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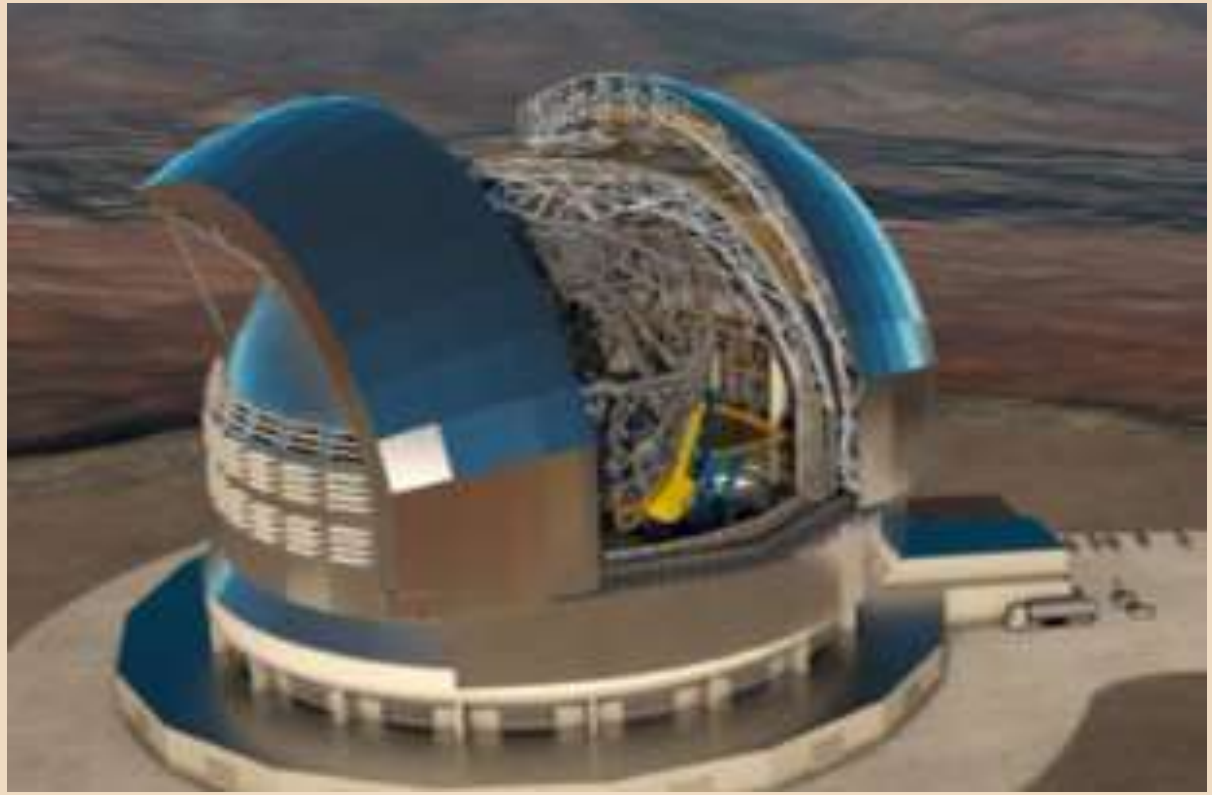
INAF ISTITUTO NAZIONALE DI ASTROFISICA

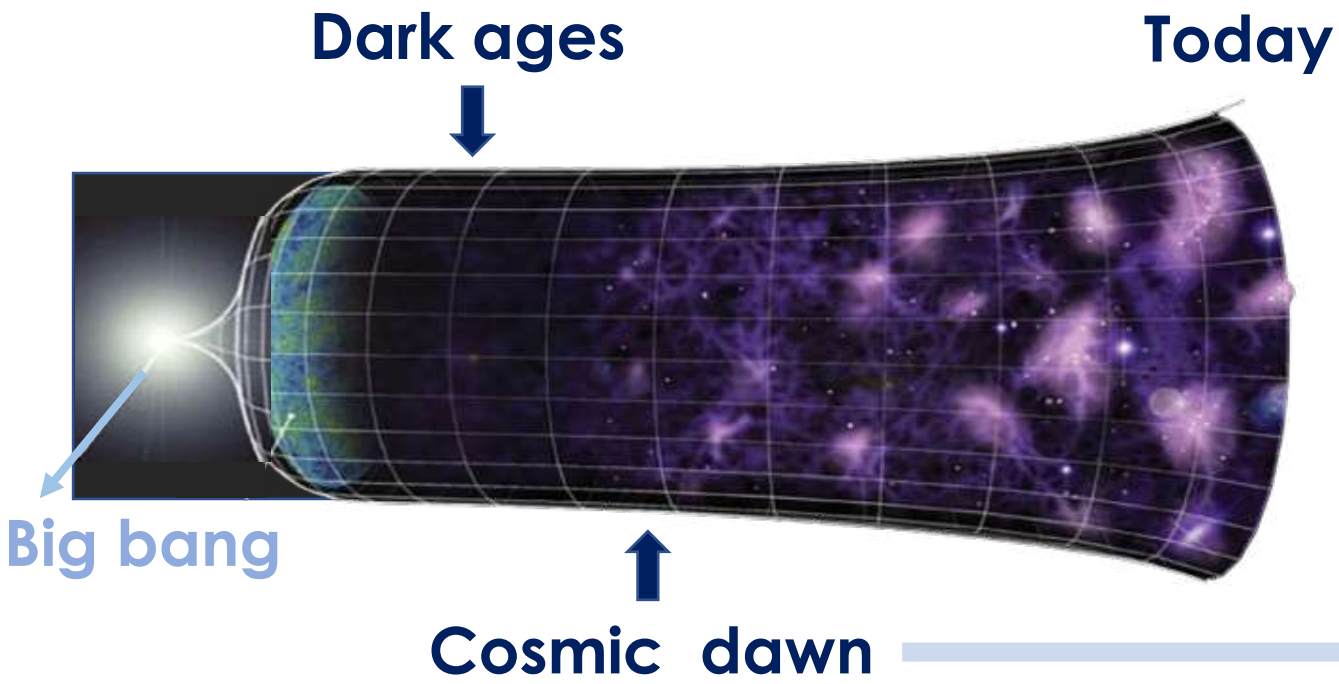
Investigating galaxy assembly and star-formation in the early Universe : current results and future perspectives

Antonello Calabrò (INAF – OAR)

with *Flaminia Fortuni, Adriano Fontana, Laura Pentericci*



JWST expectations and goals

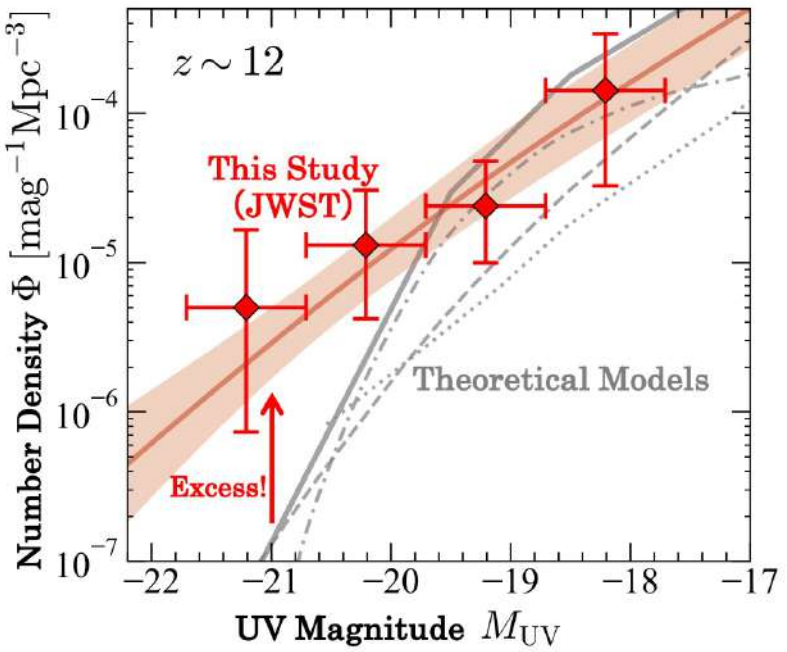


Cosmic dawn ($z \sim 10$ - 30)

- first stars (population III / II)
- formation of first galaxies
- supermassive black-hole seeds
- synthesis of metals and enrichment of the IGM

JWST most surprising results

1. Too many luminous galaxies in the first 500 Myr



Harikane et al. 2025

Possible explanations :

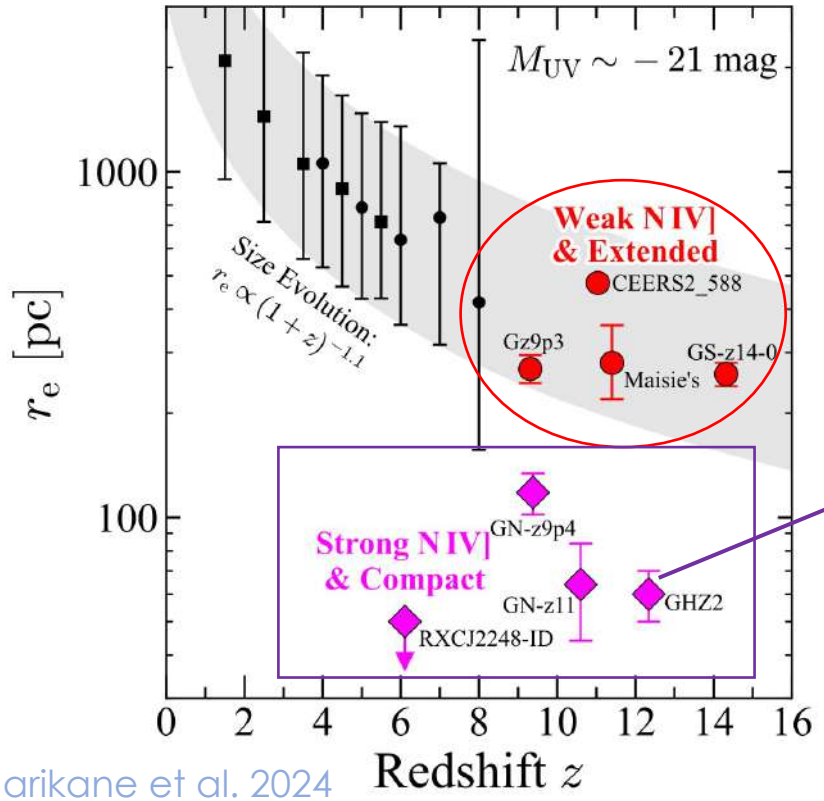
- Stellar evolution : high L/M, low metallicity, binaries, top-heavy IMF (Cueto +24)
- increased star formation efficiency ε (Kar +26, Dekel +23)
- bursty star-formation (Gelli +25), dust clearing outflows (Ferrara +24)
- AGN

baryon physics

- non standard cosmology (Menci +24)

new physics

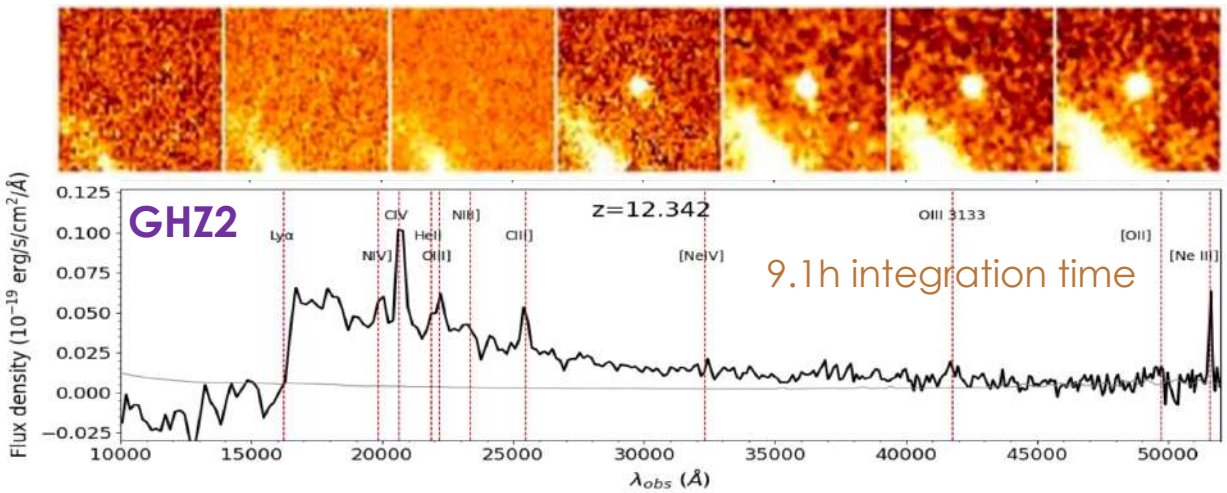
2. Surprising diversity of physical properties
   (size and emission properties are correlated)



Harikane et al. 2024

- extremely compact (size < 80 parsec)
- extreme SFR surface density ($\Sigma_{SFR} > 100\ M_\odot\ yr^{-1}\ kpc^{-2}$)
- bright (high-EW) UV emission lines

Castellano +23,+24 (incl. AC)



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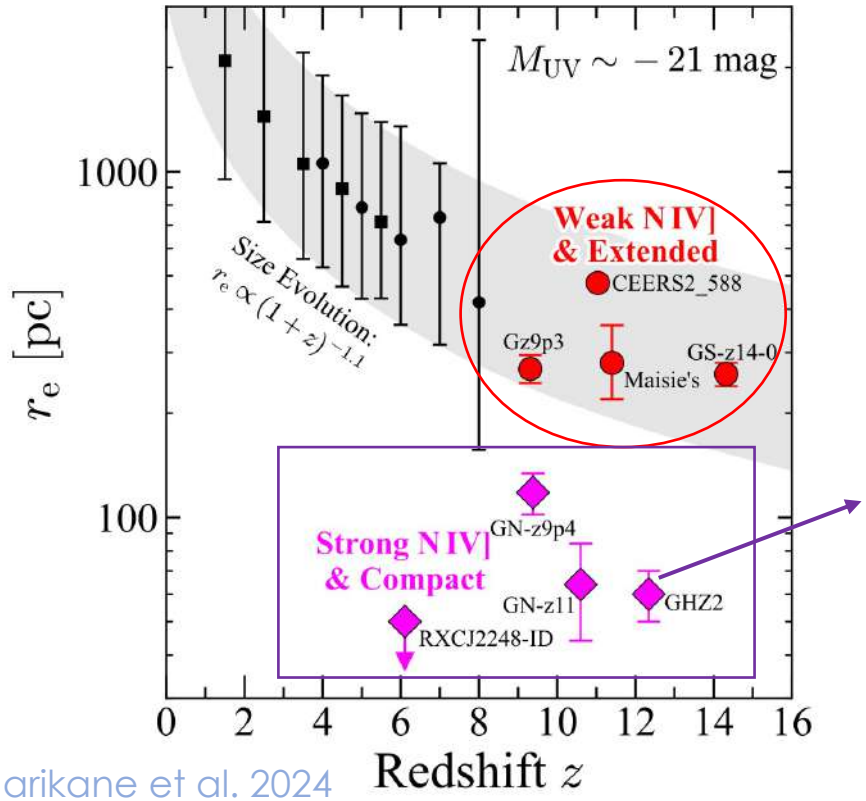
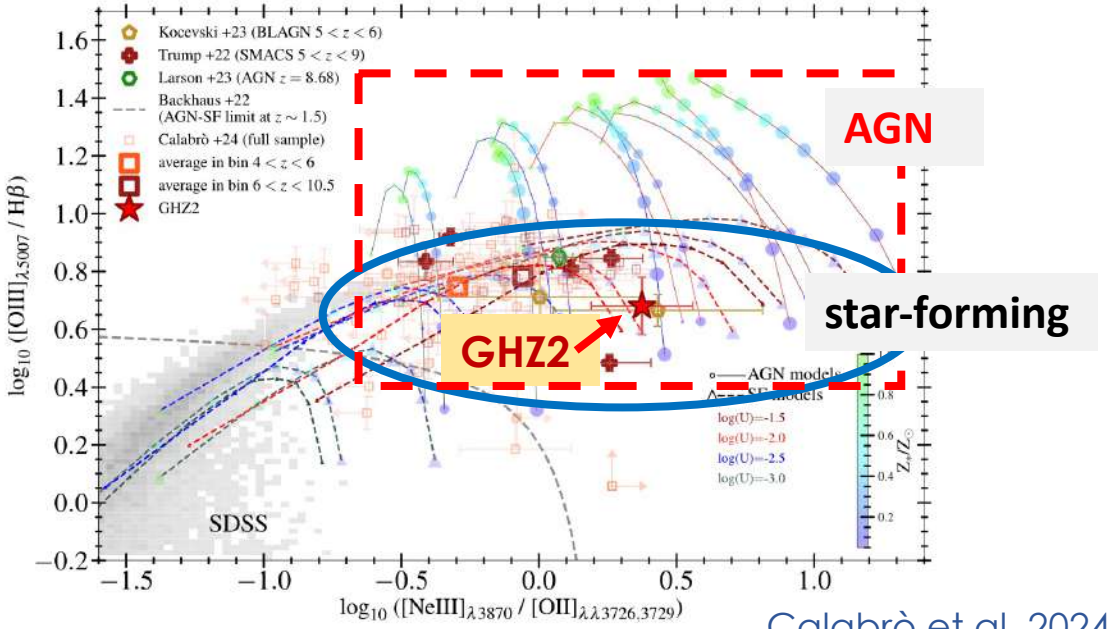


Harikane et al. 2024



Calabrò et al. 2024

- emission lines consistent with AGN and star-formation
- unique star-forming conditions : low metallicity, super-solar N/O, high gas density, extremely high ionization

  → globular cluster progenitor ?

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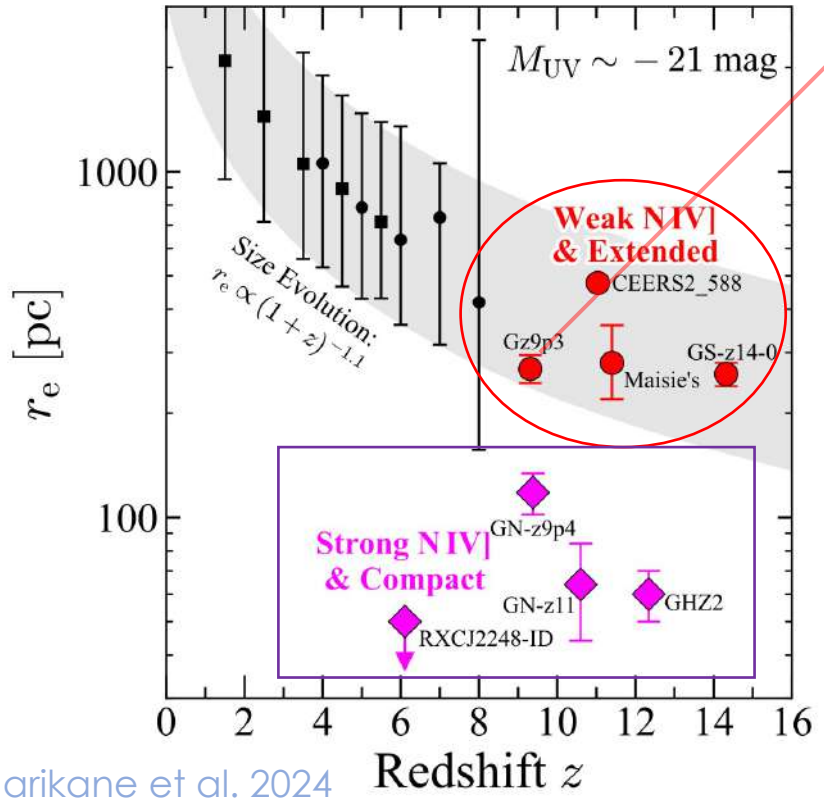
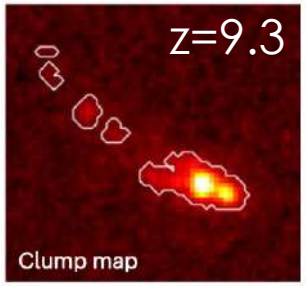
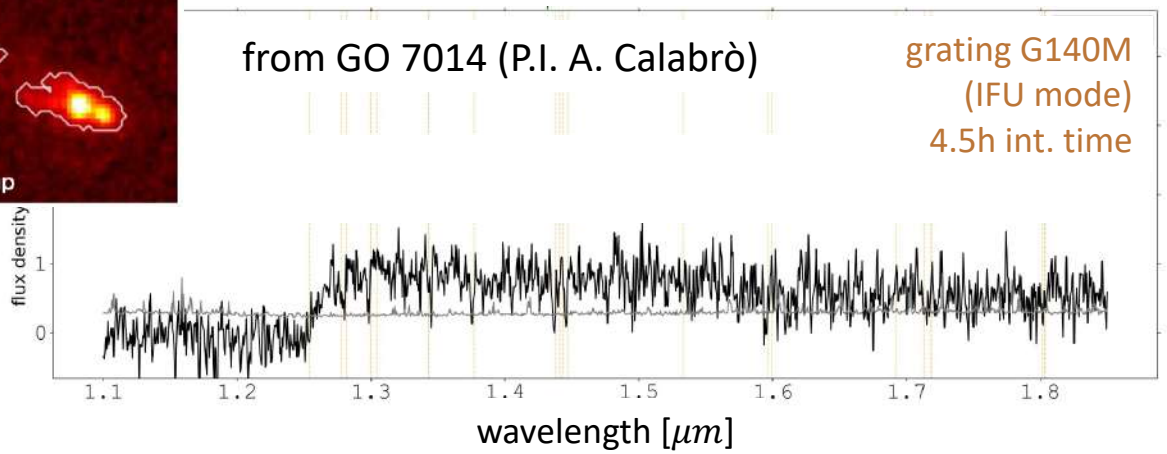
   (size and emission properties are correlated)



Harikane et al. 2024



Boyett +24 (incl. AC)



- extended, well resolved
- lower SFR surface density
- faint (or even absent) emission lines

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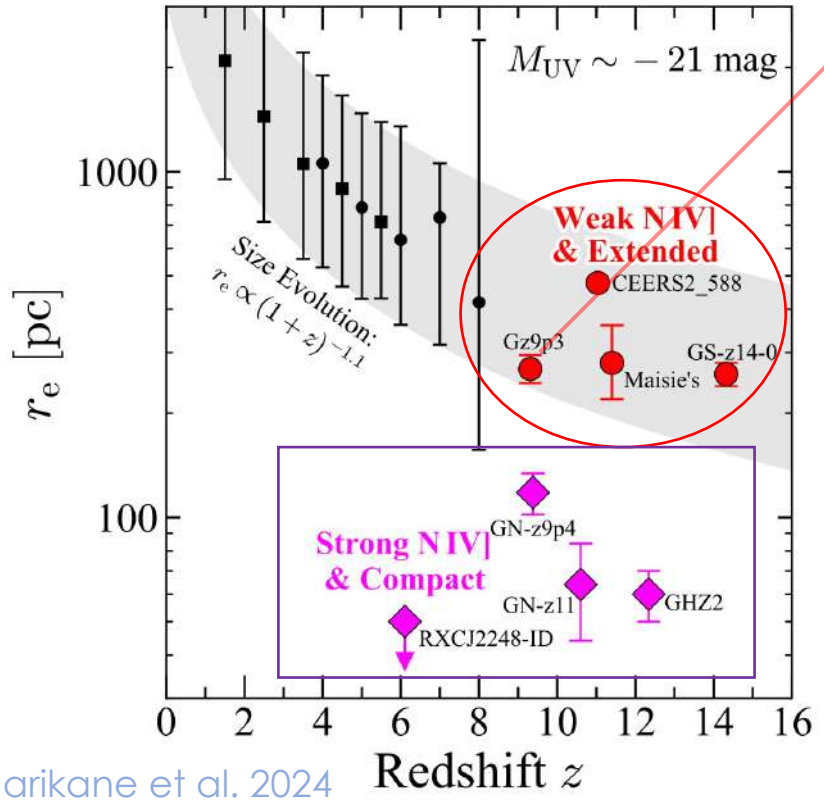

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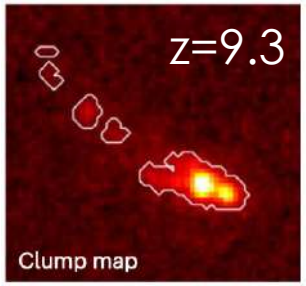

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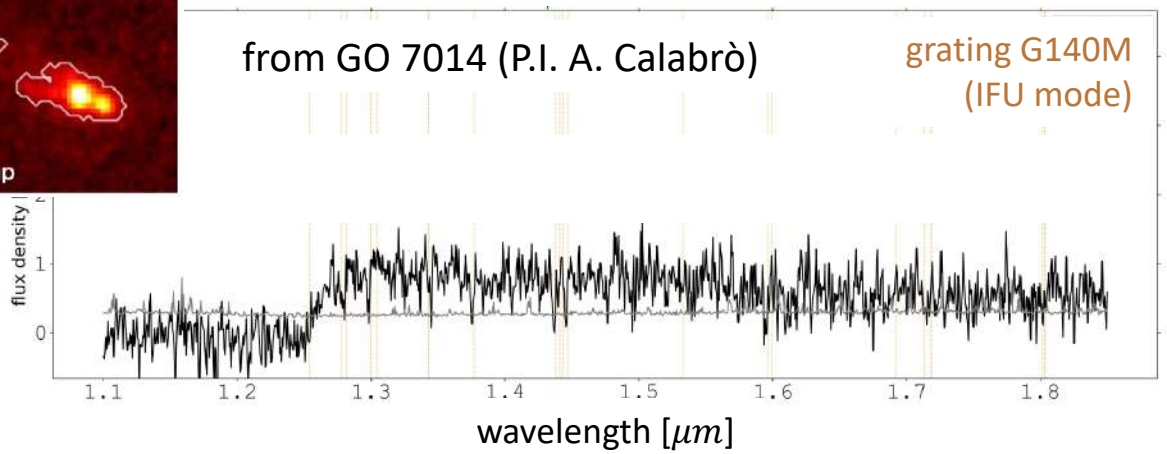
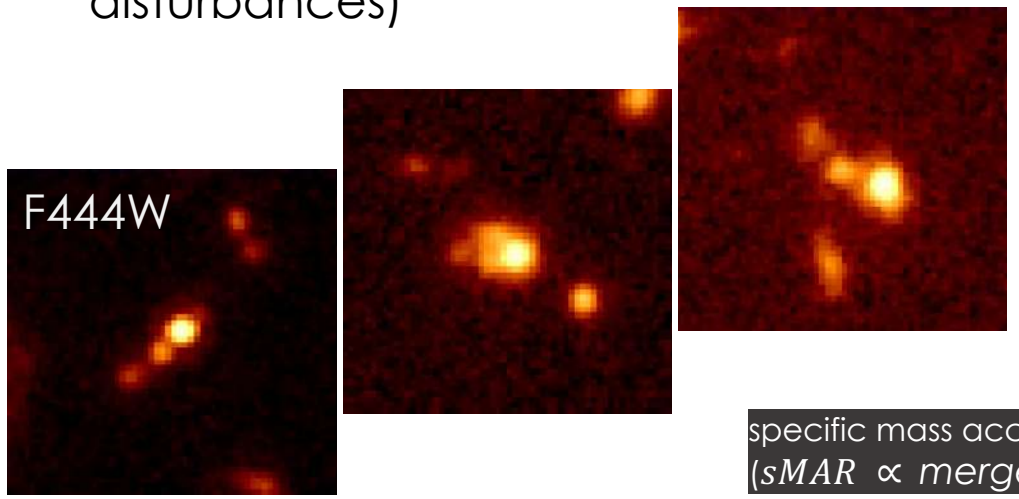


- the most distant merger known
- mergers responsible for the excess of bright galaxies ? (Harikane +24)

The role and contribution of mergers to early galaxy assembly :

Calabrò et al. 2026

- sample of 1233 galaxies at z > 5 (6 fields)
- mergers identified in F444W using Gini, M_{20} , and asymmetry (sensitive to morphological disturbances)

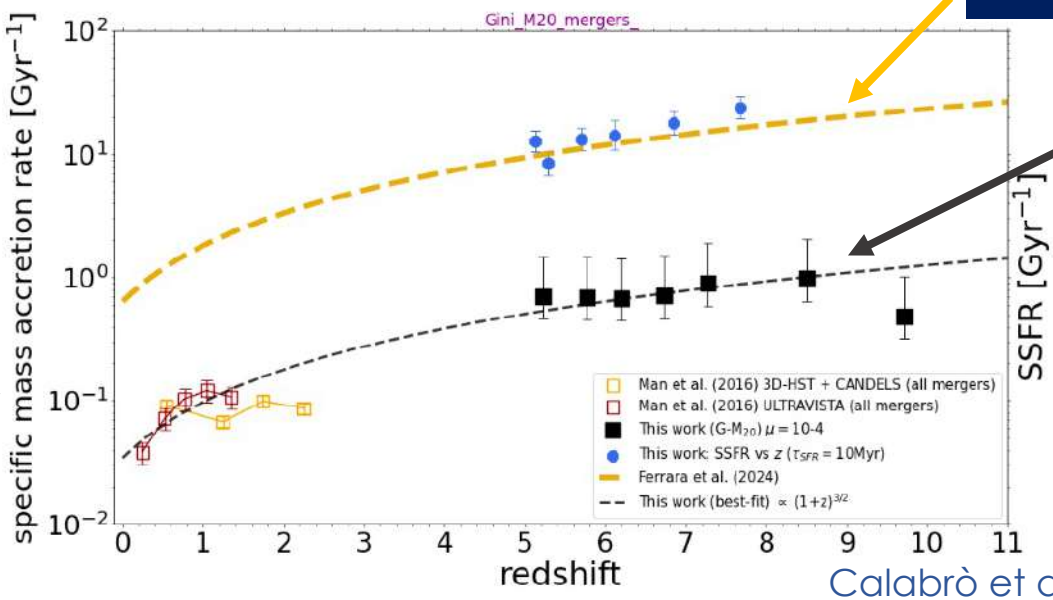


specific mass accretion rate
($sMAR \propto$ *merger rate*)

- strong increase of the merger rate from z= 0 to 10 (by > 1 dex)
  [~ 5 *mergers/galaxy/Gyr at z > 5]*
- mergers contribute only by ~ 5% - 10% to galaxy mass assembly at all epochs

in situ star-formation

mass growth from mergers



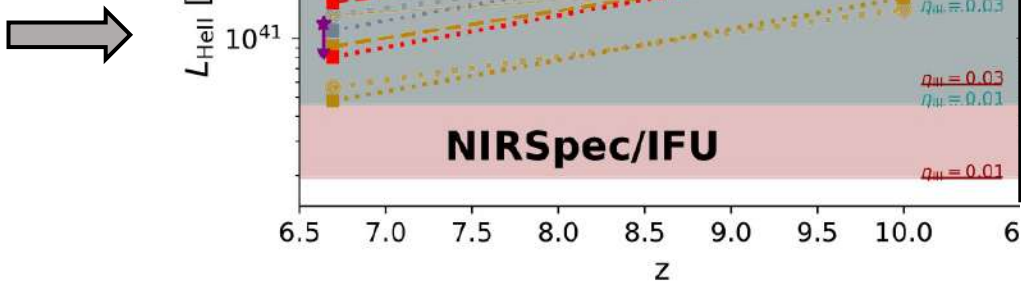
Calabrò et al. 2026

The search for population III stars

- *very massive* ($M_{star} > 100\ M_{\odot}$), *metal free* (only H and He emission lines), may explode as *Pair Instability Supernovae* (PISNe) or may directly become black-holes

- some recent claims : *HeII detection* (Maiolino +24, Wang +24), detection of *PISNe* at z = 15 Ferrara +25 [***but all need more robust confirmation***]

- according to simulations , they should be detectable at z = 6-10 around massive galaxies



Venditti +24 (incl. AC)

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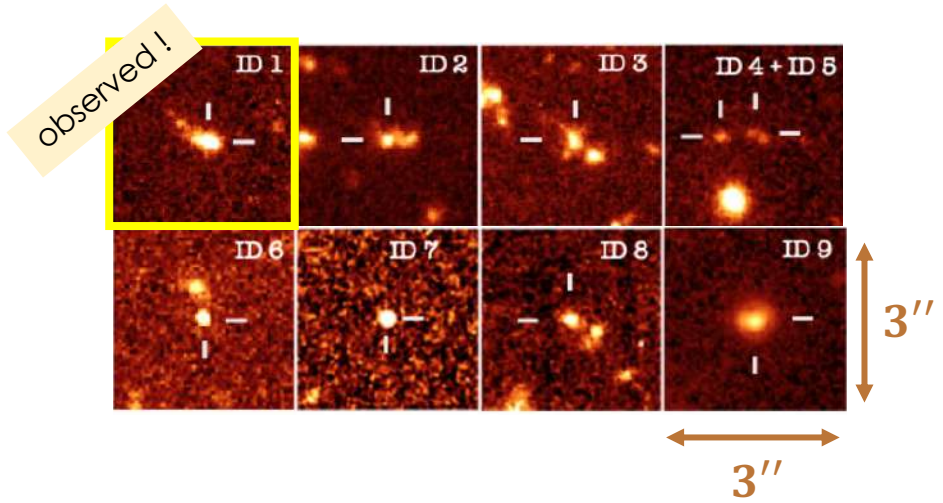
- main goal of **GO 7014** : **62.8h** of observations with **NIRSpec-IFU** of 9 massive, interacting galaxies at z=7-10



- new data are coming during the next months Stay tuned !

Summary

nature of UV bright galaxies at z > 10 yet to be understood (star-forming or AGNs ?)

pop III stars yet to be detected – GO 7014 ongoing ...

role of mergers in the formation of first galaxies and first black holes not fully understood

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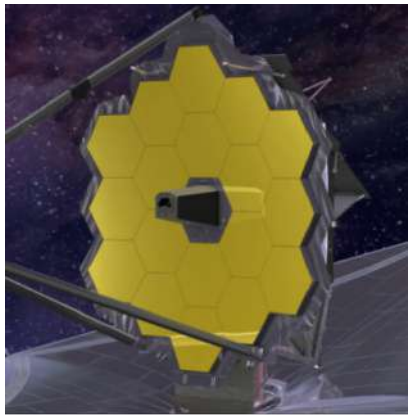
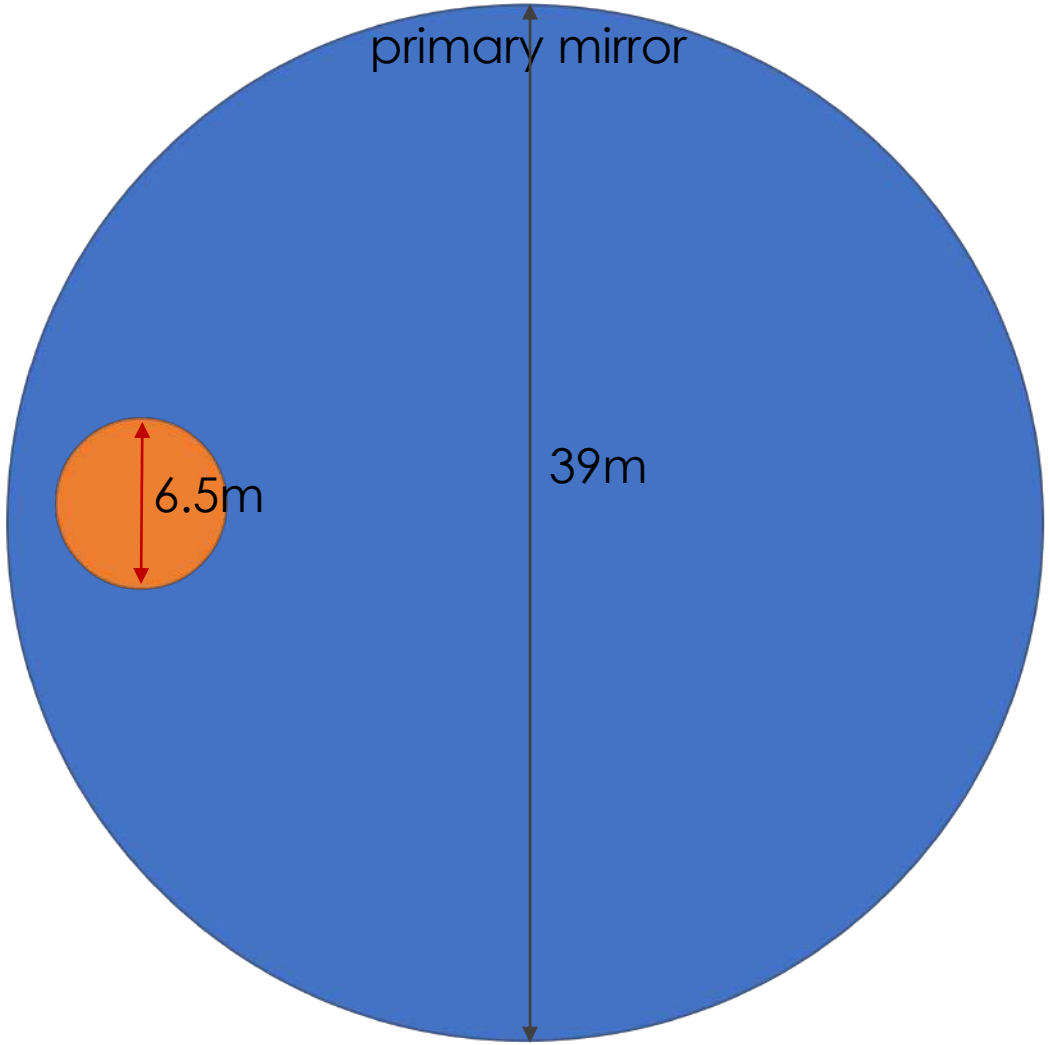
Where do we go next ?

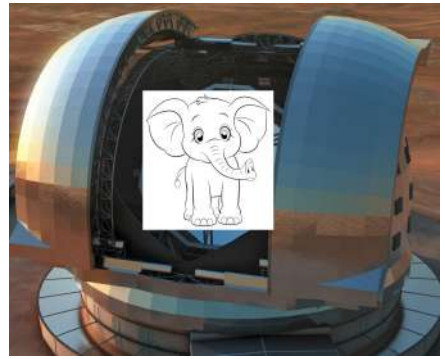
- *ALMA* will complement JWST (ALMA2040, ...)
- *Euclid* will explore the bright end of galaxy population
- VLT/MOONS will be useful for galaxy clustering
- SKA will explore reionization timescale and nature of sources (21-cm power spectrum)
- Extremely Large Telescope (ELT) : expected to outperform JWST in terms of resolution and depth

how the study of the first galaxies can benefit from **ELT** ?



James Webb





Extremely Large Telescope

- x 36 the area of JWST
- x 4-10 better spatial resolution
- spectral resolution up to 100k

imaging of GHZ2 with ELT/MICADO

simulated mock image :

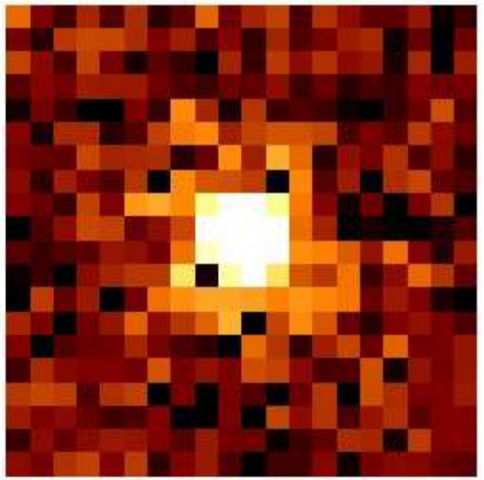
underlying Sersic profile (r_e , n, q, φ from NIRCam fitting)

central point source (AGN) with 30% of the flux

- convolution with PSF
- 5h of integration in Ks band

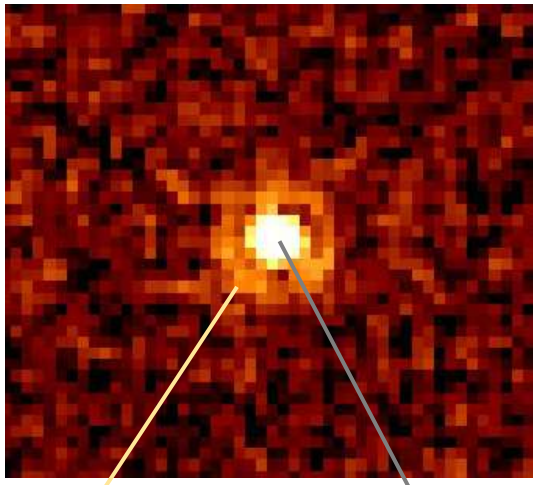
GHZ2 (z=12.34)

NIRCam F200W



0.6″

MICADO+SCAO Ks

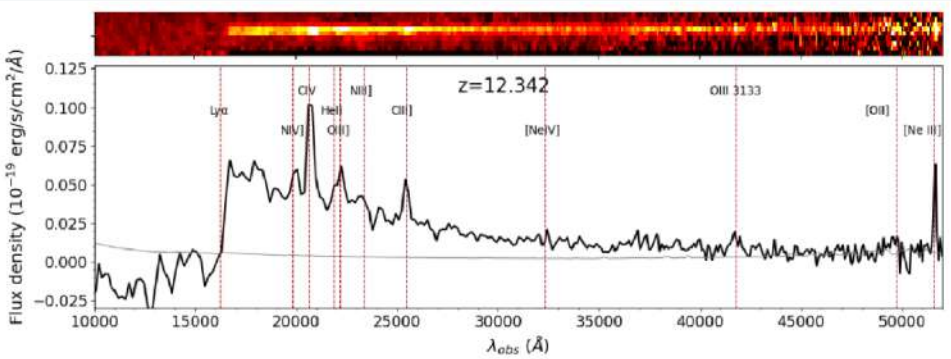


0.2″

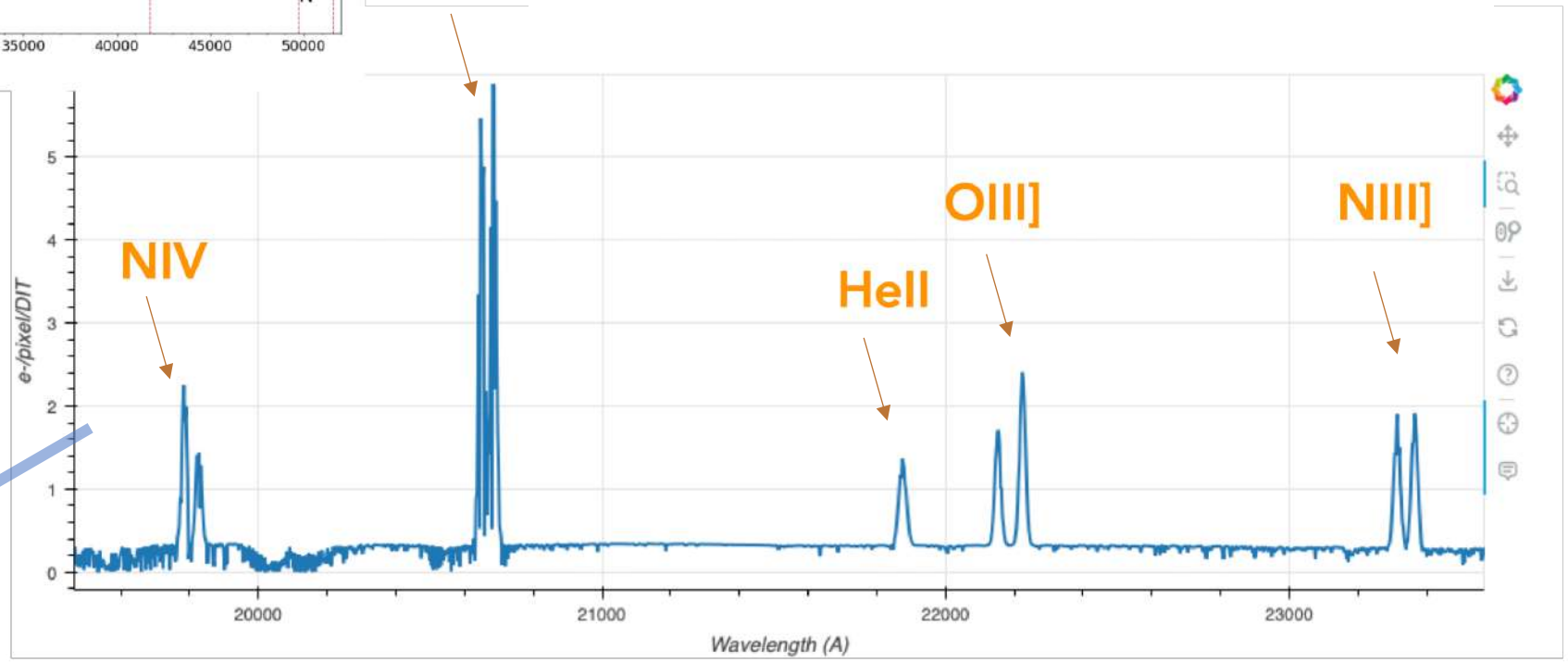
extended host galaxy

central AGN

high-resolution rest-frame UV spectrum of GHZ2 with ELT



NIRSpec (Castellano +24)



- N/O abundance
- gas density
- AGN signatures (broad CIV, HeII EW)

SHARP/ELT simulator

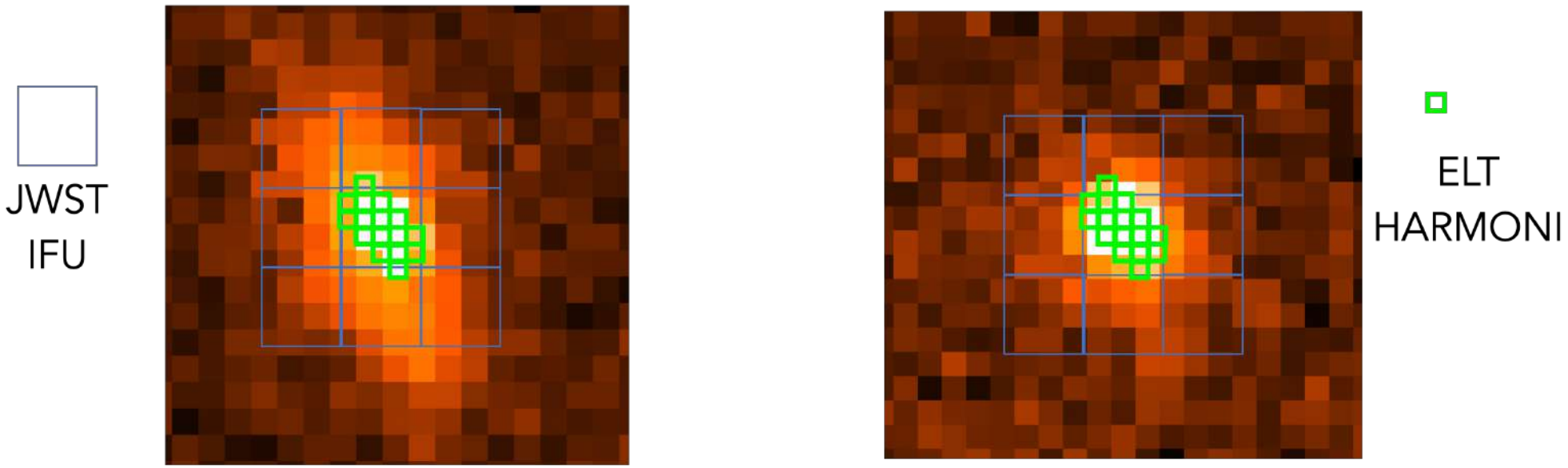
IFU (3D) spectroscopy with ELT/HARMONI

- internal kinematics
- stellar mass, SFR, and metallicity maps

GHZ1 z~10

GHZ2 z~12

Two of the brightest galaxies ever detected z>10

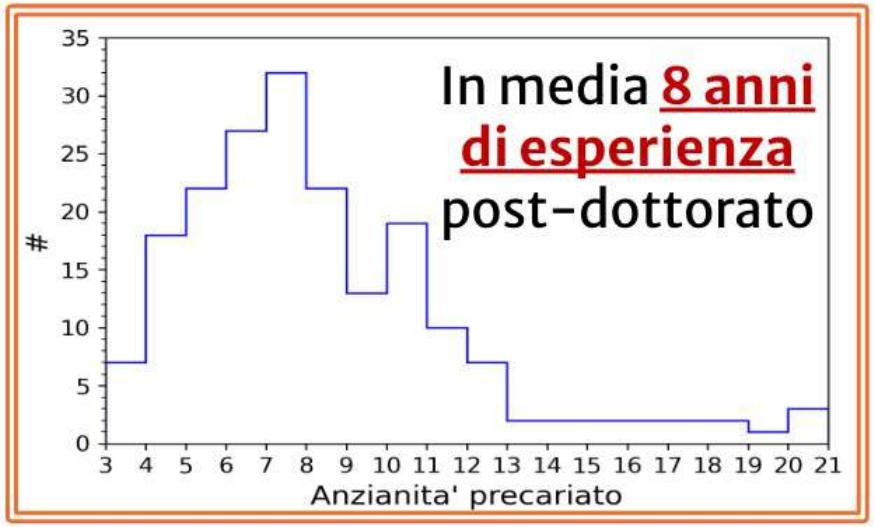


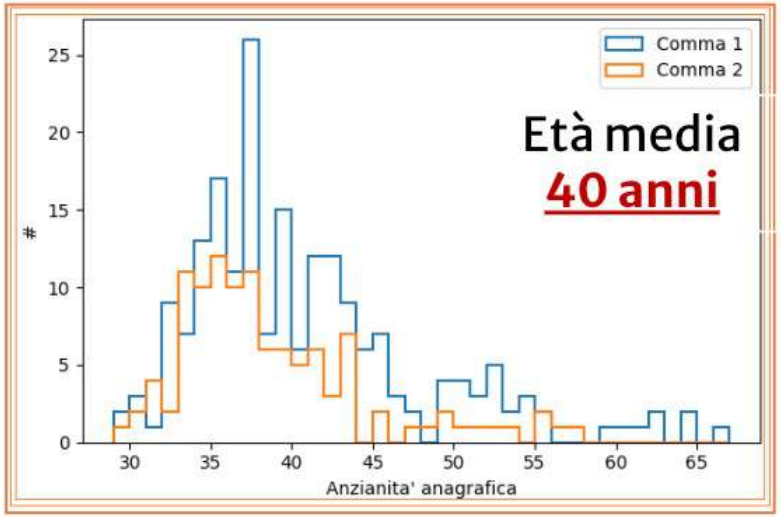
Is it a rotating disk at z=10???

Composite AGN???

La situazione del personale precario in INAF è CRITICA

1.200 Tempo Indeterminato Vs **650** precari: più di 1 precario ogni 2 persone di ruolo. Tra questi ~300 potrebbero essere assunti a tempo indeterminato con la legge Madia (che scade a fine 2026)





Più di 100 precari altamente qualificati e con esperienza decennale rischiano l'esodo da INAF

L'impatto sui progetti nazionali e internazionali in cui INAF è coinvolto sarebbe dirompente.

Per sostenere la rete stabilizzandi firmate qui!