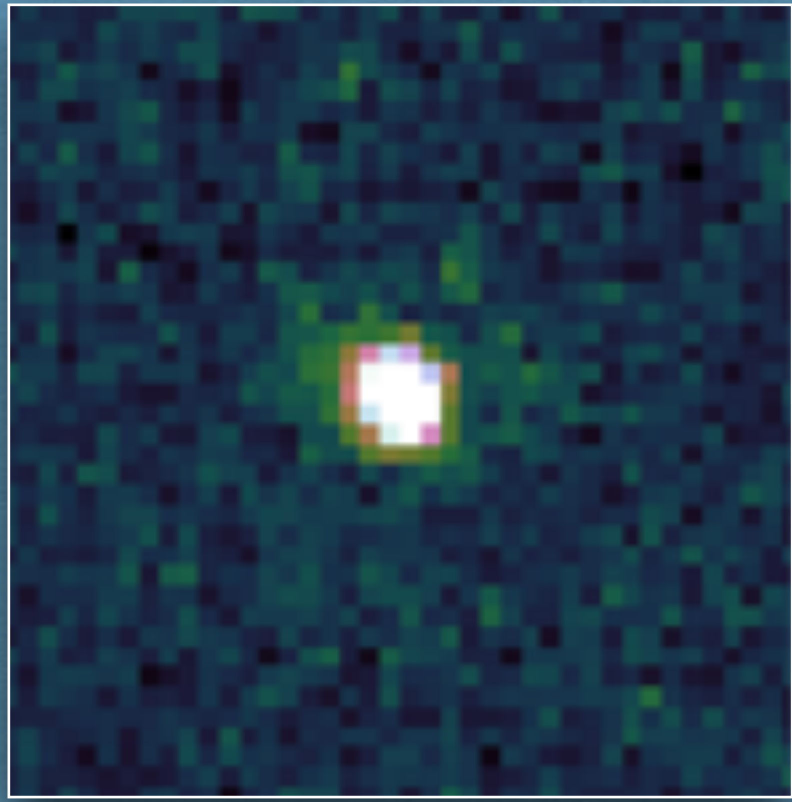
Departamento de Astronomía
Universidad de La Serena

Nebular properties of star-forming CIII]λ1908 emitters at z~3



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Llerena+22, A&A, 659, A16, 31

In collaboration with Ricardo Amorín (PhD advisor), Laura Pentericci, Fergus Cullen, Enrique Pérez-Montero, Ross McLure, Adam Carnall, Antonello Calabrò, Francesca Marchi + the VANDELS team

May 18th, 2022
XIII Estallidos Workshop

Agencia Nacional de Investigación y Desarrollo
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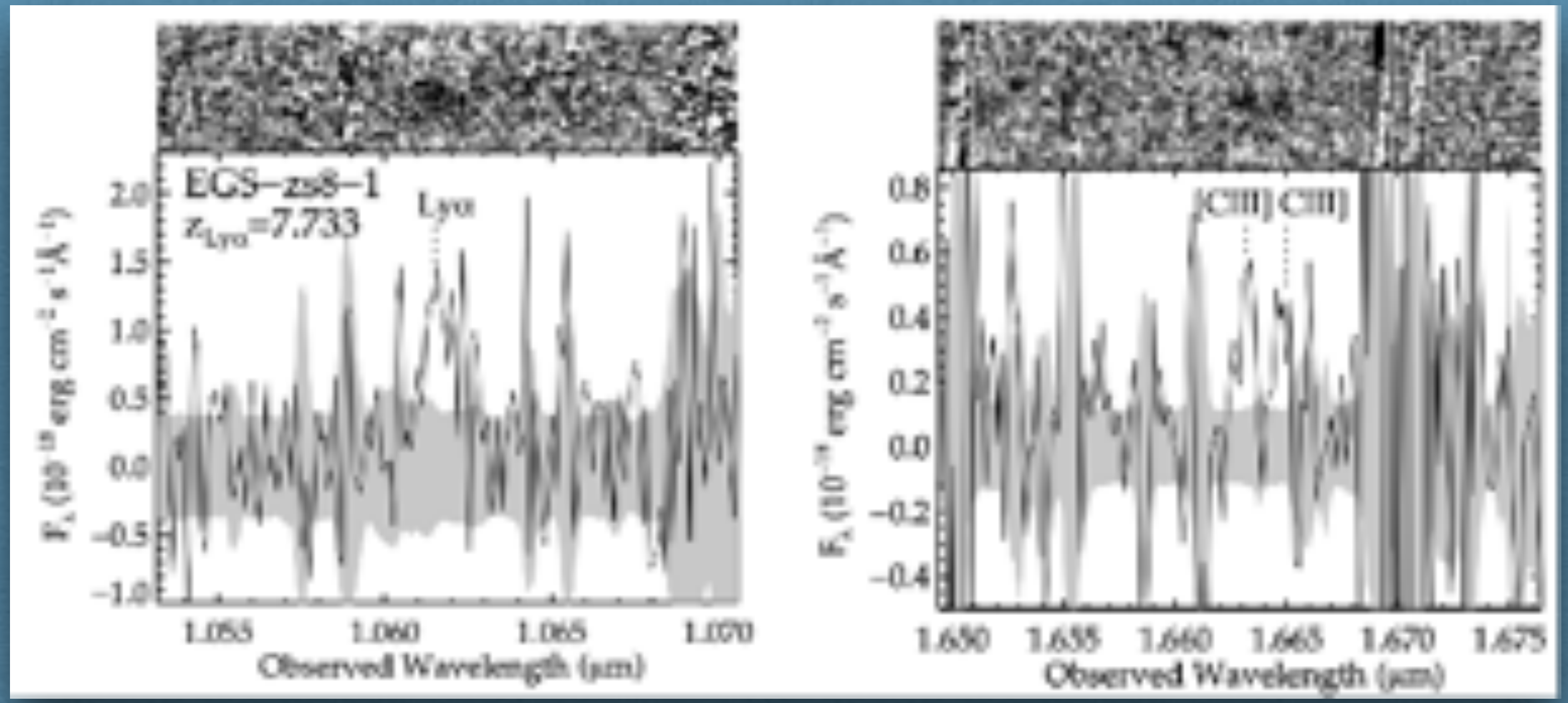
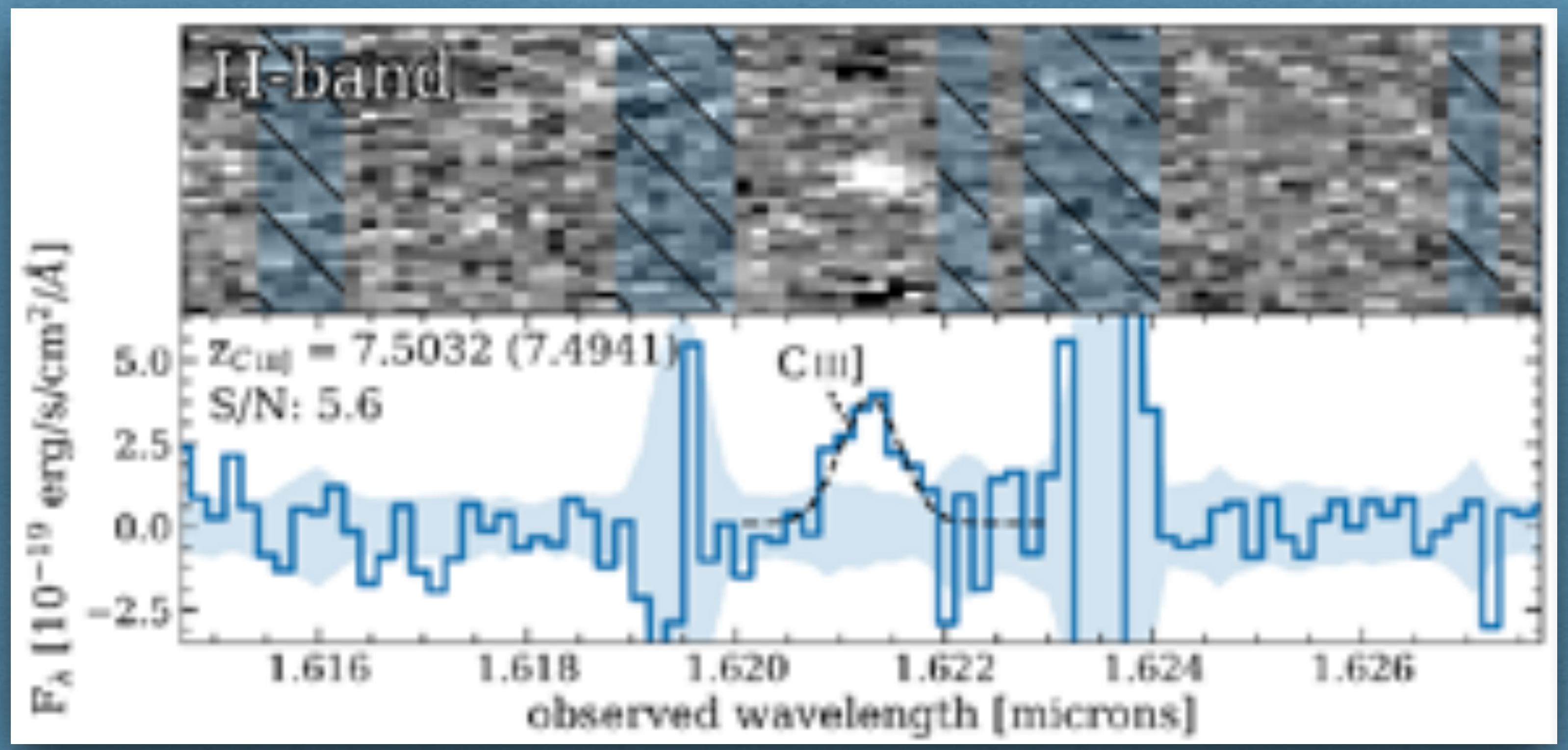
Why to study CIII]λ1908 emitters?

In the few galaxies observed at z>6, intense emission lines

Stark+17

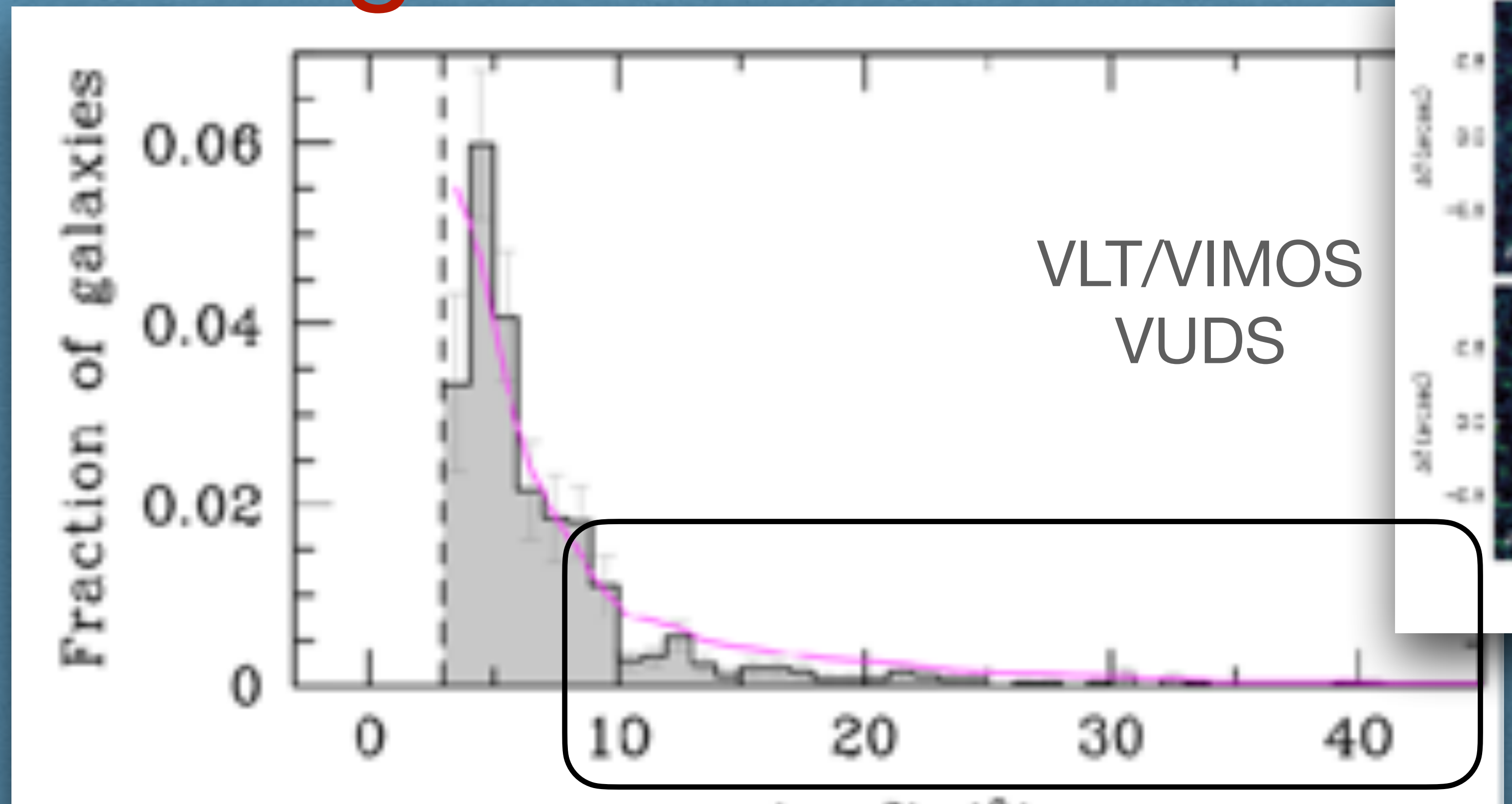


Hutchison+19

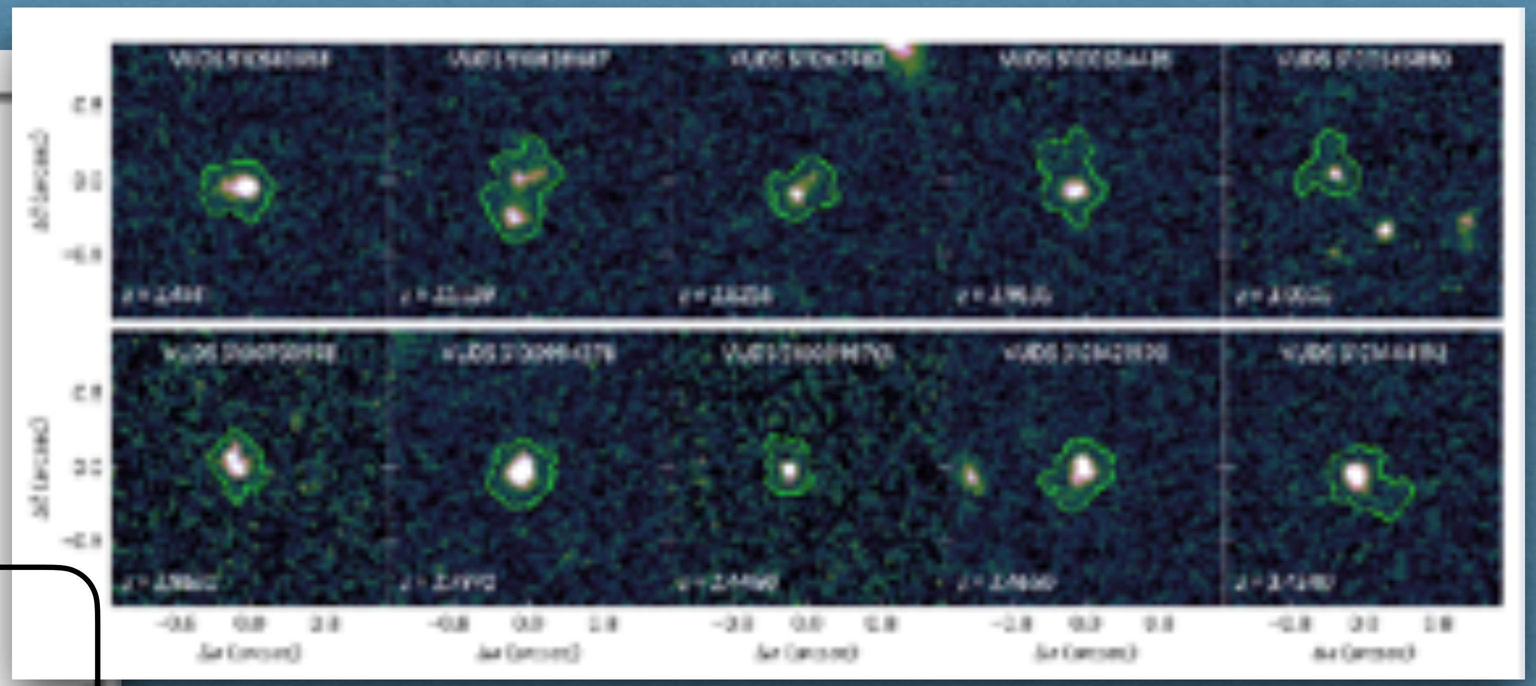


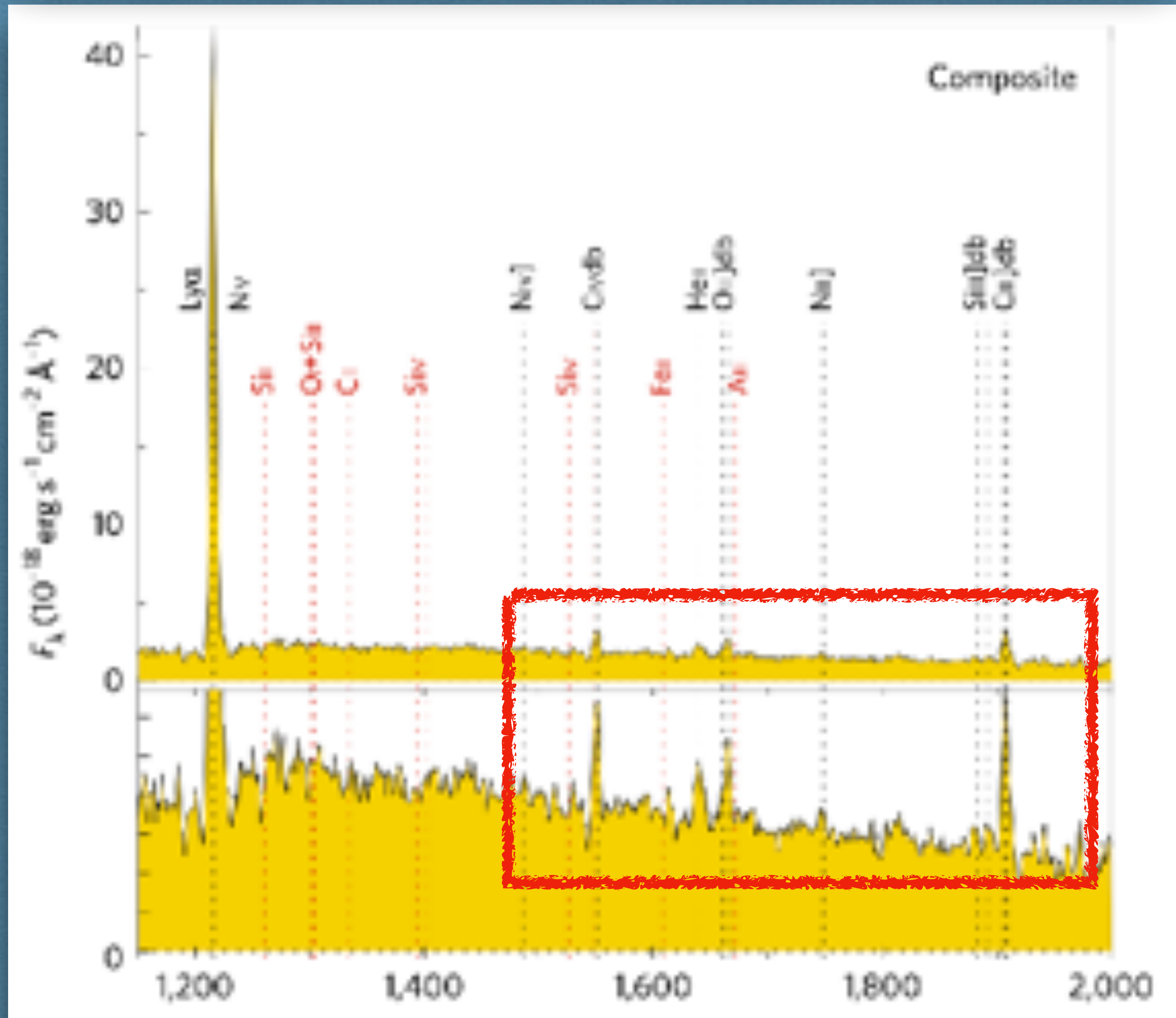
Lya is strongly attenuated in the Epoch of Reionization, which makes CIII] one of the most intense UV lines

Analogs at z~2-4



Le Fevre+19





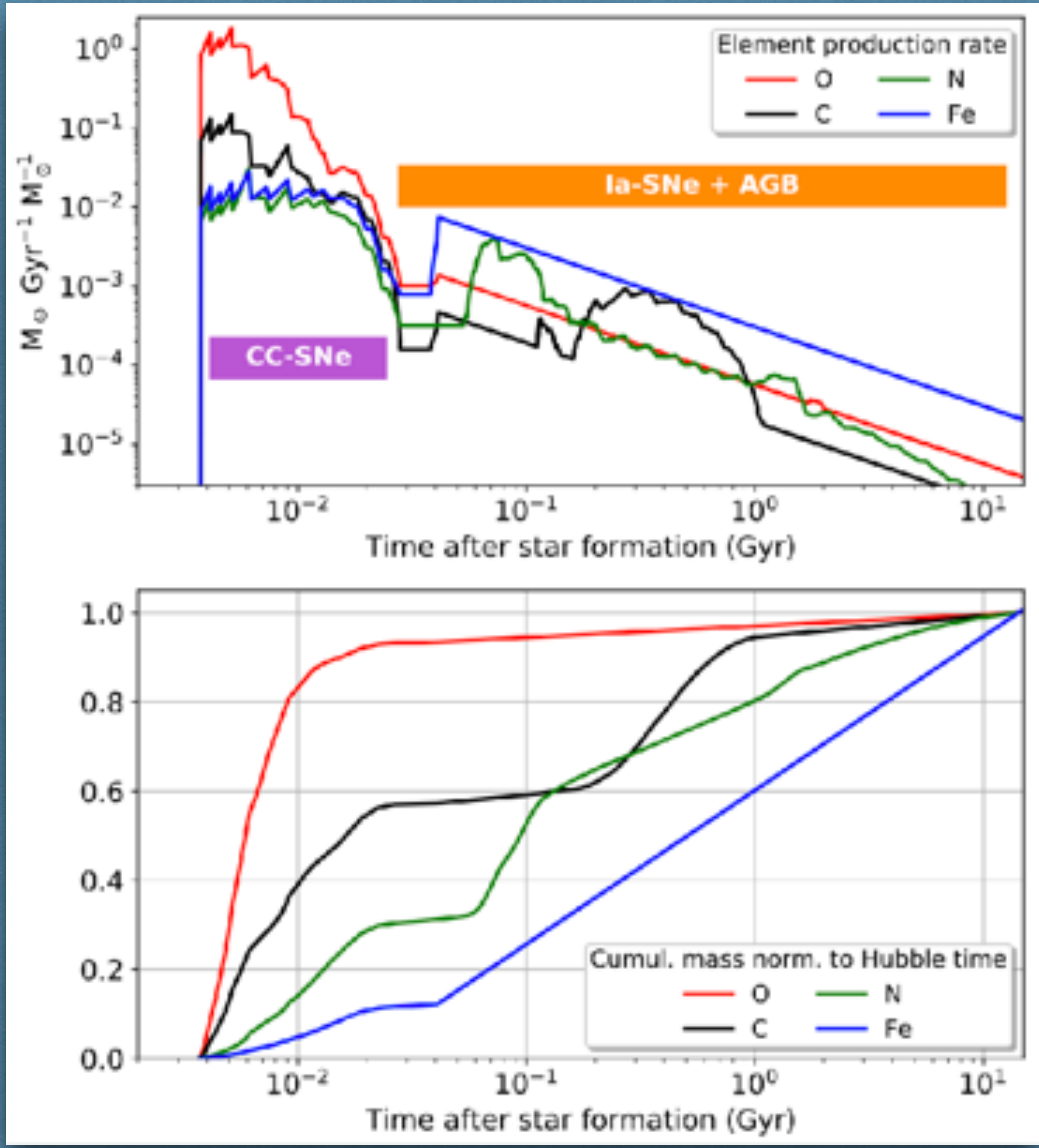
Amorin+17

More extreme population: Low stellar mass, high sSFR, compact, low gas-phase metallicity, high ionization parameter

Why do they have intense CIII] emission? What are the physical properties of “normal” CIII] emitters?

Carbon-to-oxygen (C/O)

Origen

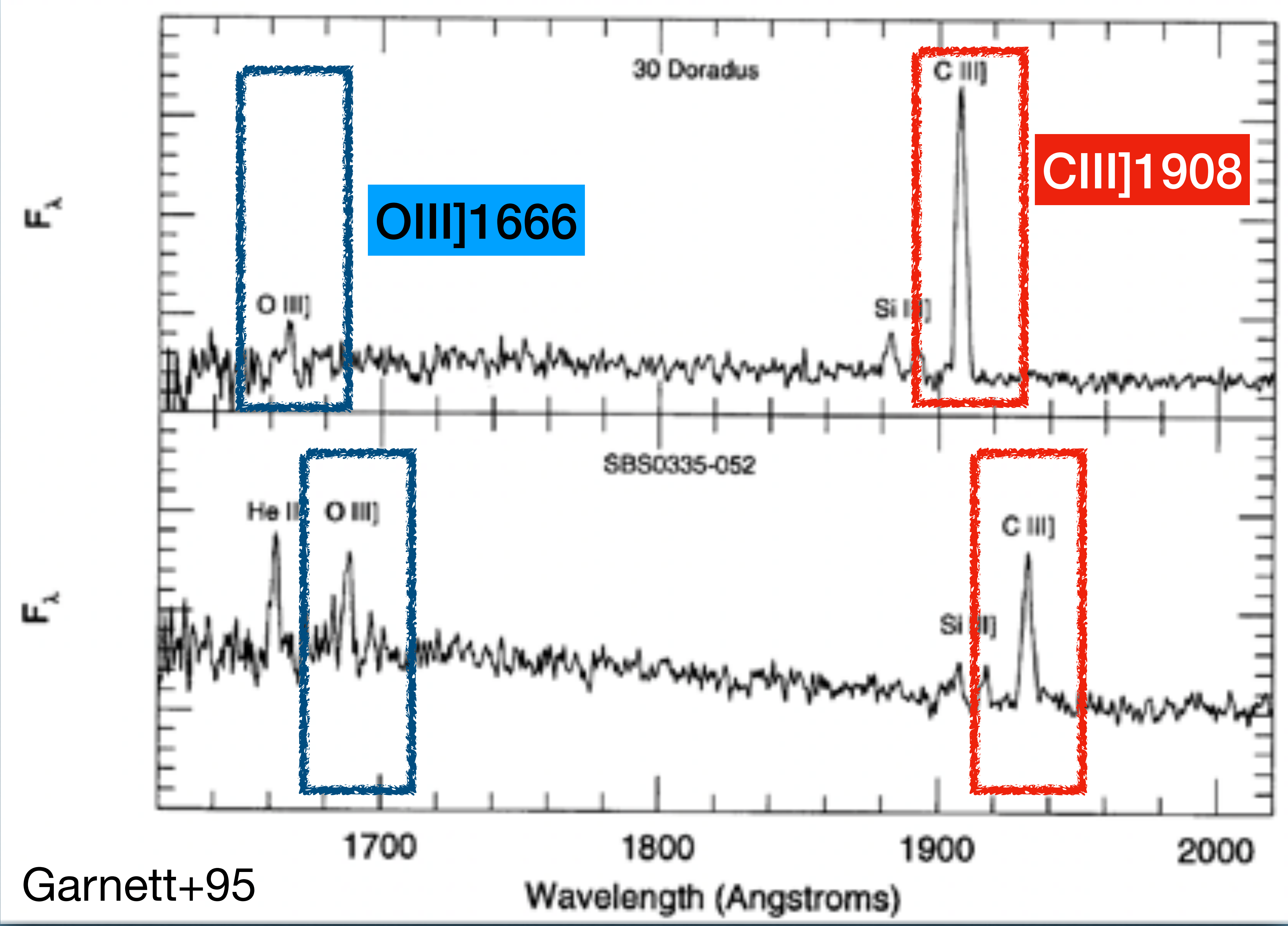


Maiolino&Mannucci,2019

No intense carbon emission lines in the rest-optical

CII4267 (very faint) has been detected in local HII regions (e.g. Esteban+02)

CIII]1908 is one of the strongest UV lines observed in low-metallicity star-forming galaxies

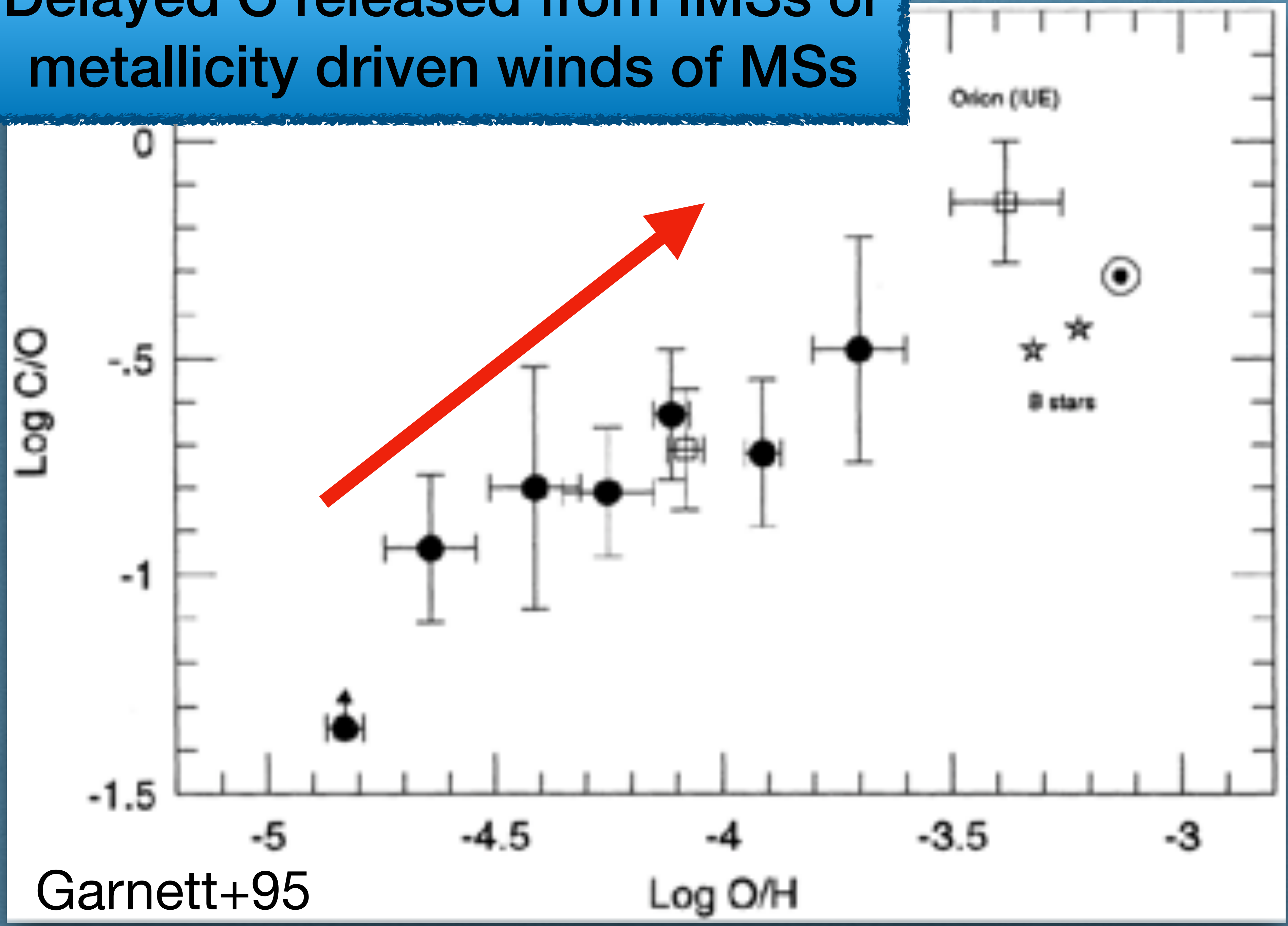


Garnett+95

C/O as chemical clock

Relative ages

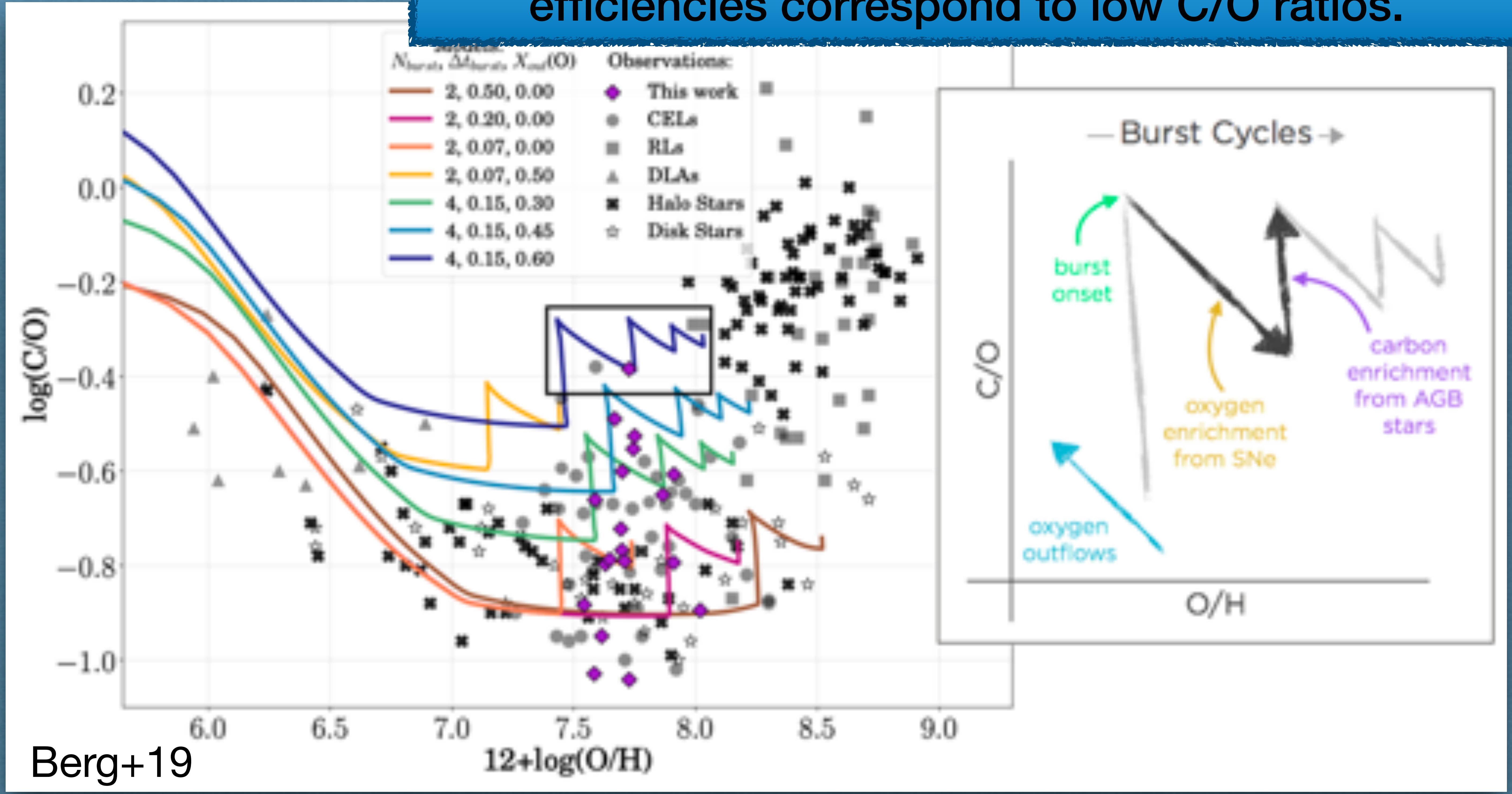
Delayed C released from IMSs or metallicity driven winds of MSs



Garnett+95

Large scatter

Longer burst duration and lower star formation efficiencies correspond to low C/O ratios.



Berg+19

Star formation history, gas fraction and inflow rates, changes in the initial mass function, may contribute to the scatter (Mattsson 2010; Mollá+15; Berg+16; Vincenzo & Kobayashi 2018; Kobayashi+20;Palla+20)

High values of C/O at low metallicity could be due to the effects of a massive inflow of pristine gas, which may lower the gas metallicity of an otherwise more chemically evolved system, without altering C/O (Nakajima+2018).

VANDELS

(VIMOS survey of the CANDELS CDFS and UDS fields)

http://vandels.inaf.it

Final Data Release in Garilli+21

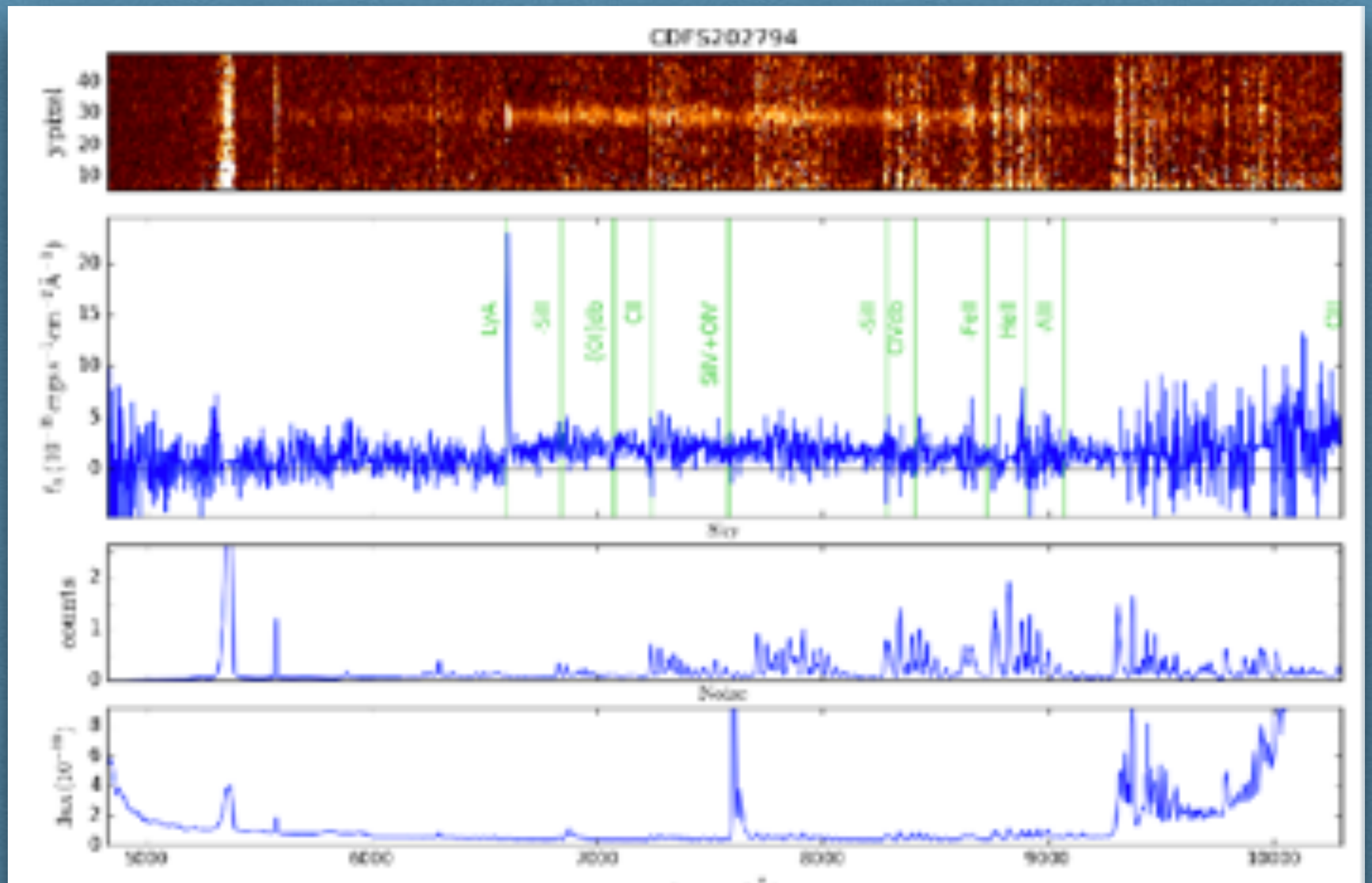
VLT/VIMOS

480–1000 nm

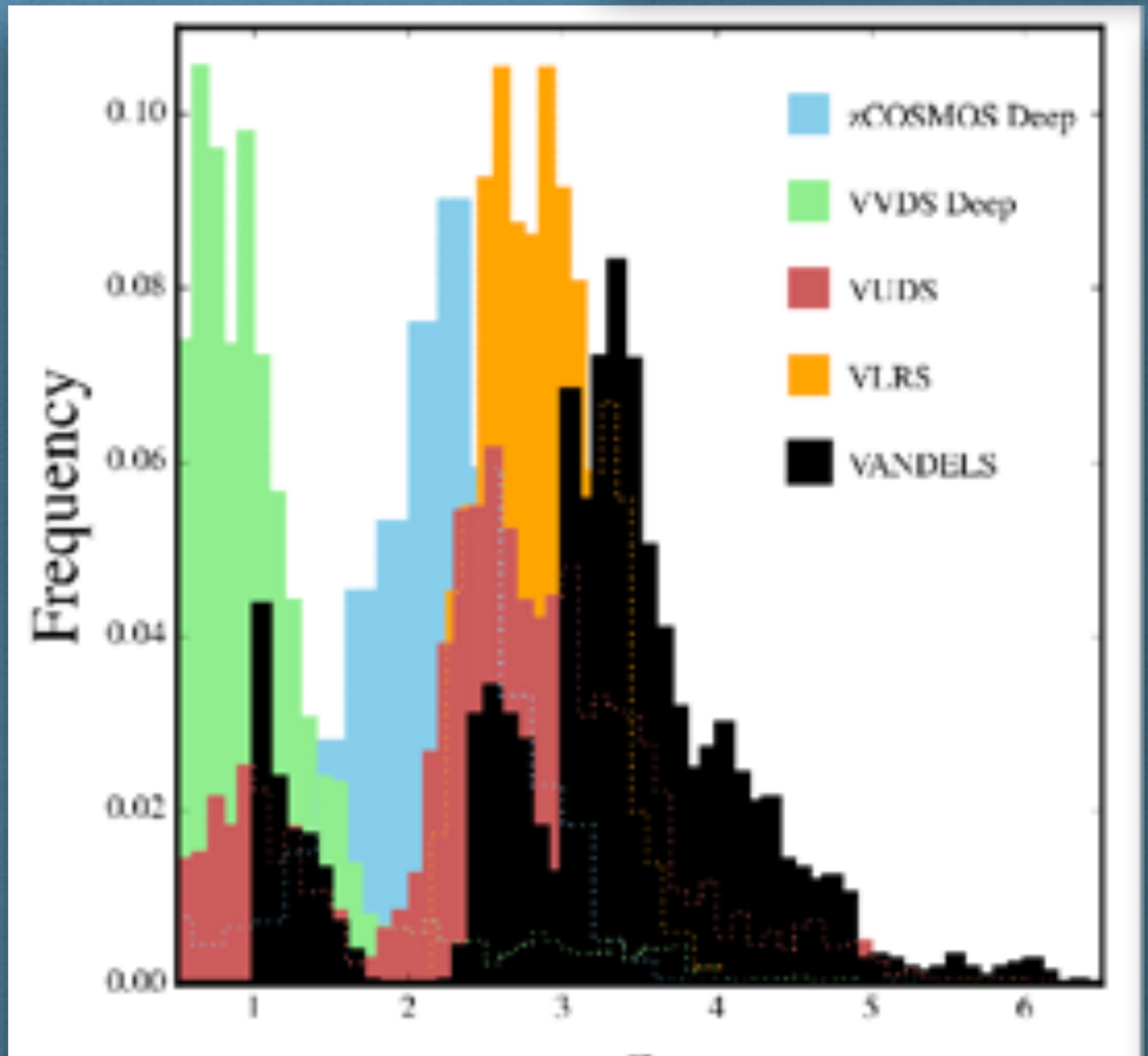
Mean spectral resolution of $R \simeq 580$.

20-80 hours per target (~2000 galaxies)

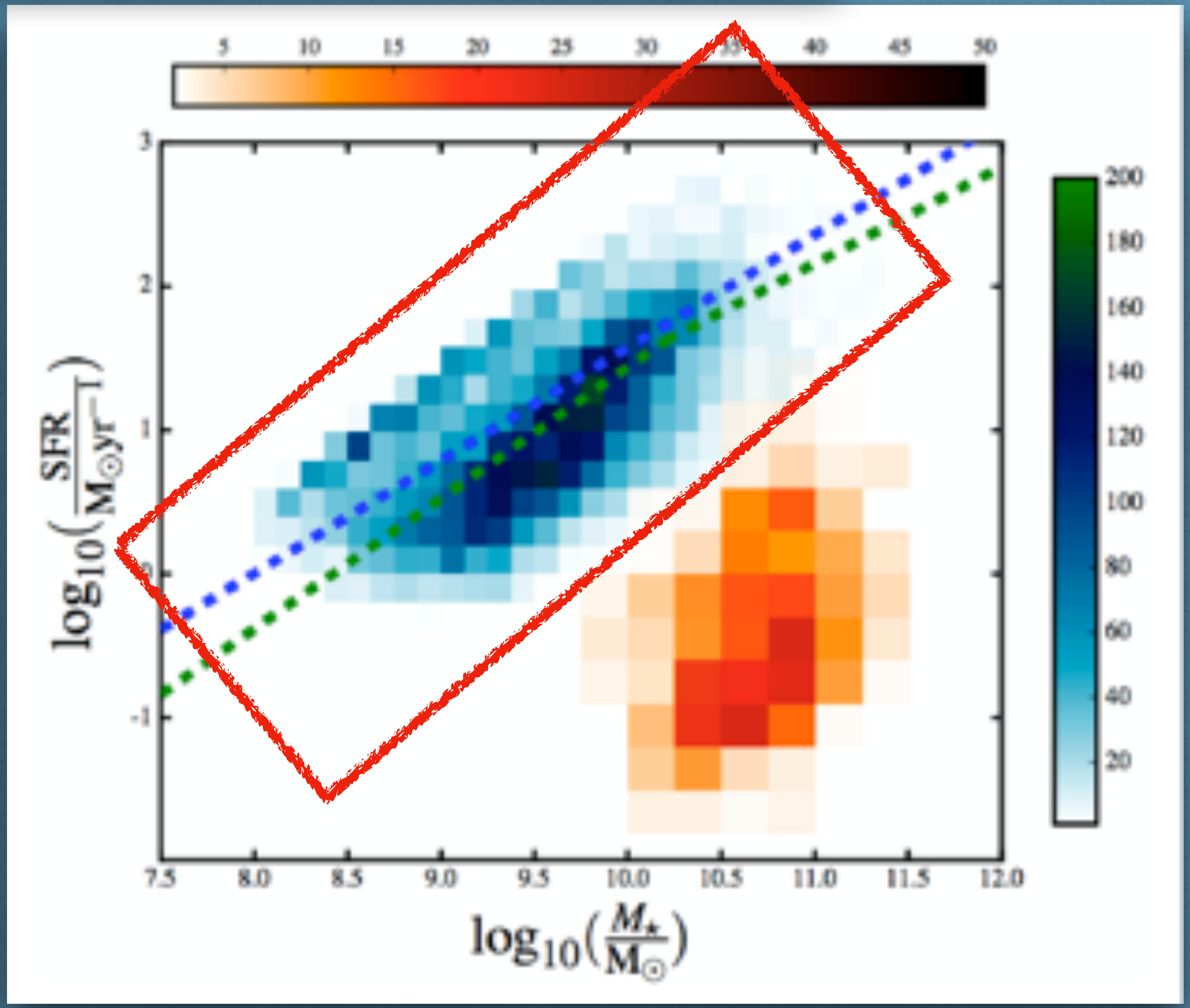
Ultra-deep surveys: increasing the S/N



Pentericci+18



McLure+18



Sample selection

VANDELS Data Release 3

Redshift >95% reliable (z=2-4)

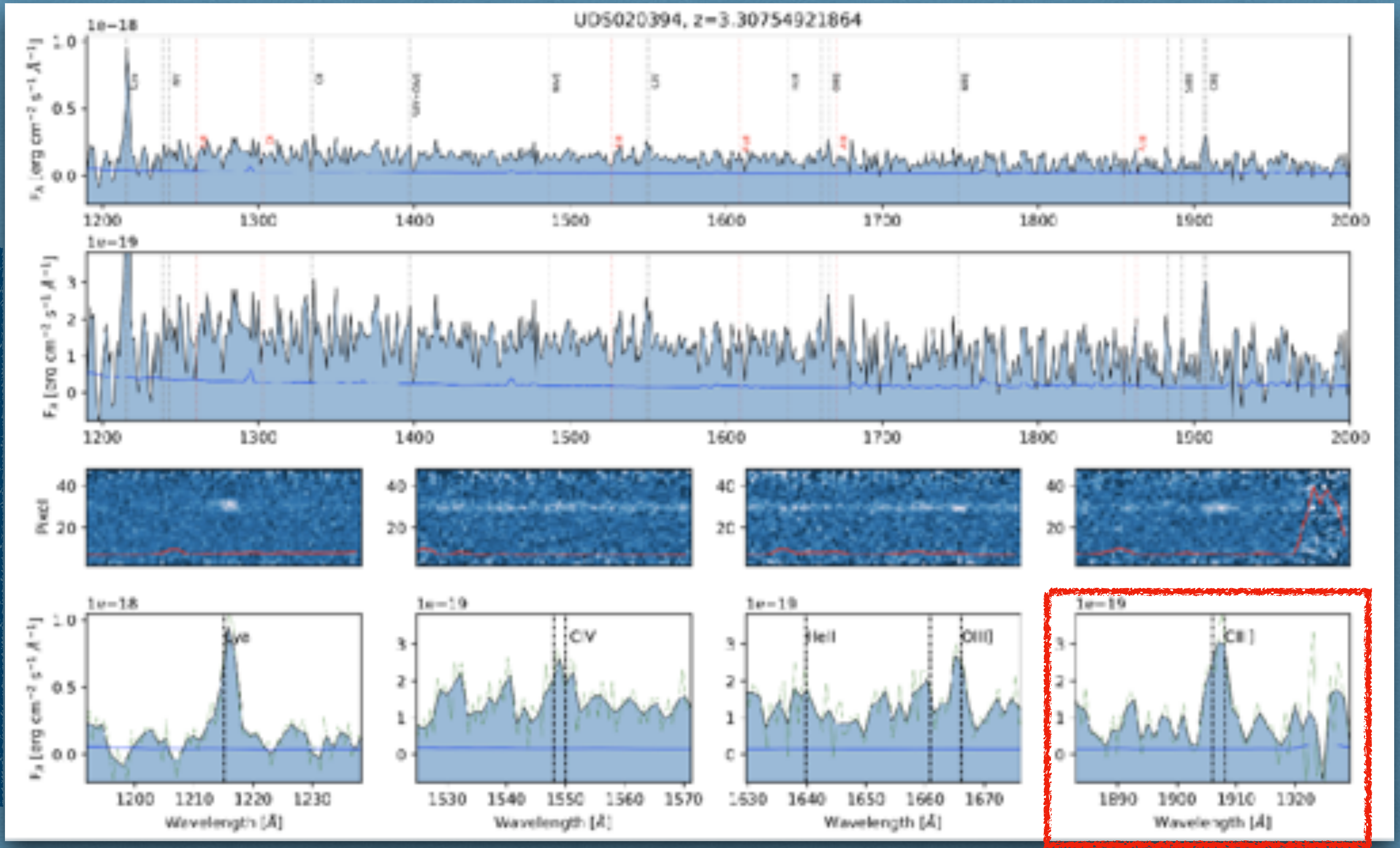
CDFS and UDS fields

CIII] S/N>3

Systemic redshift from CIII] (Marchi+19)

No X-ray counterpart

No obvious AGN



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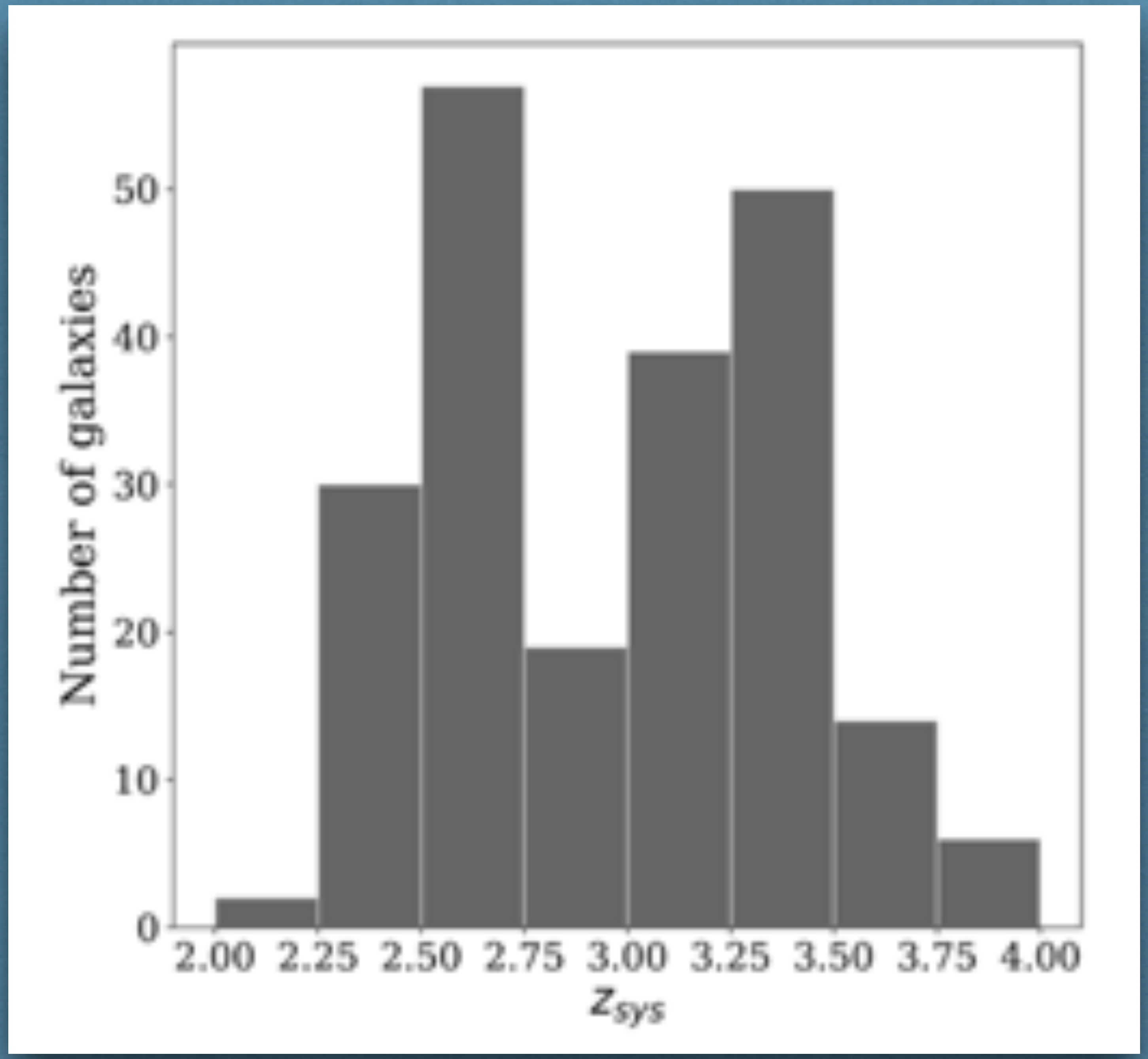
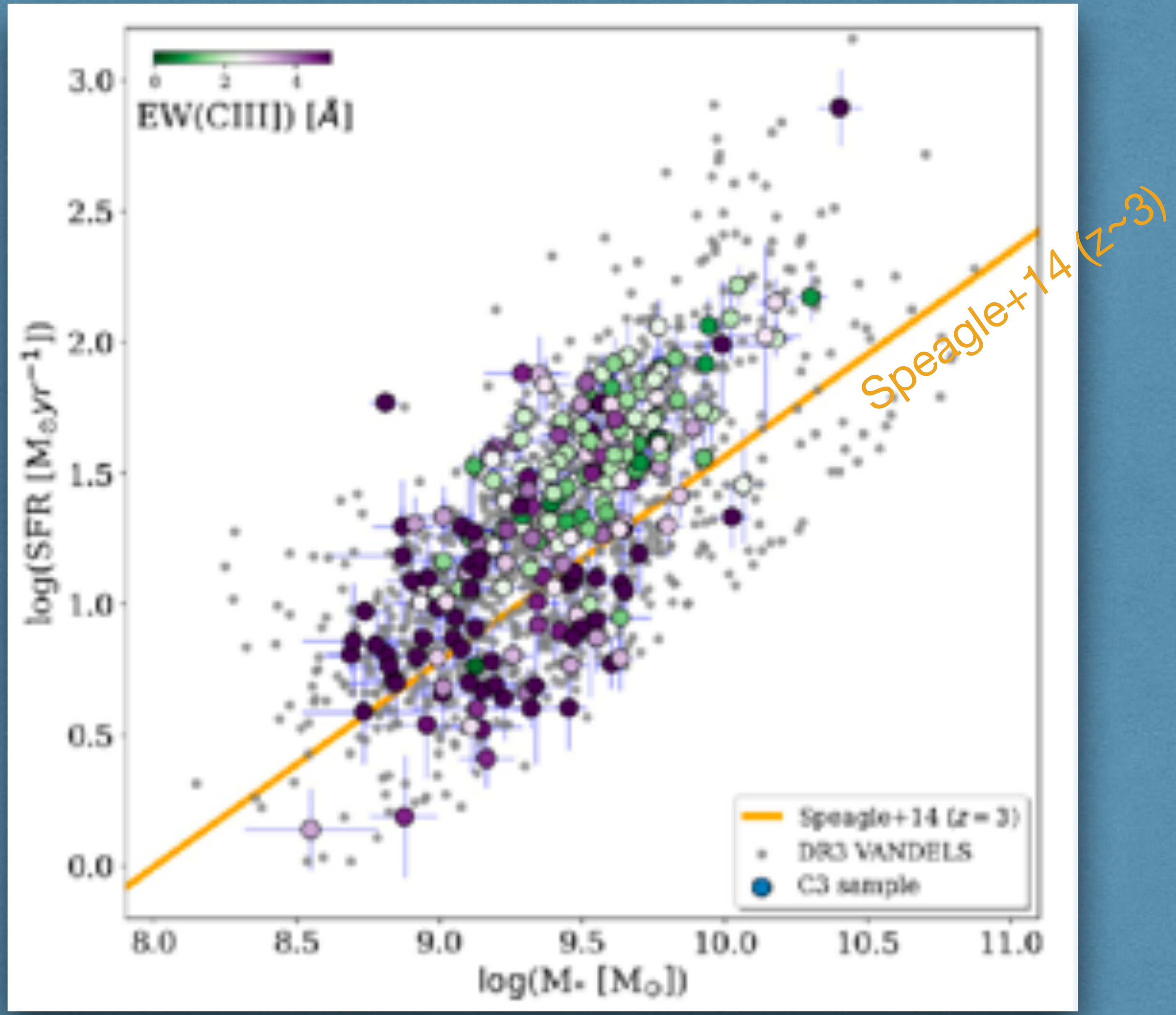


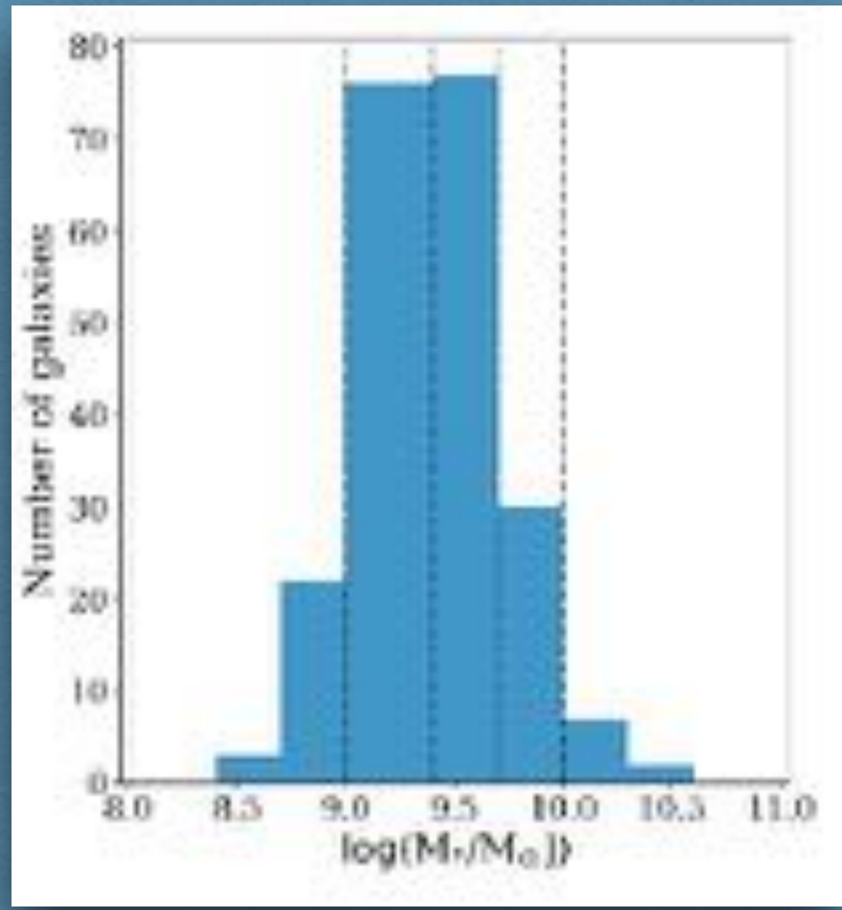
217 galaxies

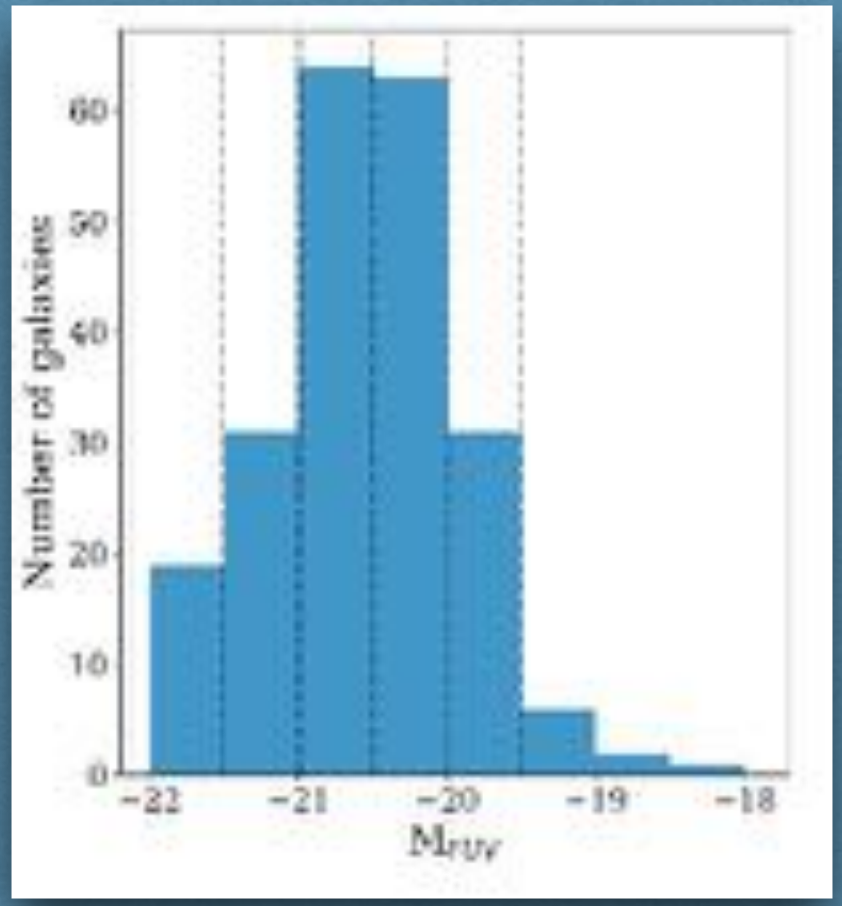
~30% parent sample

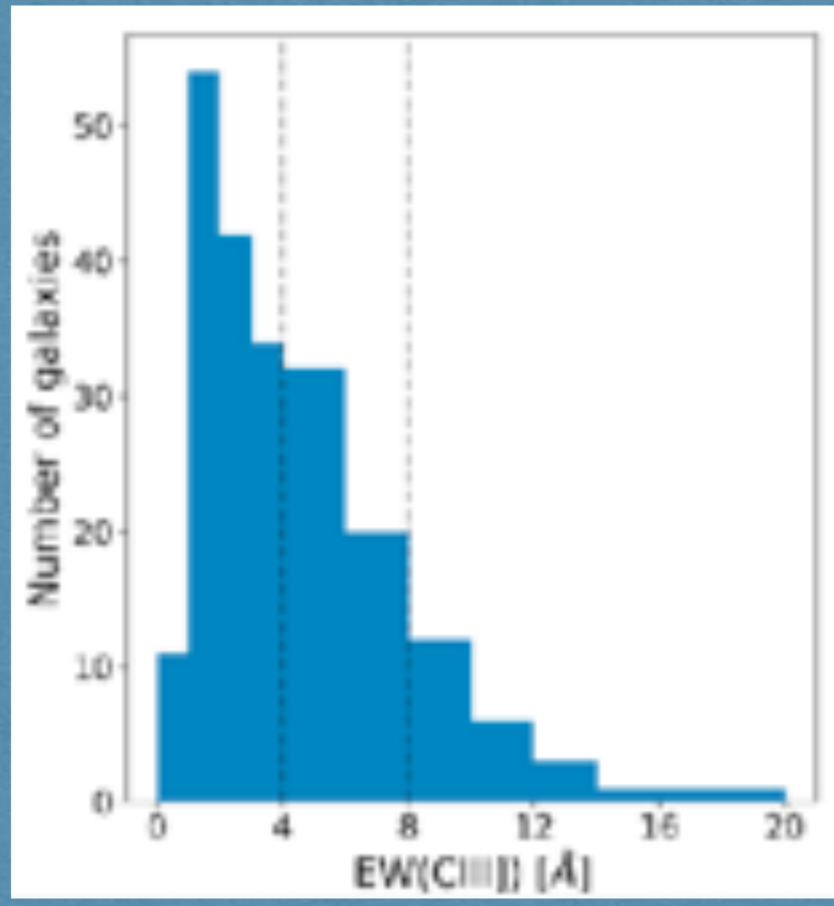


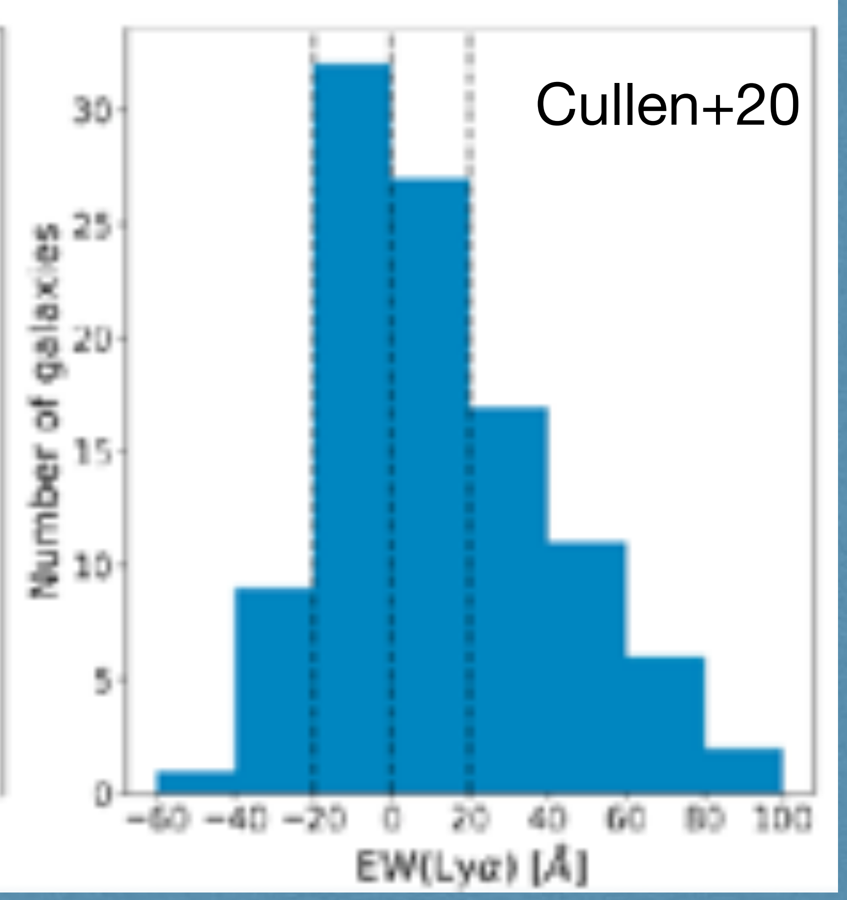
SED fitting

BAGPIPES (Carnall+2018)
Stellar mass, luminosity, dust reddening.









Stacking

Stellar mass, FUV, Ks, EW(CIII]), EW(Lya)

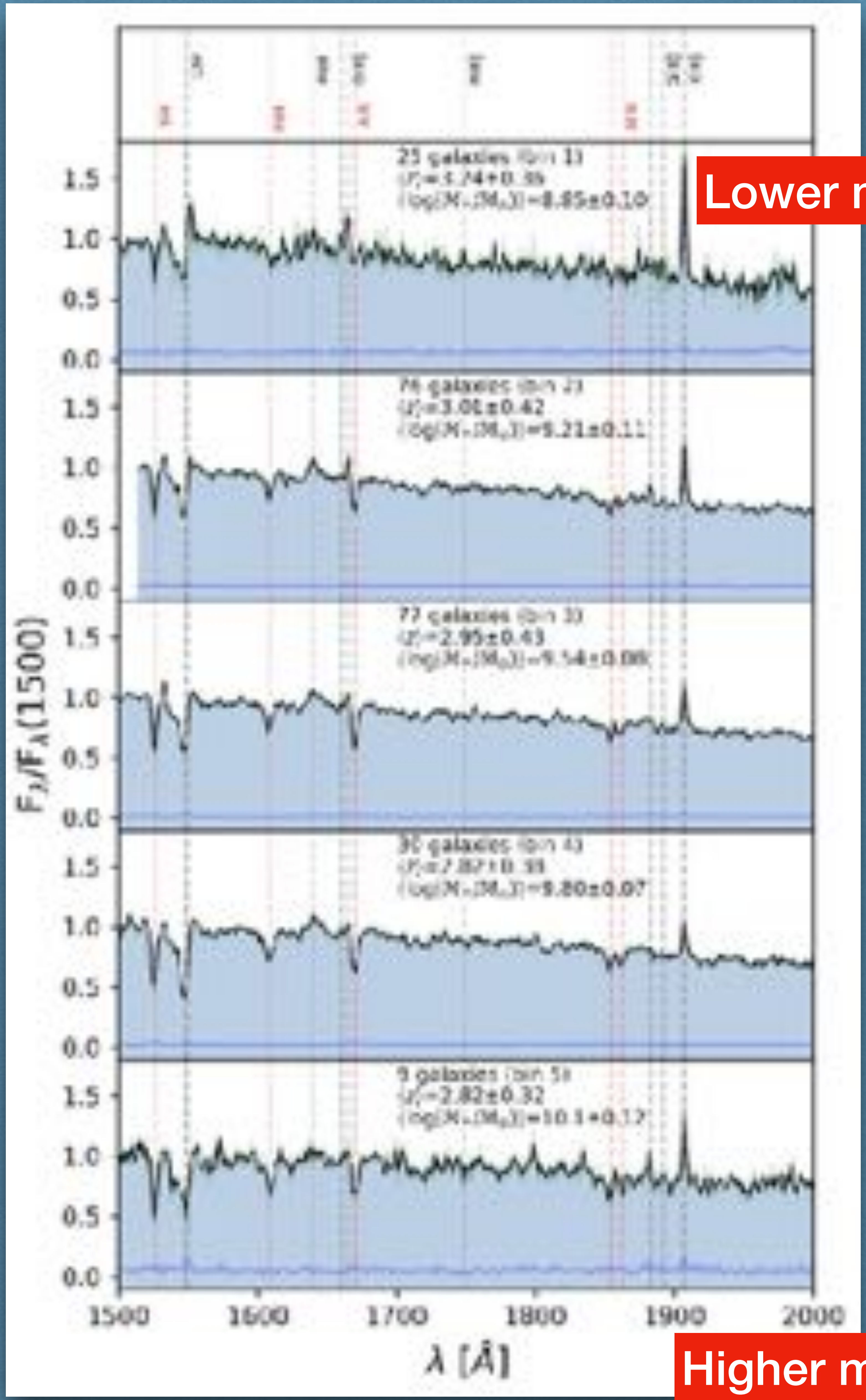
Median stack

Stack A
all galaxies in each bin

Stack B
z>2.9 galaxies

Stack C
z>2.9 galaxies with EW(Lya)>0

Stack D
z<2.9 galaxies

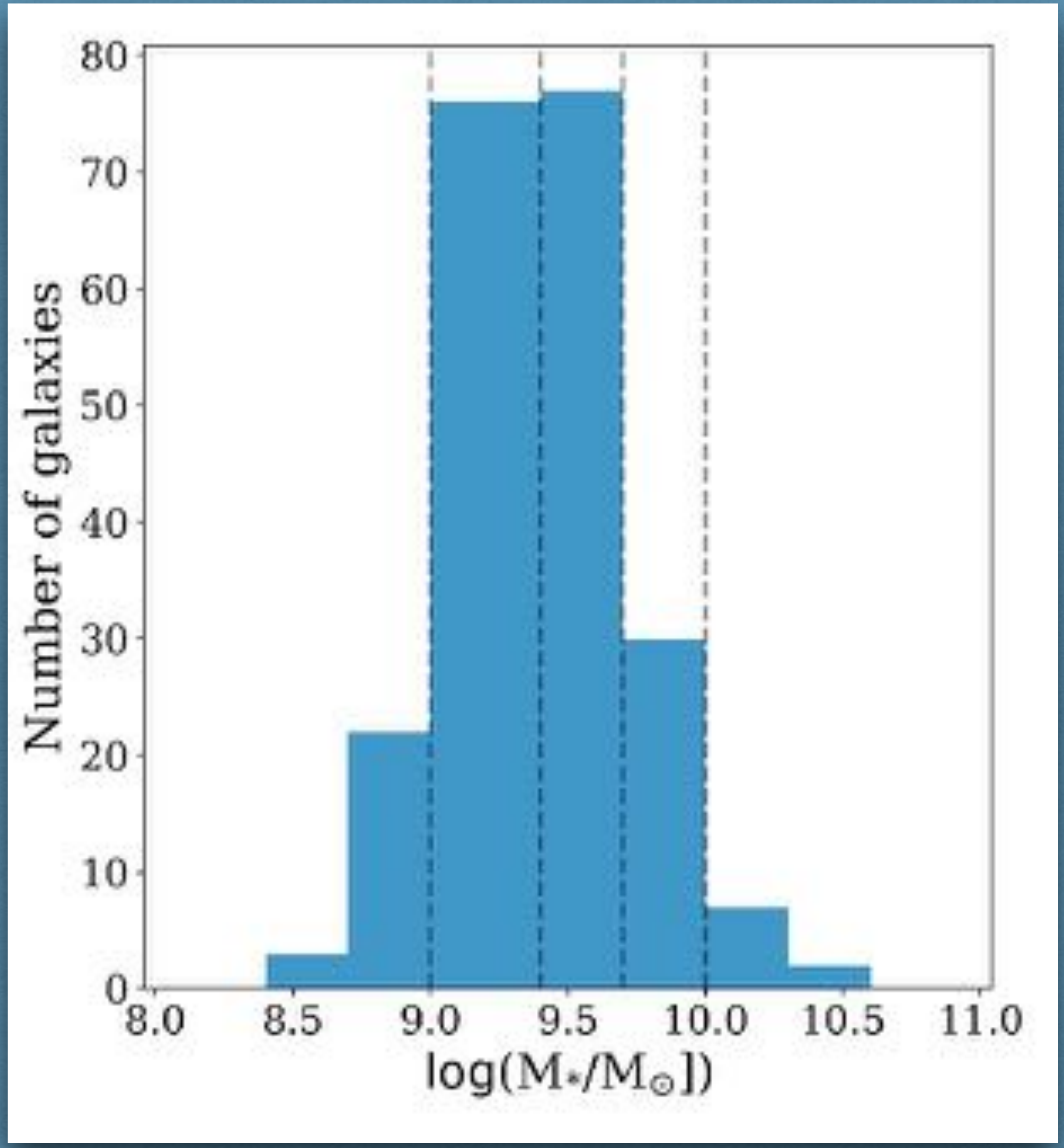


Lower mass

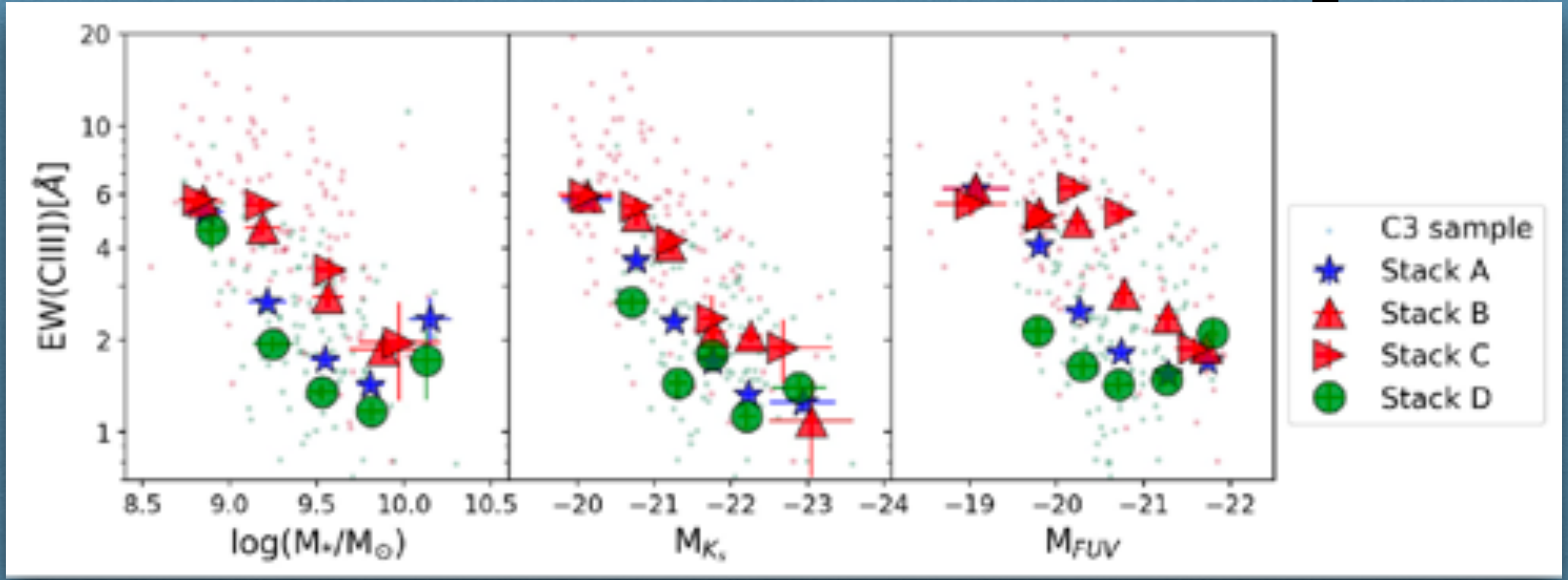
Higher mass

High ionization UV emission lines

ISM absorption lines



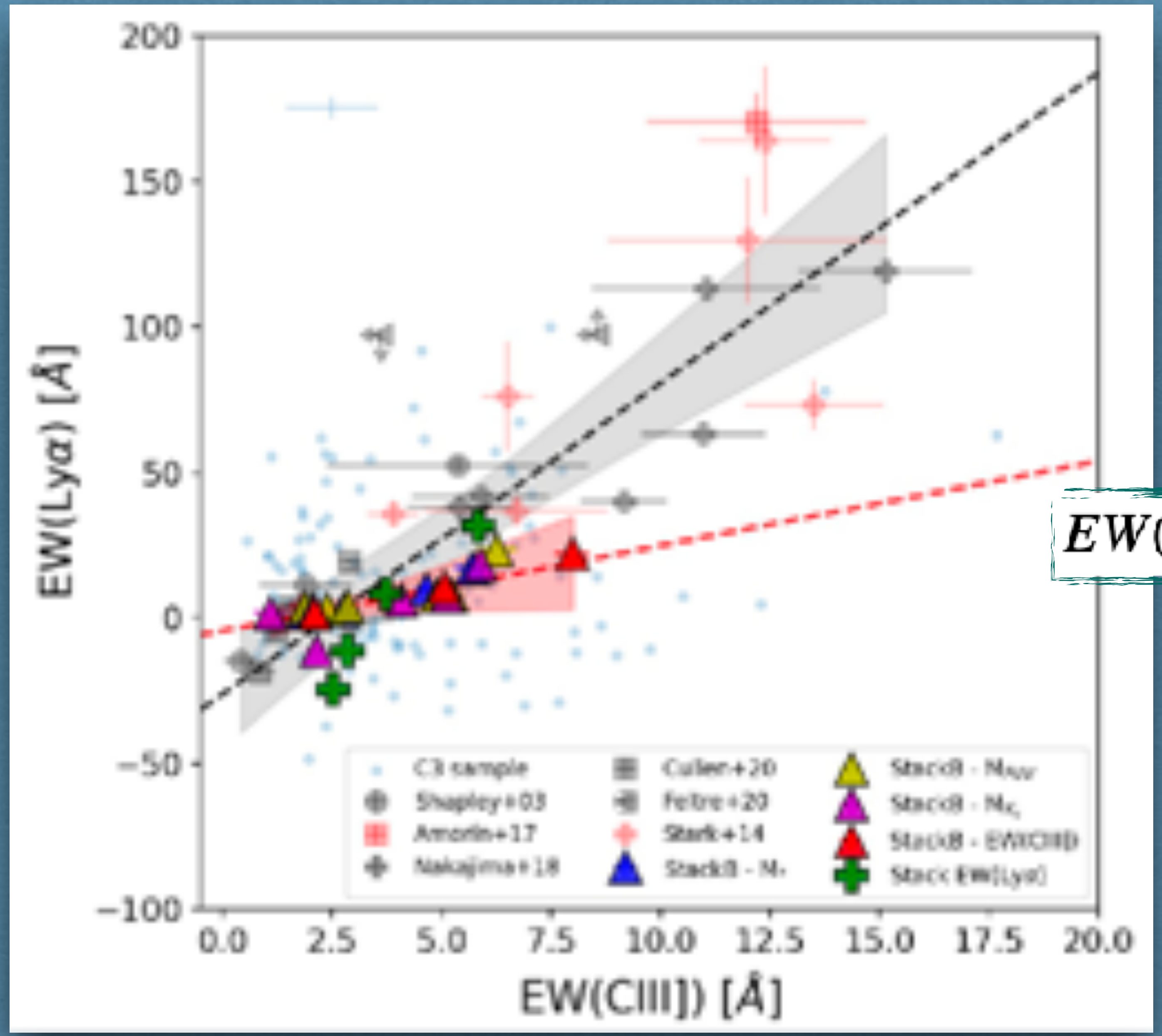
Relation between parameters



Low mass and faint (in any band) galaxies tend to have higher EW(CIII])

EW(CIII]) vs EW(Lya)

Lya is a resonant line scattered/absorbed by neutral ISM



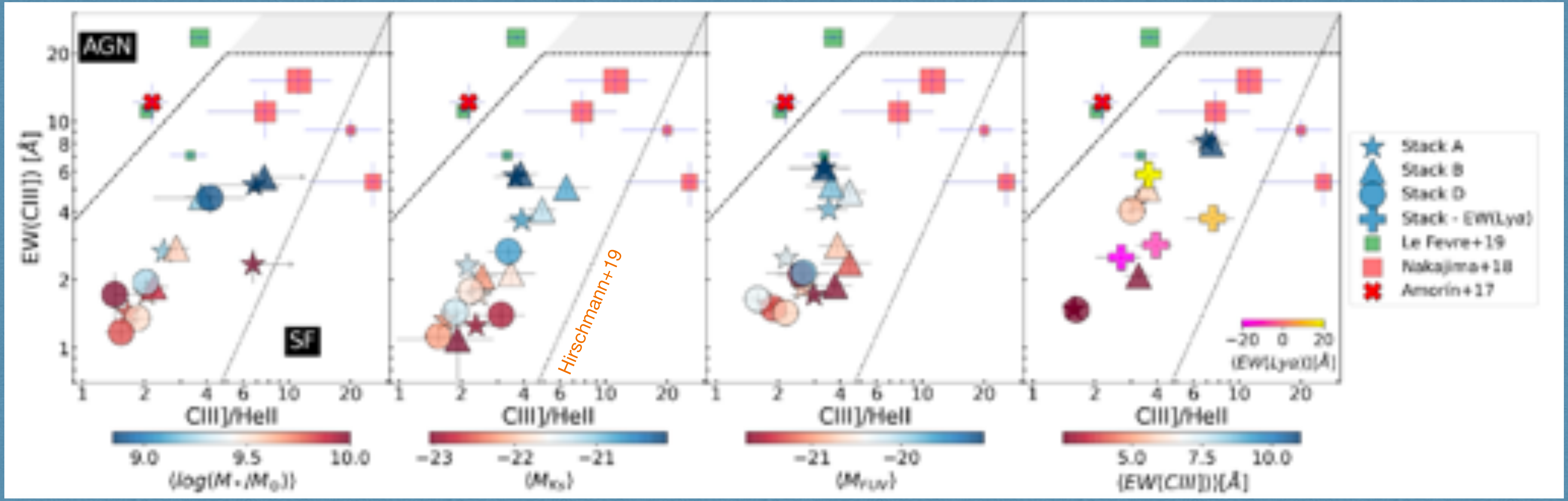
$$EW(Ly\alpha) = (2.92 \pm 0.85) \times EW(CIII]) - (4.65 \pm 2.36),$$

Caution: large scatter in individual galaxies

Useful to identify high-z galaxies where Lya is strongly attenuated

Source of ionization

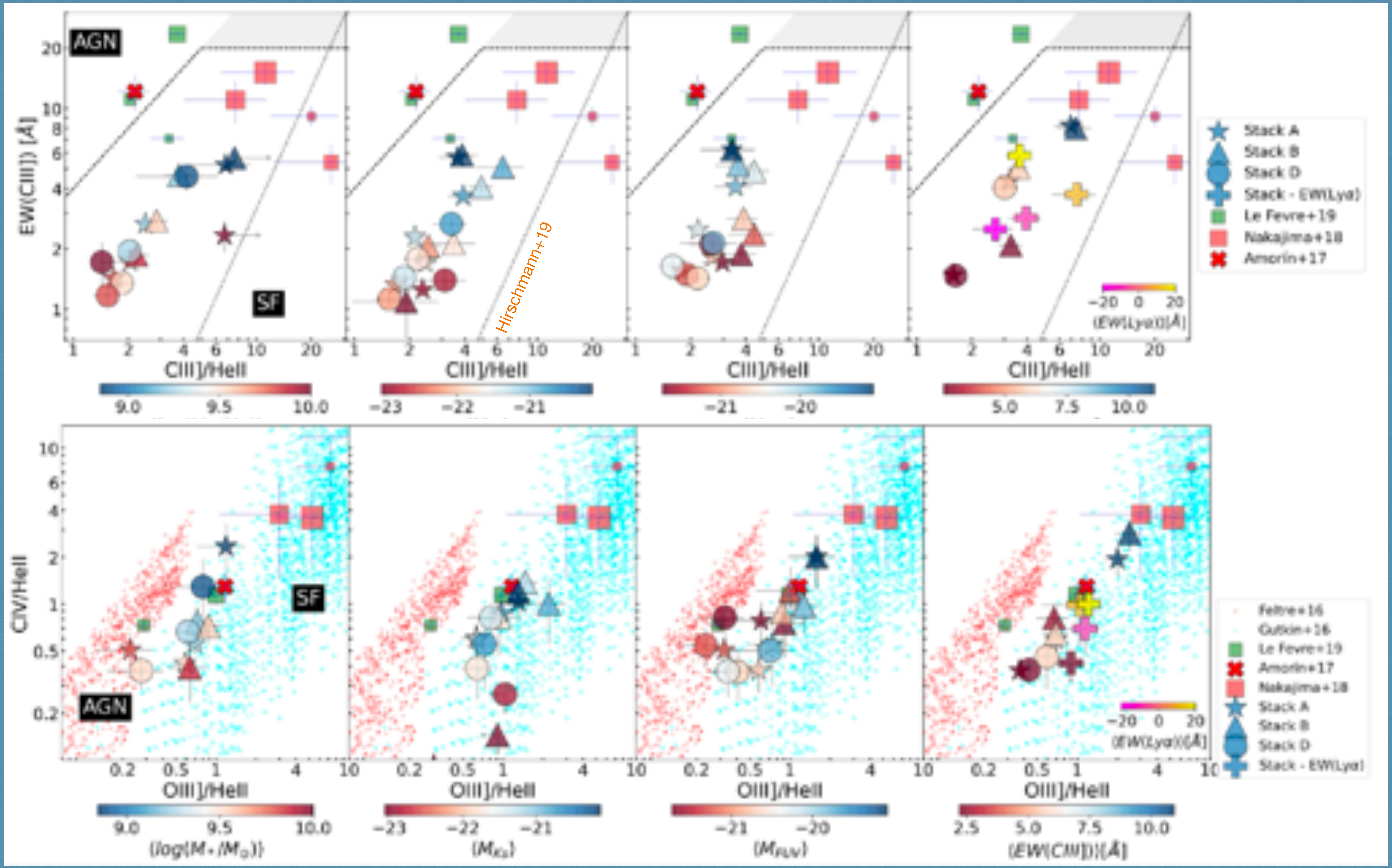
UV line diagnostic diagrams (Nakajima+18)



Constraints on the models

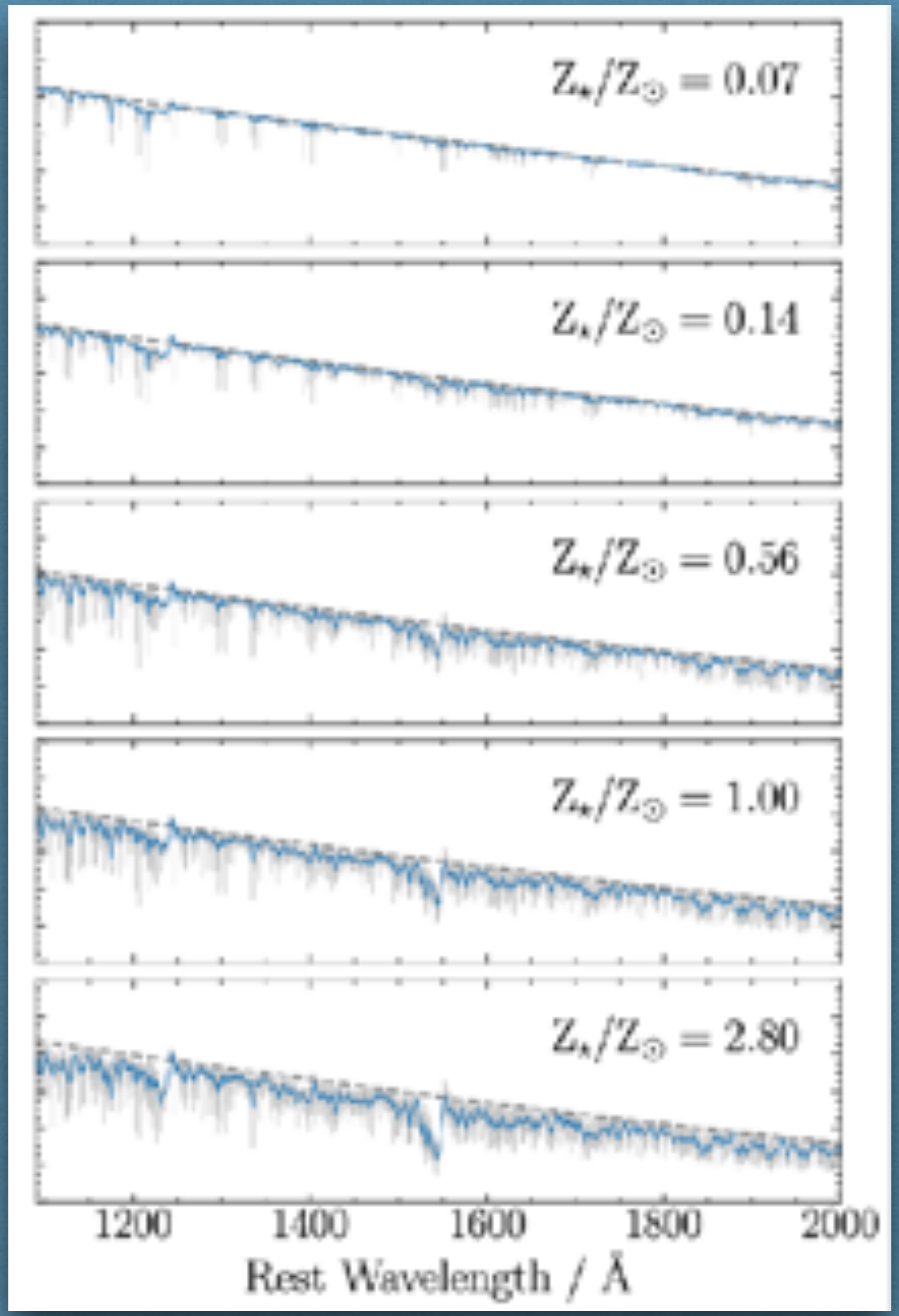
Source of ionization

UV line diagnostic diagrams (Nakajima+18)



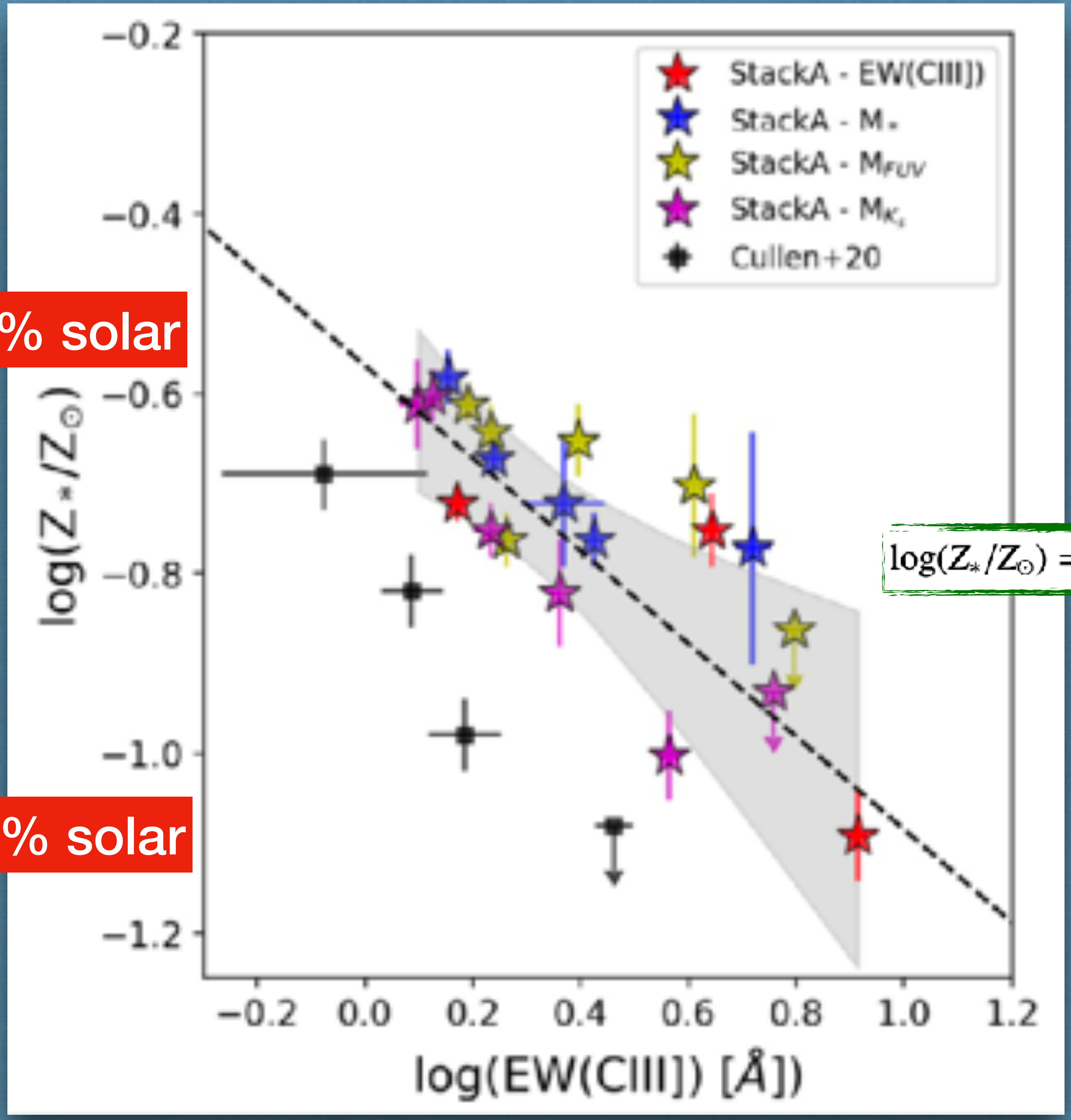
Stellar metallicity [Fe/H]

We derived stellar metallicities for all the stacks following the full spectral fitting method on Cullen+19, that is based on faint photospheric absorption features



Cullen+19

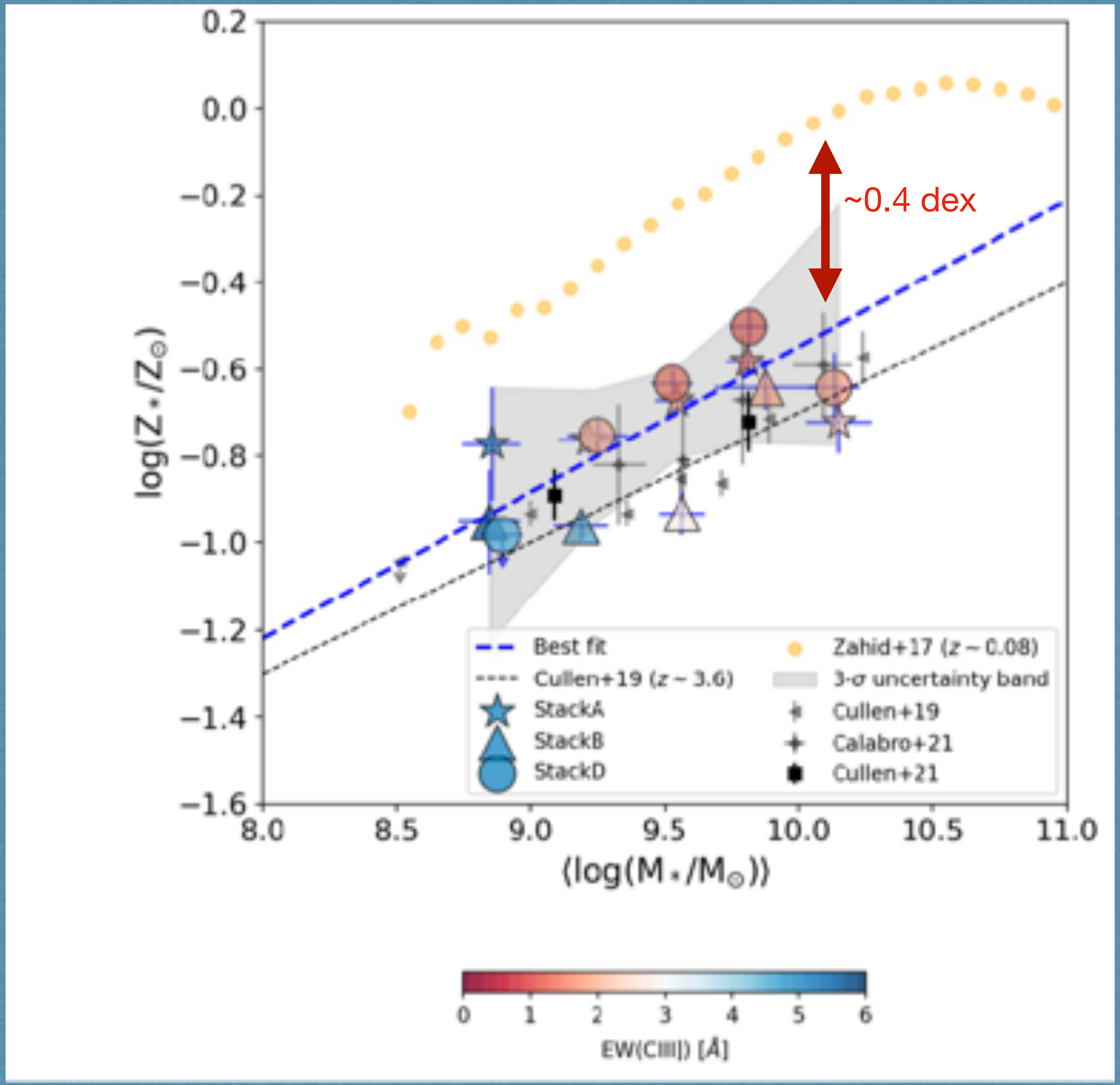
High S/N, typically >15-20



$$\log(Z_*/Z_\odot) = (-0.51\pm0.08)\times\log(EW(CIII])) - (0.57\pm0.03),$$

Strong CIII] emitters have low stellar metallicities, which lead to less cooling and higher nebular temperatures that enhance the CIII] emission.

Stellar Mass-Metallicity relation



$$\log(Z_*/Z_\odot) = (0.33 \pm 0.10) \times [\log(M_*/M_\odot) - 10] - (0.54 \pm 0.05),$$

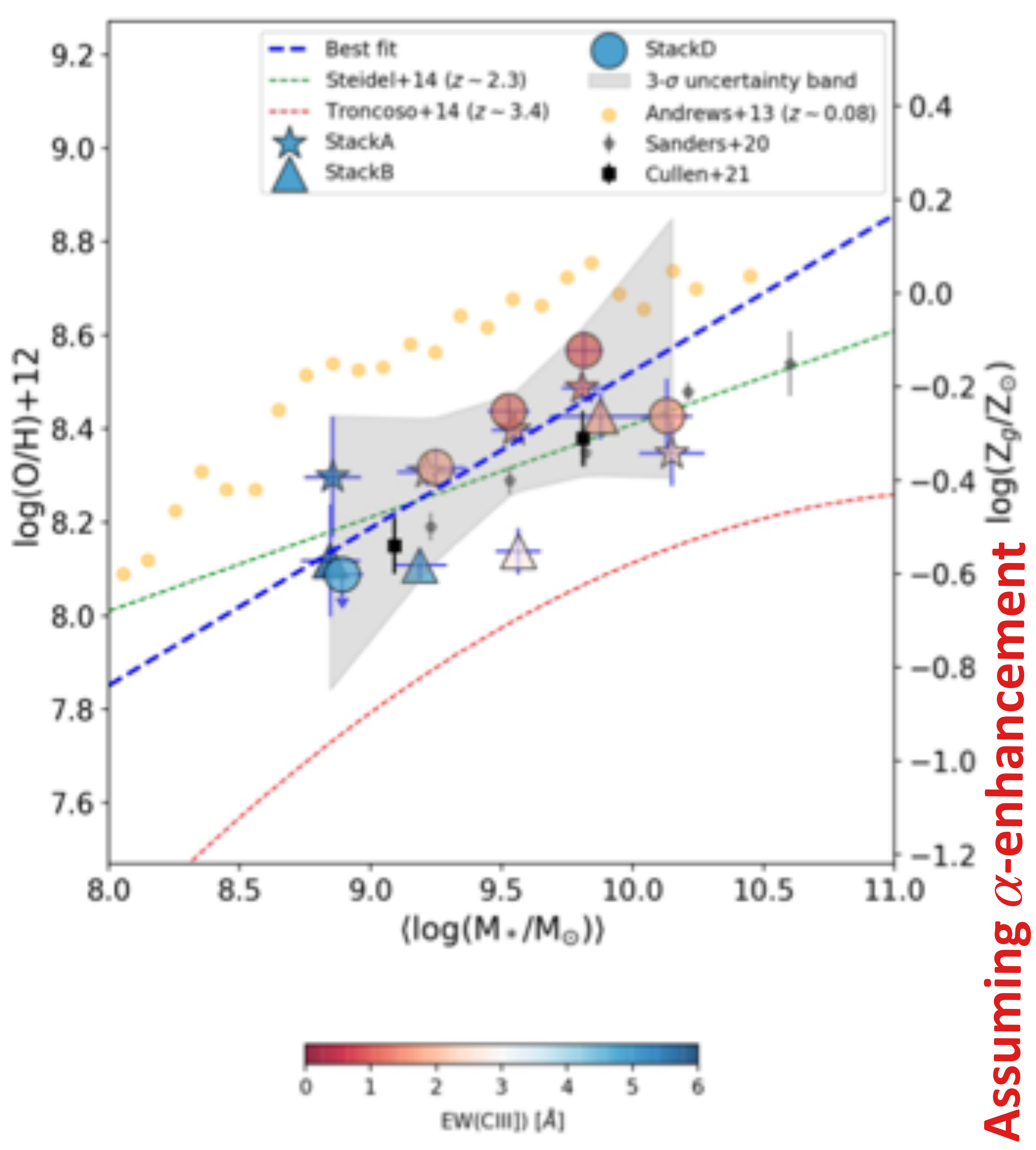
Scaling relations are important diagnostics to understand the evolution of galaxies.

The MZR is shaped by different physical processes such as strong outflows produced by stellar feedback, infall of metal-poor gas

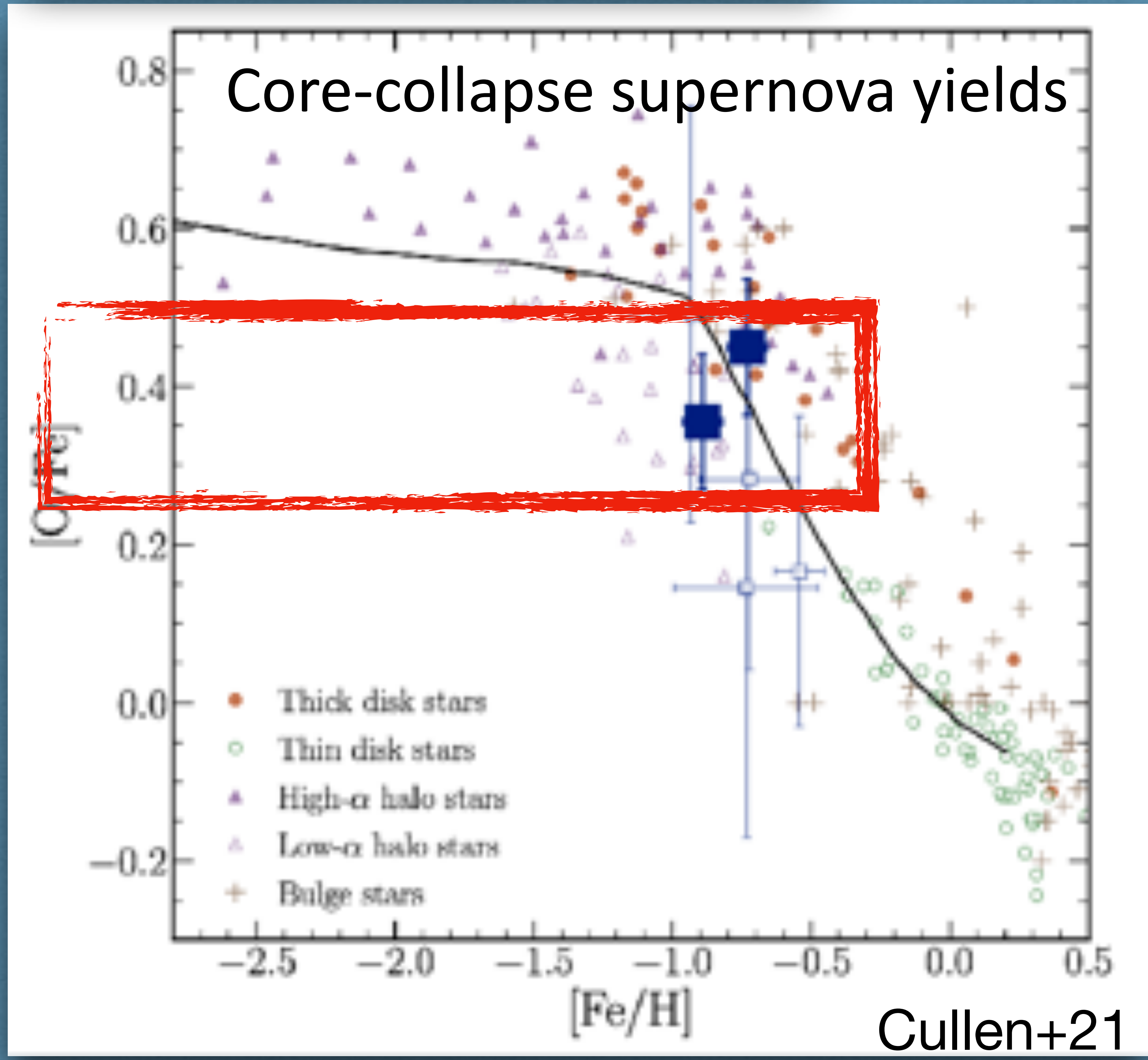
Consistent with strong redshift evolution up to z~3

Stellar Mass-Metallicity relation

Gas-Phase



$$[O/Fe] = [O/H] - [Fe/H].$$



- Young stellar populations
- Hard stellar ionizing spectrum

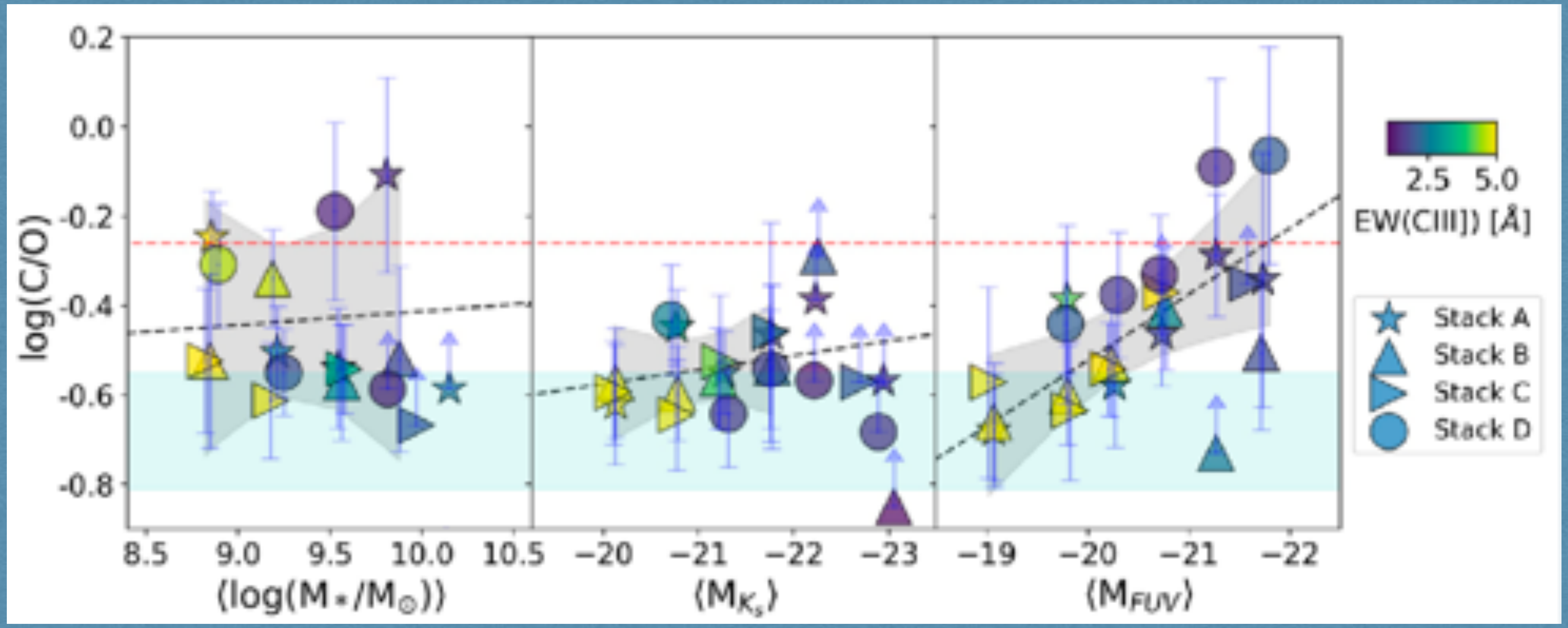
Follow-up: gas-phase metallicity VANDELS + NIR

CIII] emitters follow a stellar mass-metallicity relation consistent with previous results (both stellar and gas-phase)

Carbon-to-oxygen

HII-CHI-mistry-UV (Perez-Montero+17)

C/O ratio is calculated using CIII]1909 and OIII]1666 + CIV1550 for correction by ionization parameter. The method is based on the comparison of the nebular emission-line ratios with those predicted by a large grid of photoionization models.



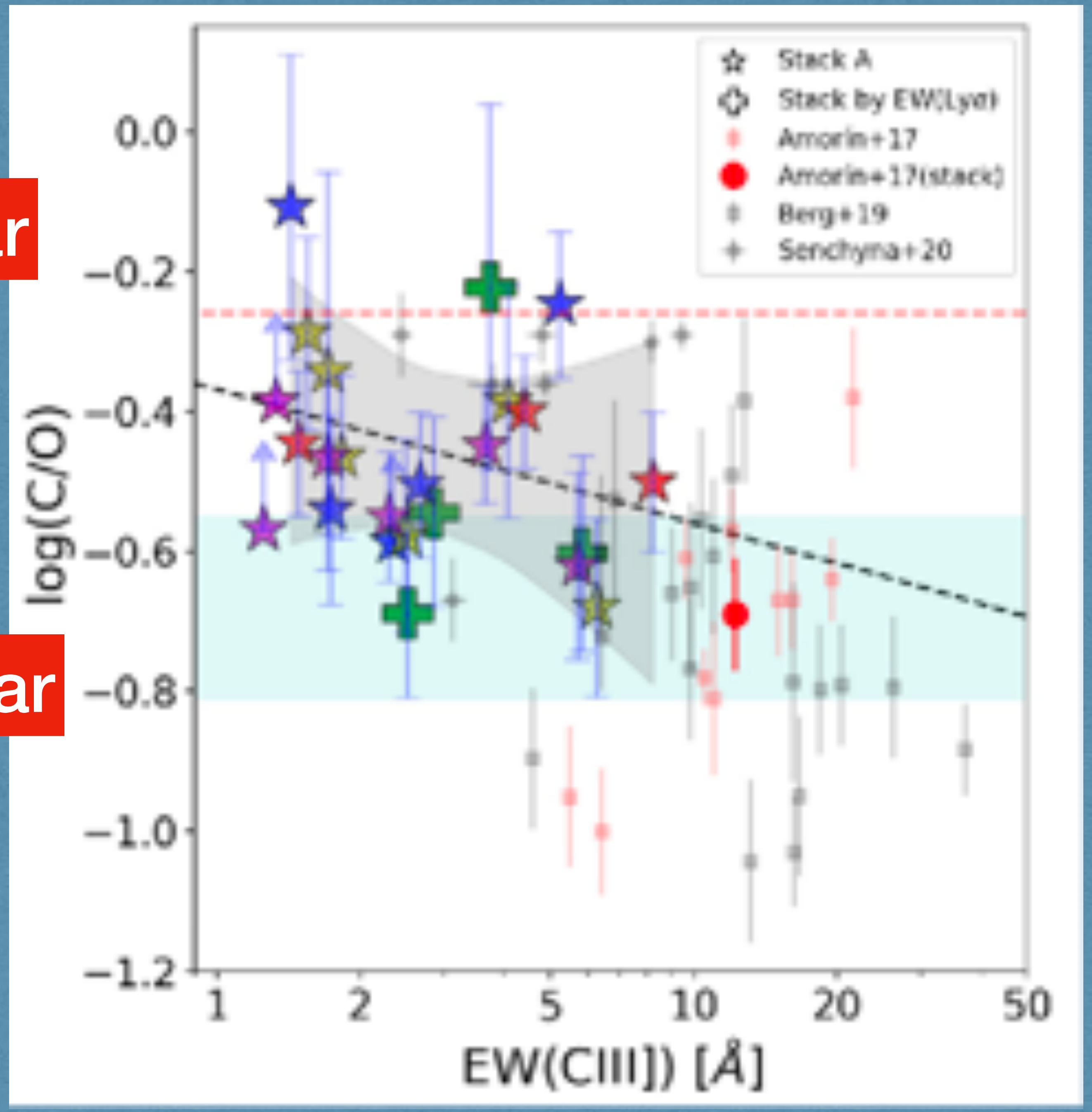
We find an increase of C/O with FUV luminosity

Same trend with SFR

We find a decrease of C/O with EW

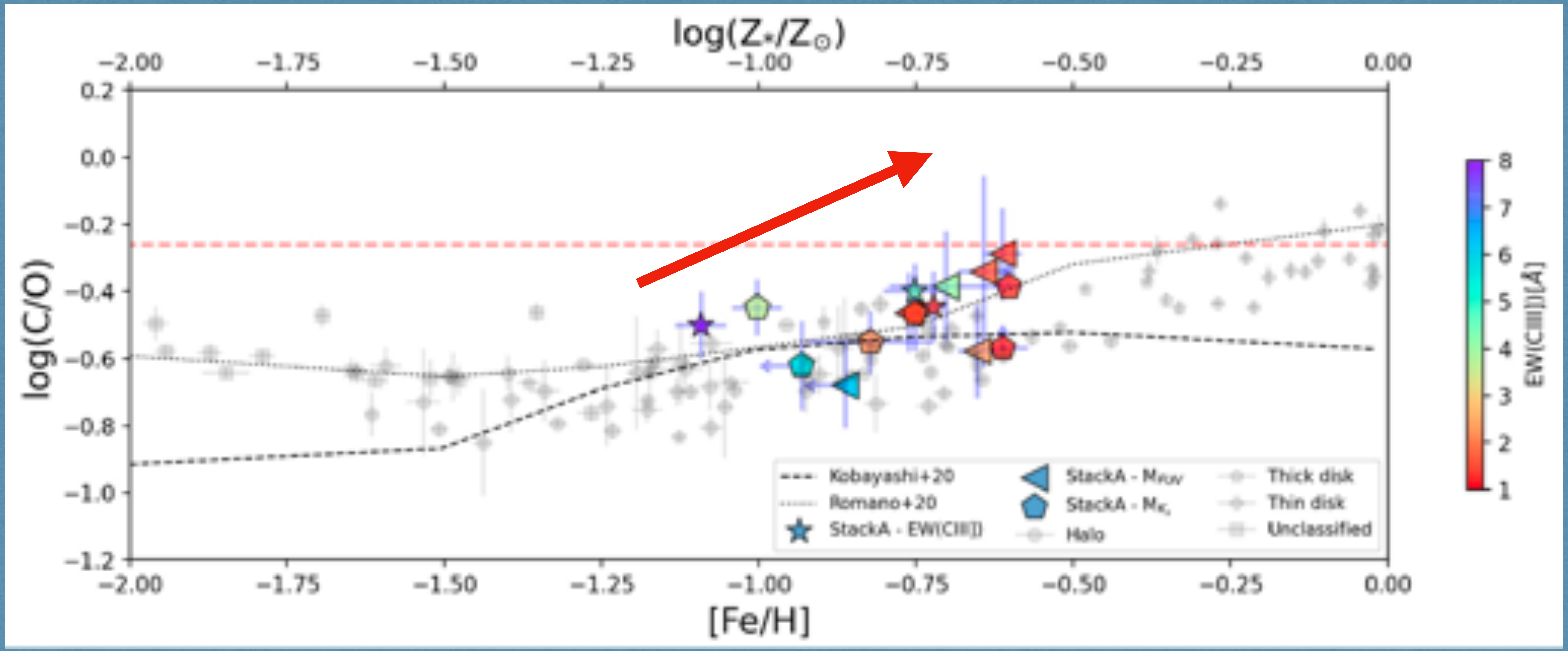
150% solar

38% solar



Insights on chemical enrichment

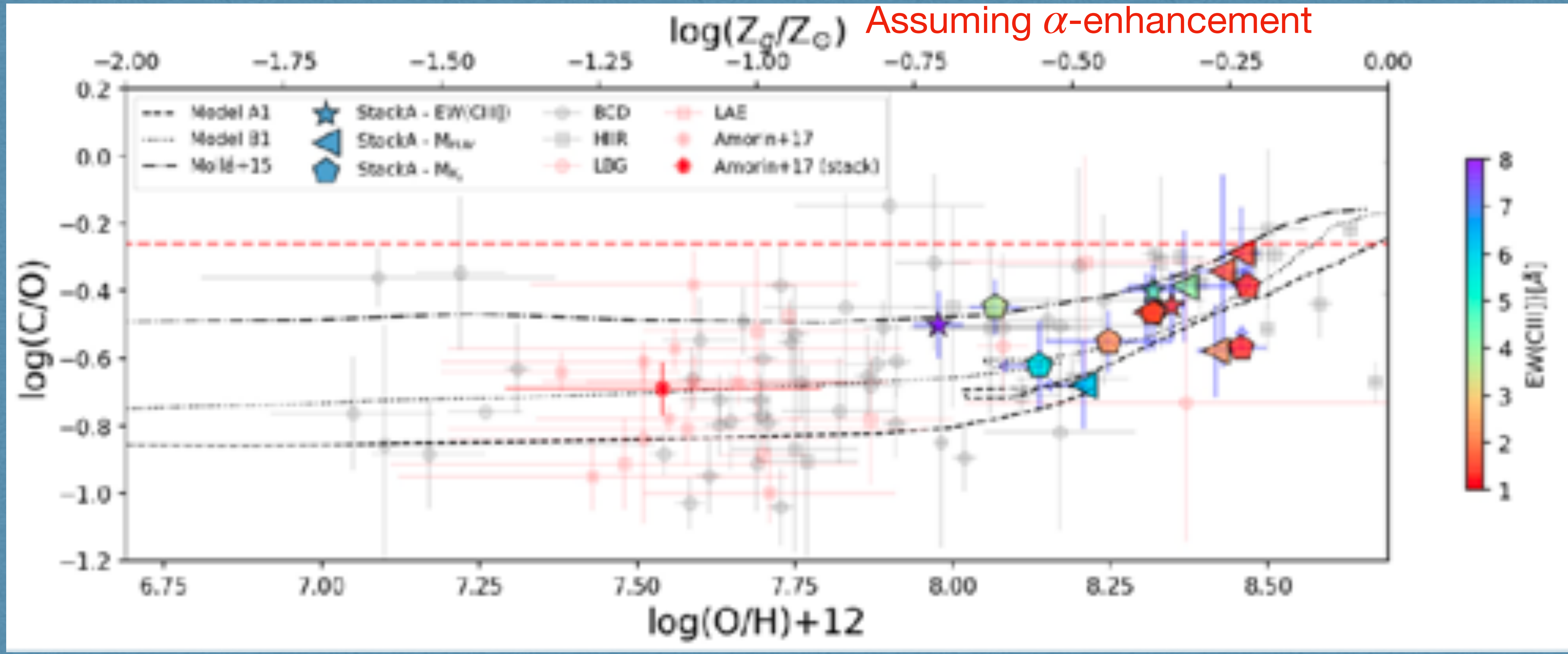
C/O-metallicity relation



More metal-poor have younger stellar populations

Consistent with thick disk stars

This suggests that these local 10 – 12 Gyr old stellar populations likely formed from similar material (in terms of enrichment properties) to the massive O/B-type stellar populations we observe in the rest-frame FUV spectra of galaxies



Conclusions

- CIII] emitters in VANDELS are MS star-forming galaxies powered by stellar photoionization.
- EW(Lya) and EW(CIII]) appear correlated. Large scatter at lower EWs.
- High EW(CIII]) show lower stellar metallicities. For Z_*<0.1Zsun, EW(CIII])>10A.
- Stellar Mass-Metallicity relation of CIII] emitters at z=3 consistent with strong redshift evolution in agreement with previous results.
- Fainter galaxies have lower C/O, higher EW(CIII]), and lower Z_*, spectra dominated by massive stars (younger, more ionized gas).

On going + future work: NIR follow-up

- NIRVANDELS (Cullen+21)
- CIII] emitters in VUDS: VLT/X-shooter (PI. Amorin, R.)