

GLASS ERS

Through the looking **GLASS**:
A JWST exploration of Galaxy
Formation and Evolution from
Cosmic dawn to present day

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&

The GLASS-ERS Team (PI: T. Treu)

Science Drivers

1) The Epoch of Re-ionization

- Which objects are responsible for re-ionizing the Universe?
- What are the physical parameters of the ionizing population?
- How do these compare with parameters of galaxies after the EoR?
- When was the Universe fully ionized, i.e. when did the EoR end?
- Is the spatial extent/position of Ly α similar to after the EoR?

2) The Baryon Cycle

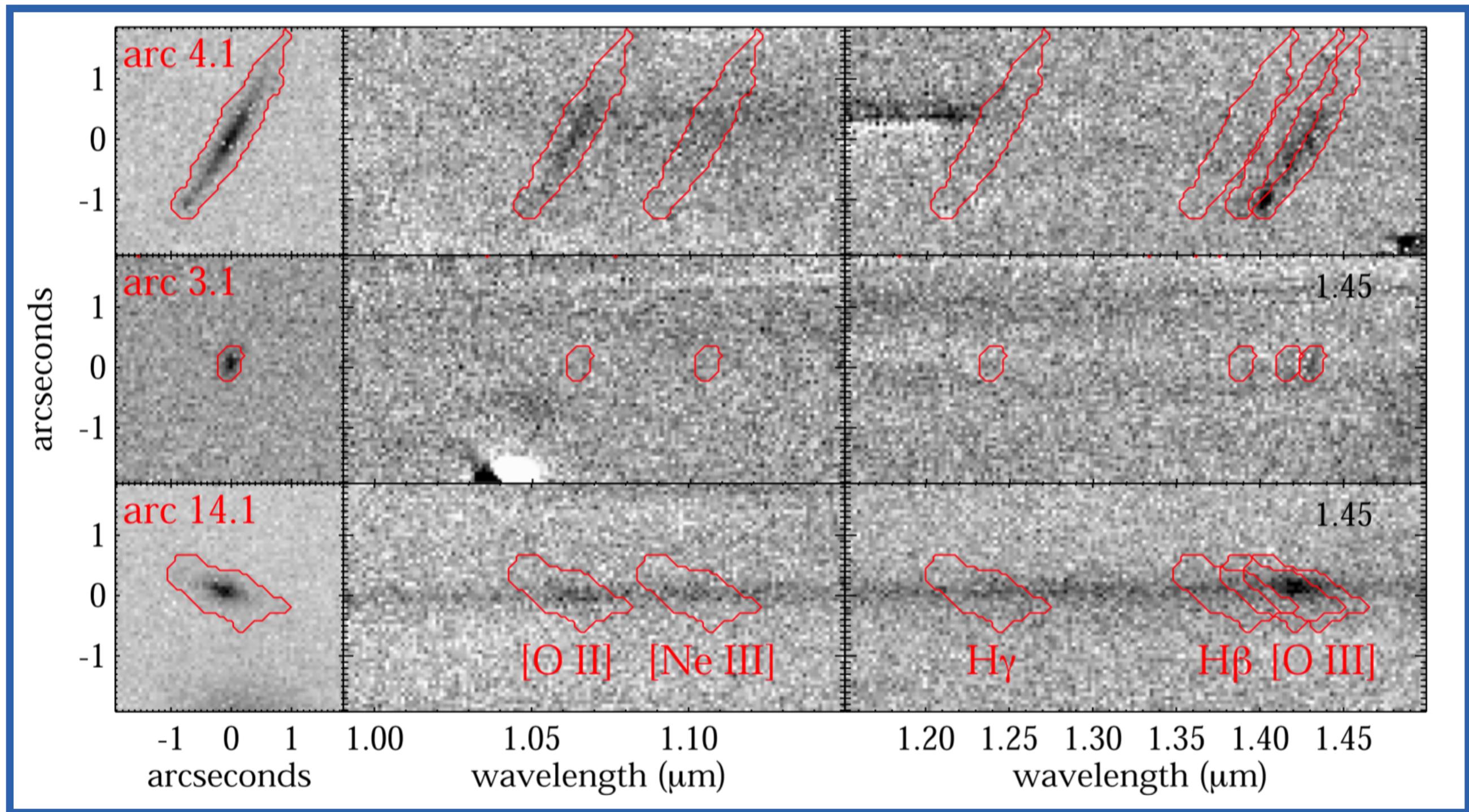
- How do baryons cycle in and out of galaxies?
- How are baryons redistributed in the ISM and CGM?
- How are metals and dust spatially distributed out to $z \sim 3.5$?
- Is that different from the metal distribution $z < 2$?
- What is the metal content of galaxies in the EoR?

GLASS (P.I. T. Treu)

THE GRISM LENS-AMPLIFIED SURVEY FROM SPACE

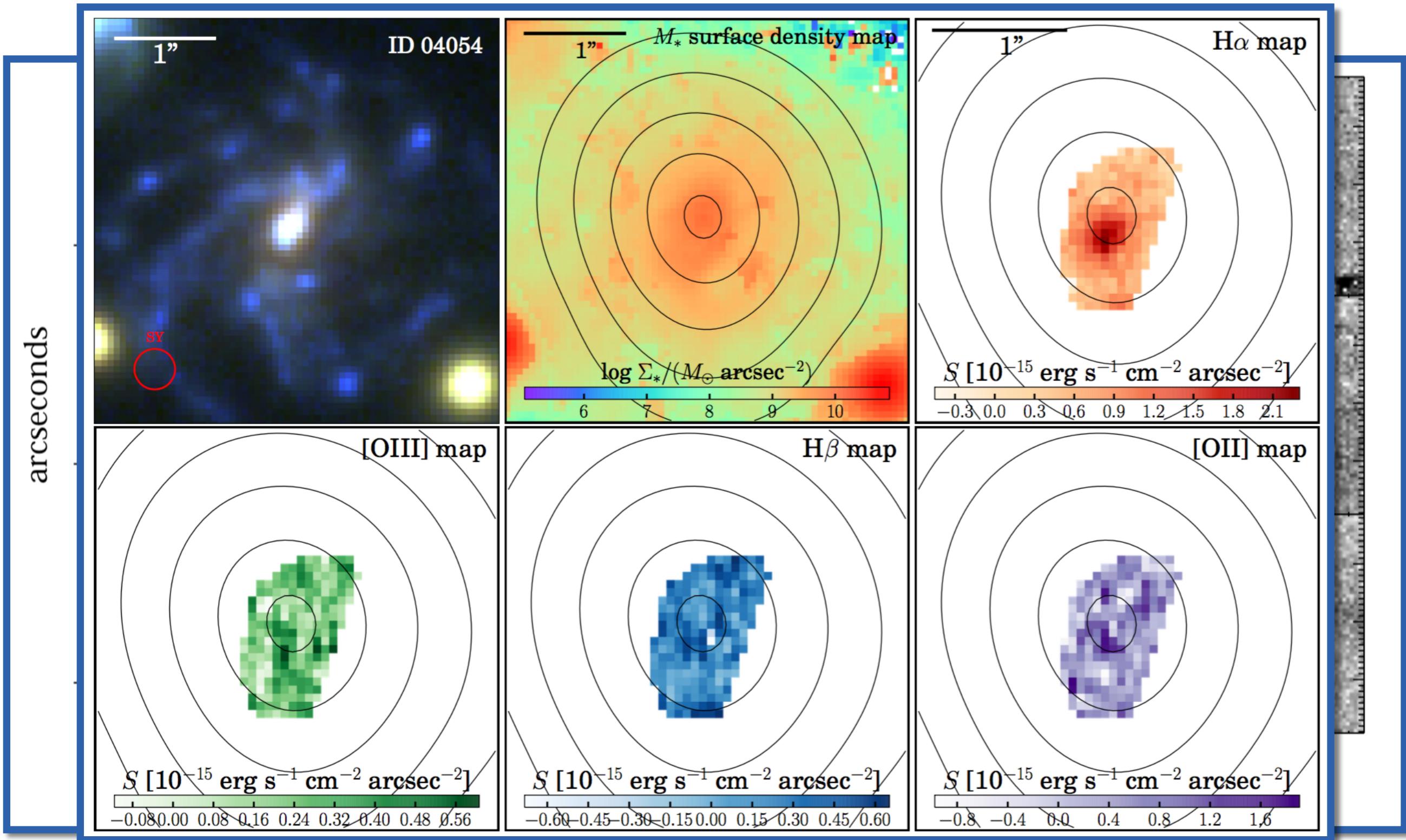
- HST Grism Spectroscopy of 10 Massive Galaxy Clusters (Incl. HFF)
- Wavelength coverage:
 - Cluster: 8000Å - 16500Å (**G102 + G141**) 140 orbits (~90 hours)
 - Parallel: 5500Å - 10000Å (**G800L**) 140 orbits (~90 hours)
- Spectroscopic 1σ limits: $5\text{e}-18 \text{ erg/s/cm}^2$ (excl. 2 PAs and μ)
- Details about the survey:
 - KBS+14, Treu, KBS+15, <http://glass.astro.ucla.edu/>
- Data releases:
 - <https://archive.stsci.edu/prepds/glass/>

Metallicity from HST grisms



Jones+15, Wang+17, Wang+in prep.

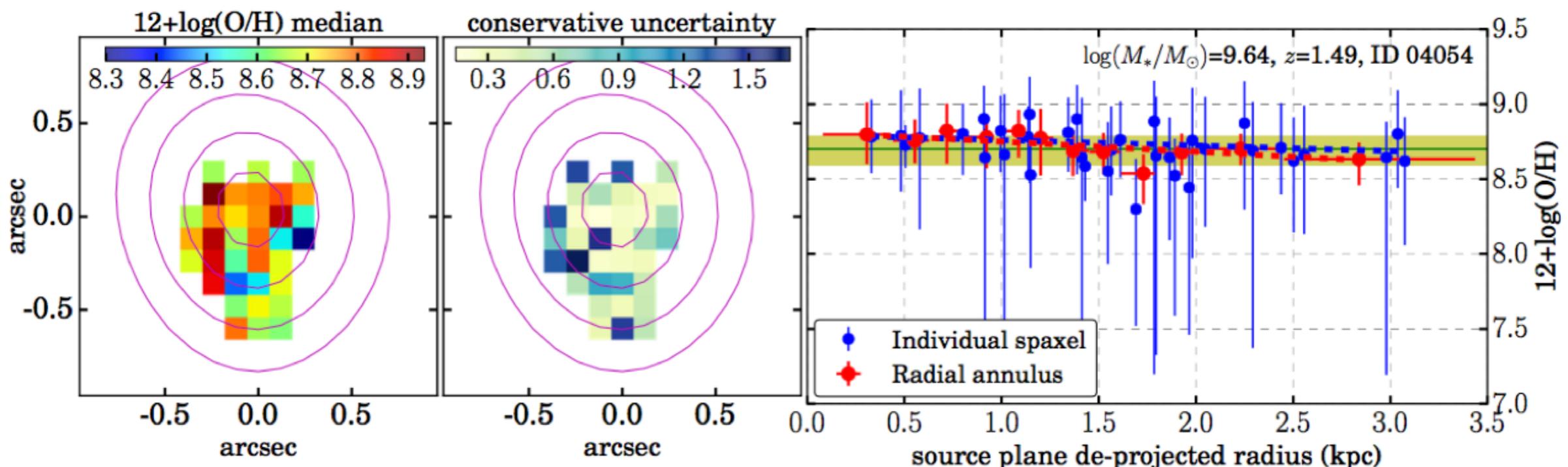
Metallicity from HST grisms



Jones+15, Wang+17, Wang+in prep.

Metallicity from HST grisms

- Bayesian inference of gas-phase metallicity (and $A_{v,\text{neb.}}$; $f_{H\beta}$) from f_{EL}
 - Based on Maiolino+2008 calibrations
 - But no direct comparison to M08 calib. avoiding biases at low S/N



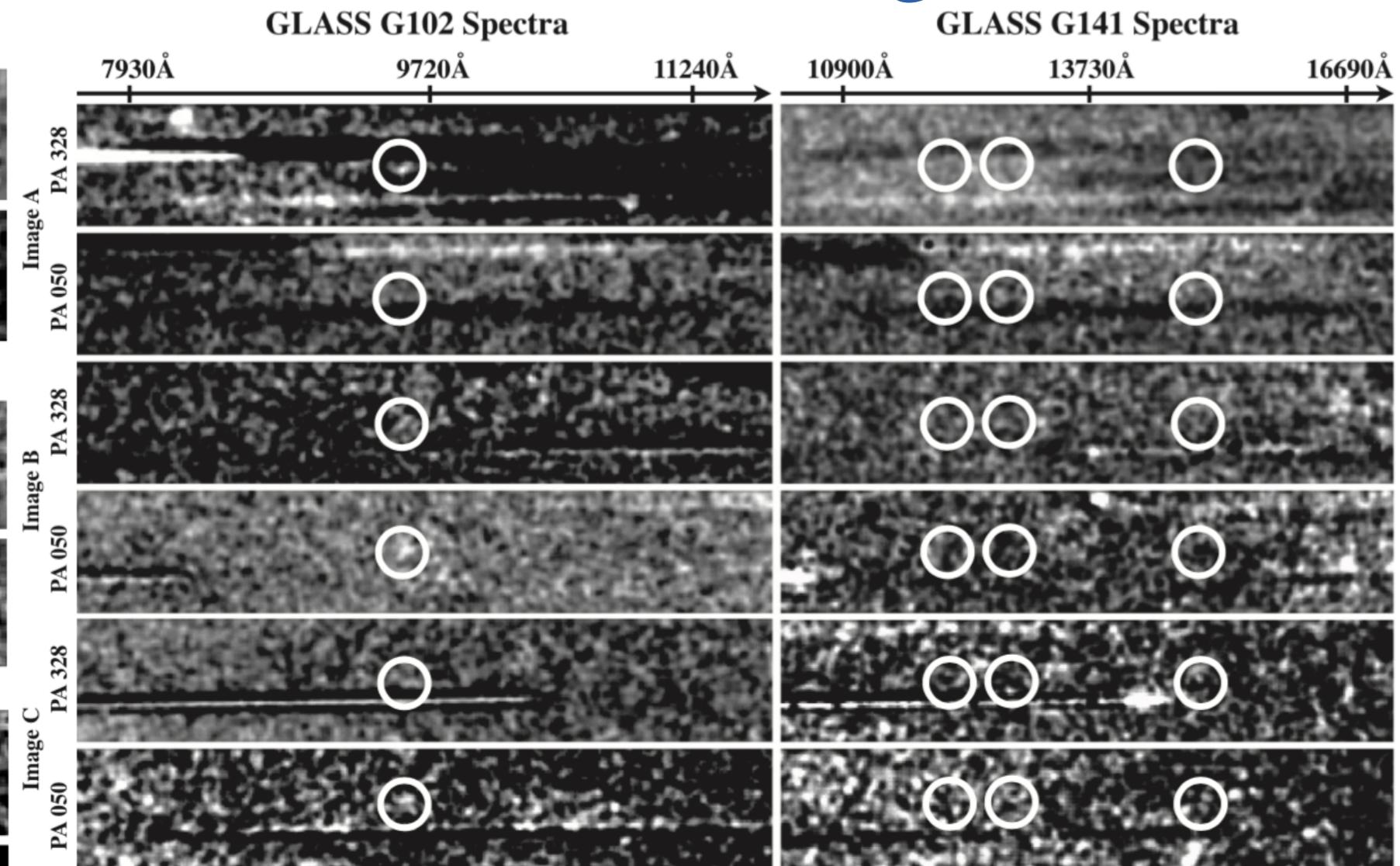
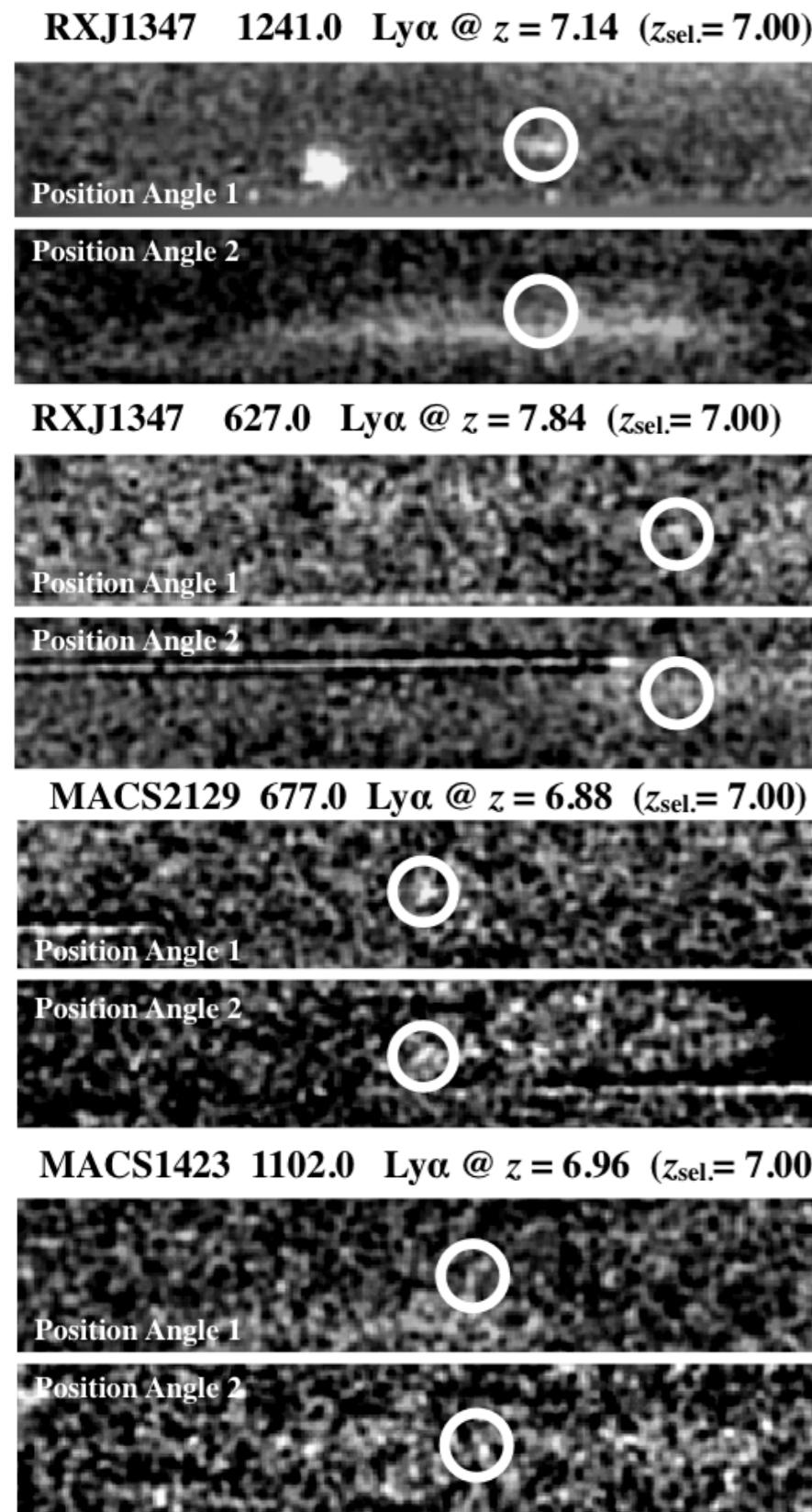
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AIP
KBS+16



Probing the EoR with the HST grisms



Huang+16 Ly α @ 6.85

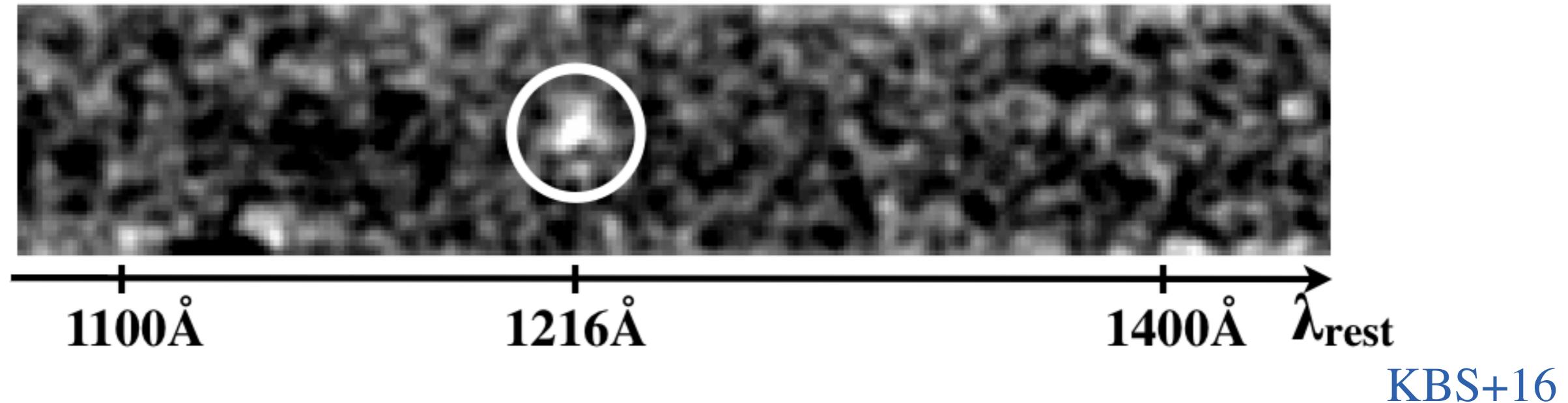
Expected [OIII] @ 157
Expected CIV @ 6.85
Expected CIII @ 6.85

Several LAEs confirmed with ground-based follow-up

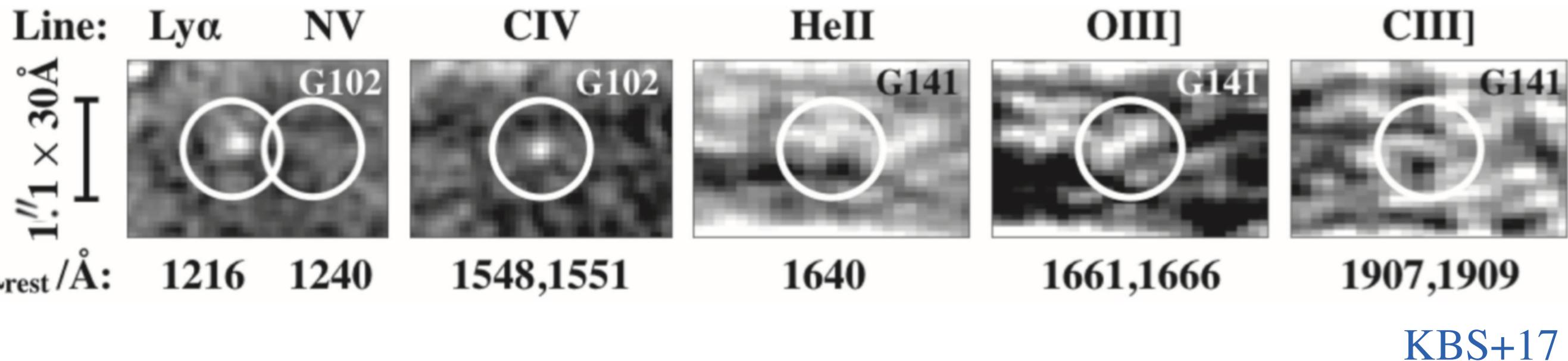
Probing intrinsic parameters:
 M^* down to a few $\times 10^6$
 L_{UV} down to $\sim 0.15 \times L^*_{\text{UV}}$

Probing the EoR with the HST grisms

Probing the spatial extent of Ly α at $z \sim 7$ in stack of LAEs from 6 clusters



Detecting rest-frame UV lines (probing galaxy physics) of lensed $z = 6.11$ source



GLASS ERS (P.I. T. Treu)

<http://glass.astro.ucla.edu/ers/>

- Build on the experiences gained from **GLASS** wrt. science drivers:
 - Which sources re-ionized the Universe?
 - How do baryons cycle in and out of galaxies?
- Aim:
 - Obtain NIRISS slitless spectroscopy on a massive galaxy cluster
 - Complement with NIRSpec high-resolution
 - Attach NIRCAM parallels for $z > 7$ dropout selections and SED science
- Slitless: We know Ly α is extended and sometimes offset from continuum
- Slitless: Slit losses are real

Target: A2744

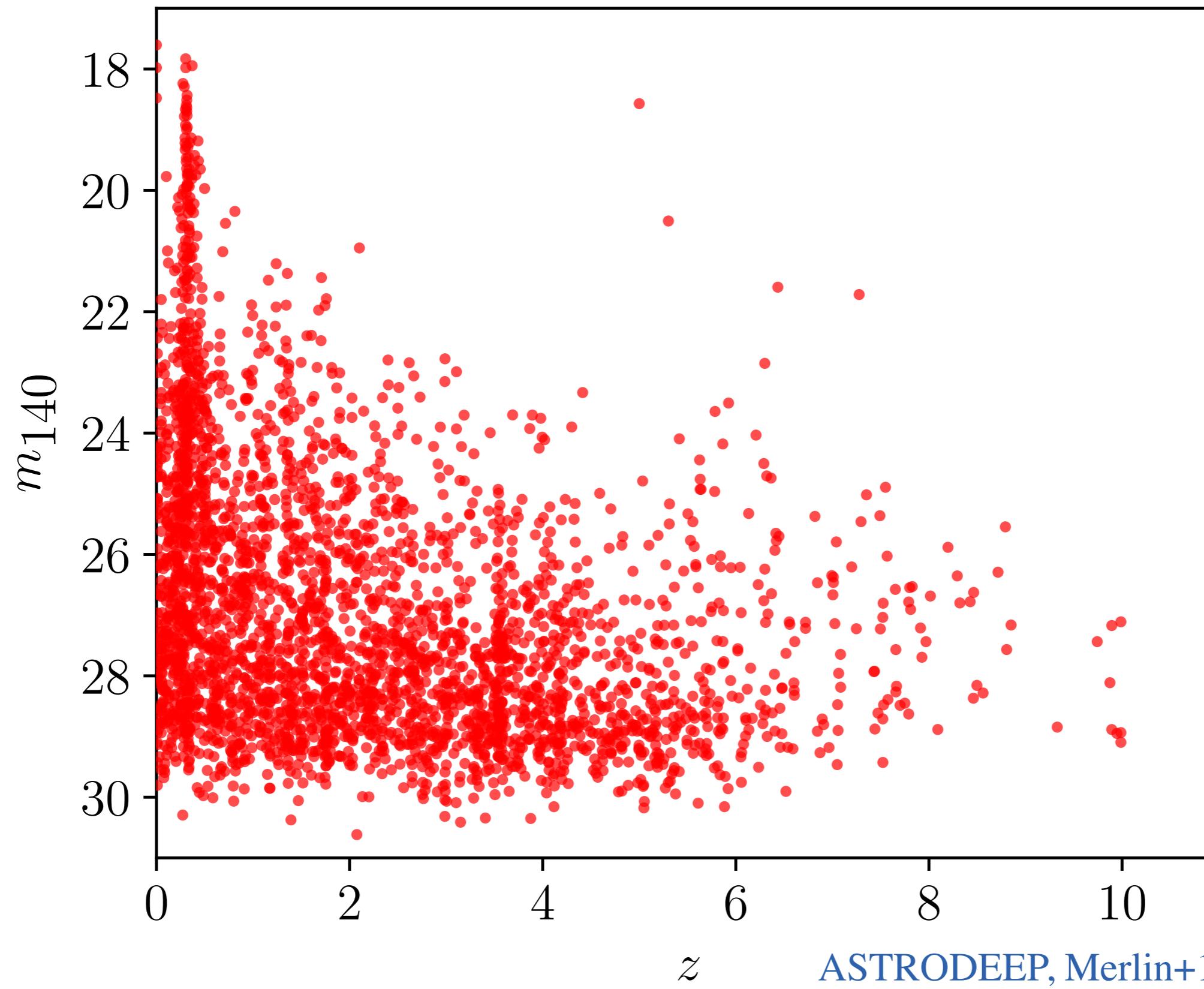


Available Ancillary data:
(for target selection and comparison)



etc.

Target: A2744 Sources

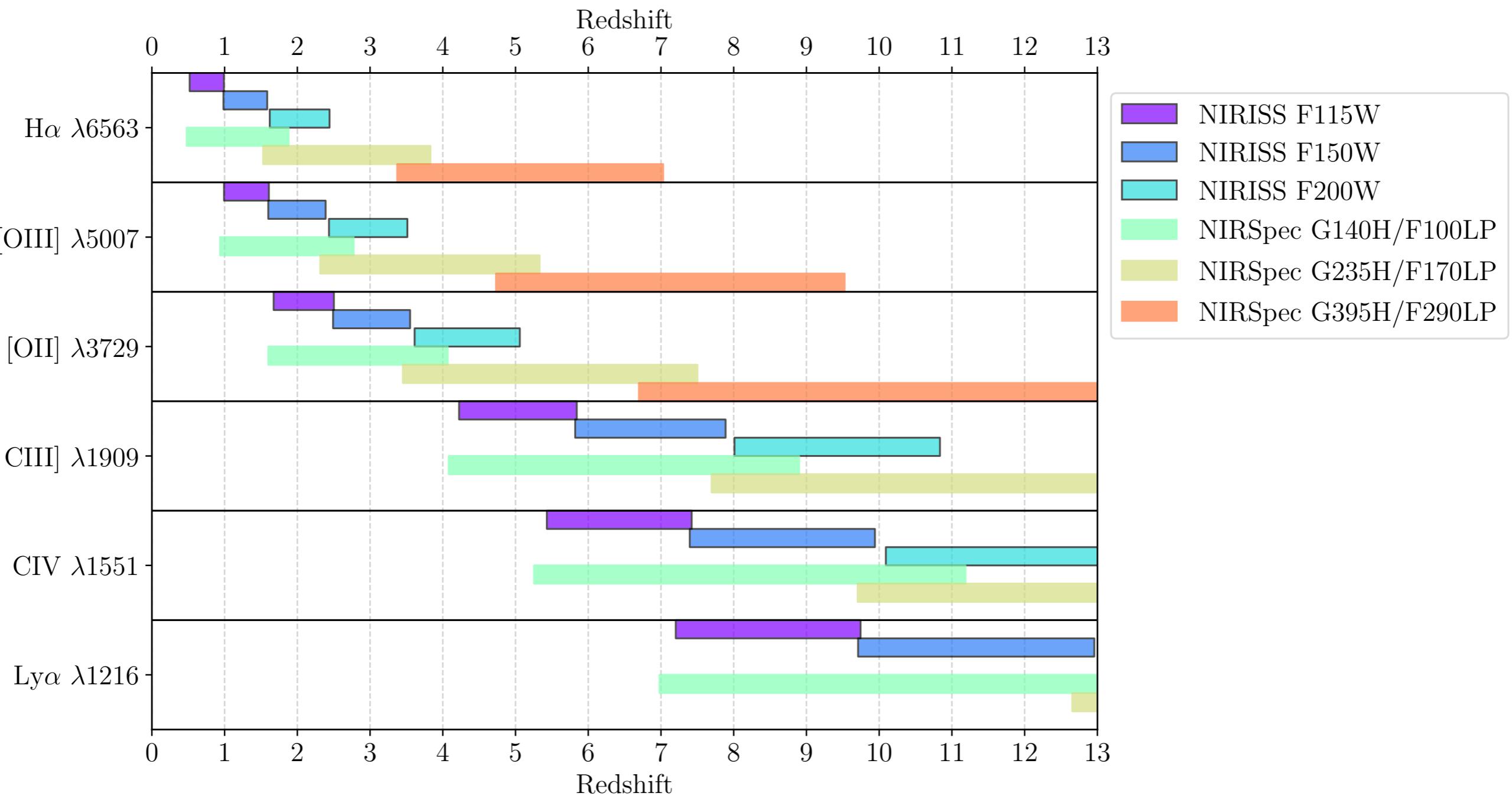
 z

ASTRODEEP, Merlin+16, Castellano+16

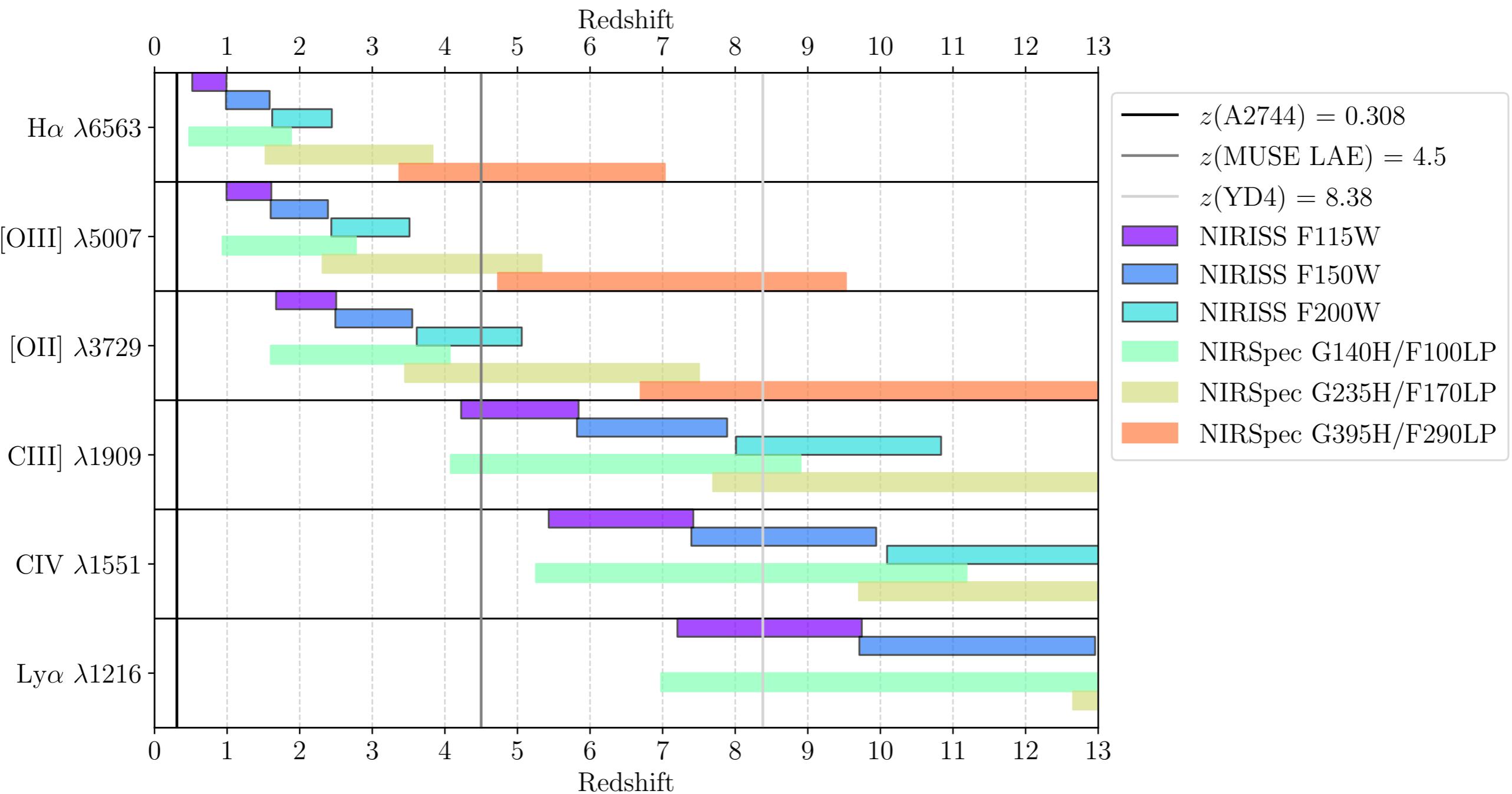
Spectroscopy

- NIRISS Wide Field Slitless Spectroscopy
 - $R \sim 150$
 - F115W, F150W, F200W dispersed in both row & column direction
 - 35000 seconds in total
- NIRSpec Multi Object Spectroscopy with the MSA
 - $R \sim 2700$
 - F100LP, F170LP, F290LP
 - 52000 seconds in total

Emission Line Coverage



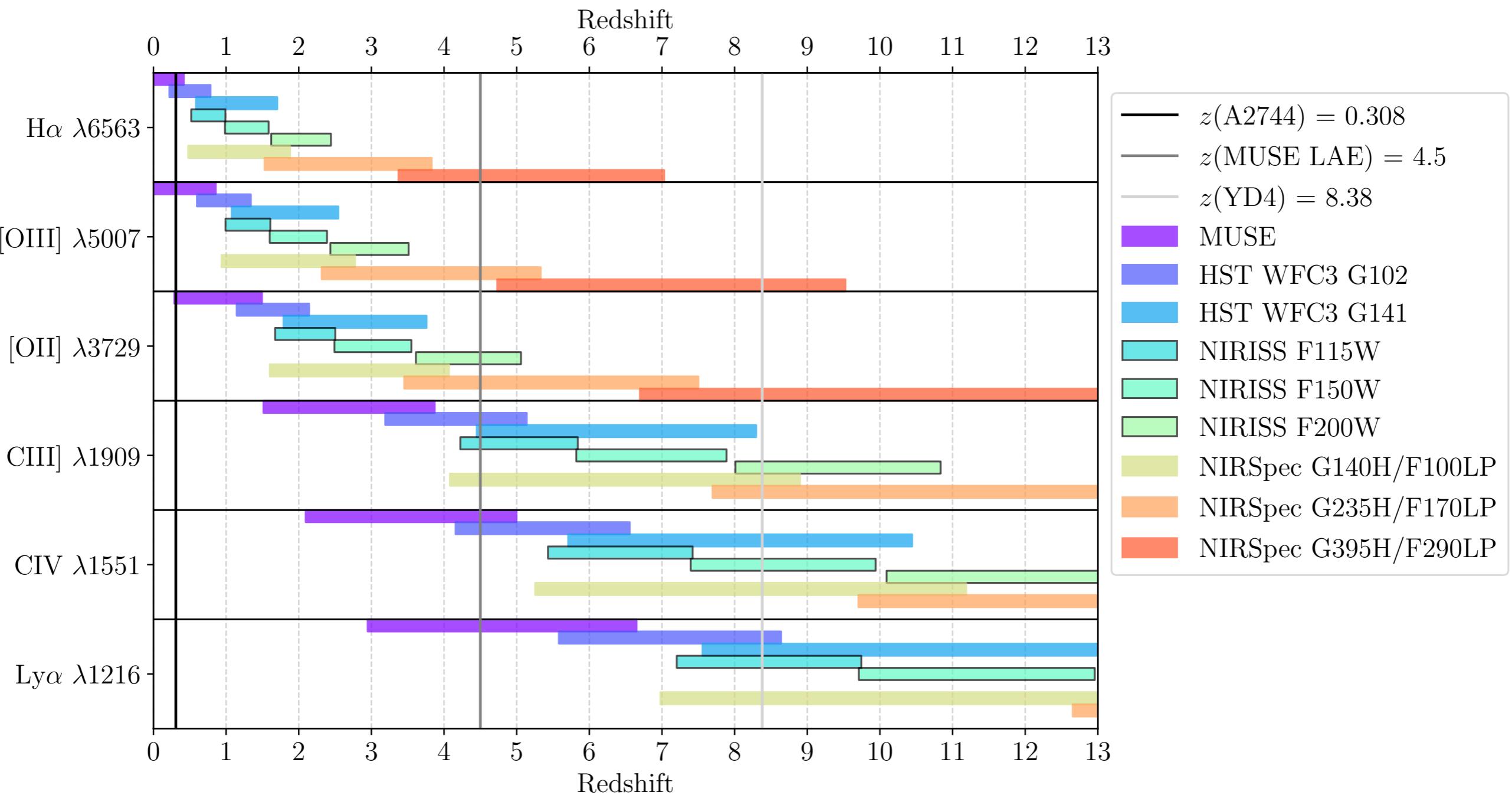
Emission Line Coverage



A2744-YD4: Photmetry: Zheng+14, Ishigaki+15, Atek+14,15

Spectroscopy: KBS+16 (Ly α non-detection) Laporte+17 Ly α & [OIII] 88 μ m

Emission Line Coverage

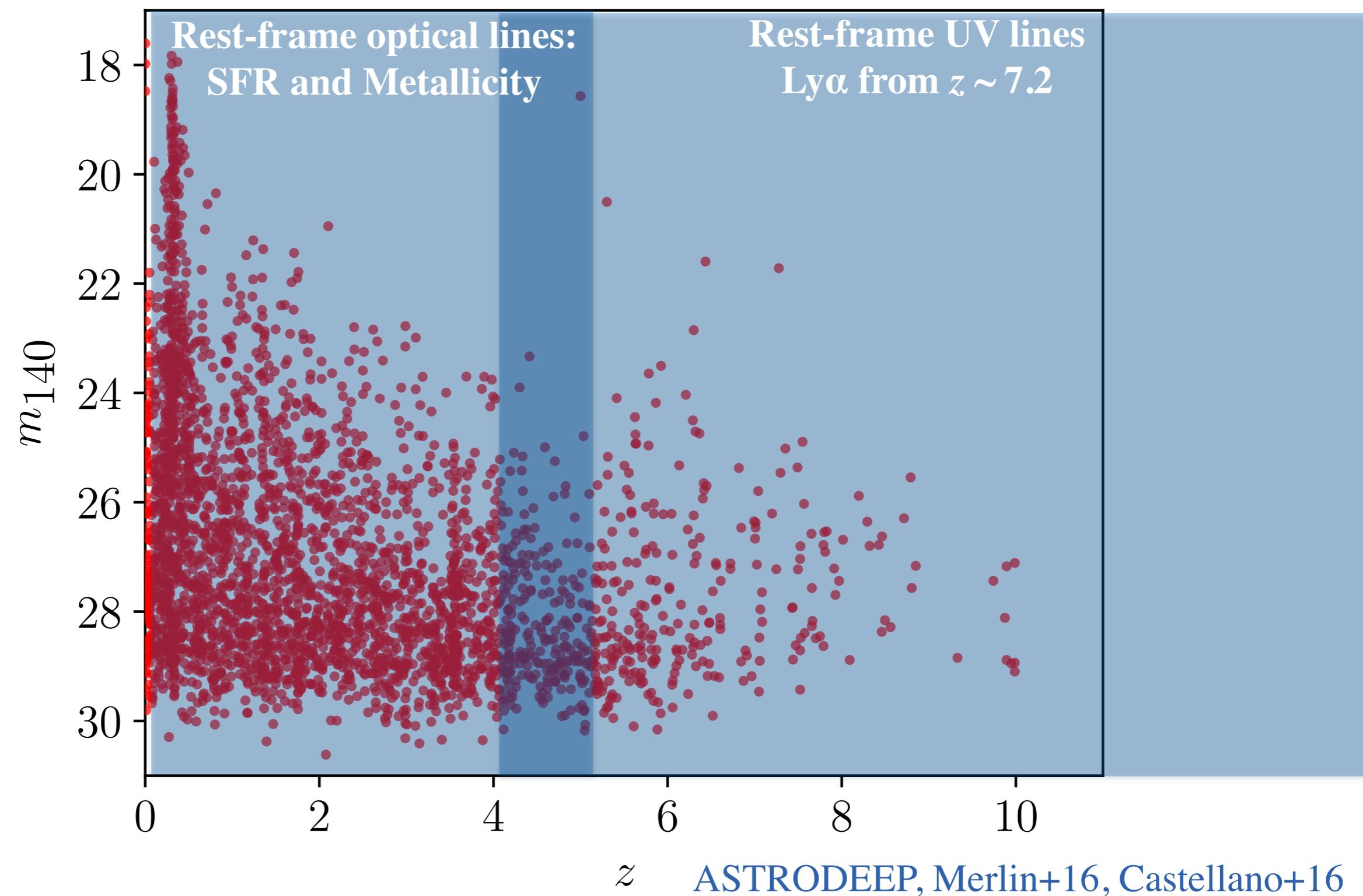


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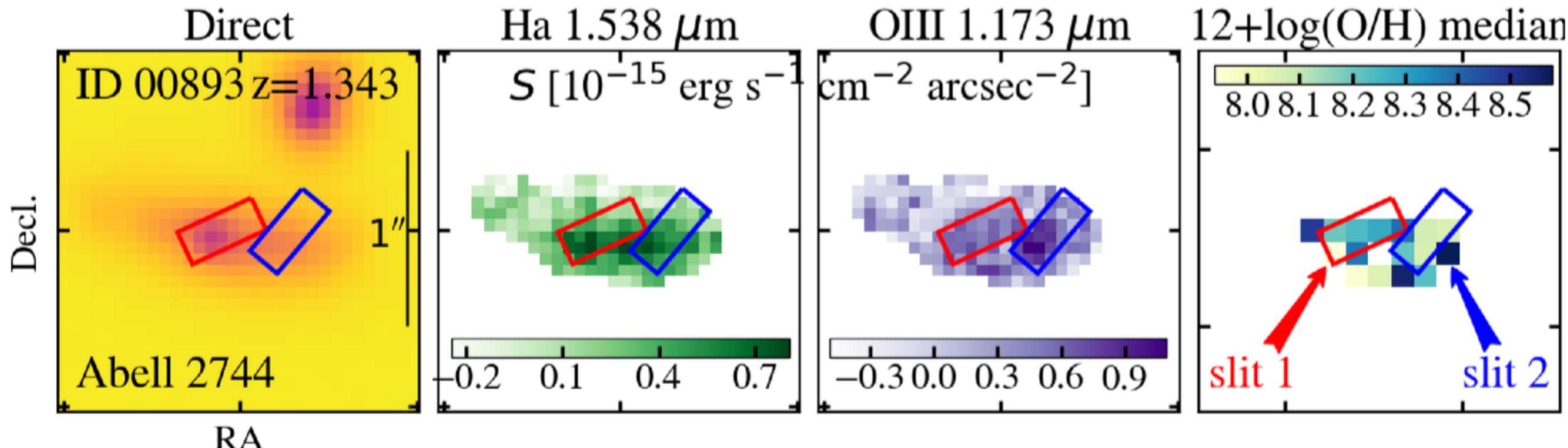
Extending z -coverage of parameter space

NIRSpec high-resolution for selected subsamples



Metallicity comparison with NIRSpec

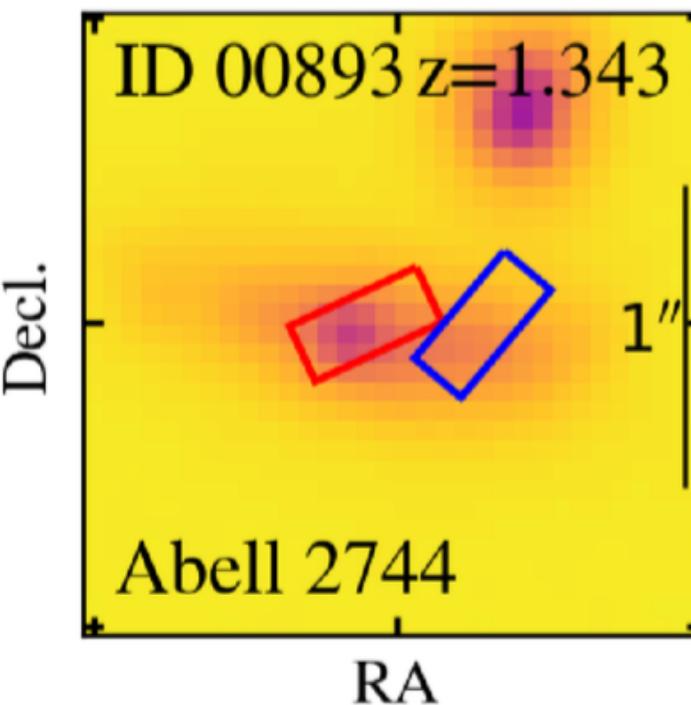
- Sub-kpc spatially resolved metallicity at $z > 1$



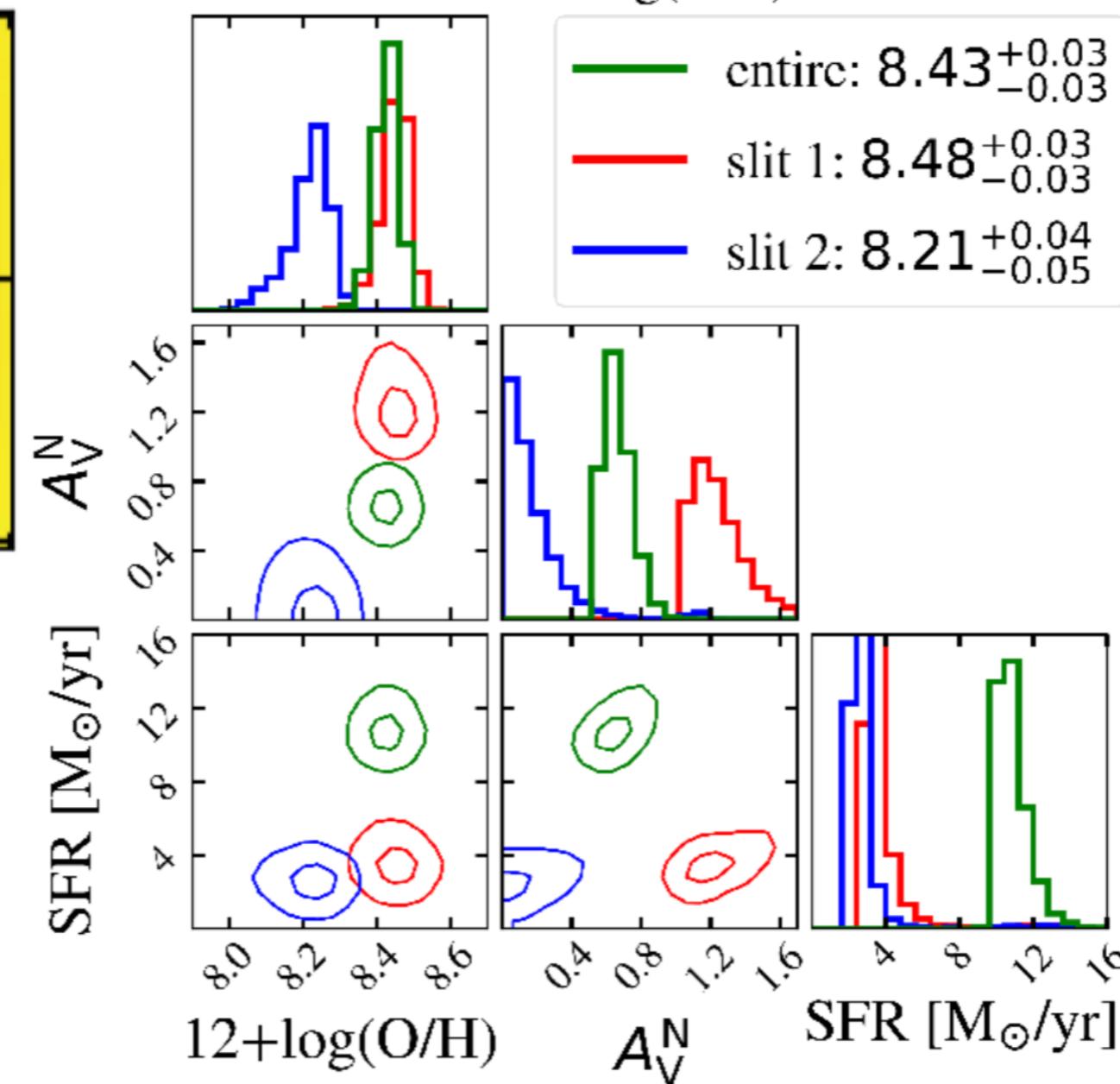
Metallicity comparison with NIRSpec

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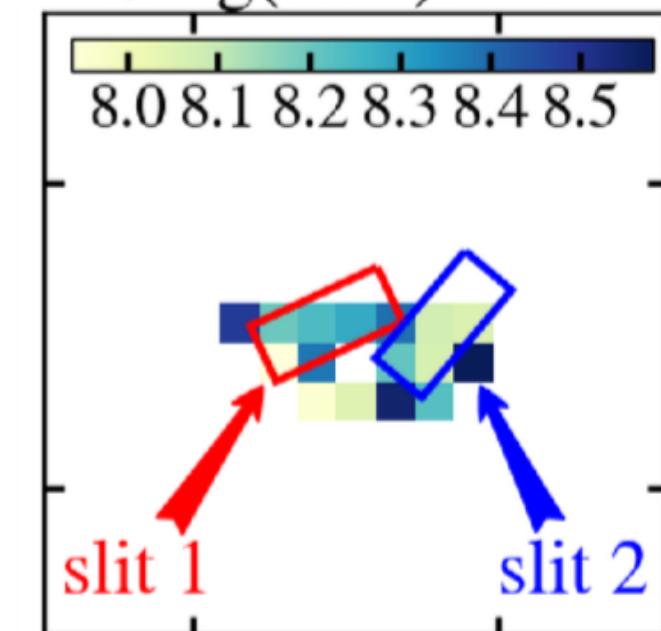
Direct



simulated 12+log(O/H) measurements



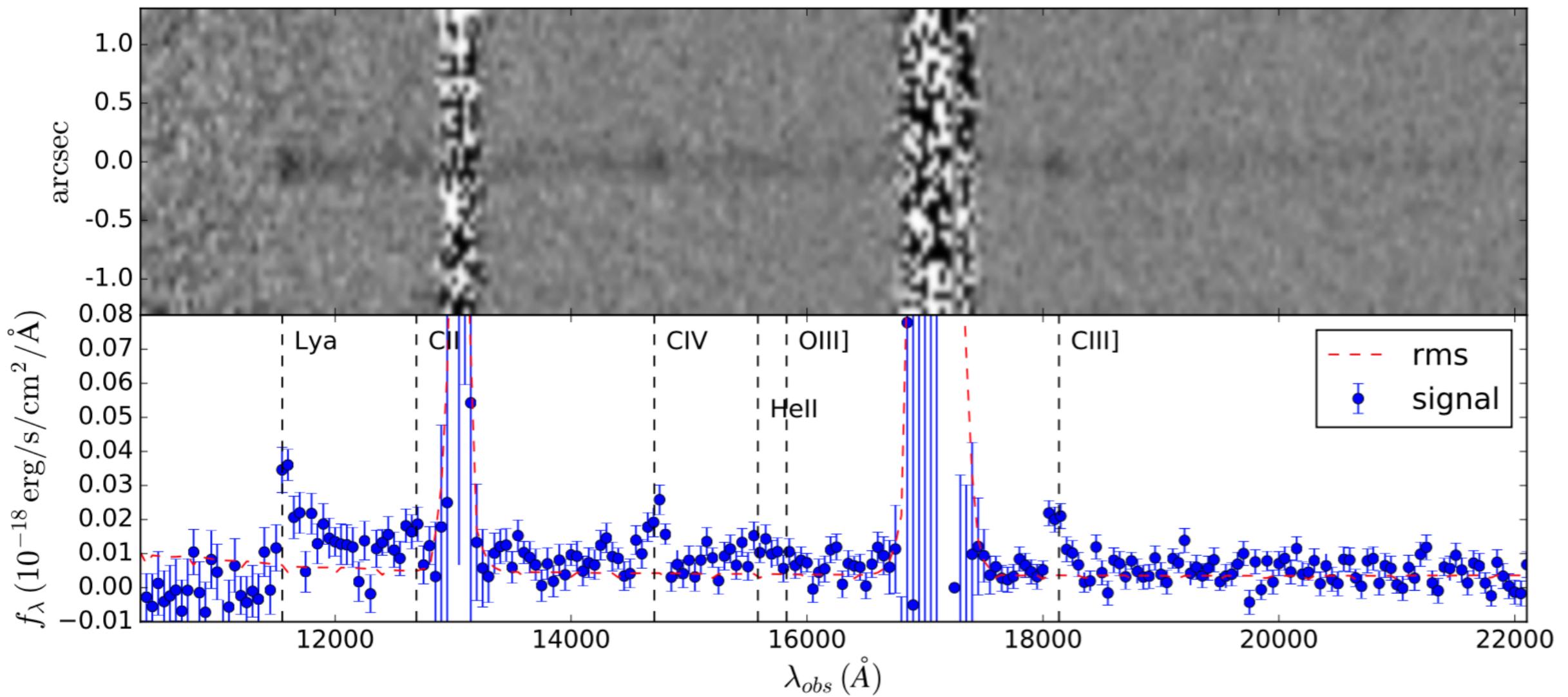
12+log(O/H) median



- Assess bias in Z estimate from slit-based (NIRSpec) spectroscopy.

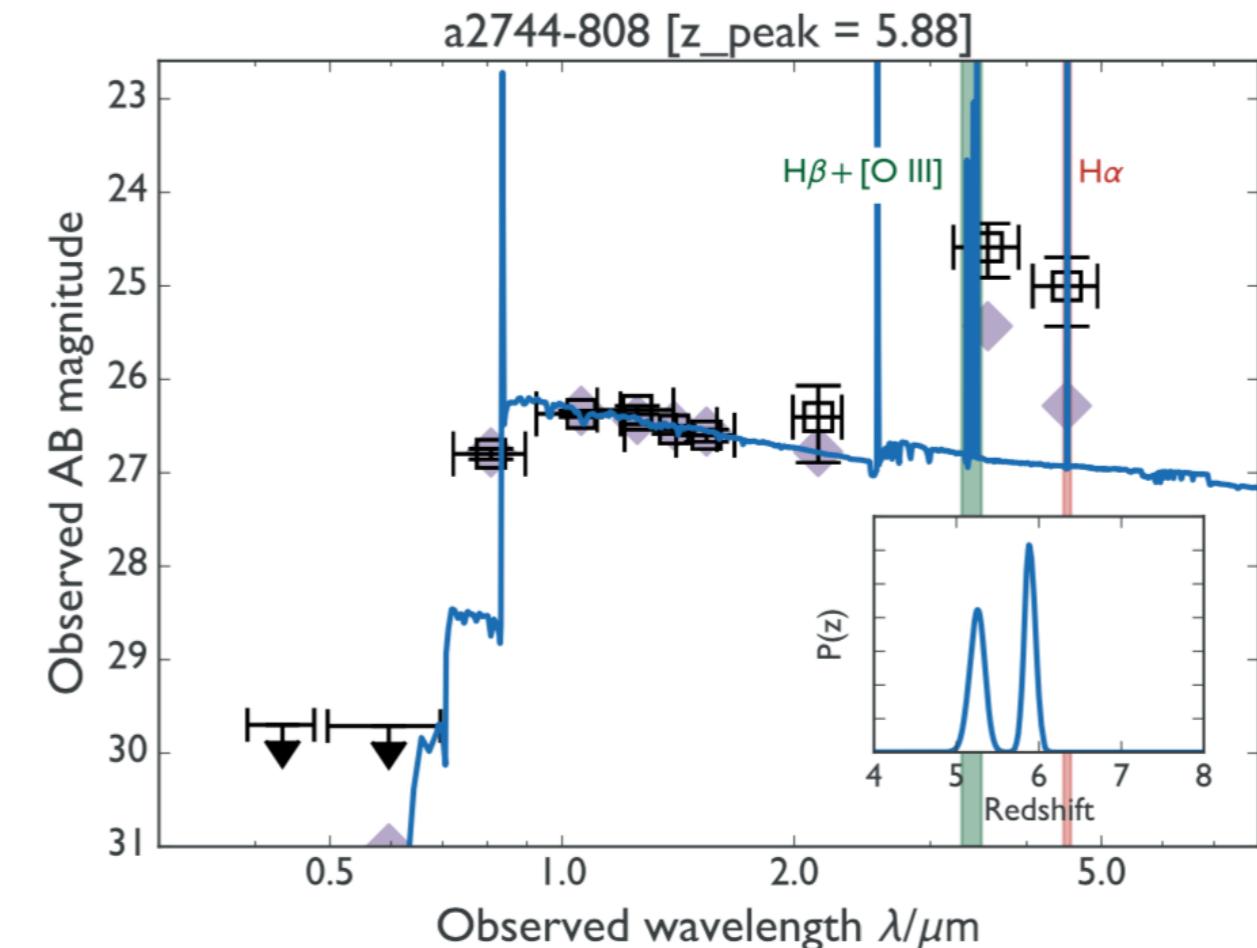
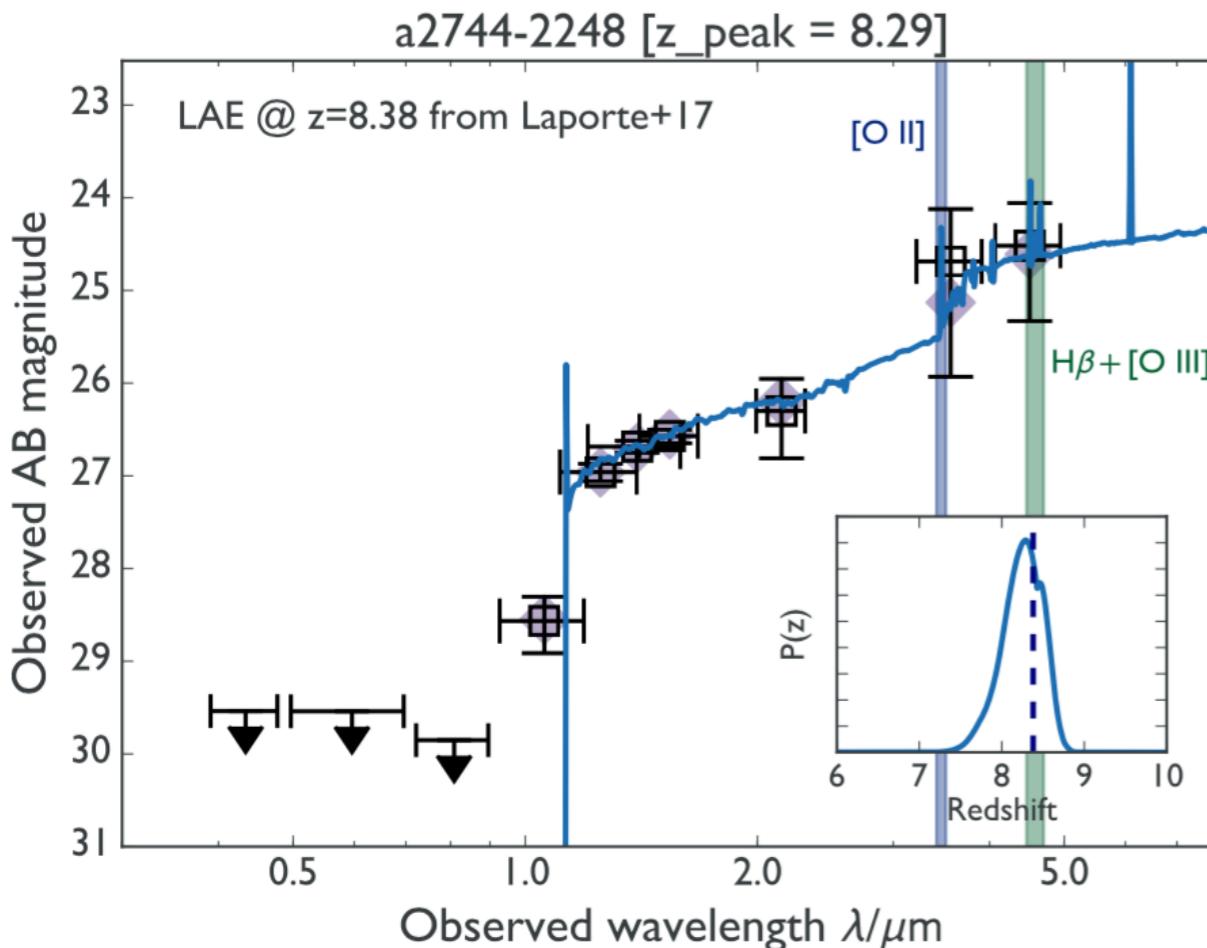
Continuum and UV lines at $z \sim 8.5$

- 27 AB mag $z = 8.5$ galaxy simulated for NIRISS depth
- Ly α flux 4×10^{-18} cgs (EW $\sim 30\text{\AA}$)
- CIII] and CIV are 2×10^{-18} cgs

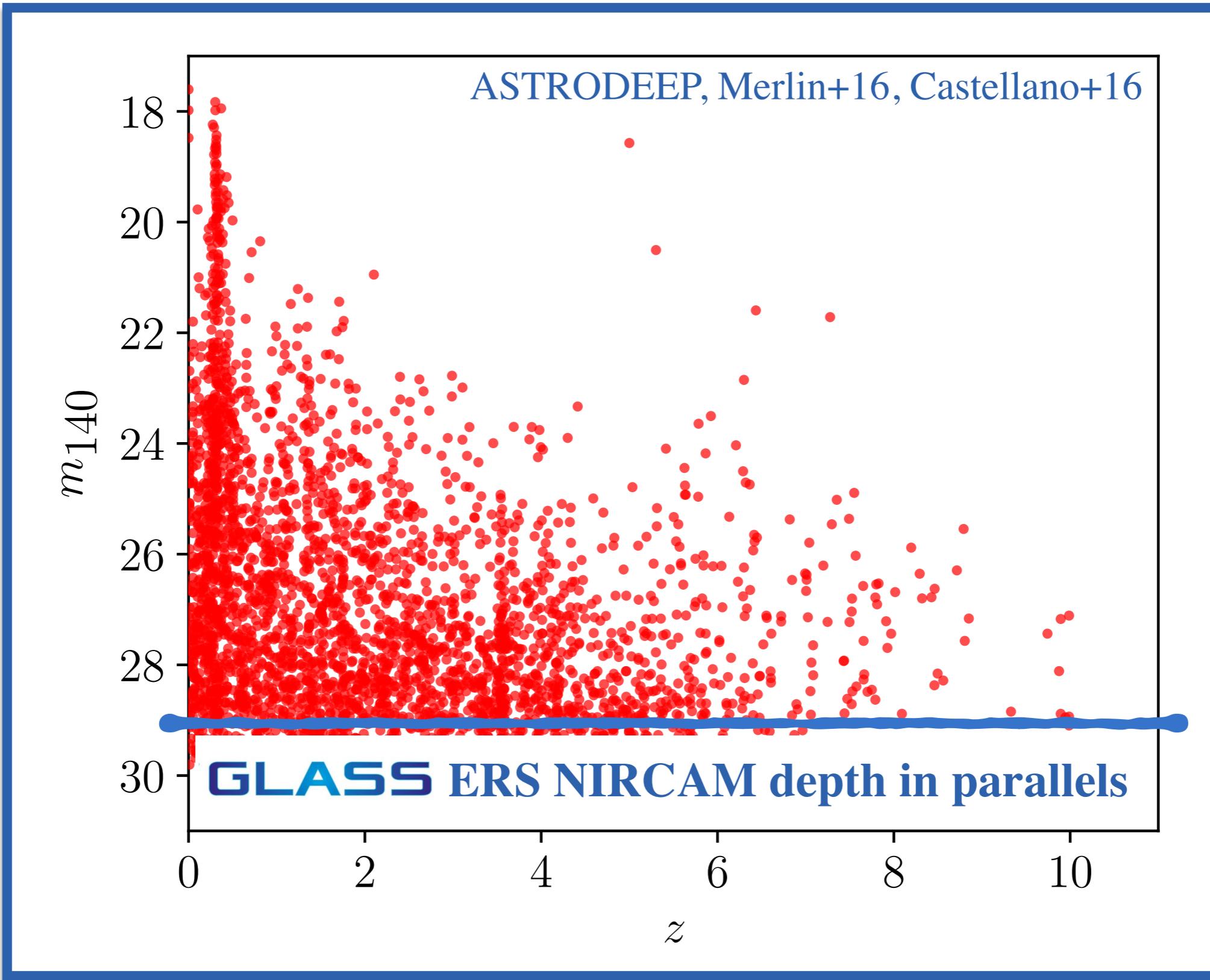


Observations: Imaging

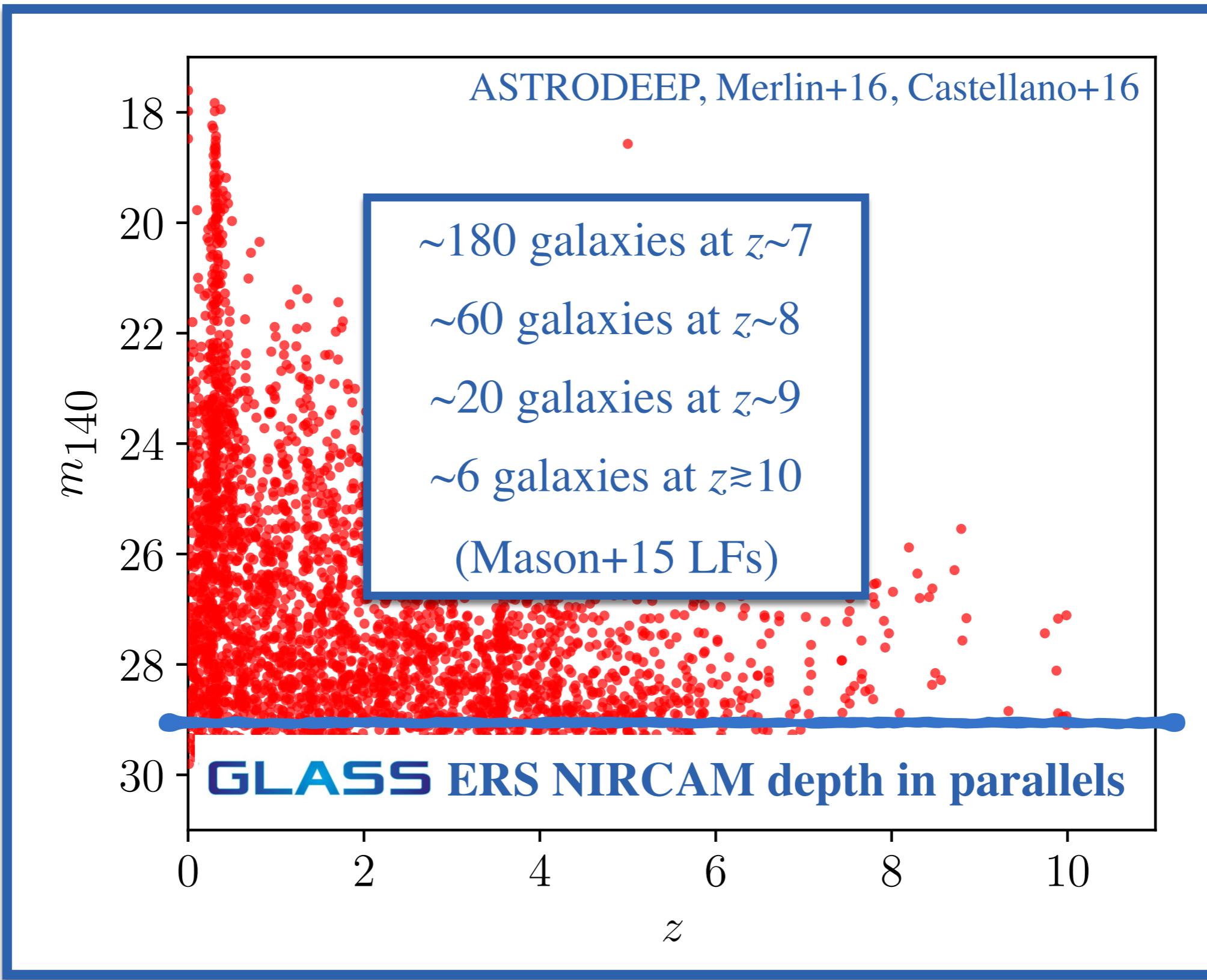
- NIRCAM imaging in parallel to spectroscopic modes
 - SW: F090W, F115W, F150W, F200W $(7879\text{\AA} - 22594\text{\AA})$
 - LW: F277W, F356W, F444W $(23933\text{\AA} - 50996\text{\AA})$
 - 30000 seconds ($m_{AB} \sim 29$) + 50000 seconds ($m_{AB} \sim 29.4$)



Observations: Imaging



Observations: Imaging



Stage I:

- Object-based multi-instrument exploration tool
- R.A./Dec. based NIRISS forced-extraction tool
- Spectroscopic templates of $z > 5$ source
- Spectral quantities and catalogs
- NIRCAM-parallel catalogs of $z > 7$ galaxy candidates

Stage II:

- Quantitative comparisons of NIRISS and NIRSpec spectra
- Updated and improved version of stage I products

Summary:

- Unanswered questions:
 - Who re-ionized the Universe?
 - How do baryons cycle in and out of galaxies?
- **GLASS** results helped narrowing the answers at $z \lesssim 8$ and $z \sim 1$
 - Ly α objects at $z \sim 7$ & Metallicity and SFR maps at $z \sim 0.5\text{-}2$
- **GLASS ERS** will push to higher redshifts with JWST:
 - NIRISS grisms, NIRSpec MSA and NIRCAM imaging on A2744
 - Provide grism tools and NIRISS-NIRSpec comparison

GLASS ERS TEAM

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