IGM Observation
μExCAD
~MUlti-line observation with EXtended [CArbon-II] halo Detection~

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Task

初期宇宙(赤方偏移およそ 2 以遠)の IGM/CGM について新たな知見が得られる 多波長観測 を自由に立案せよ。既存の望遠鏡、近い将来稼働が見込まれる計画の別は問わない。

Plan any multi-wavelength observations that will provide new insights into IGM/CGM in the early universe (beyond about redshift 2). It does not matter whether it is an existing telescope or a project that is expected to be operational in the near future.

by Umehata-san

参考文献:

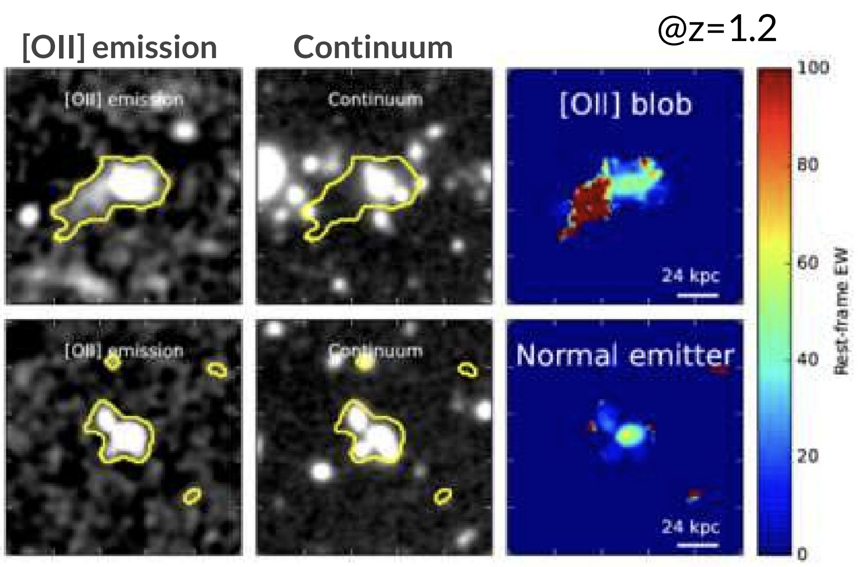
Umehata et al. 2019: https://ui.adsabs.harvard.edu/abs/2019Sci...366...97U/abstract

Fu et al. 2021: https://ui.adsabs.harvard.edu/abs/2021ApJ...908..188F/abstract

Vidal-Garcia et al. 2021: https://ui.adsabs.harvard.edu/abs/2021arXiv210510202V/abstract

Search for [OII], [OIII] blob & CGM physics

- It has been observed at z<1.5
- < metal-rich gas outflow
- < AGN, star-formation



[OII] 3726, 3728Å
[OIII] 5007Å

Yuma et al. 2017

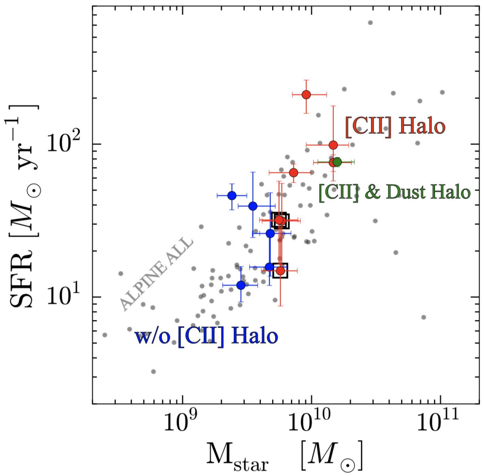
We want to observe [OII], [OIII] blobs at **higher redshift** (z>2)

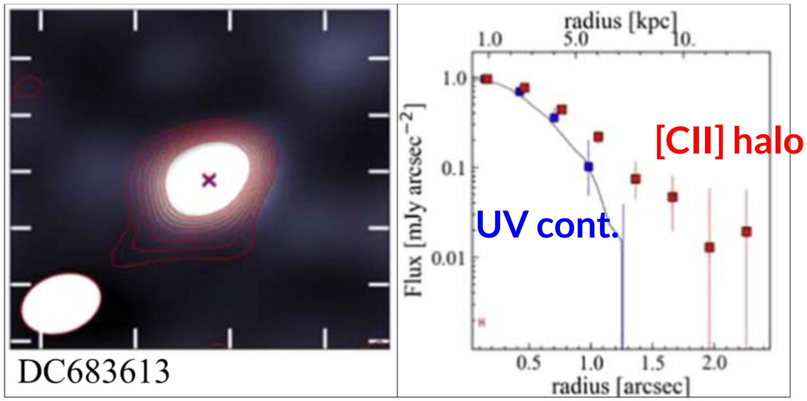
Target

ALPINE sources with [CII] halo detection (Fujimoto+20)

- 6 sources at z~4.5 / 2 sources at z~5.7
- normal star-forming galaxies

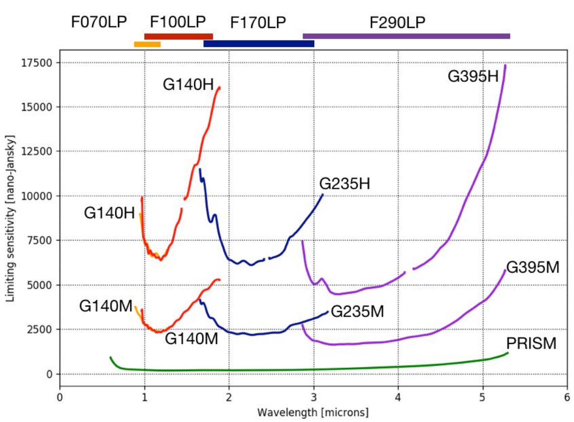
  (10 < SFR/[Msun/yr] < 100, log(Ms)~10)





Fujimoto+20

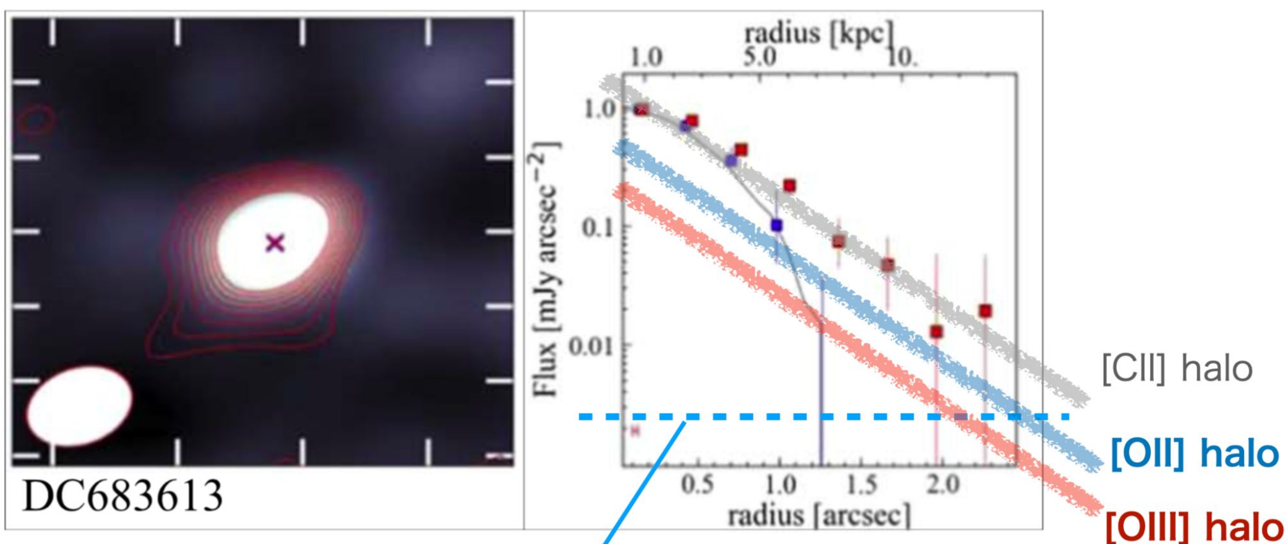
JWST



NIRSpec/IFU sensitivity

(credit : JWST User Documentation)

- **Tagget line** : [OII], H-beta, [OIII]
- **Disperser-filter combination** :
  - G235M/F170LP (1.66 – 3.17 μm)
  - G395M/F290LP (2.87 – 5.27 μm)



z ~ 5.5

JWST sensitivity
S/N=10, 10000s

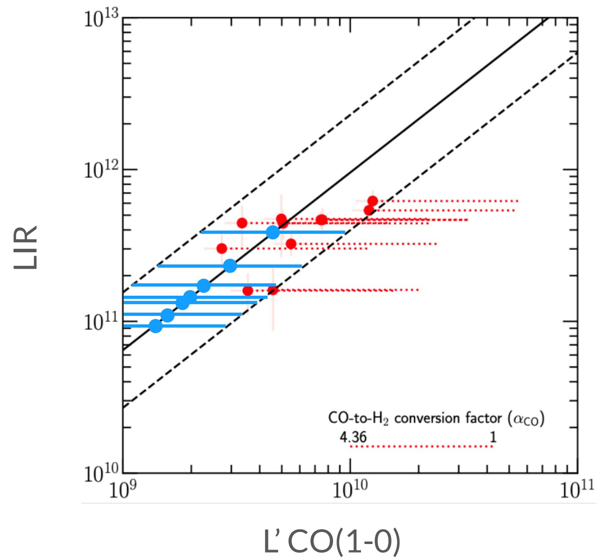
NIRSpec/IFU FoV : 3'' x 3''

Fujimoto et al.2020

ALMA observation

- Observed frequency : band3 (84-119 GHz)
- Target line: CO (5-4)
  → lowest transitions observable with ALMA
- 2 sources are possibly detected by ~3 sigma

  (Continuum sensitivity: ~5μJy)



adapted from Dessauges-Zavadsky+2020

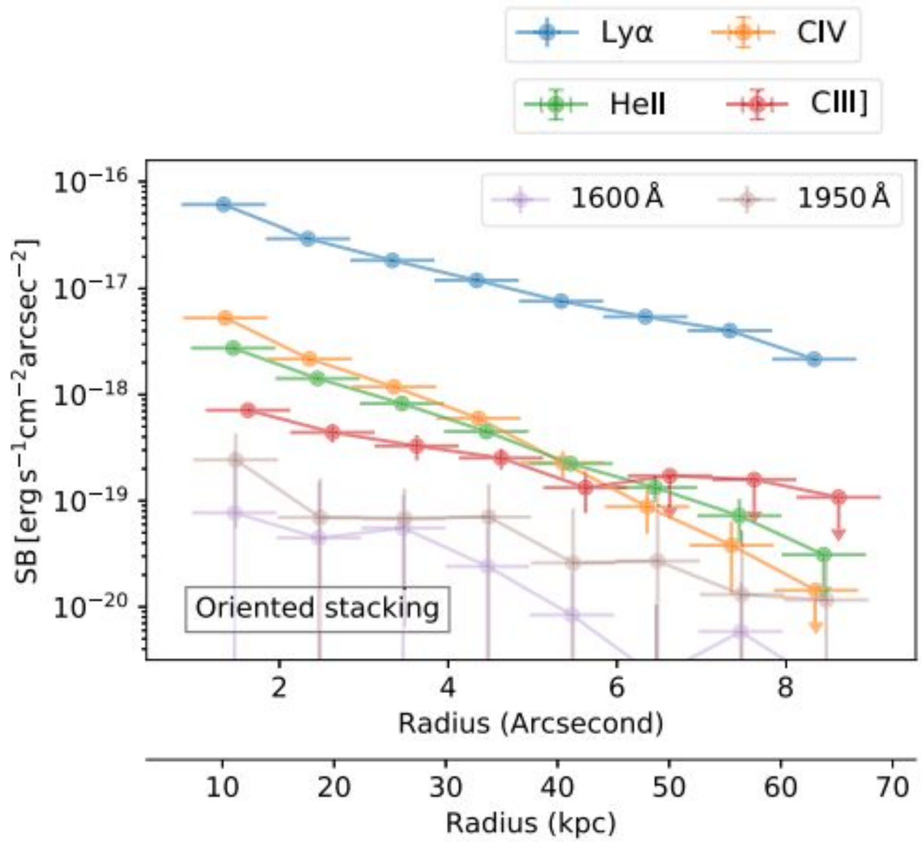
Target name (Fujimoto+2020)	Total observation time
VC5110377875 (z=4.5505)	~10h
DC881725 (z=4.5777)	~16h

Metal abundance profile

Guo et al. (2020) have investigated surface brightness (SB) profile of the metal lines for QSOs at z ~ 3.

SB profile of the nebular and molecular lines for the normal SFGs at z ~ 4.5, 5.7.

Metal enrichment and gas phase in CGM around normal high-z SFGs.



Guo et al. (2020)

Outflow/inflow

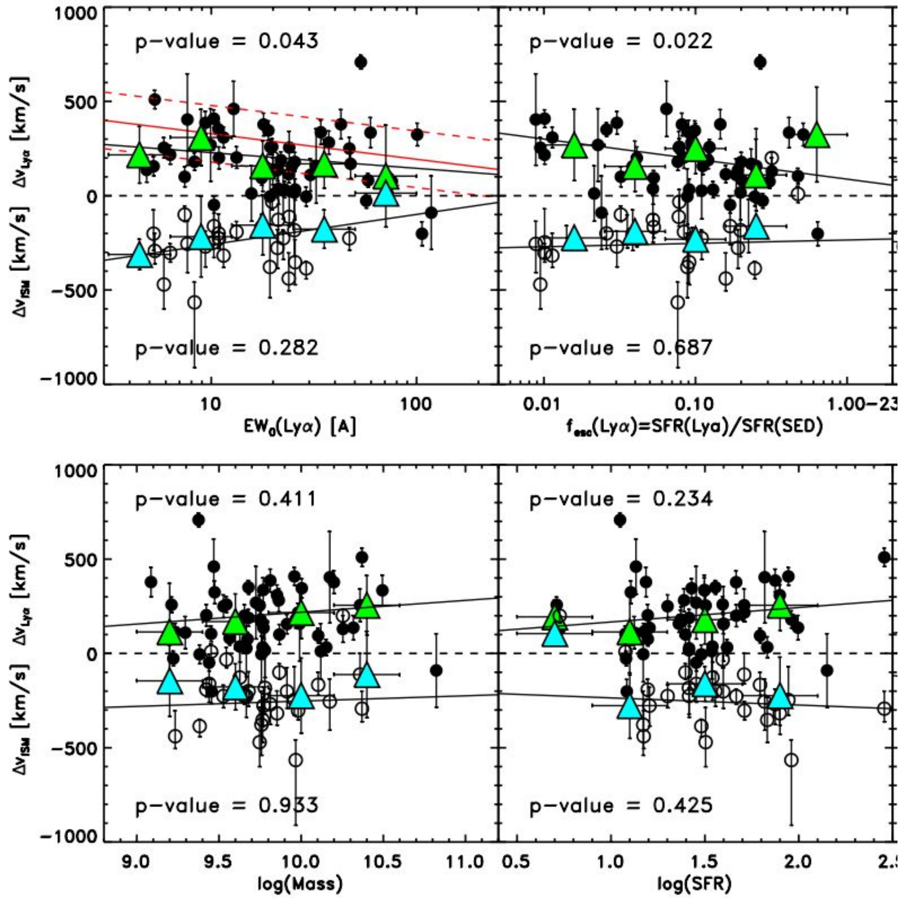
Cassata et al. (2020)

Velocity offset among the emission lines.

-> Inflow or outflow

Connection with galaxy formation.

gas accretion, feedback



SFR, sSFR profile

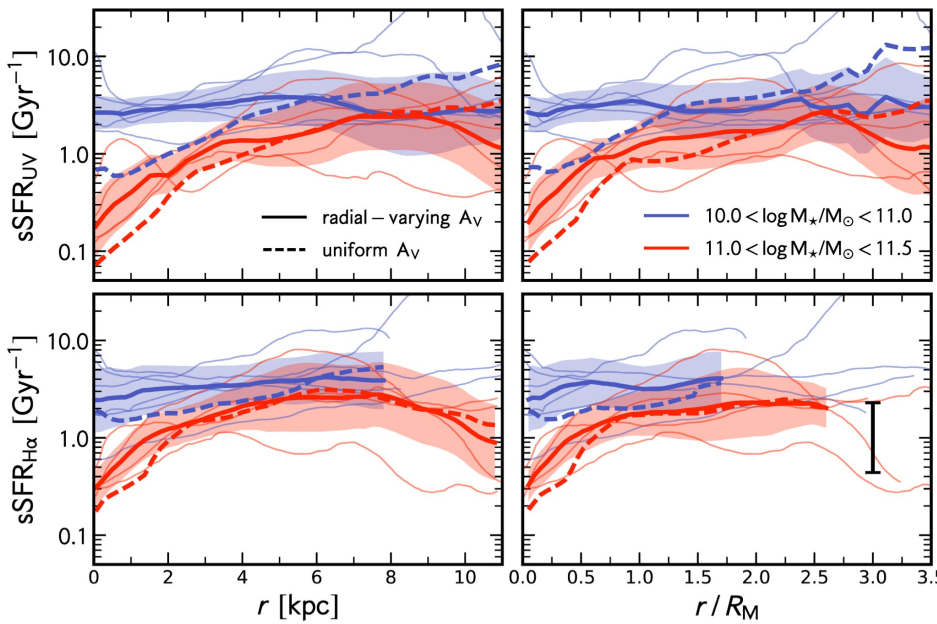
$$\mathrm{SFR}(M_\odot \text{ year }^{-1}) = (1.4 \pm 0.4) \times 10^{-41} L[\mathrm{OII}](\mathrm{ergss}^{-1})$$

$$\mathrm{SFR} > 0.33 \times 10^{-41} \frac{L_{[\mathrm{OIII}]}}{\mathrm{ergs}^{-1}}$$

- How does the sSFR profile at z=4 compare to z=2?
- Understand where star formation occurs in the galaxy

Whether there are any signs of quenching

z=2 star-forming galaxies



$$\mathrm{sSFR}(r) = \Sigma_{\mathrm{SFR}}(r)/\Sigma_{\mathrm{M}}(r)$$ (S. Tacchella et al. 2018)

[OIII]/[OII] ratio

Studying the ionisation state of star-forming galaxies

- Understanding the ionisation state of galaxies as a function of position by looking at the [OIII]/[OII] ratio in a 2D map.

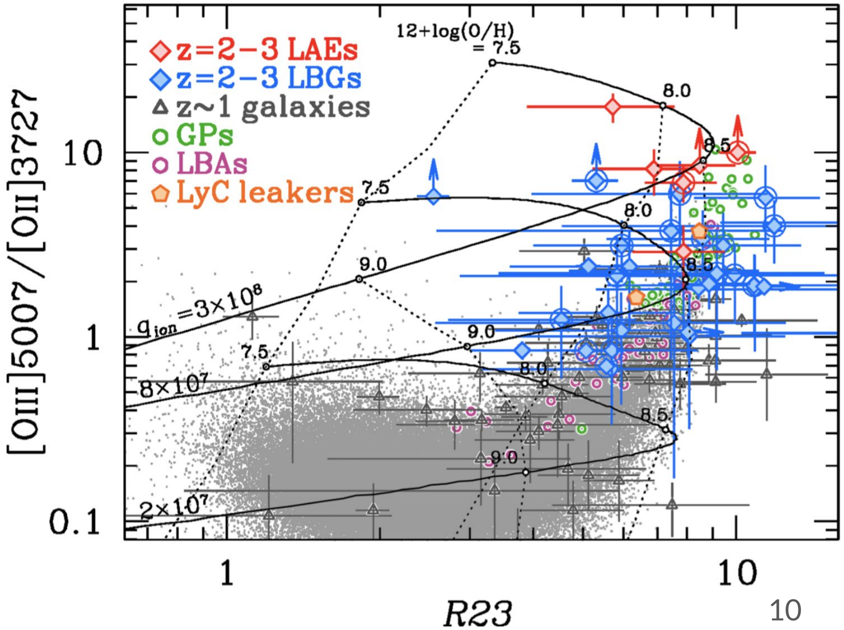
- Ionisation parameters and metallicity

(1) Star-forming galaxies at z=2-3 have higher values than the local [OIII]/[OII] ratio

(2) From local to z=3, the [OIII]/[OII] ratio is mass dependent.

→ How about z=4 star-forming galaxies.

Nakajima & Ouchi 2014



Summary

- [OII], [OIII] blobs have been observed at $z<1.5$.
- We target ALPINE at $z\sim4.5$ and 5.7 sources with [CII] halo detection.
- JWST can detect [OII], H-beta and [OIII] lines.
- ALMA possibly can detect CO (5-4) line in two galaxies.
- We investigate metal abundance and gas phase in halos around the SFGs, as well as the connection between the CGM and galaxy formation.

back up: sensitivity calculation of ALMA observation

log(LIR) = (1.17 ± 0.03) log(L' CO(1−0)) + (0.28 ± 0.23) from Dessauges-Zavadsky+2015

log(LIR) reference: Béthermin+2020, Fudamoto+2020 (calculated from IRX-β relation)

L' CO(1−0) → L' CO(5−4): assuming luminosity ratio from Kirkpatrick+2019

Peak flux density: integrated flux divided by FWHM assuming [CII] line width is similar to CO that

target	redshift	RA[hh:mm:ss]	Dec[deg:min:s]	I co(Jykm/s)	FWHM(km/s)	L log10(L/Lsolor)	LIR-2.23	LIR-2.62
DC396844	4.5424	10:00:59.64	1:53:47.23	1.86	287	9.06	11.21	11.23
DC488399	5.6704	10:03:01.15	02:02:35.82	1.24	303	9.03	10.81	10.97
DC630594	4.4403	10:00:32.62	02:15:28.44	1.04	260	8.79	11.09	11.13
DC683613	5.542	10:00:09.43	02:20:13.91	0.95	216	8.9	11.16	11.12
DC880016	4.5415	9:59:55.18	02:38:08.18	0.89	274	8.74	11.02	11.04
DC881725	4.5777	10:00:13.56	02:38:16.85	1.09	198	8.84	11.36	11.34
VC5100537582	4.5501	10:01:33.52	01:50:20.40	0.71	206	8.65	10.25	10.66
VC5110377875	4.5505	10:01:32.33	02:24:30.27	2.77	234	9.23	11.58	11.57

from Béthermin+2020, Fudamoto+2020