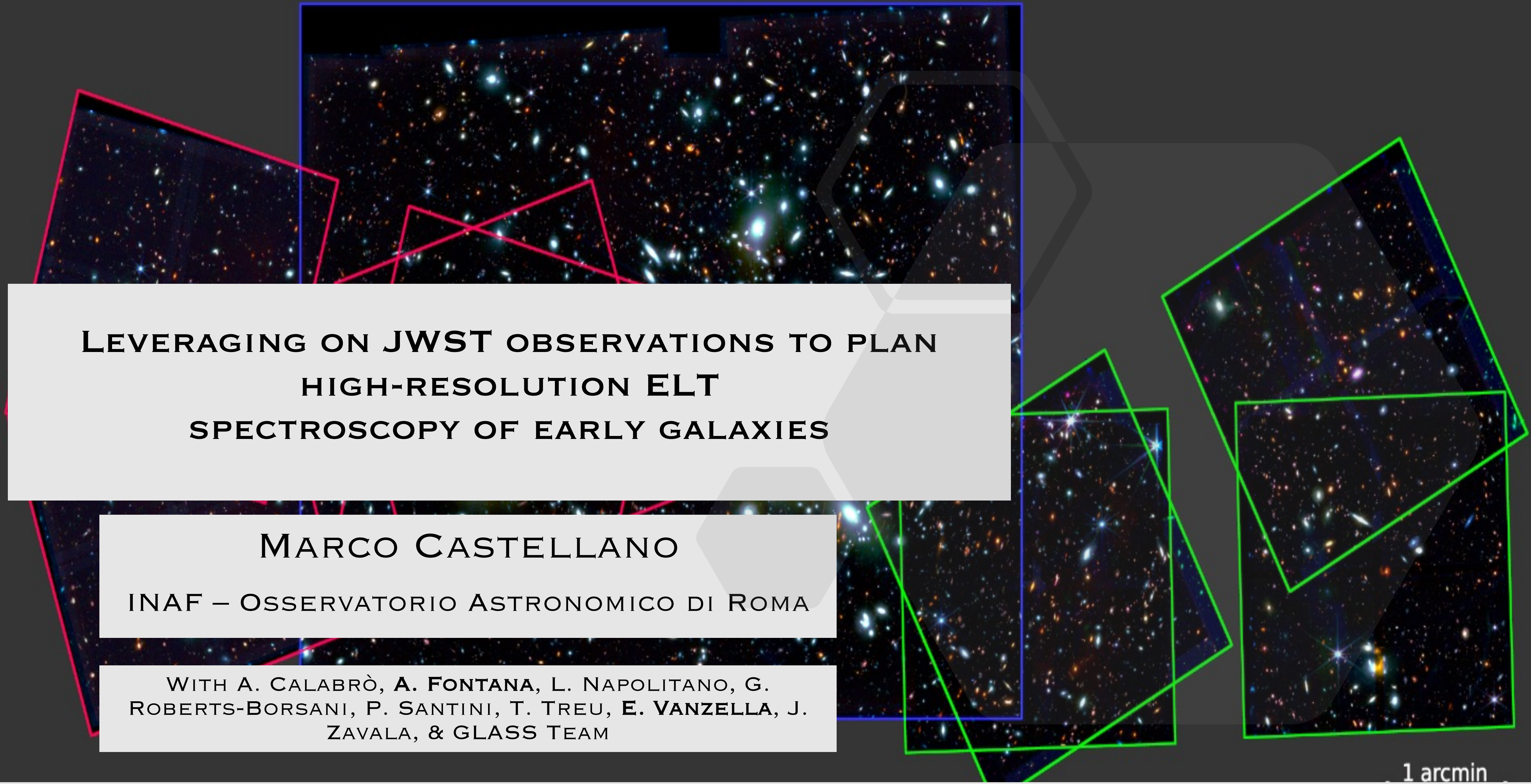


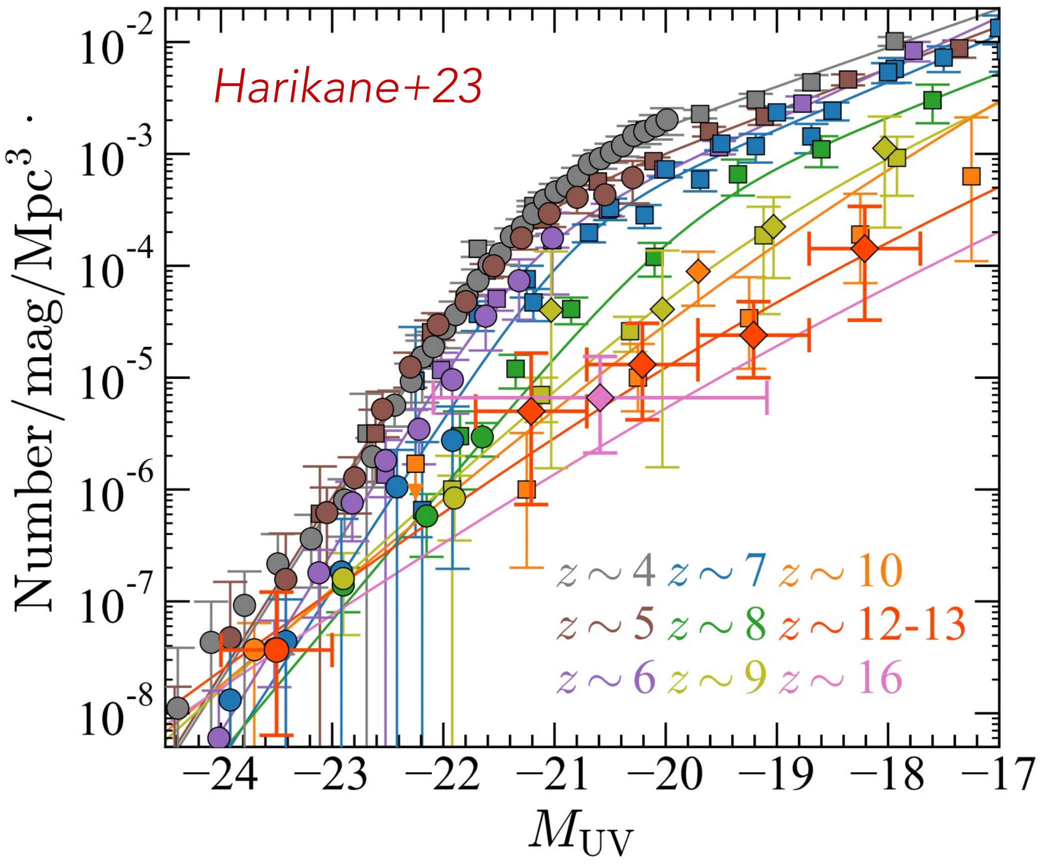
Leveraging on JWST observations to plan high-resolution ELT spectroscopy of early galaxies

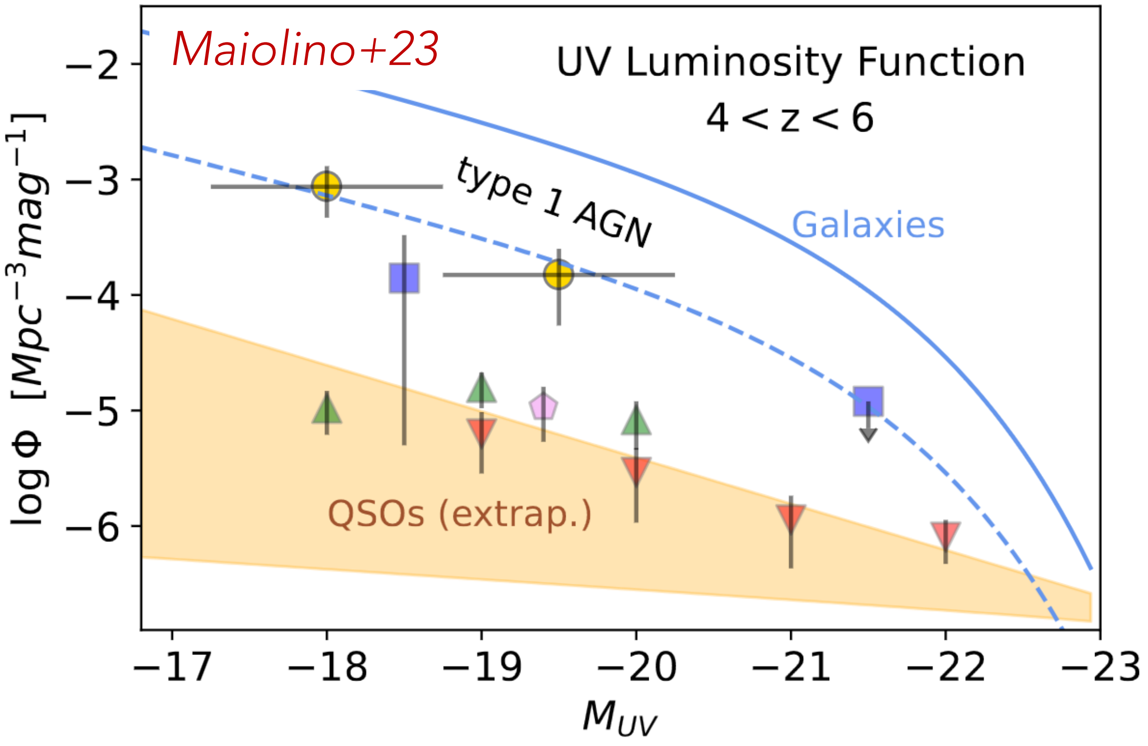
Marco Castellano

INAF – Osservatorio Astronomico di Roma

With A. Calabrò, **A. Fontana**, L. Napolitano, G. Roberts-Borsani, P. Santini, T. Treu, **E. Vanzella**, J. Zavala, & GLASS Team

Consensus on the excess of bright galaxies (and AGN)





A high abundance of bright galaxies at z>9

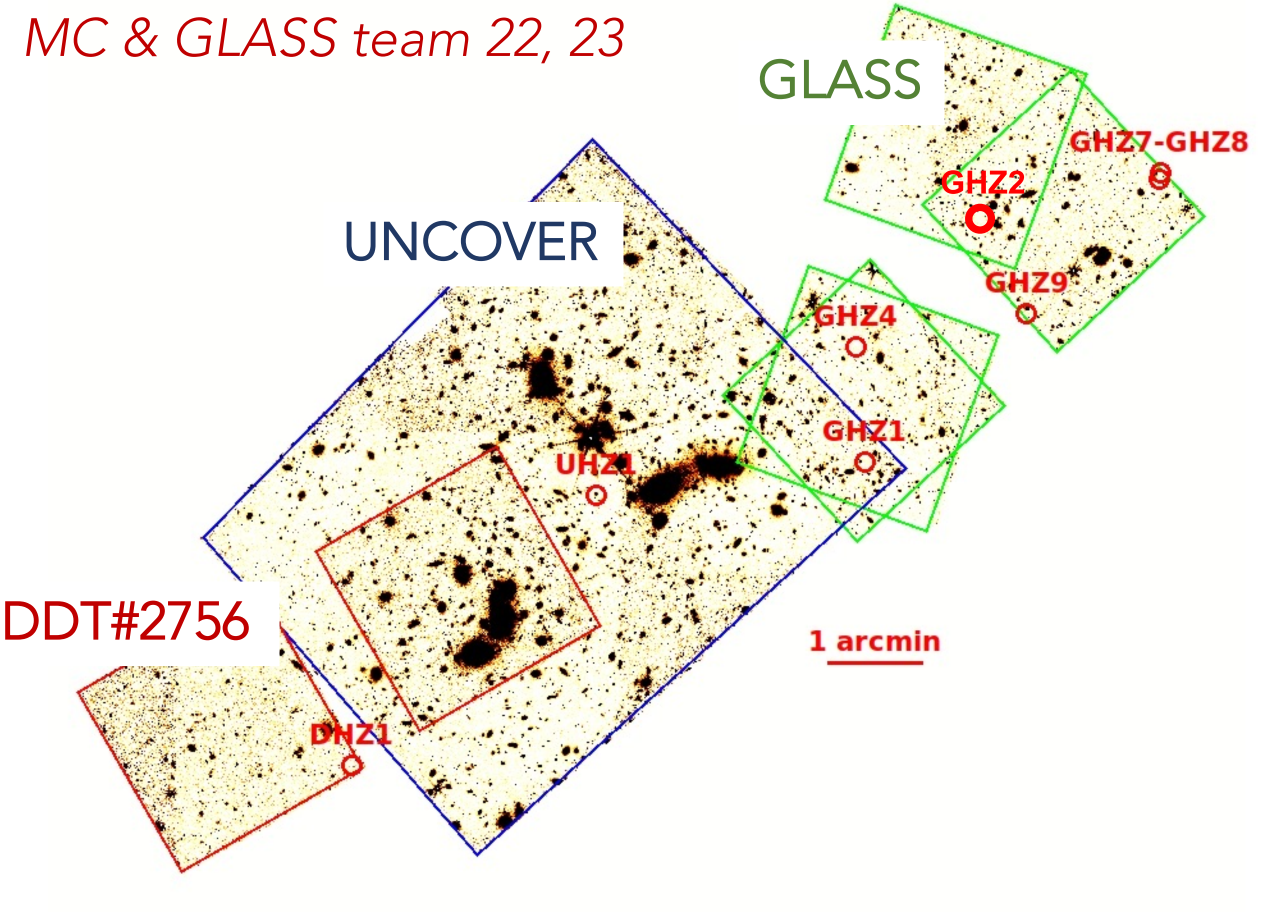
MC+22,+23, Finkelstein+23,+24; Donnan+23, McLeod+24, Harikane+23,+24; Perez-Gonzalez+23 and many others

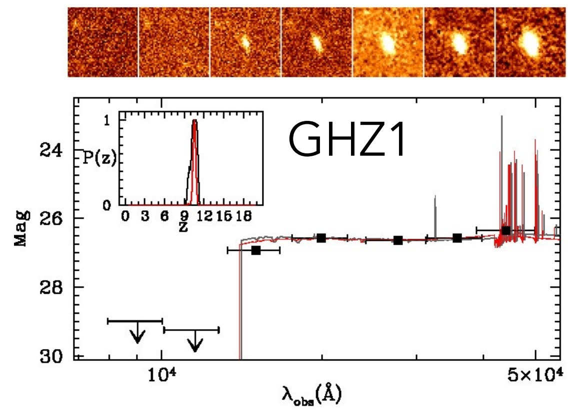
A large number of AGN at high-redshift

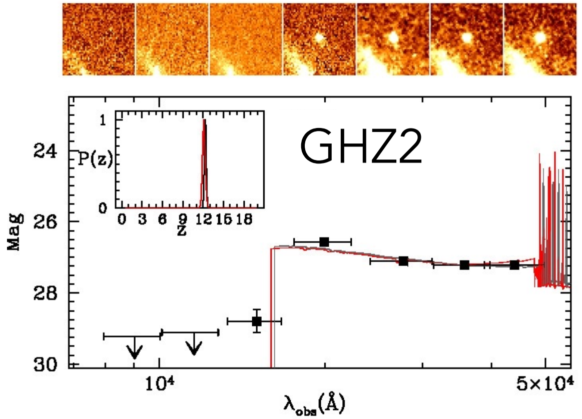
Barro+23, Matthee+23, Kocevski+23, Labbe+23, Furtak+23, Larson+23, Greene+23, Bogdan+23 and many others

HIGH-REDSHIFT GALAXIES IN THE ABELL 2744 REGION

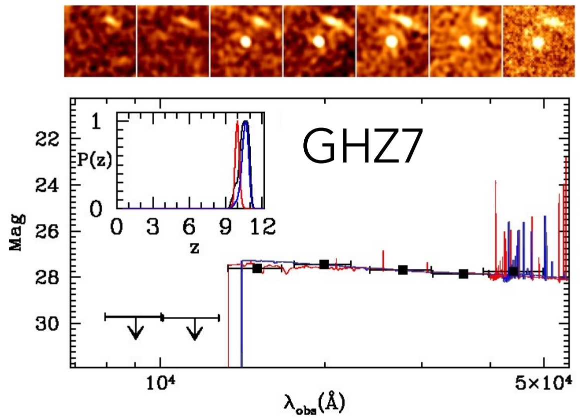
MC & GLASS team 22, 23

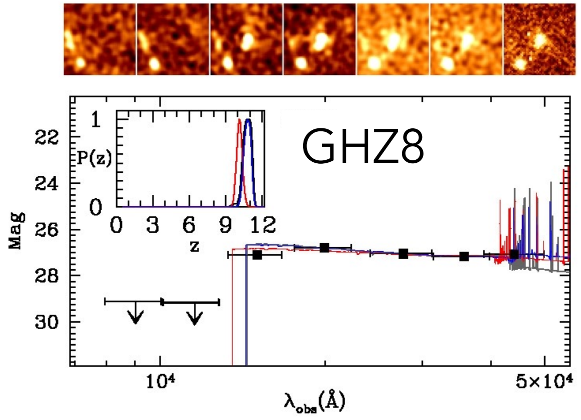






The first "unexpected" bright galaxies in JWST surveys: GHZ1 (z~10) and GHZ2 (z~12) (MC+22, Naidu+22)





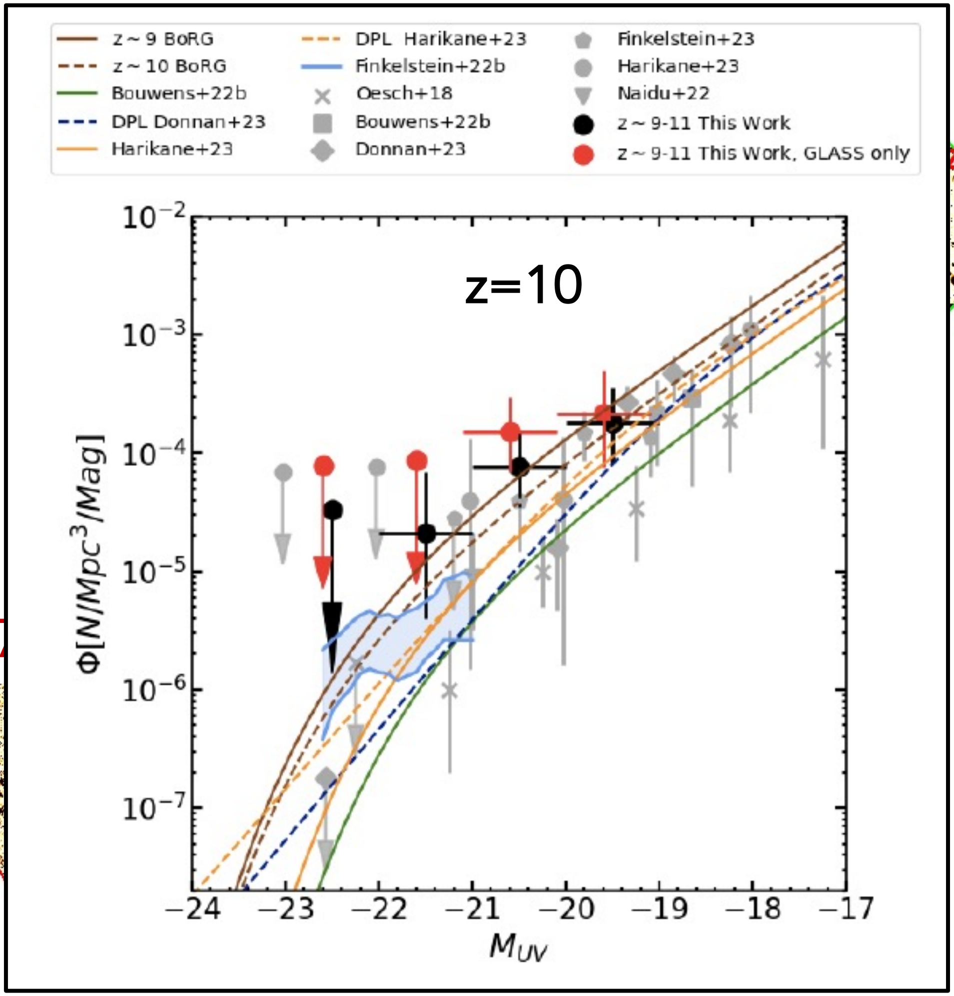
Robust candidates at z>9 analysed in several works, with a high density localized in the GLASS-ERS region. MC+22,+23, McLeod+23, Atek+23.

Seven bright z~10 LBGs suggesting an overdensity in the A2744 region (MC+23).

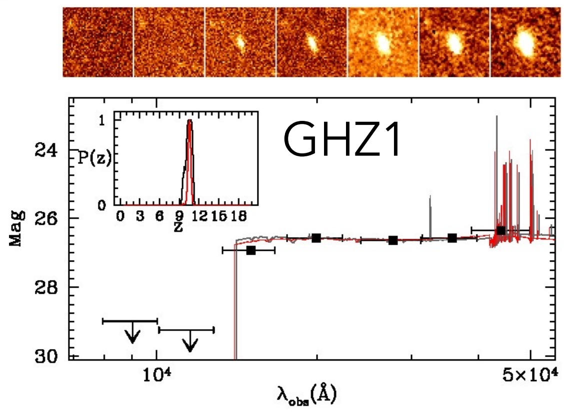
An excess of z~10 galaxies in the A2744 region

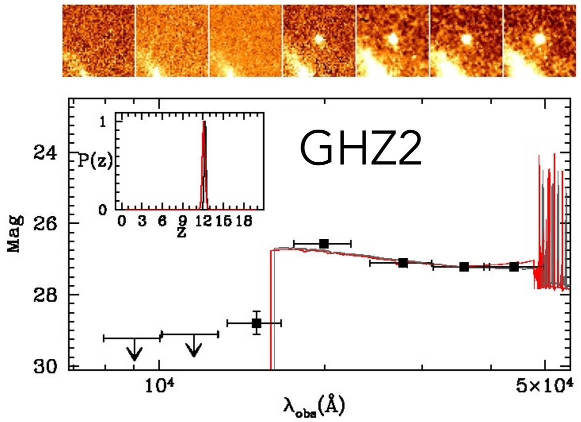
MC &

DDT#2



The UV LF at z~10 in the region is even higher than other JWST estimates





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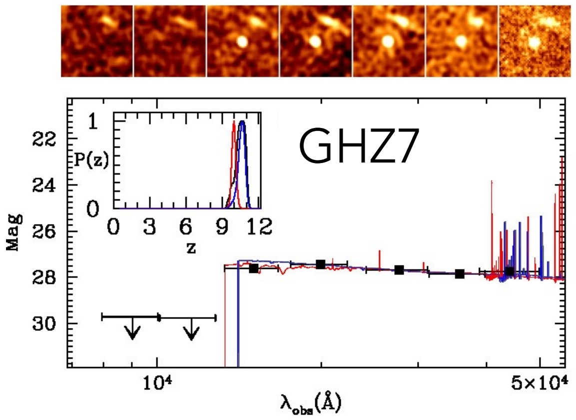
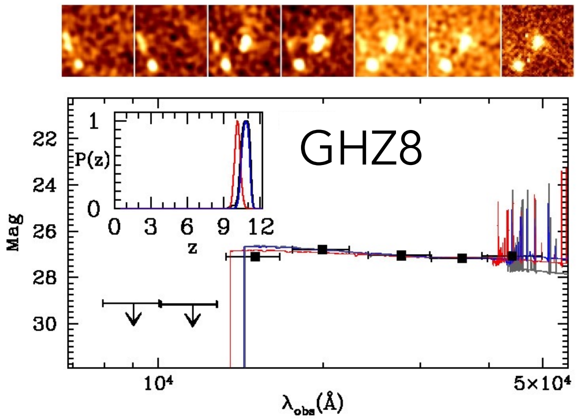
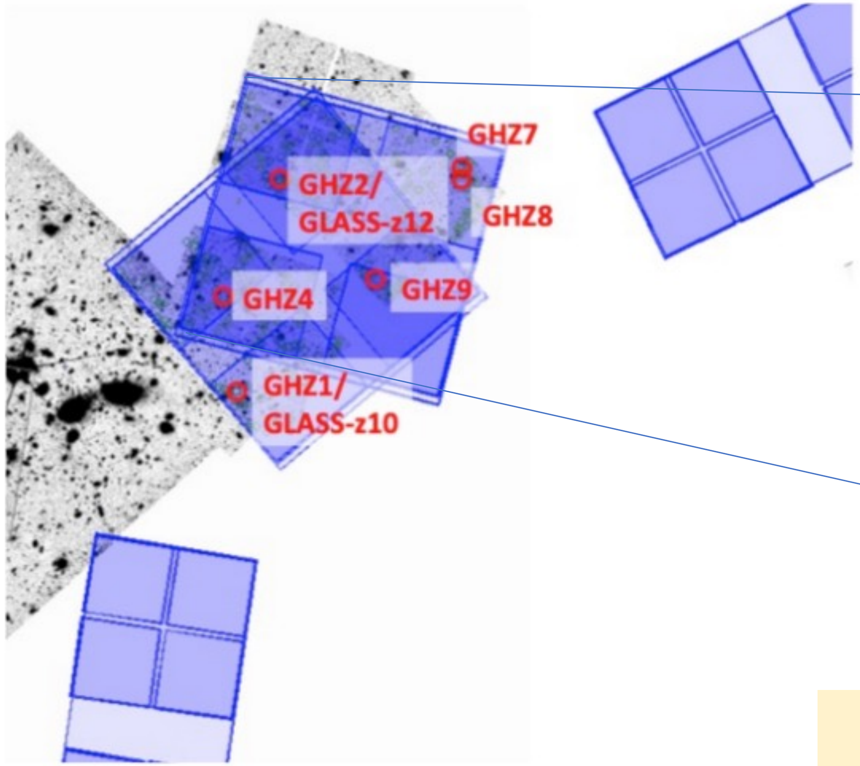
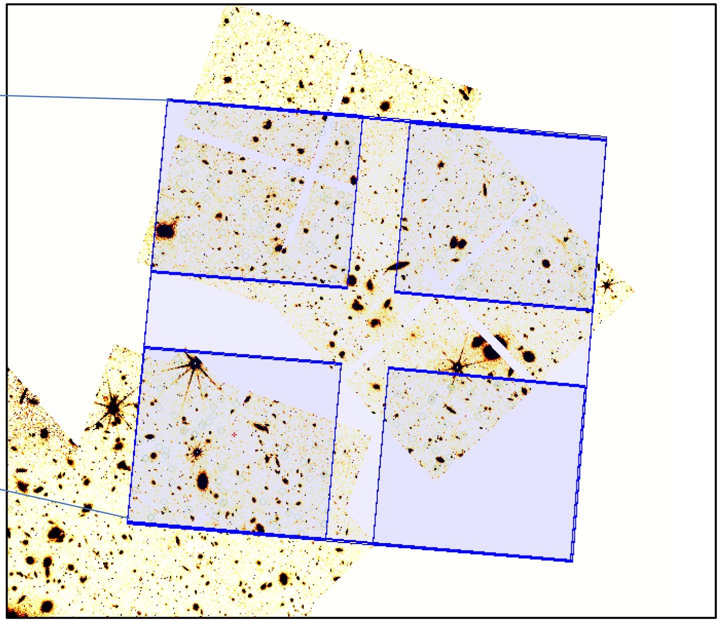


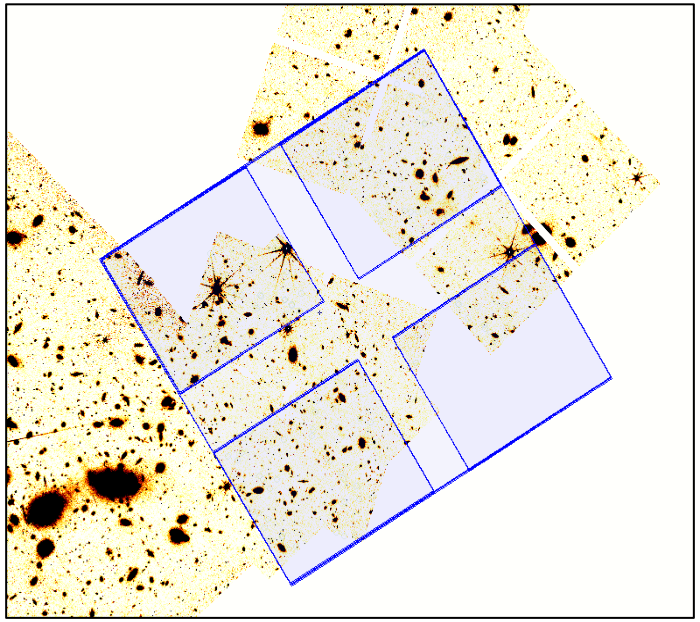


Seven bright z~10 LBGs suggesting an overdensity in the A2744 region (MC+23).

NIRSpec follow-up of GLASS-ERS (GO-3073)







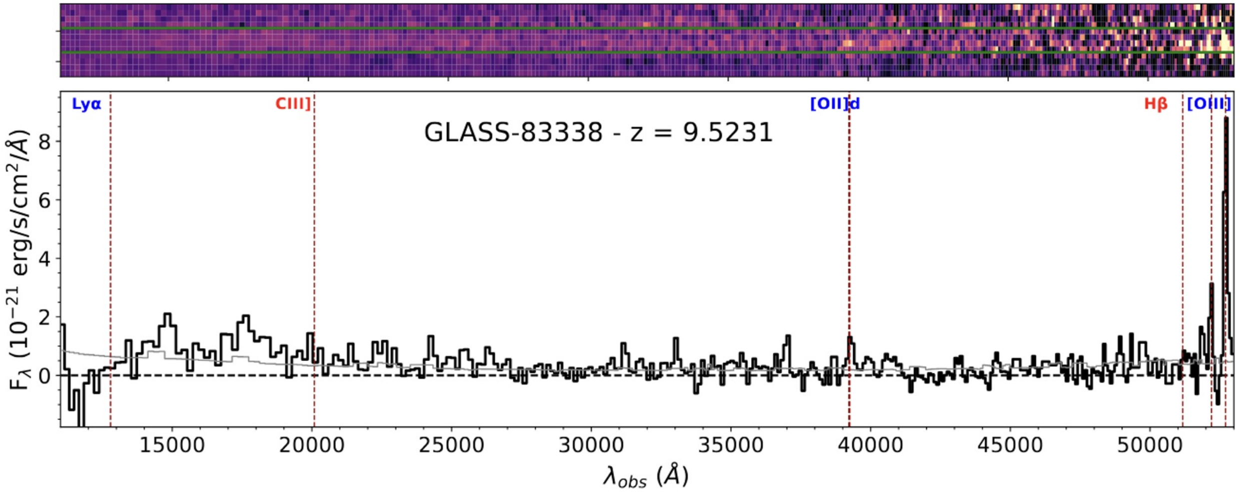
First pointing.
Observed on Oct. 25 2023
Primary targets: GHZ2, GHZ7, GHZ8, GHZ4, GHZ9

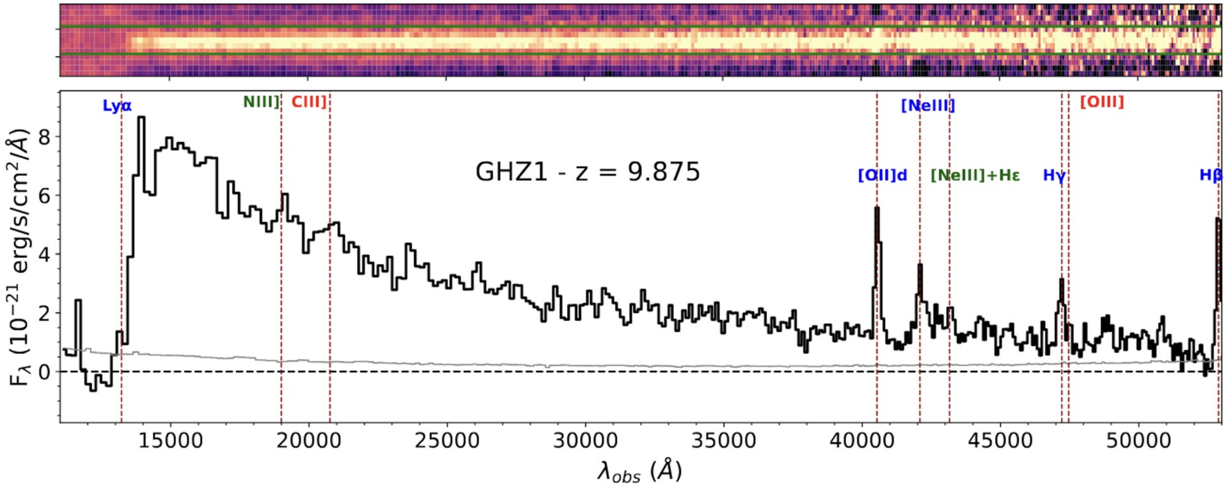
Second pointing.
Observed in July 2024
Primary targets: GHZ1, GHZ4, GHZ9

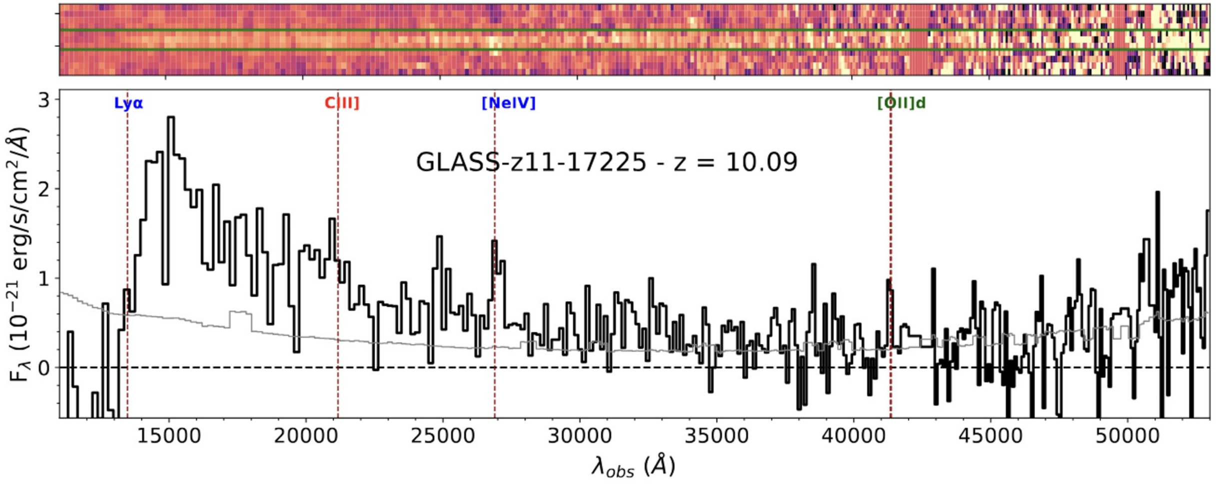
12 hours of NIRSpec PRISM on two pointings to confirm z~9-12 galaxies in the GLASS-ERS parallel

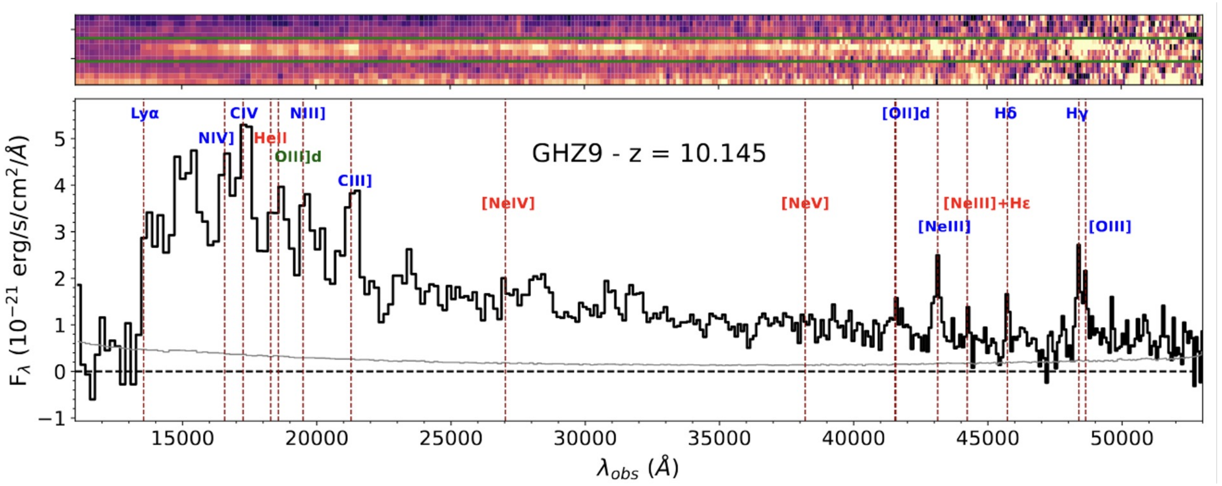
+ two flanking fields with NIRCam to extend the sample and map the potential overdensity

Spectroscopic confirmation of the z>9 sample





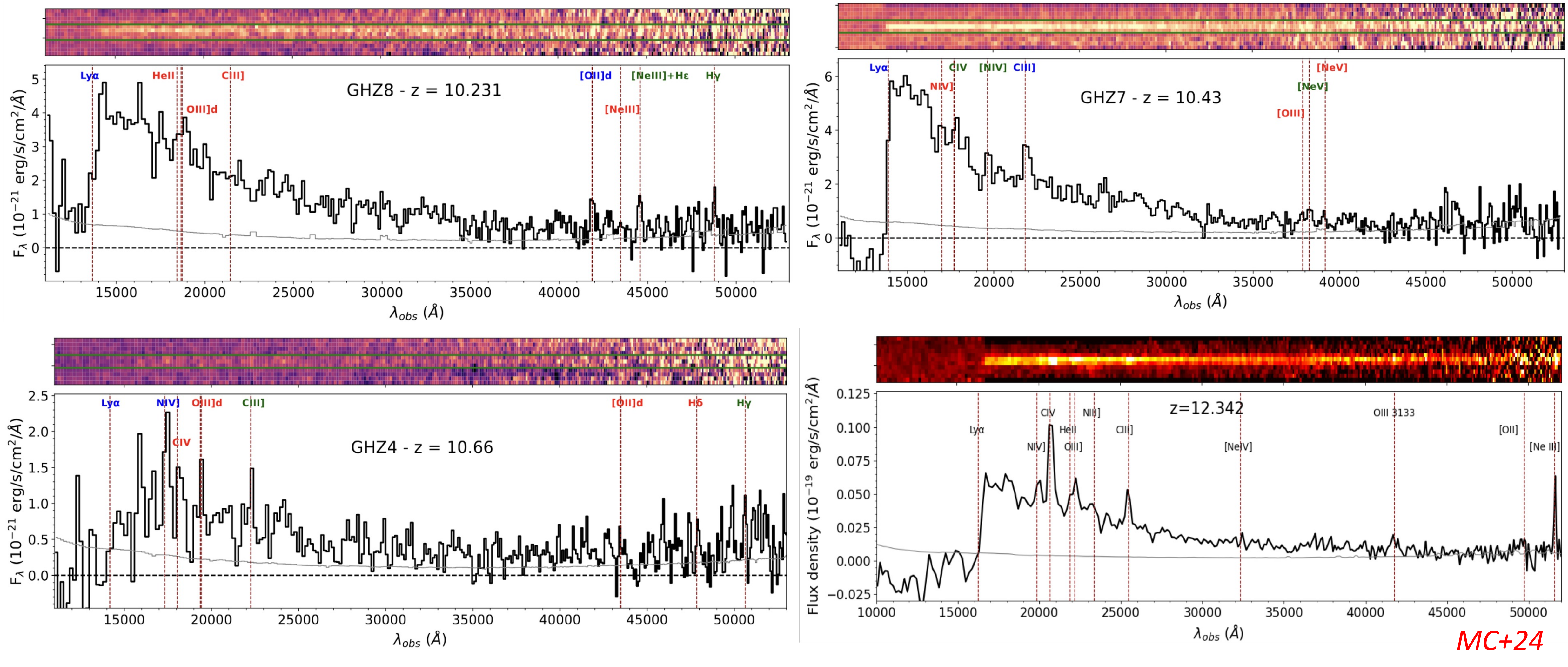




All primary targets from MC+22, +23 confirmed, plus 2 objects from other samples (Atek+23, McLeod+23)

Napolitano, MC+ subm.

Spectroscopic confirmation of the z>9 sample



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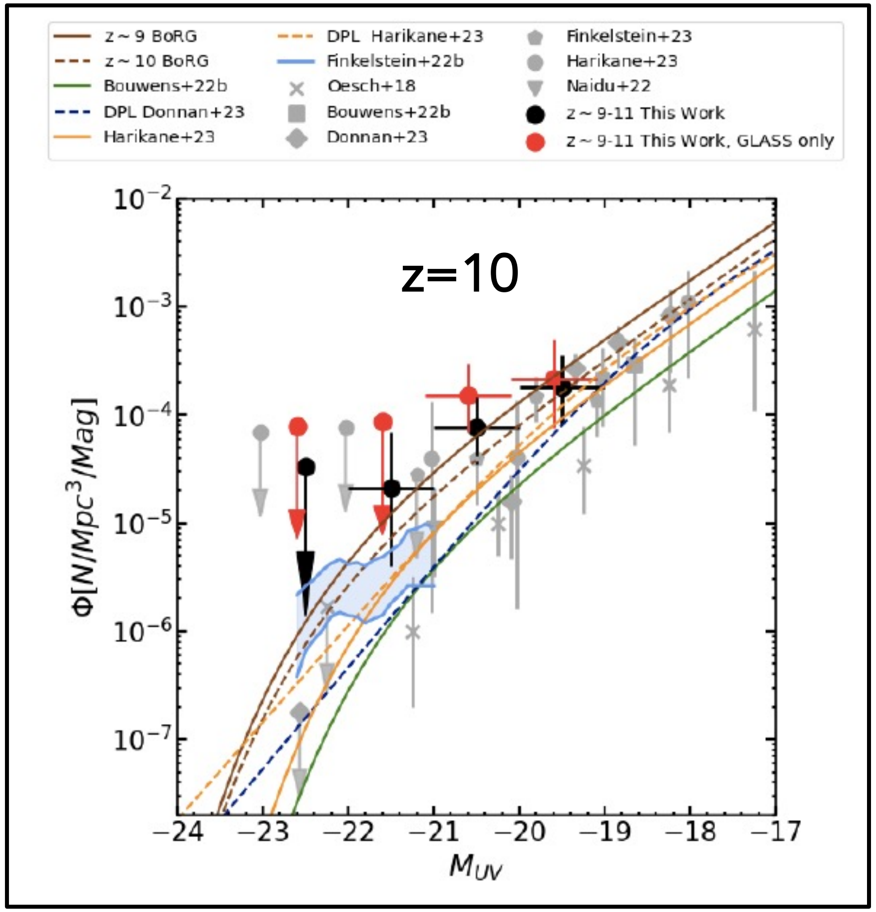

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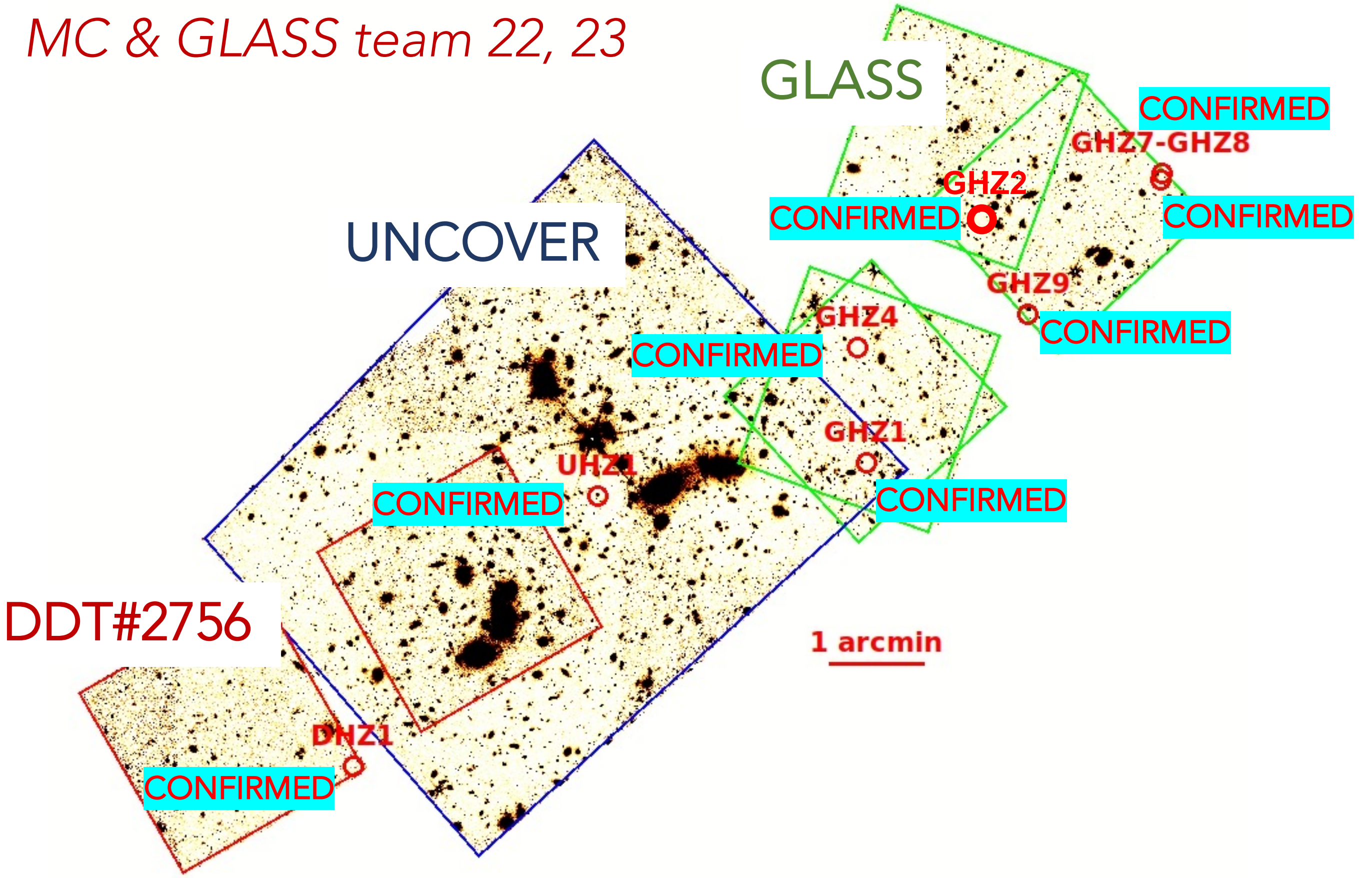
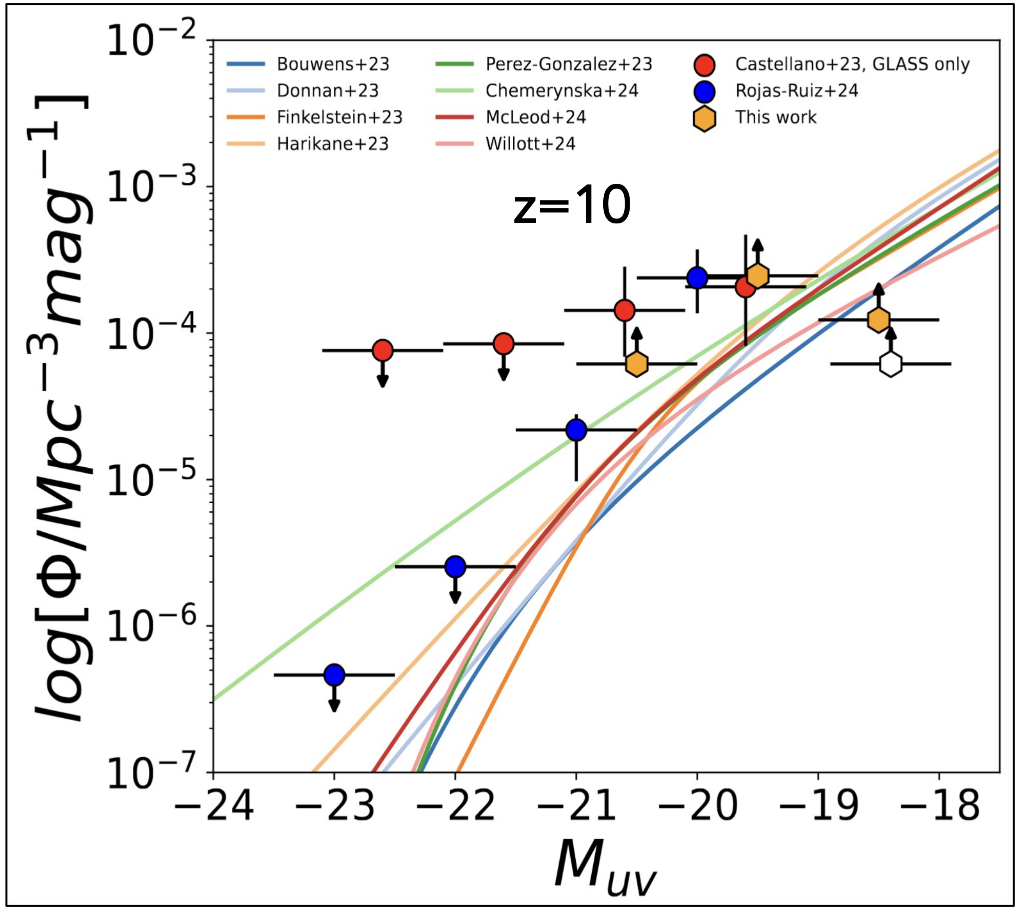


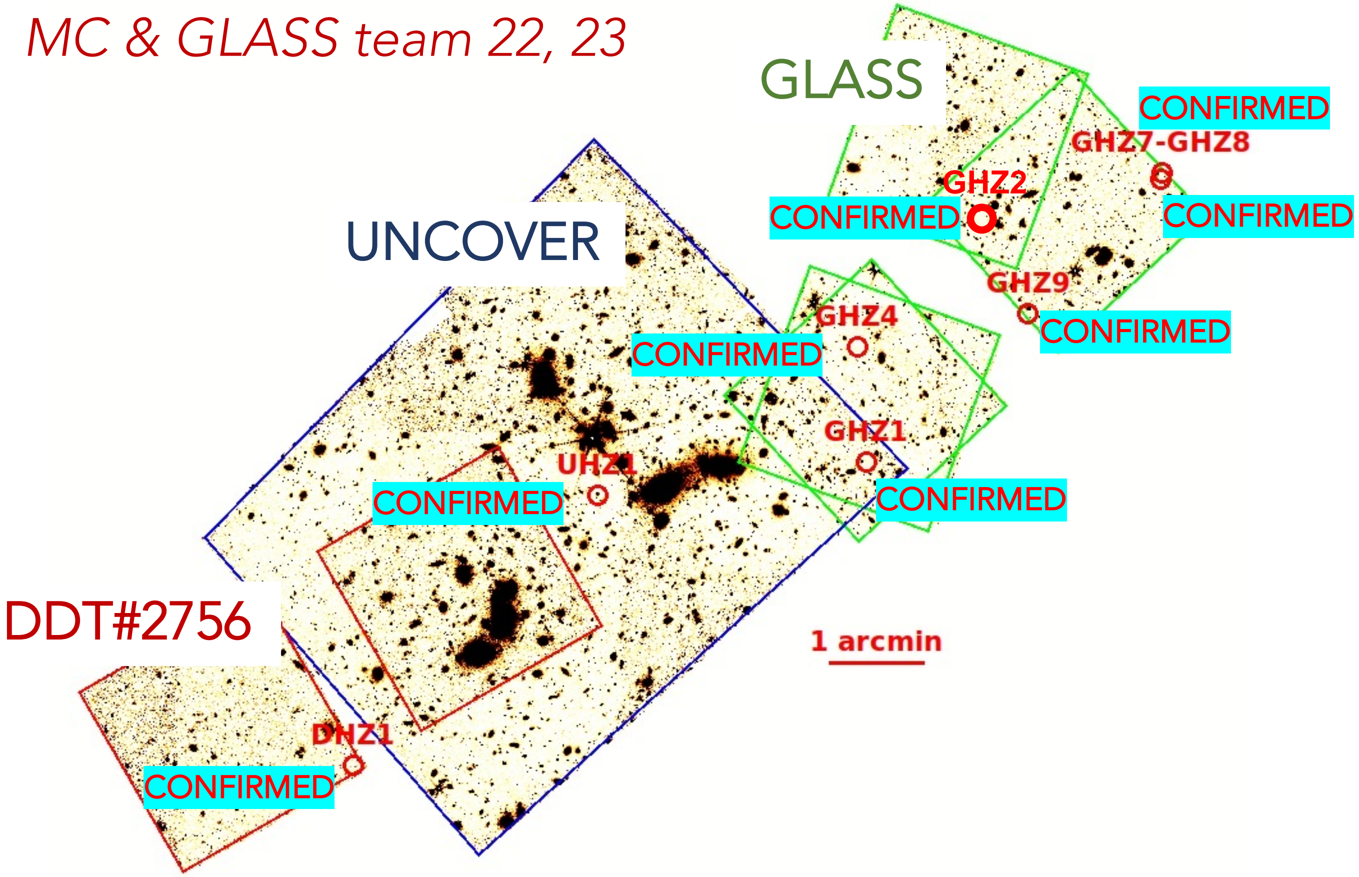
The **high-abundance** of z>9 galaxies is ***real***, the **additional z=10 excess** in the GLASS region is ***real.***

Napolitano, MC+ subm.

Spectroscopic confirmation of the high abundance at z>9



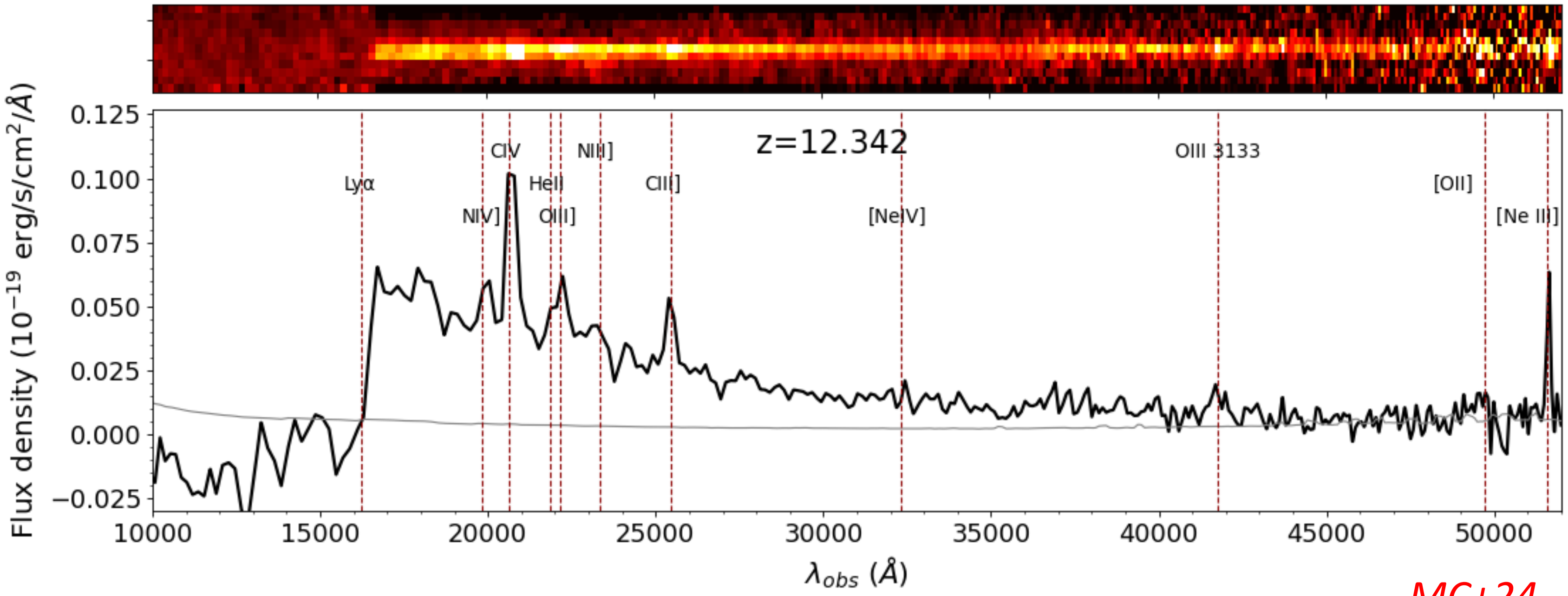
MC & GLASS team 22, 23



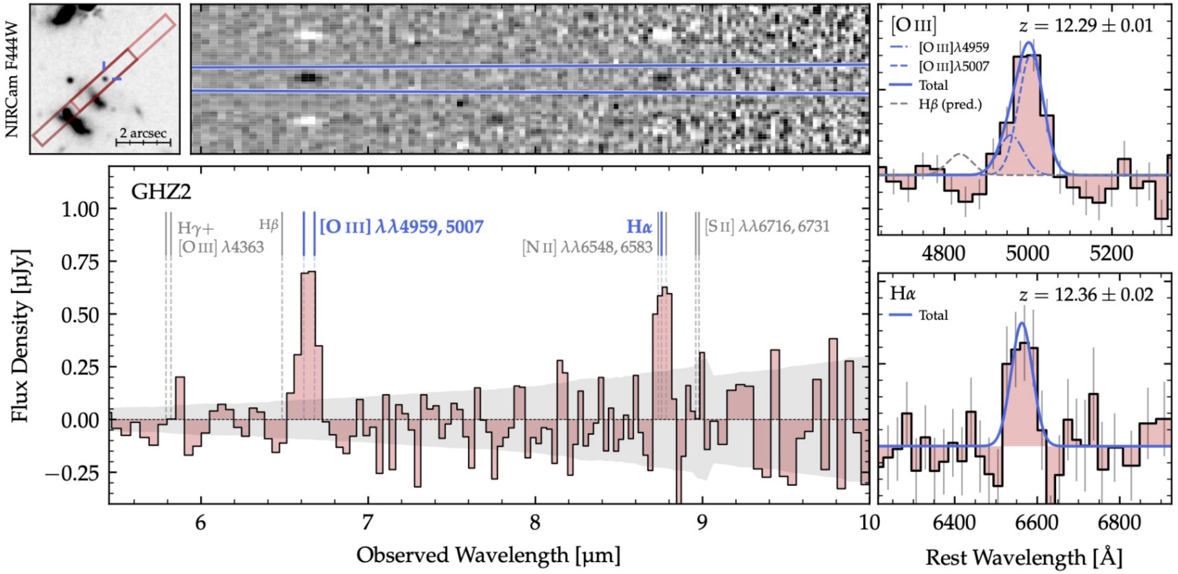
The **high-abundance** of z>9 galaxies is ***real***, the **additional z=10 excess** in the GLASS region is ***real.***

Napolitano, MC+ subm.

Spectroscopic confirmation of GHZ2/GLASS-z12 at z=12.3



MC+24

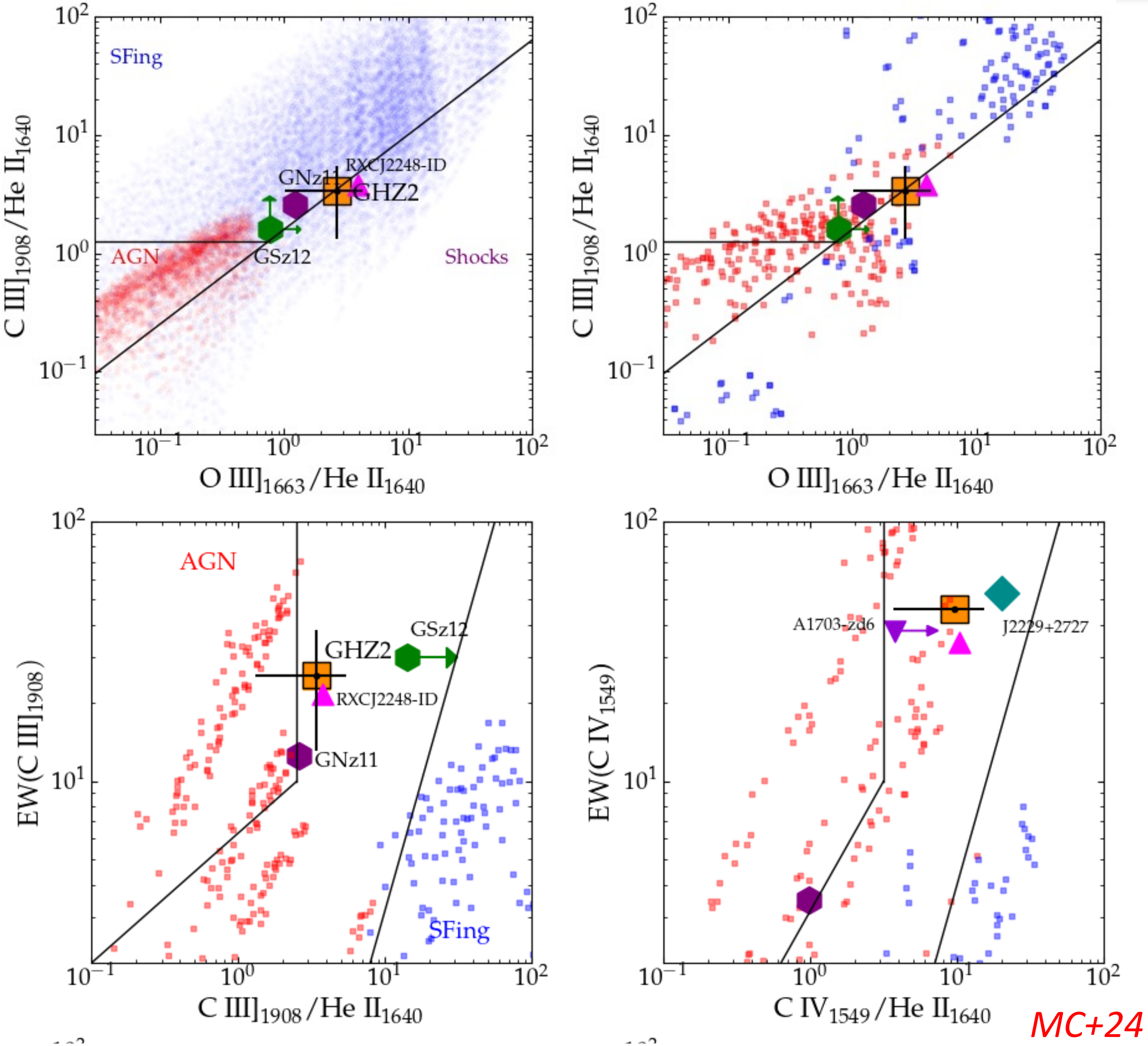


GHZ2/GLASS-z12 confirmed at z=12.34 by both NIRSpec and MIRI.

(z_{phot} =12.3 in MC+22, *zphot* code, the first JWST selections were not that bad after all…)

Zavala, MC+24 Nature in press.; Calabrò, MC+24

Star formation or AGN in GHZ2/GLASS-z12?



UV-BPT diagrams and EW diagnostics

Models from Feltre+16, Gutkin+16, Nakajima & Maiolino 2022.

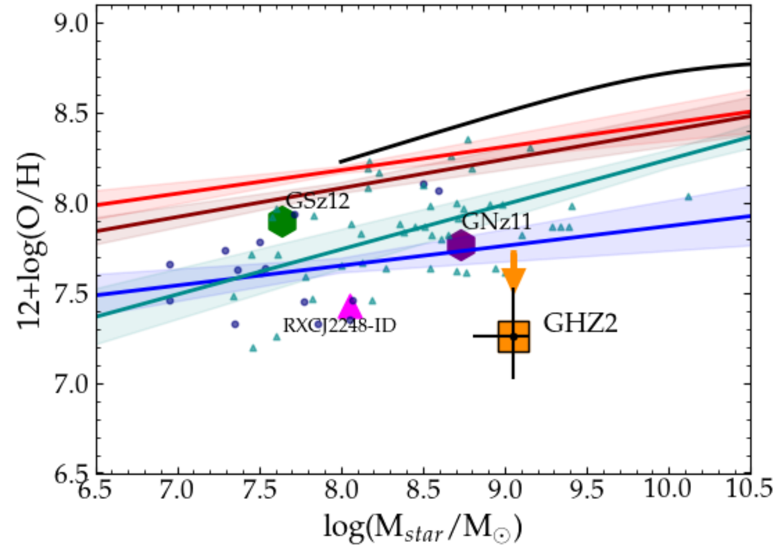
Selection criteria from Mingozzi+23, Hirschmann+19

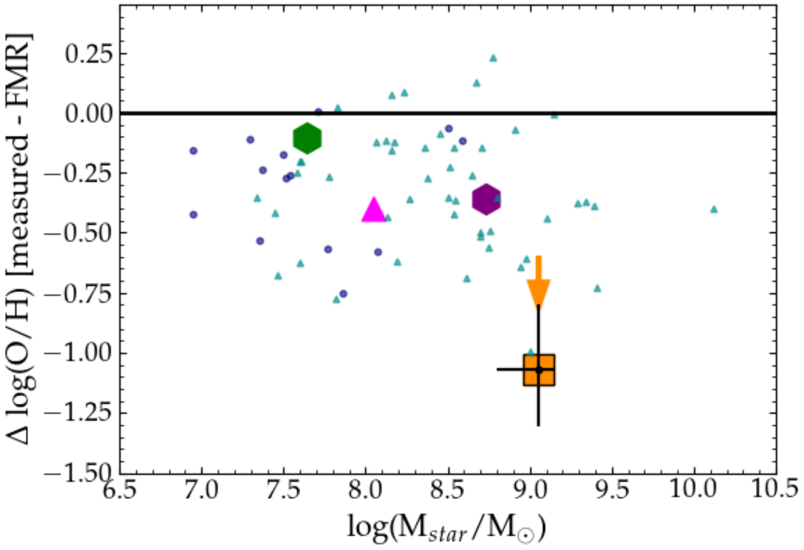
Line ratios compatible with both AGN and star-formation. EW compatible with AGN and composites.

GNz11: Bunker+23, Maiolino+23
GSz12: D'Eugenio+23
RXCJ2248-ID: Topping+24
A1703-zd6: Stark+15
J2229+2727: Izotov+24

Blue: star-forming models
Red: AGN models

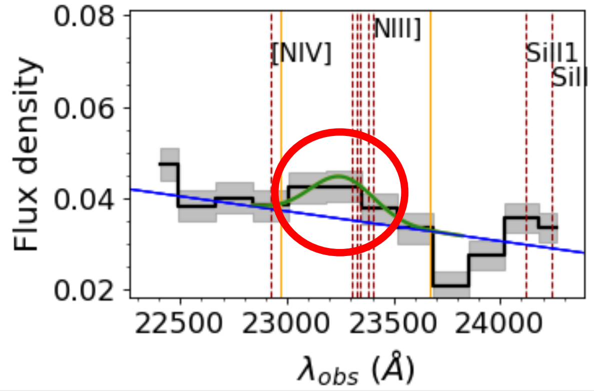
A low metallicity, highly ionizing, N-enhanced galaxy?





$M_{\rm UV}$	-20.49 ± 0.01
UV slope	-2.39 ± 0.07
$\log(M_{\rm star}/{\rm M}_\odot)$	$9.05^{+0.10}_{-0.25}$
SFR (${\rm M}_\odot\ {\rm yr}^{-1}$)	$5.2^{+1.1}_{-0.6}$
sSFR (${\rm Gyr}^{-1}$)	$4.7^{+5.1}_{-1.0}$
$\Sigma_{\rm SFR}$ (${\rm M}_\odot\ {\rm yr}^{-1}\ {\rm kpc}^{-2}$)	75 ± 4
Σ_M (${\rm M}_\odot\ {\rm pc}^{-2}$)	$16.2^{+1.1}_{-5.4} \times 10^3$
A_V (mag)	$0.04^{+0.07}_{-0.03}$
12 + log(O/H)	$7.26^{+0.27}_{-0.24}$
$\log U$	-1.78 ± 0.28

Star-forming scenario for GHZ2:
Compact star-forming region hosting star clusters with massive stars enriching ISM with Nitrogen (GC progenitor?).
Low metallicity, high ionization parameter, likely Ly-c emitter.
Significant deviation from the FMR



Metallicity and ionization :

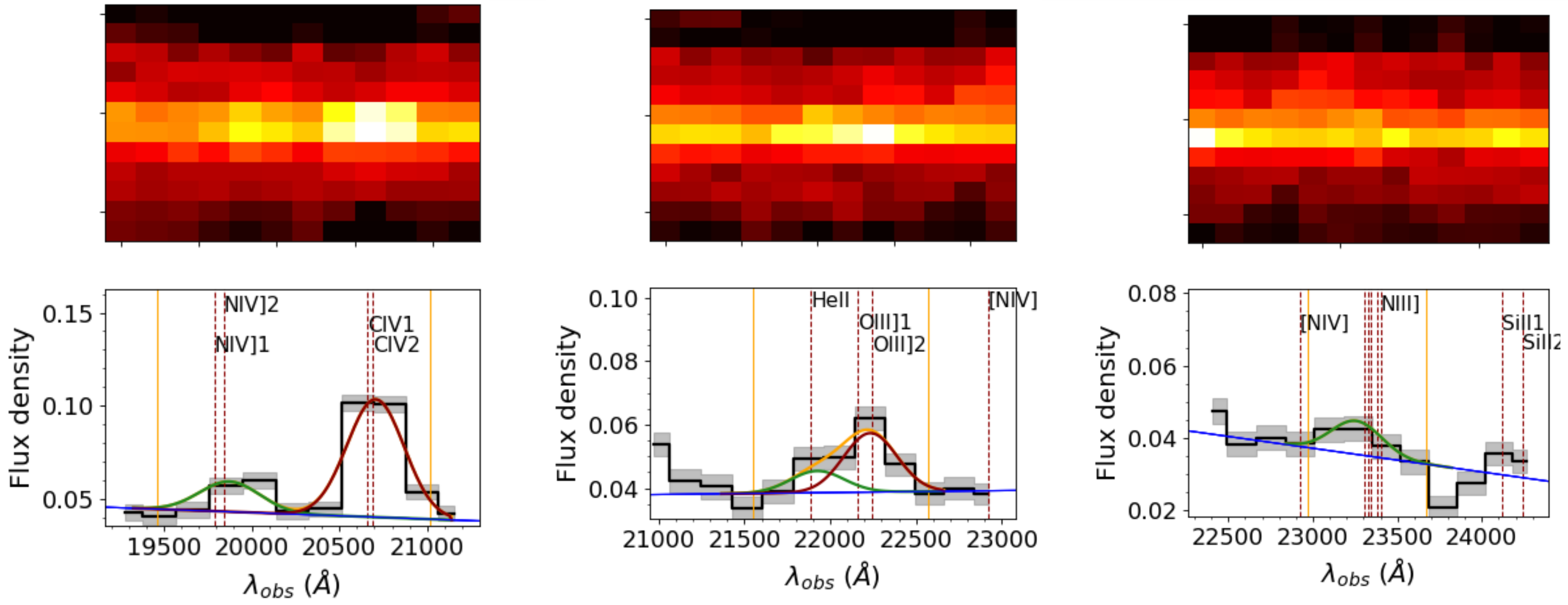
$Z < 0.1\ Z_{sun}$
log(U) > -2
N/O ~ 4-5 x solar *
C/O ~ 0.2-0.5 x solar

Global properties :

Very compact R_h<100 pc
log(M)>8.5 M_{sun}
SFR ~5-10 M_{sun}/yr

* NIII] meas. dependent on local continuum estimate, to be confirmed at higher resolution

We need high resolution to understand GHZ2/GLASS-z12



Several emission lines detected at high SNR:

NIV]λ1488, CIVλ1549, HeII λ1640, OIII] λ1663, CIII] λ1909, OII] λ3727, [NeIII] λ3868

NIV]λ1488 doublet: density probe, N-abundance

CIVλ1549 doublet: broad components, winds, C-abundance

HeII λ1640: ionization source

OIII] λ1663 doublet: density probe, metallicity

NIII] λ1750 multiplet: density probe, N-abundance

Resolving blended lines and doublets is fundamental to understand ISM conditions and ionization sources.

R>1000 is needed in most cases

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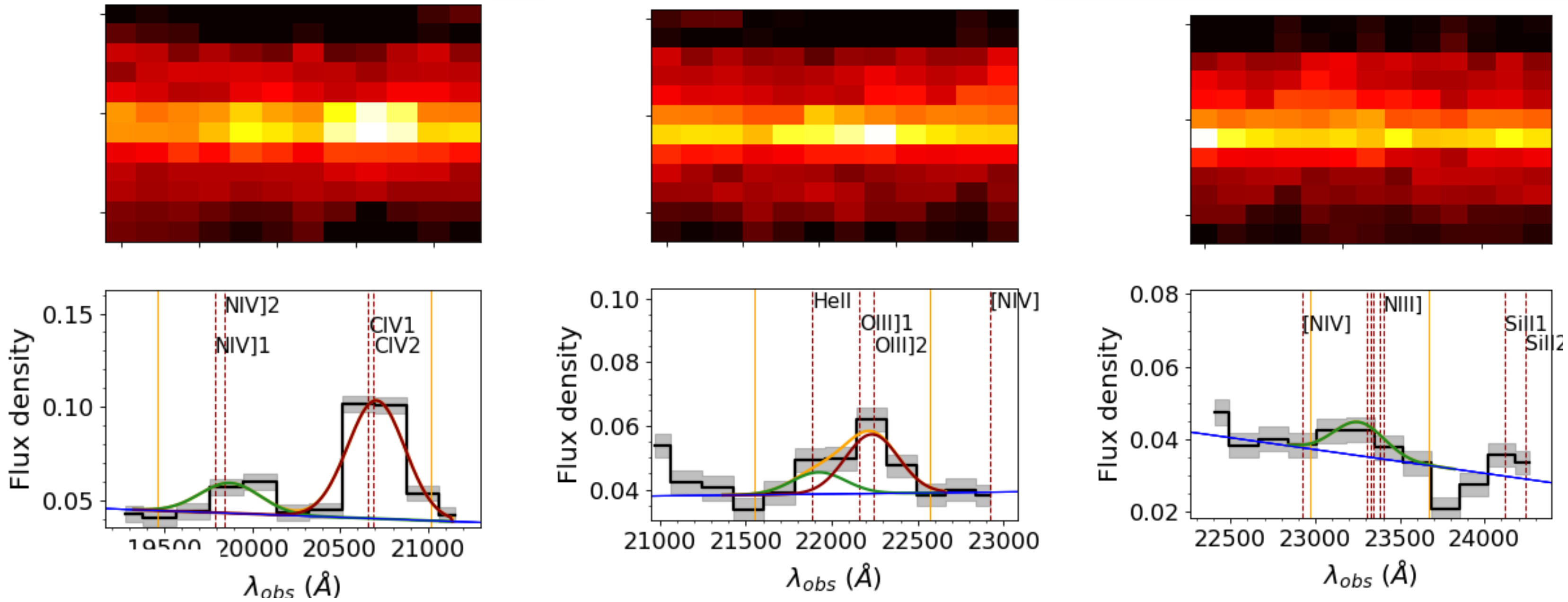

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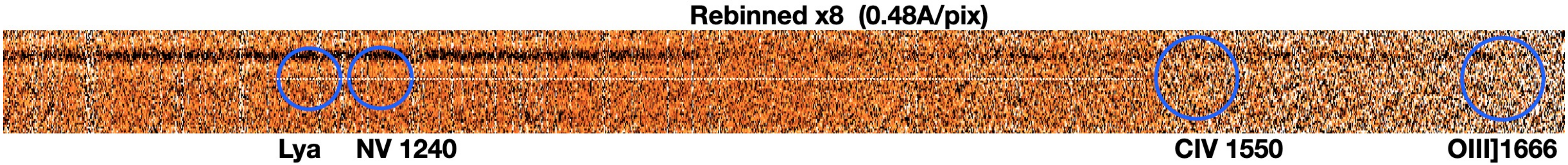
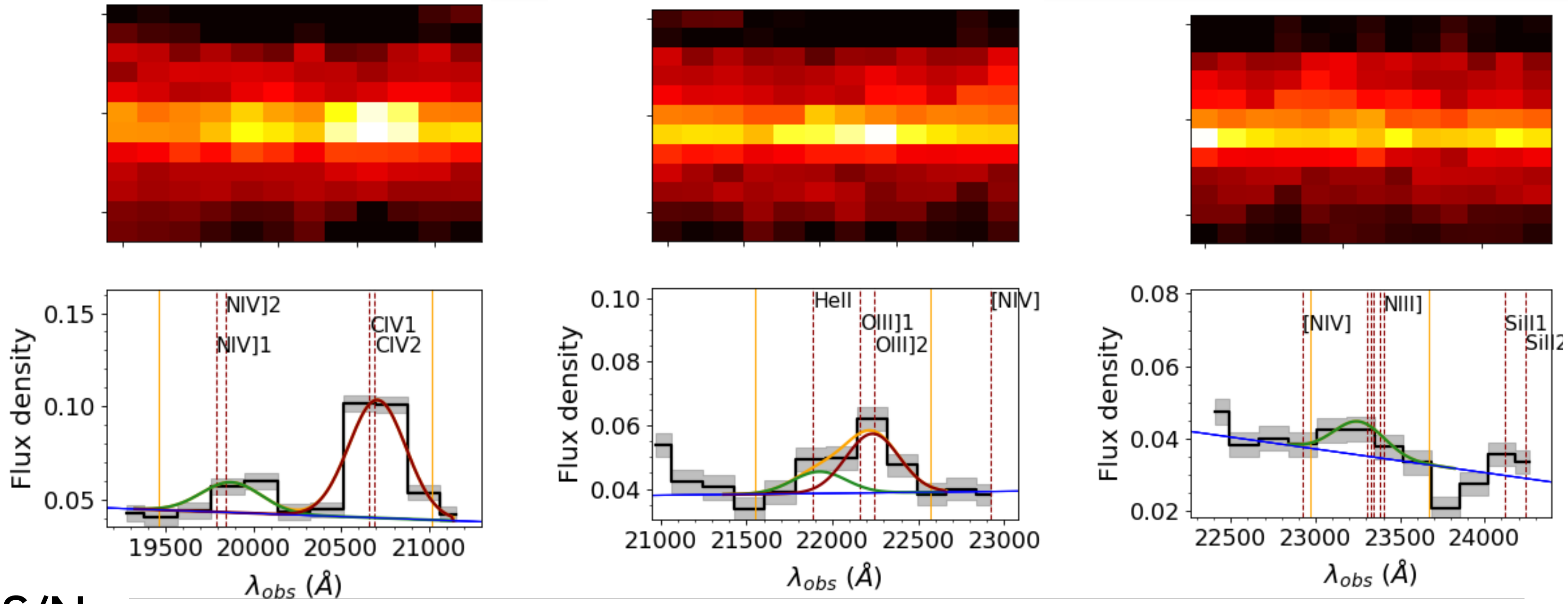


30 hours spectroscopic follow-up with X-Shooter (PI Vanzella) compared to NIRSPec PRISM. SNR~4 detection of CIV (after some binning). Highest redshift reached from the ground.

Enables *limits* where NIRSpec PRISM is heavily affected by ISM and IGM: NVλ1240<1/4 CIVλ1550

MC+24

We need high resolution to understand GHZ2/GLASS-z12



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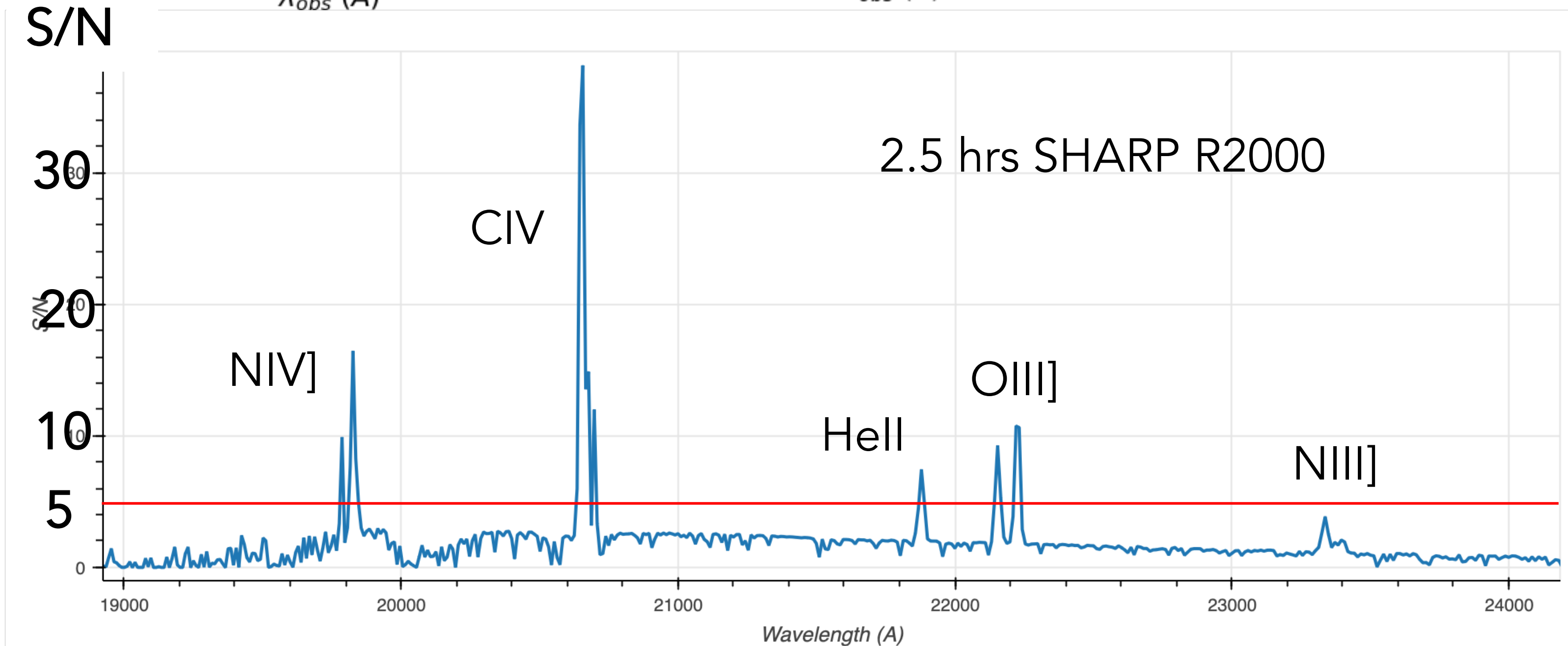
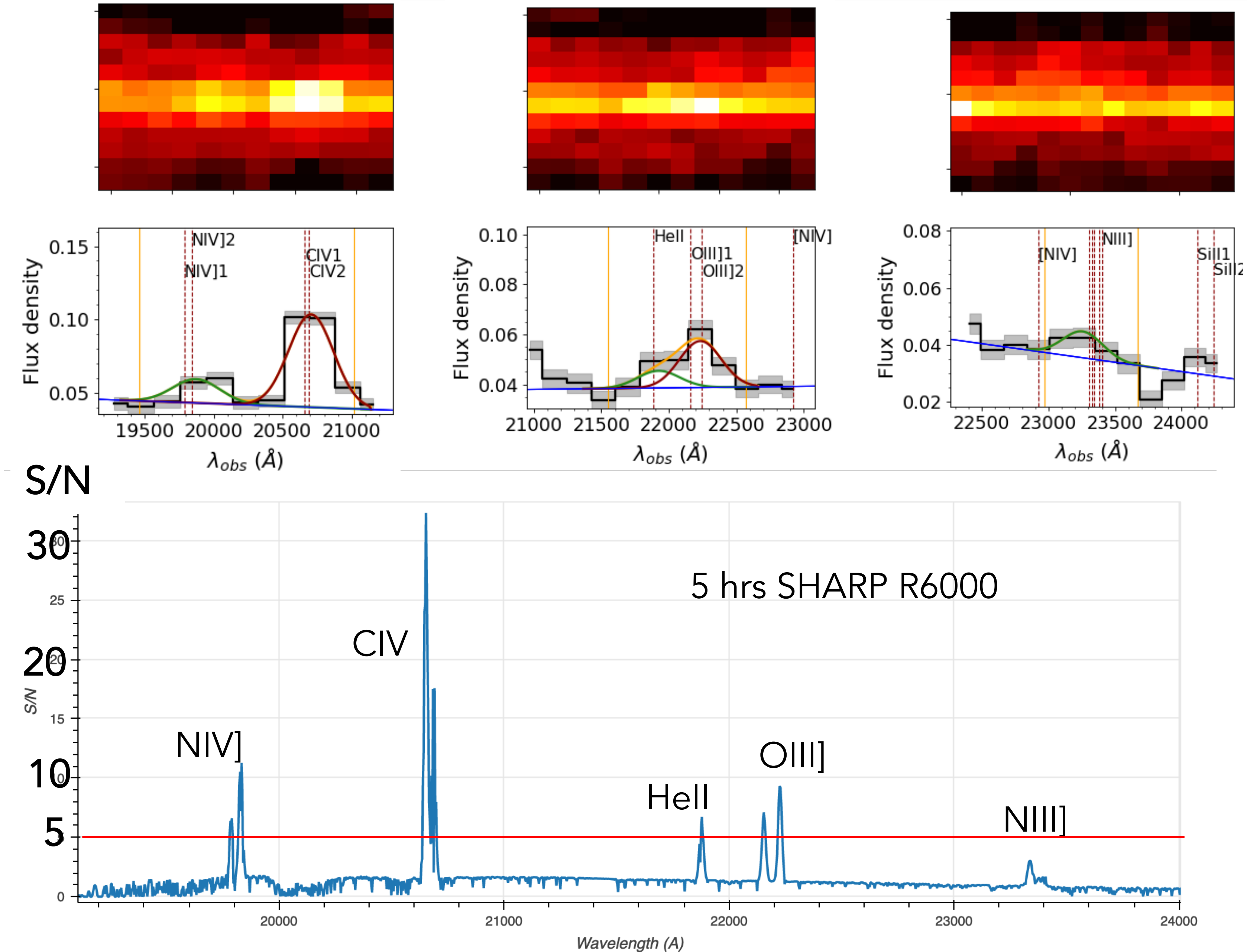


A few hours with SHARP R=2000 will measure most of the line components at SNR>5

We need high resolution to understand GHZ2/GLASS-z12



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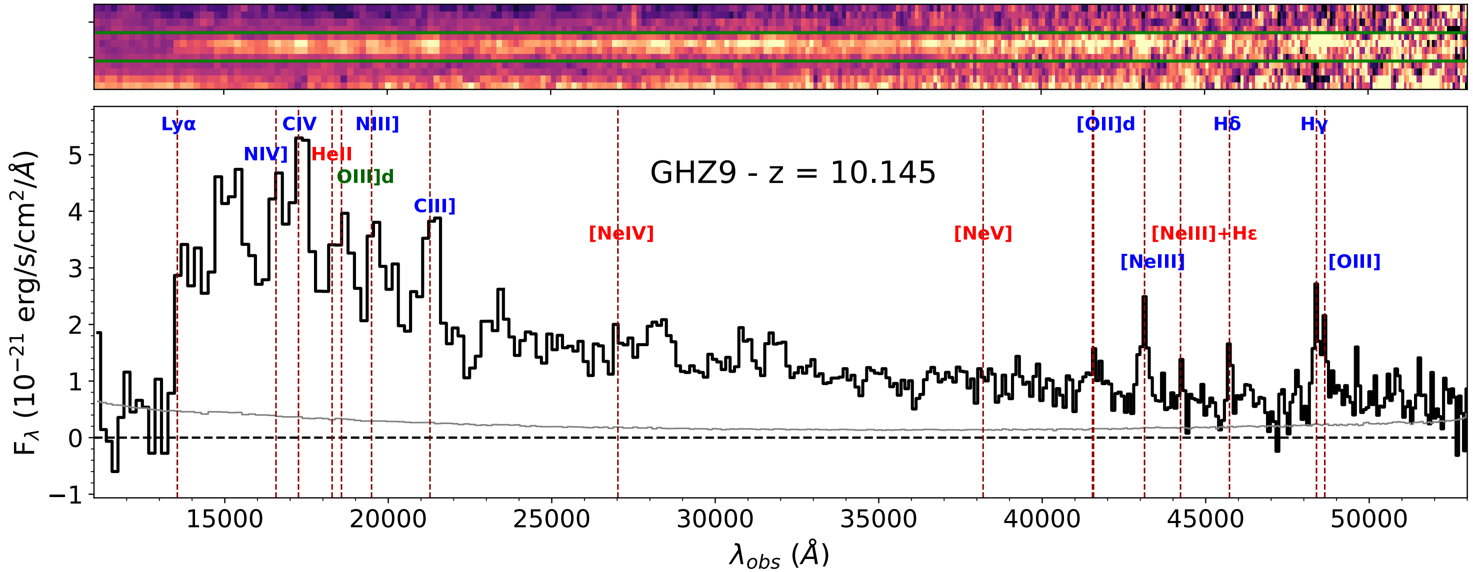
A few hours with SHARP R=6000 will measure most of the line components at SNR>5

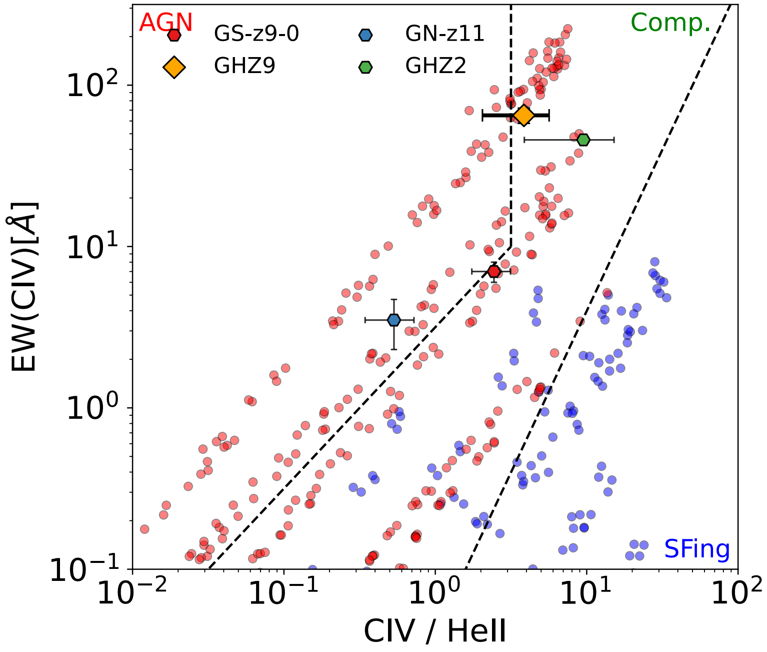
The AGN candidate GHZ9 at z=10.145

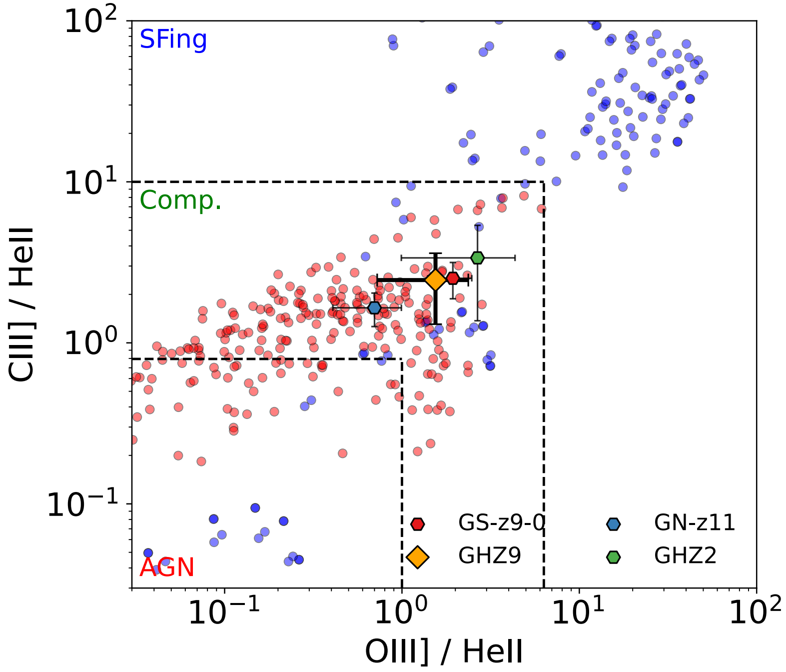


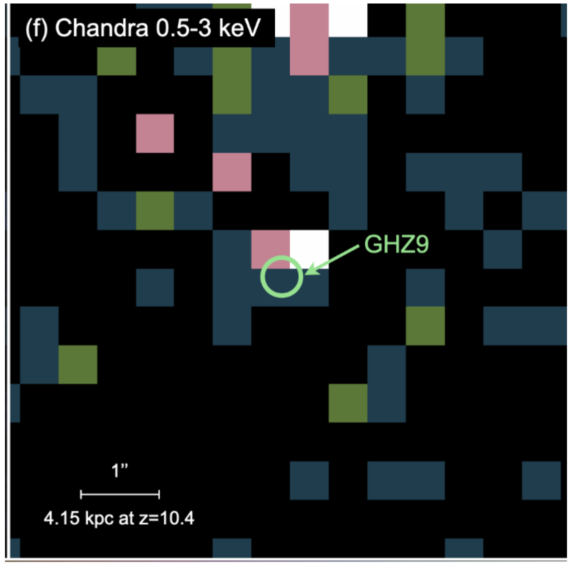
Line ratios and EW compatible AGN and composites.

Nitrogen-enhanced.

Associated to X-ray emission implying a M_{BH}~10^8 M_{sun}



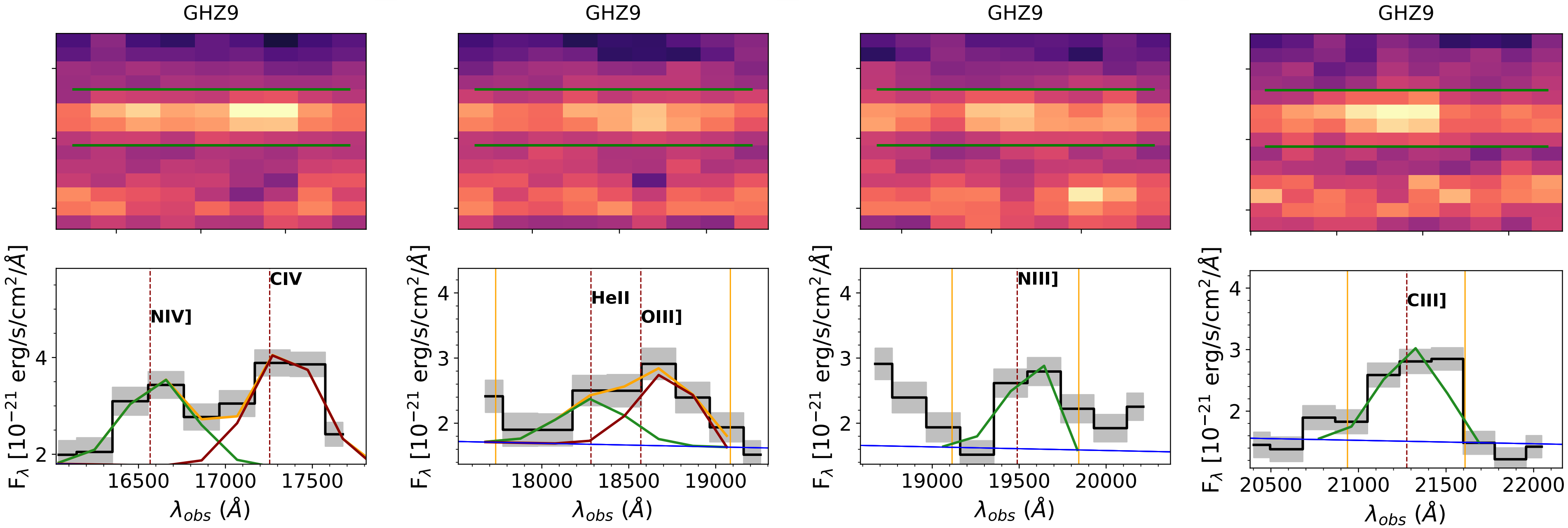




Napolitano, MC+ in prep.

Kovacs+24

WE NEED HIGH RESOLUTION TO UNDERSTAND GHZ9



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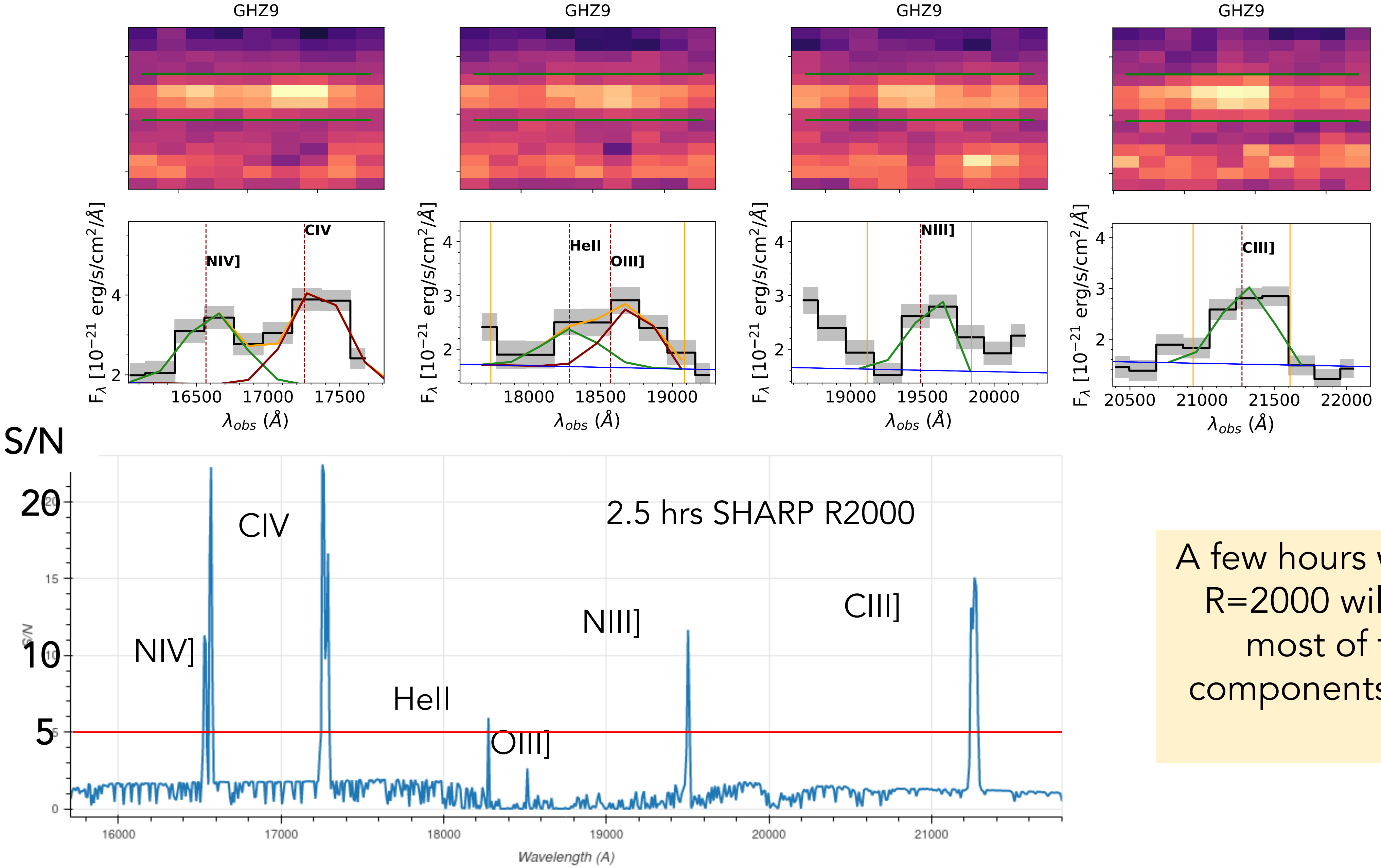
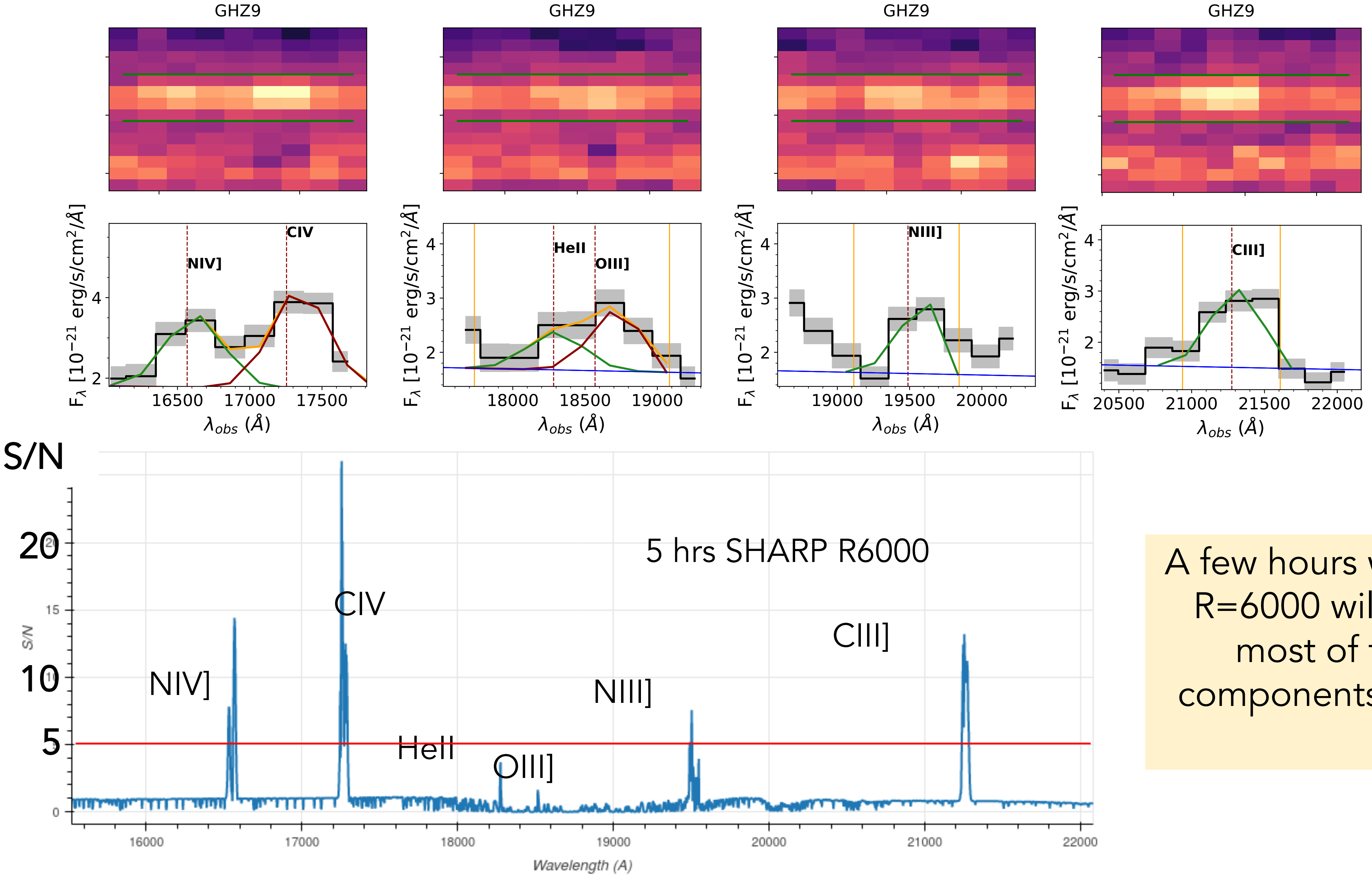
R>1000 is needed in most cases

We need high resolution to understand GHZ9



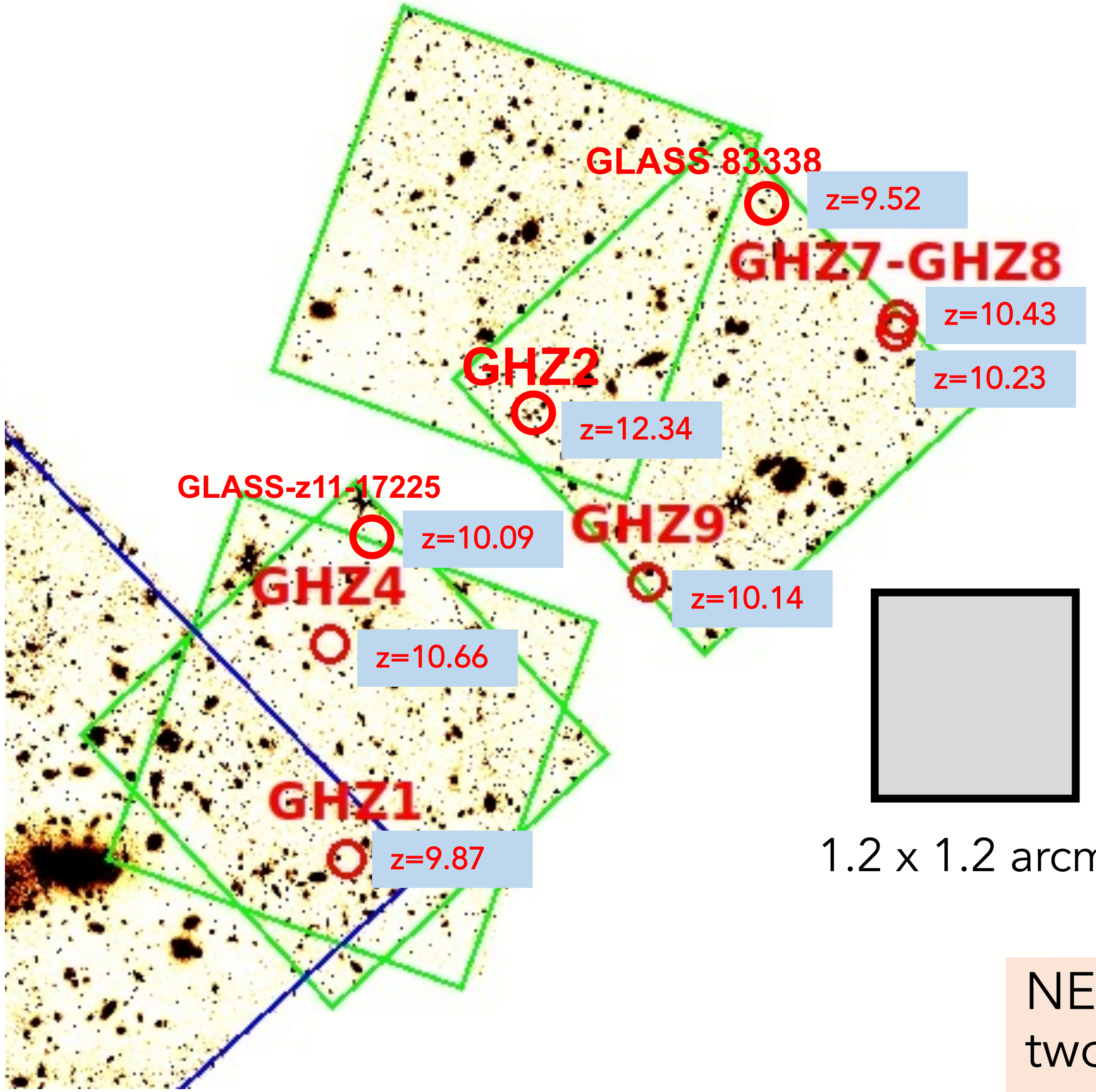
A few hours with SHARP R=2000 will measure most of the line components at SNR>5

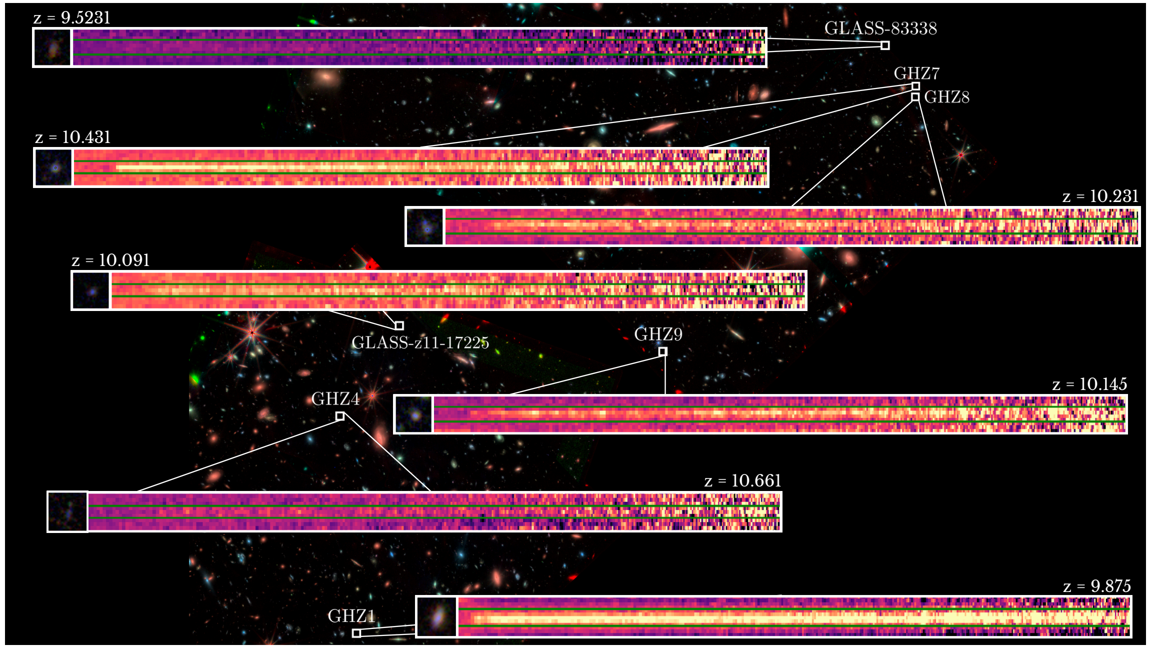
We need high resolution to understand GHZ9



A few hours with SHARP R=6000 will measure most of the line components at SNR>5

We need high resolution to understand GHZ9

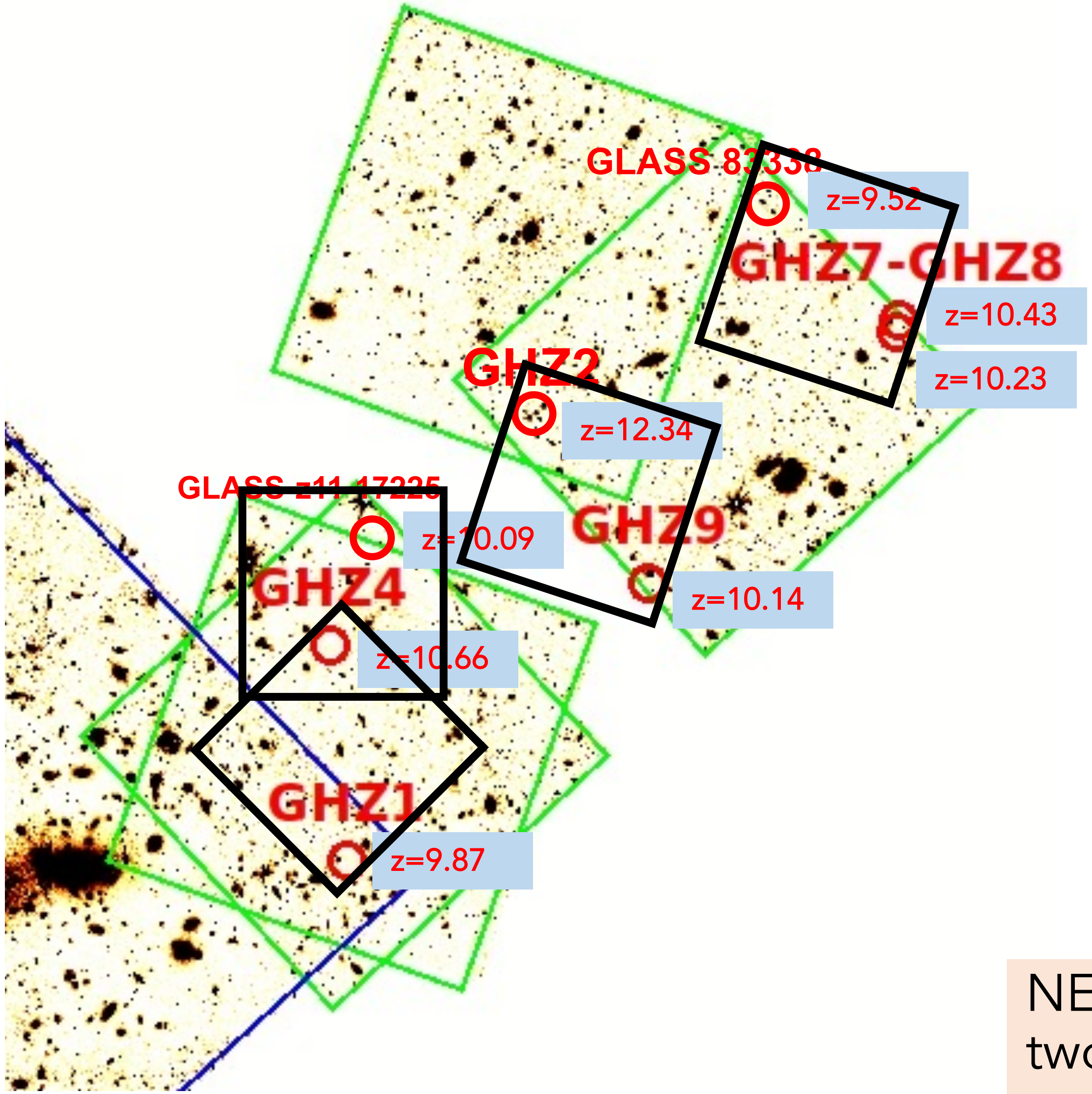


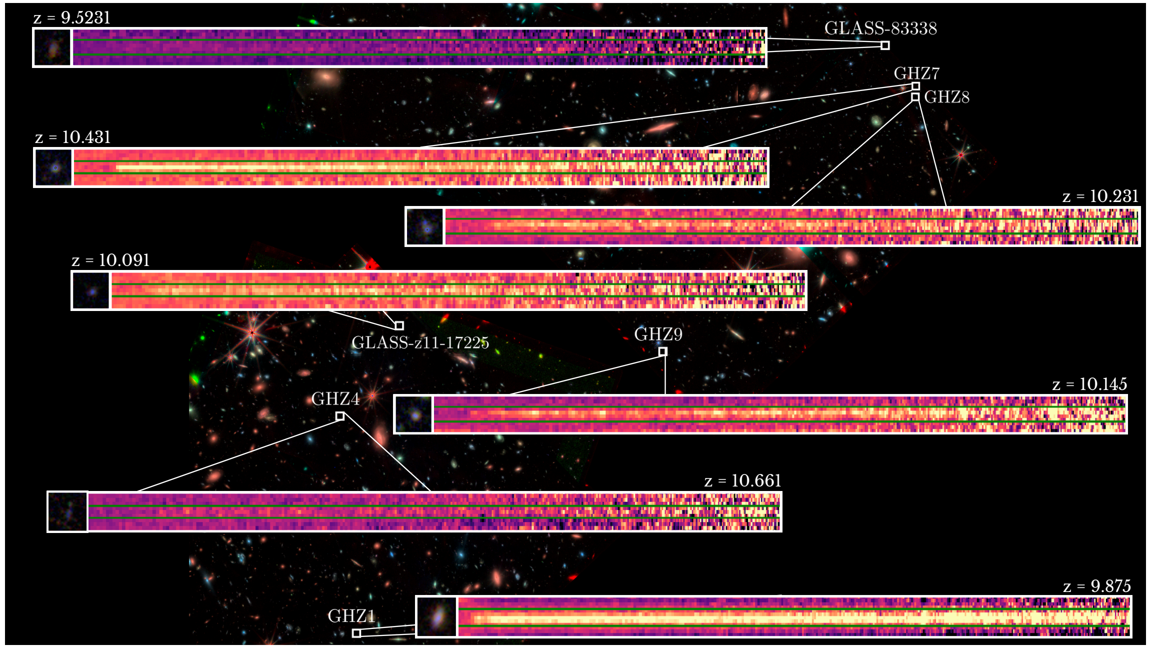


1.2 x 1.2 arcmin

NEXUS AO-corrected FoV large enough to observe two/three targets at once in the GLASS-ERS region.

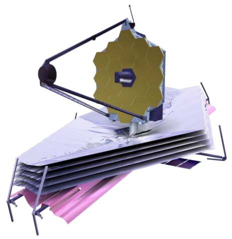
We need high resolution to understand GHZ9





NEXUS AO-corrected FoV large enough to observe two/three targets at once in the GLASS-ERS region.

Take-home messages



- JWST has discovered a high abundance of galaxies and AGN at high-redshift. Why? Many hypothesis on the table.
- Spectroscopic follow-up of these objects is essential to answer these questions.
- The A2744 field is among the richest to explore at z>9.
- NIRSpec GO-3073: successful confirmation of 8 galaxies at z~9-12 including the M_{UV}=-20.5 object GHZ2/GLASS-z12 at z=12.34, and the likely AGN GHZ9 at z=10.145.
- High-resolution is essential to constrain the physical properties of these ambiguous objects.
- SHARP-NEXUS can efficiently observe them at R=2000/6000 in a modest amount of time. Two/three targets per FoV in the GLASS-ERS region.
- Ideal timeframe: JWST is collecting and performing first investigations of bright galaxies at cosmic dawn, providing plenty of targets for higher-resolution ELT MOS and IFS.