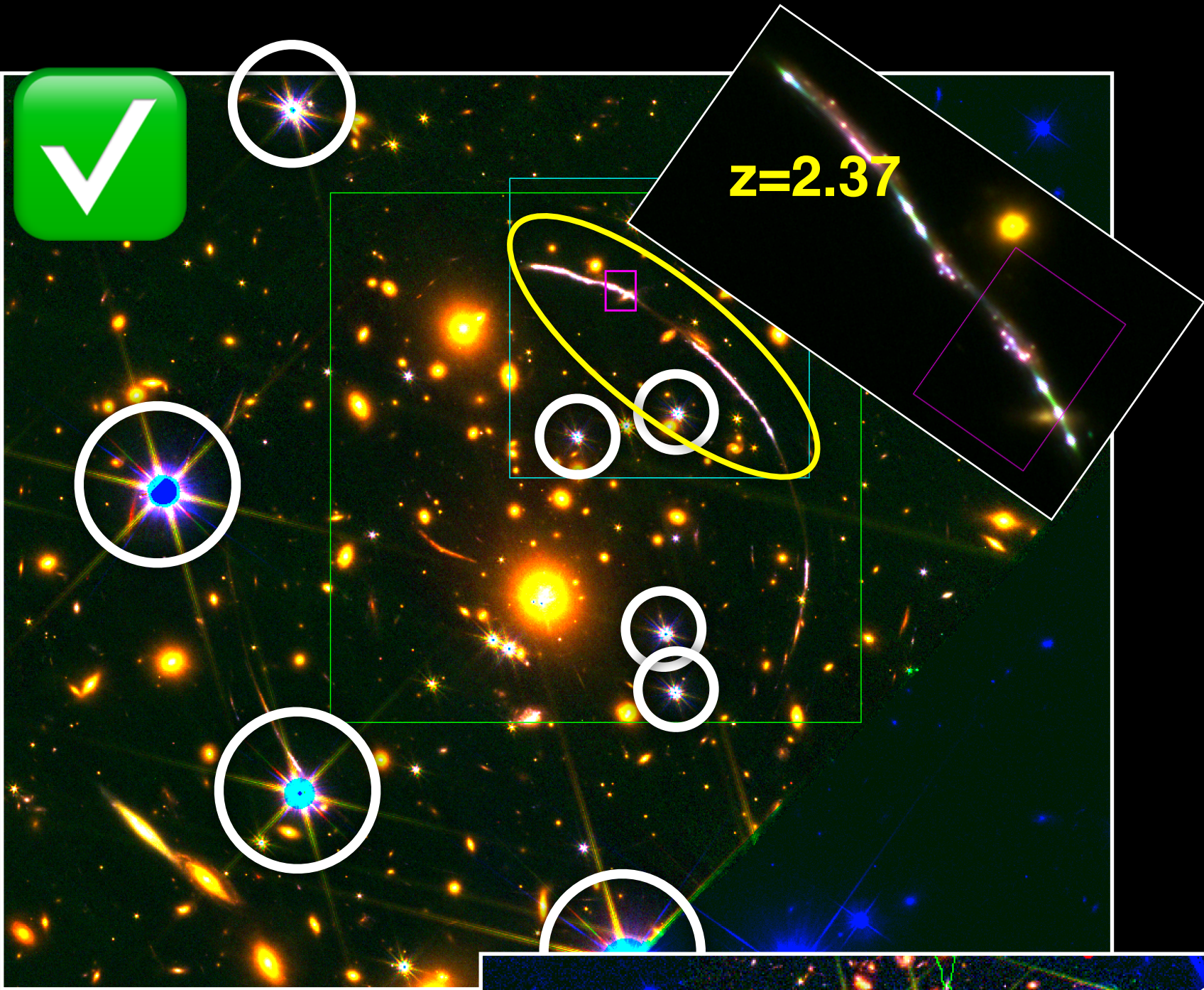


Work in progress!

Currently only bulge
and disk are included.

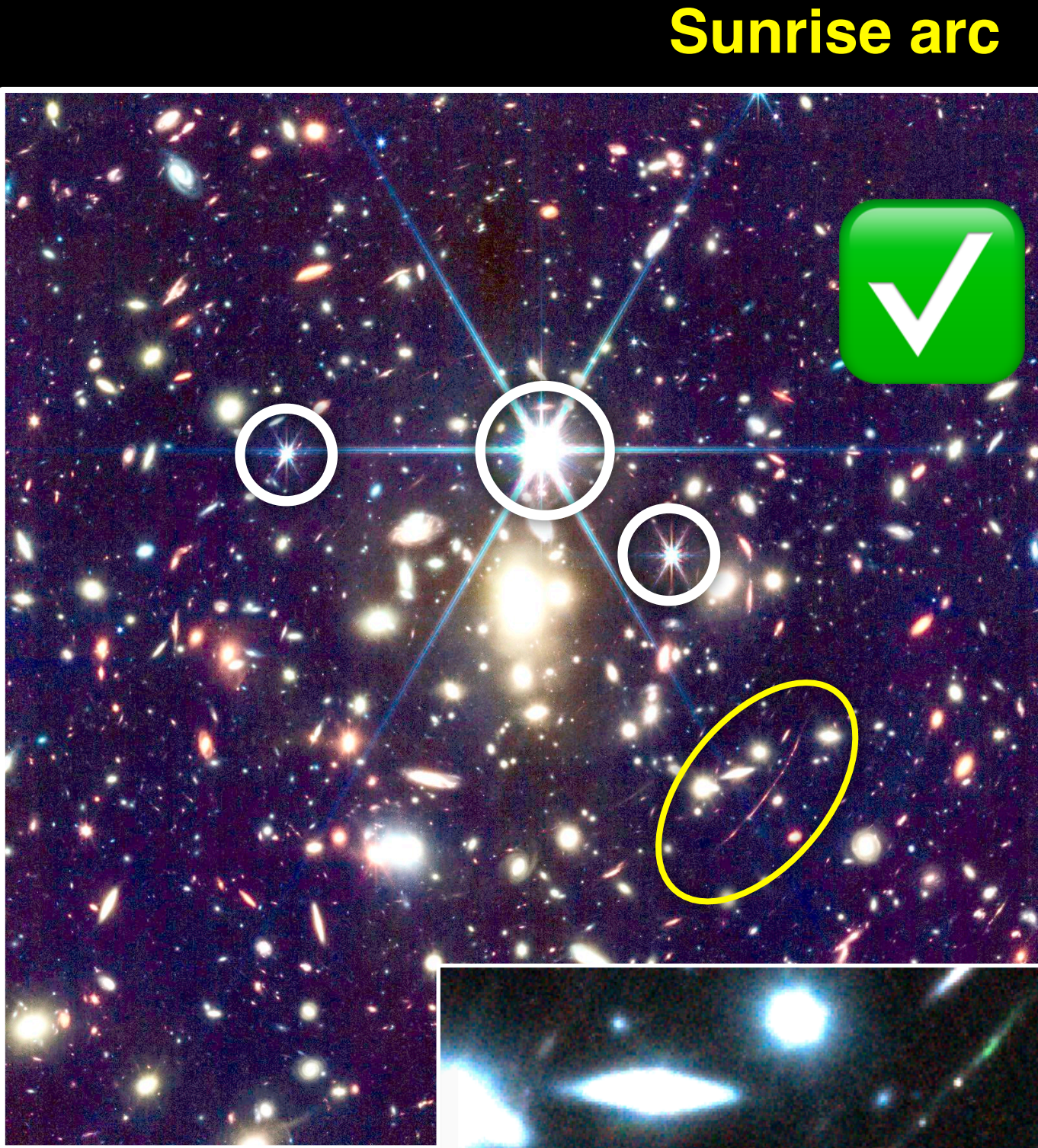
Spiral arms and
clumps to be
added.

MORFEO-MICADO: eventually dozens of lensed fields with good asterism (strehl 50-60%)



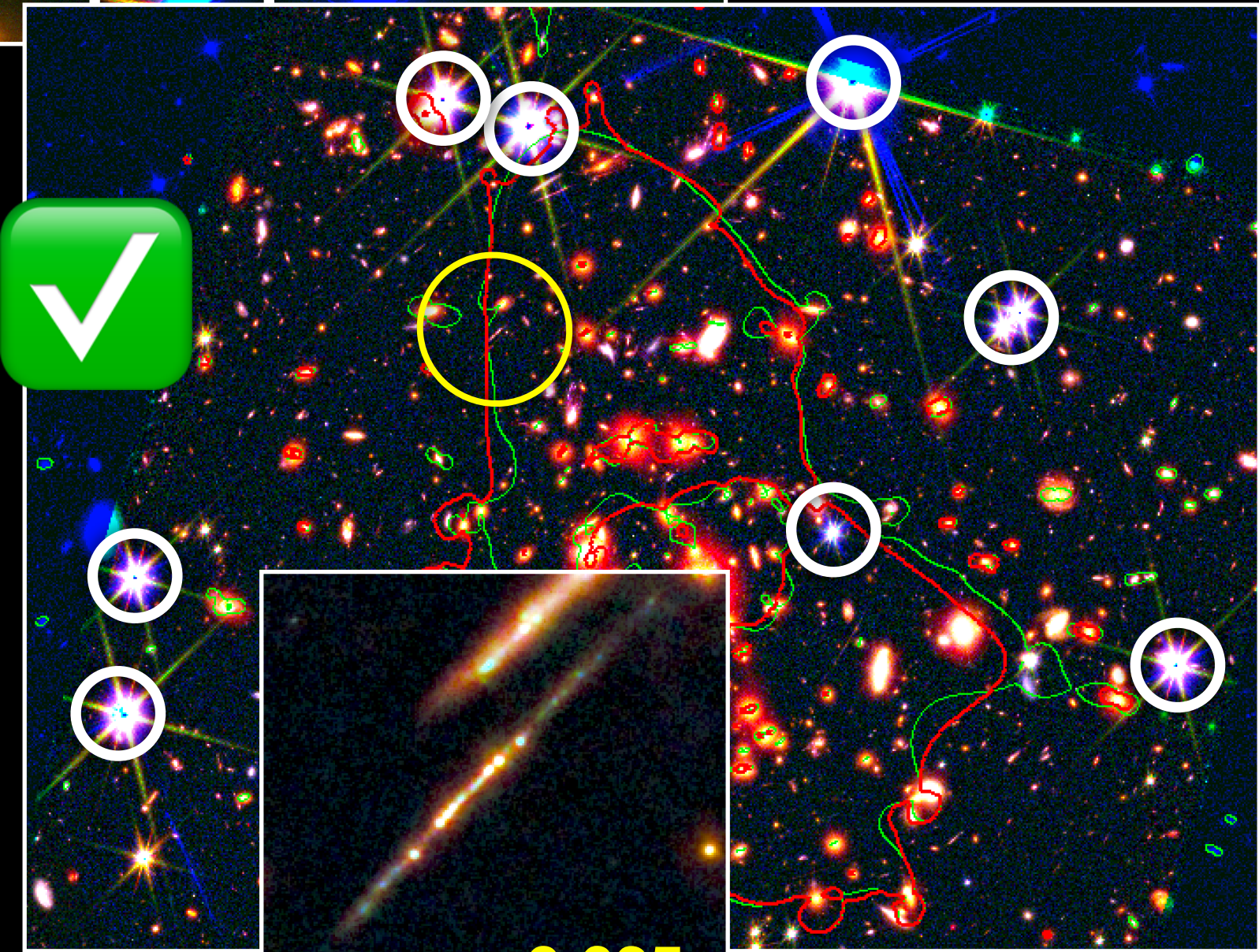
$z=2.37$

VENUS (PI Fujimoto, 300h, cycle 4,5 LP)
NIRCam (250h)
NIRSpec (50h)
Over **60** galaxy clusters



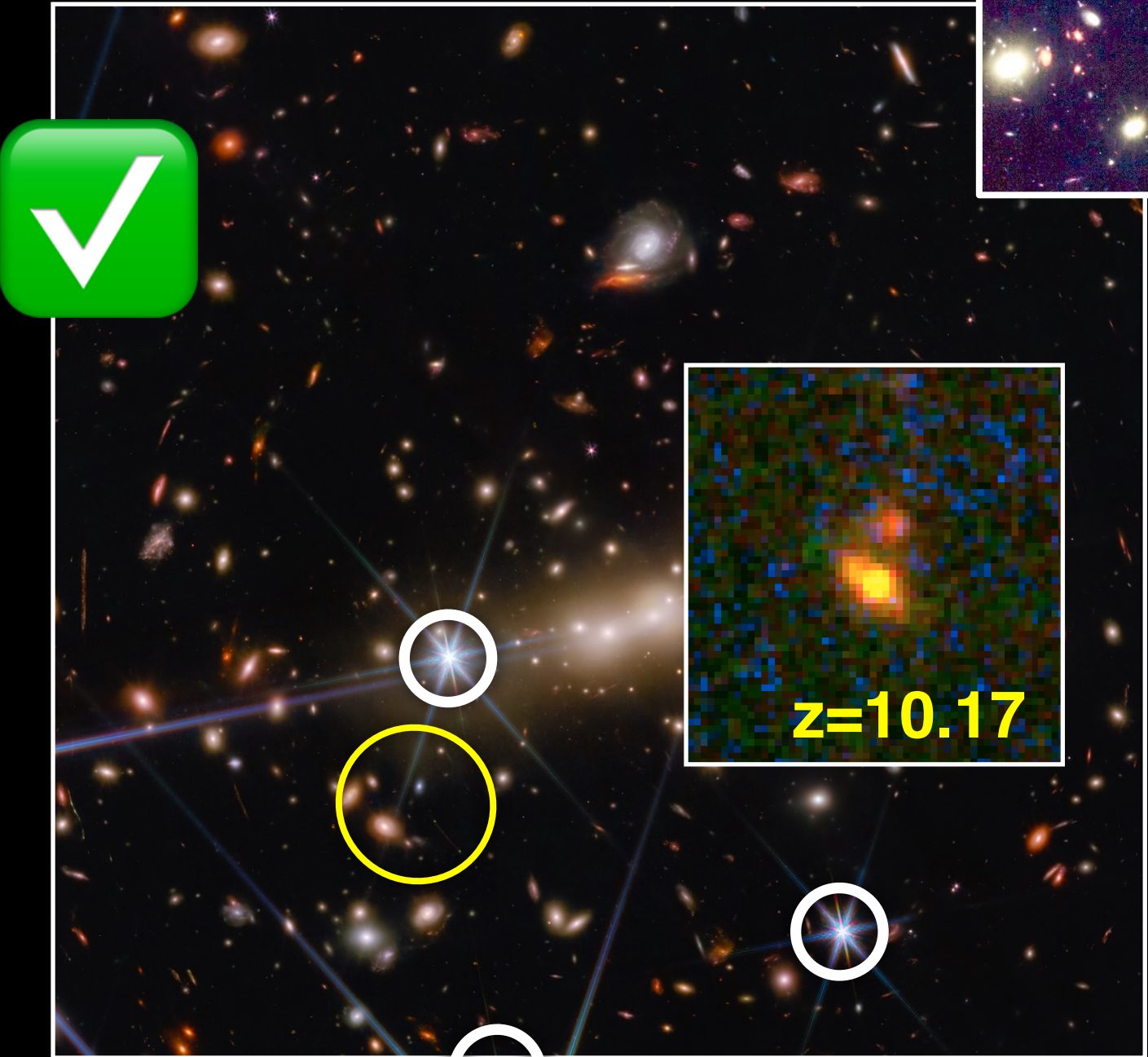
Sunrise arc

Sunburst arc



$z=9.625$

Cosmic Gems



$z=10.17$

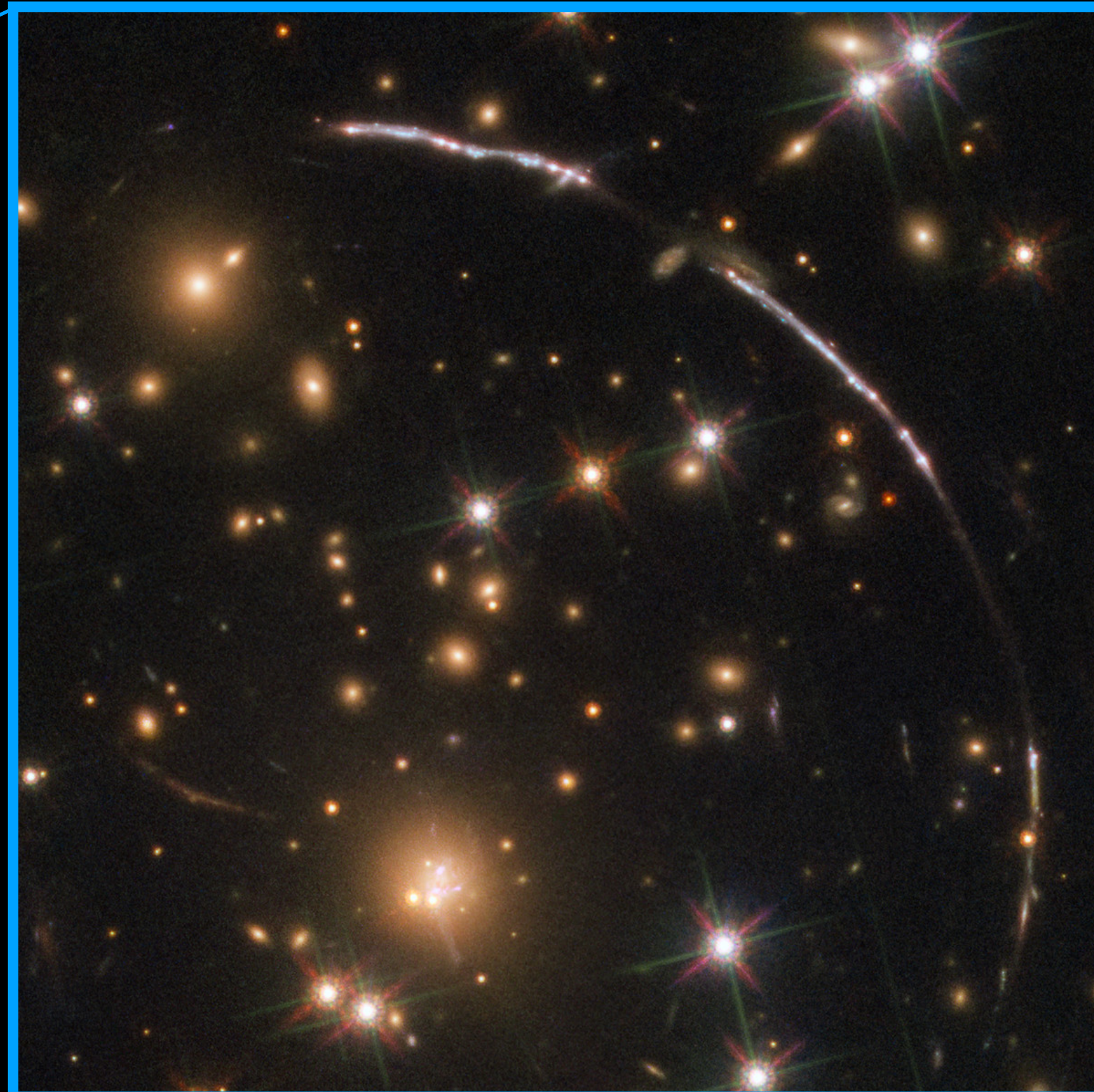
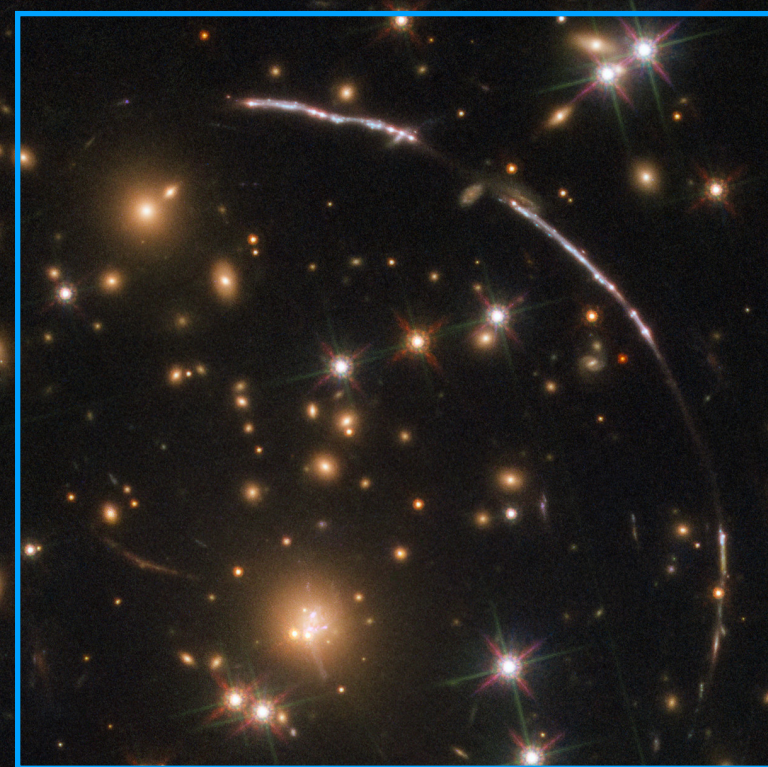


$z=5.97$

See also Eros
Vanzella's talk

The case of the Sunburst arc

110 stars in the field
35 suitable NGS



The case of the Sunburst arc

110 stars in the field
35 suitable NGS

“Best” PSF

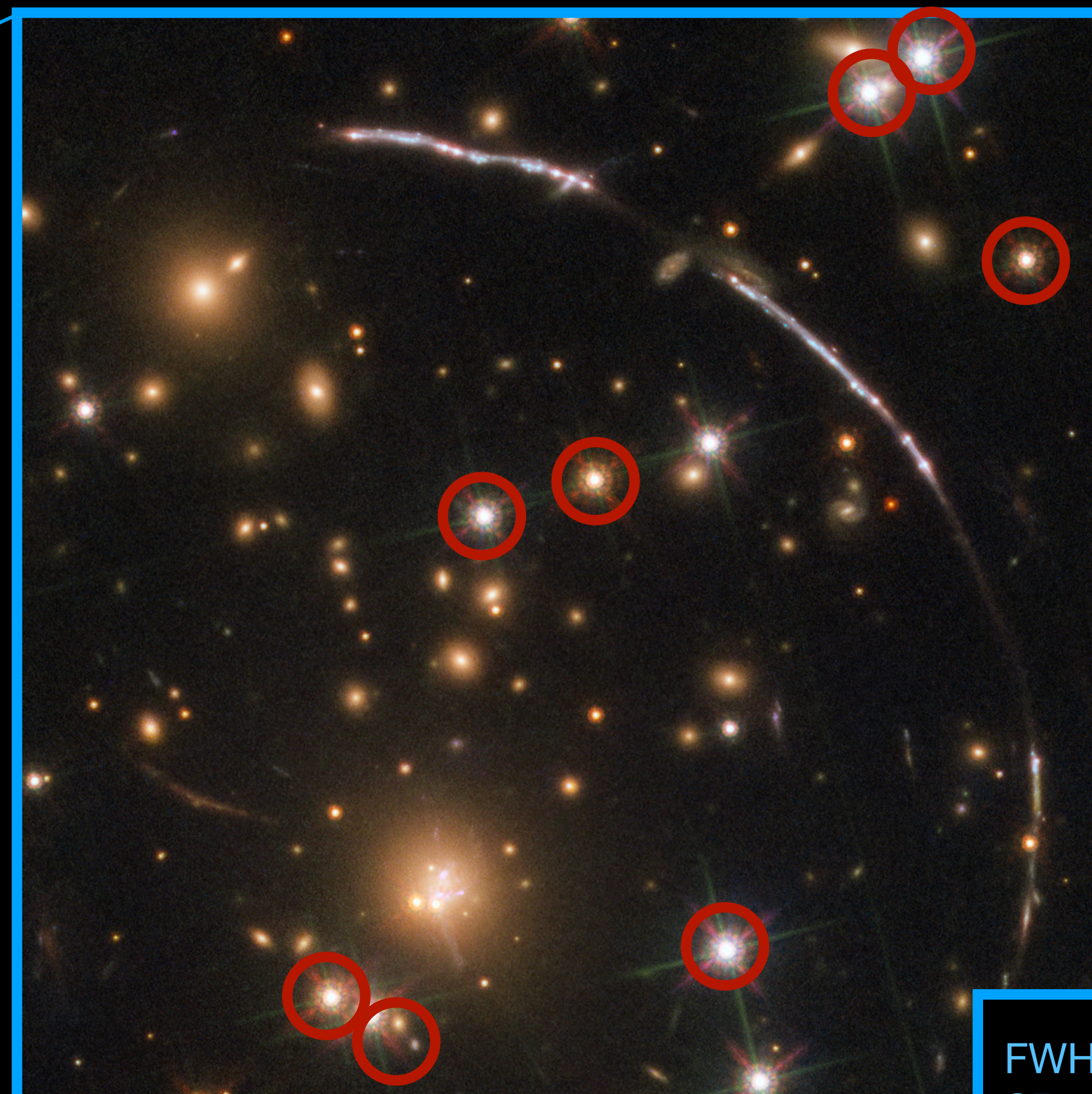
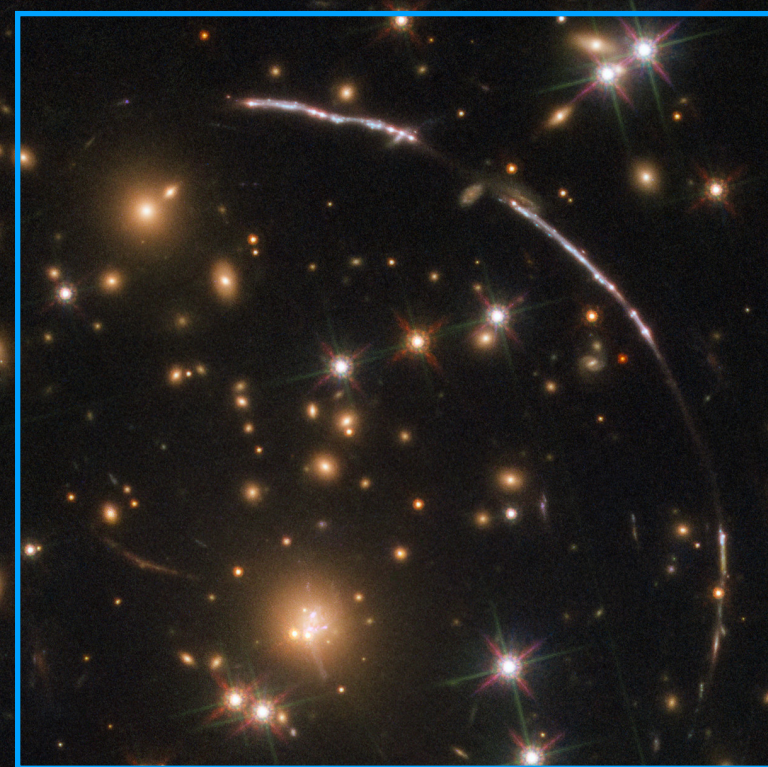
FWHM ~ 12 mas
SR ~ 0.5

Tens of suitable asterisms for this pointing
In K band:
60% of asterisms give SR $> 45\%$
30% of asterisms give FWHM < 12.5 mas



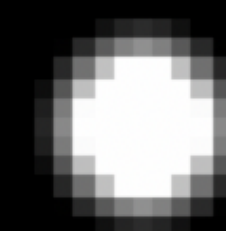
The case of the Sunburst arc

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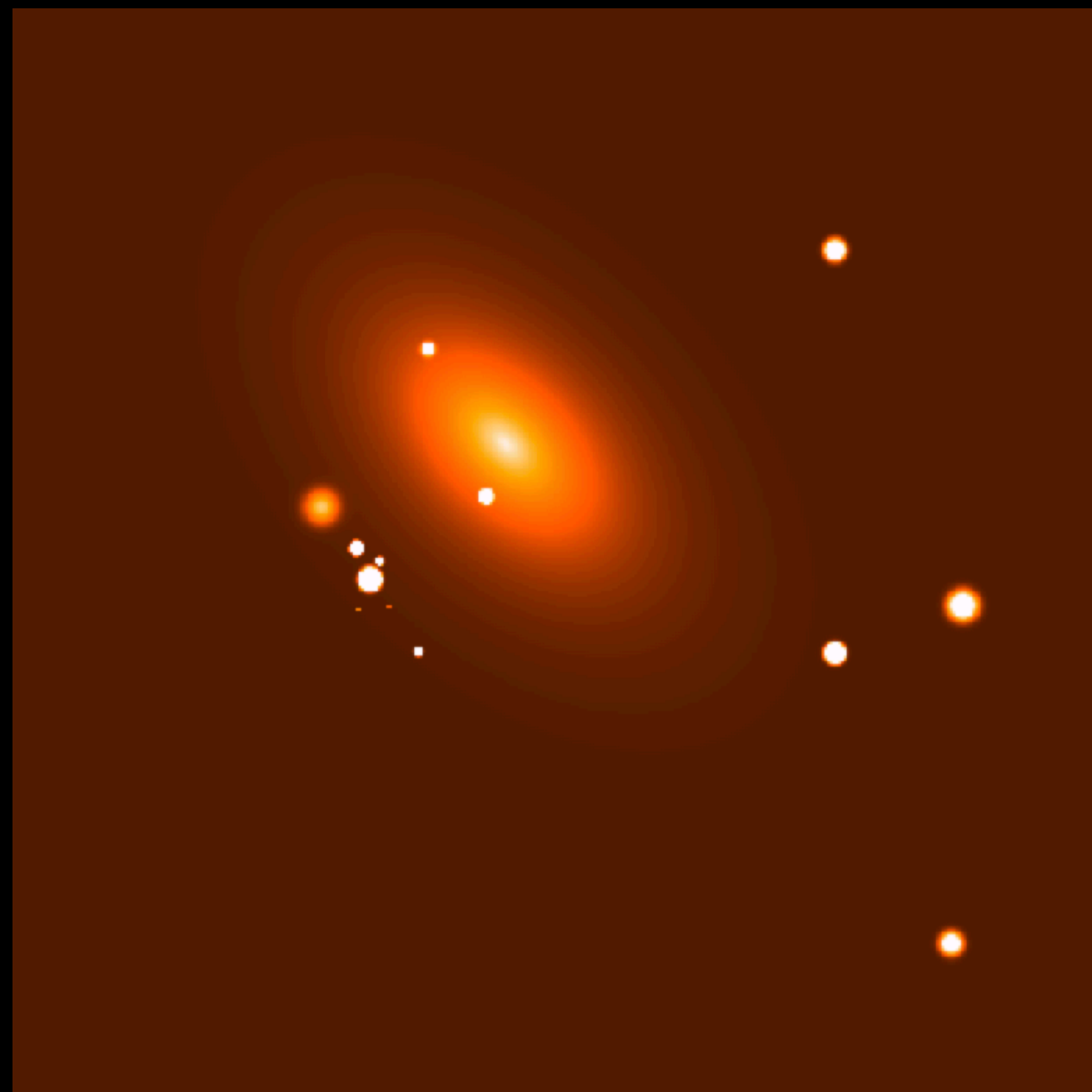
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An extremely lensed “Sunburst-like” case

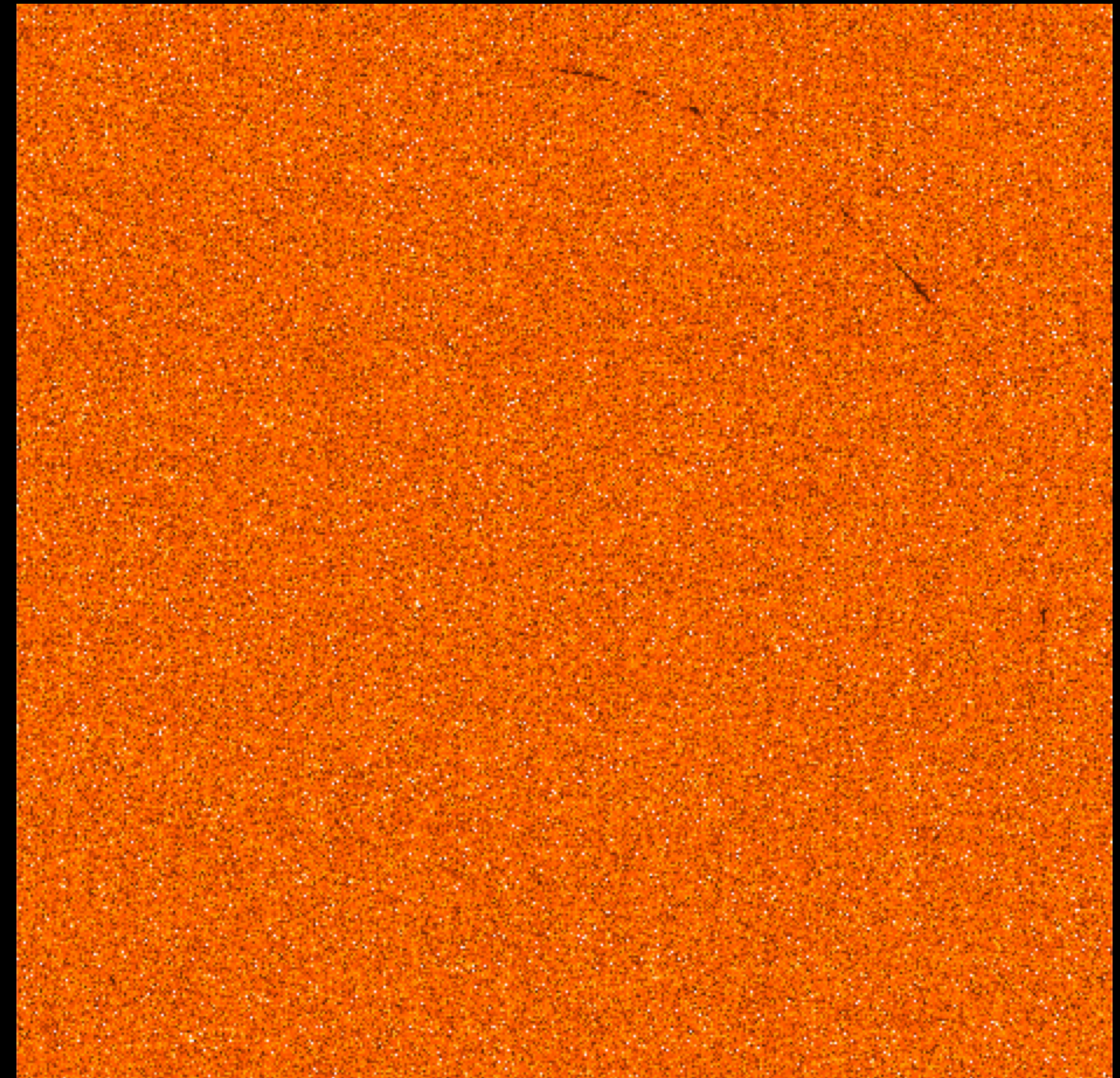
Source plane model “Sunburst-like”



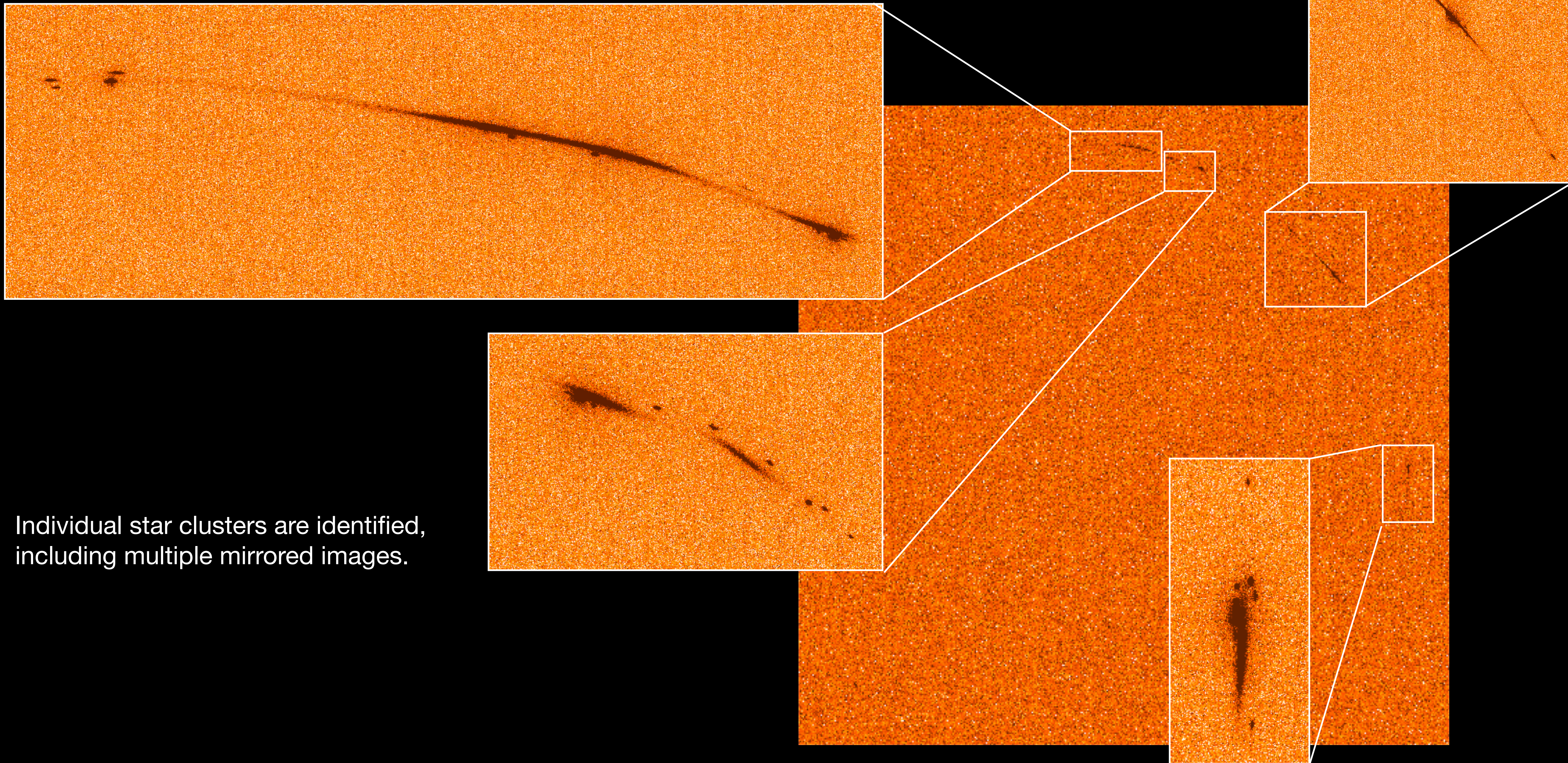
Lensing



Mock Micado+Morfeo (H band) - $t_{\text{exp}} \sim 5\text{h}$

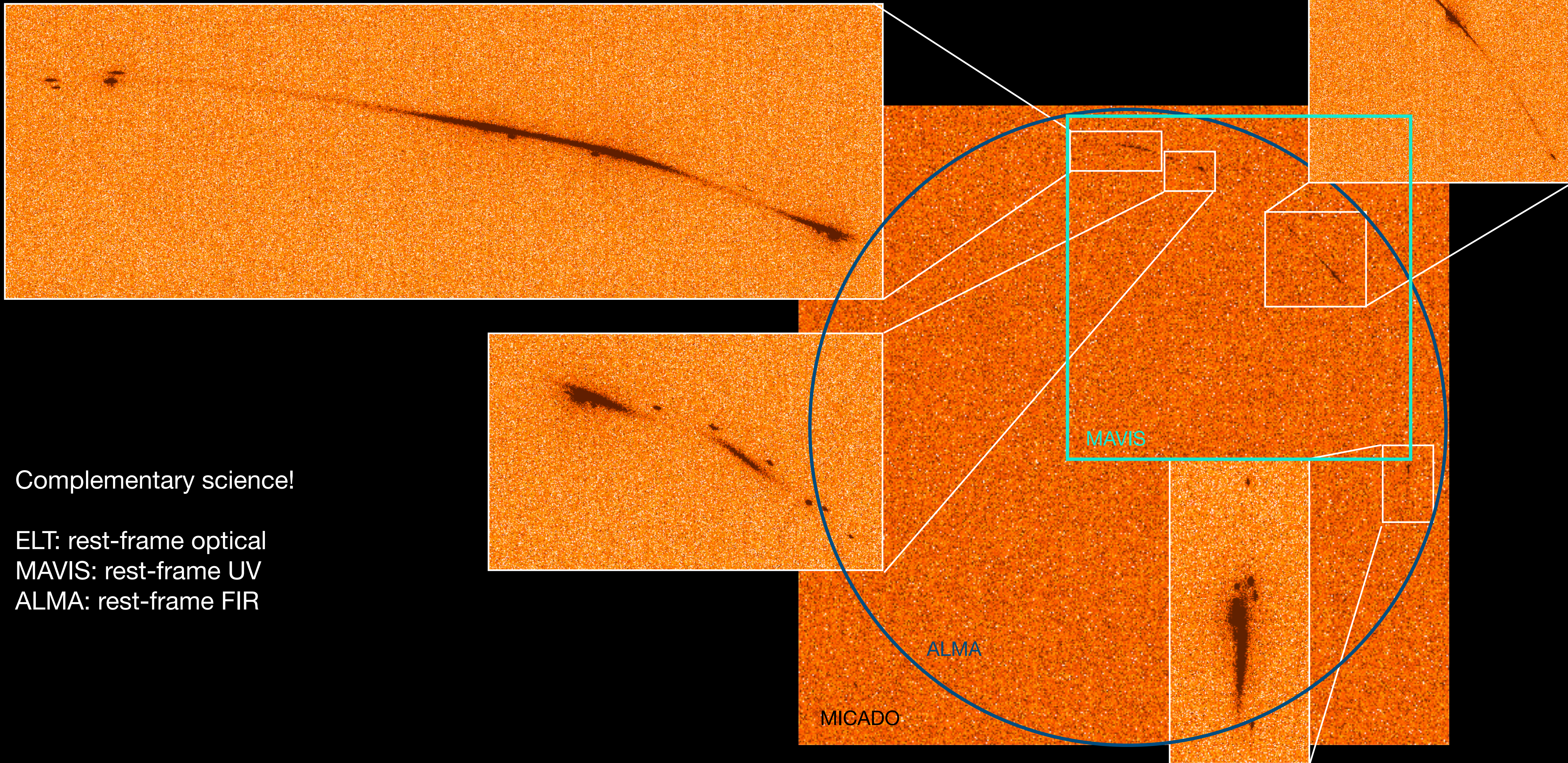


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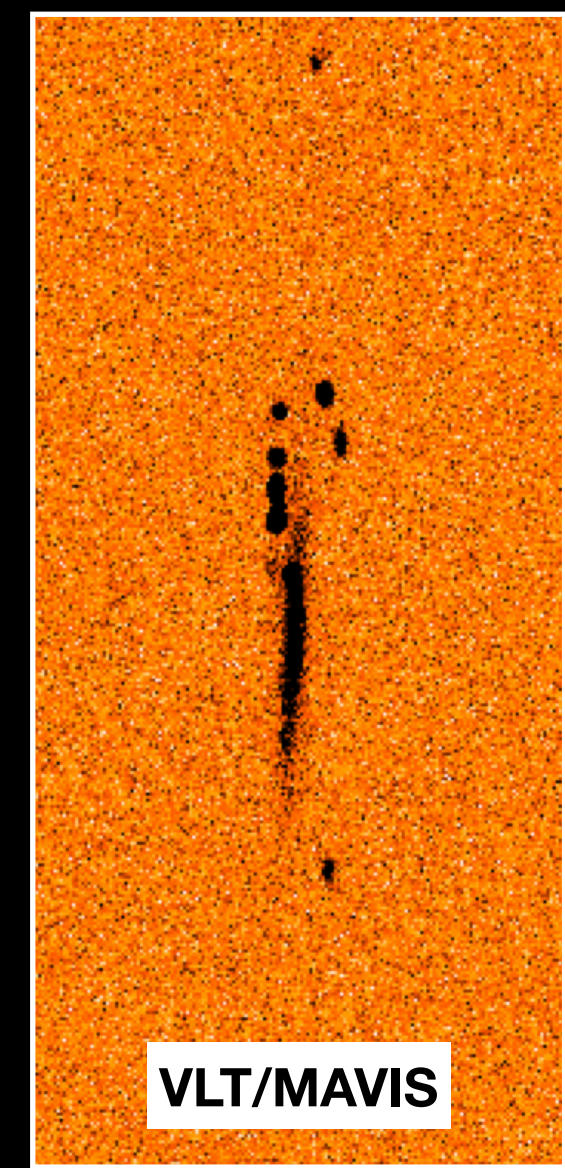
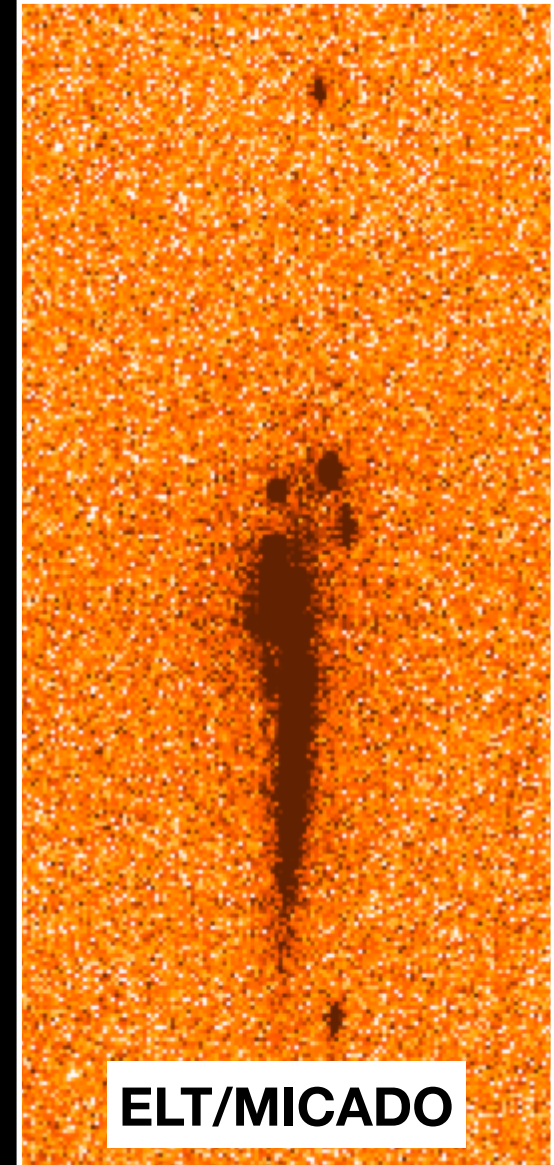
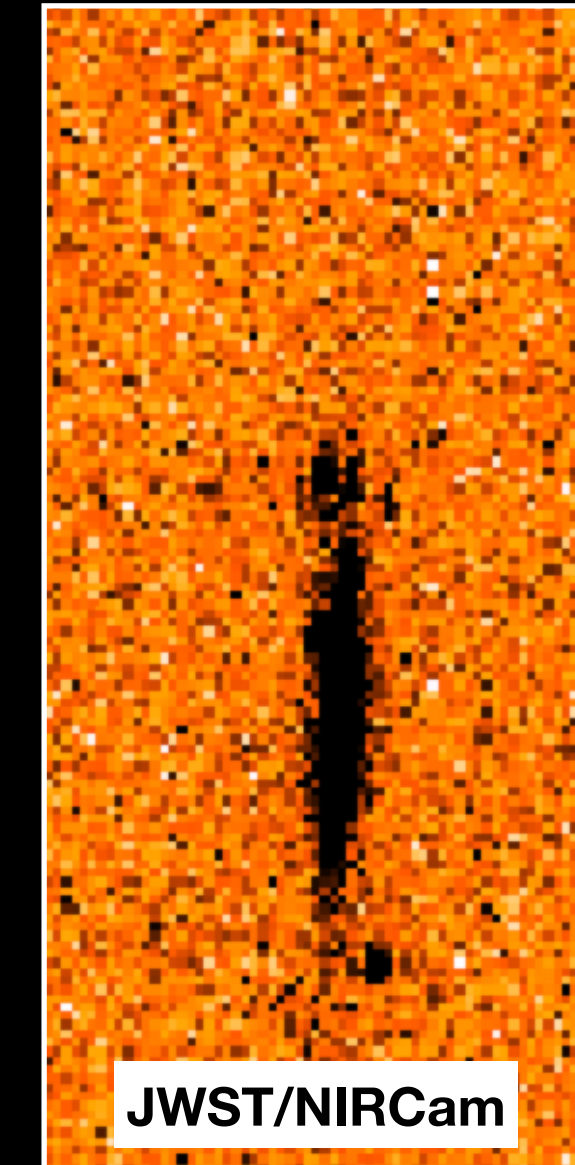
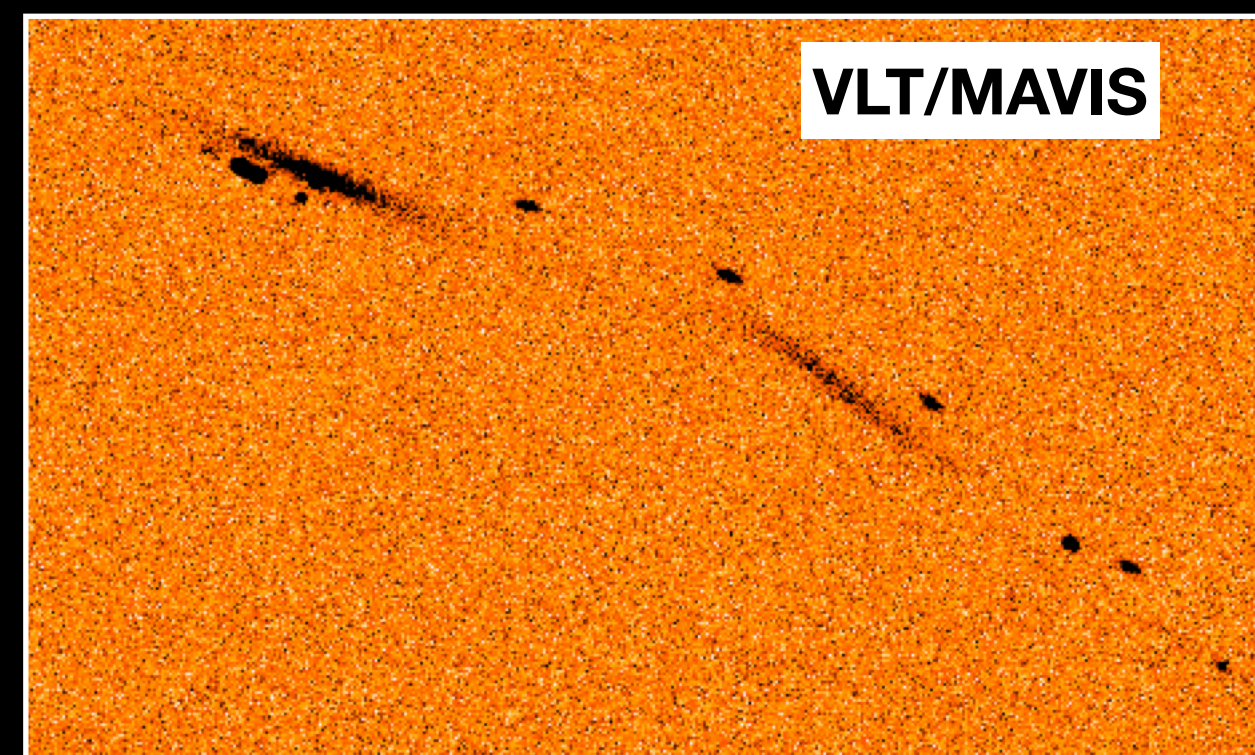
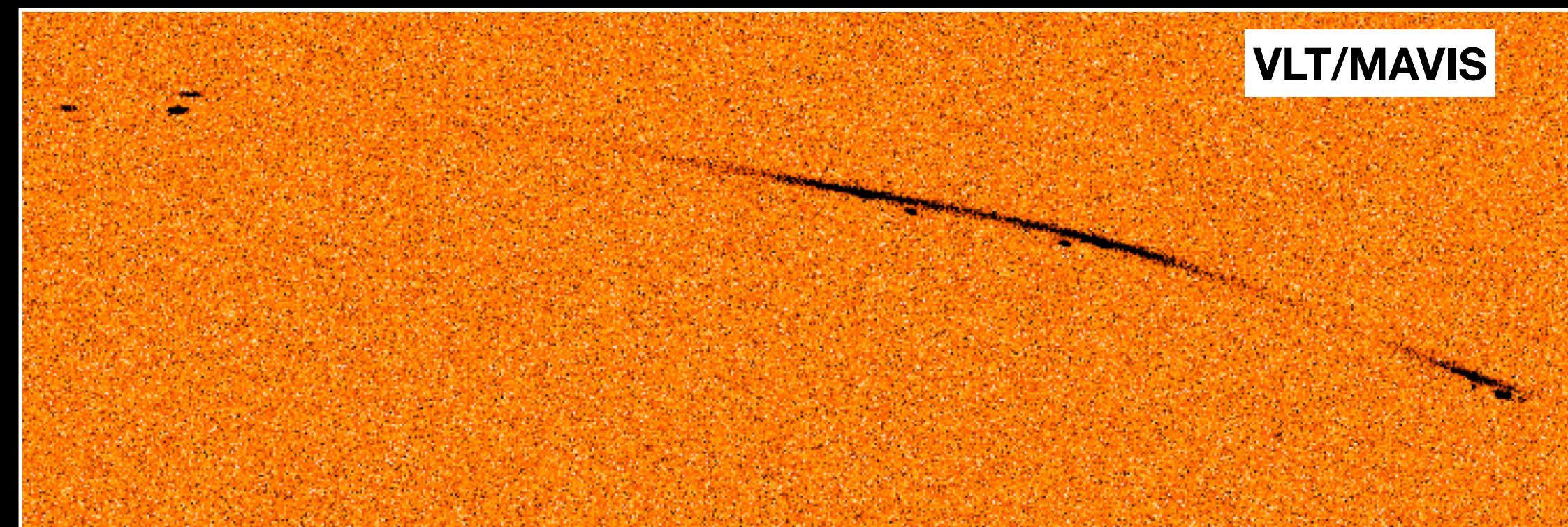
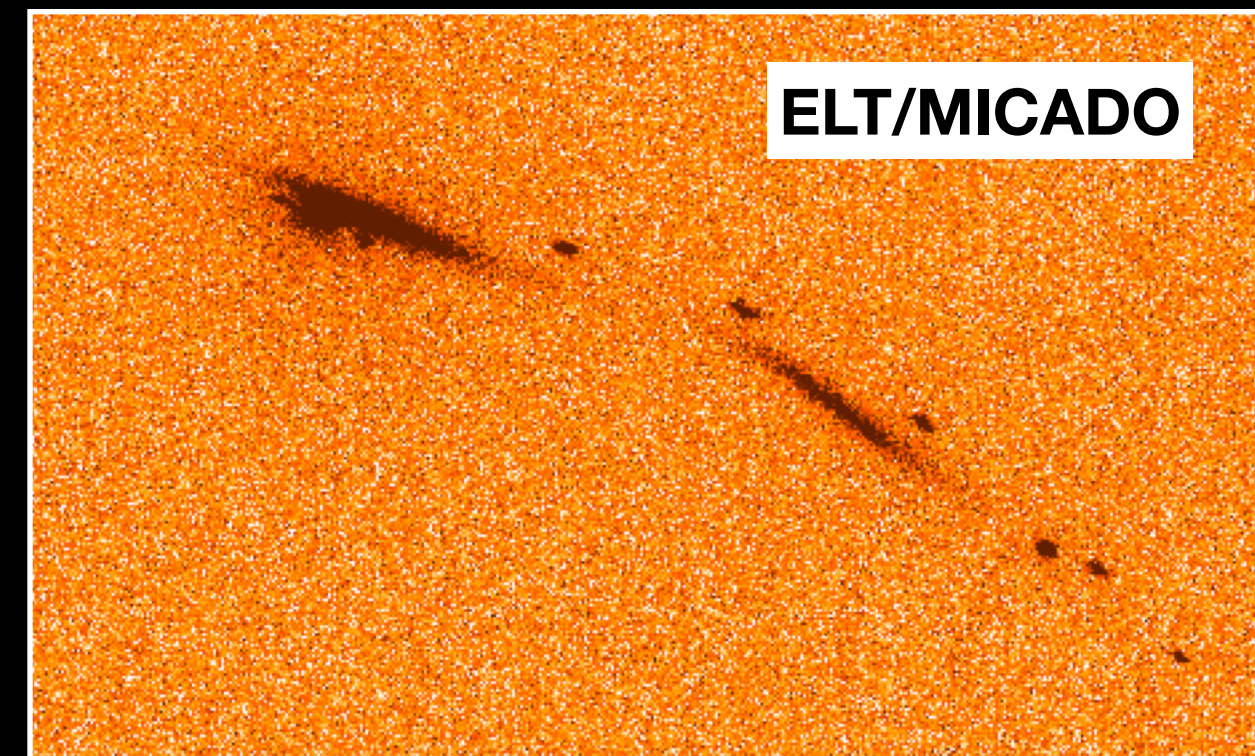
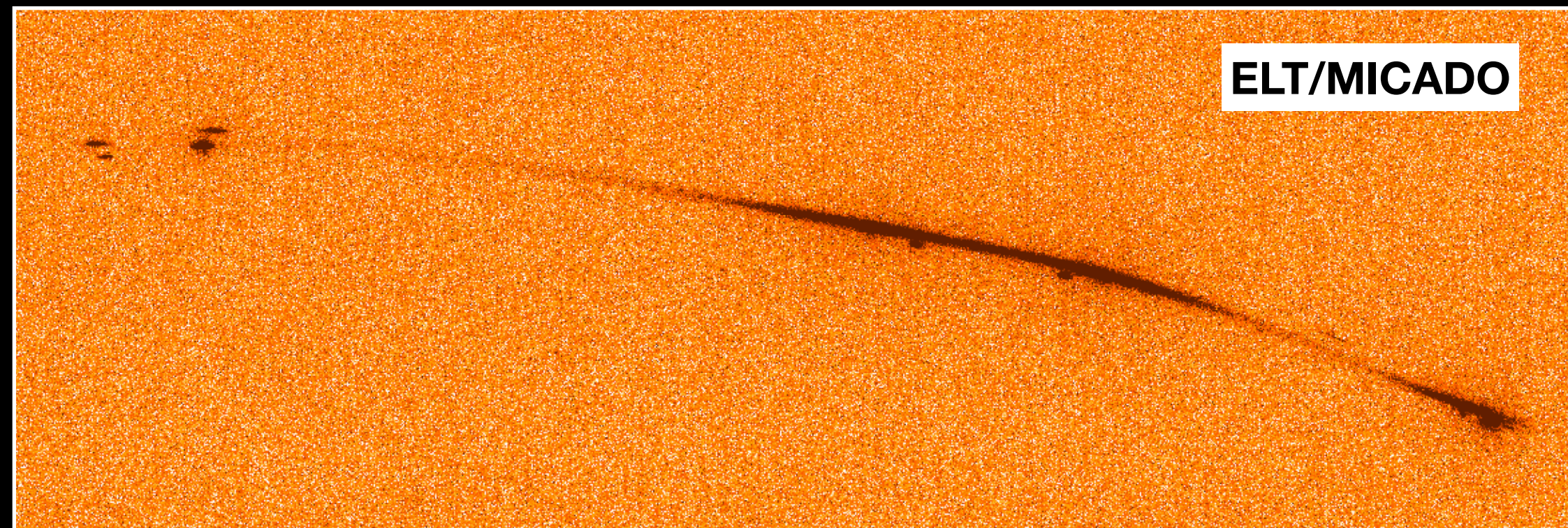
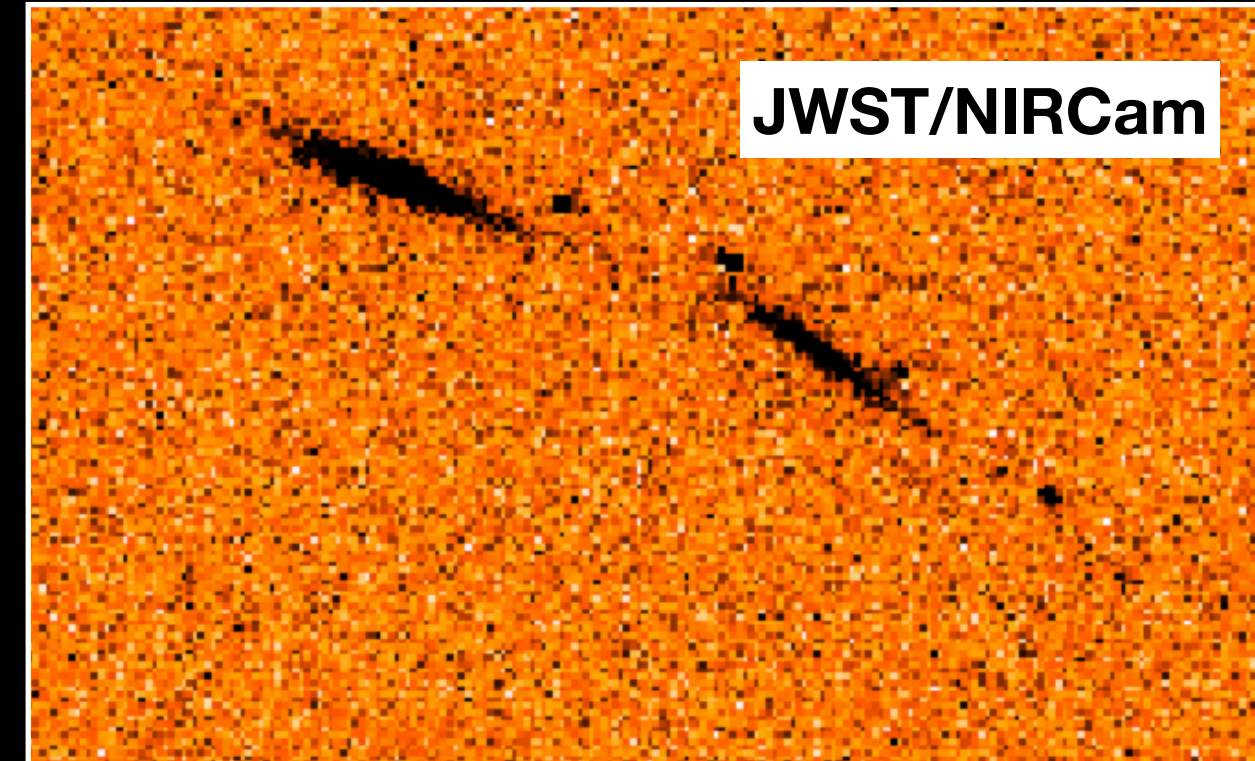
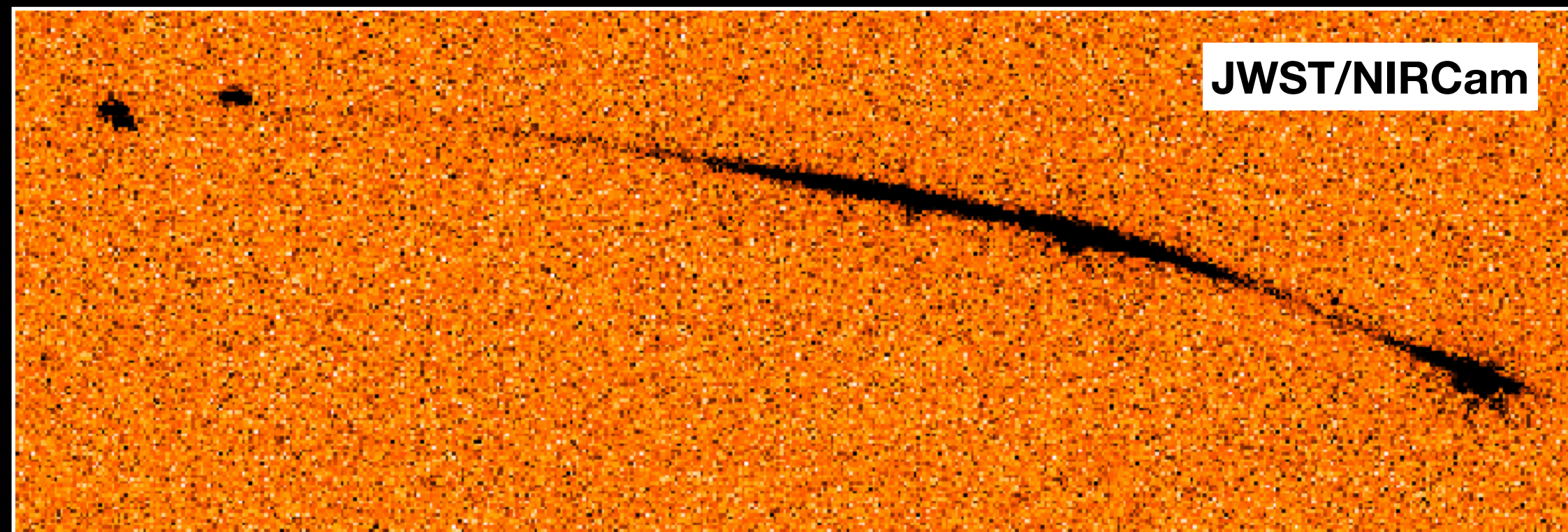


Individual star clusters are identified,
including multiple mirrored images.

An extremely lensed “Sunburst-like” case: synergies

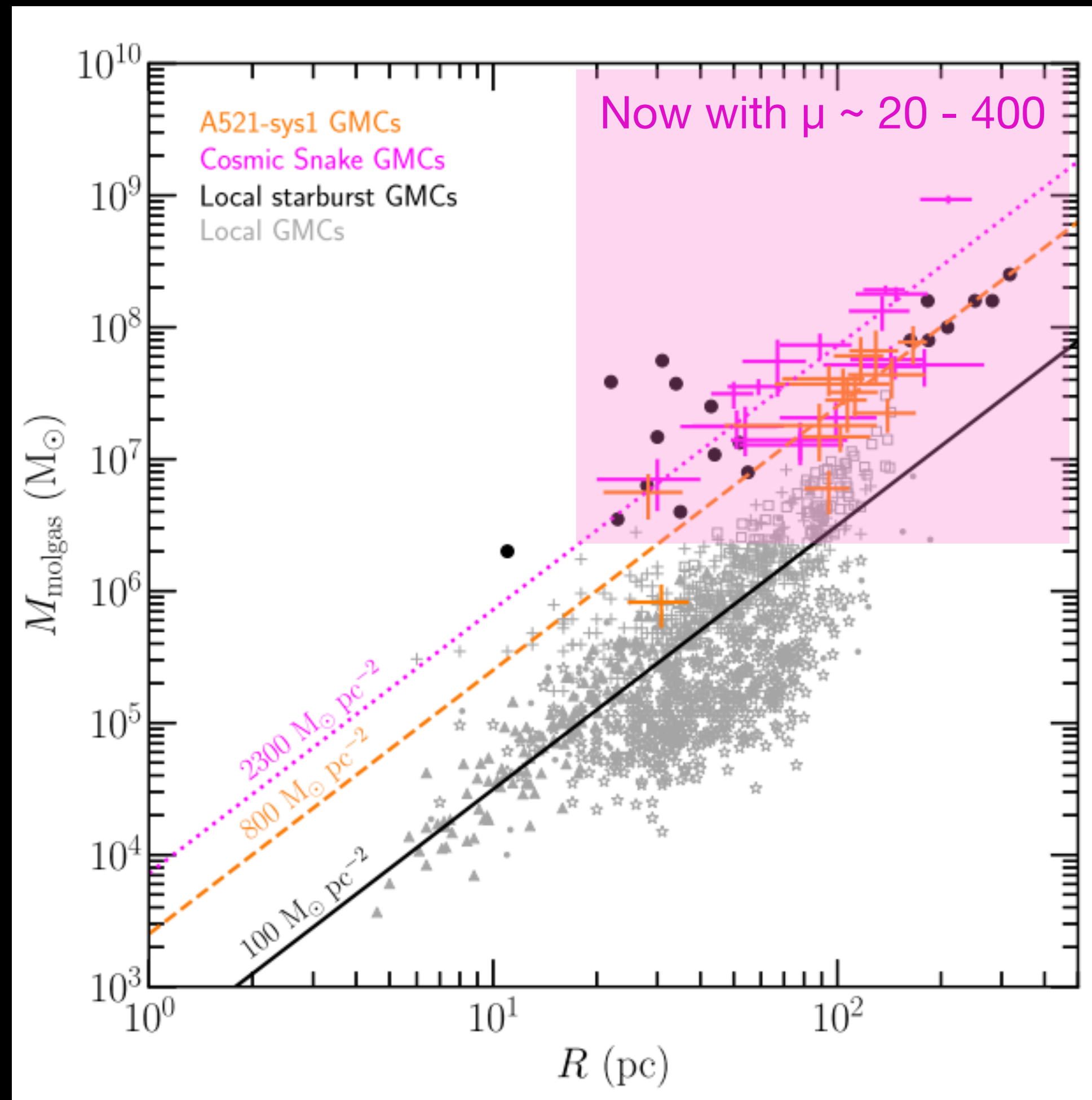


An extremely lensed “Sunburst-like” case: synergies



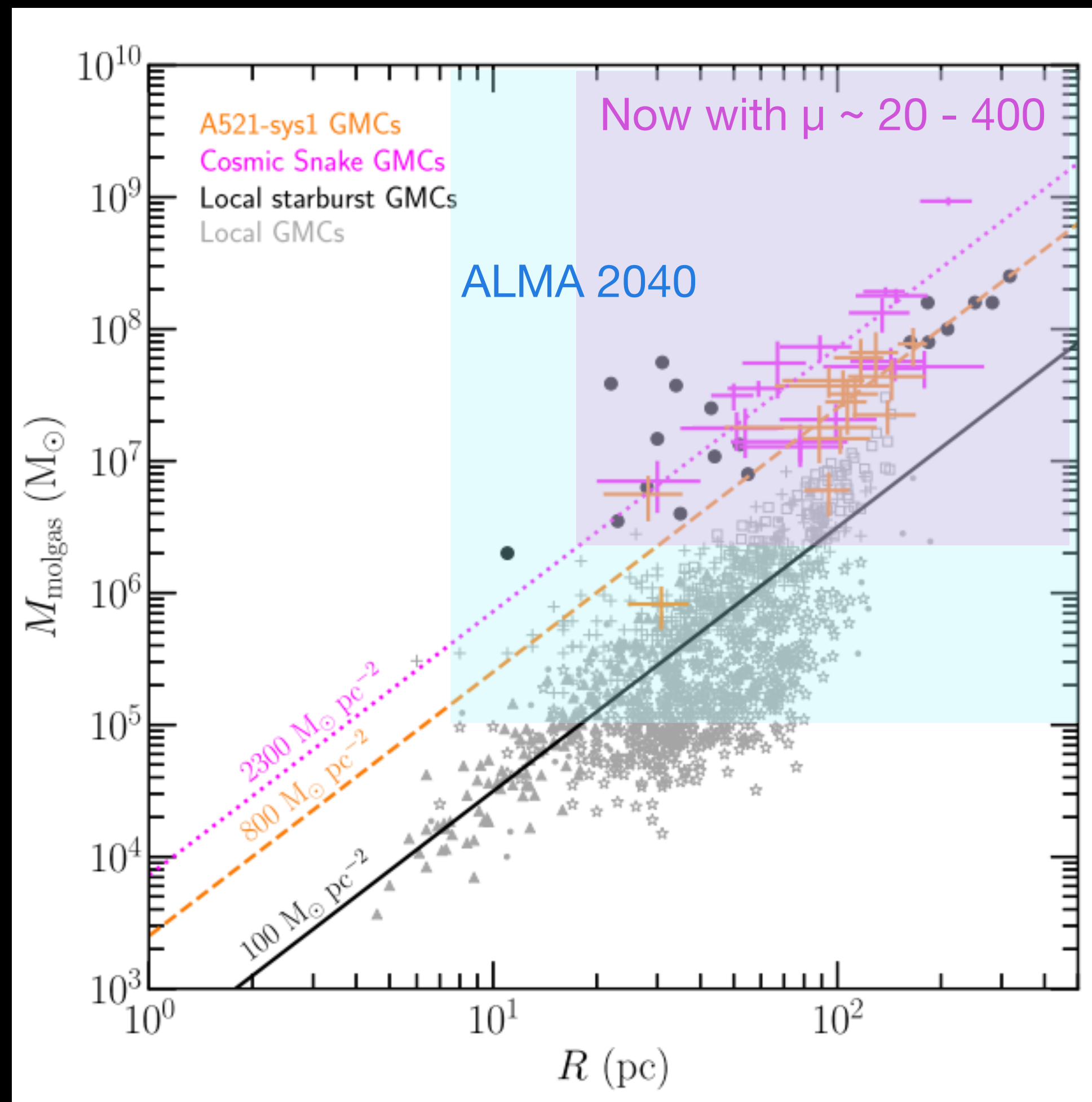
5h integration

An extremely lensed “Sunburst-like” case: synergies



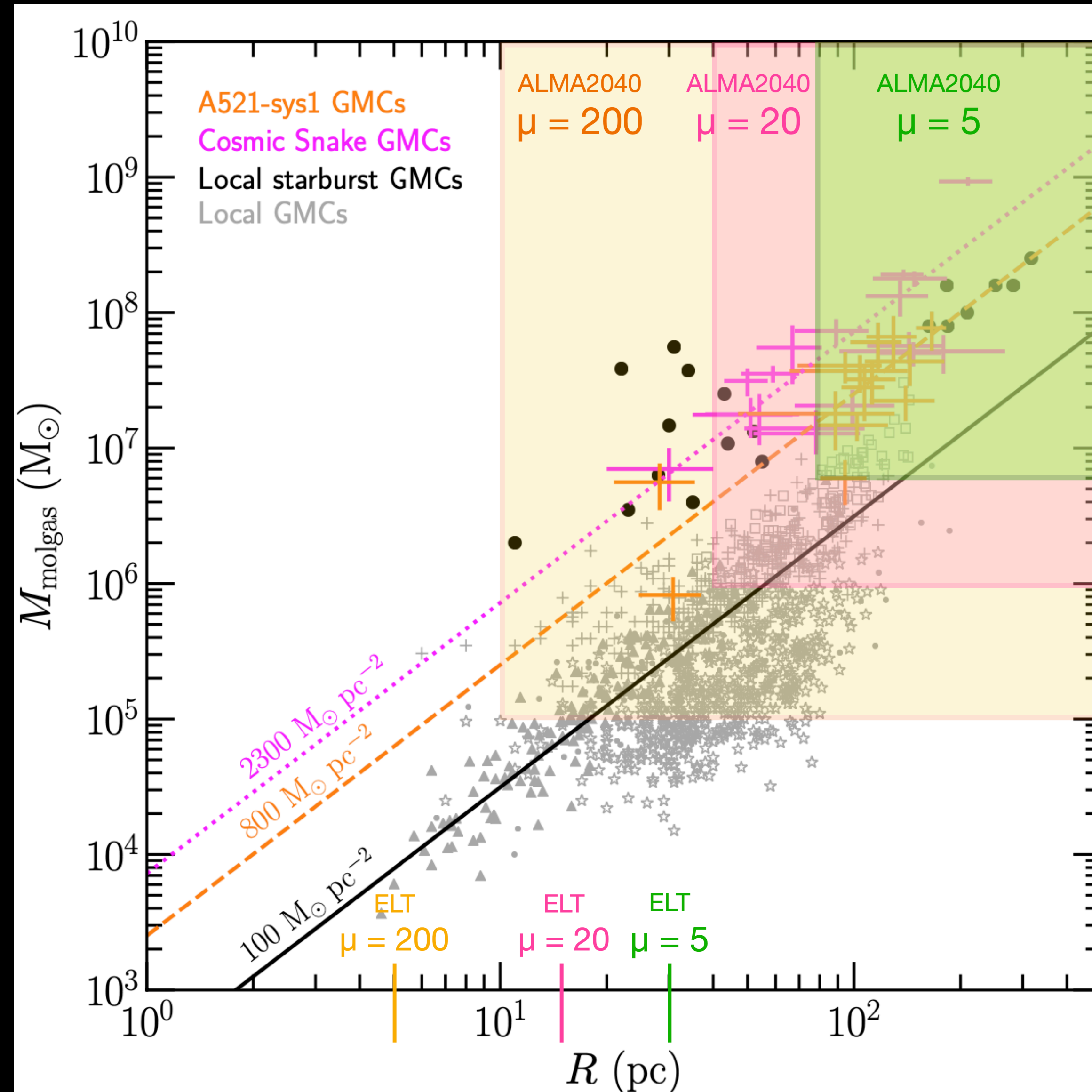
Current ALMA

An extremely lensed “Sunburst-like” case: synergies



Foreseen increase in sensitivity $\sim 5\text{-}10\times$

An extremely lensed “Sunburst-like” case: synergies



Foreseen increase in sensitivity $\sim 5\text{-}10\times$

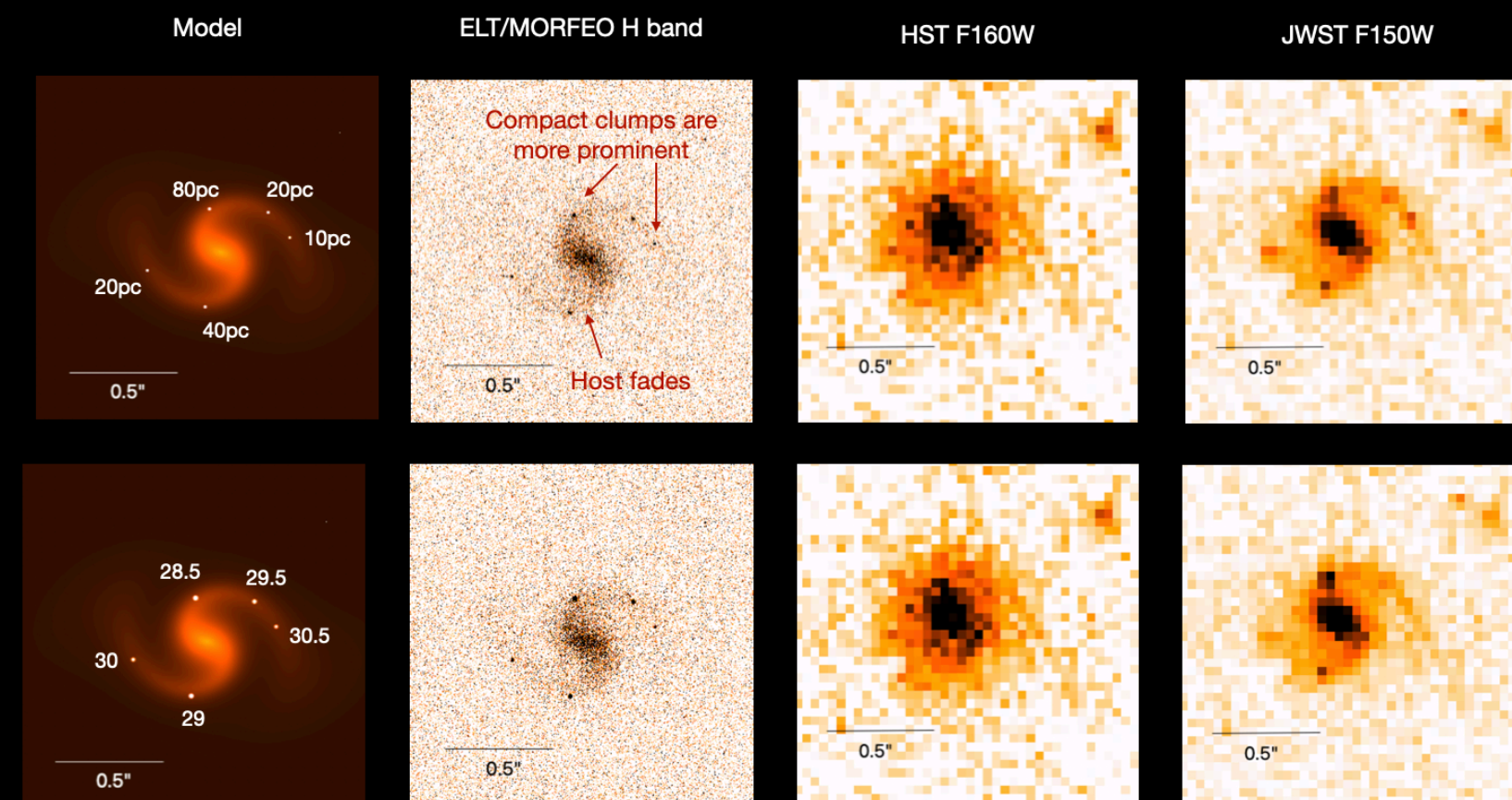
We can probe similar M_{mol} gas as local GMCs at high- z in modestly lensed galaxies ($\mu \sim 20$)

Interested in knowing more or contributing?

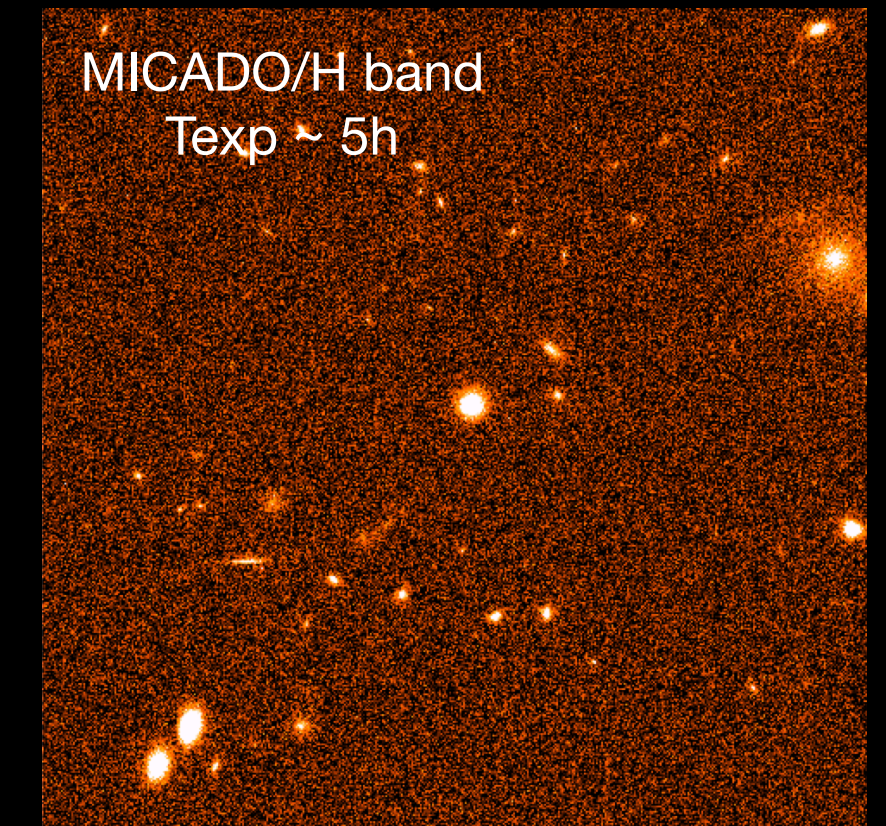
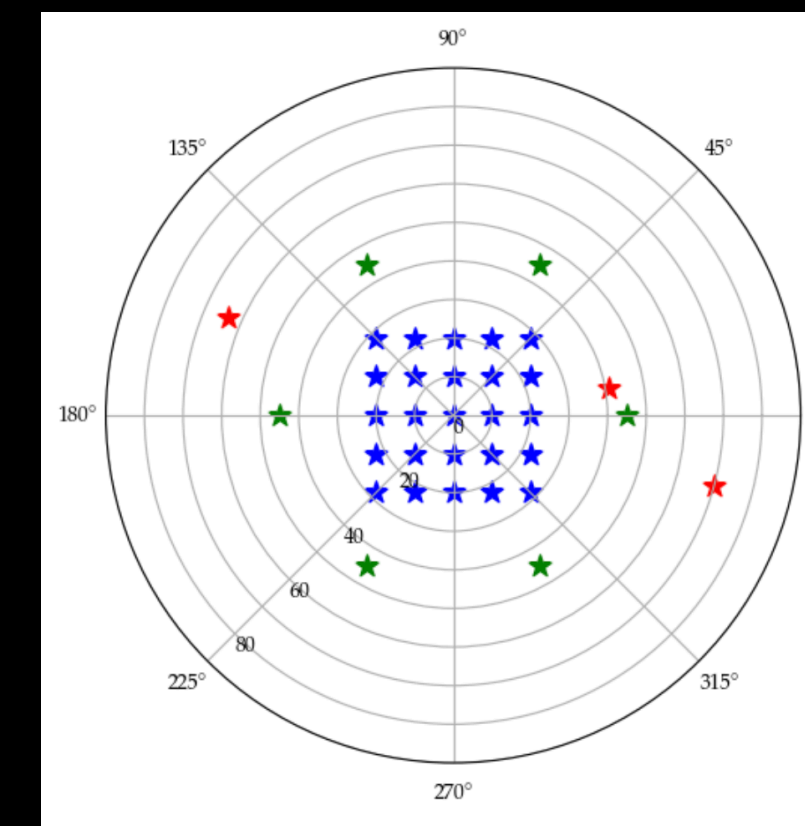
<https://www.euroalma2040.com/>

Summary

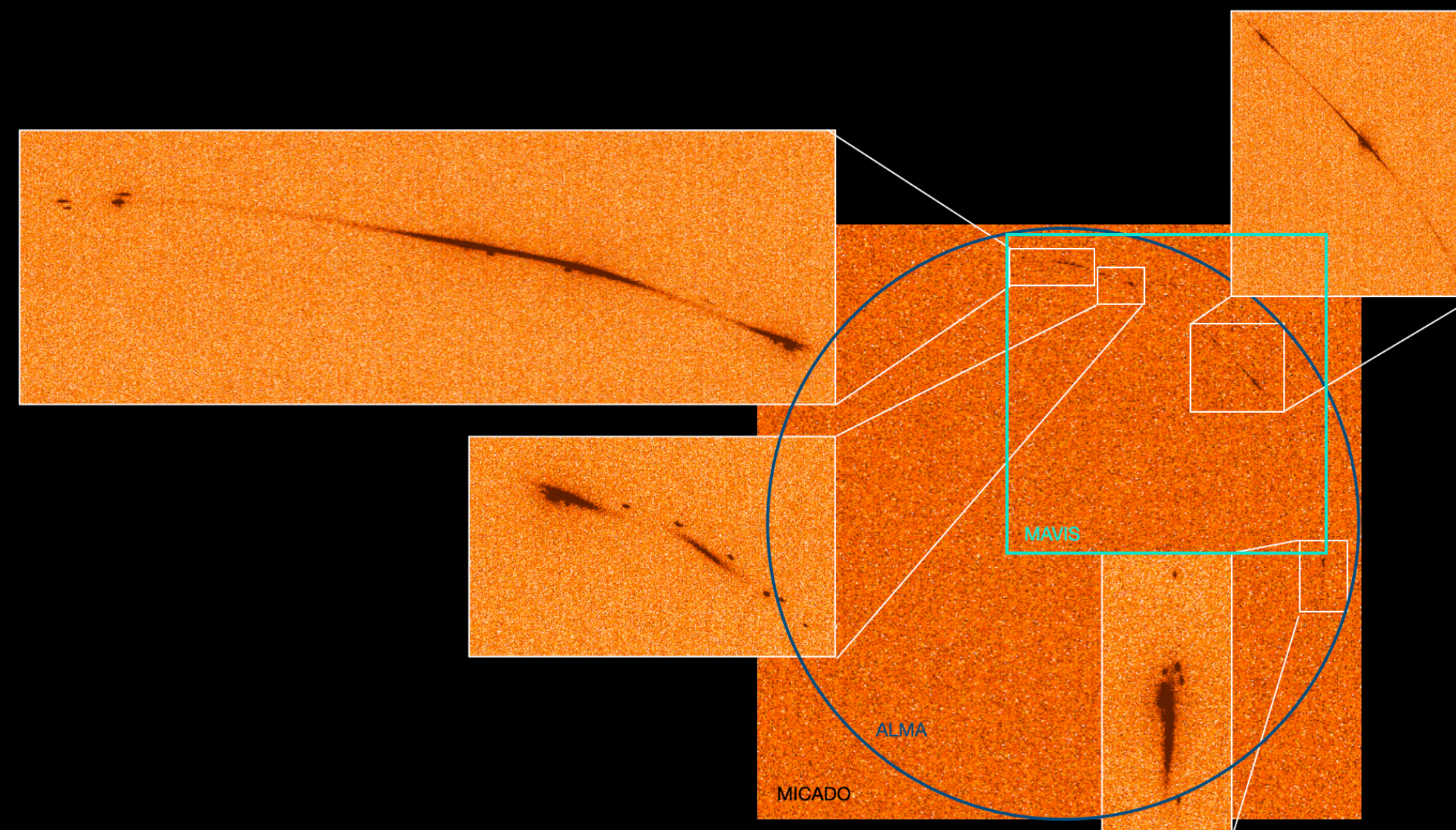
Measuring clumps' size is key for understanding their origin, properties.
and role in galaxy evolution —> suitable NGS asterisms are needed



Exploring how the PSF varies throughout the FoV
will help to quantify observables (Re, mag)



Expanding to lensing fields
(e.g., Sunburst)



Synergies with VLT/MAVIS
and ALMA (incl. ALMA2040)
will open new multi-wavelength paths
to discovery