8 Aug 2022
Galaxy-IGM workshop

The EIGER project

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on behalf of the EIGER team

The EIGER project

JWST GTO 1243 PI Simon Lilly

***E**mission-line galaxies and **I**ntergalactic **G**as*
*in the **E**poch of **R**eionization*

Large spectroscopic galaxy surveys using 110 hours of JWST

Eiger is a famous beautiful mountain in Switzerland.

Team

Switzerland

S. J. Lilly, J. Matthee
R. Mackenzie

Japan

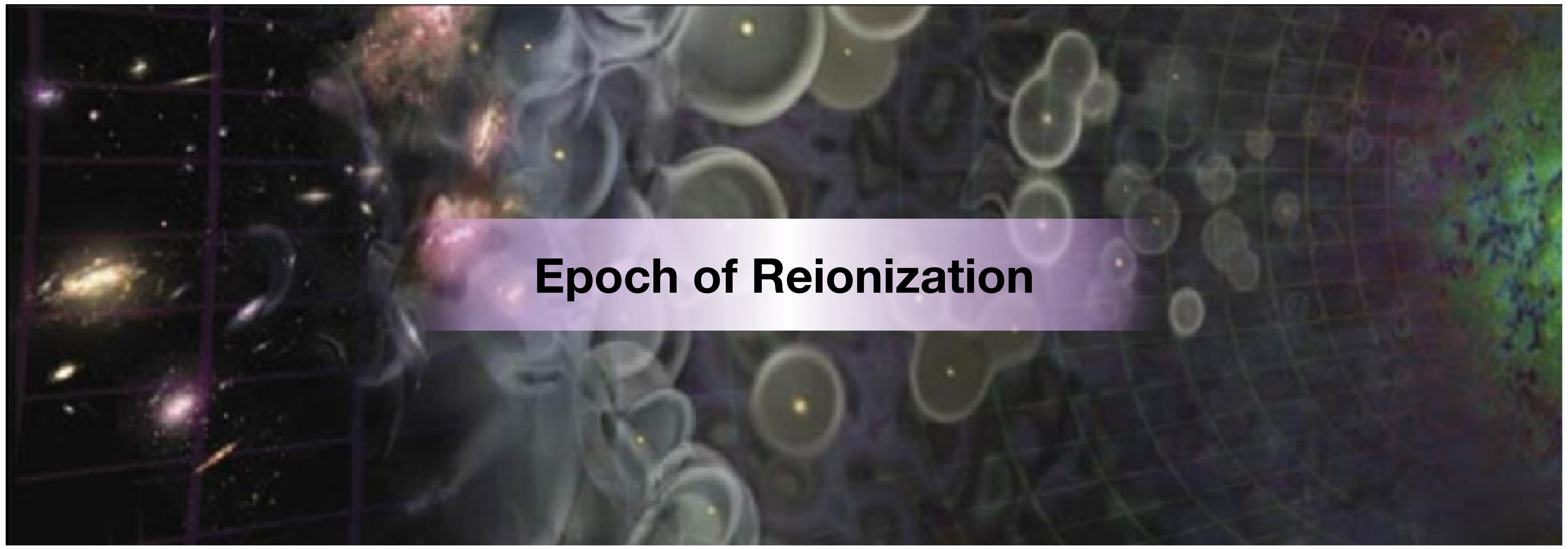
DK

US

R. Simcoe, R. Bordoloi
A-C. Eilers

Exploring the tail end of reionization

Present-day Universe | Reionization complete | First galaxies | First stars



Loeb, 2006, Scientific American

Recombination

z=0 | z~6 | z~15 ? | z~20–30 ? | z=1100

Time

To understand reionization, we need to observe **galaxies** *and* **intergalactic gas (IGM).**

They are often carried out independently,

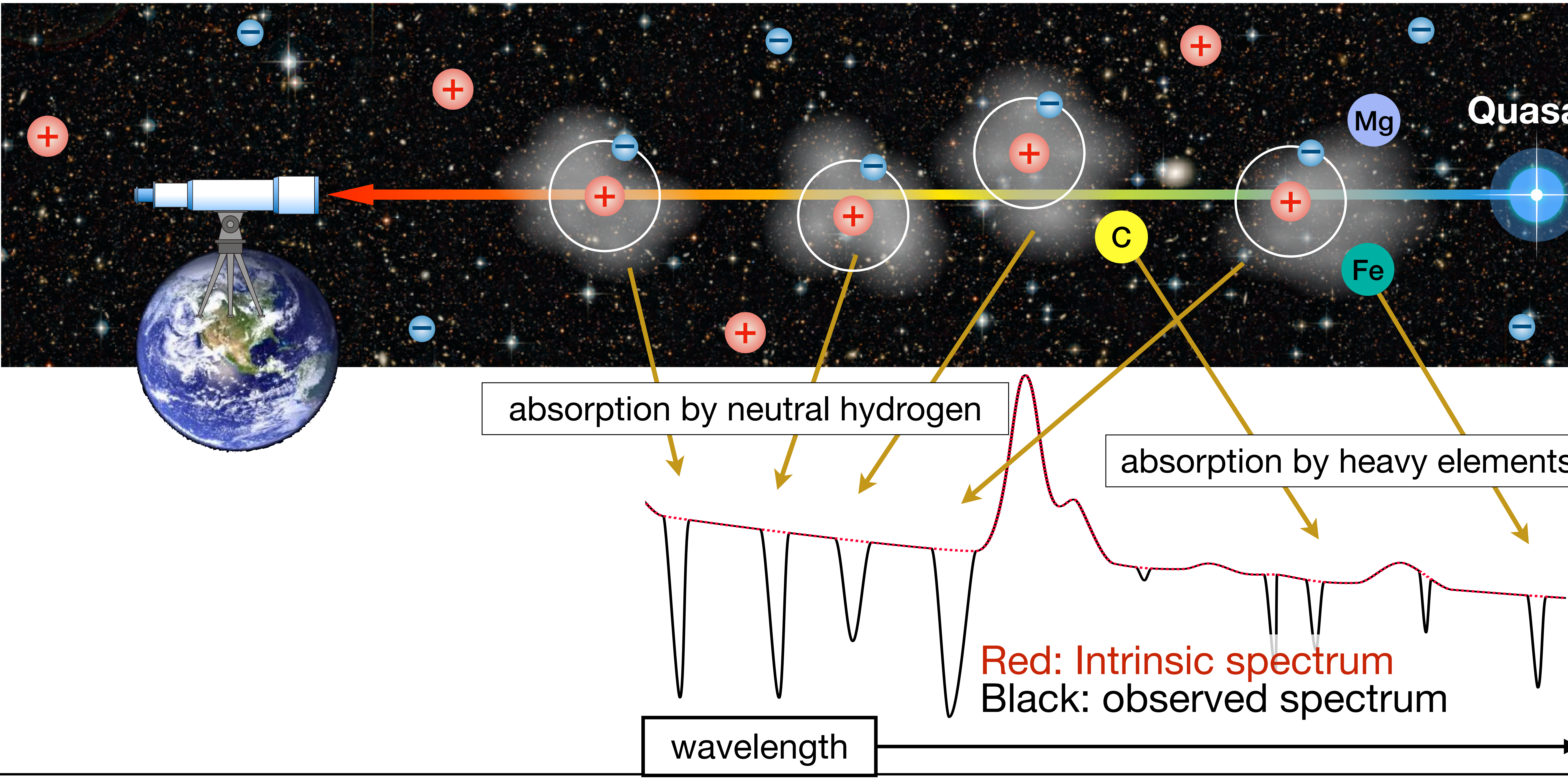
but reionization is the result of interactions between galaxies and the IGM.

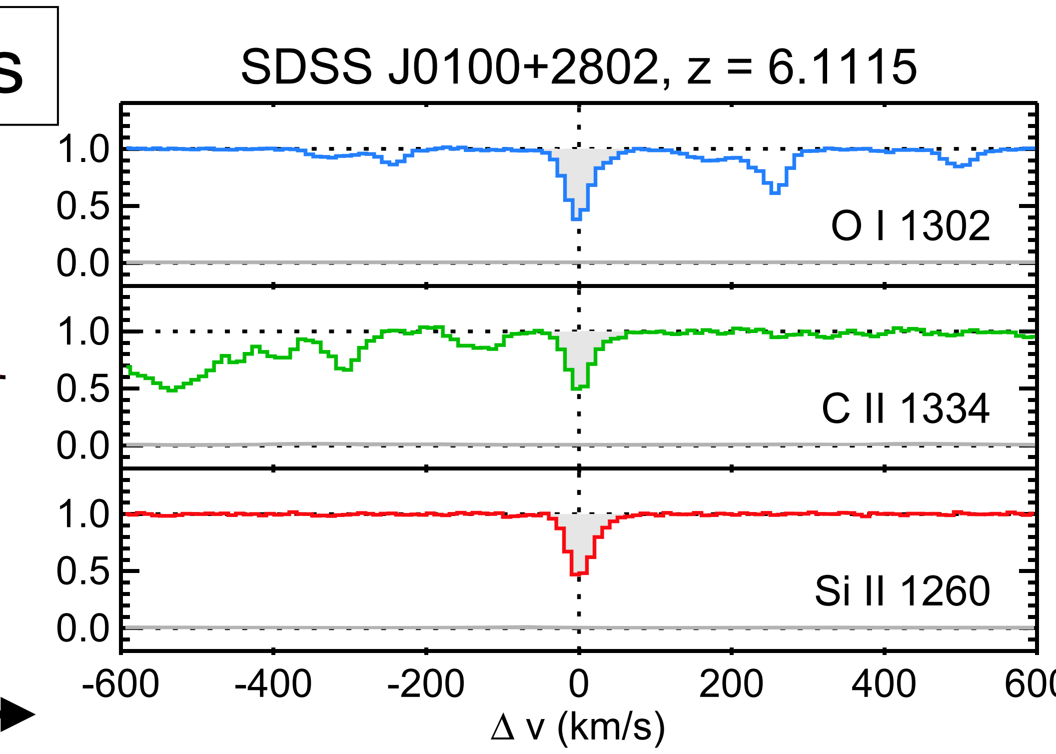
EIGER will do both in the same lines of sight.

Probing the IGM *and* galaxies in the EoR

The diffuse gas hardly emits light,
but we can measure its physical conditions using background "candles".

The absorption of the candle's light tells us about the properties of the intervening matters along the line of sight – e.g., the amount of neutral hydrogen and some heavy elements.





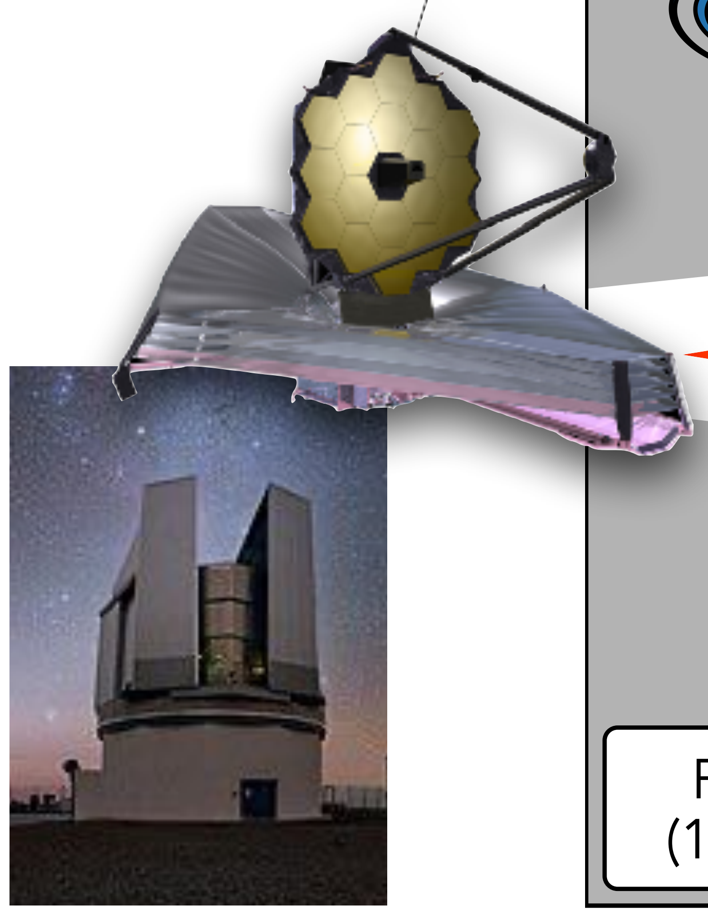
EIGER's strategy and major goals

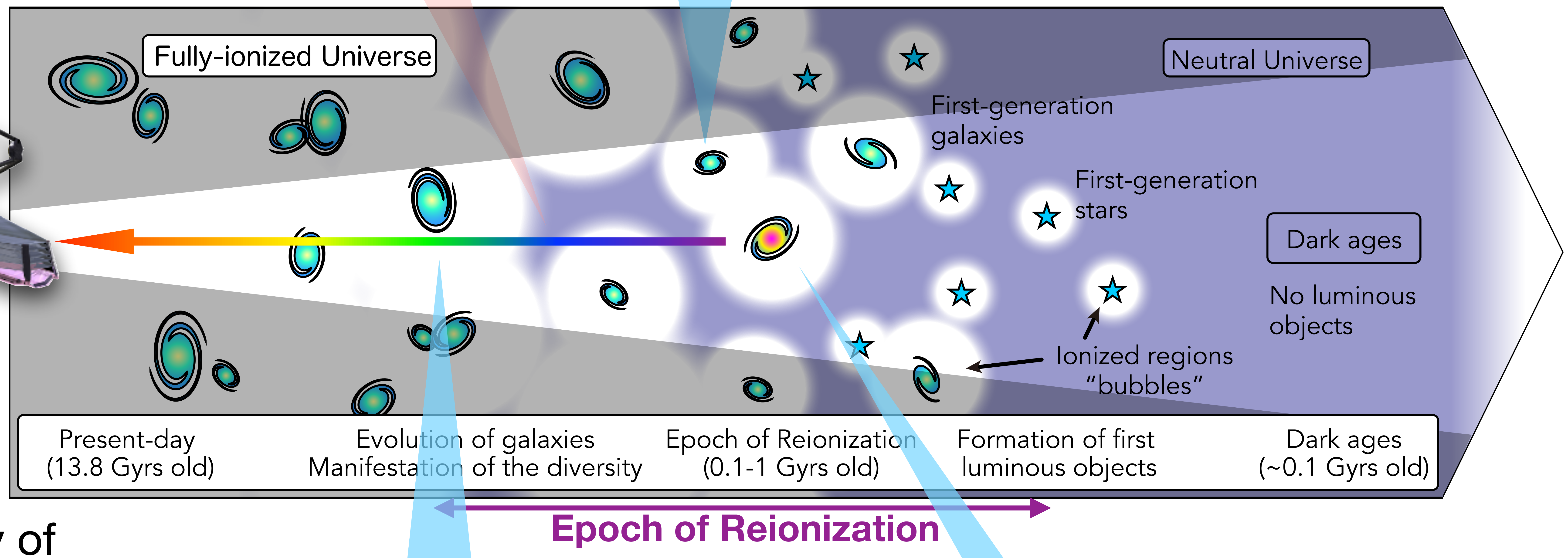
Correlating the galaxies with the diffuse IGM in the Universe

The line-of-sight IGM/CGM properties are probed by the quasars' spectra

Processes of **cosmic reionization** and the role of galaxies

Galaxy survey with JWST





Deep spectroscopy of the quasars with ground-based telescopes

Interplay between galaxies and **the inter/circum-galactic gas**

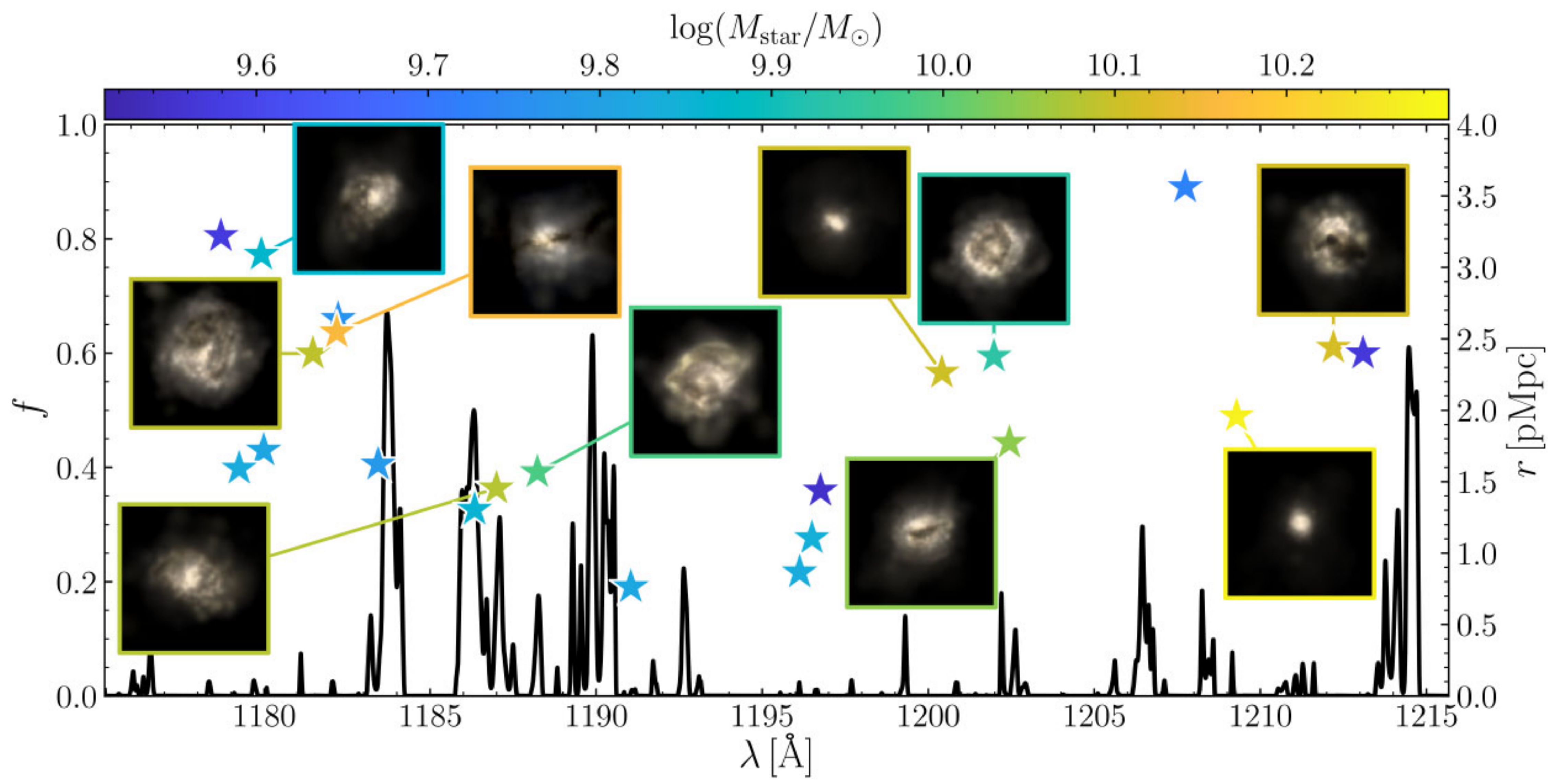
Formation of the earliest **supermassive black holes**

Galaxy vs. IGM optical depth at small scales (<10 Mpc)

Cross-correlation between individual galaxies and Ly-alpha transmission spikes

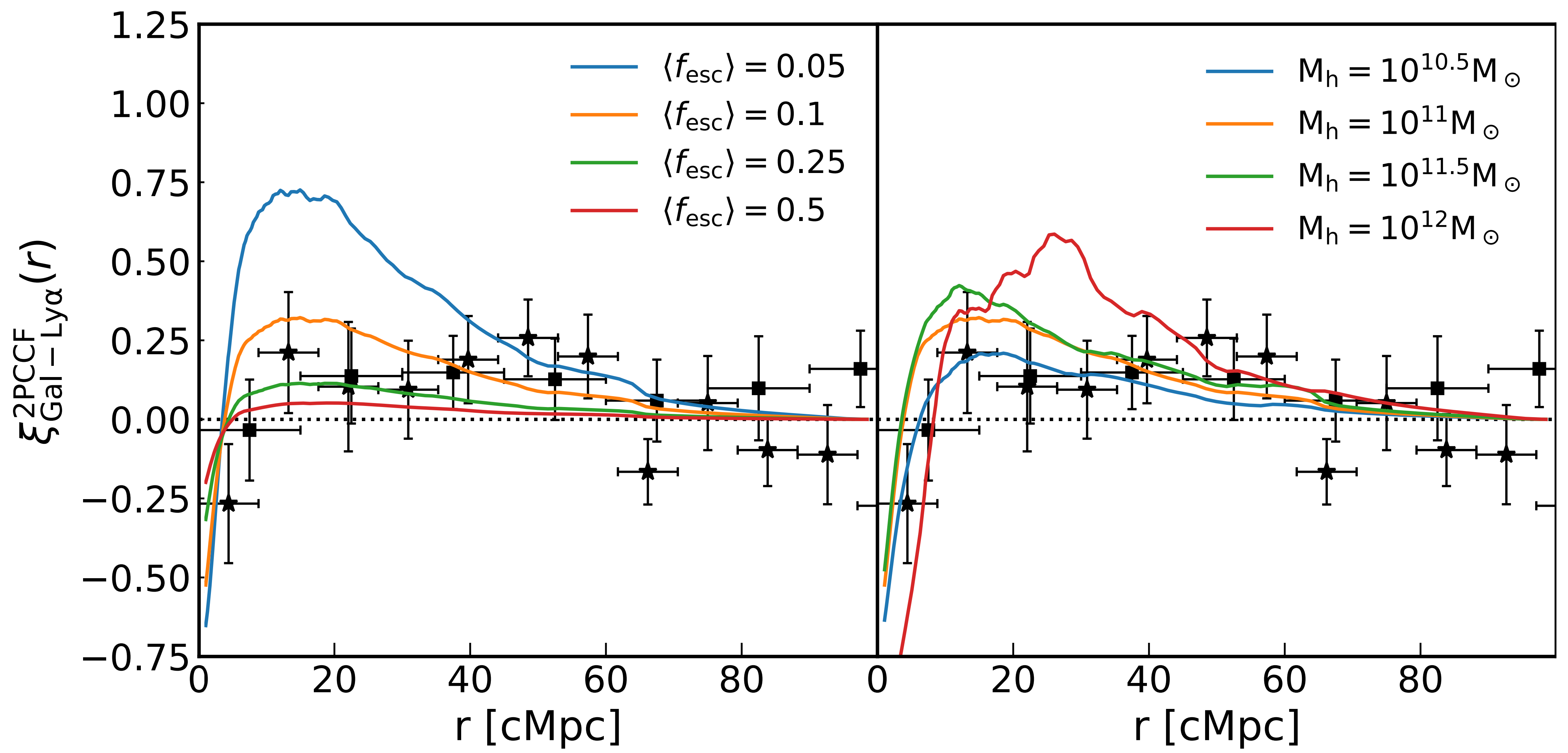
➡ the properties of galaxies mainly responsible for reionization and ionized bubbles

Simulated sight-line view
(galaxy distribution vs Lyα transmission)



The THESAN simulation (Garaldi+2022)

Sims predict different cross-correlation shapes for different recipes.



Kakiichi+18, Meyer+22

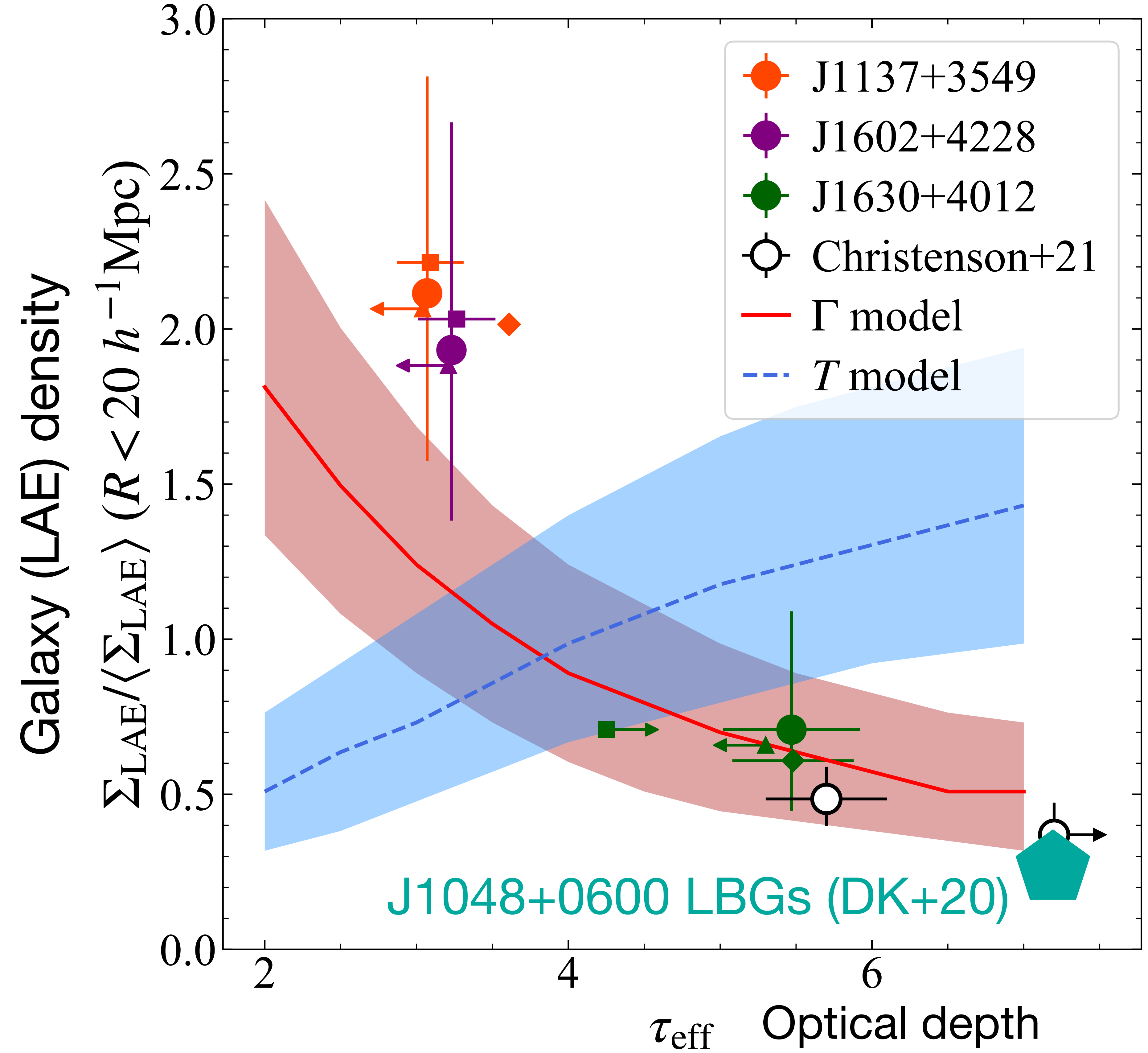
Galaxy vs. IGM optical depth at large scales

Our Subaru/HSC observations are accumulating evidence that the galaxy density is anti correlated with the IGM Lyα optical depth.

These all supports scenarios in which reionization is mainly caused by highly inhomogeneous UV radiation field dominated by galaxies' radiation.

EIGER is highly complementary!
We will further examine the models and study small-scale physics.

NEW RESULTS!



Ishimoto, Kashikawa, DK+22
accepted in MNRAS

Observations

Target quasars

Based on metal-absorption systems, Lyα forest, and availability of high-quality spectral data.
We have been accumulating new complementary observations
in these fields and the quasars themselves.

Name	z	Features	Schedule
J0100+2802	6.3258	Ultraluminous. Many metal absorption systems (incl. 3 OI)	**Aug, 2022**
J0148+0600	5.98	Extremely long Lyα trough	Dec, 2022 – Jan, 2023
J1120+0641	7.084	Highest-z quasar as of the proposal submission. Some absorption systems. Targeted in NIRSpec GTO.	
J1148+5251	6.4189	Many metal absorption systems (incl. 4 OI)	
J1030+0524	6.308	Well studied. Many absorption systems.	Apr – Jun, 2023
J159-02	6.35	Strong MgII at z~6	

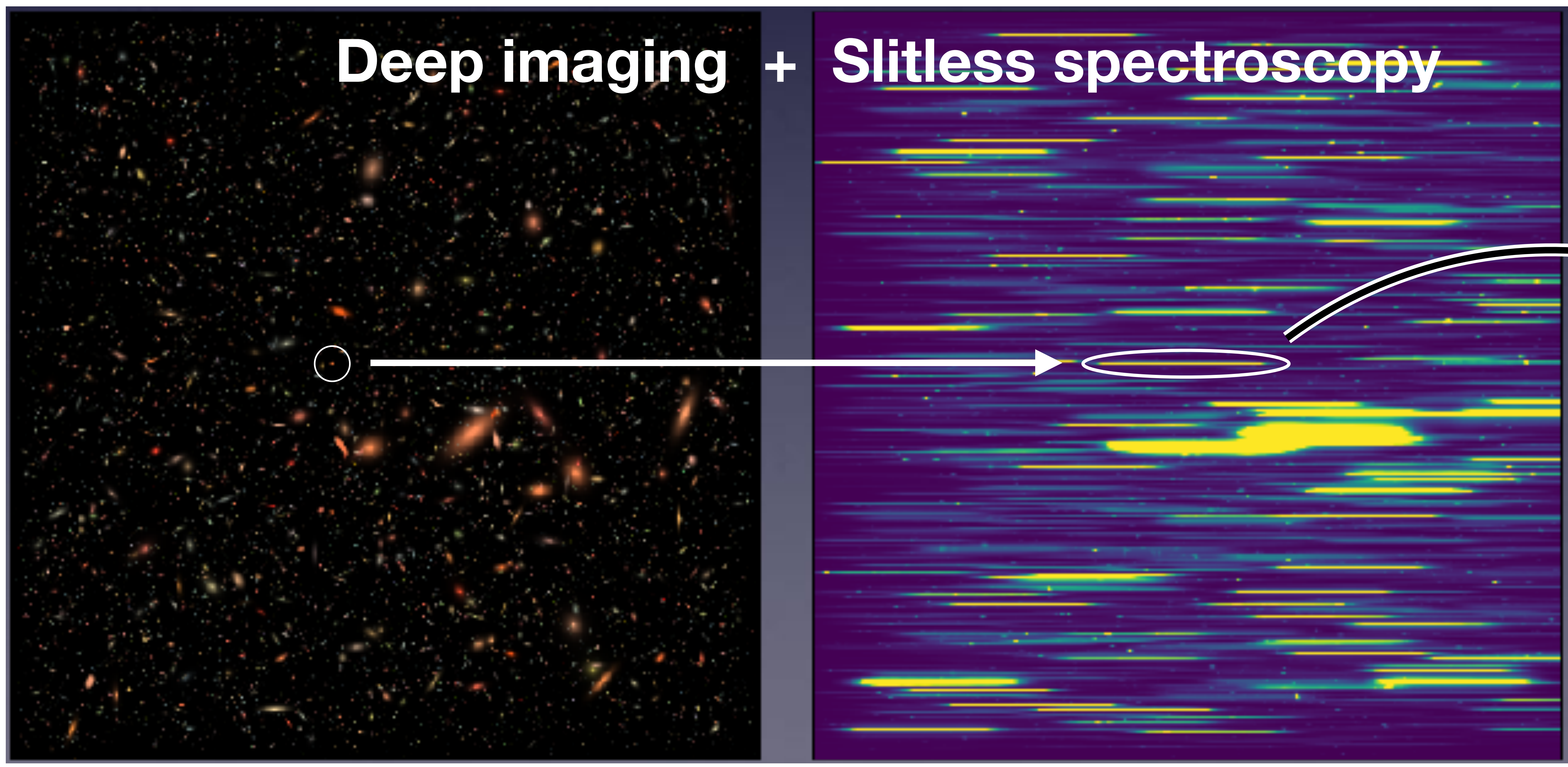
NIRCam WFSS

We will perform **"wide field slitless spectroscopy (WFSS)"**

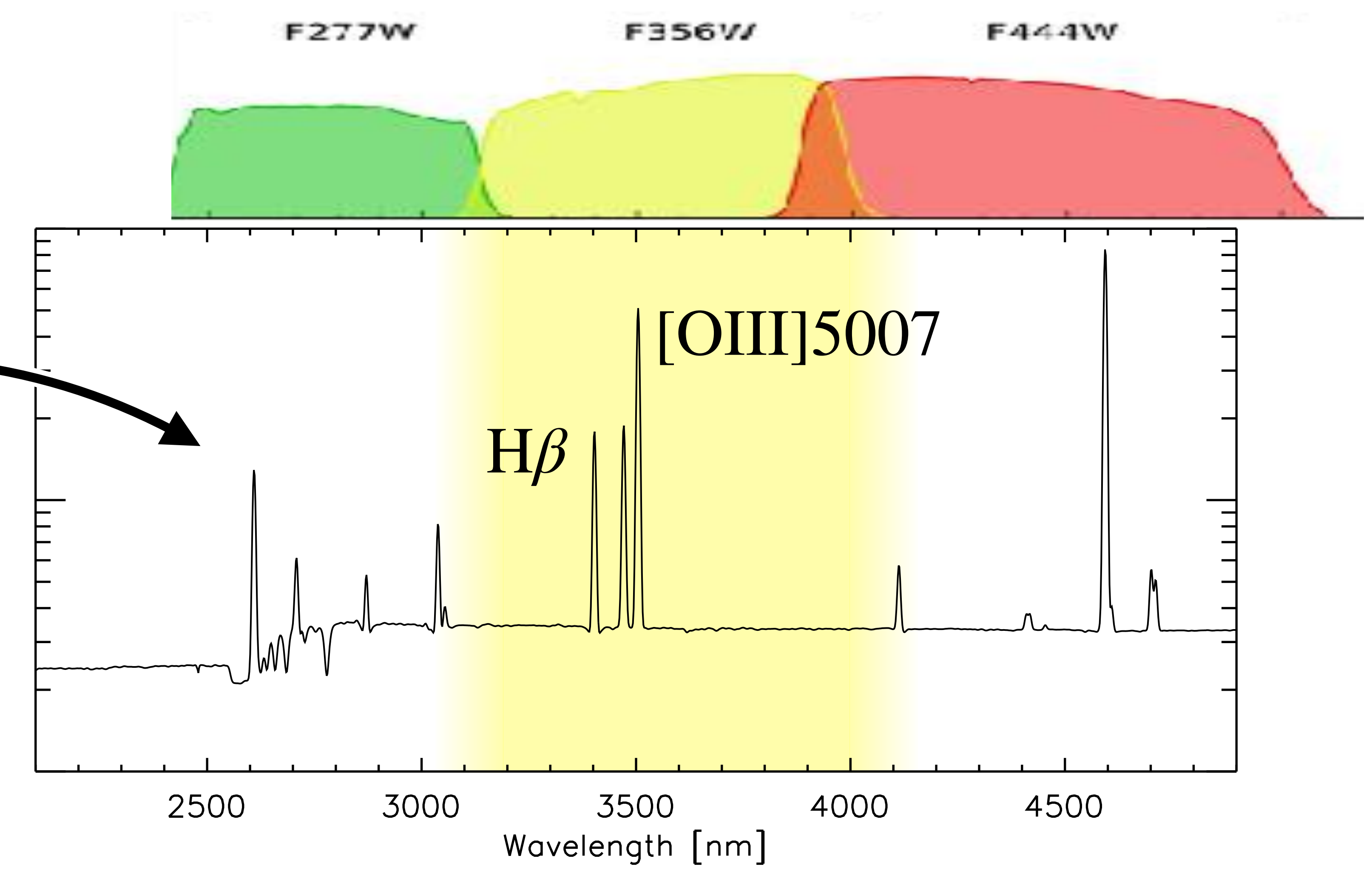
➡ We can obtain spectra from **all** objects in the field of view in one observation.

Pros:
- No pre-imaging and configuration of spectrograph
- No bias due to pre-sample selection

Cons:
- Spectra from different objects are blended
- Background noise level tends to be higher



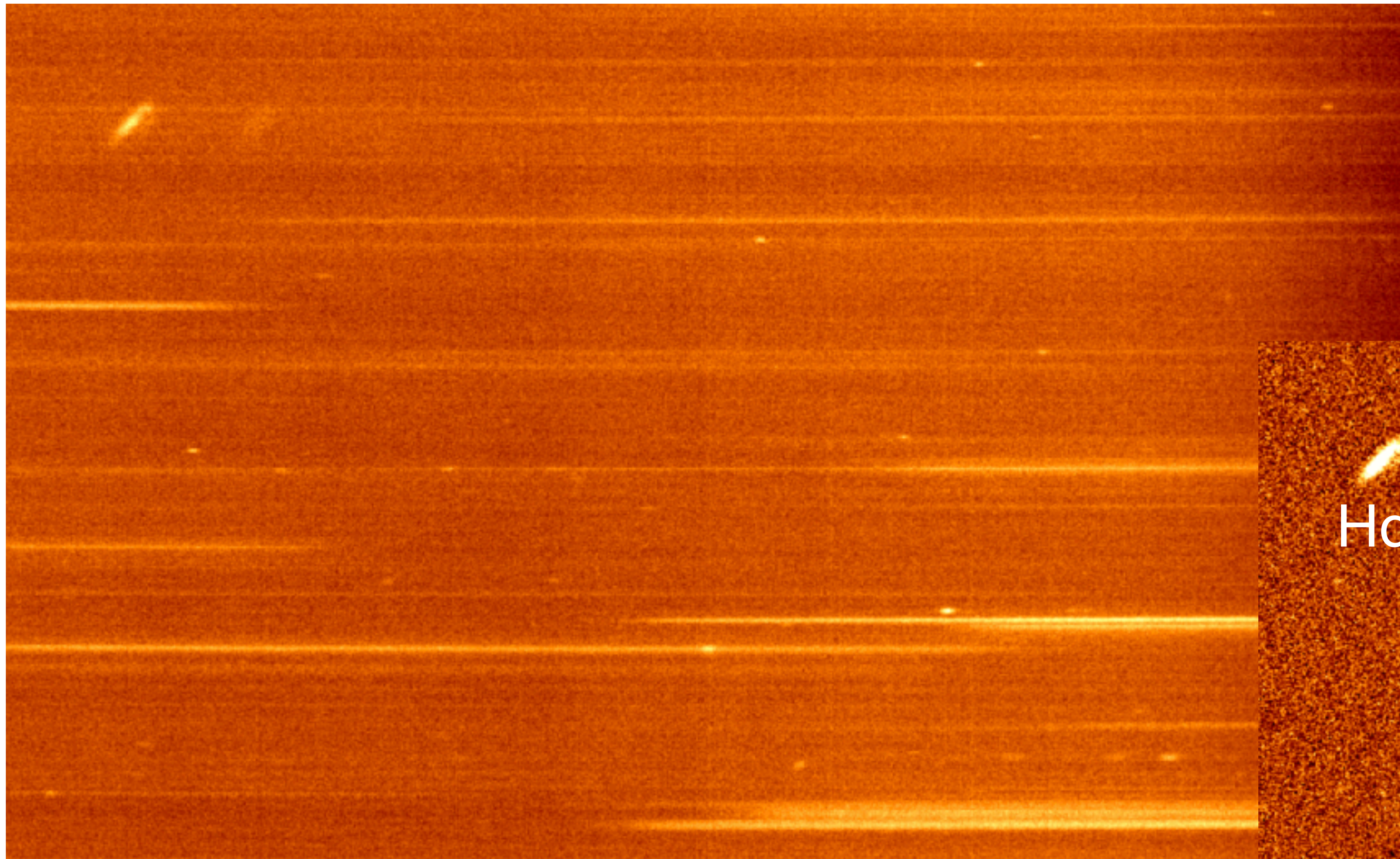
JWST observation simulation by N. Prizkal



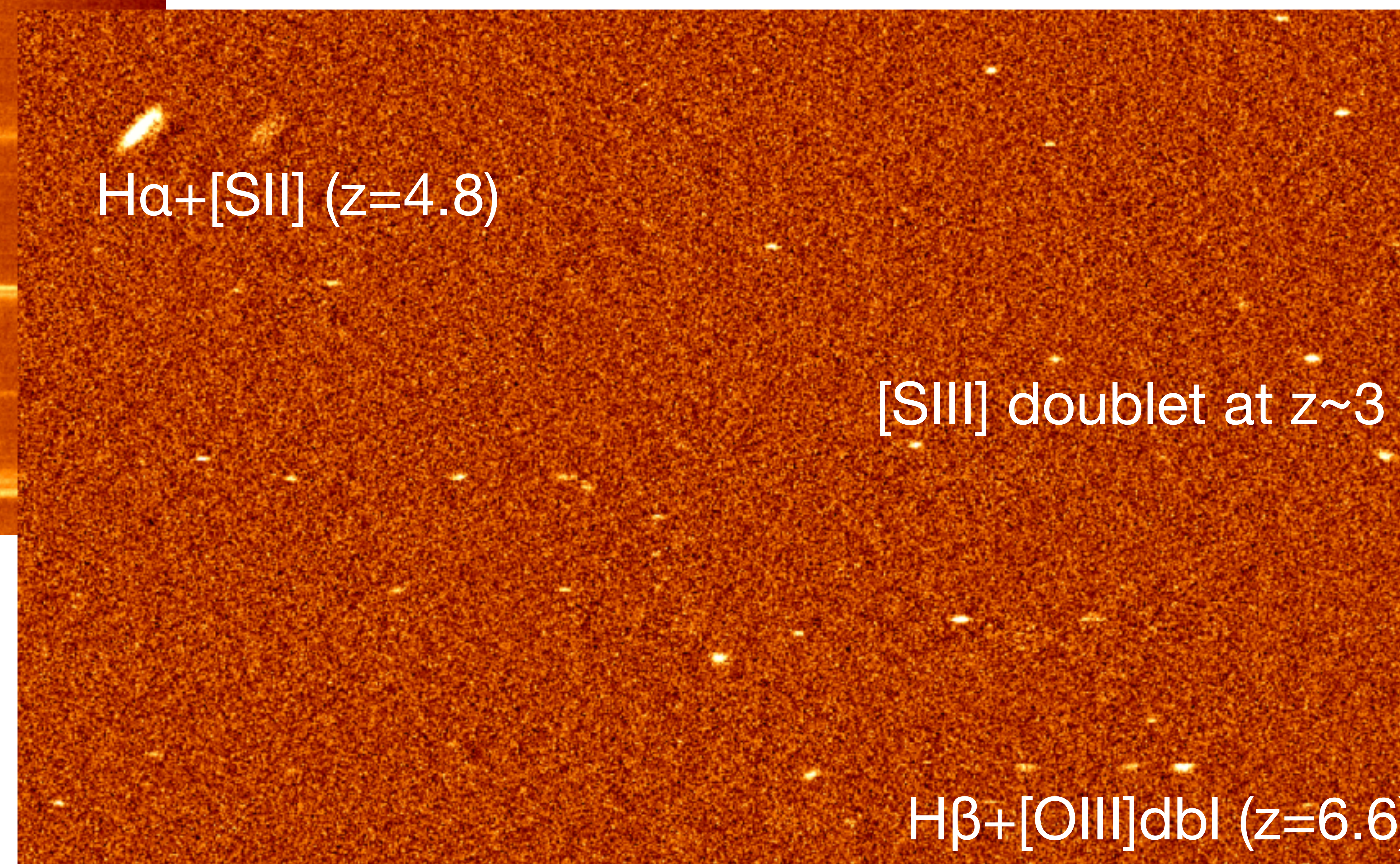
Typical galaxy spectrum at z = 6

Simulating WFSS

Simulated grism image



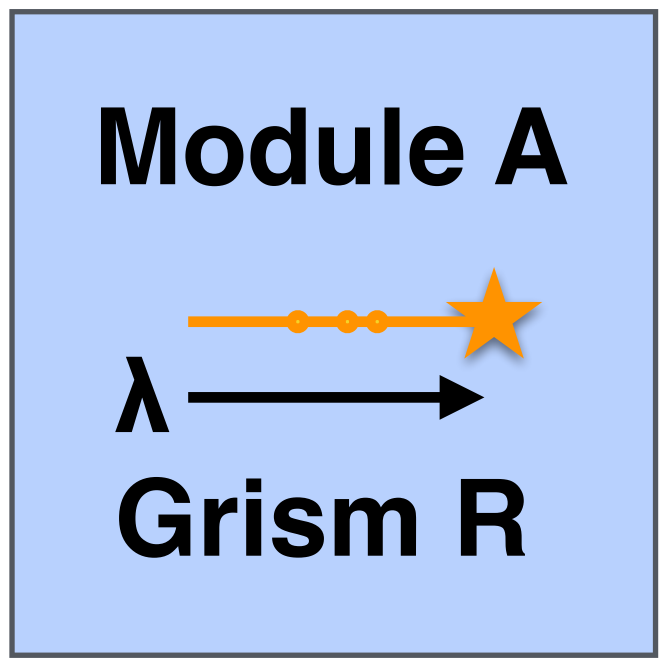
"Emission-line" image with
continuum-subtraction

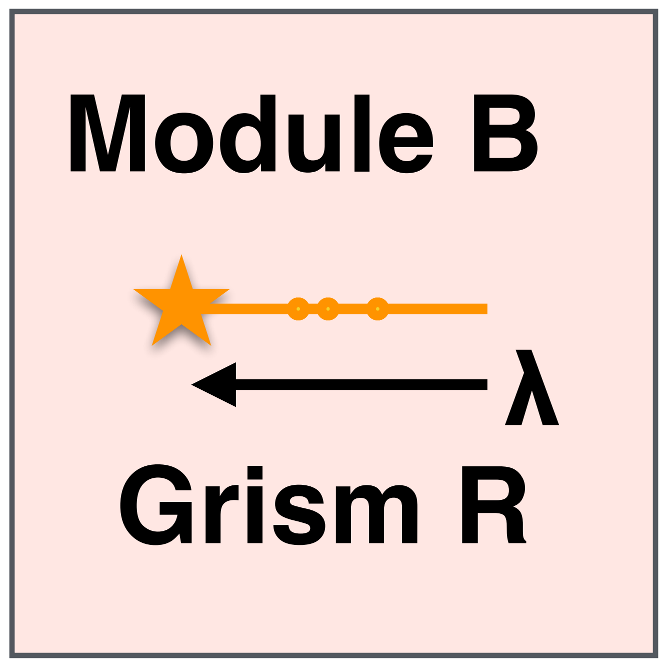


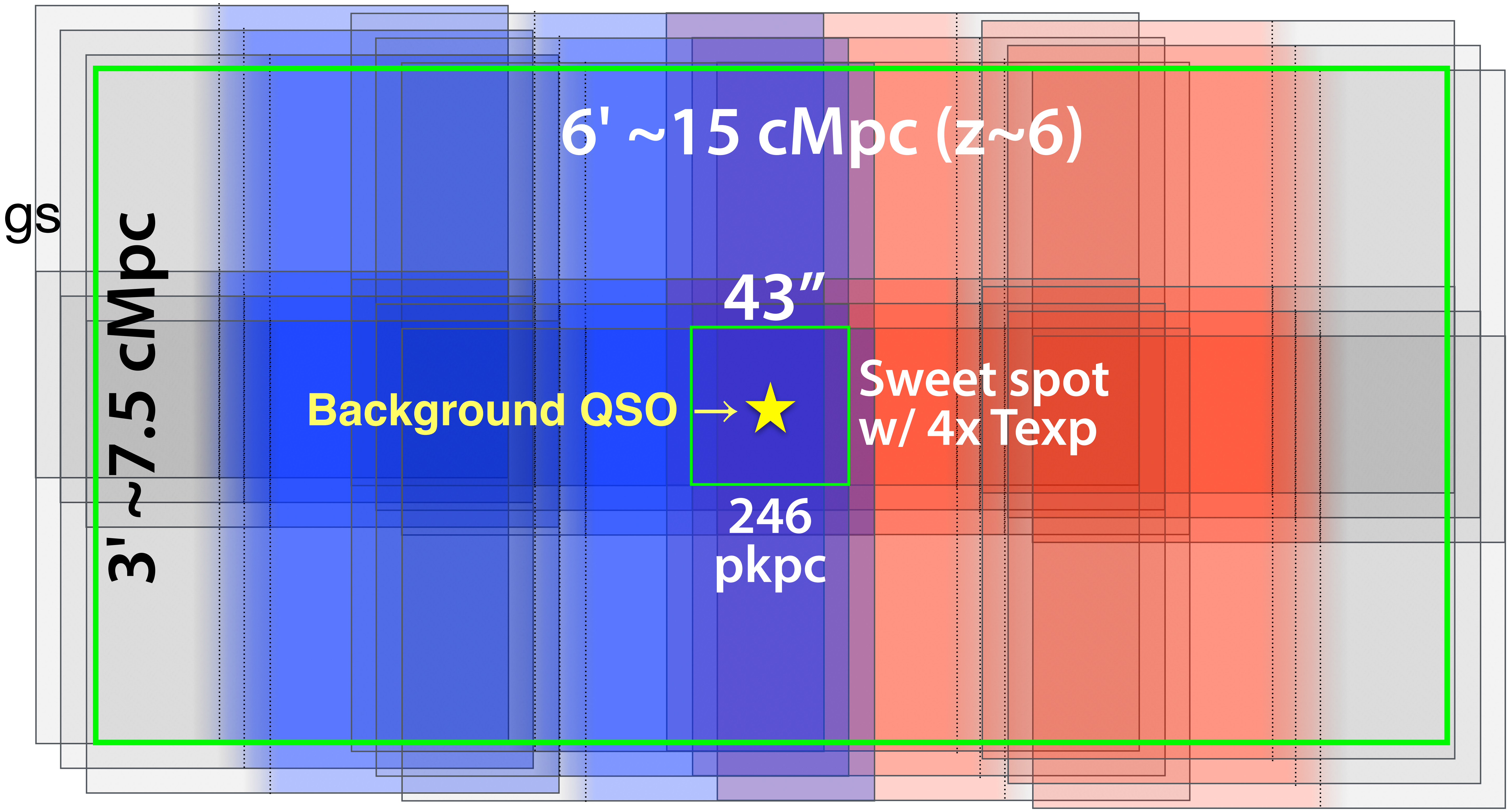
Mosaiced observing field

NIRCam FoV: two 2.2' x 2.2'

Mosaic with four separate pointings







x 6 target quasar fields

Simultaneous imaging in short wavelengths

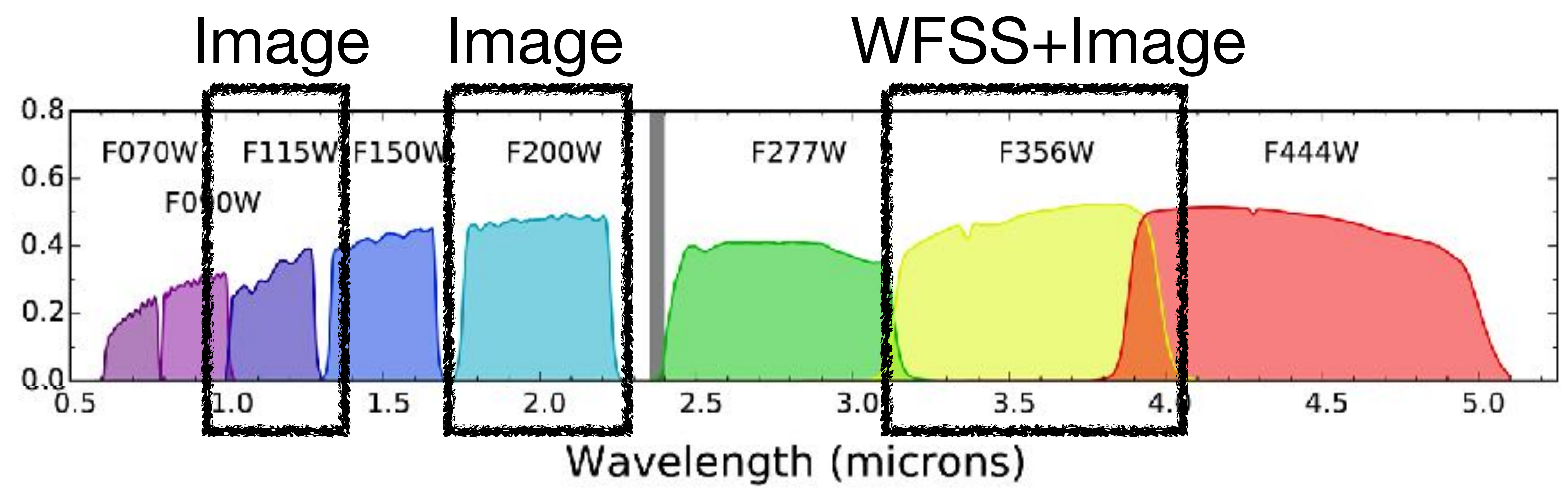
F115W (J), F200W (K) + F356W

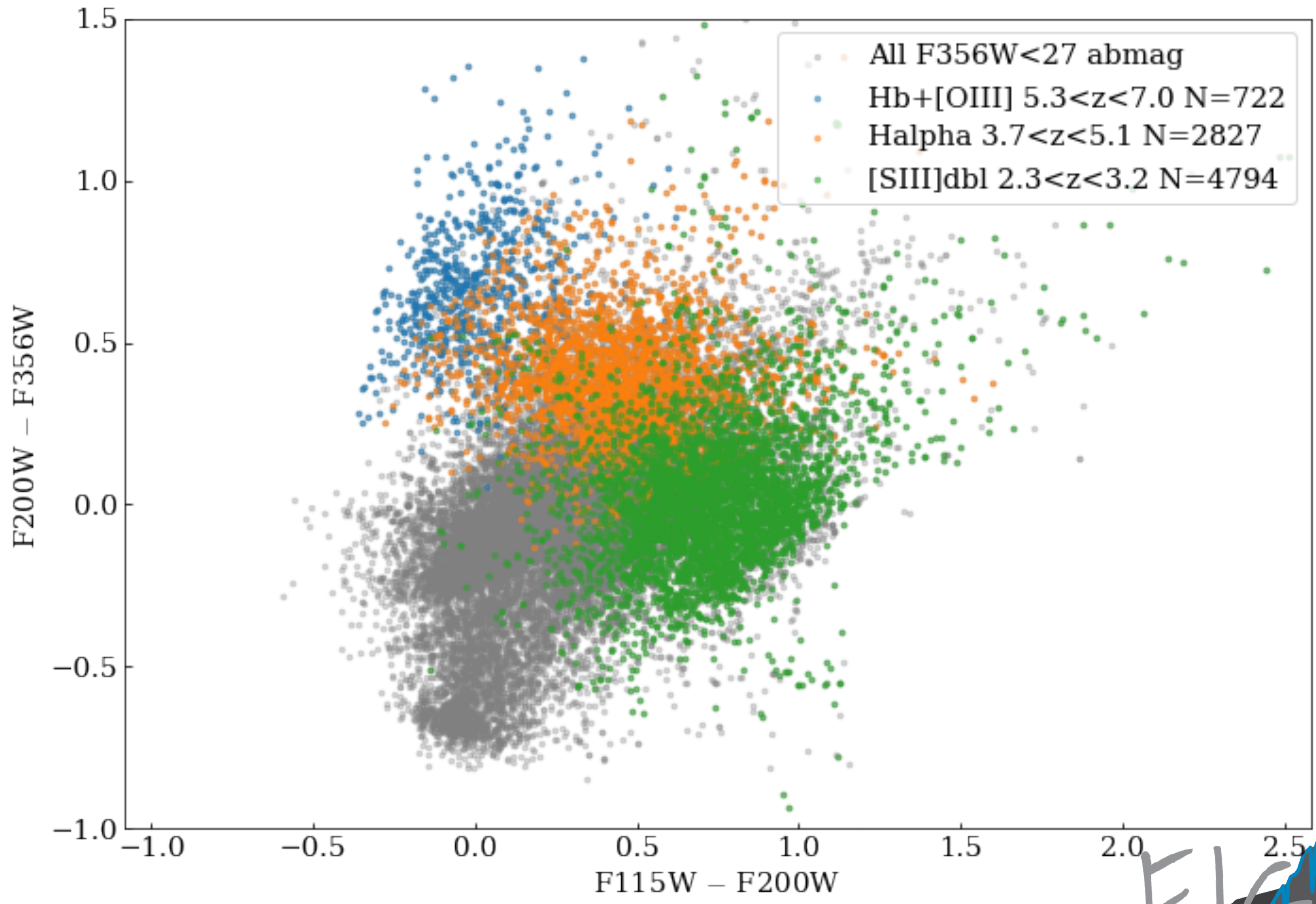
two bluer filters: rest FUV + NUV for z~6

+

HST photometry in the majority of the observing regions

Good photo-z can solve degeneracy in spec-z with a single line detection.





Expected number counts

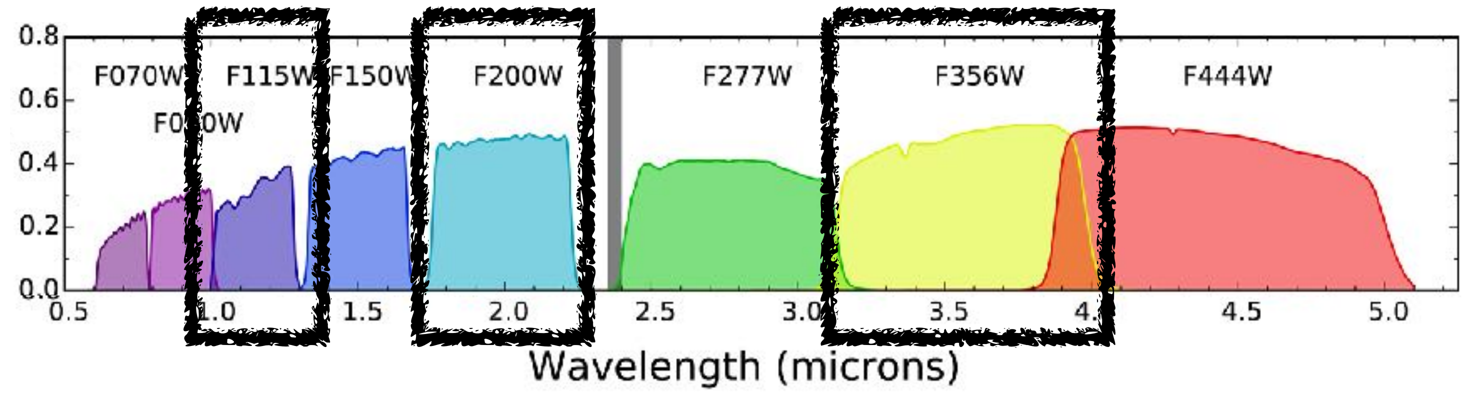
Emission line	redshift range	Assumed EW_0 (e.g., Smit+13,16)	Expected ***N per field***	Total sample size from 6 fields
[OIII]5007	5.3<z<7.0	500Å	~60	**~360**
Hα	3.7<z<5.1	400Å	~230	**~1400**

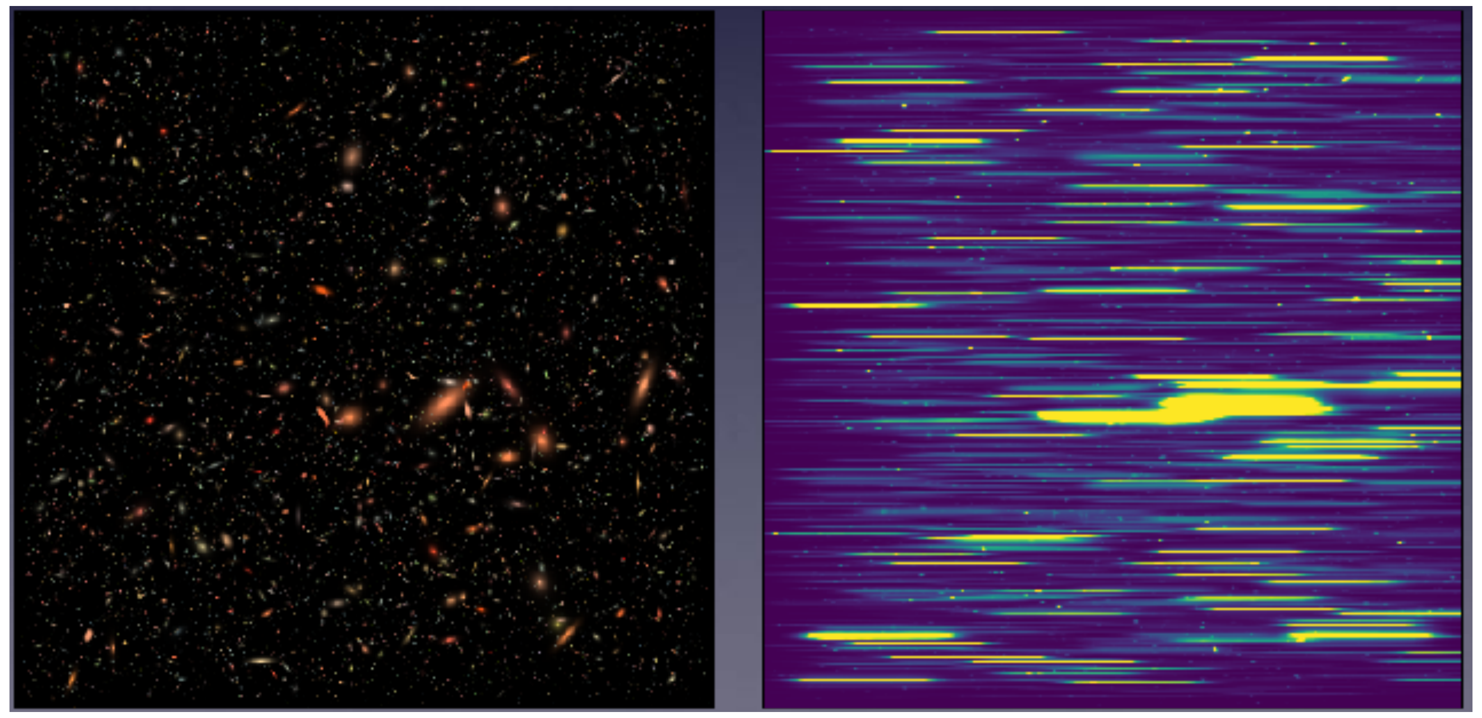
Assuming Bouwens+15 UV LF and $m_{365} \sim m_{\mathrm{UV}}$

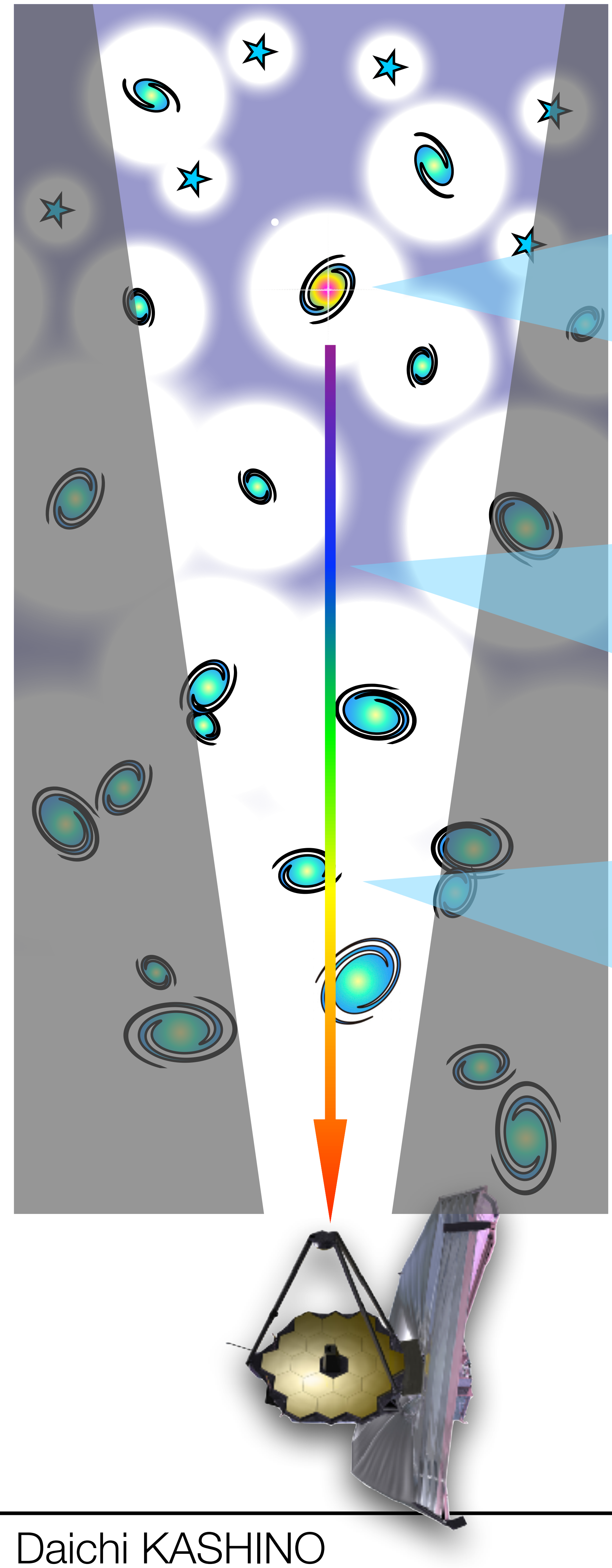
Mode	Filter	Nominal exposure per pointing	Sensitivy at 5σ (point source)
LW WFSS	F356W	~2 hr	(line) ~ 3e-18 $erg/s/cm^2$
LW imaging	F356W	~500 sec	27.9 abmag
SW imaging (1)	F115W	~1 hr	28.3 abmag
SW imaging (2)	F200W	~1 hr	28.6 abmag

Summary

*E*mission-line galaxies and *I*ntergalactic *G*as in the *E*poch of *R*eionization







Primary science goals

Formation of earliest **super massive black holes**

Role of galaxies in **cosmic reionization**

Interplay between galaxies and **the intergalactic gas**