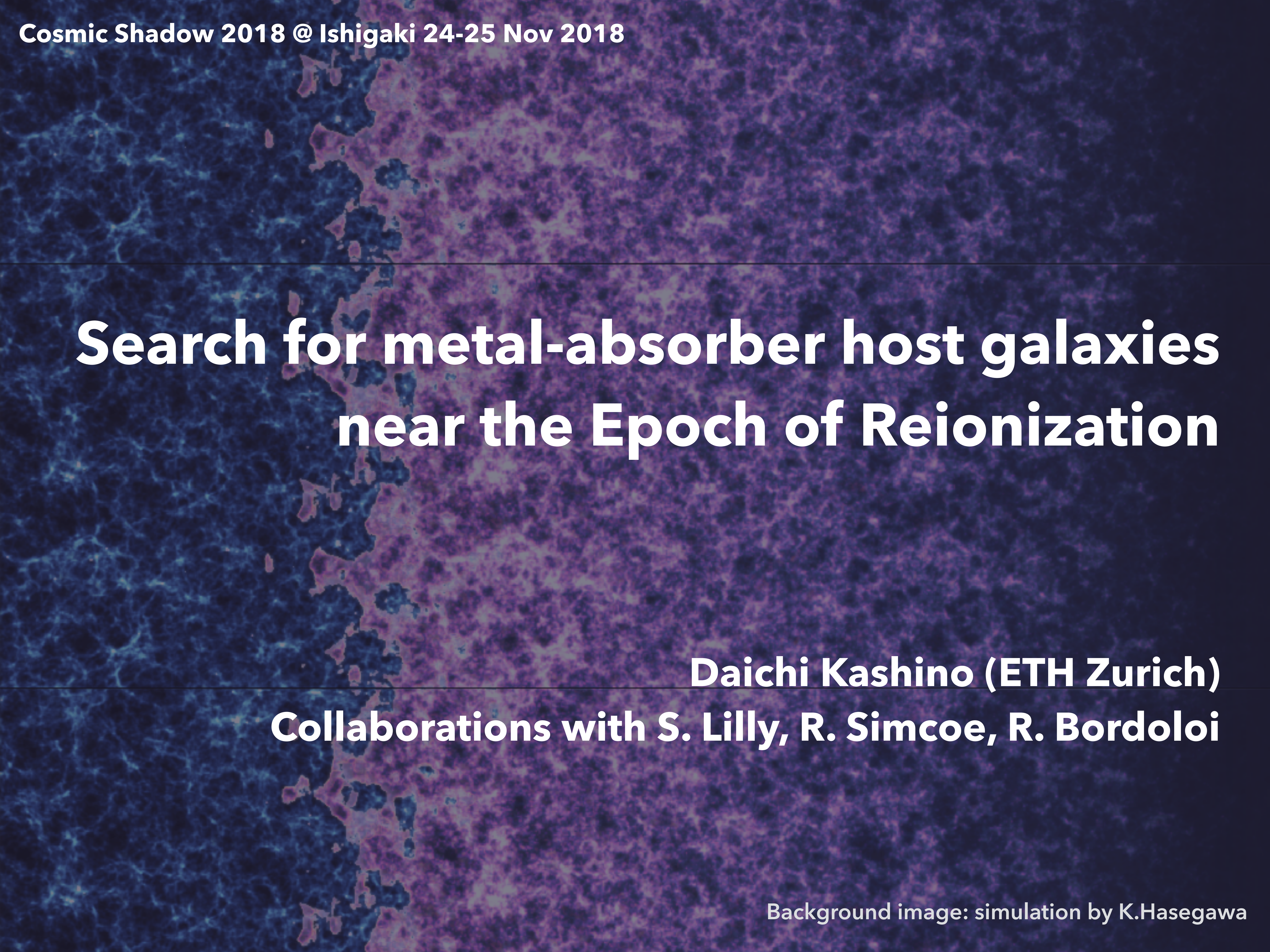
Cosmic Shadow 2018 @ Ishigaki 24-25 Nov 2018

Search for metal-absorber host galaxies near the Epoch of Reionization

Daichi Kashino (ETH Zurich)
Collaborations with S. Lilly, R. Simcoe, R. Bordoloi



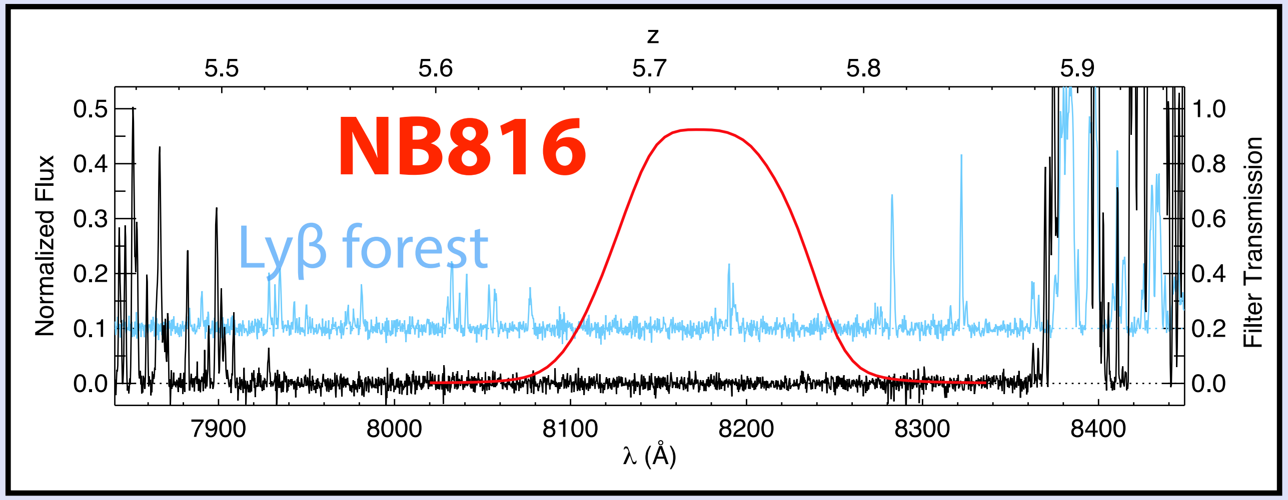
Background image: simulation by K.Hasegawa

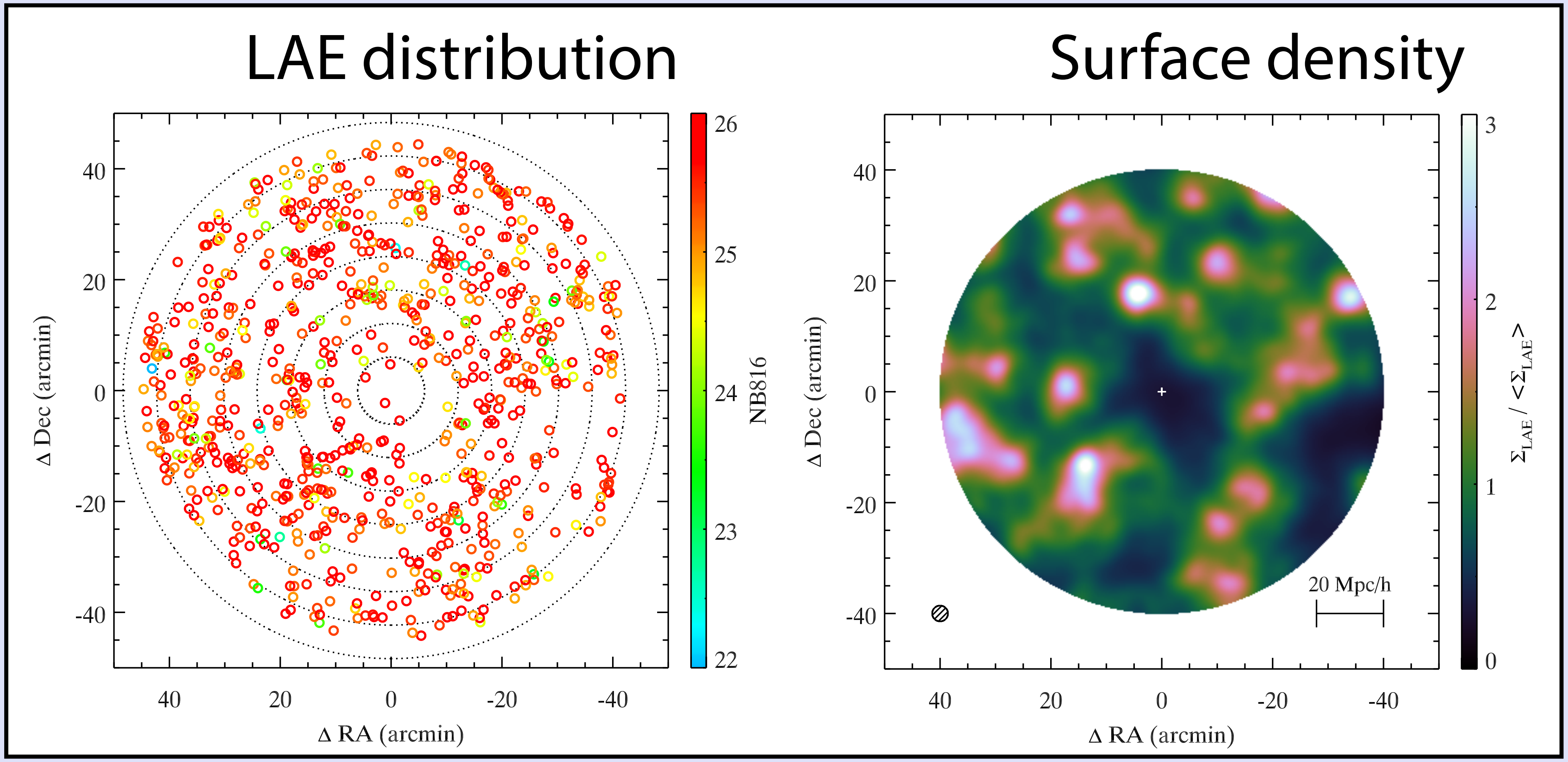
Recent report by Becker et al. 2018

LAE survey with NB816 (z=5.7) in the field of QSO0148+0600, corresponding to the long dark trough.

High-τ_{HI} is likely to be associated with high LAE surface density.

The fluctuating-Γ_{HI} model is preferred.





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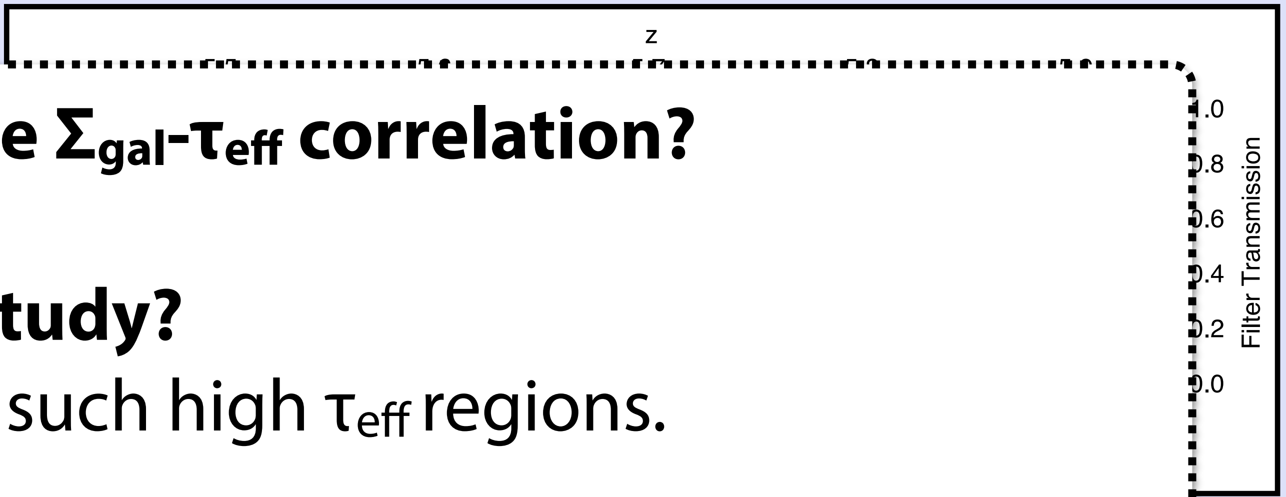
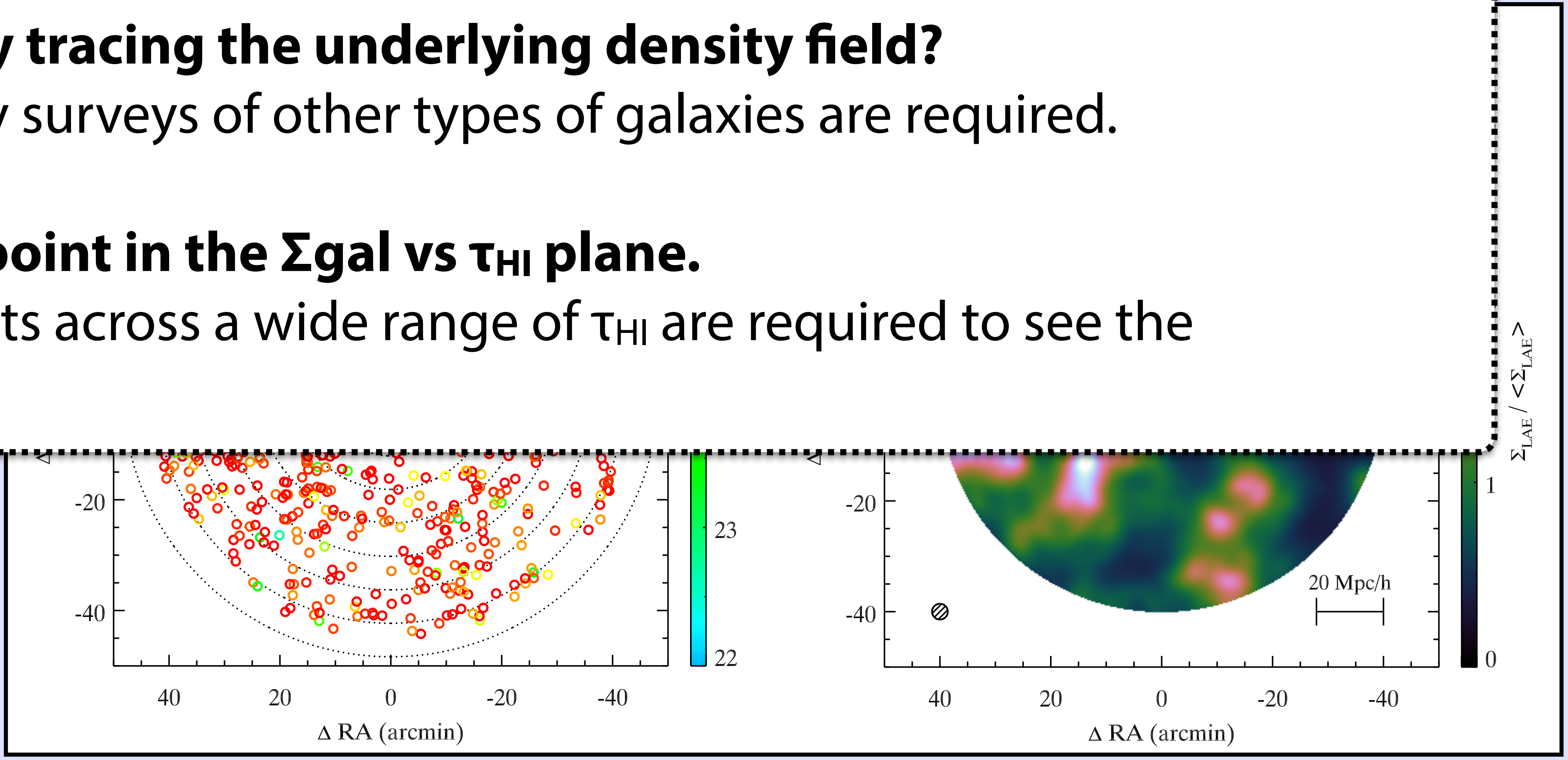


Is this really the evidence of a negative Σ_{gal}-τ_{eff} correlation?

Are LAEs really suited to this kind of study?
Lyα emission is ***definitely*** suppressed in such high τ_{eff} regions.

Are LAEs really tracing the underlying density field?
Complimentary surveys of other types of galaxies are required.

Only a single point in the Σgal vs τ_{HI} plane.
More data points across a wide range of τ_{HI} are required to see the correlation.



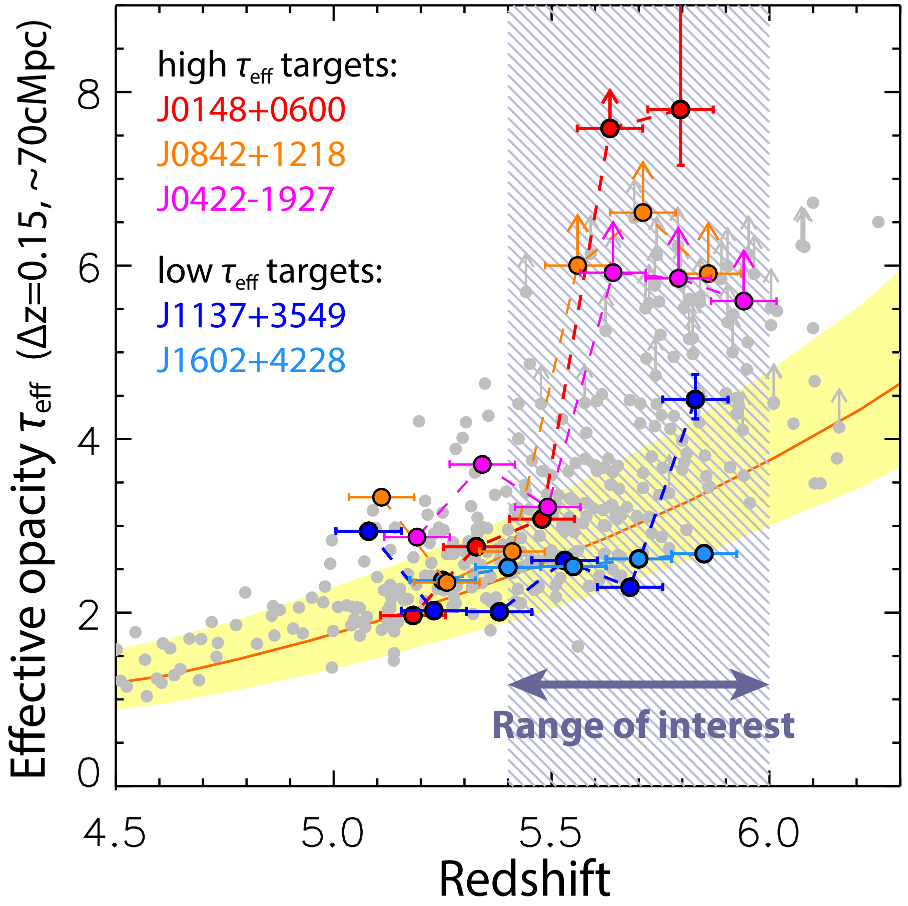
Subaru/HSC:

Approved in S18B, S19A

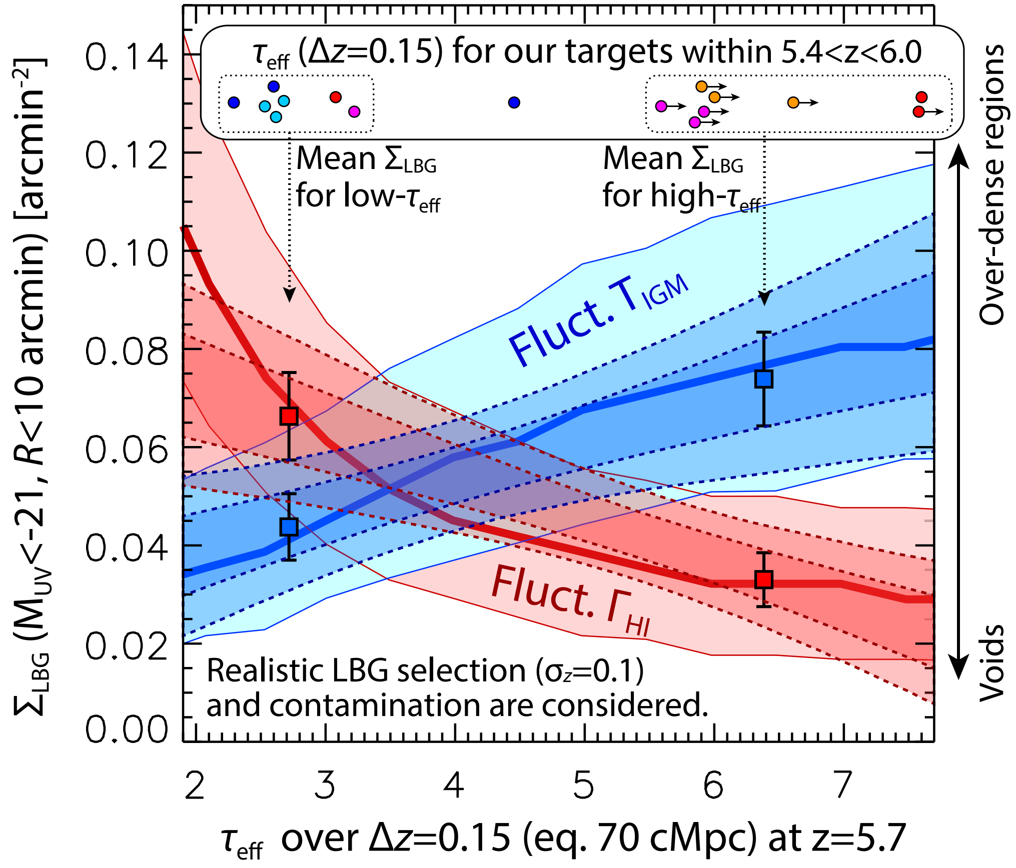
Revealing the τ_{HI}—Σ_{gal} relation over large scales

LBG selection with ***r, i, z*** ($z<=25.7$), aiming to detect *N*~250 per HSC FoV

Target quasars



Predicted constraints



Collaboration with Kashikawa-san's LAE survey in QSO fields
=> direct test of possible suppression of LAE/LBG where we know τ_{eff}

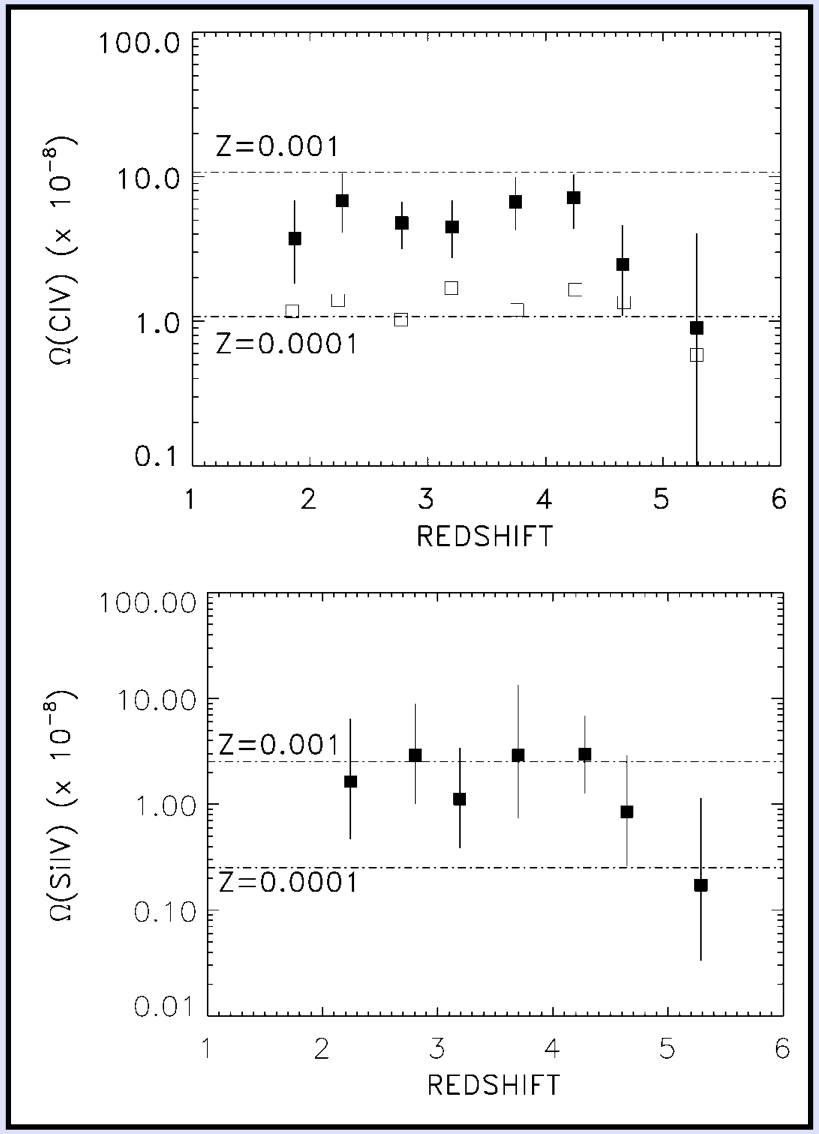
Today's talk

1. Background
2. Our projects starting up right now using JWST, ALMA and MUSE
3. Summary

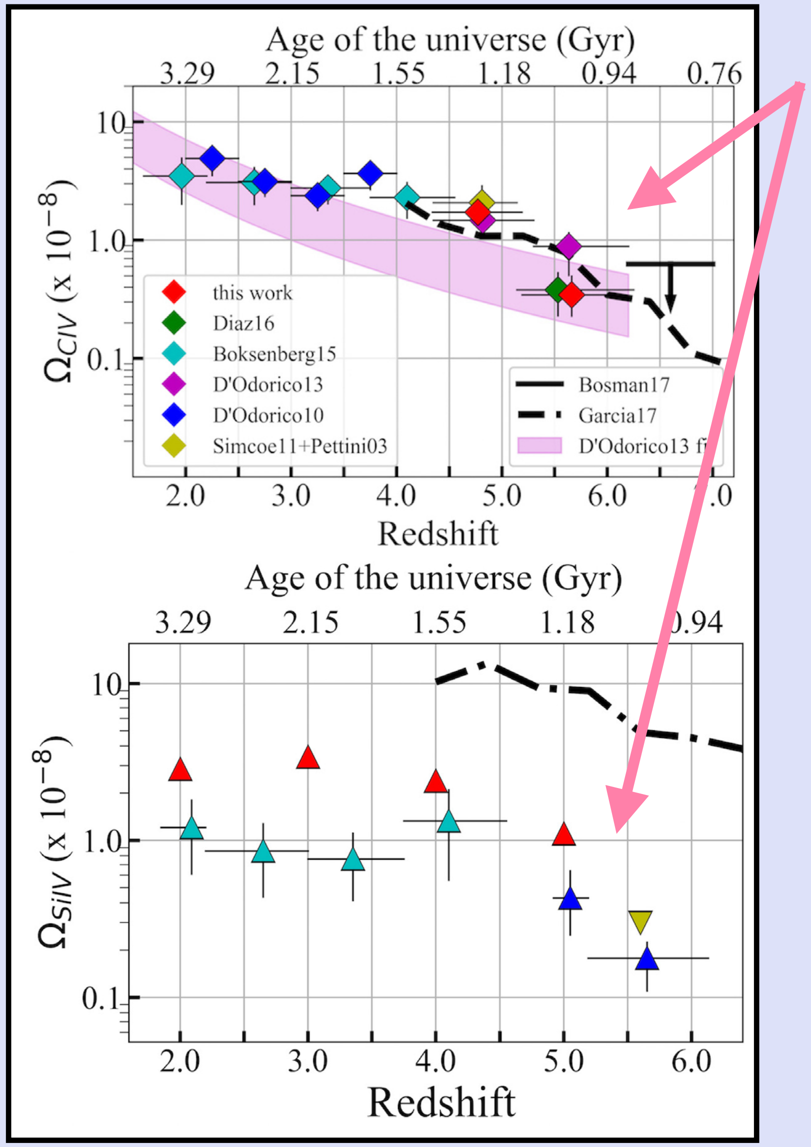
Background

Metal absorption systems back to z~6

- High-z quasars started to be found by SDSS back to z~6 around 2000, and recently, many z~6 quasars ($O(10^2)$) are being discovered by various wide surveys.
- Astronomers have studied metal pollution of the IGM and metal budget of the Universe using absorption lines seen in quasar spectra.



Songaila 00



Codoreanu+18

A downward trend in Ω_{CIV} / ΩS_{SiIV} discovered at z>5.

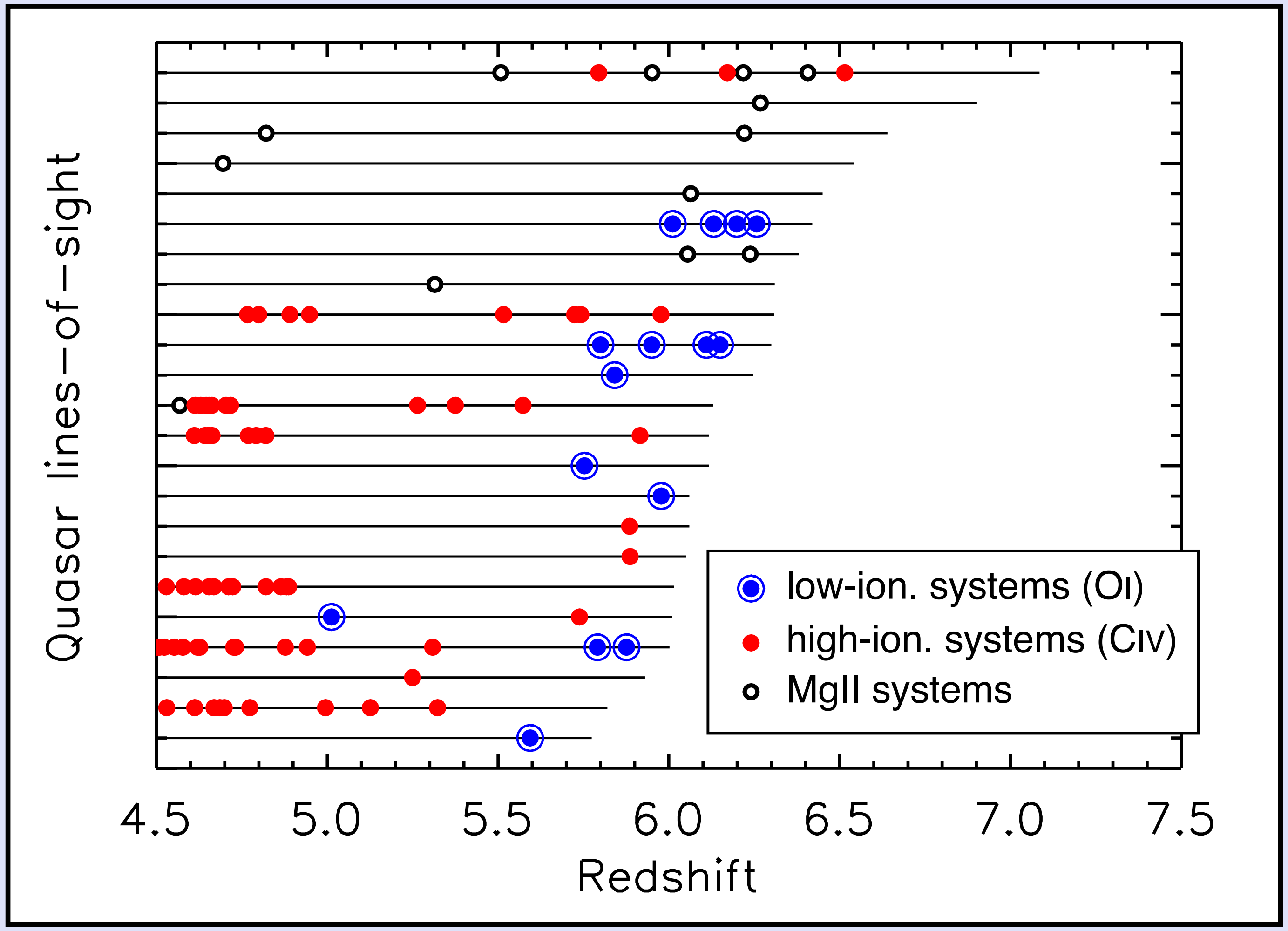
What cause the decline in Ω_{CIV} at z>5 ?

- **the evolution of metal abundance?**
- **change in ionization condition?**

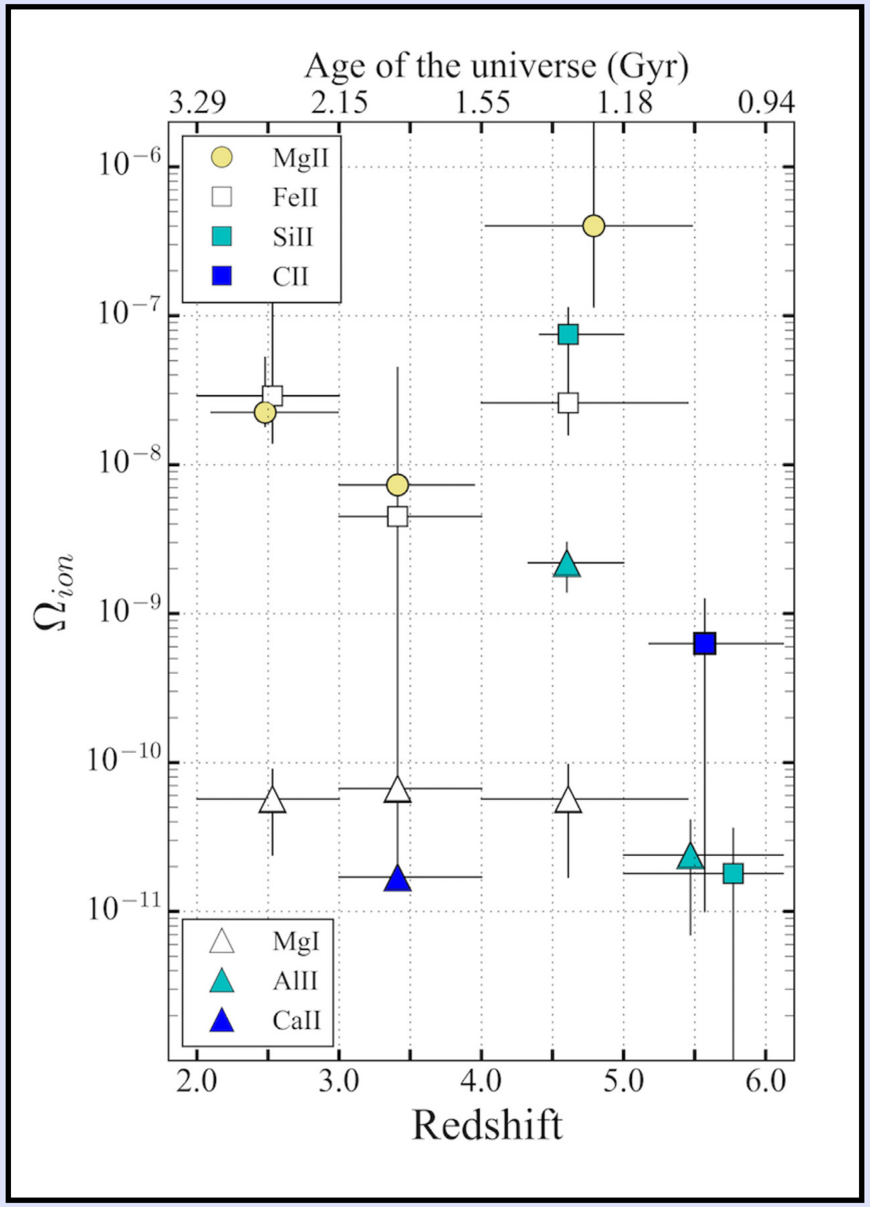
see also e.g., Simcoe 06, Simcoe+11, Becker+06, 09, 11, Ryan-Weber+09, D'Odorico+10,13, Chen+17, Bosman+17

Metal absorption systems back to z~6

Excess of *low-ionization* $\mathrm{O_I}$ (+SiII, CII) systems at z>5.5 (Becker+06)
— Evidence of change in ionization background



Compilation from the literature

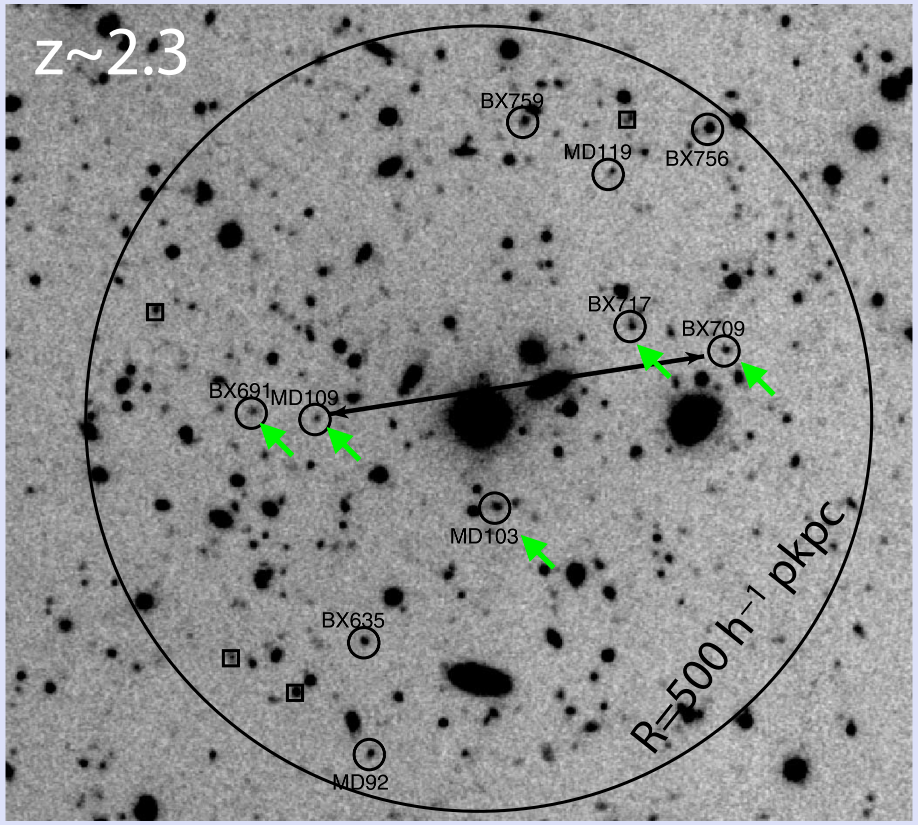


Codoreanu+18

The evolution of Ω_{ion} of low-ionization ions remains poorly constrained.

Host galaxies of metal absorption systems

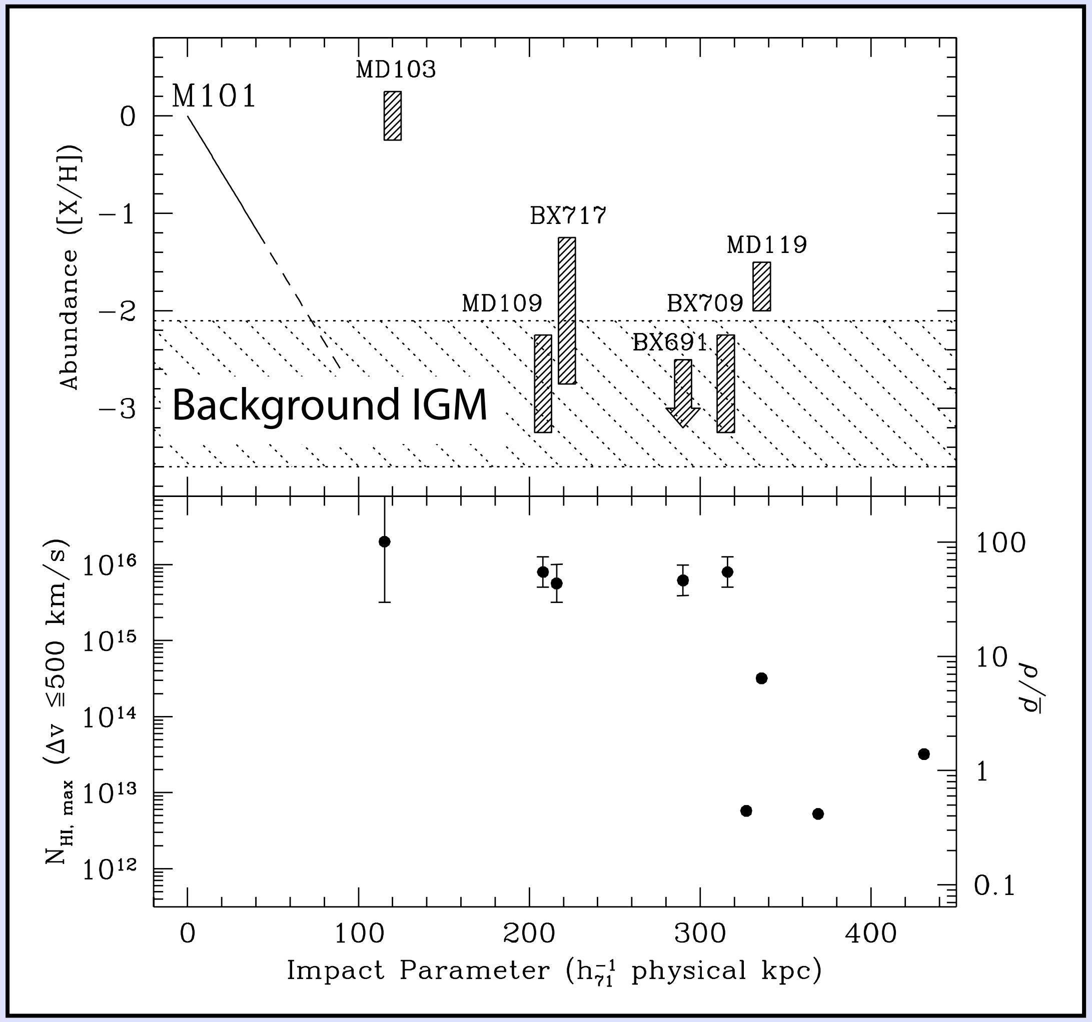
At intermediate redshifts (Simcoe+06)

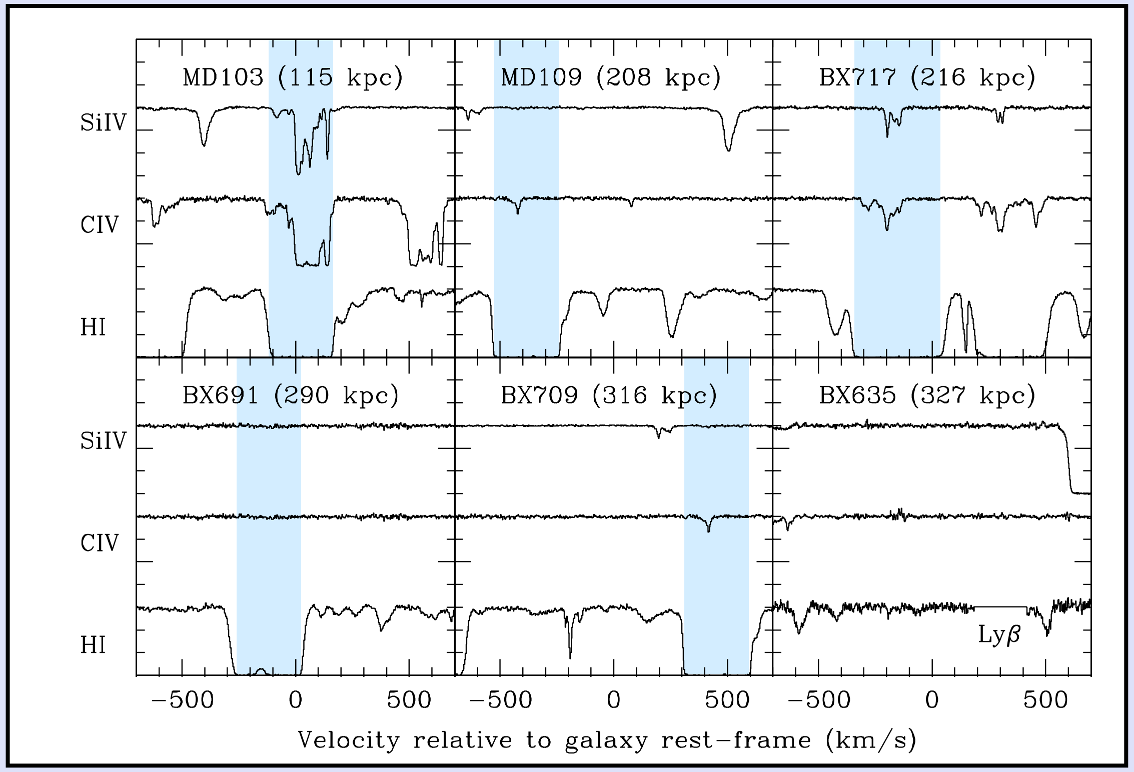


Possible hosts of a strong Lyα + C_{IV} absorber found up to ~320 pkpc from the quasar sightline.

(but, can we say they are really hosts with such large *b*?)

Remarkable metal enhancement at ~100 pkpc.





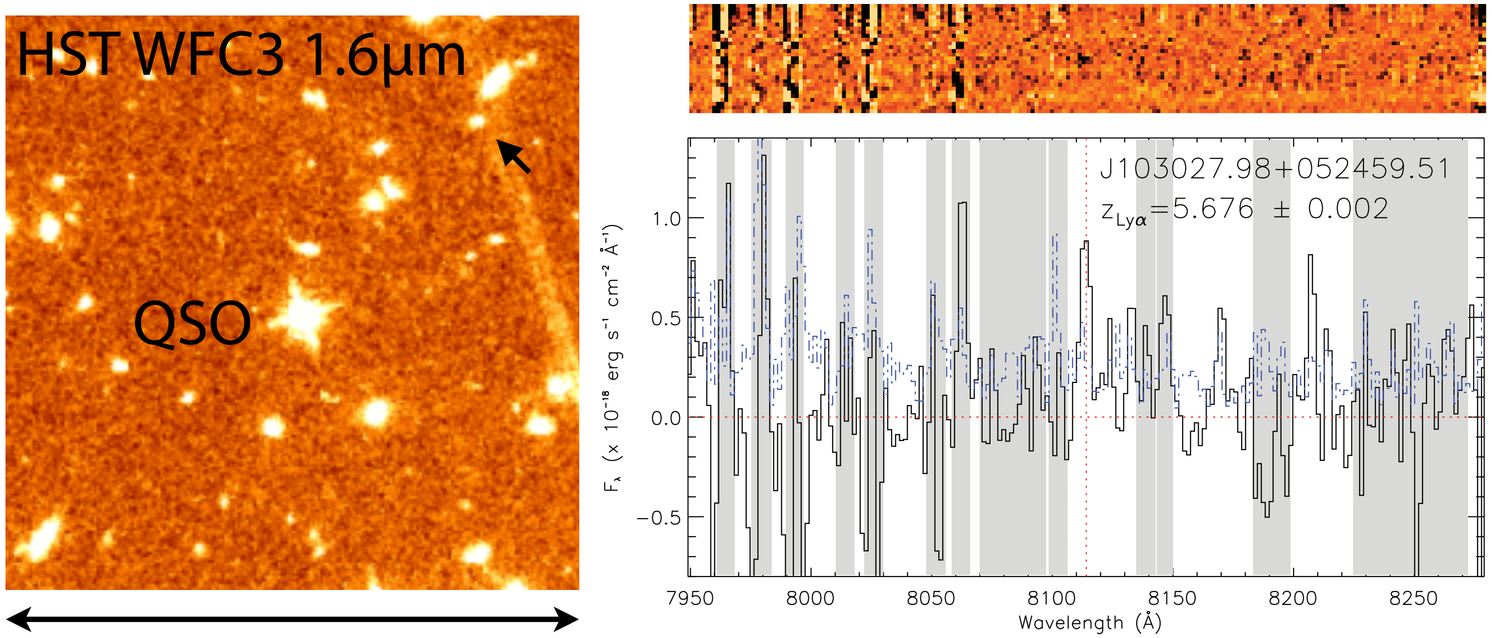
At further higher redshifts, spectroscopy is more challenging…

Few identifications at $z\gtrsim4$

Possible identification via Lyα at z=5.7

(b=79 pkpc, dv=−240 km/s)

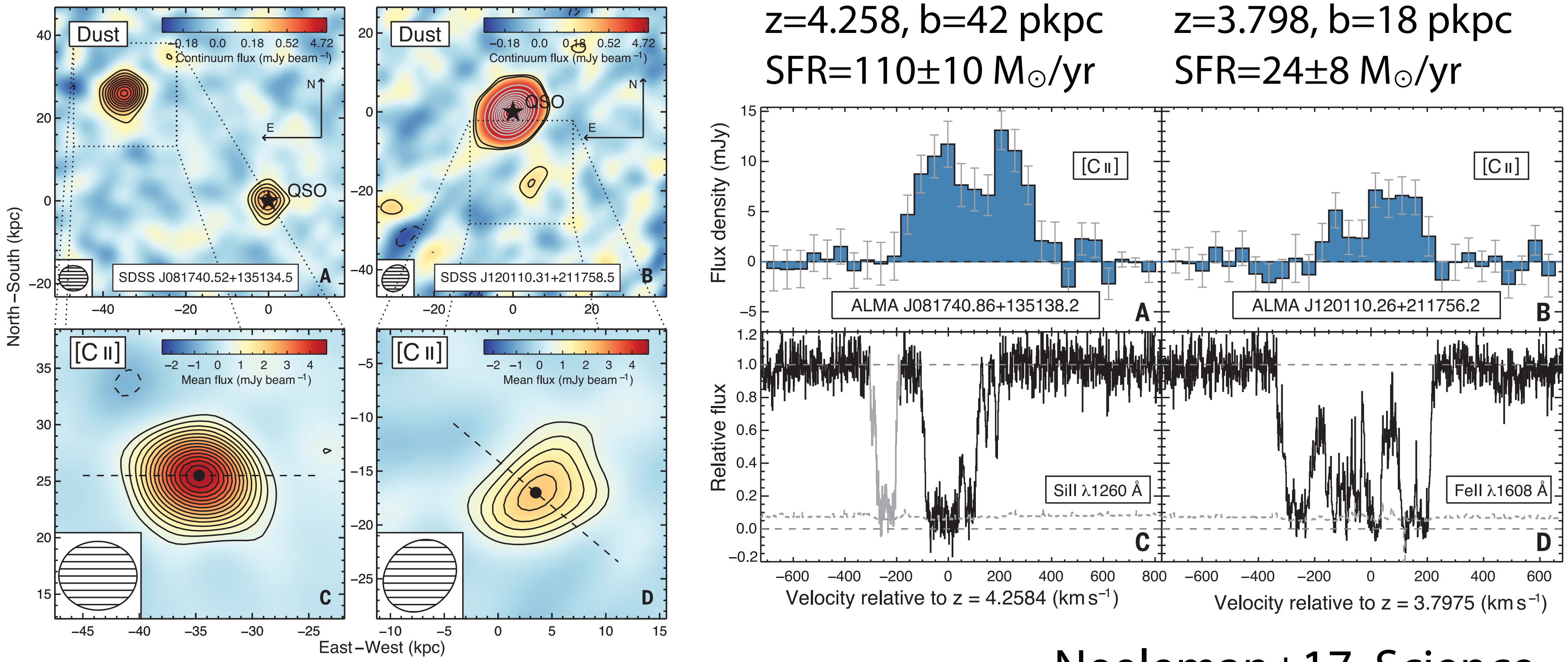
But no consistent detection is found in a MUSE cube
(preliminary)



30 arcsec = 176 pkpc

Díaz+11

Alternative tracer at high redshifts [CII]158μm with ALMA



z=4.258, b=42 pkpc
SFR=110±10 M☉/yr

z=3.798, b=18 pkpc
SFR=24±8 M☉/yr

Neeleman+17, Science

Few identifications at z≳4

Possible identification via Lyα at z=5.7
(b=79 pkpc, dv=−240 km/s)

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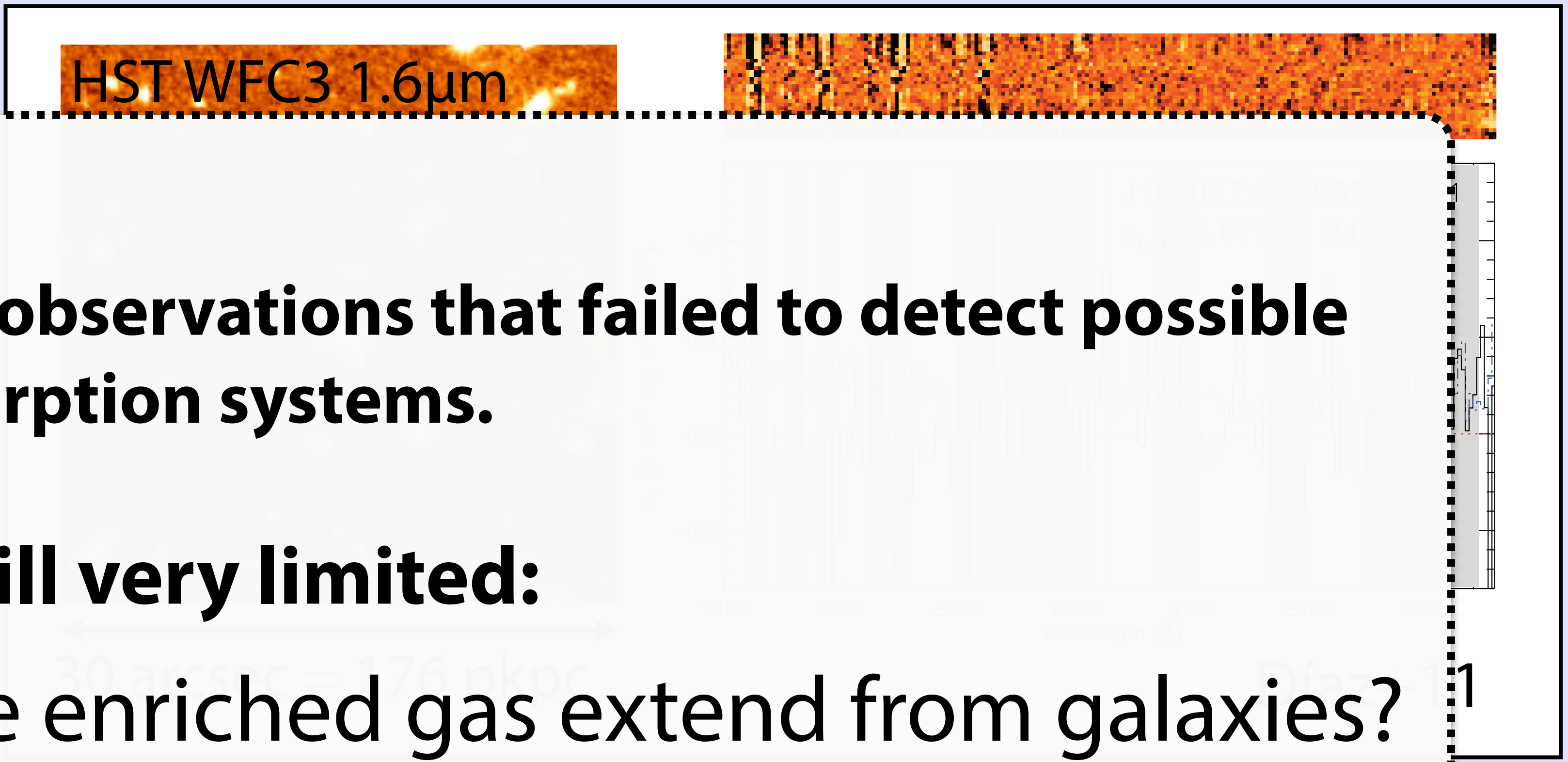
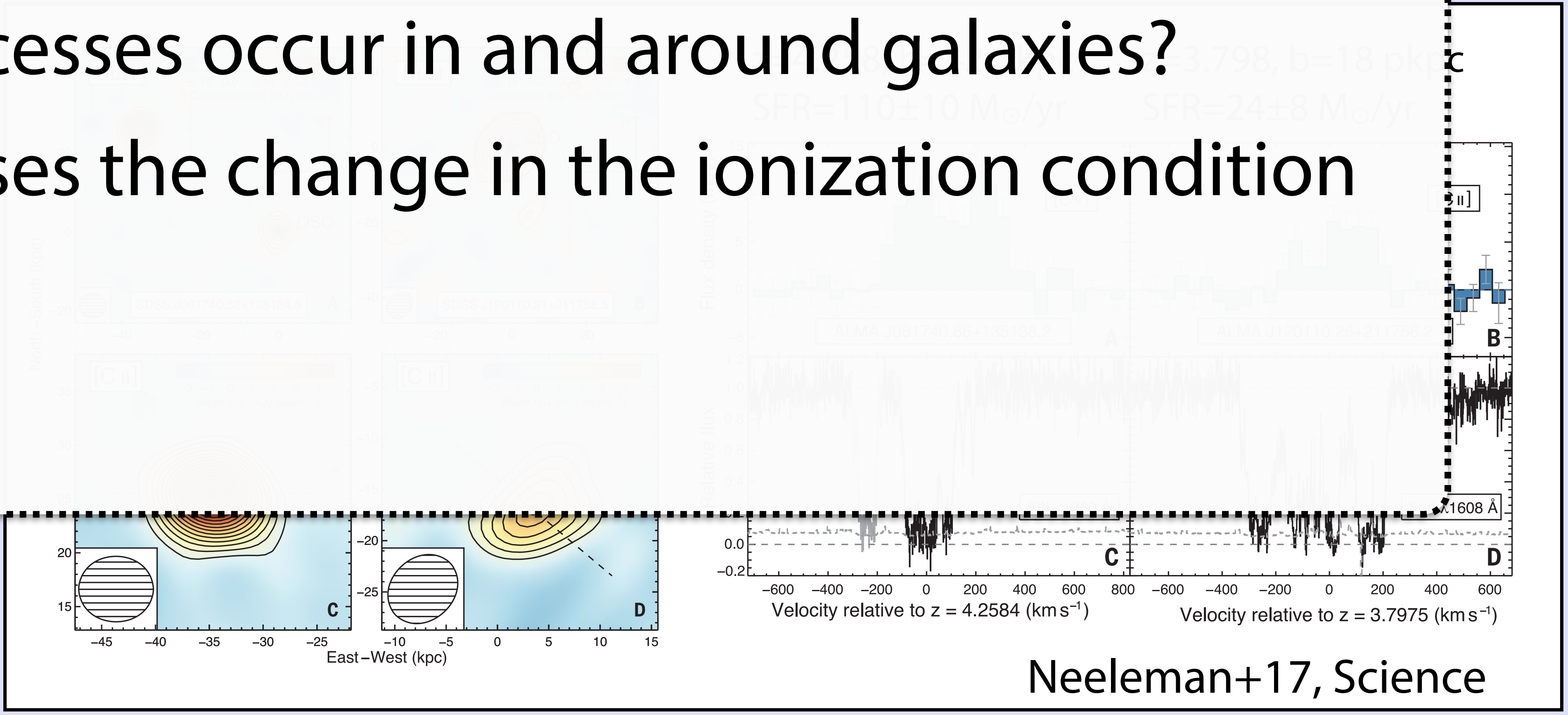


Alternatively at high redshifts
[CII]158μm with ALMA



Neeleman+17, Science

On the other hand,
there have been many observations that failed to detect possible DLA and/or metal absorption systems.

Our knowledge is still very limited:

- How far does the enriched gas extend from galaxies?
- What processes occur in and around galaxies?
- What causes the change in the ionization condition at z~5.5 ?

Our projects starting up right now

- **JWST/NIRCam WFSS** as an ultimate study
- **ALMA and MUSE** to search for absorber hosts

Our GTO program:

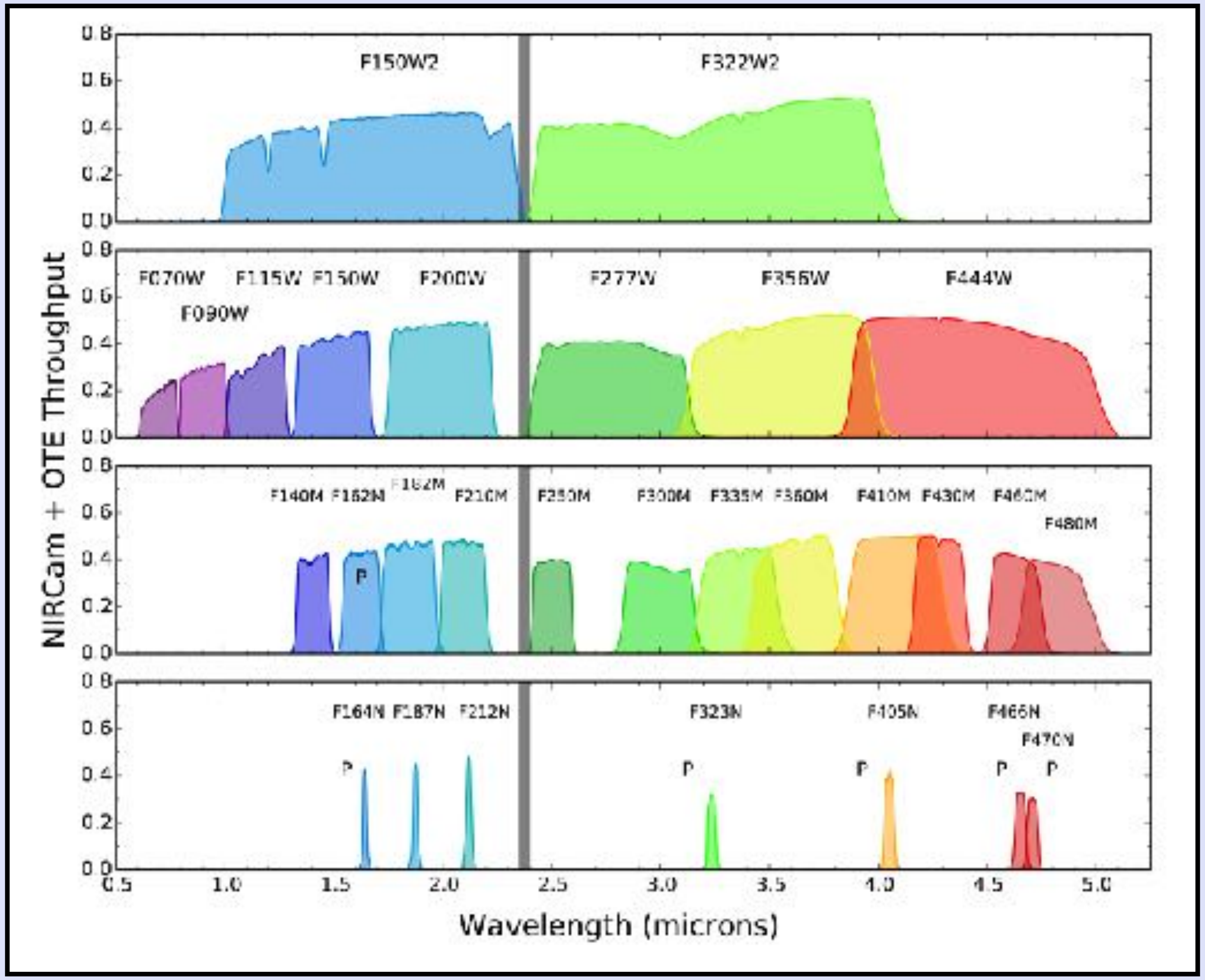
Exploring the end of cosmic reionization

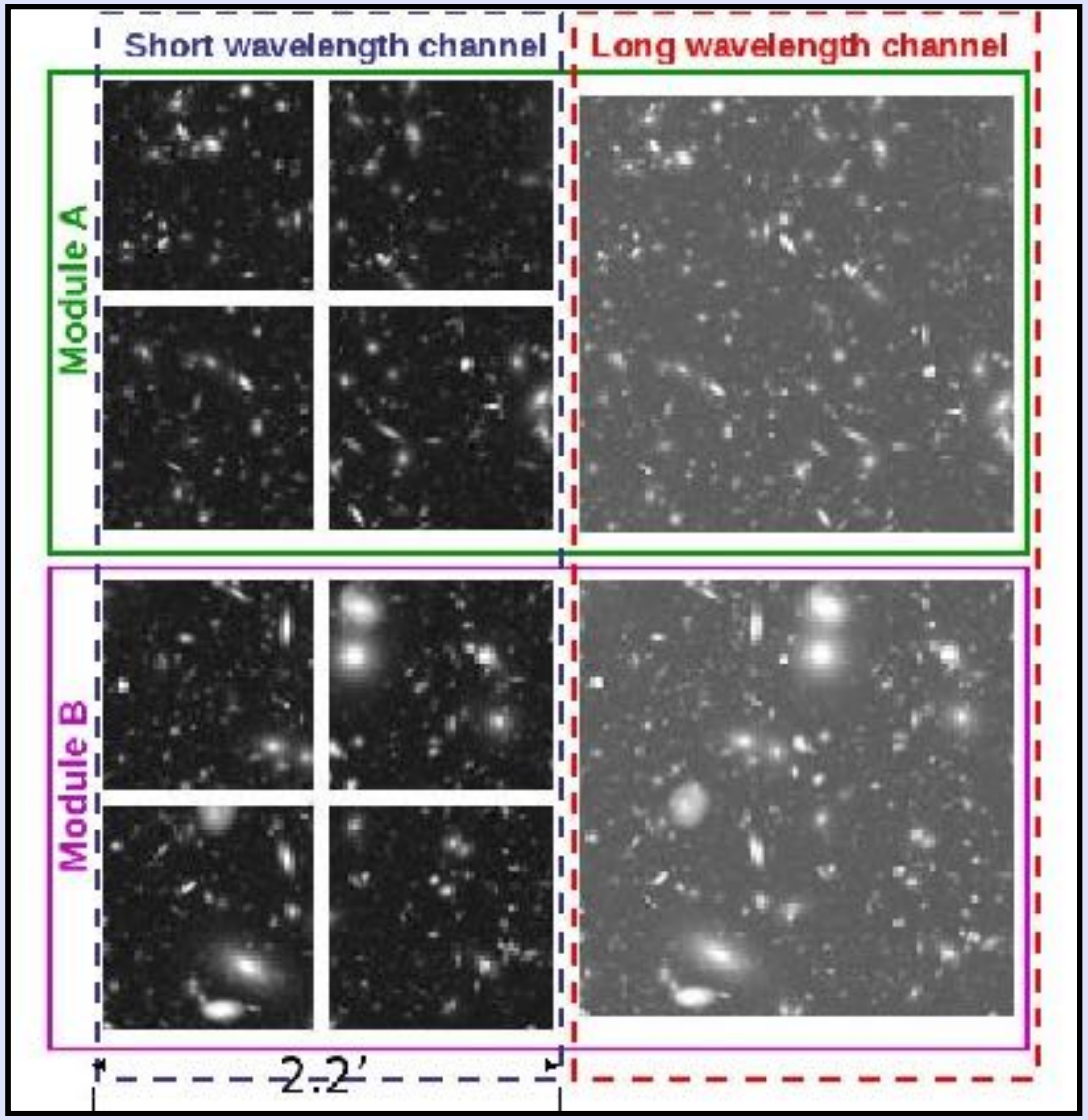
PI Simon Lilly, ETH Zurich
In collaboration with Rob Simoe, Rongmon Bordoloi (MIT)

Instrument	What we can do?
Near-InfraRed Camera **NIRCam**	• Imaging at 0.6–5.0 μm in two 2.2′ x 2.2′ FoVs • Wide-field Slitless spectroscopy (WFSS; R~1000) • Coronagraphic imaging
Mid-InfraRed Instrument **MIRI**	• Imaging at 5.6–25.5 μm in 74" × 113" FOV • Low-resolution slitted and slit less spectroscopy • IFU spectroscopy in 4.9–28.8 μm • Coronagraphic imaging
Near-InfraRed Spectrograph **NIRSpec**	• MOS with multi-shutter assembly at 0.6–5.3 μm • 3″ x 3″ IFU spectroscopy • High contrast single object spectroscopy
Near InfraRed Imager and Slitless Spectrograph **NIRISS**	• Low-res. (R~150) WFSS in 0.8–5.0 μm (2.2′ x 2.2′ FoV) • Single object slit less spectroscopy • Aperture-masking interferometry (beyond λ/D) • Imaging at 0.9 and 5.0 μm

Primary survey camera: NIRCam (PI Marcia Rieke)

- Simultaneous dichroic imaging of 0.6 - 2.3 µm and 2.4 - 5.0 µm, over two 2.2′ x 2.2′ FoVs
- Wide-field Slitless spectroscopy (WFSS; R~1000) in long-wavelength
- Coronagraphic imaging

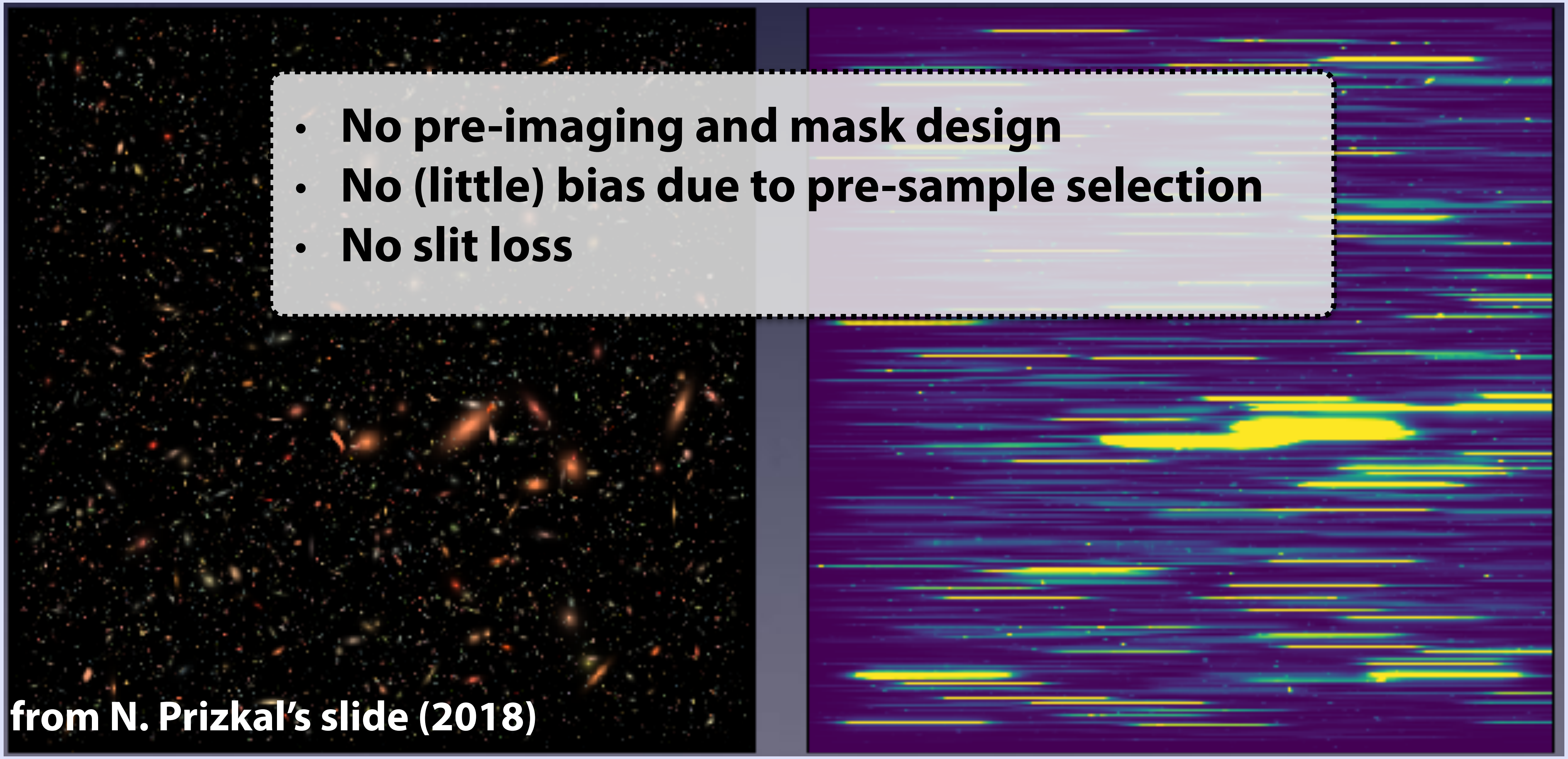




Wide-field slitless spectroscopy with NIRCam

“**Slitless**” spectroscopy with grism

➡ We can obtain spectra for **all** objects in the FoV **simultaneously**



- **No pre-imaging and mask design**
- **No (little) bias due to pre-sample selection**
- **No slit loss**

from N. Prizkal’s slide (2018)

Wide-field slitless spectroscopy with NIRCam

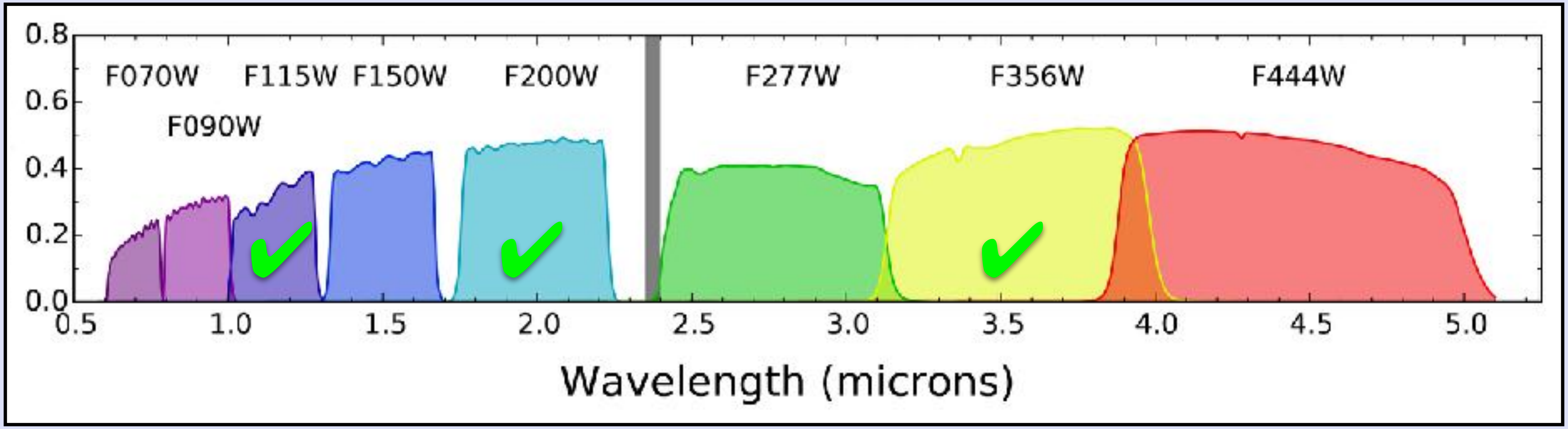
Where should we observe?

➡ Where we have the direct measurements of τ_{eff} = **high-z quasar fields**

ID	z_{QSO}	**Opacity** τ_{eff}	**Absorption sys.**
J0148+0600	5.98	very long, opaque ($\tau>7$) GP trough	-
J0100+2802	6.33	high $\tau\sim3-6$	4 OI ($5.8<z<6.2$)
J1030+0524	6.31	large variation $\tau\sim2$–7	4 CIV ($5.5<z<6.0$), 4 CIV ($z\sim4.8$)
J1148+5251	6.44	large variation $\tau\sim3$–6	4 OI ($6.0<z<6.3$)
J1120+0641	7.08	almost saturated τ	CIV ($z=6.5$), MgII ($z=6.4$)
PSO J159-02	6.35	No data yet	MgII absorption

Filter strategy

We will blindly detect star-forming galaxies at z=5–7 through strong Hβ+[OIII] lines.



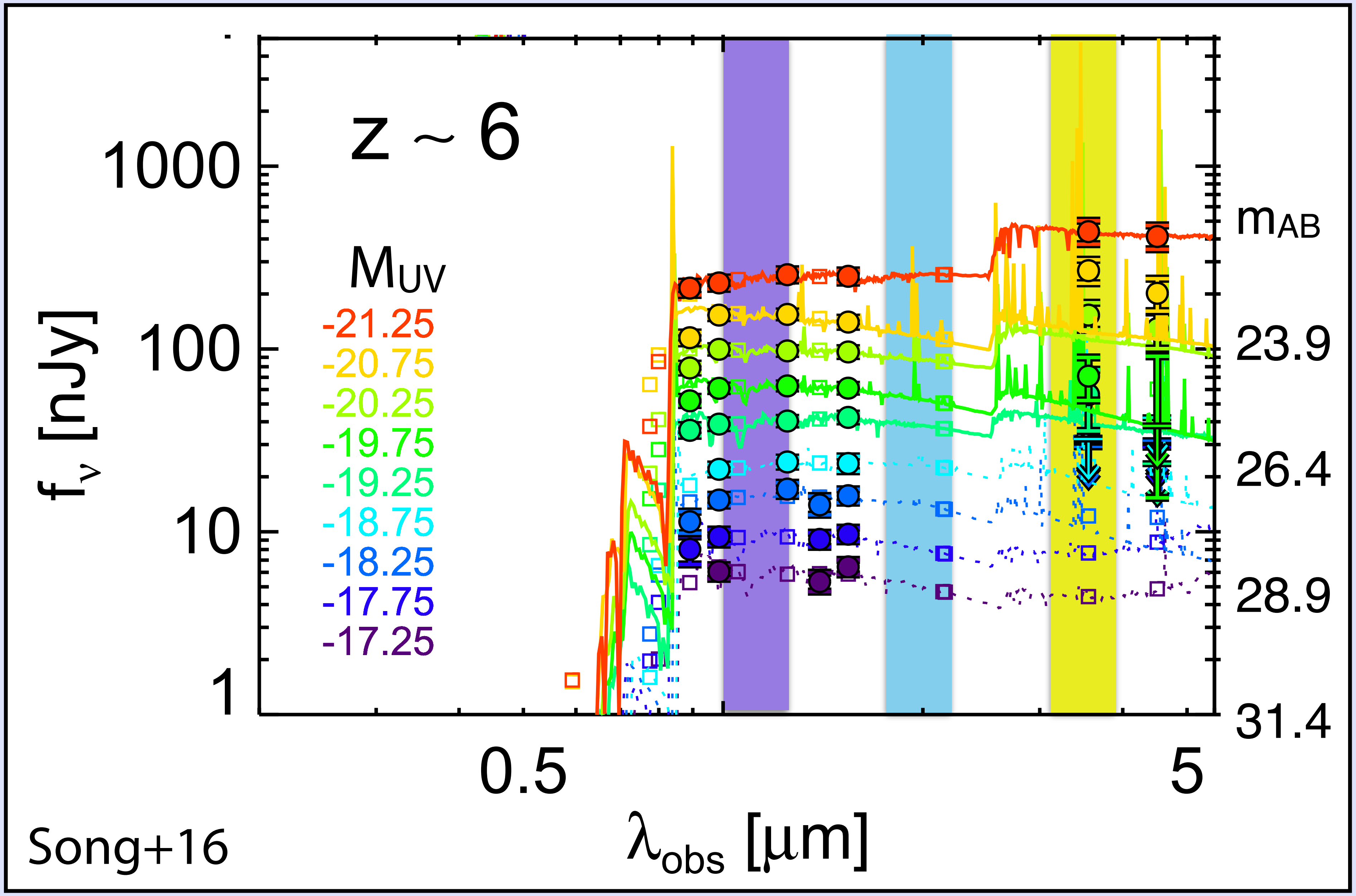
Short-wavelength unit
Imaging in F115W and F200W
Texp=3700 sec / pt.

Long-wavelength unit
Grism(+imaging) in F356W
Texp=7500 sep

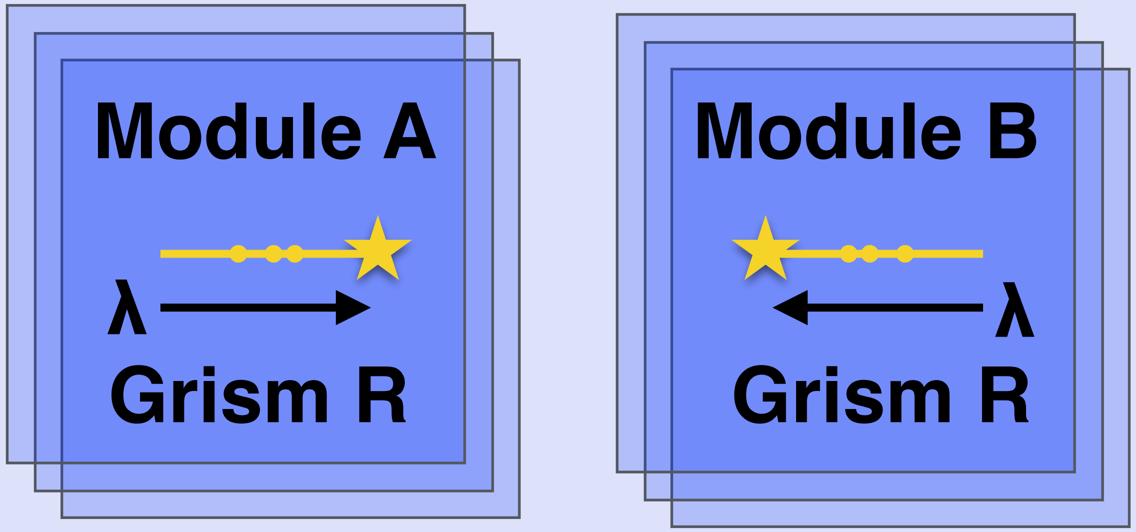
SW imaging and LW grism can be conducted simultaneously!

Filter strategy

This combination of the three filters (0.9, 2.0, 3.6 μm) is very suited to characterize the global properties (M_V, β_{UV} and D_{4000}) of z~6 galaxies, **like the commonly-used BzK technique at z~2.**

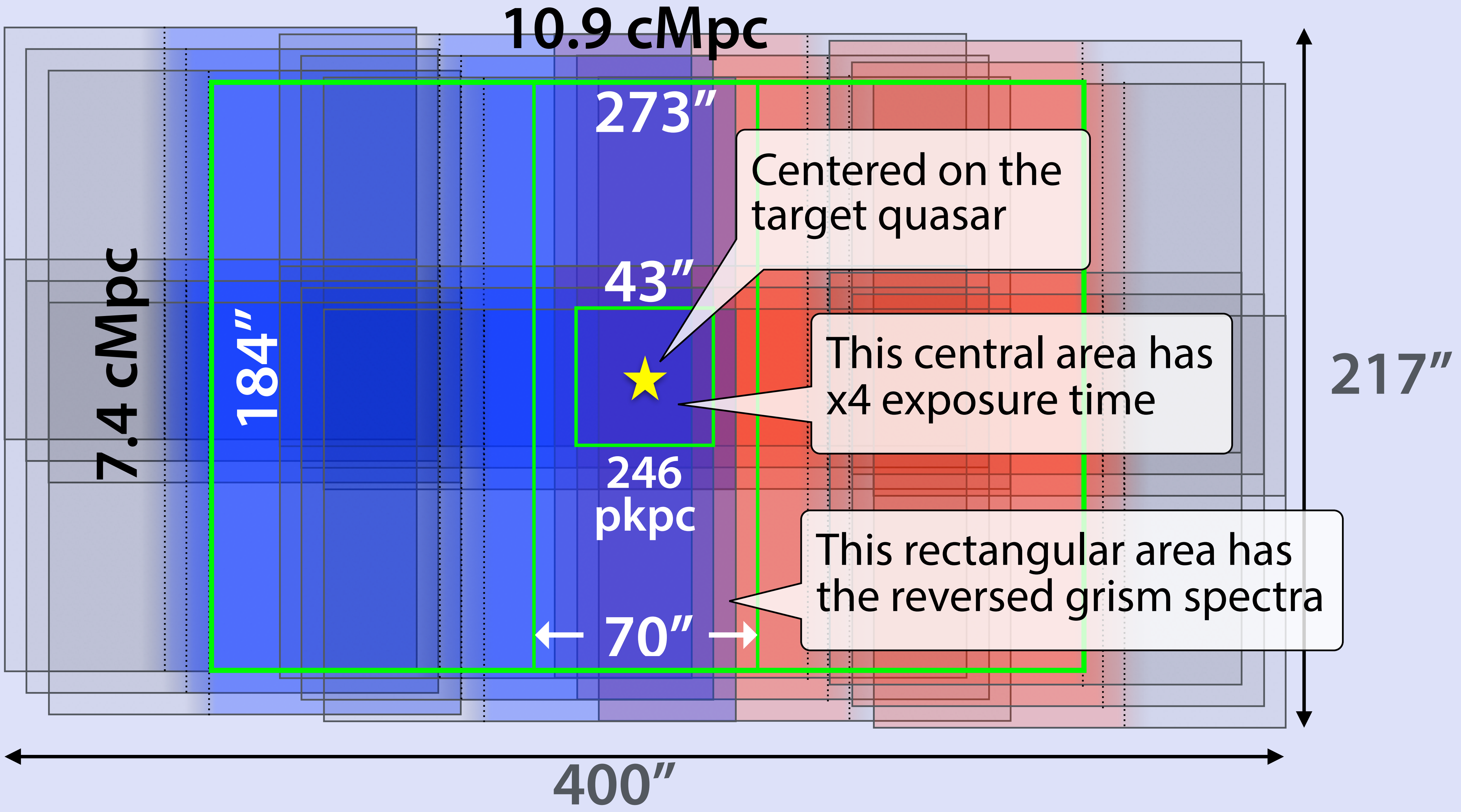


“Wedding cake” mosaic design



Primary dithers

4 Mosacs

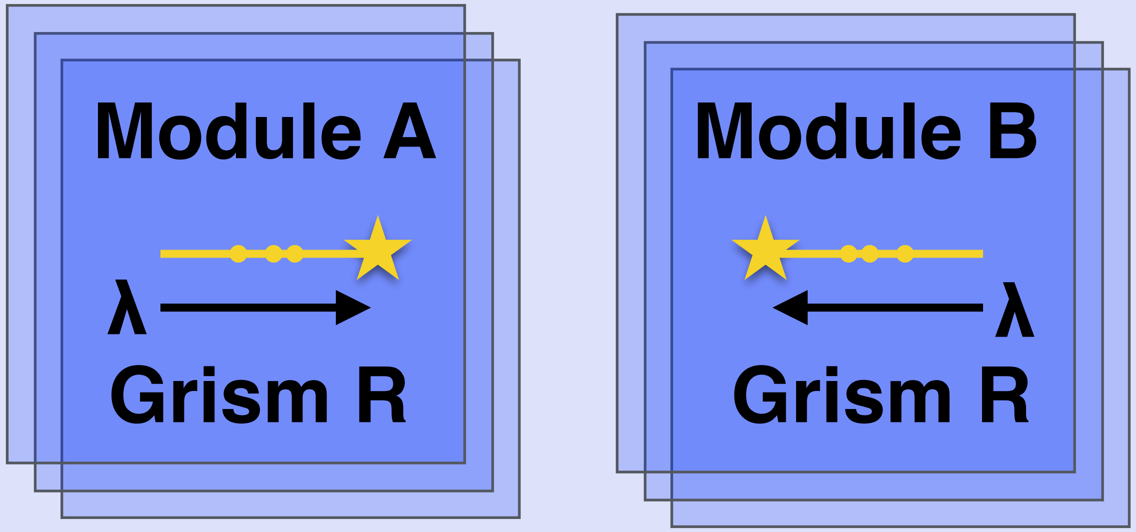


Centered on the target quasar

This central area has x4 exposure time

This rectangular area has the reversed grism spectra

“Wedding cake” mosaic design



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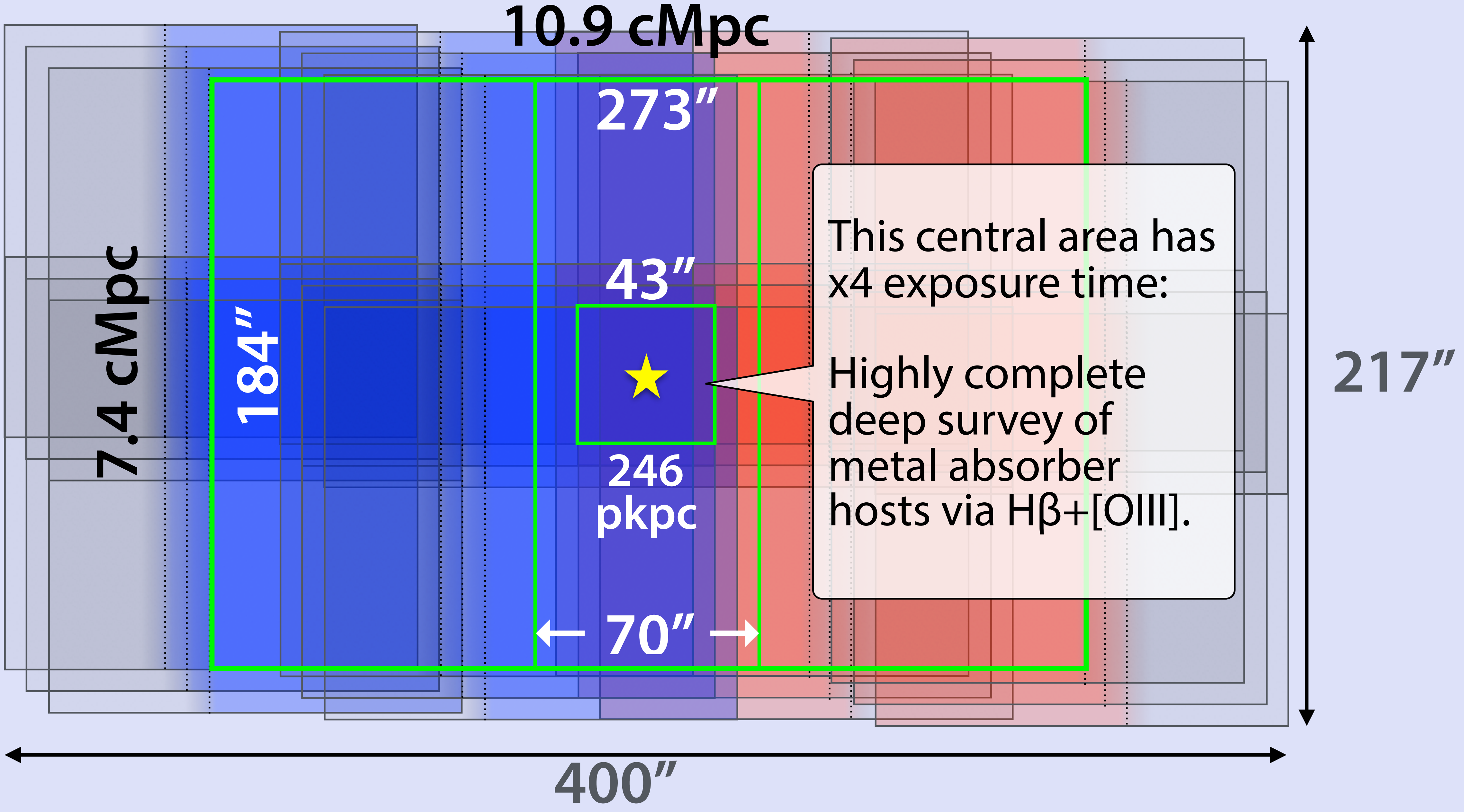


This central area has x4 exposure time:

Highly complete deep survey of metal absorber hosts via Hβ+[OIII].

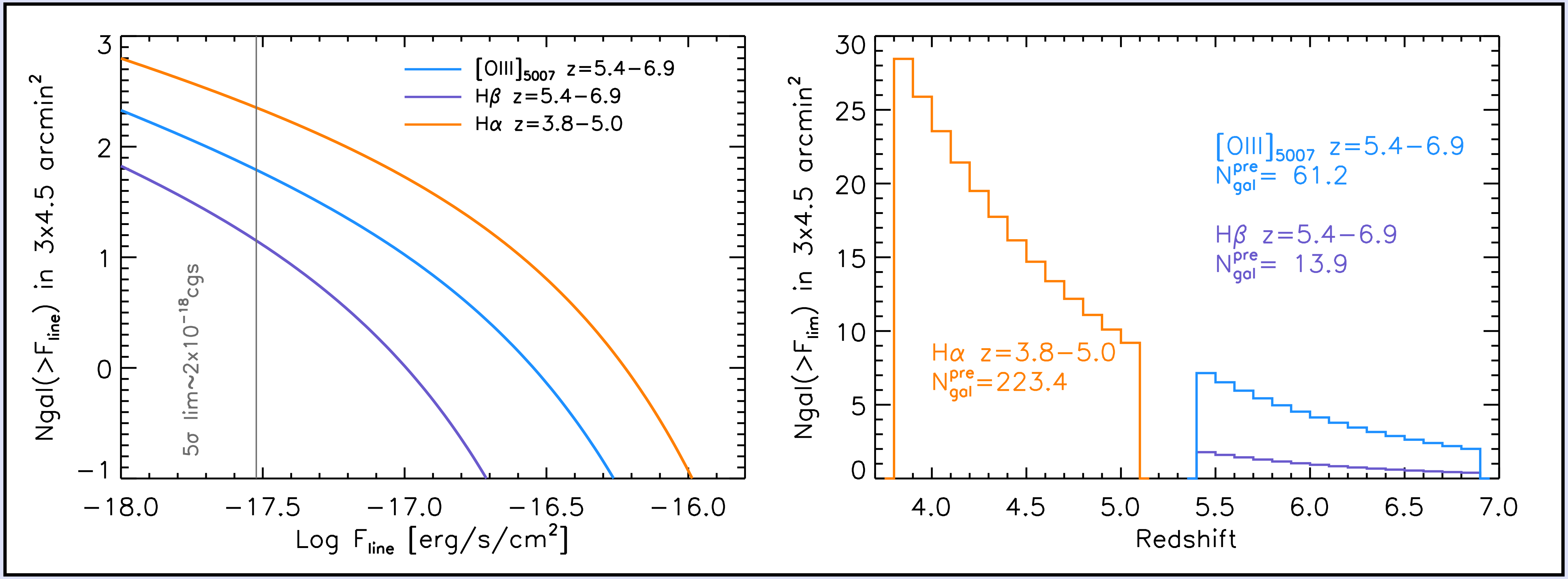
Exposure time and sensitivity

Total science time	Plan	Filter	Exposure/ pointing	Max. exp. (x 4)	Sensitivy at 5σ (point source)
11.1 hr / field (overheads ~ 7 hr) 60.5 hr for six fields (110 hr incl. overheads)	**SW 1**	F115W	3865 sec	4.3 hr	28.3 abmag
	SW 2	F200W	3865 sec	4.3 hr	28.6 abmag
	LW direct images	F356W	537 sec	0.45 hr	27.9 abmag
	LW Grism	F356W	7730 sec	8.6 hr	~ 3e-18 erg/s/cm^2

Four times the nominal exposure time for the central sweet spot!

Expected number of detections in the “WIDE” layer

Based on observations of UV LFs, but also very sensitive to the assumption of EW([OIII]5007).



Assumptions: Bowens+2015 UV LFs, $M_{UV}=M_{[3.6]}$, EW_0([OIII]5007) = 600Å at z=6.0, EW_0(Hα)=400Å at z=4.5, EW∝$(1+z)^{1.2}$ (e.g., Smit+15, Labbe+13)

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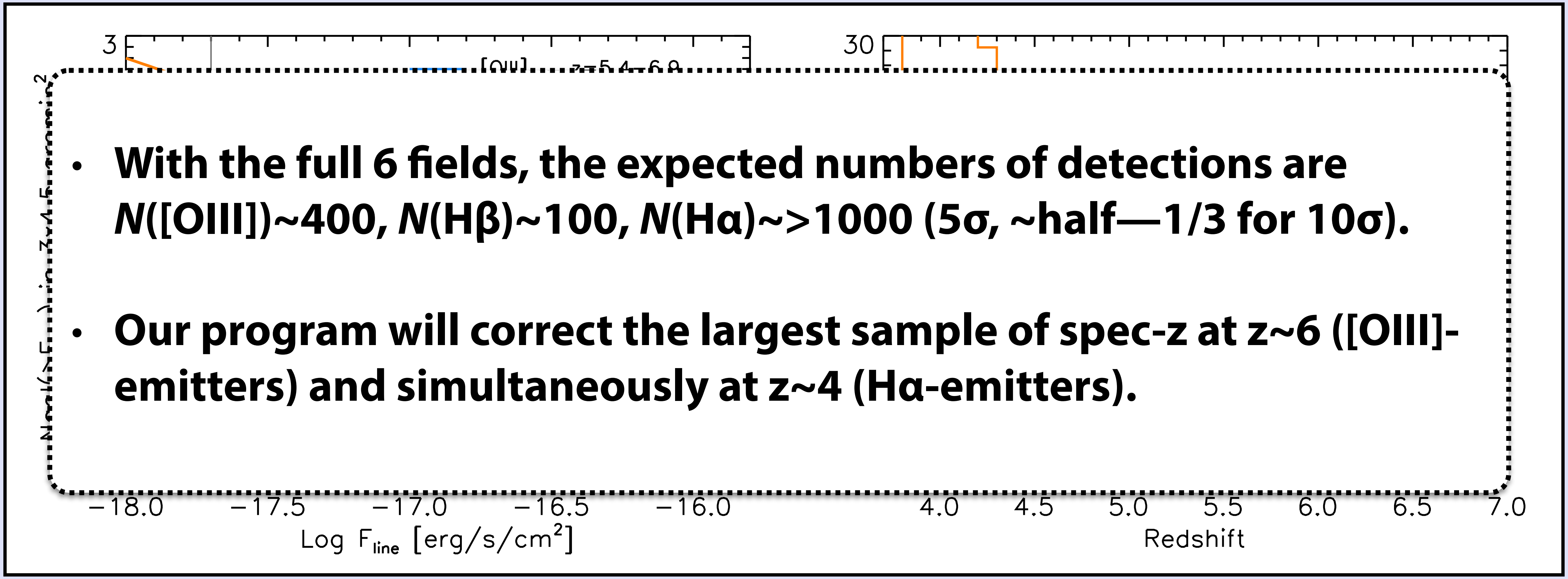
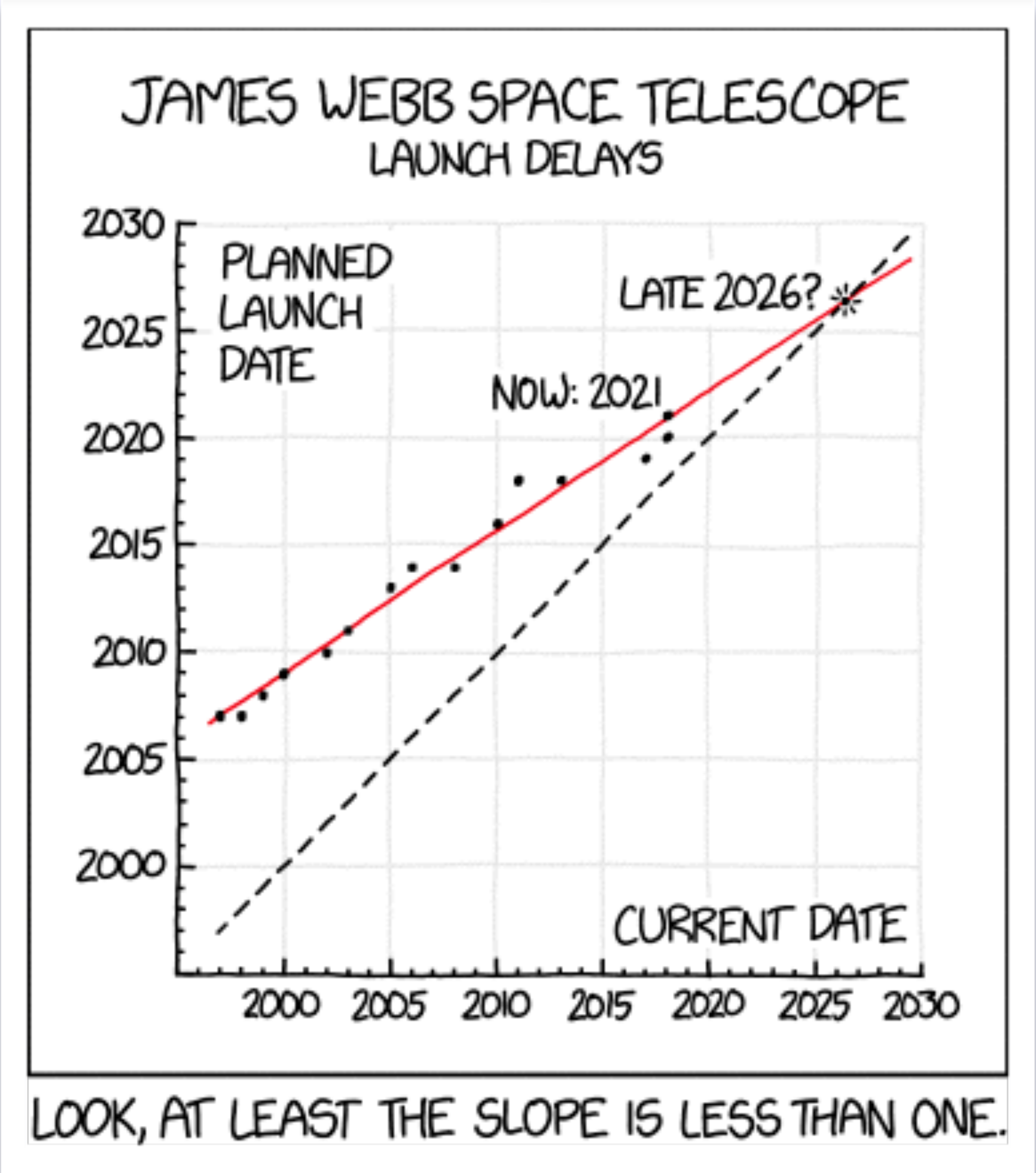


- **With the full 6 fields, the expected numbers of detections are *N*([OIII])~400, *N*(Hβ)~100, *N*(Hα)~>1000 (5σ, ~half—1/3 for 10σ).**
- **Our program will correct the largest sample of spec-z at z~6 ([OIII]-emitters) and simultaneously at z~4 (Hα-emitters).**

Assumptions: Bowens+2015 UV LFs, $M_{UV}=M_{[3.6]}$, EW_0([OIII]5007) = 600Å at z=6.0, EW_0(Hα)=400Å at z=4.5, $EW \propto (1+z)^{1.2}$ (e.g., Smit+15, Labbe+13)

When will JWST fly?

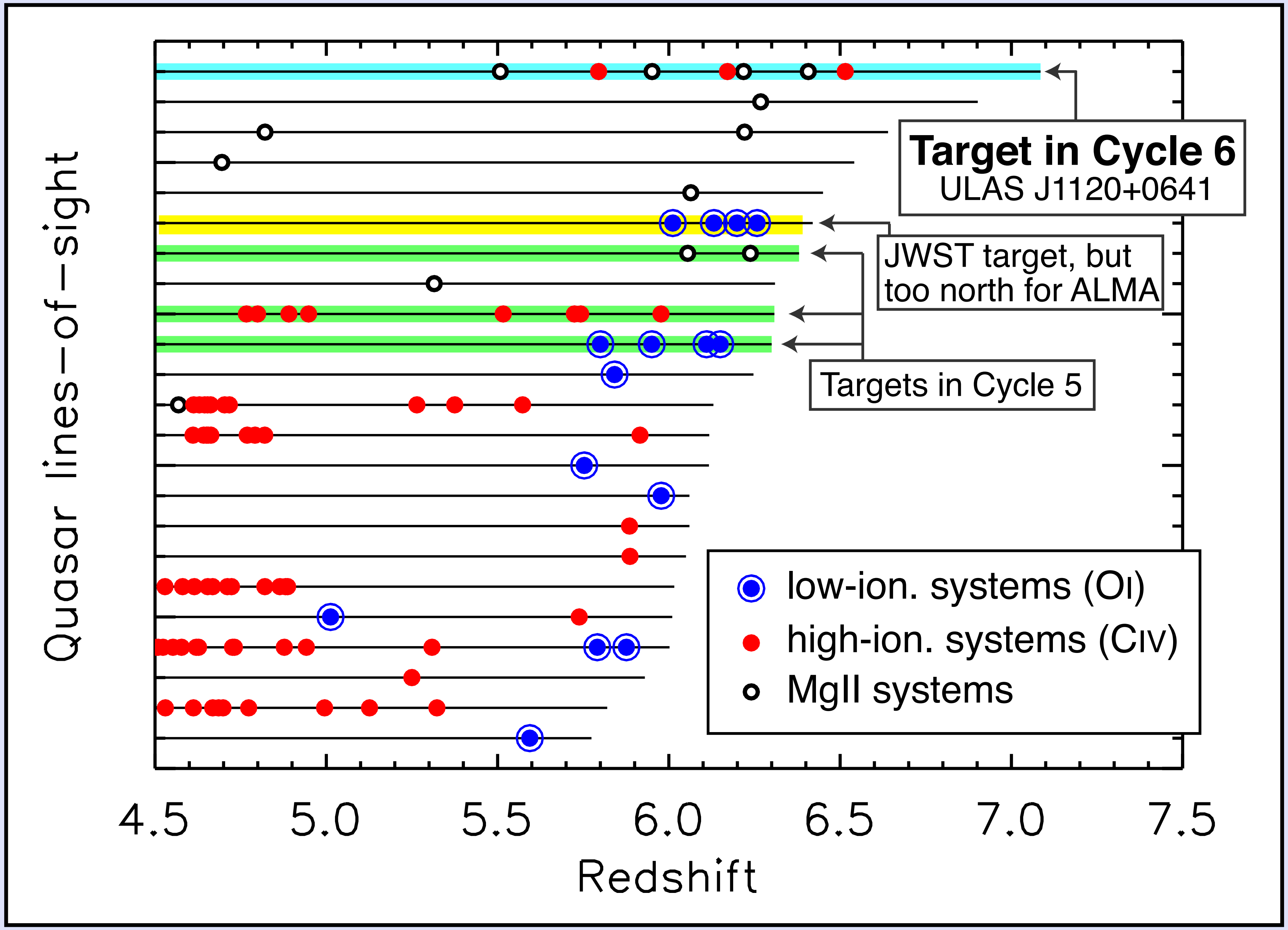
- Currently, being re-scheduled in 2021.



LOOK, AT LEAST THE SLOPE IS LESS THAN ONE.

Search for host galaxies of metal absorption systems by ALMA (approved) and MUSE (proposed)

Summary of absorption systems towards z>6 quasars

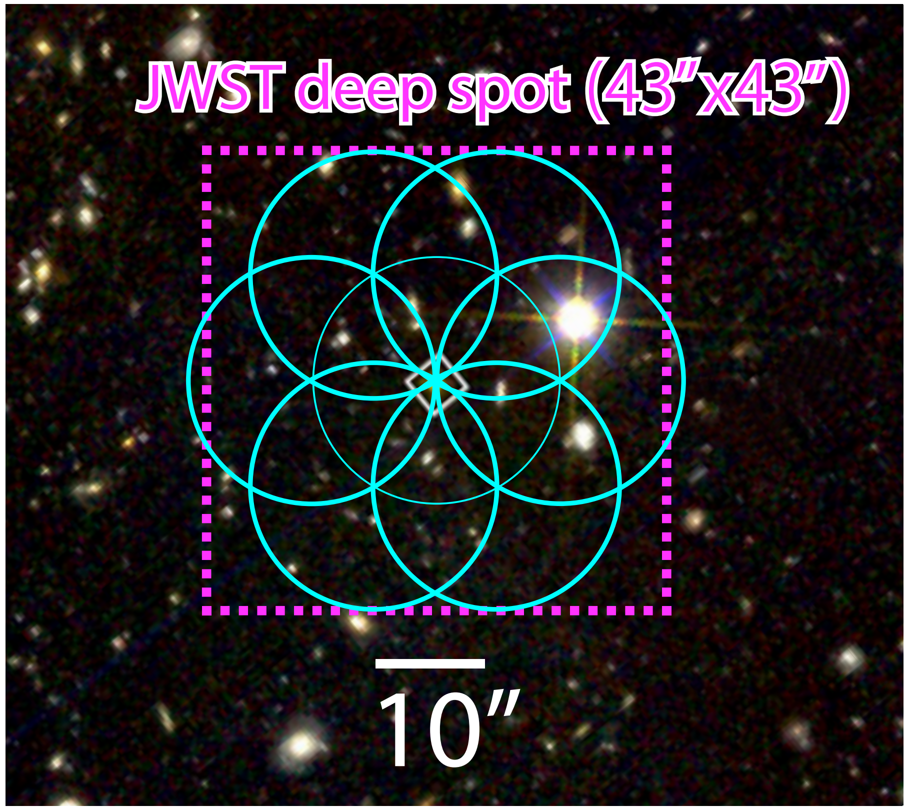


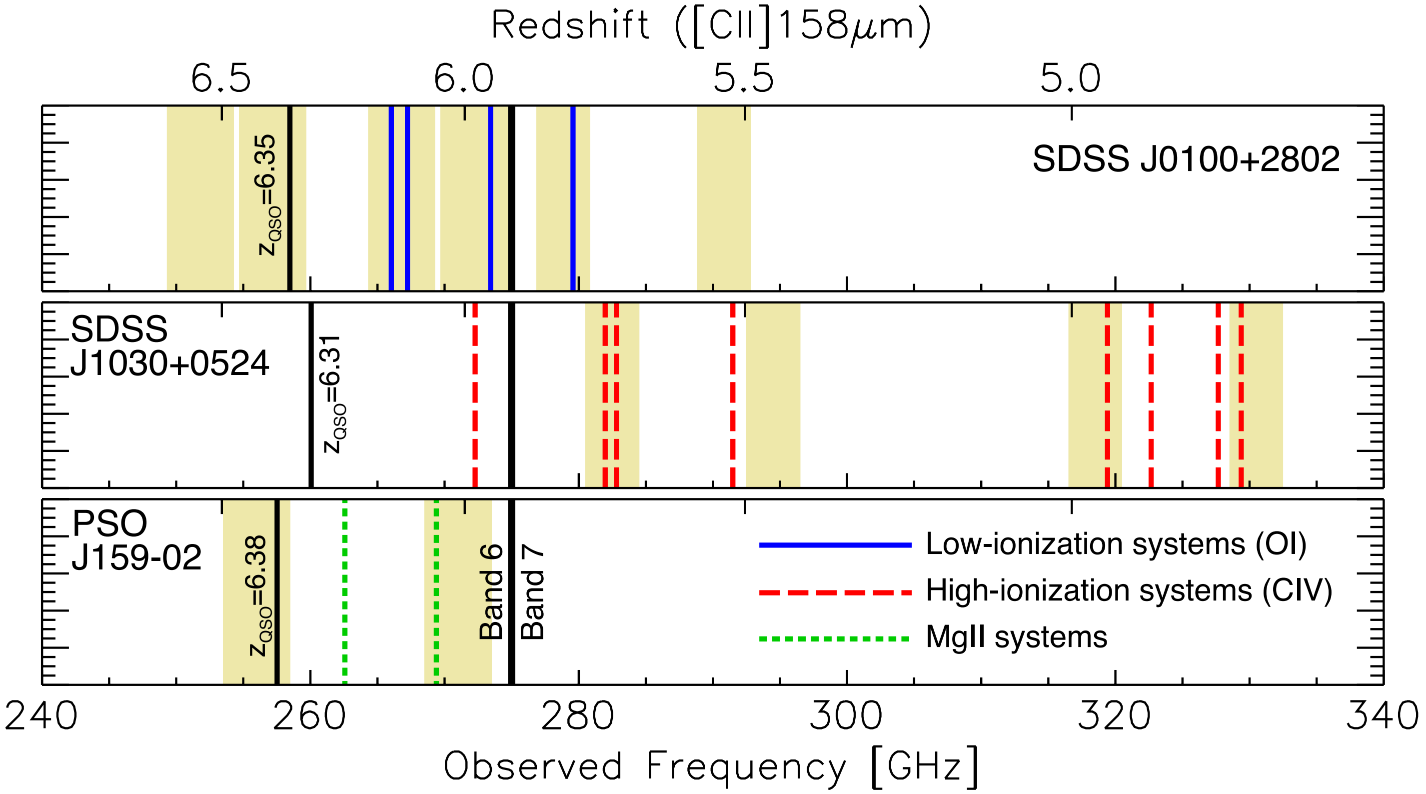
Our 6 JWST targets are highlighted.

Blind search for [CII]158μm emission associated to the metal absorption lines at z~>5 with ALMA

in our JWST target fields

Approved in Cy. 5 and 6



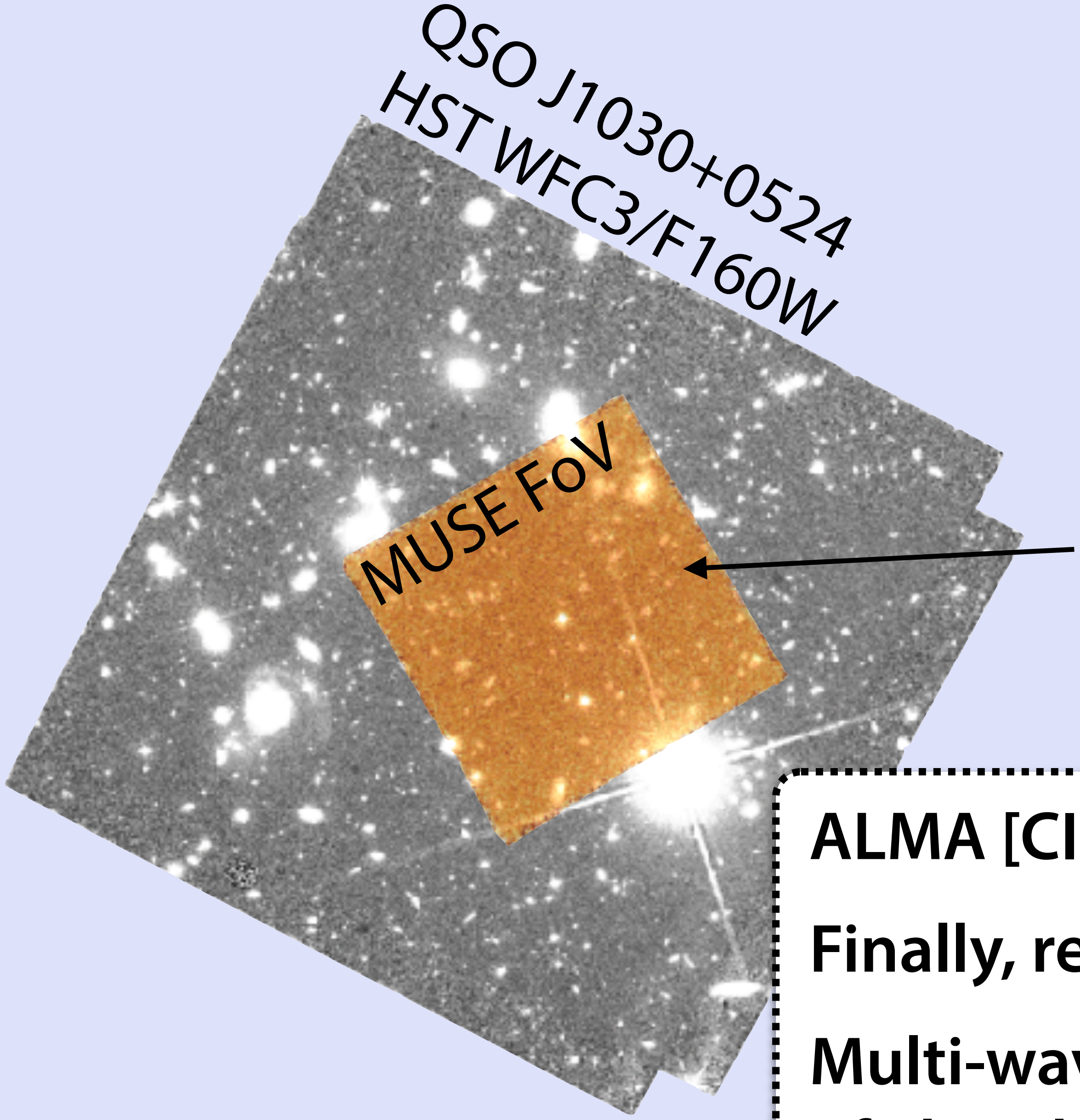


~6 min per each pointing for $L_{[CII]}\sim10^{8.5}L_{\odot}$ (SFR~20–40 $M_{\odot}$/yr) at S/N=5

All proposed observations in Cya 5 have been executed. [CII]158μm of the quasars and some continuum objects are detected, but **no clear detection of [CII]158μm are not discovered for far at a glance of the data cubes…**

Blind search for Lyα emission associated to the metal absorption lines at z~>5 with MUSE

in our JWST target fields



- Successful detections by MEGAFLOW (Schroetter+16)
- Two fields proposed currently (VLT Period 103)
- Two more fields will be proposed in P104.
- A 6-hr cube in the field of QSO J1030+0524 is public.

ALMA [CII]158μm + MUSE Lyα + HST deep images

Finally, rest-frame optical grism images by JWST

Multi-wavelength comprehensive search and study of absorber host galaxies

Summary:

- Identification of the host systems of metal absorbers at $z>4$–5 will revolutionize our knowledge about baryon processes in and around galaxies.
- Our JWST program will provide a large sample of [OIII]-emitters at $z\sim6$, and highly complete search along the quasar sightlines.
- We are making big synergy of JWST + ALMA and MUSE for search and (if ~~detected~~ exit) subsequent detailed studies of absorber hosts near the EoR .