An Overview of Our Research Activities:

Observing Galaxies in Wide x Deep Optics & IR

Yongming Liang

(Postdoc@ObsCos Group)

Observational Cosmology Group:

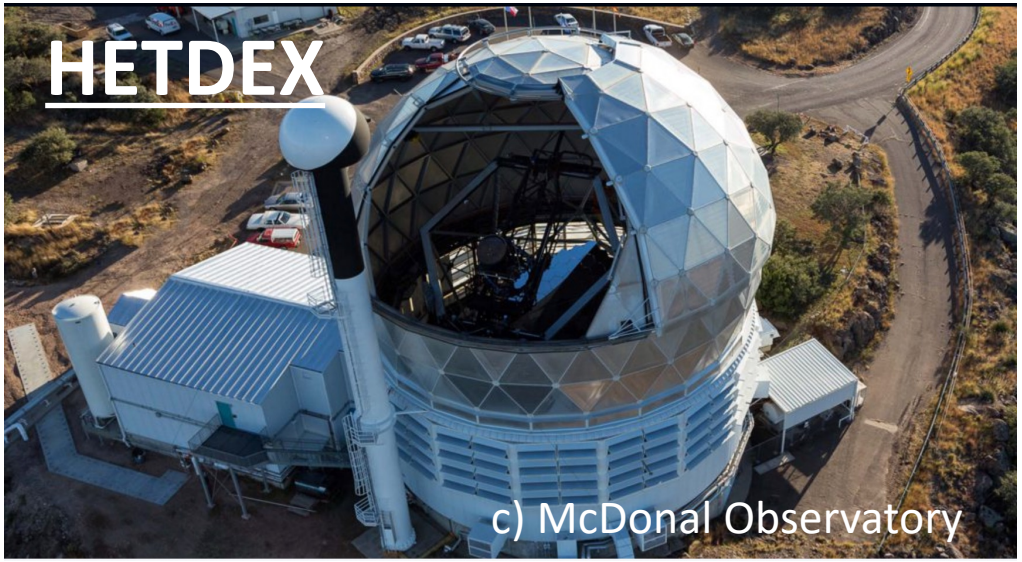
M. Ouchi, Y. Ono, Y. Harikane, Y. Liang, D. Sun, Y. Xu, H. Umeda, A. Matsumoto, C. Zhu, H. Yanagisawa, M. Nakane, Y. Kageura, R. Idomura (secretary)

ICRR Institute for Cosmic Ray Research University of Tokyo

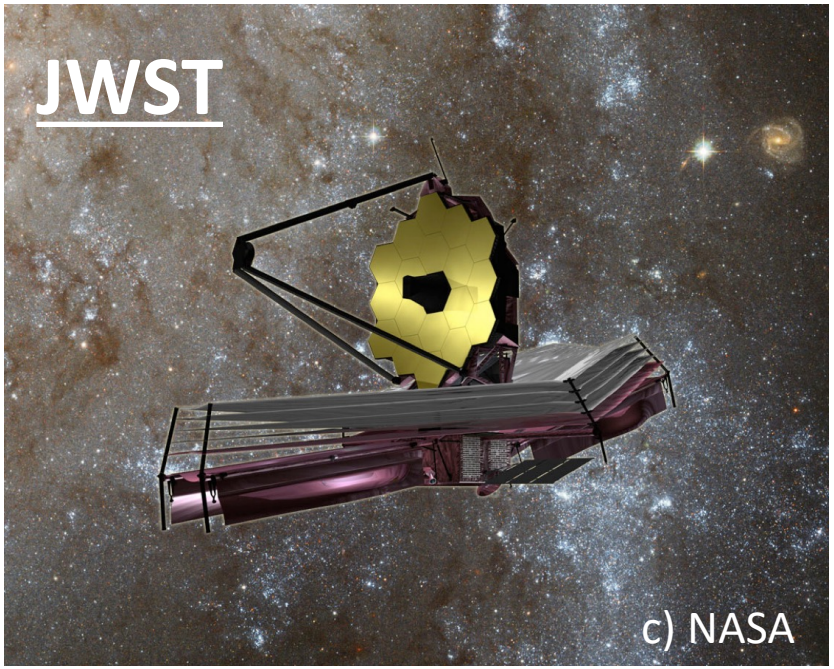
東京大学 THE UNIVERSITY OF TOKYO

Our Members in FY2024

- Total of 13 members including 8 students
- Conducting wide variety of researches on observational cosmology/galaxy formation

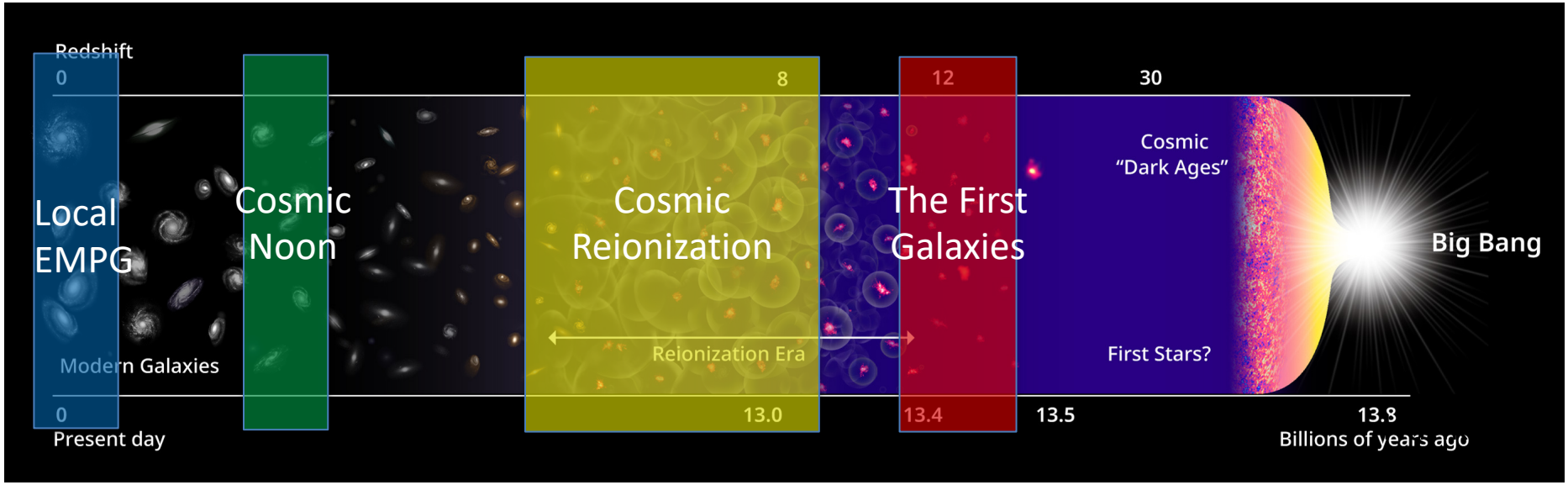


c) NAOJ



Observing Early Universe at z>2

- Key to understand several important processes
  - Large-scale structure formation
  - Cosmic reionization
  - First galaxy formation/galaxy evolution/AGN-galaxy
  - Star formation at high redshifts (star formation efficiency, IMF)



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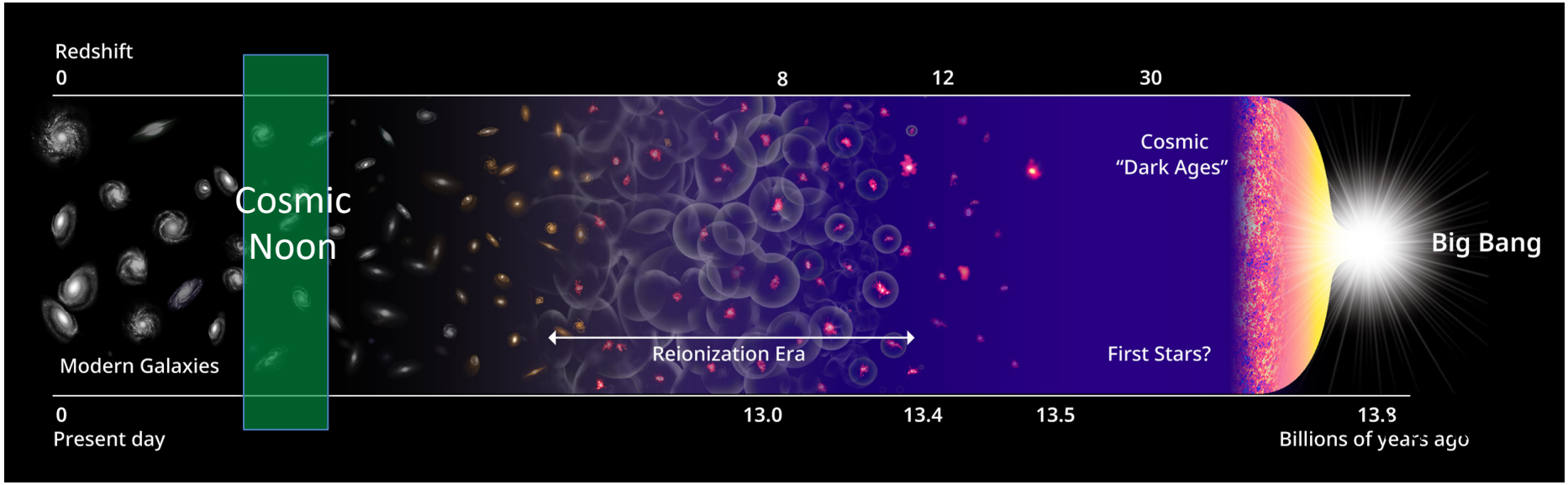
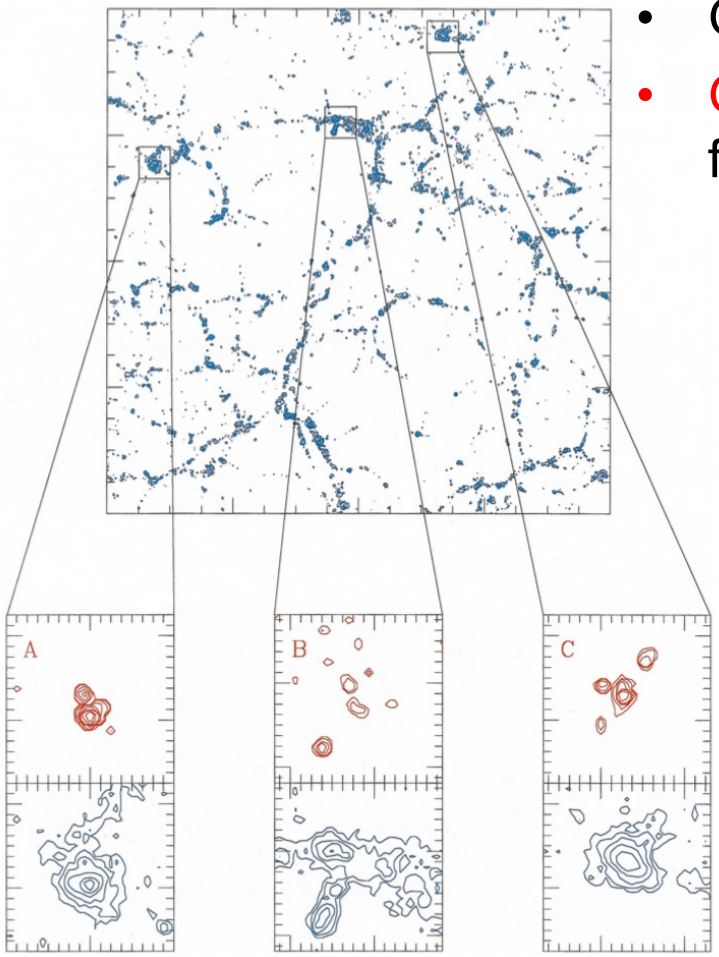
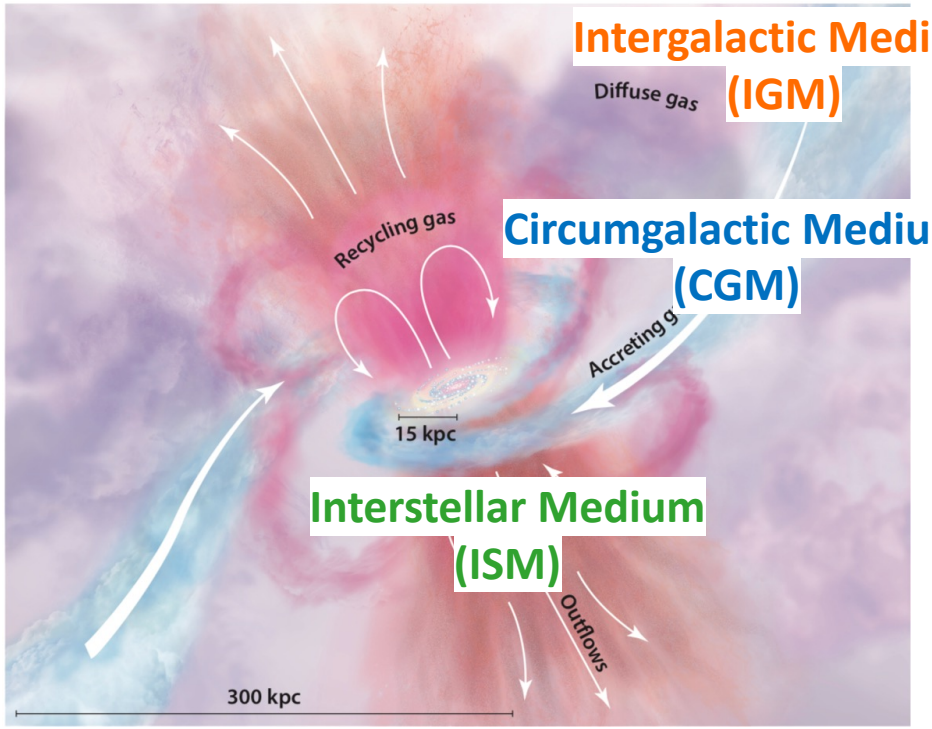


Structure Formation and Evolution



Cen & Ostriker 2000
(simulation)

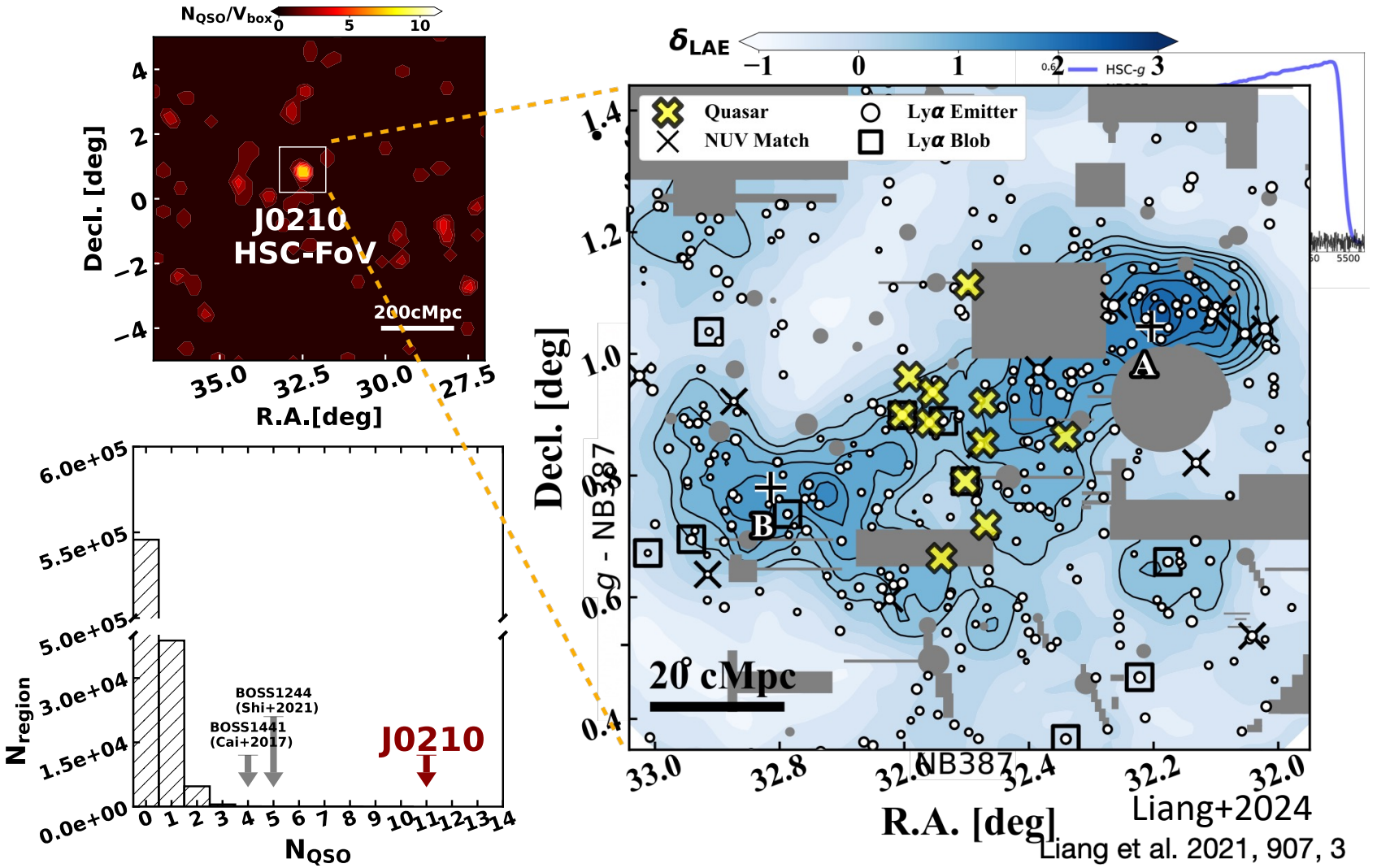
- Galaxy preferentially form in cosmic nodes
- Gas-Galaxy interplay is critical in galaxy formation and evolution



Tumlinson+2017

The Densest QSOs at z~2

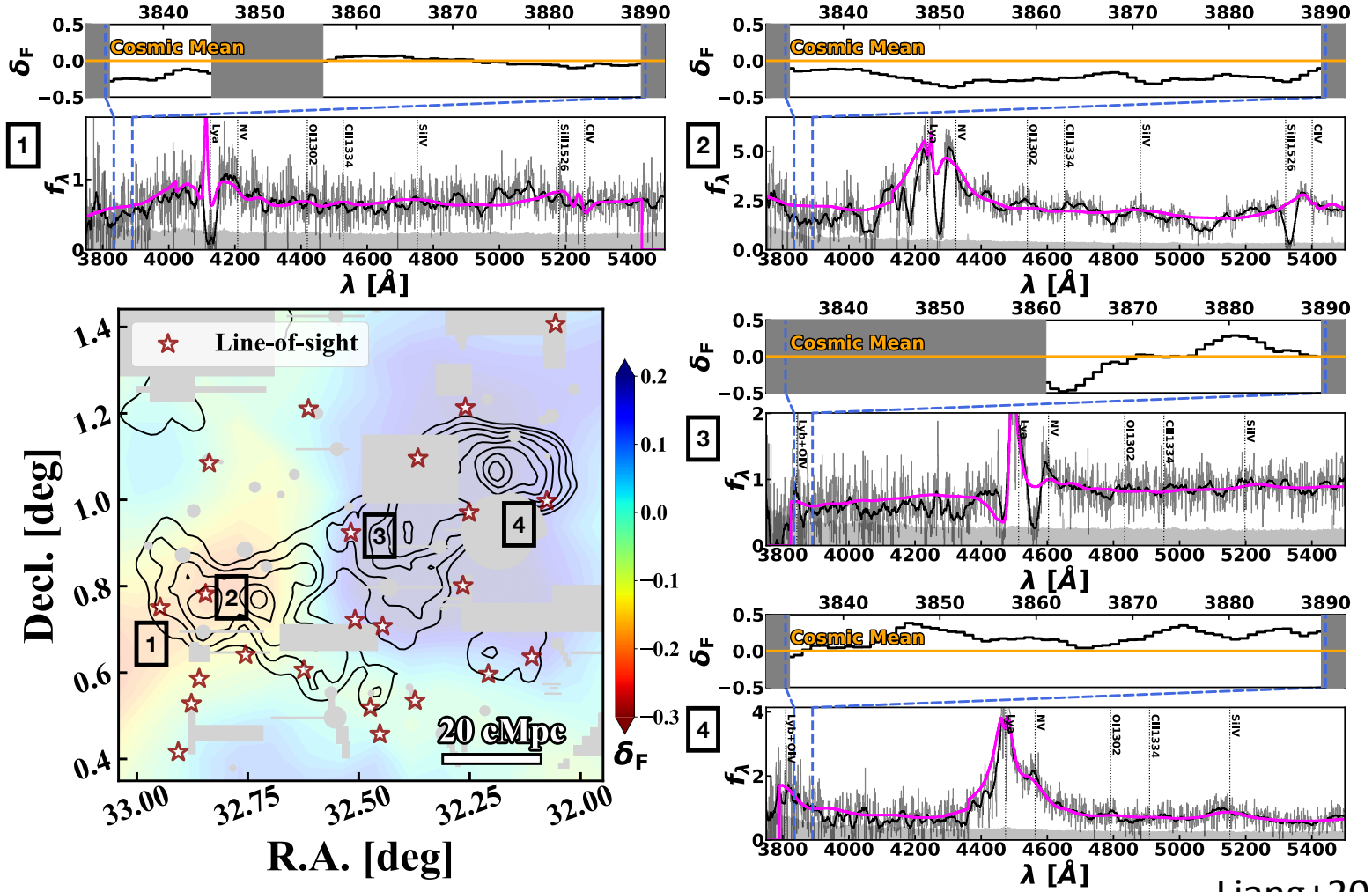
- QSO overdensity of 30x the cosmic mean (at 17σ)
- With spatial offset to galaxies – Lyα emitters mapped by Subaru/HSC



Liang et al. 2021, 907, 3

The Densest QSOs at z~2

- Reconstruct IGM tomography using spectra of background quasars.
- A bimodal ionizing structure is identified.

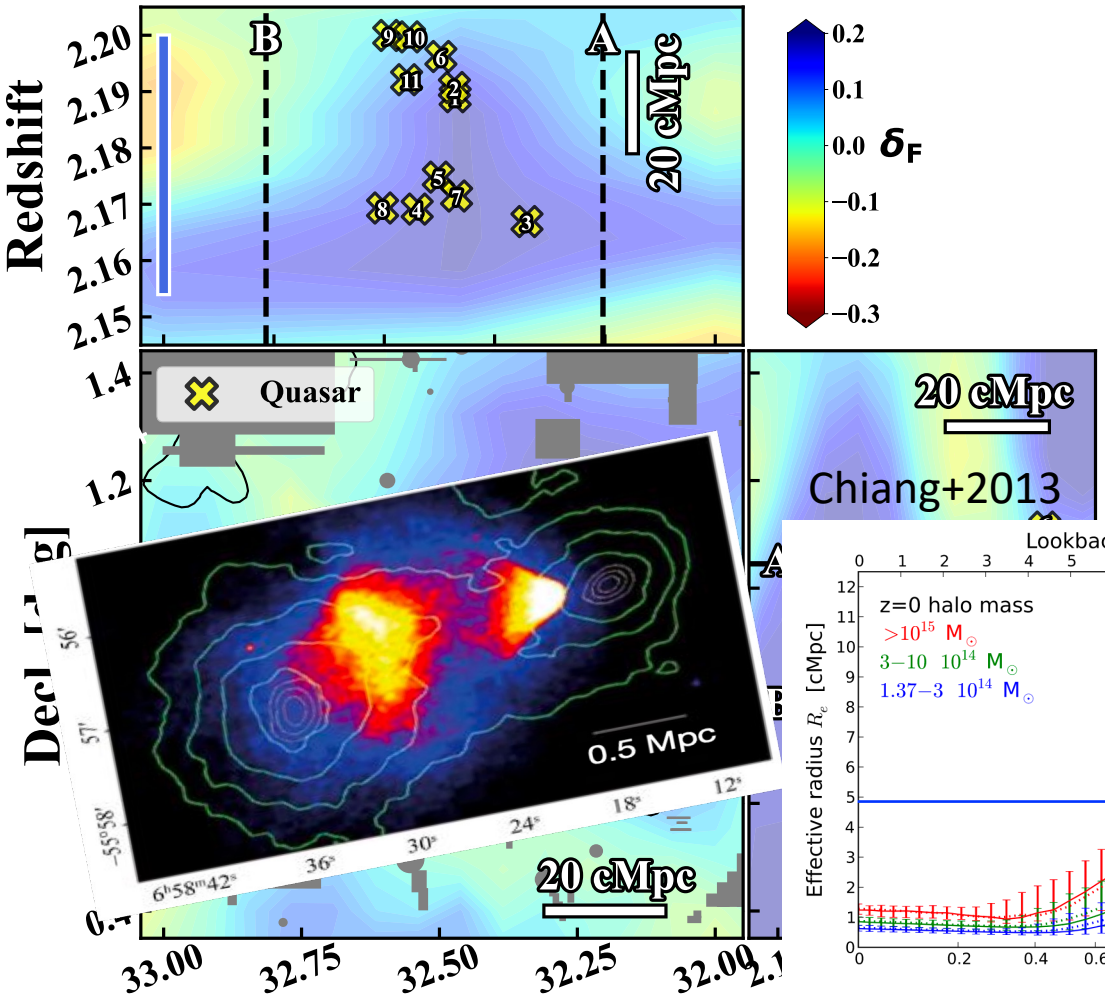


Liang+2024

The Densest QSOs at z~2

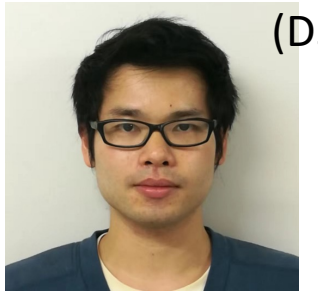
- An extreme protocluster with preheating IGM/rich dust?
- A progenitor of cluster merger in the local universe?

Cosmic Himalayas



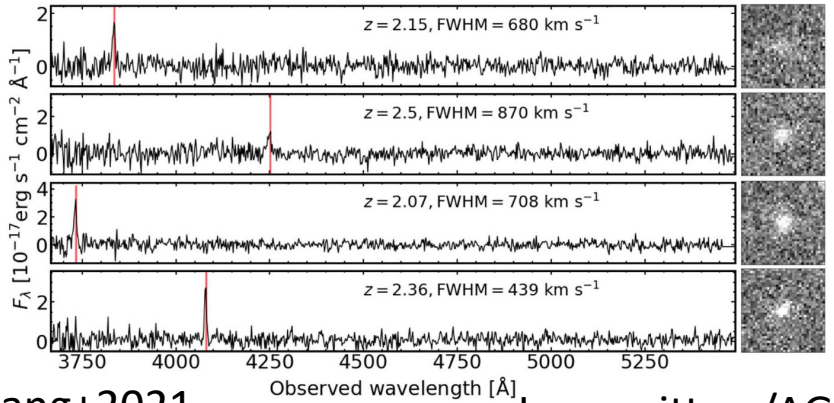
Galaxy-IGM correlation at z~2

Sun, Dongsheng (D3)



- Galaxies & AGNs from HETDEX (3D spec) + SDSS quasars in the bg.
- Ionization + gravitational well.

HETDEX
Hobby-Eberly Telescope Dark Energy Experiment

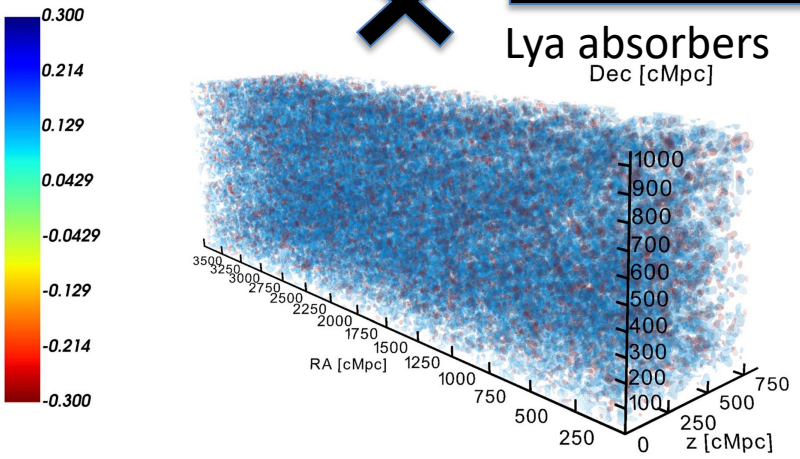


Zhang+2021

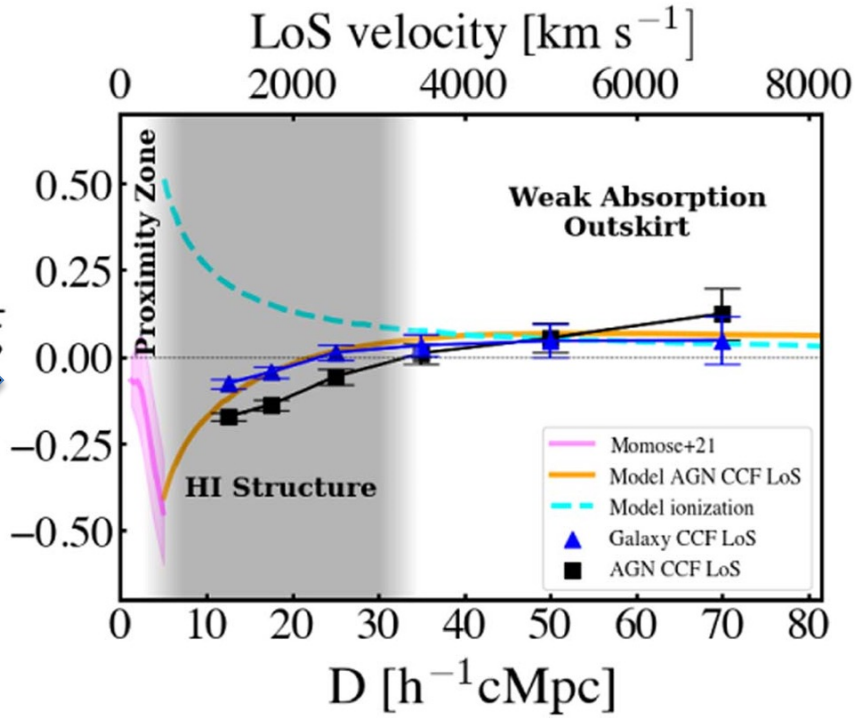
Lyα emitters/AGNs

×

Lya absorbers



$D\xi$



Sun+2023

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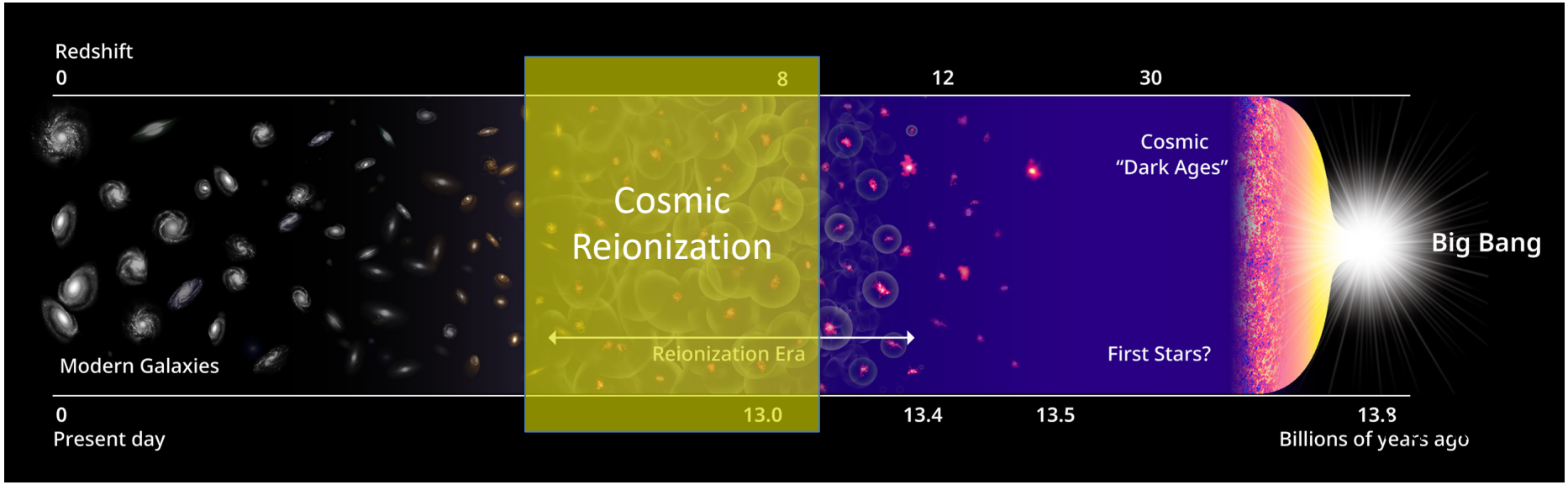
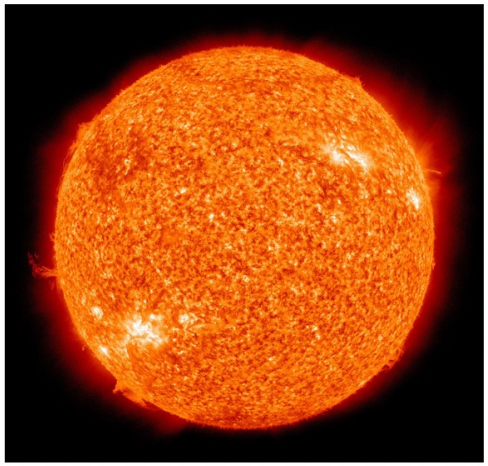


Distance Galaxies are…

- Faint: 25-30 magnitudes, x10^{10} fainter than Sirius
- Red: due to redshift $\lambda_{obs}=(1+z) \times \lambda_{int}$
  - Hubble space telescope: up to 1.6um (z~11)
- Need a large infrared telescope → JWST

Sun -27 mag

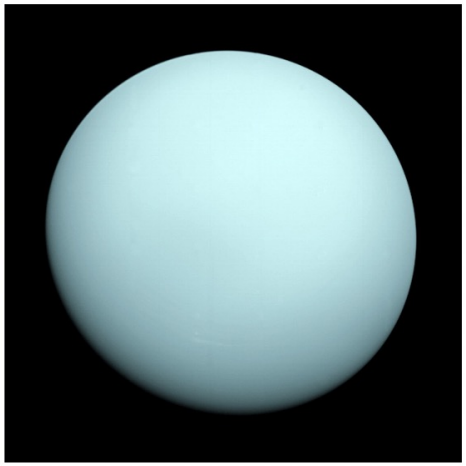


(NASA)

Sirius -1 mag

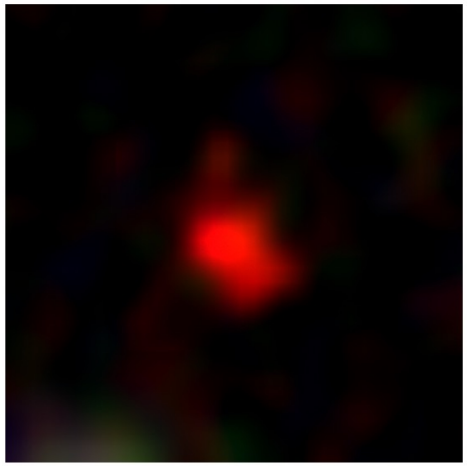
(STScI)

Uranus 6 mag



(NASA)

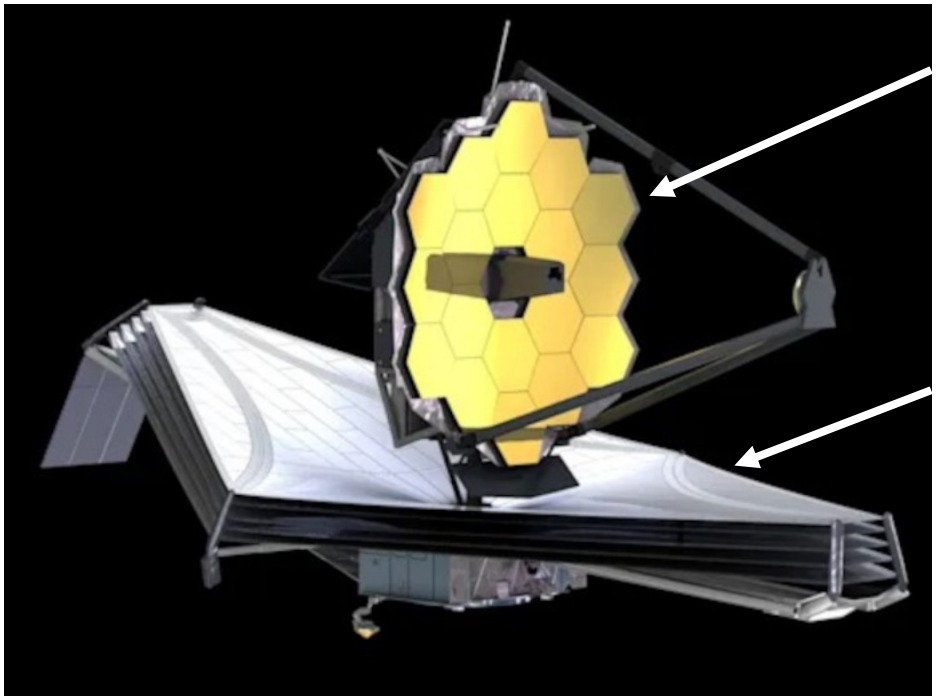
Distant galaxy
25 mag



(Harikane et al.)

James Webb Space Telescope (JWST)

- Infrared telescope with 6.5m-diameter mirror
  - Hubble: 2.4m
  - Launch on 2021 Dec. 25th, first data on 2022 July 12th



Main mirror (6.5m-diameter)
Combination of 18 segment mirrors
Gold-coated

Sun-shield
Keeping 40 K by shielding sunlight

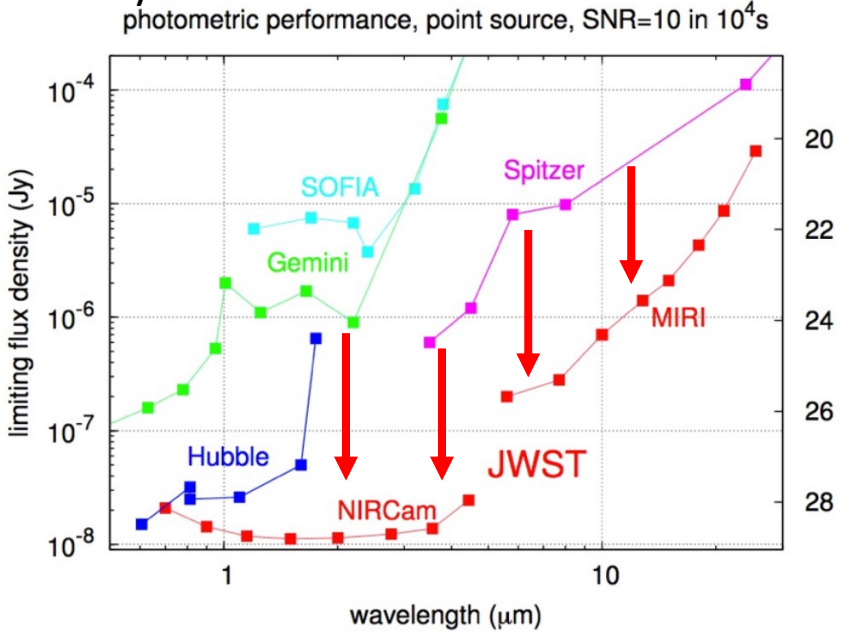
NASA

Comparison with Other Telescopes

- Sensitivity improved by x10-1000 at infrared

Sensitivity

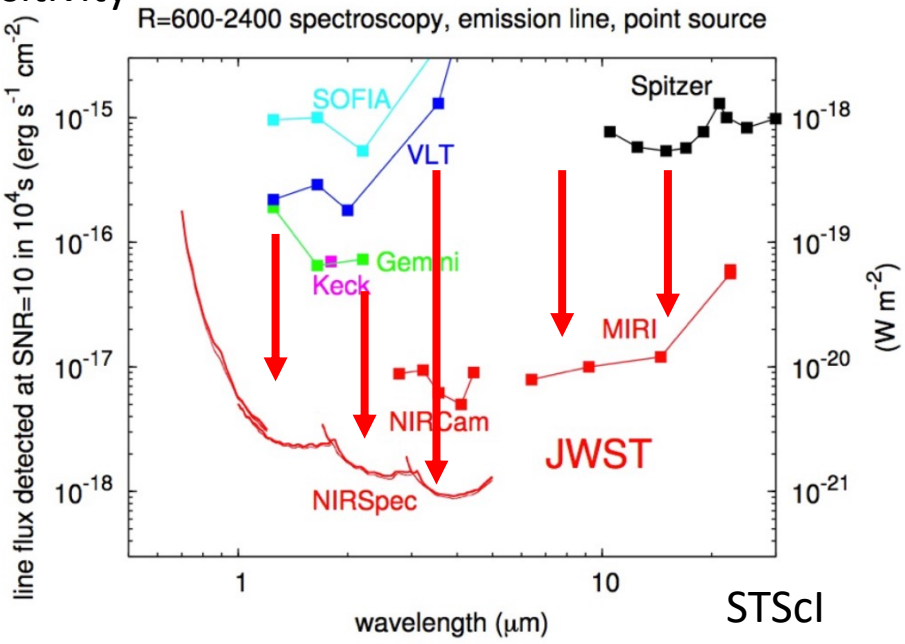
Imaging



Wavelength [μm]

Sensitivity

Spectroscopy



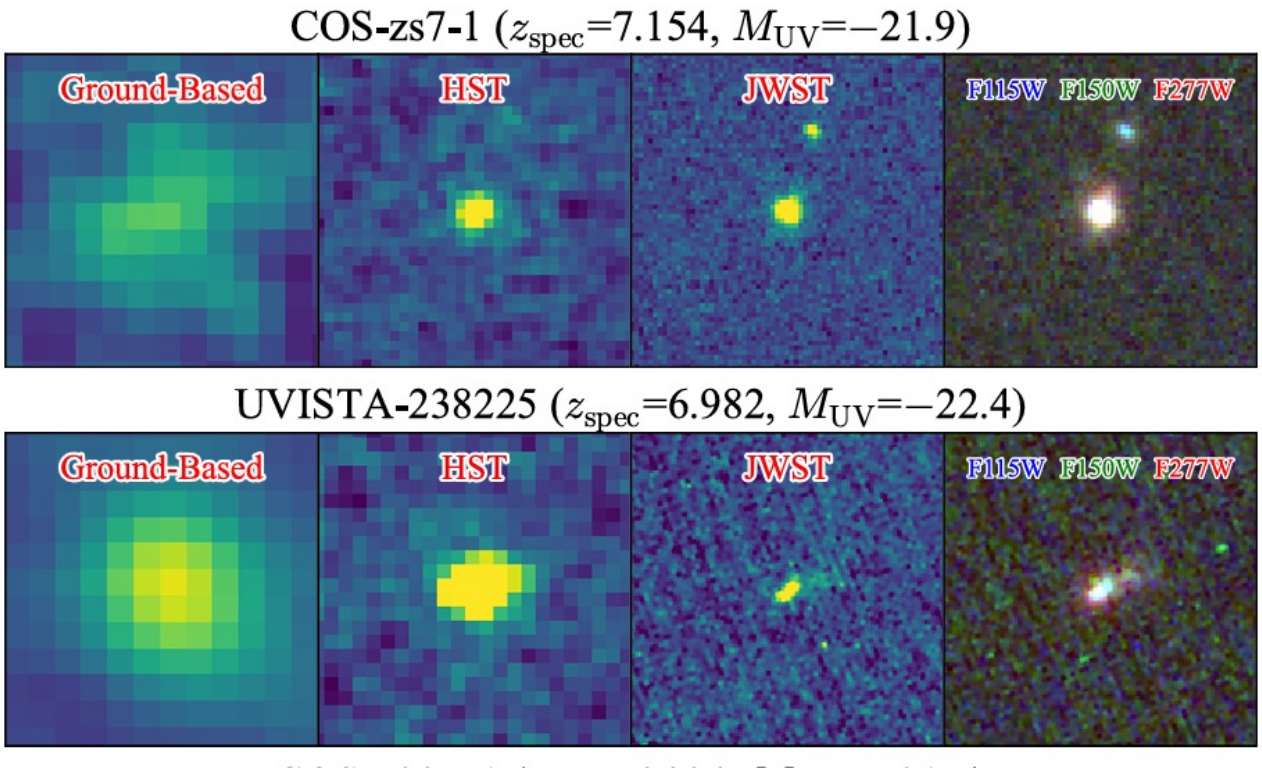
STScI

Wavelength [μm]

https://www.stsci.edu/jwst/about-jwst/history/historical-sensitivity-estimates

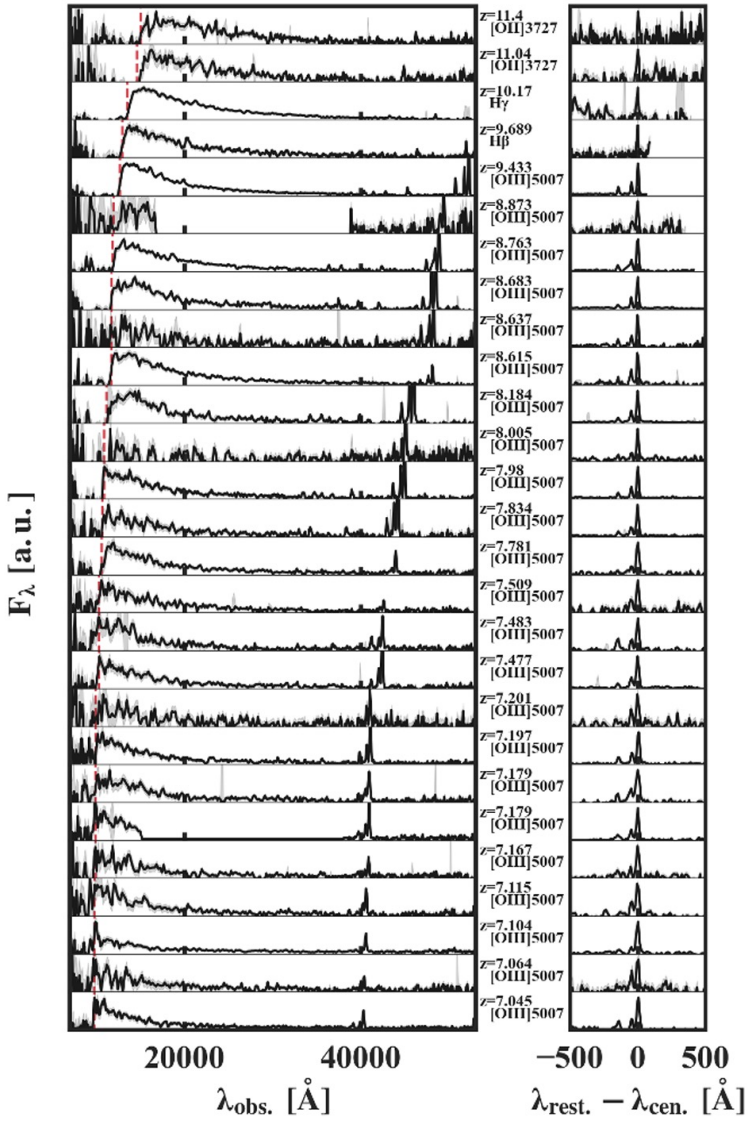
Comparison with Other Telescopes

- Spatial resolution by from 0.6”@ground to <0.1”



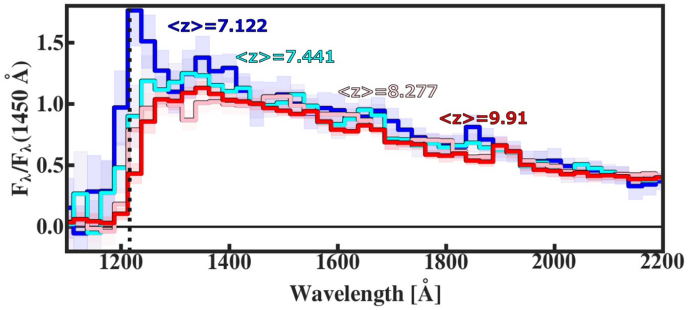
Harikane+24b

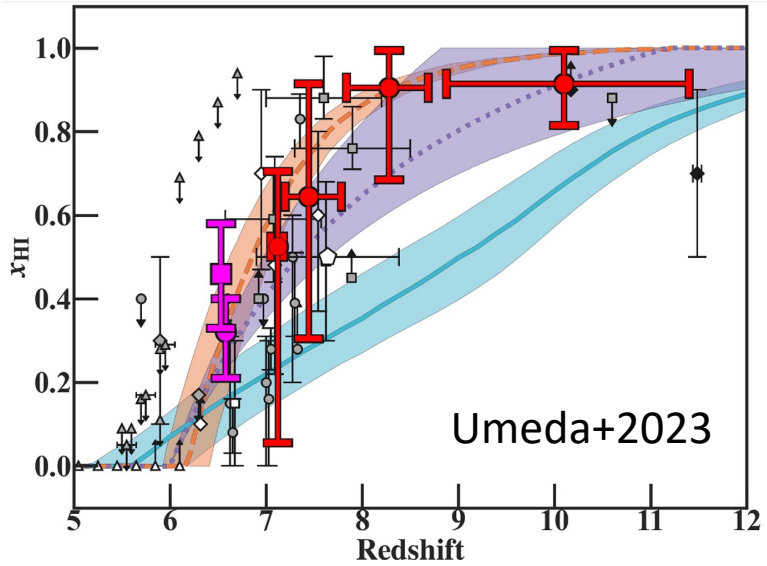
HI Fraction at z=7-12 Obtained by Lyα Damping Wing Absorption



- Stack galaxies with luminous continua detected by JWST
- The first constraint of X_HI beyond z=7.

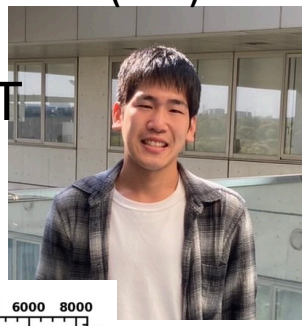
Umeda, Hiroya (D2)



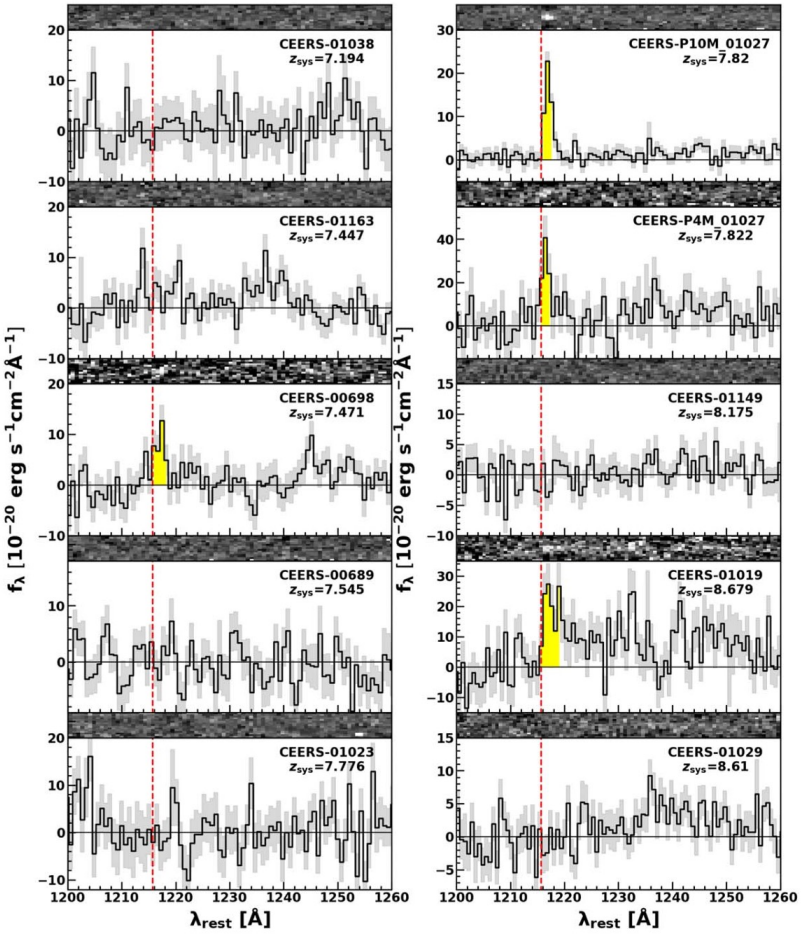


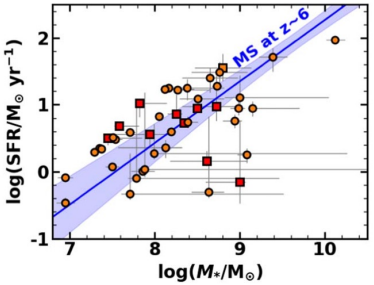
HI Fraction at z=7-13 Obtained by Lyα Equivalent Width

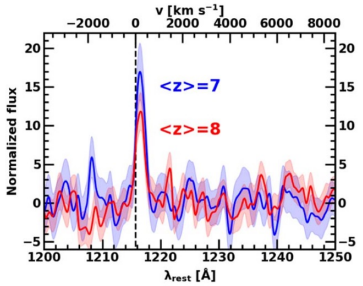
Nakane, Minami (M2)

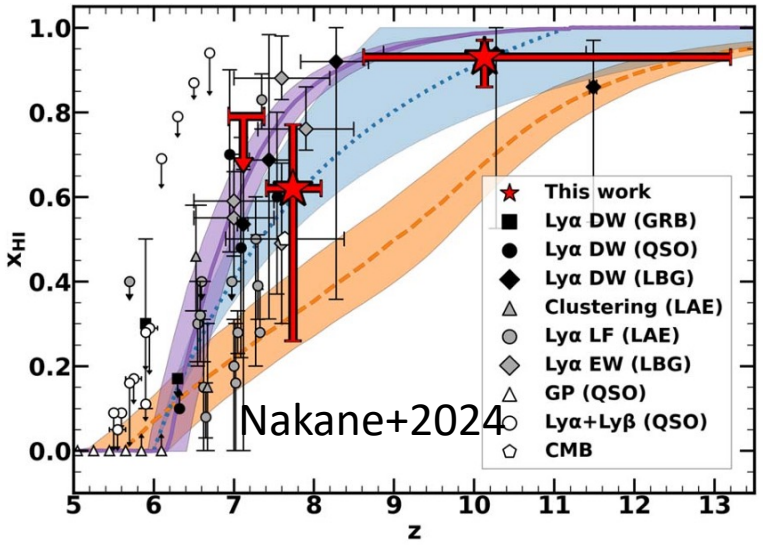


- Stack galaxies with Lyα emission detected by JWST
- Clear indication of a late cosmic reionization.





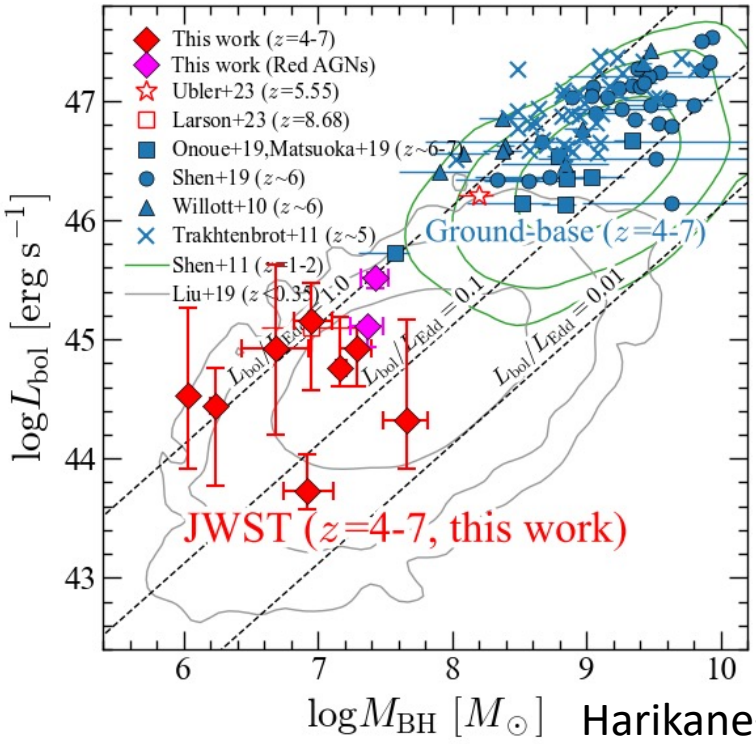




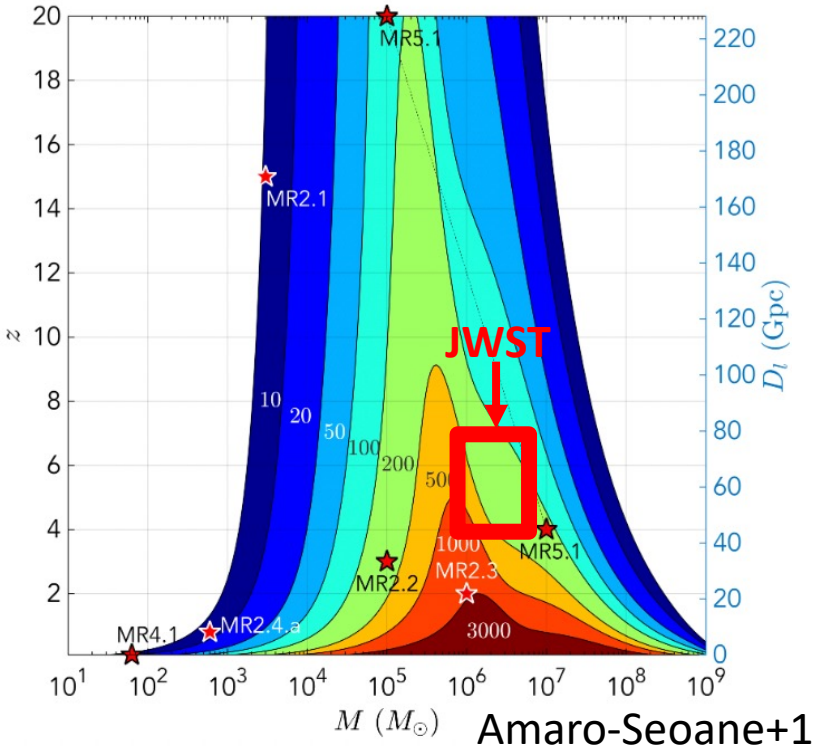
Many AGNs at z>4!

Harikane, Yuichi
(Assistant Prof.)

- M_{BH}~10^6-10^7 M_{sun} higher than z~0 M_*-M_{BH} relation
  - Significantly lower M_{BH} than quasars at z>4
  - BH-BH binary of these BHs can be detected with LISA?



Harikane+23b



Amaro-Seoane+17

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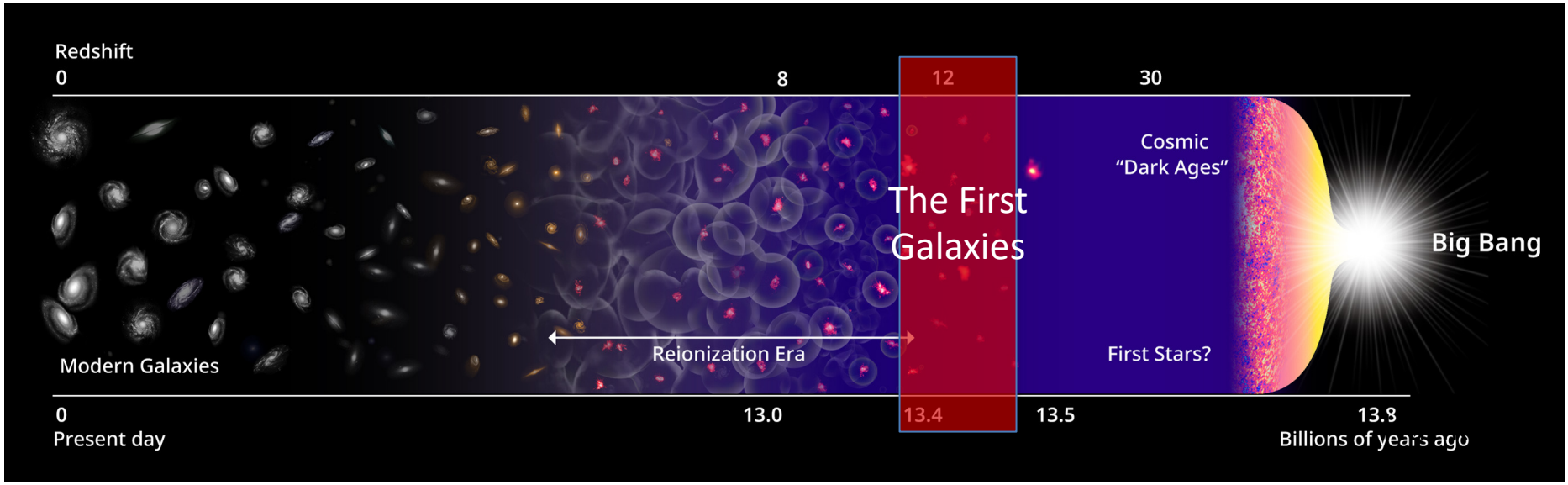
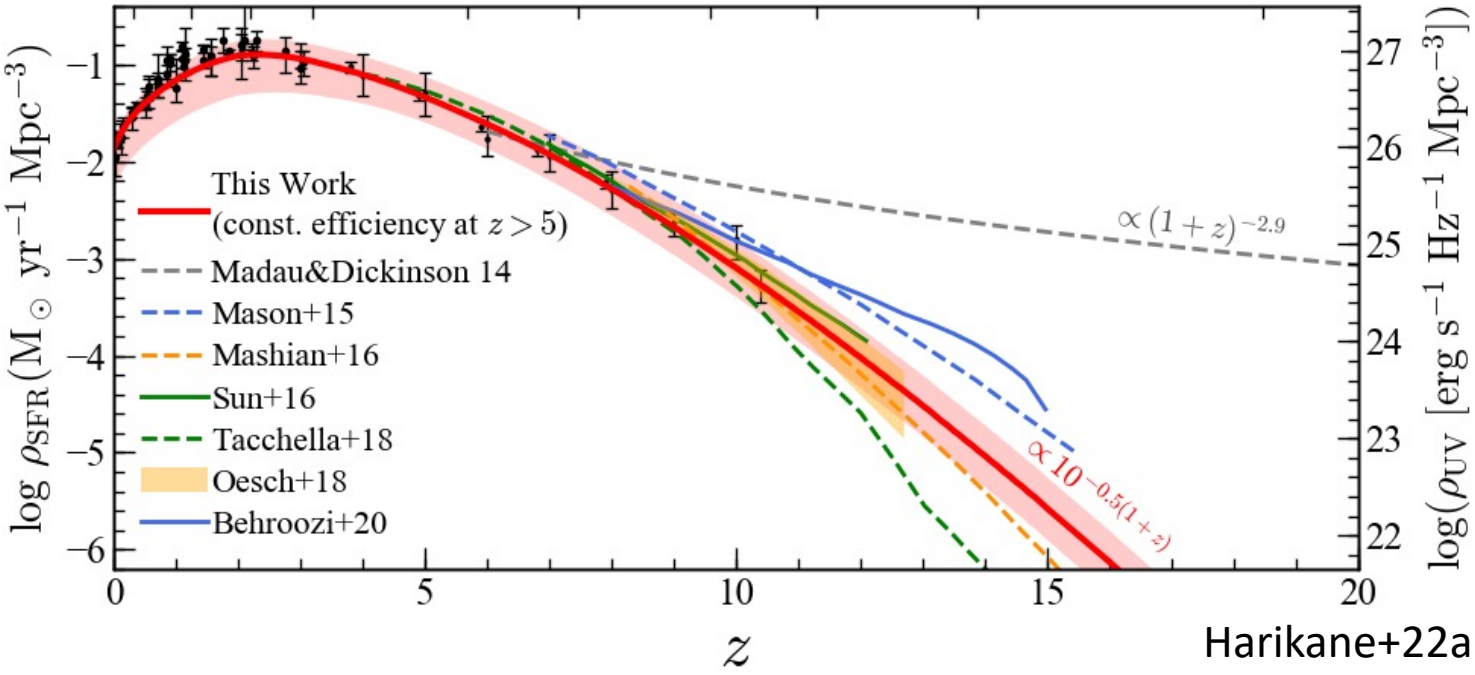


Cosmic Star Formation Rate Density

- SFR density evolution at z~0-10
  - HST results (e.g., Bouwens+15, Finkelstein+15)
- Constant star formation efficiency model (SFR/(dM_h/dt))
  - Reproducing evolution at z=0-10, $10^{-0.5(1+z)}$ at z>10



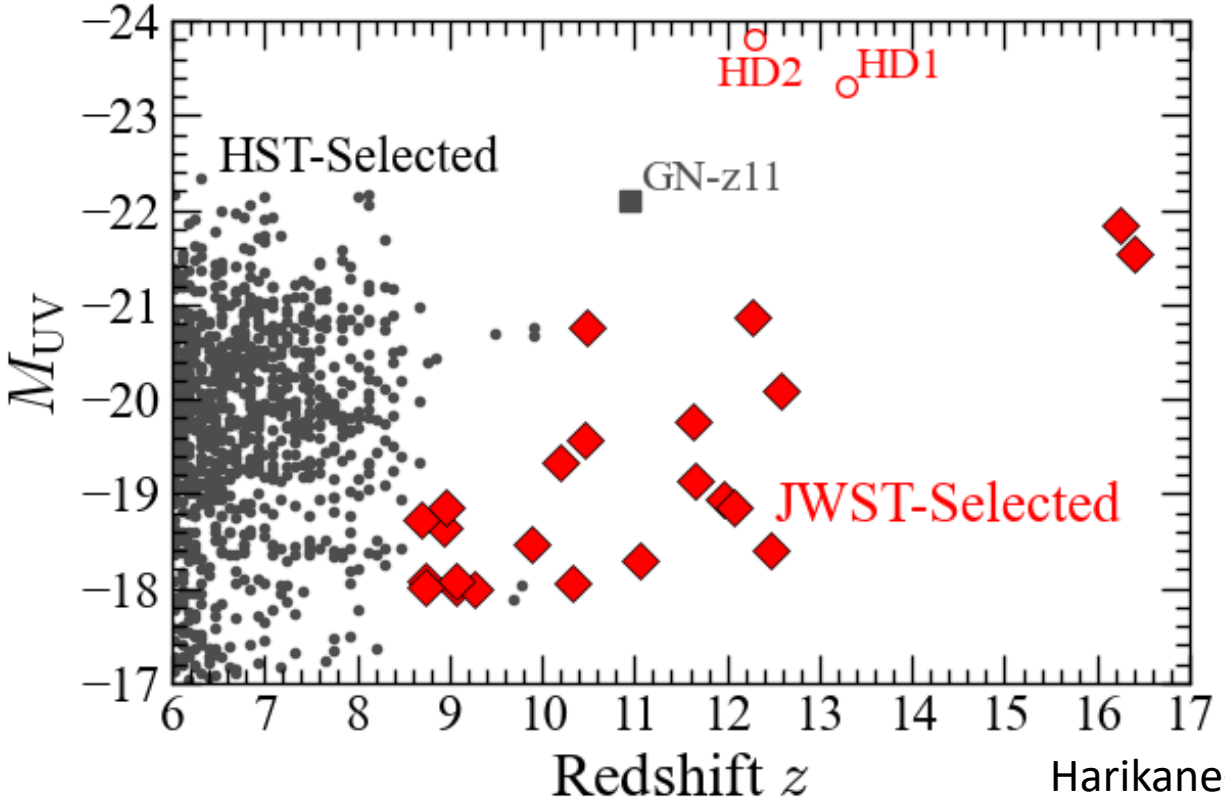
Harikane+22a

See also e.g., Madau+14, Bouwens+15,20, Mason+15, Tacchella+18,…

JWST Galaxy Sample at z~9-16

- A total of 23 galaxy candidates at z~9-16
  - 90 arcmin^2 from ERO+ERS NIRCam images
  - Lyman break color selection + photo-z

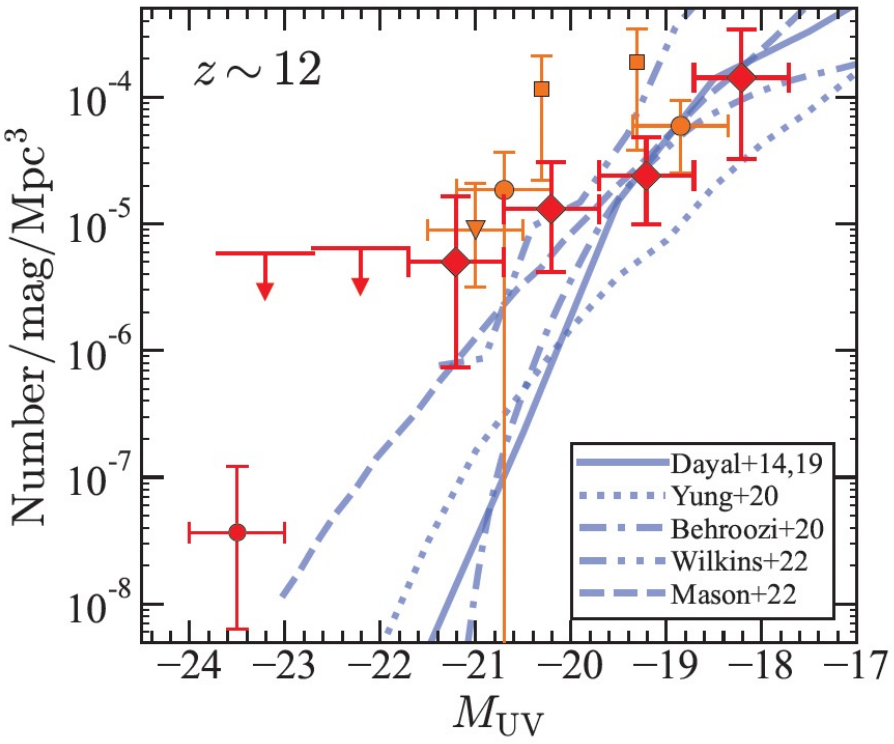
Harikane, Yuichi
(Assistant Prof.)

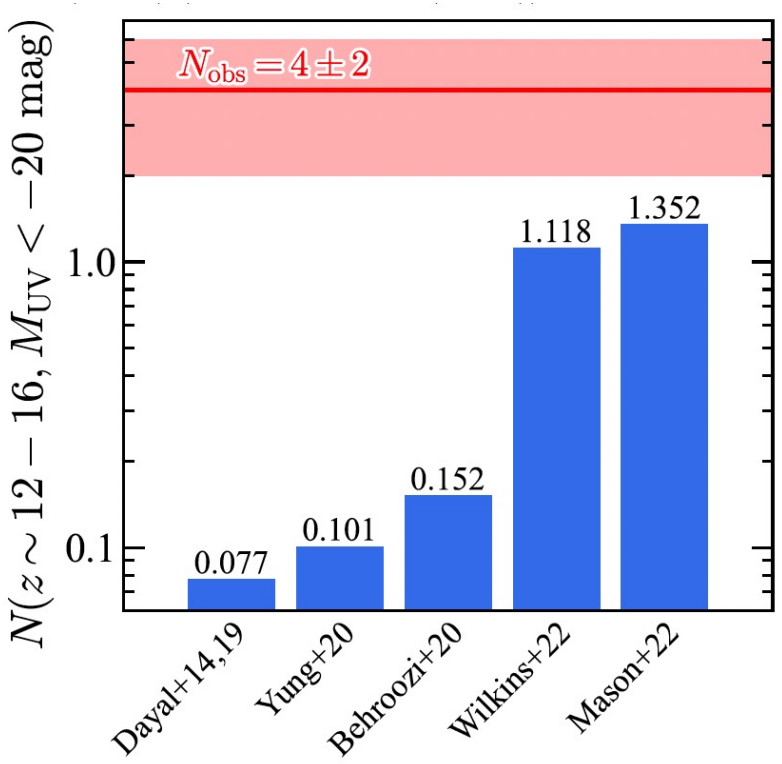


Harikane+23a

Comparison with Models

- Surprisingly larger number of galaxies than models
  - Tension between models and observations



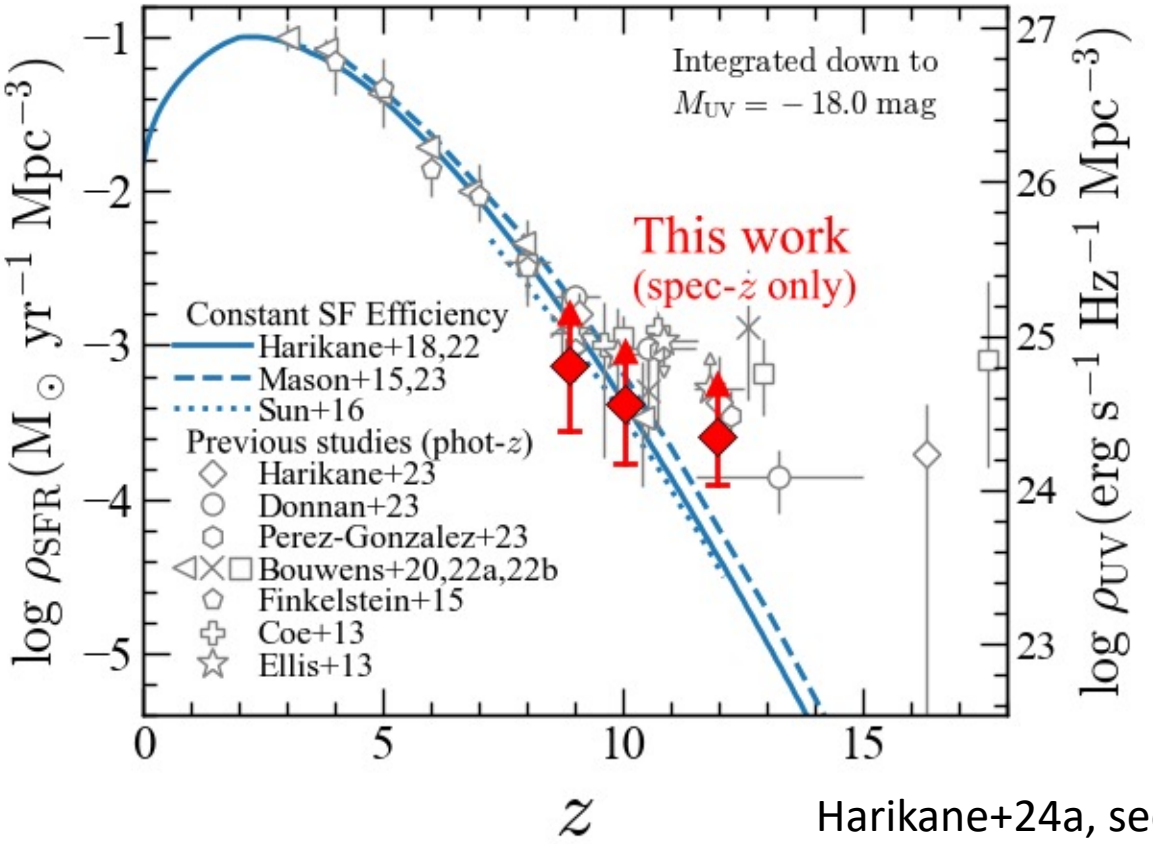


Harikane+23a

Spec-z Cosmic SFR Density at z=9-12

- UV→SFR: $SFR(M_\odot\ \mathrm{yr}^{-1}) = \mathcal{K}_{\mathrm{UV}} L_{\mathrm{UV}}(\mathrm{erg\ s^{-1}\ Hz^{-1}})$

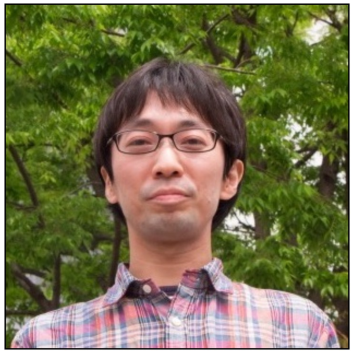
  $\mathcal{K}_{\mathrm{UV}} = 1.15 \times 10^{-28}\ M_\odot\,\mathrm{yr}^{-1}/(\mathrm{erg\ s^{-1} Hz^{-1}})$
- Tension with constant efficiency models at z>10



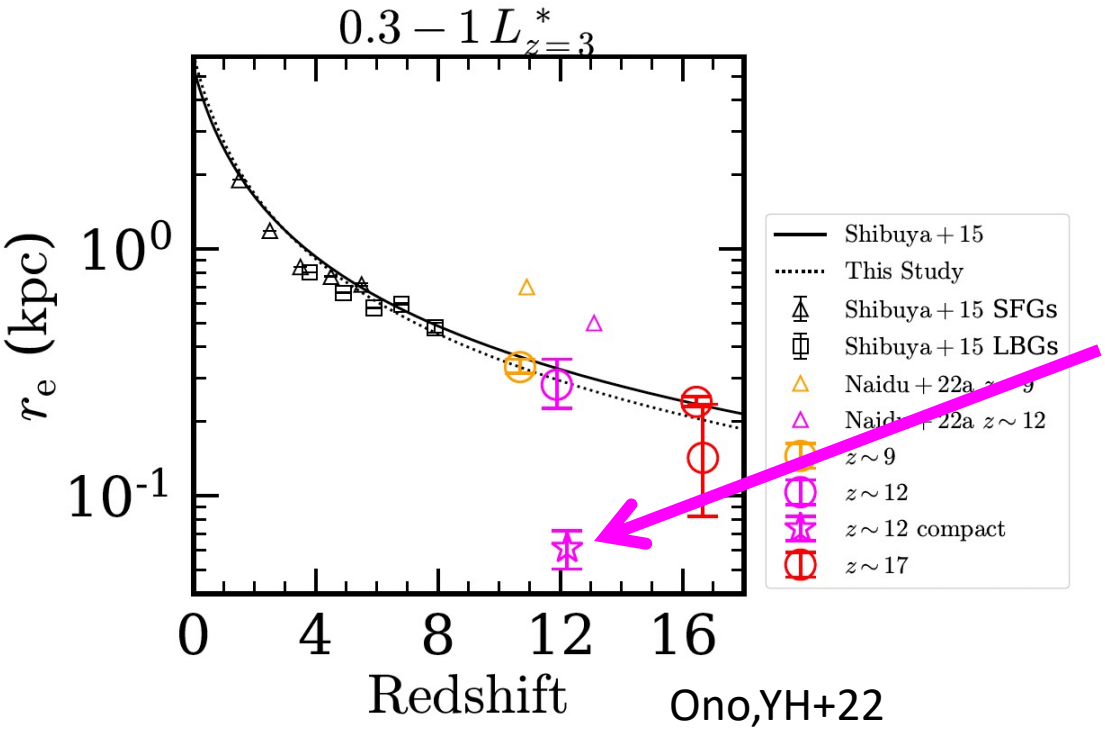
Harikane+24a, see also Bouwens+22

Size of z>10 Galaxies

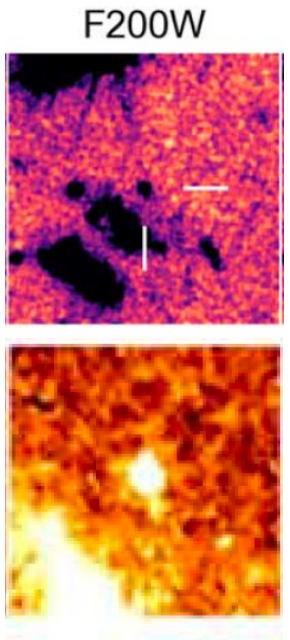
- R_e=200-300 pc w/ Sersic index=1-1.5 (disk)
  - Consistent w/ size evolution at z=9-16 w/ $(1+z)^{-1.2}$
- GL-z12-1 is very compact (r_e=60 pc)
  - Why this galaxy is so compact?



Ono, Yoshiaki
(Assistant Prof.)



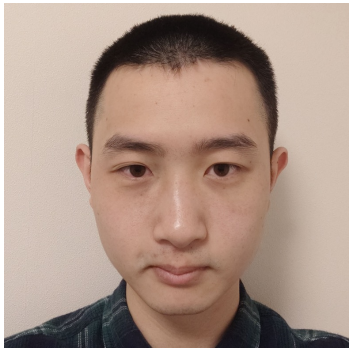
Ono,YH+22



Naidu+22

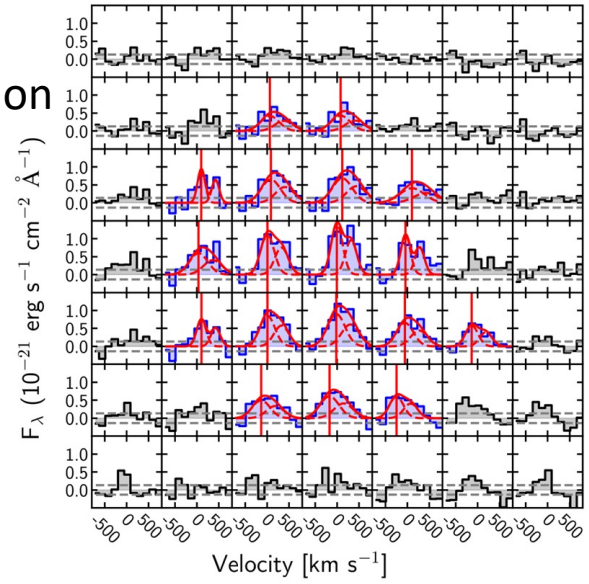
Castellano+22

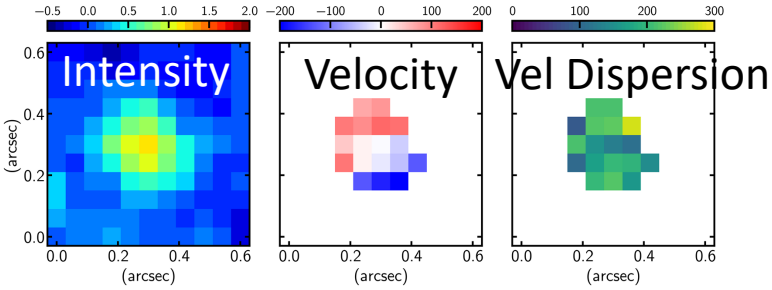
Dynamics of GN-z11

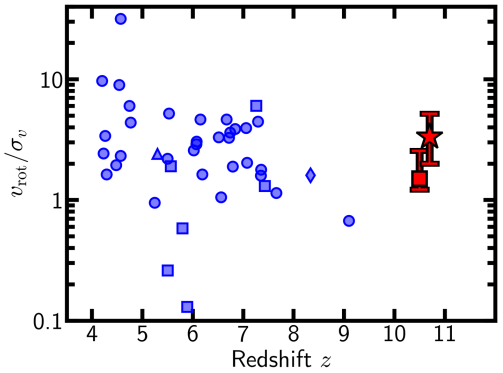


- Dynamics of the most luminous z>11 galaxy, mapped by JWST/NIRSpec IFU observation (res~0.1”)

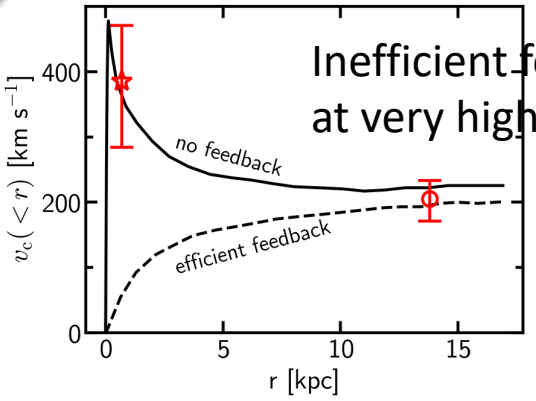
CIII] emission







Xu, Yi (D2)



Inefficient feedback at very high-z?

Xu+2024

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