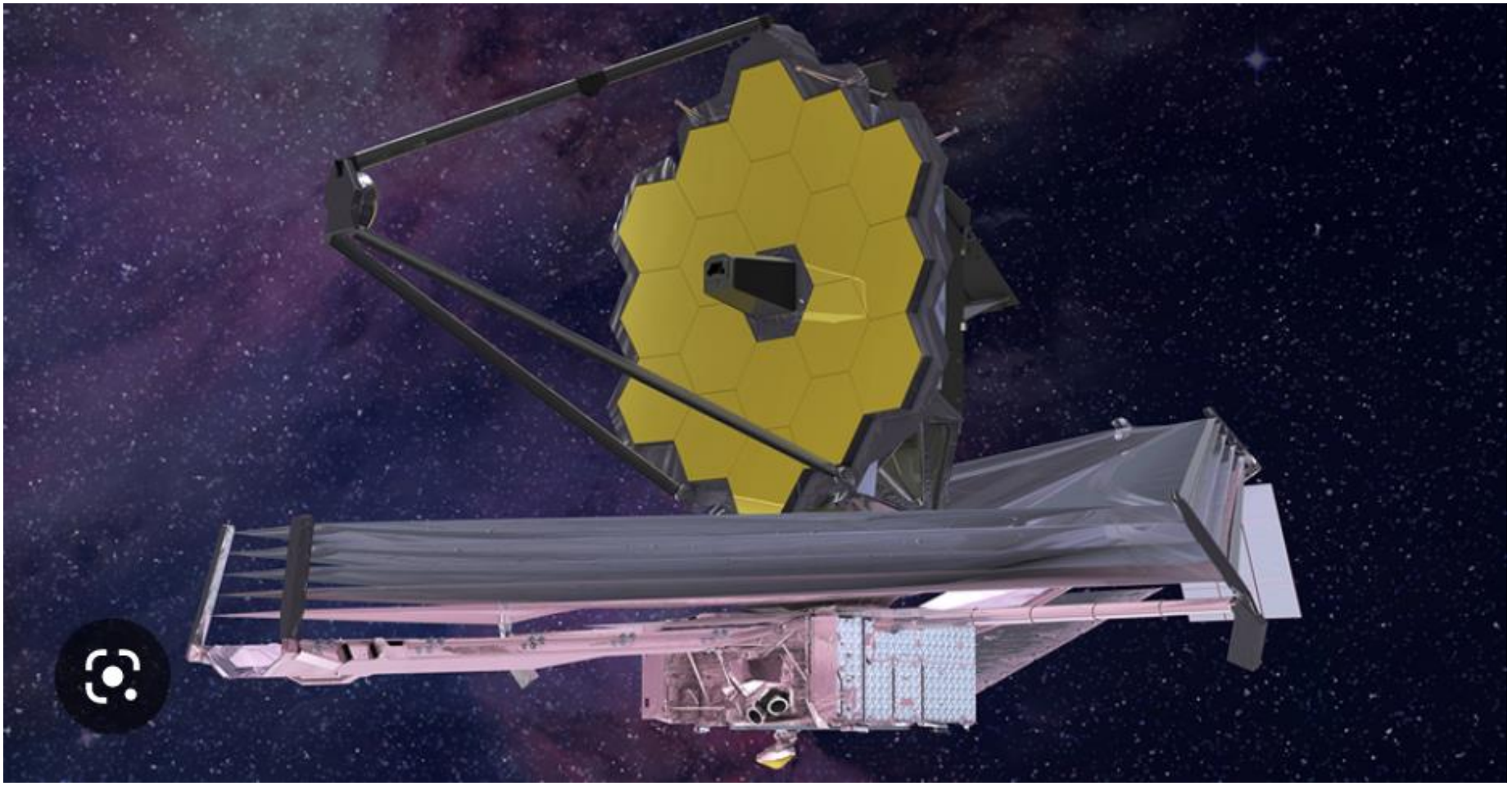
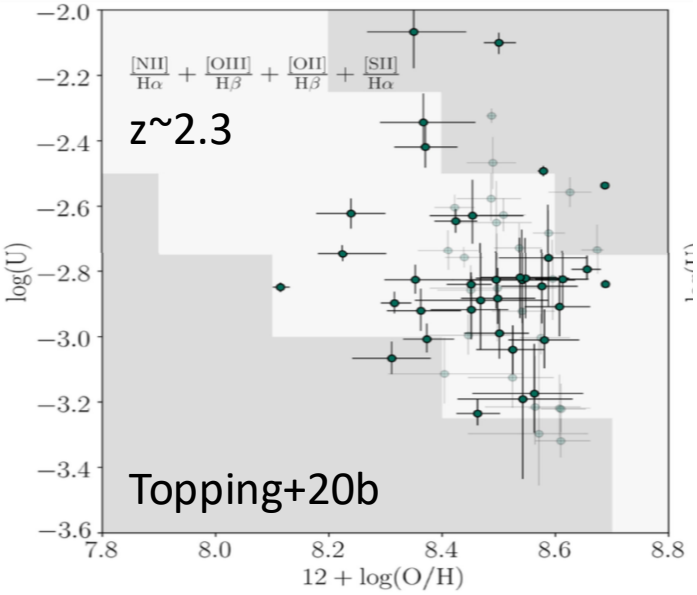
Ionization Parameters / Nebular Attenuation Curves and Dust Covering Fractions with JWST

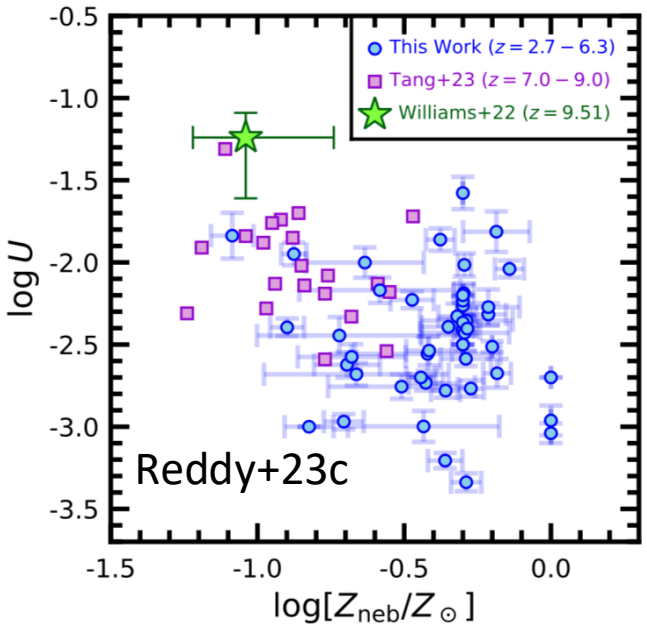
Sintra: At Edge of the Universe

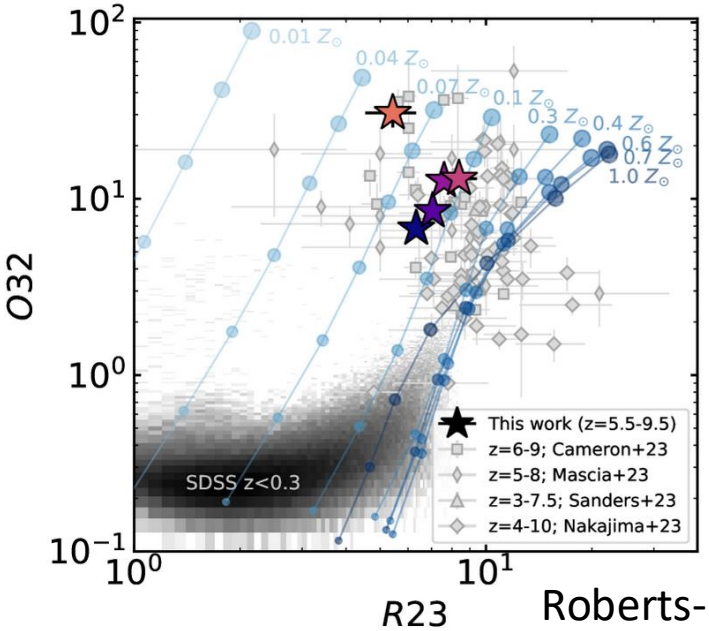
Naveen Reddy (University of California, Riverside)
Alice Shapley, Ryan Sanders, Michael Topping, and the AURORA team



Inferences of Ionization Parameters at High z





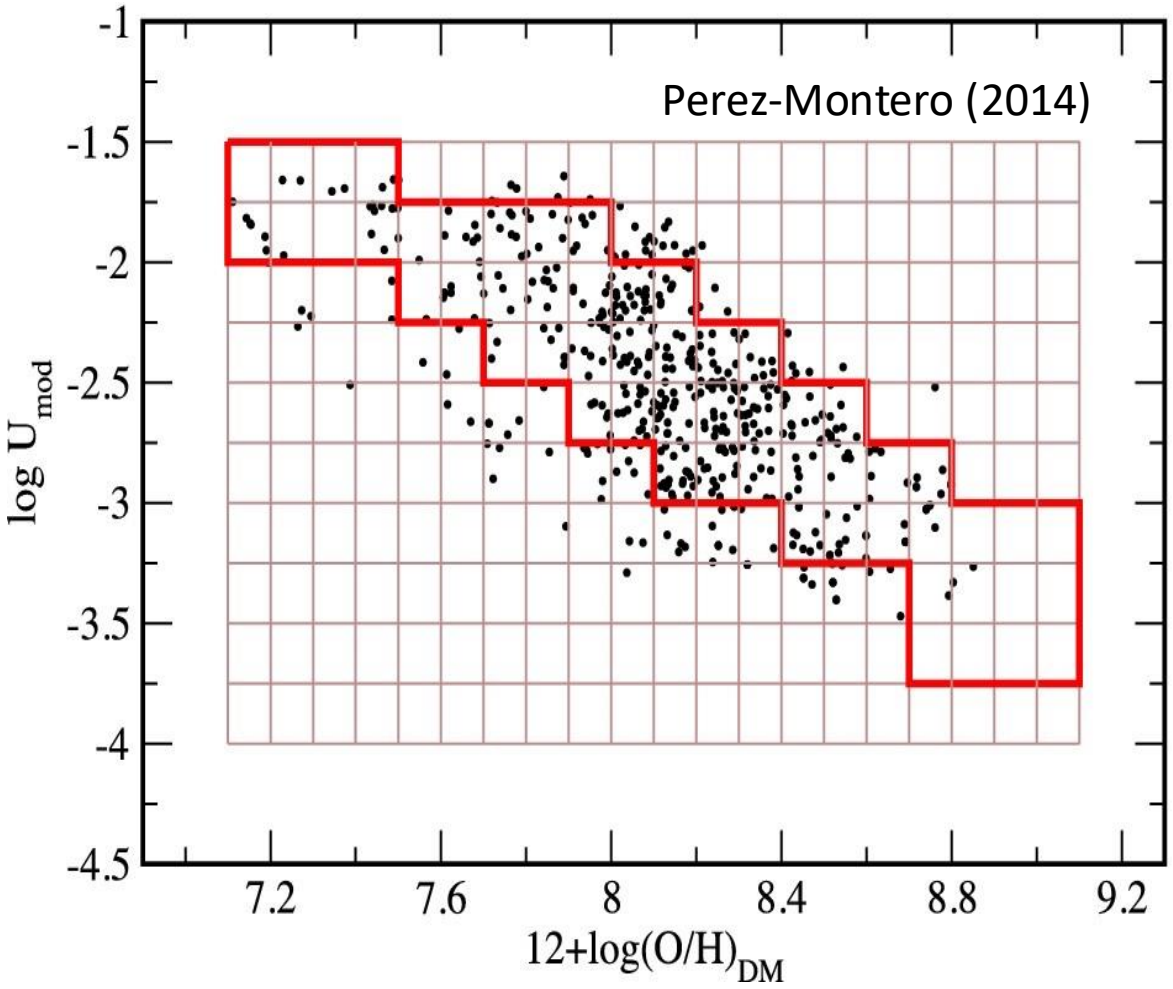


Roberts-Borsani+24

see also:
Brinchmann+08, Liu+08, Shimakawa+15, Masters+16, Bian+16, Kaasinen+17, Kashino & Inoue (2019), Papovich+22

What drives the high ionization parameters at high redshift?

What drives the elevated *U* in high-redshift galaxies?



Metallicity?

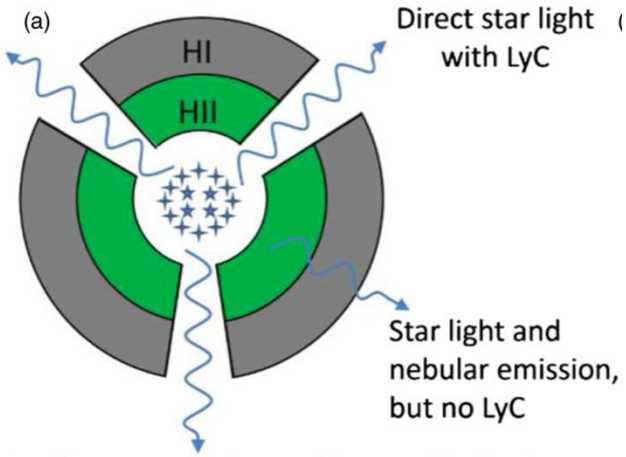
Challenges with the low-z interpretation:

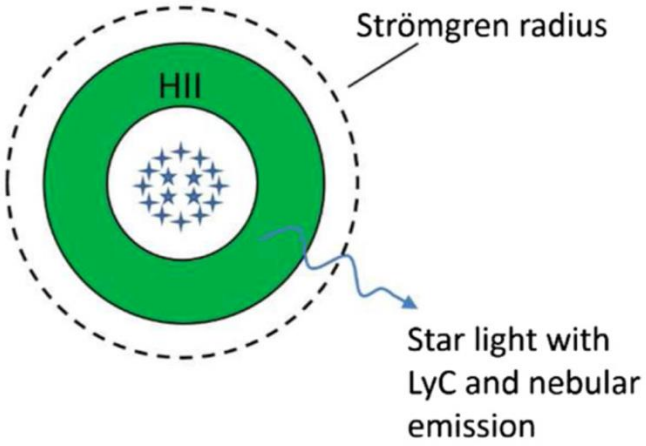
1) alpha-enhancement (Steidel+16, Cullen+19, Topping+20, Reddy+22)

1) uniformly low stellar metallicities

Gas density is an important factor

Factors that affect *U*





$$\log U = \frac{Q(\mathrm{H})}{4\pi R_{\mathrm{s}}^2 n(\mathrm{H}) c}$$

$$R_{\mathrm{S}}^3 = \frac{3Q}{4\pi \langle n_{\mathrm{H}} \rangle^2 \alpha_B}$$

$$\epsilon = \left[\frac{\langle n_{\mathrm{H}} \rangle}{n_{\mathrm{H}}} \right]^2$$

$$U \propto Q^{1/3} n_e^{1/3} \epsilon^{2/3}$$

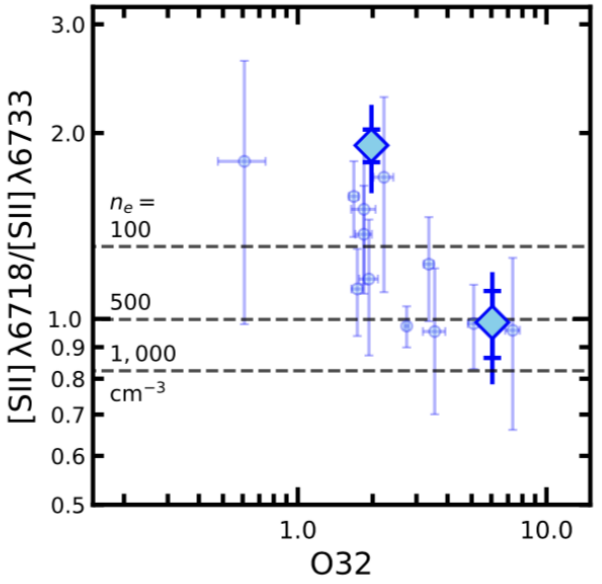
$$\log U = \frac{Q(\mathrm{H})}{4\pi R_{\mathrm{cl}}^2 n(\mathrm{H}) c}$$

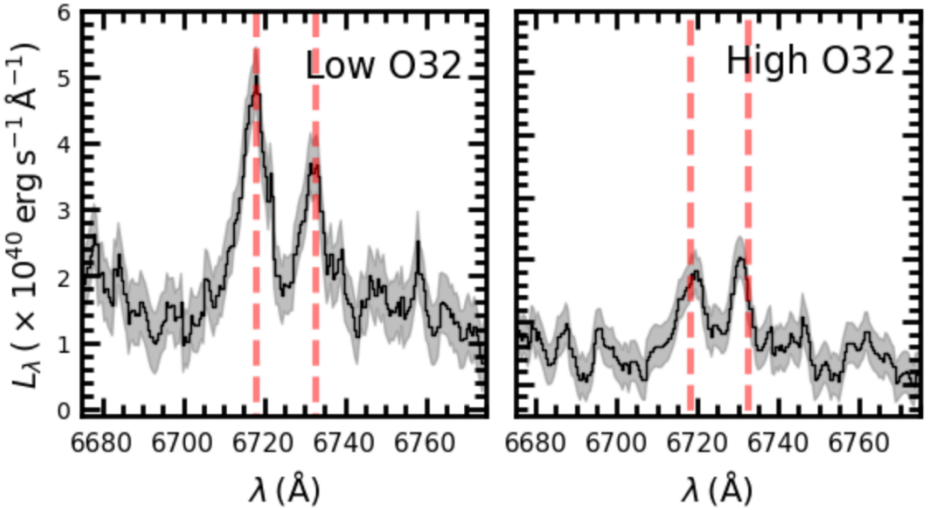
Depends on both the ionizing source *and* how the gas is distributed

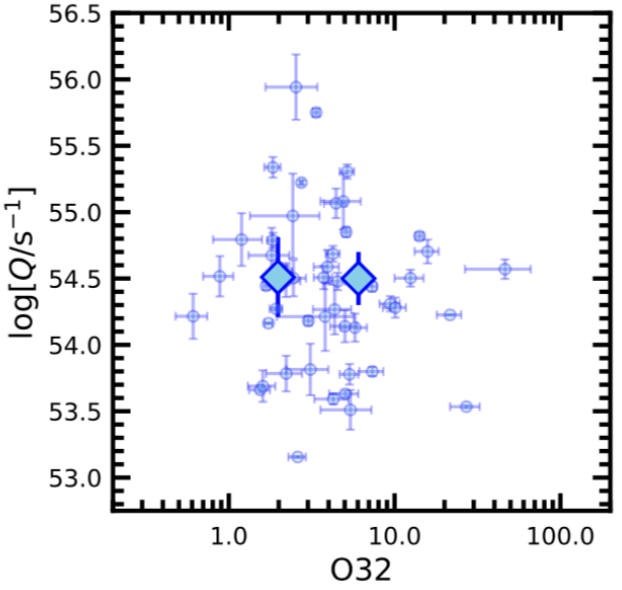
Can use O32 and/or Ne3O2 as a proxy for *U*

Sample of z=2.7-6.3 Galaxies from CEERS:

Electron Density (from [SII]) and Ionizing Photon Rate





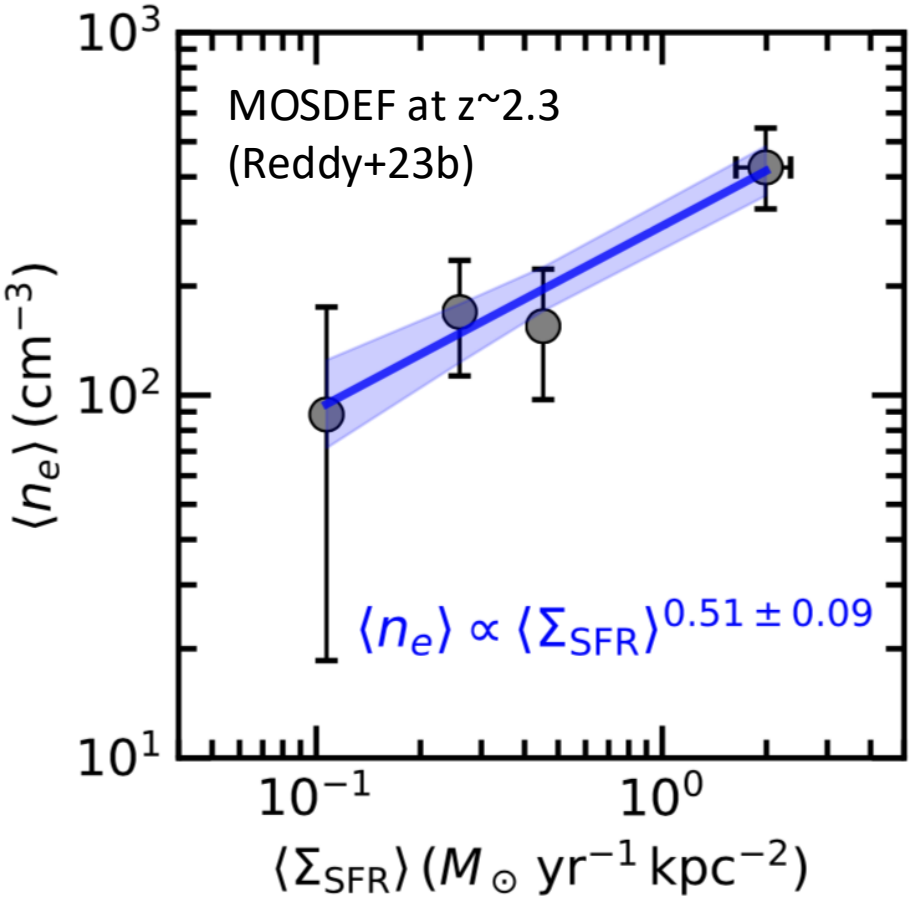


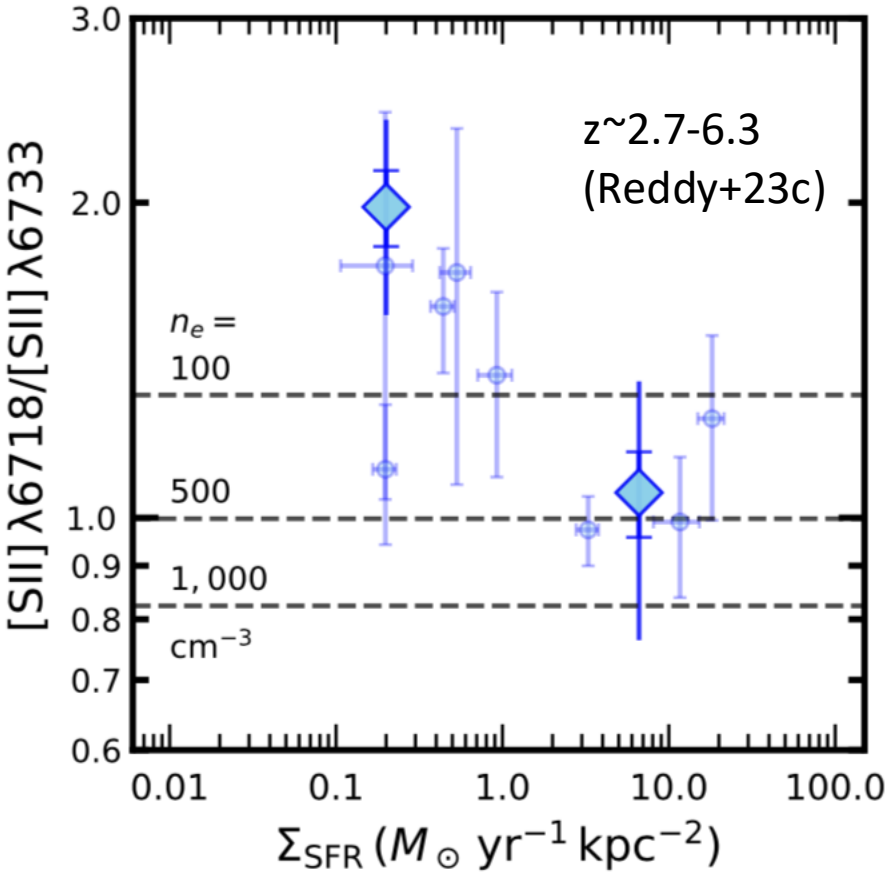
Evidence of high n_e in galaxies with high O32

No apparent change in <Q>

Reddy+23c

What about Star-Formation-Rate Surface Density?

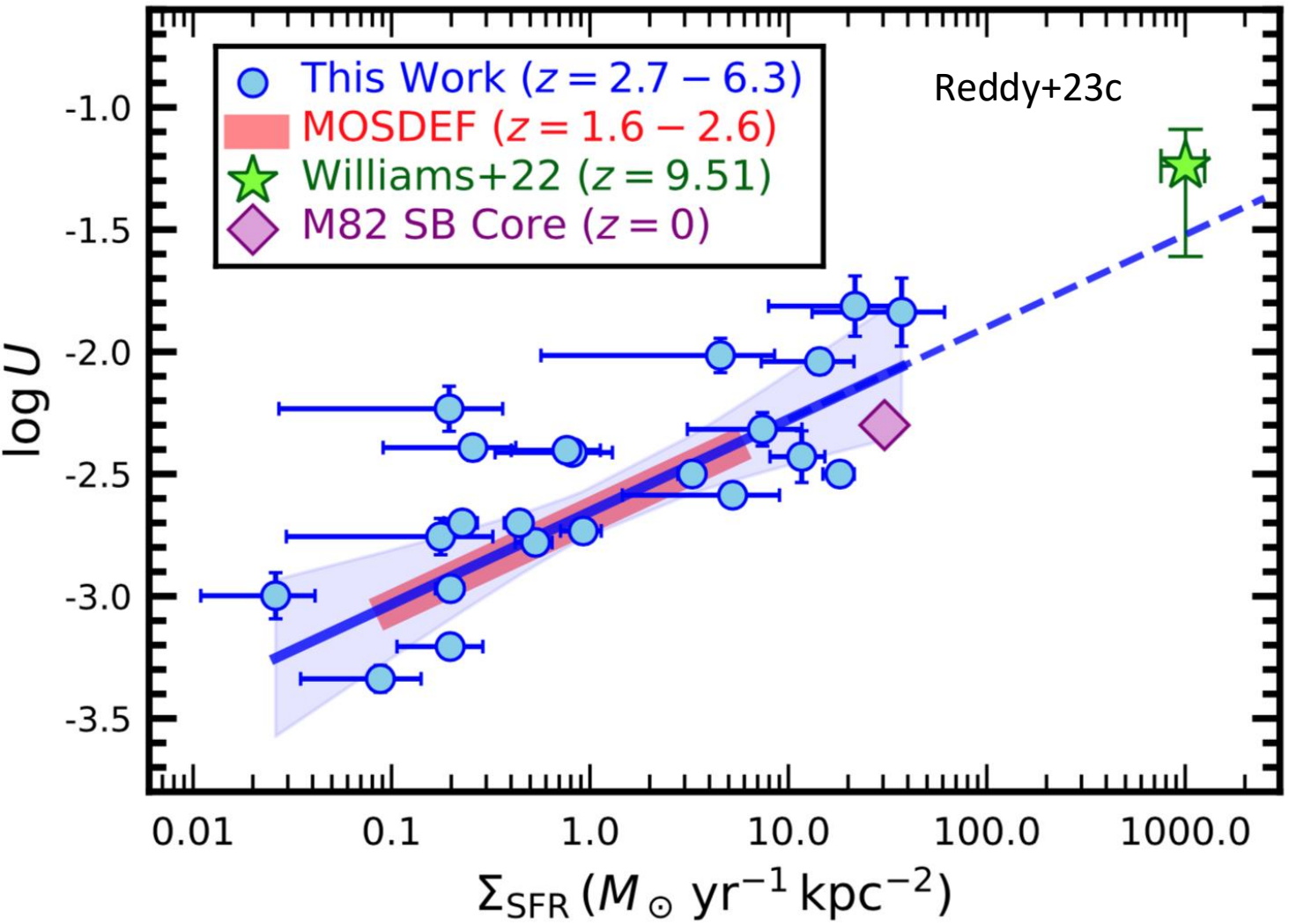




Significant correlation between electron density and SFR surface density

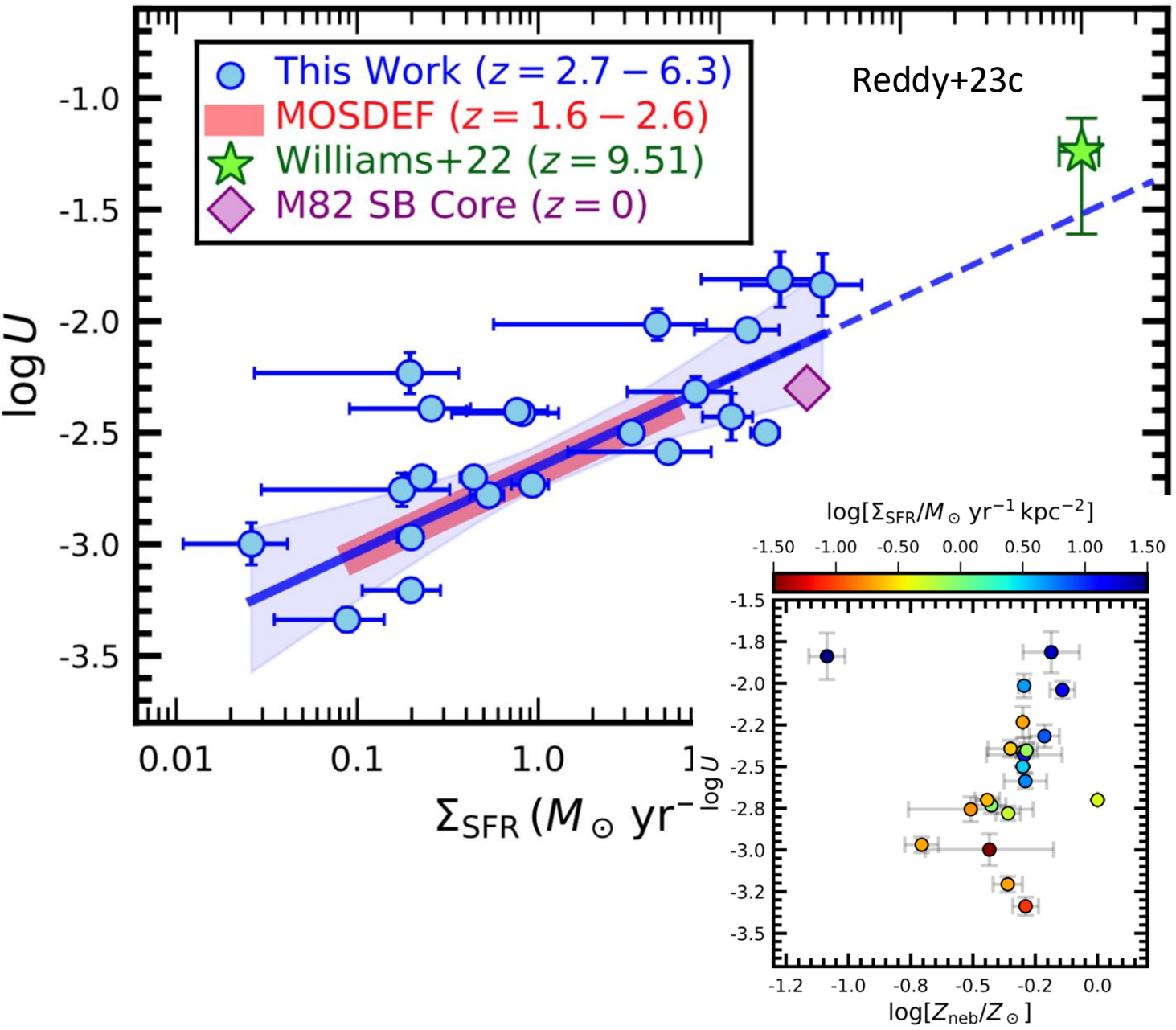
see also Shimakawa+15, Jiang+19

U vs. SFR Surface Density



Brinchmann+08,
Shirazi+14,
Bian+16,
Papovich+22,
Reddy+23b

U vs. SFR Surface Density



Brinchmann+08,
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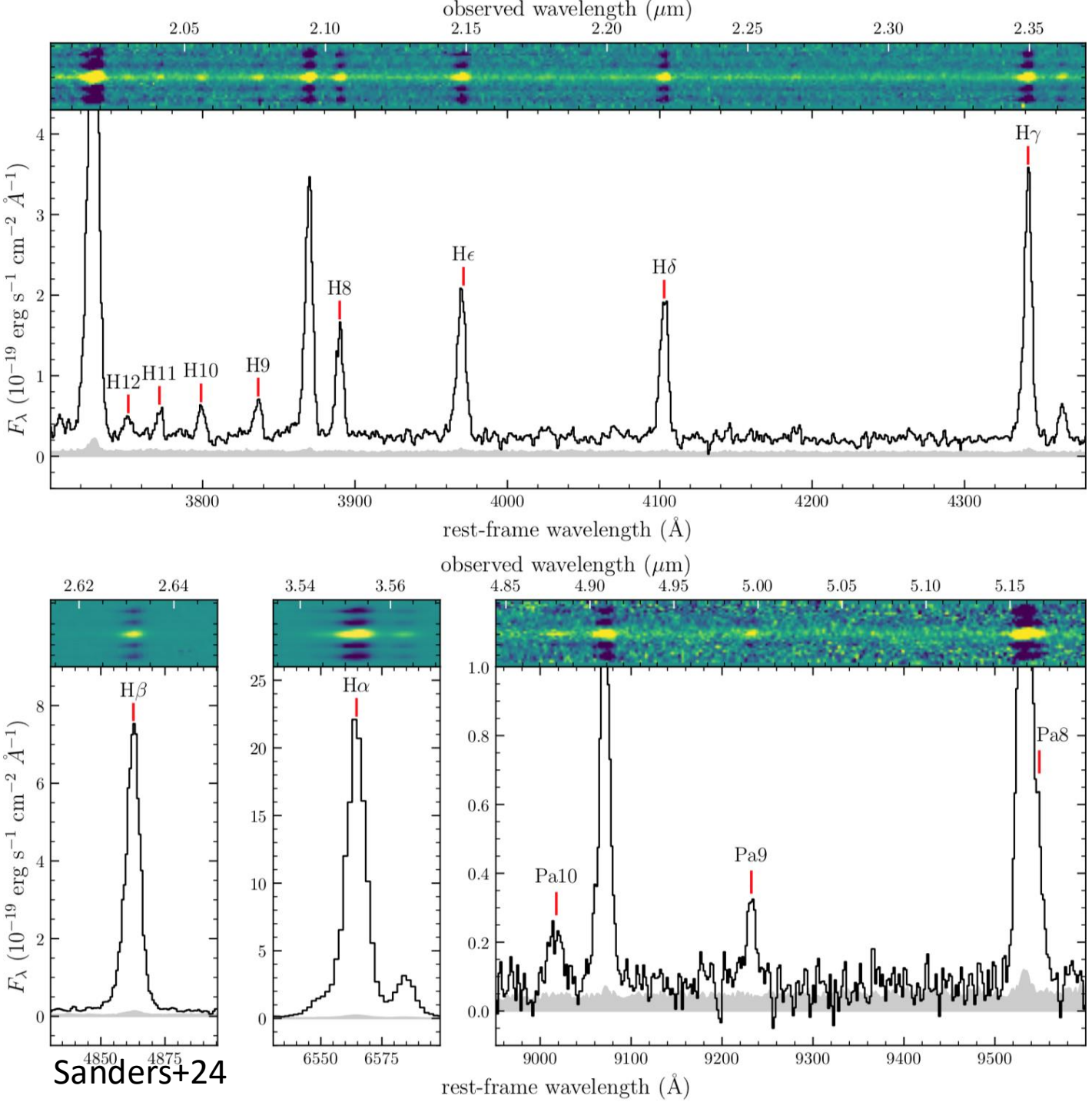
Reddy+23b

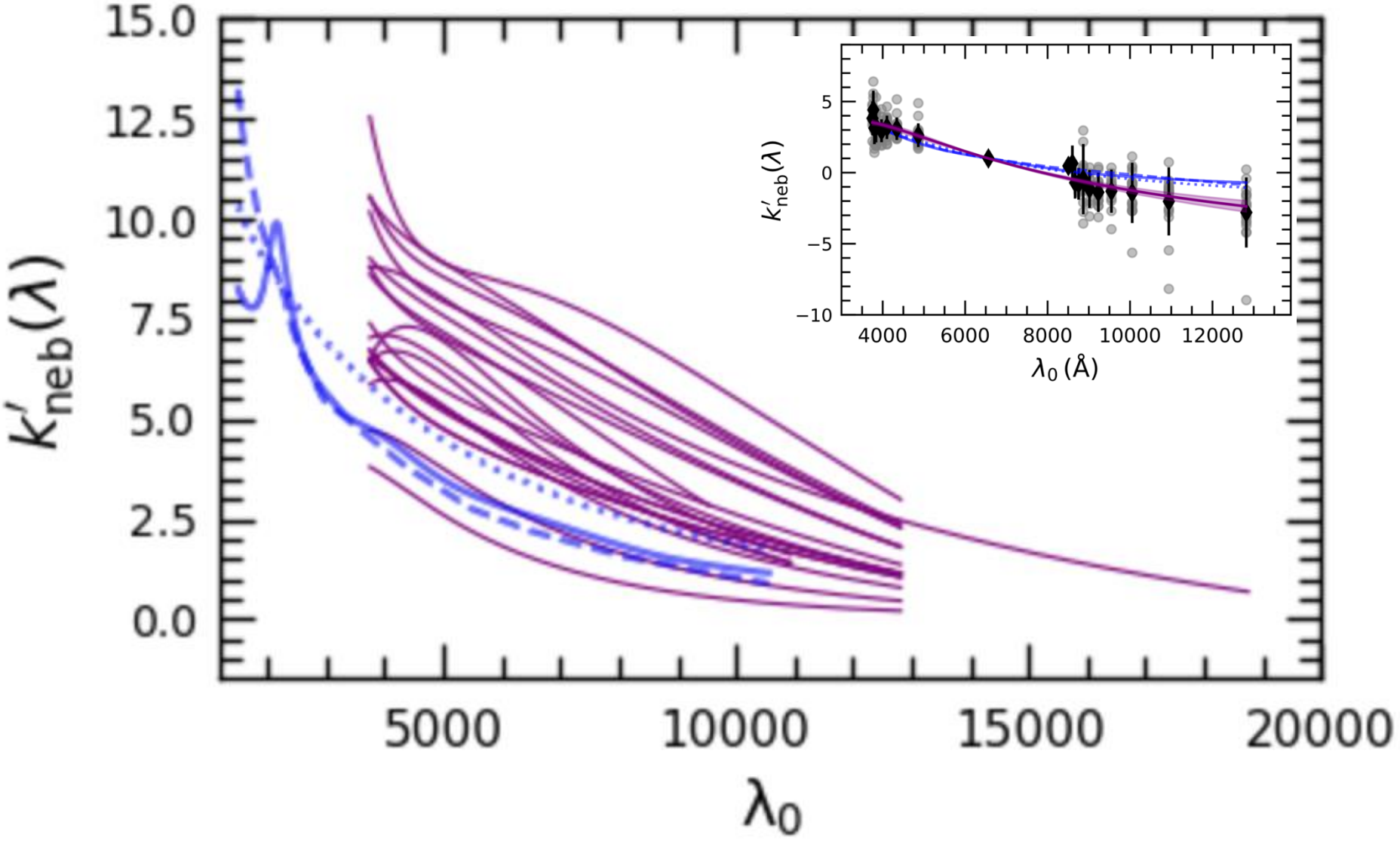
Scatter driven by Σ_{SFR}

High S/N detections of multiple Balmer and Paschen lines from the JWST/NIRSpec AURORA survey.

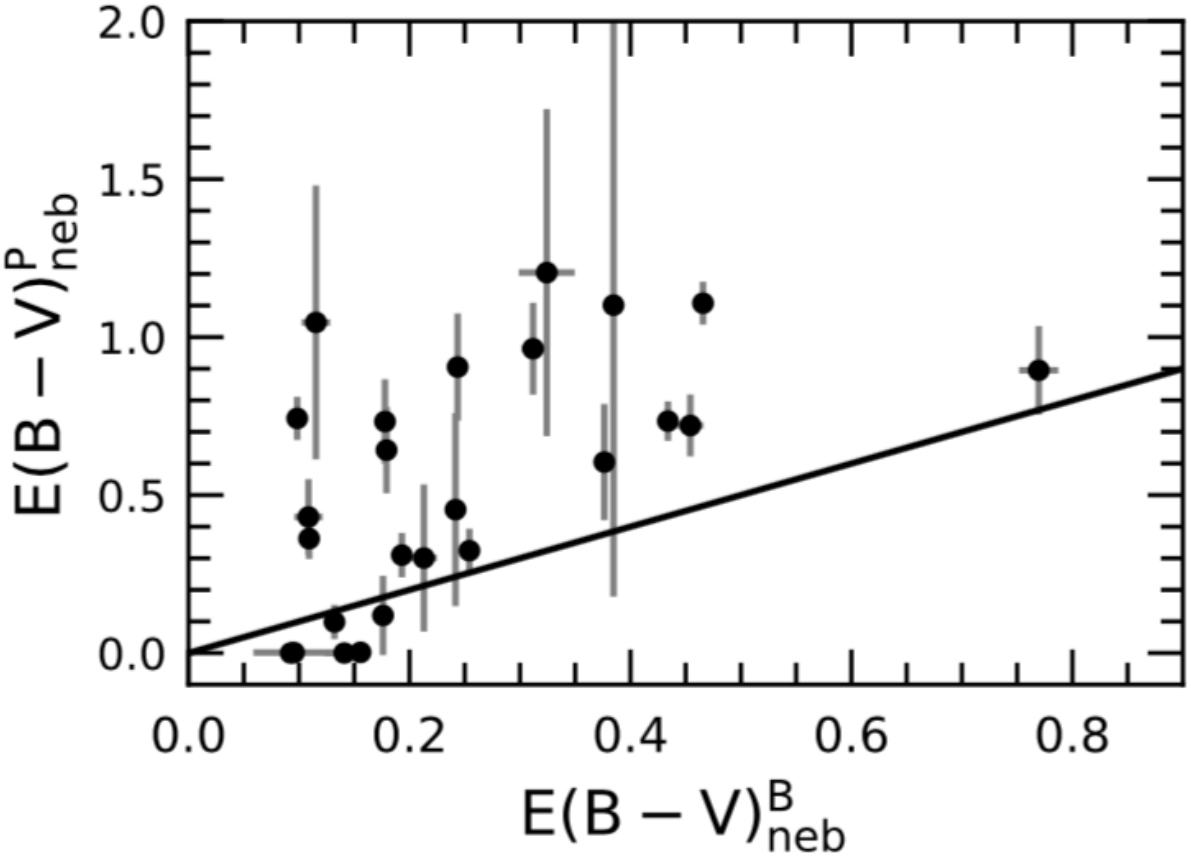


Sanders+24

Effective Nebular Attenuation Curves

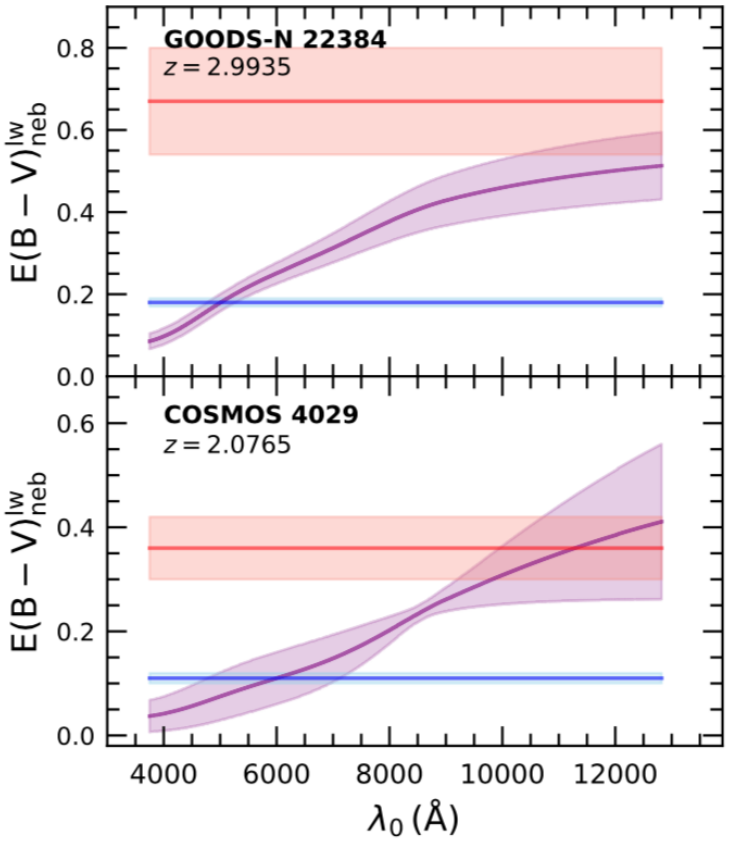


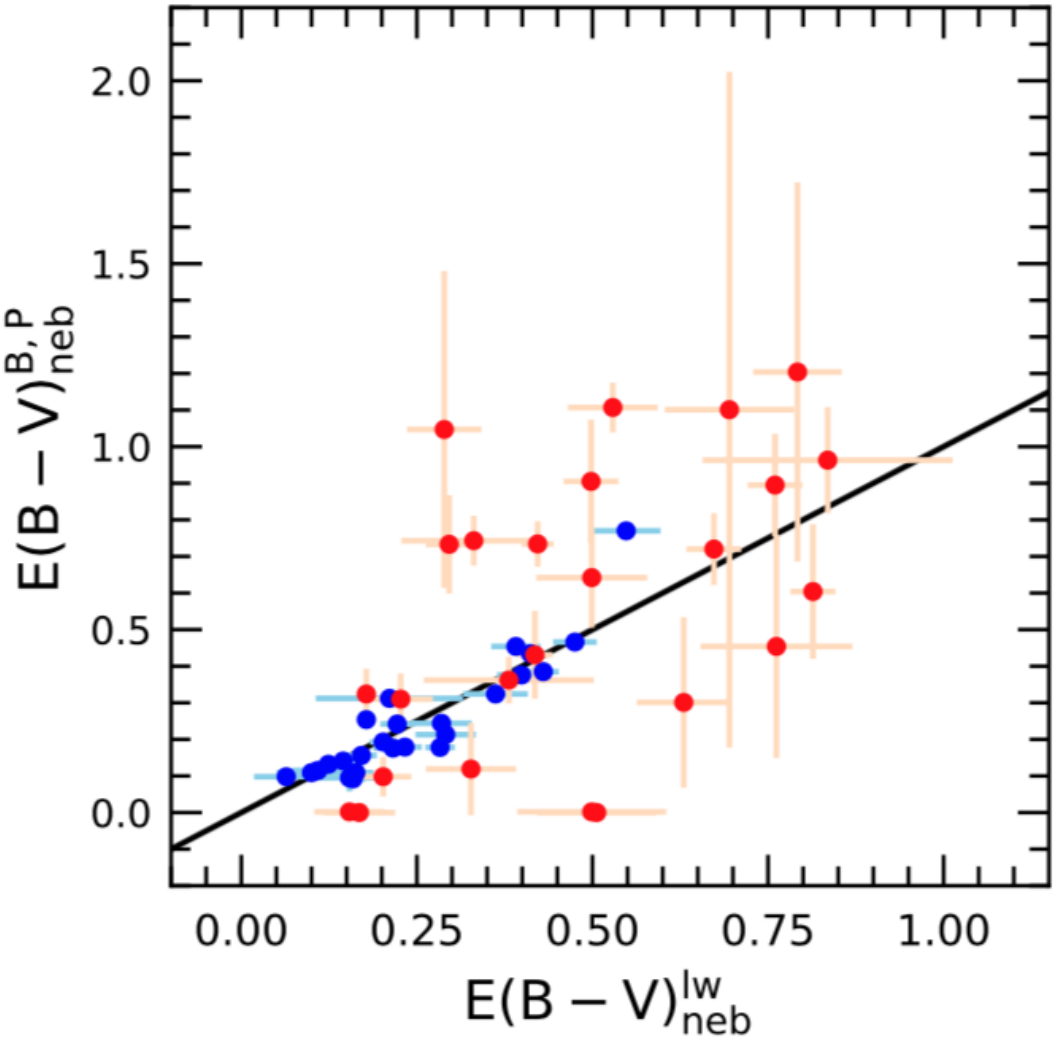
Apparent Discrepancies between Balmer and Paschen-inferred Reddening



Differences in optical depth can account for differences in Balmer and Paschen reddening

Light-weighted Nebular Reddening with Subunity Dust Covering Fraction





Take-away points:

- Gas density important for interpreting the ionized state of the ISM at high redshift: scatter in U at fixed Z_{gas} correlates with SFR surface density

- Diversity of nebular attenuation curves, can be accounted for by assuming a sub-unity covering fraction of dust