Unraveling Cosmic Metallicity: The FIRSST View on Protoclusters at Cosmic Noon

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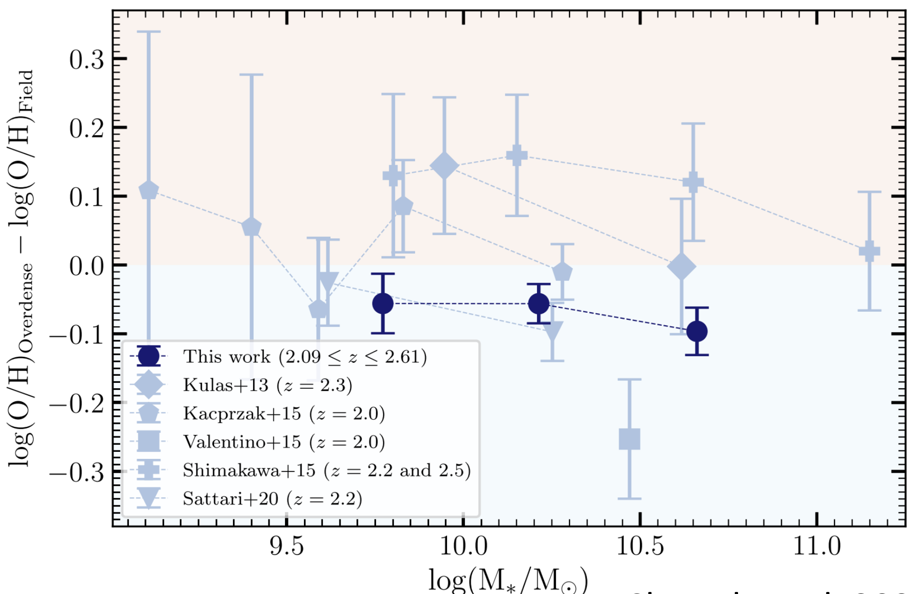
Metallicity
A Key Indicator of Galaxy-Environment Interactions

- Stellar mass – metallicity relation (MZR) is sensitive to:
  - Star-formation history
  - Inflows from the cosmic web
  - Stellar and AGN driven outflows
  - Environmental effects (e.g., ram pressure stripping, harassment, starvation)

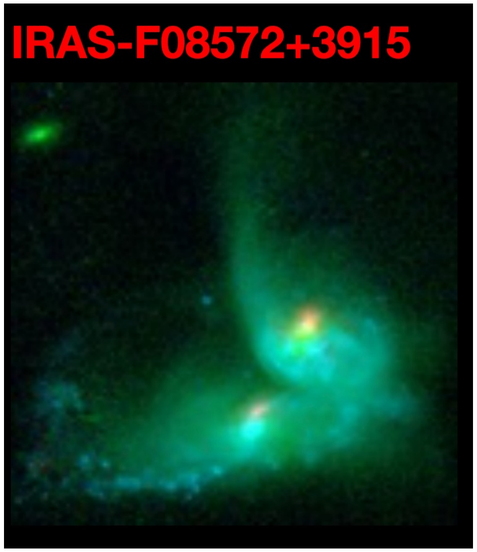
- Conflicting results on the environmental dependence of MZR at cosmic noon
  - Galaxies in overdensities have lower metallicities than "field" counterparts (e.g., Valentino+2015, Chartab+2021, Sattari+2021, Calabrò+2022)
  - Galaxies in overdensities are metal enhanced compared to fields galaxies (Kulas+2013, Shimakawa+15)
  - No significant environmental effect (e.g., Kacprzak+15)



Chartab et al. 2021

Metallicity
A Key Indicator of Galaxy–Environment Interactions

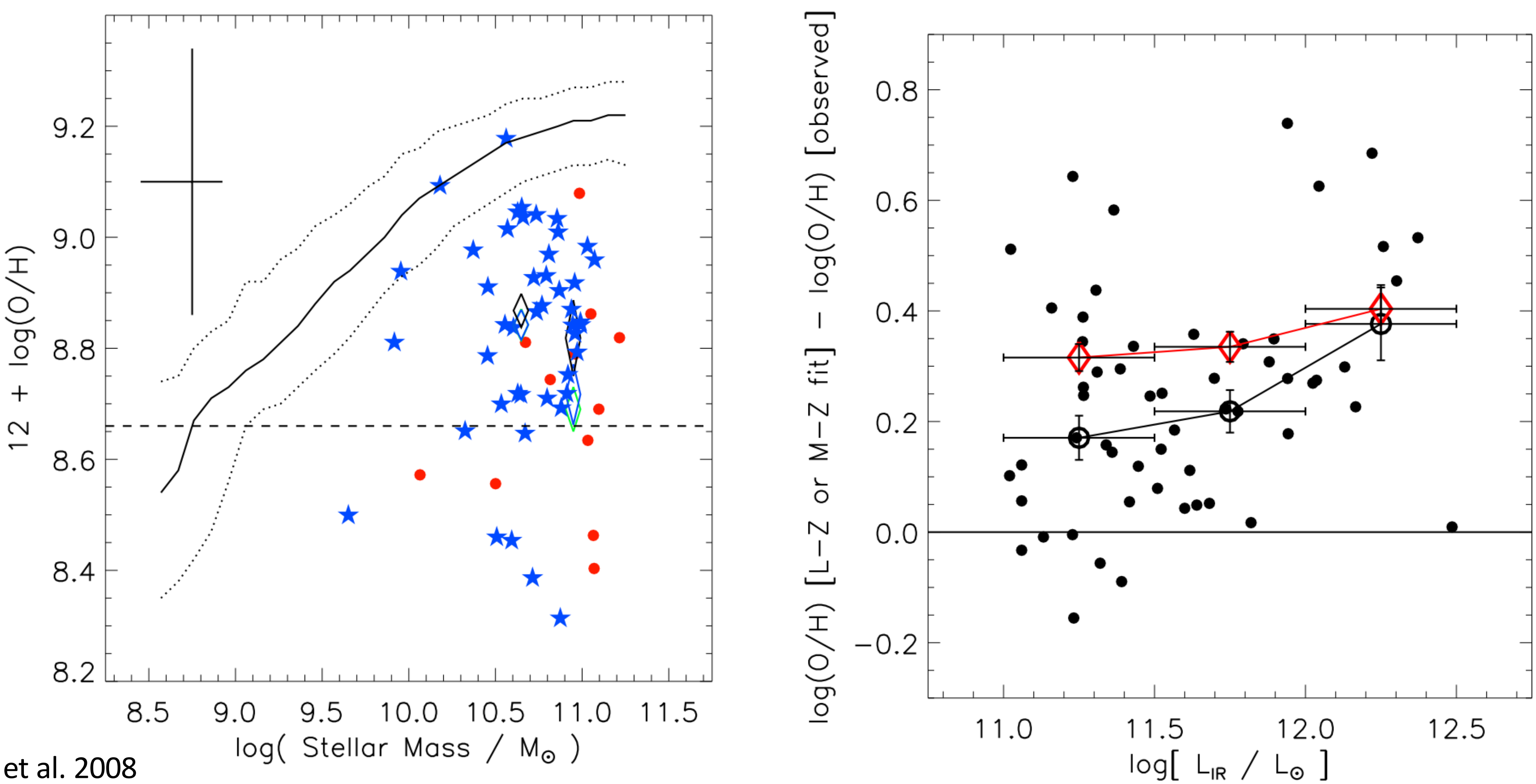
- Reliance on rest-optical emission lines for gas-phase metallicity measurements in studies
- Questioning the robustness of optical metallicities in extreme environments at cosmic noon
- Examining potential biases from dust obscuration using local Ultraluminous Infrared Galaxies (ULIRGs)
- ULIRGs are rare at z<0.3
- Notable rise in ULIRG density at redshifts $z \geq 1$



HST ACS/WFC I-band (814 nm)

Optical metallicity of ULIRGs

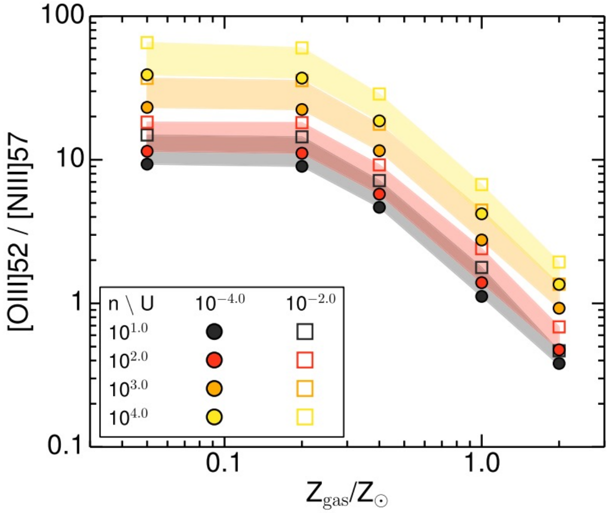
- The gas-phase metal abundances of local ULIRGs, with oxygen abundance used as a proxy for metallicity, inferred from optical emission lines appear to lie ~0.4 dex below the now well-established stellar mass-metallicity relation for star-forming galaxies, when the two populations are compared at the same stellar mass.

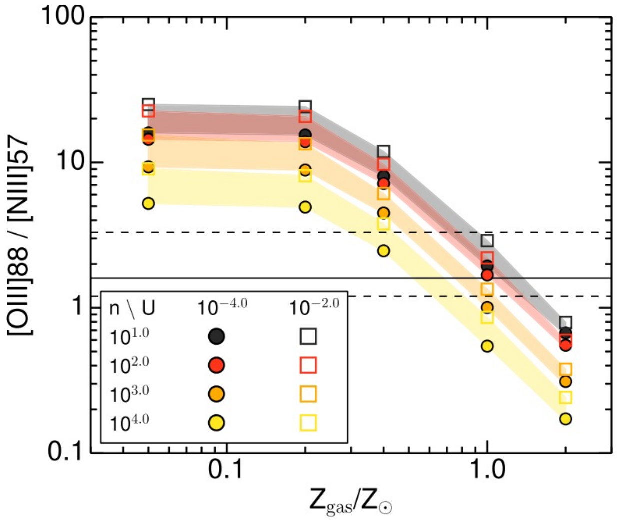


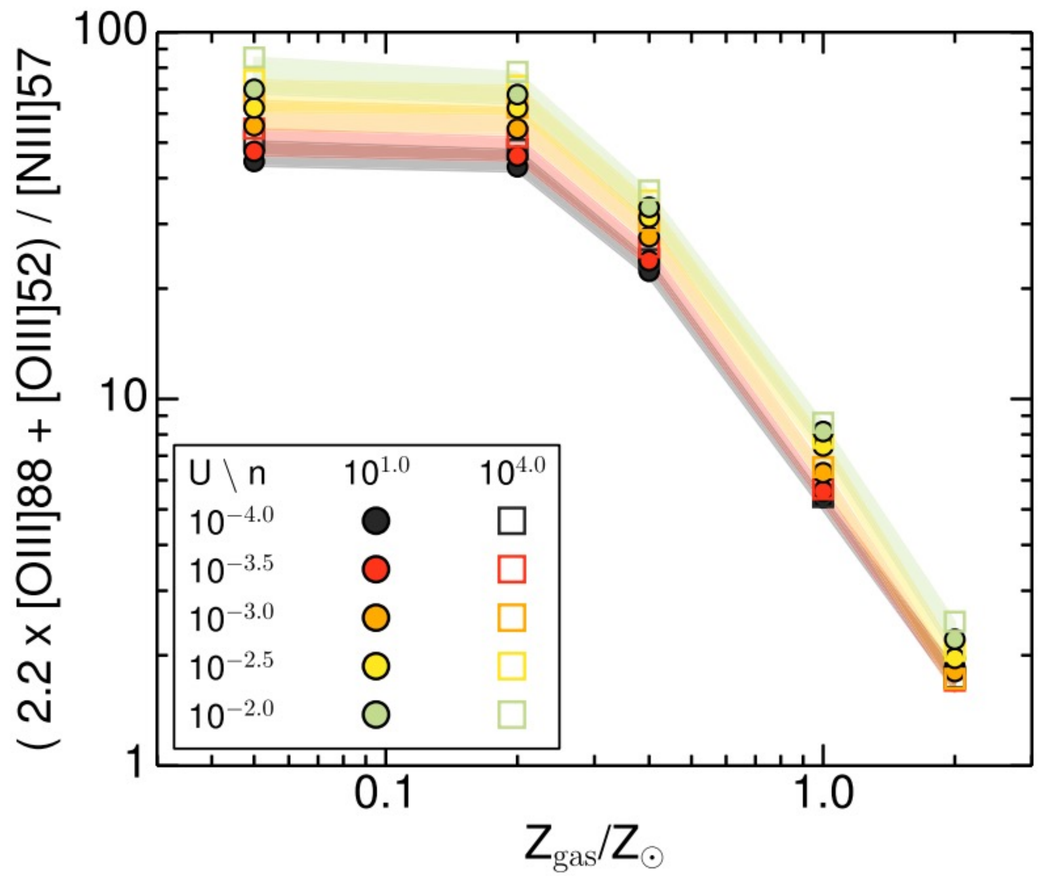
Rupke et al. 2008

Far-infrared metallicity diagnostics

- ❑ At constant metallicity, the [O III]52 µm/[N III]57 µm ratio varies inversely with density compared to the [O III]88 µm/[N III]57 µm ratio.



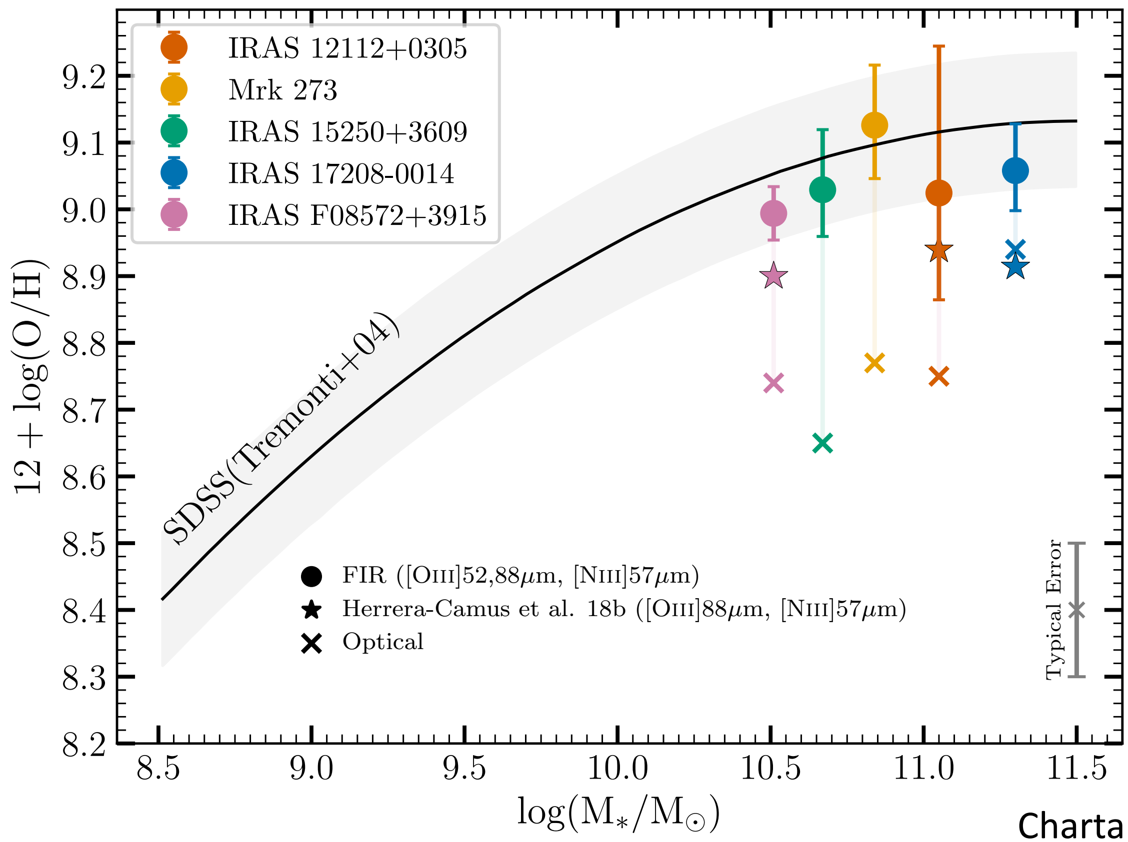




Pereira-Santaella et al. 2017

Where do ULIRGs locate on MZR?

These FIR-based, extinction-insensitive metallicity measurements indicate that ULIRGs lie on the mass-metallicity relation of star-forming galaxies. They also do not indicate unusual metal deficiencies in ULIRGs, as one would conclude with optical line ratios alone.

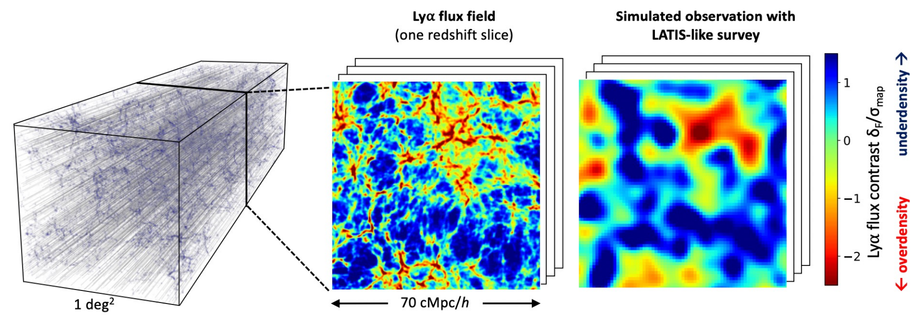


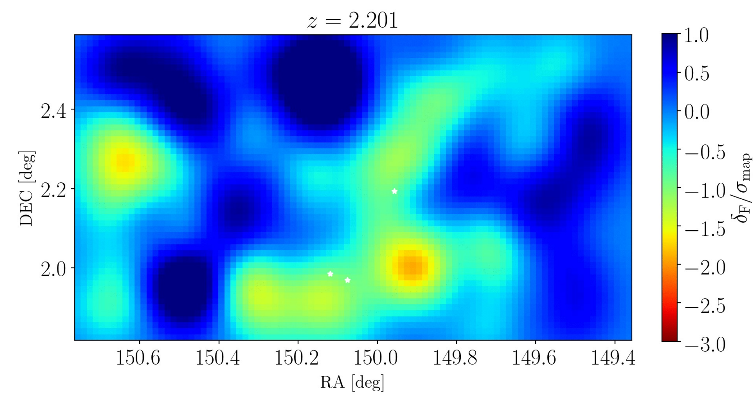
Chartab et al. 2022

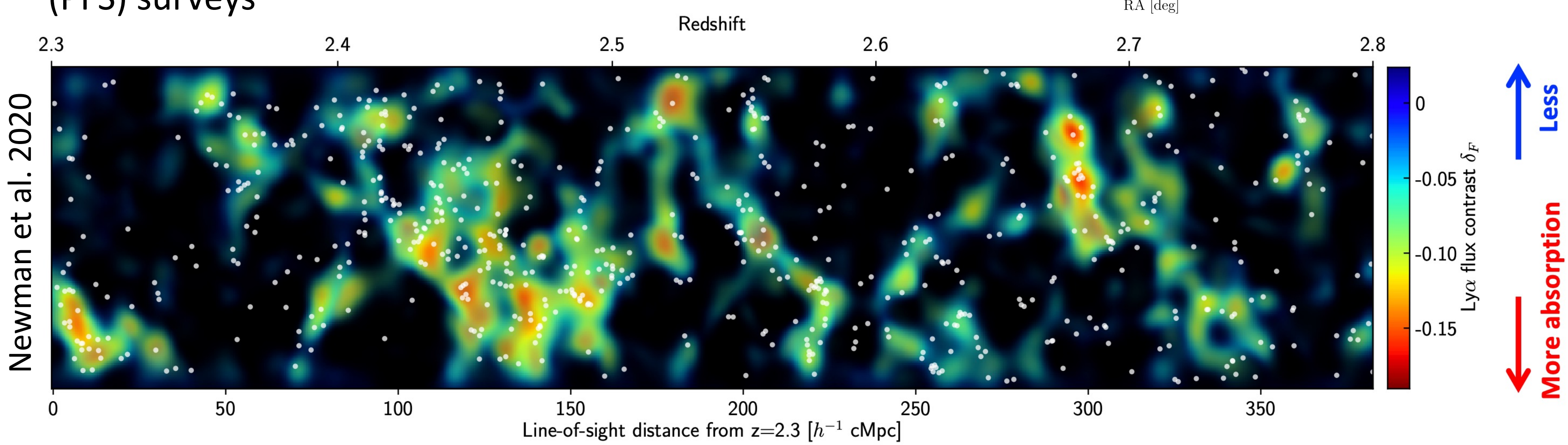
Optical metallicity measurements may yield biased results for highly dust-obscured galaxies expected to be prevalent in high-redshift protoclusters!

Robust Protocluster Candidates for FIR Spectroscopic Follow-Up

- The Lyα Tomography IMACS Survey (LATIS)
- H I absorption traces density field on large scales
- Mapping the z = 2.2-2.8 universe over 1.8 deg^2 = 10^7 $cMpc^3$
- ~5-year program from 2018A to 2022B (~60 nights)
- Deep 12-hour exposures (SNR ~ 2 in the Lyα forest); R~970
- 10x larger than CLAMATO (K.G. Lee et al.) with similar sightline density
- Future Subaru Prime Focus Spectrograph (PFS) surveys

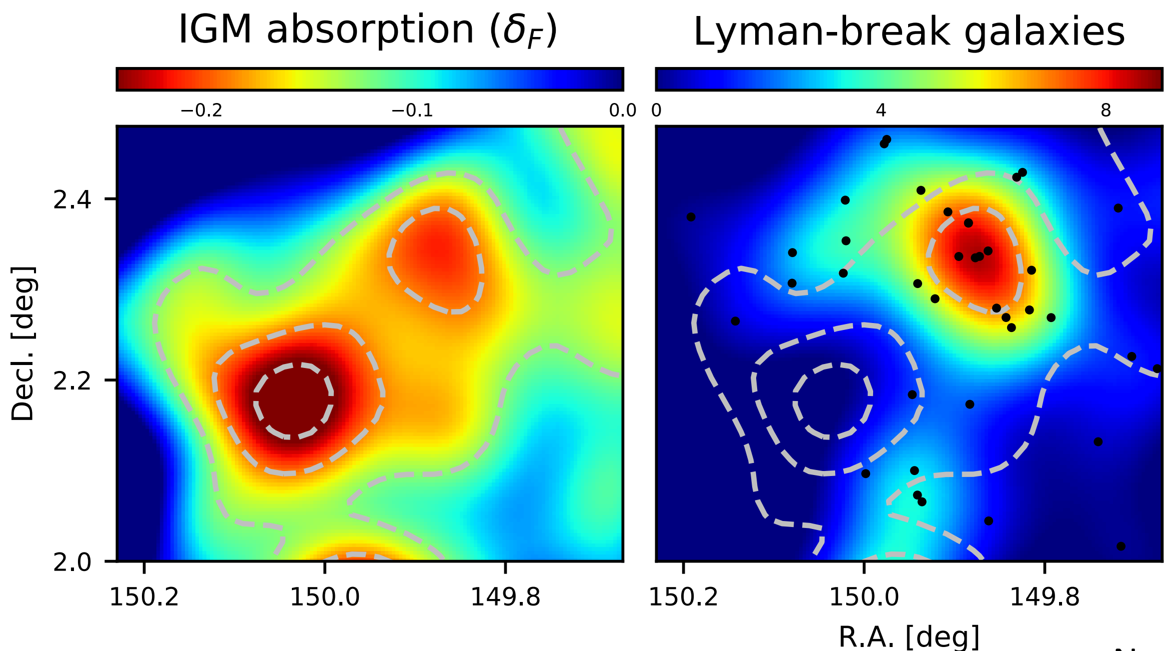






Ultraviolet-dim protoclusters

- Some structures with high absorption have fewer galaxies than expected from their dark matter counterparts in simulations

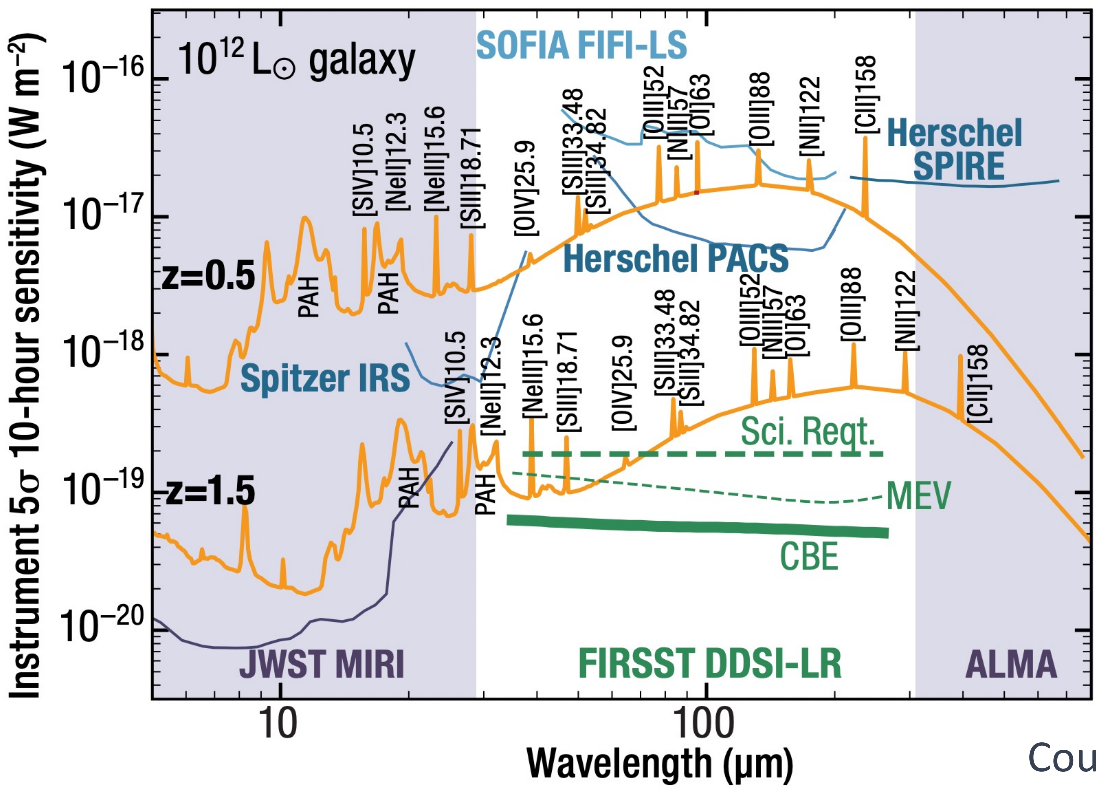


Newman et al. 2022

- Are these UV-dim structures populated by quenched galaxies, or are they dust-obscured?

FIR metallicity measurements of UV-dim protoclusters

- Scientific Case: FIR spectroscopy of UV-dim protoclusters to measure key FIR lines (e.g, [O III]52,88 μm and [N III]57 μm) for determining robust metallicities and studying environmental dependence of MZR in these extreme environments at cosmic noon.



Courtesy of FIRSST

THANK YOU!