Title: The enriched circumgalactic and intergalactic medium of star-forming dwarf galaxies

Speakers: Nishant Mishra

Collection/Series: Cosmic Ecosystems

Date: July 30, 2025 - 12:00 PM

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Abstract:

The circumgalactic/intergalactic medium (CGM/IGM) represents a significant baryon reservoir for sustaining star formation and provides insights into the inflows, outflows, and feedback history of galaxies. Star-forming dwarf galaxies, with their shallow potential wells, are predicted to drive metal-enriched gas into the CGM/IGM. Therefore, a census of the CGM around dwarf galaxies can provide insights into the stellar feedback. We present highly sensitive absorption-line measurements in quasar sightlines adjacent to 91 isolated dwarf galaxies with a median stellar mass of $M_{star}/M_{sun} \approx 8.4$ from the Cosmic Ultraviolet Baryon Survey (CUBS). This survey uses HST absorption spectroscopy to access a range of ion transitions from $0.077<z<0.73$ such as the Lyman-series transitions for HI, as well as a range of multiphase metal lines including low (e.g. CII, SiII), intermediate (e.g. CIII, SiIII) and high (e.g. CIV, OVI) ions. The CUBS Dwarfs sample represents a nine-fold increase in the number of star-forming field dwarf galaxies with CGM constraints on neutral hydrogen and metal absorption lines. We find that low and intermediate ionization metal absorption is rare and limited to the inner CGM of dwarf galaxies. In contrast, highly ionized OVI is commonly observed in sightlines that pass within the virial radius of a dwarf, and OVI detection rates are non-negligible at projected distances of 1-2x the virial radius. These measurements show that the OVI-bearing phase of the CGM/IGM accounts for the majority of the oxygen budget from star-formation, and the kinematic distribution of absorption systems suggests that a relatively modest fraction of this gas is formally unbound from the halo. Time permitting, I will show photoionization analysis of one system with evidence of absorption in the inner-CGM with α-enhancement characteristic of core-collapse supernovae driven winds.

The circumgalactic medium of dwarf galaxies: A sensitive laboratory for feedback

Nishant Mishra
University of Michigan

In collaboration with: Sean Johnson, Gwen Rudie, Hsiao-Wen Chen, Fakhri Zahedy, Zhijie Qu and the CUBS team

Cosmic Ecosystems, August 2025

Mark's Homework Assignment

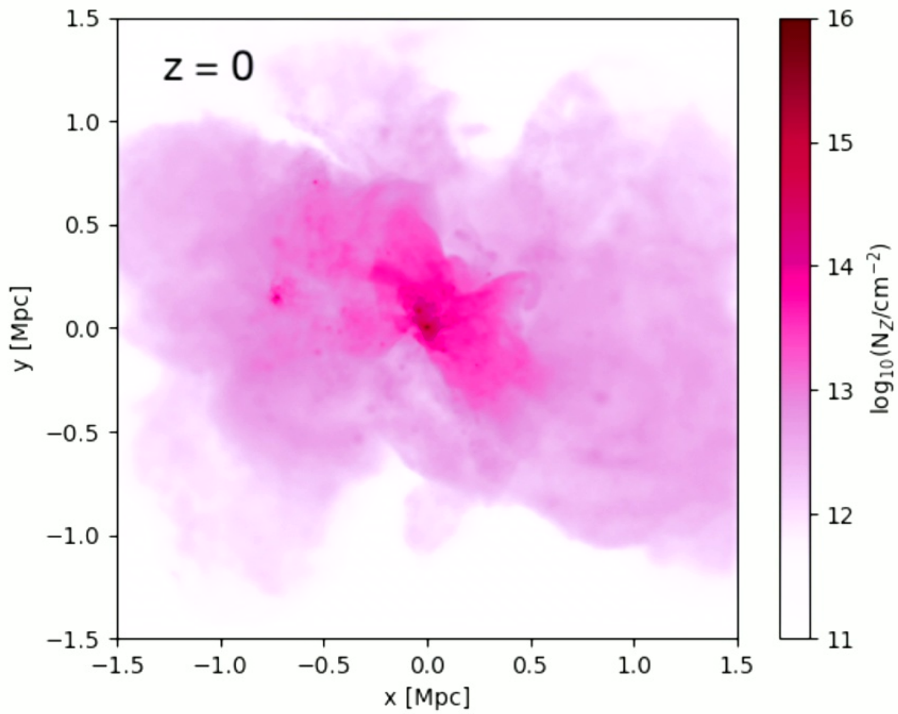
Radial baryon distribution (yes!) **(In dwarf galaxies)**

Measure specific feedback energy (partial?…)

Understand SN feedback crisis (partial?…)

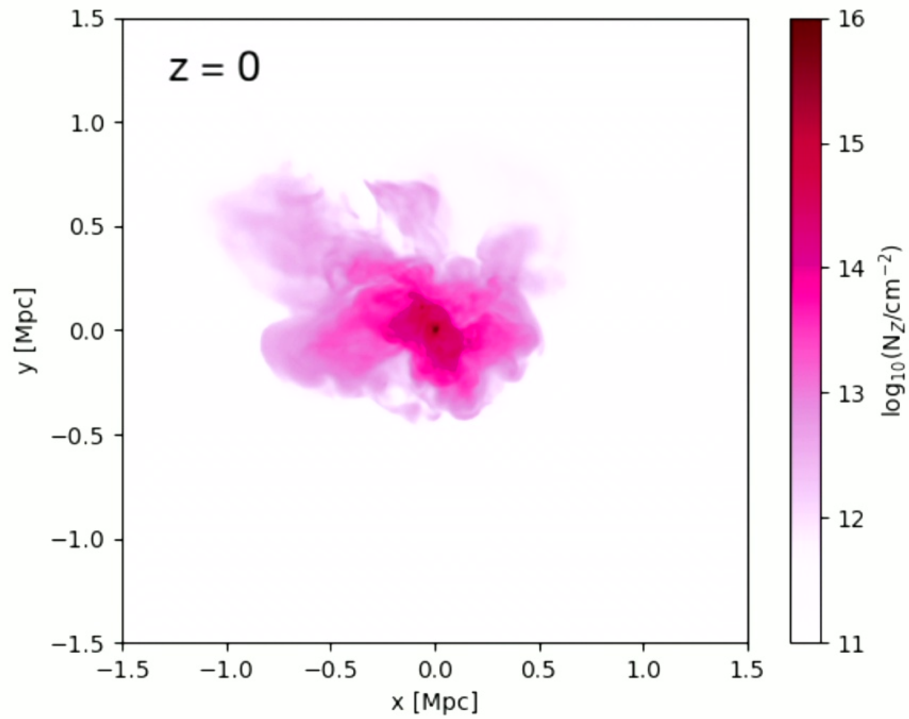
Assess feedback coupling (partial?…)

The CGM of dwarf galaxies are sensitive to supernova feedback mechanisms



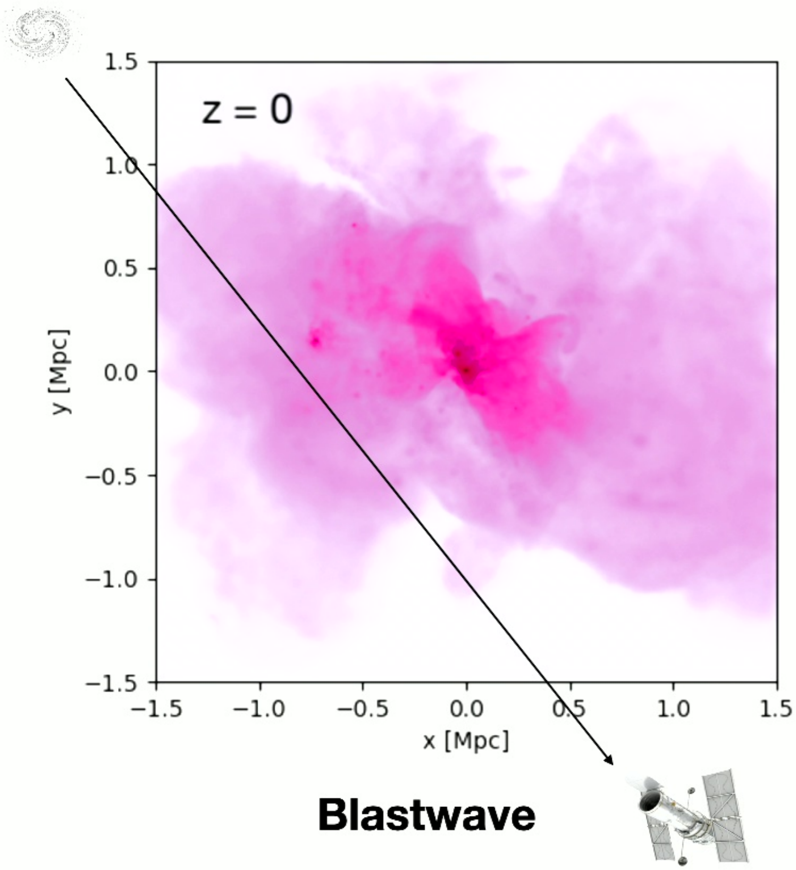
Blastwave

Mina et al. (2021)



Superbubble

Dwarf CGM is sensitive to supernova feedback mechanisms



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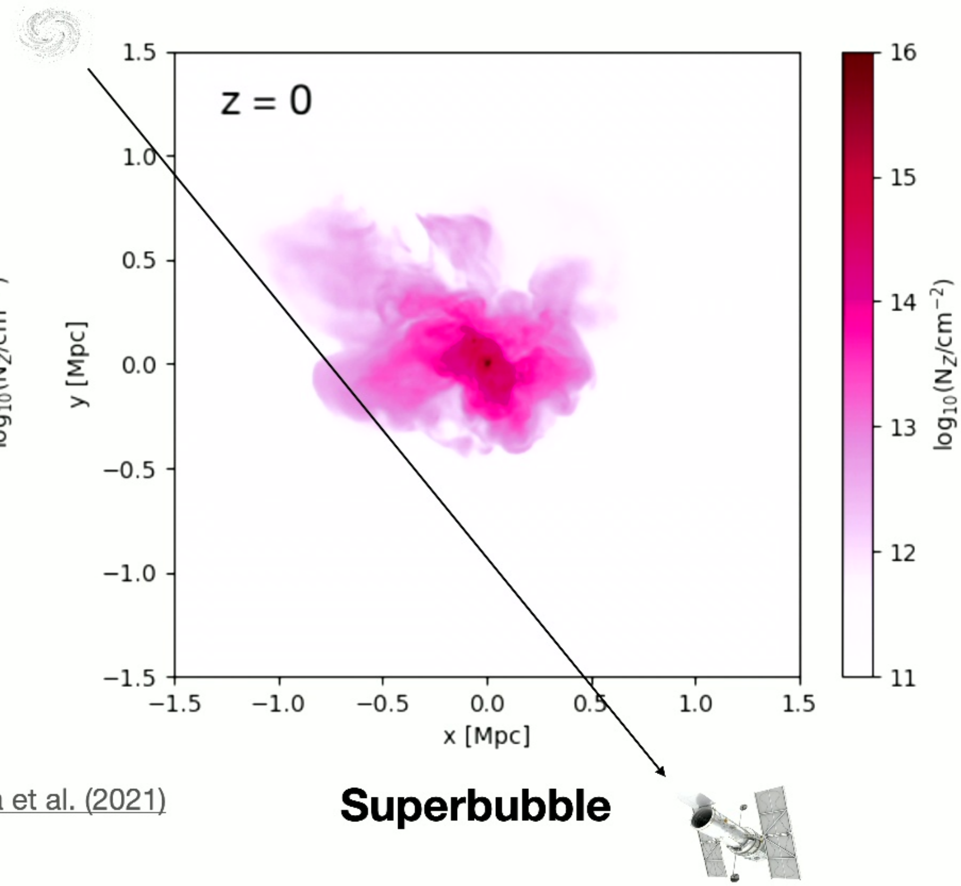
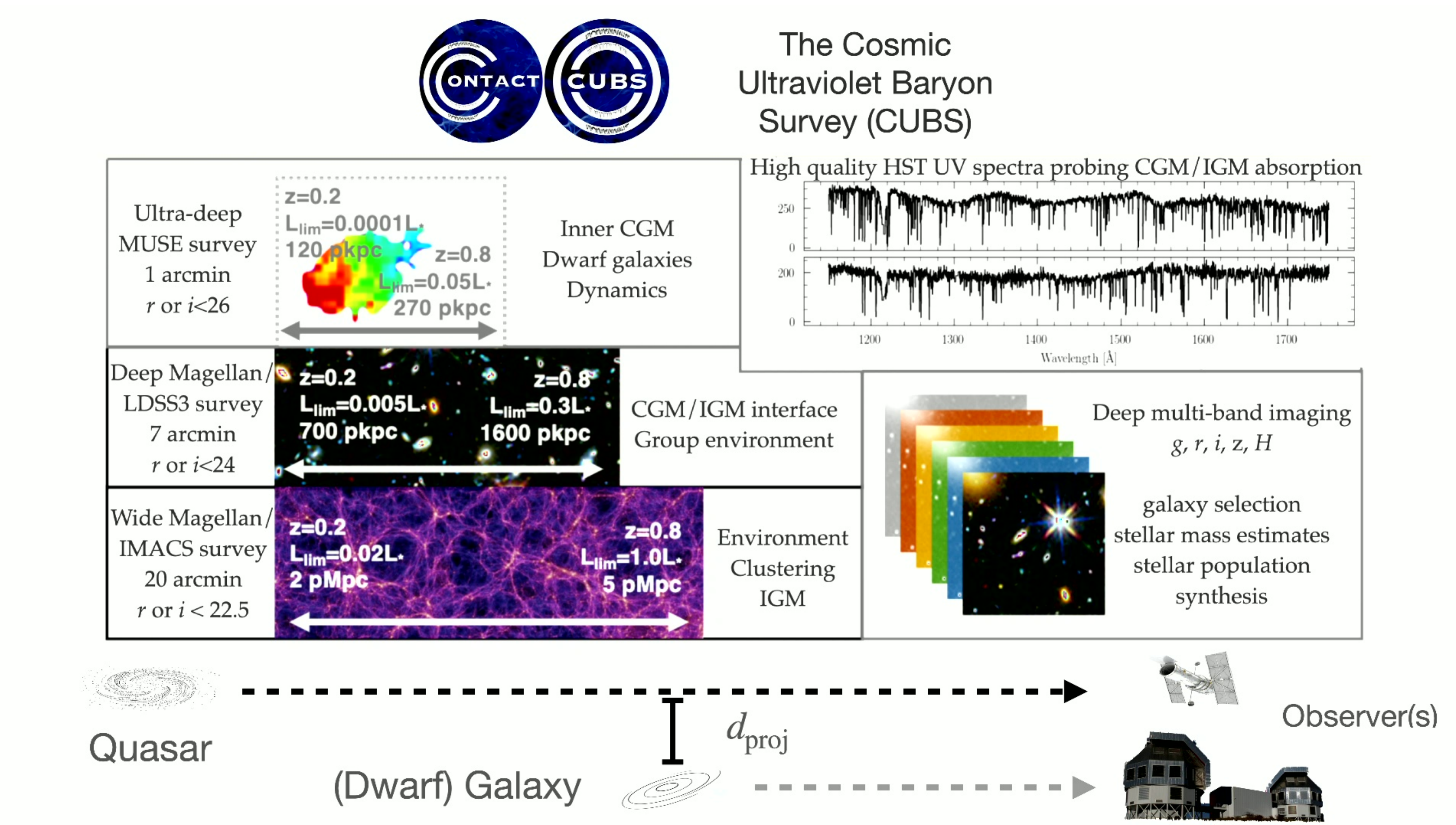


Superbubble


ONTACT
CUBS
The Cosmic Ultraviolet Baryon Survey (CUBS)
Ultra-deep MUSE survey
1 arcmin
r or i<26
z=0.2
Llim=0.0001L*
120 pkpc
z=0.8
Llim=0.05L*
270 pkpc
Inner CGM
Dwarf galaxies
Dynamics
High quality HST UV spectra probing CGM/IGM absorption
250
0
200
0
1200
1300
1400
1500
1600
1700
Wavelength [Å]
Deep Magellan/LDSS3 survey
7 arcmin
r or i<24
z=0.2
Llim=0.005L*
700 pkpc
z=0.8
Llim=0.3L*
1600 pkpc
CGM/IGM interface
Group environment
Deep multi-band imaging
g, r, i, z, H
galaxy selection
stellar mass estimates
stellar population synthesis
Wide Magellan/IMACS survey
20 arcmin
r or i < 22.5
z=0.2
Llim=0.02L*
2 pMpc
z=0.8
Llim=1.0L*
5 pMpc
Environment
Clustering
IGM
Quasar
dproj
(Dwarf) Galaxy
Observer(s)

Selecting isolated dwarfs in CUBS

Select galaxies with

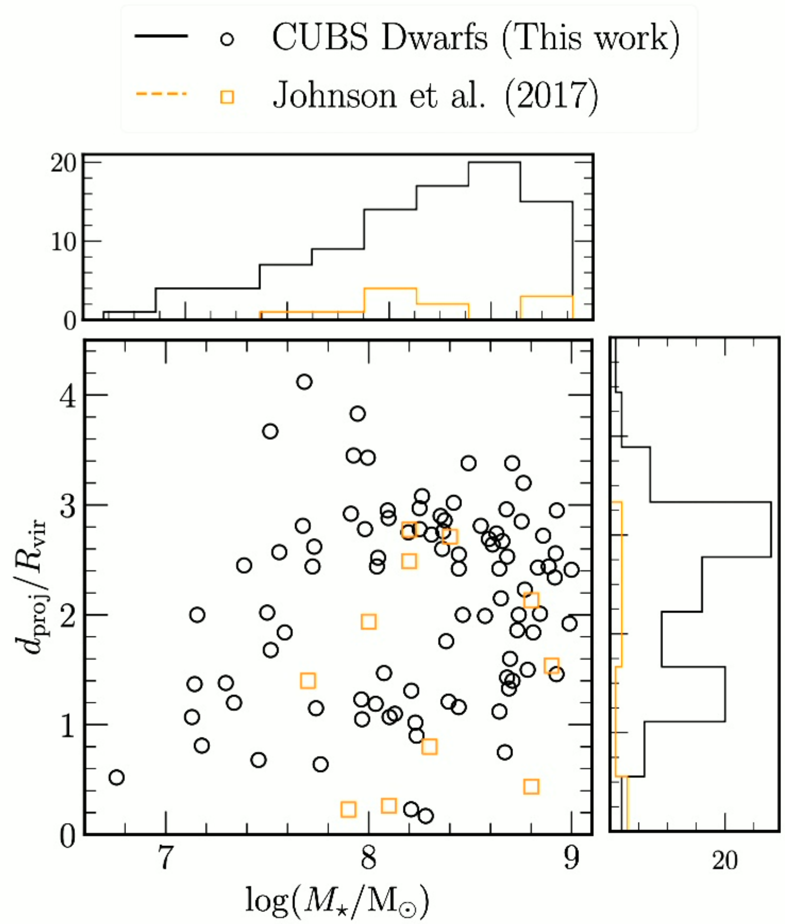
$\log M_\star/\mathrm{M}_\odot < 9$ **and**

$0.077 < z < 0.77$

Isolated against galaxies

$\log M_\star/\mathrm{M}_\odot > 9$ **to 500 km/s and 500 kpc**

102 low mass systems selected



Why go beyond the local universe?

Select galaxies with
$\log M_\star/\mathrm{M}_\odot < 9$ **and**
$0.077 < z < 0.77$

Isolated against galaxies
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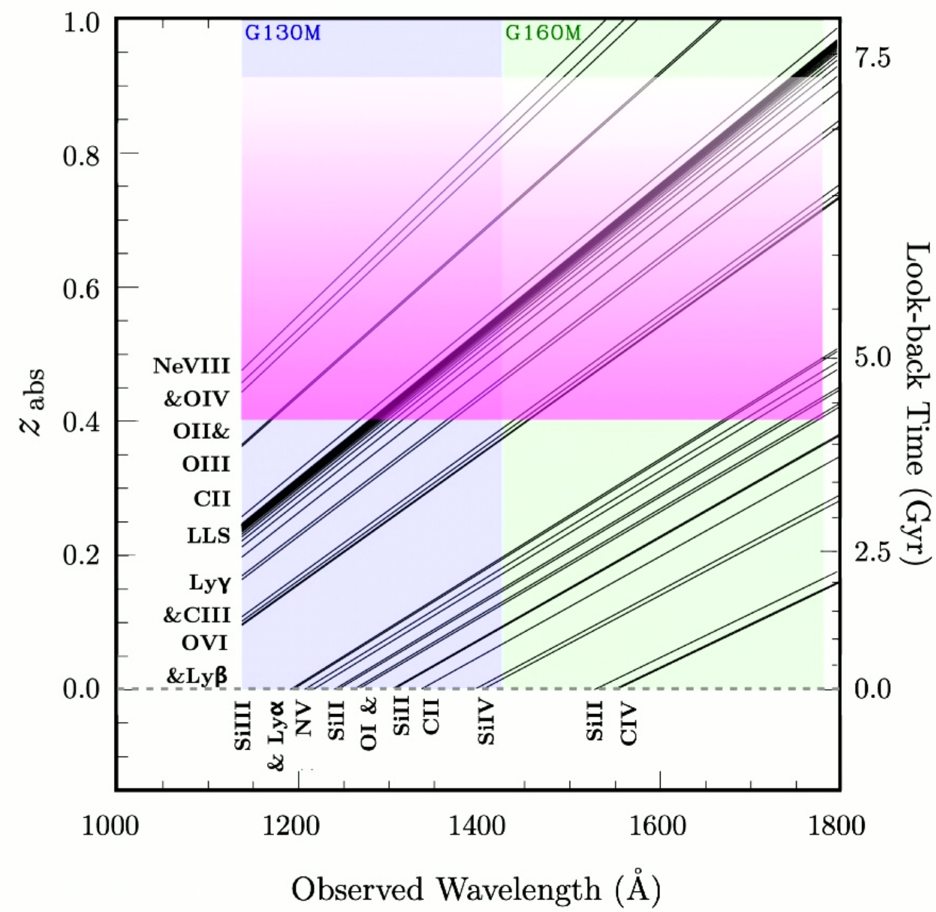
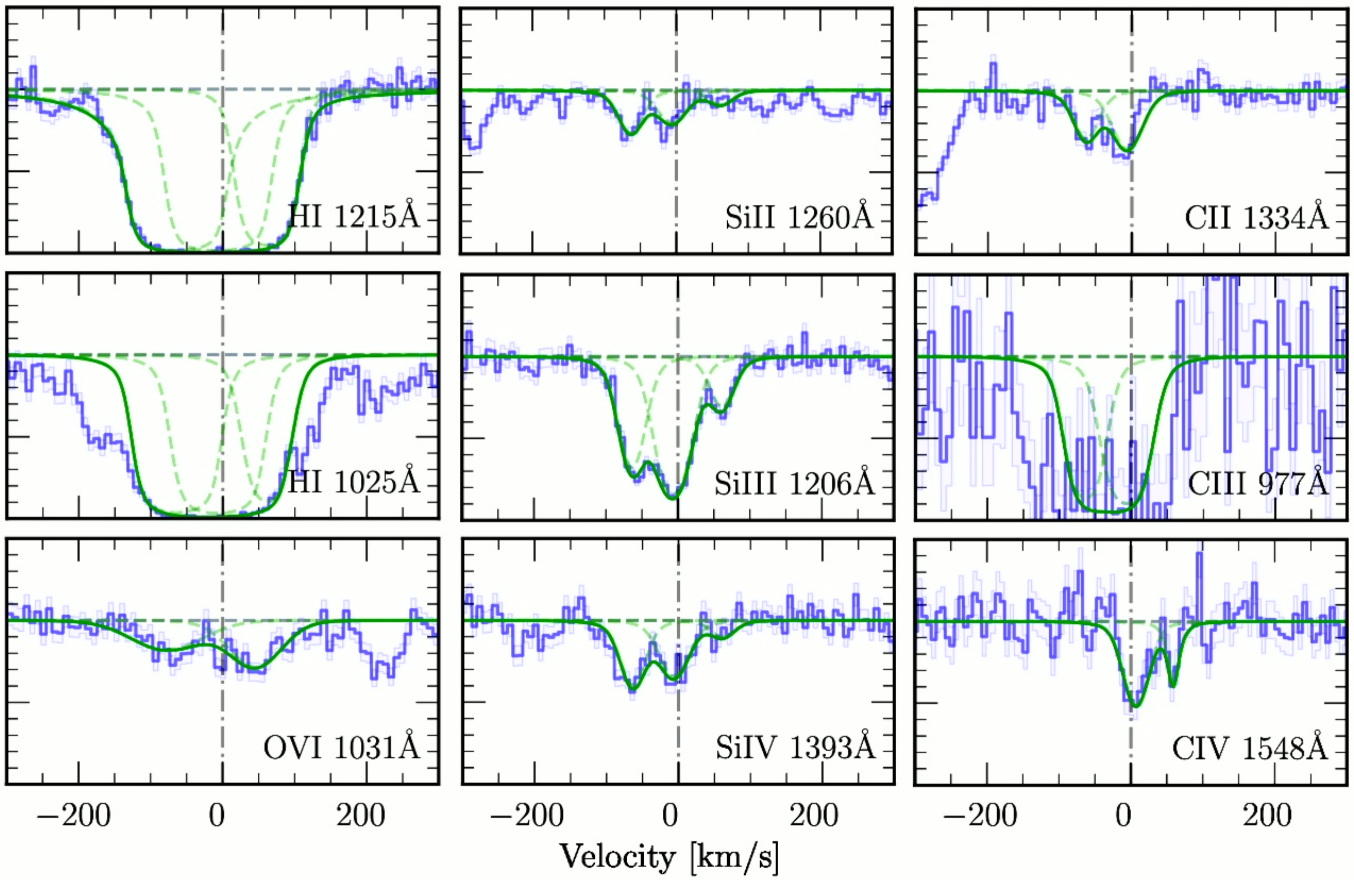
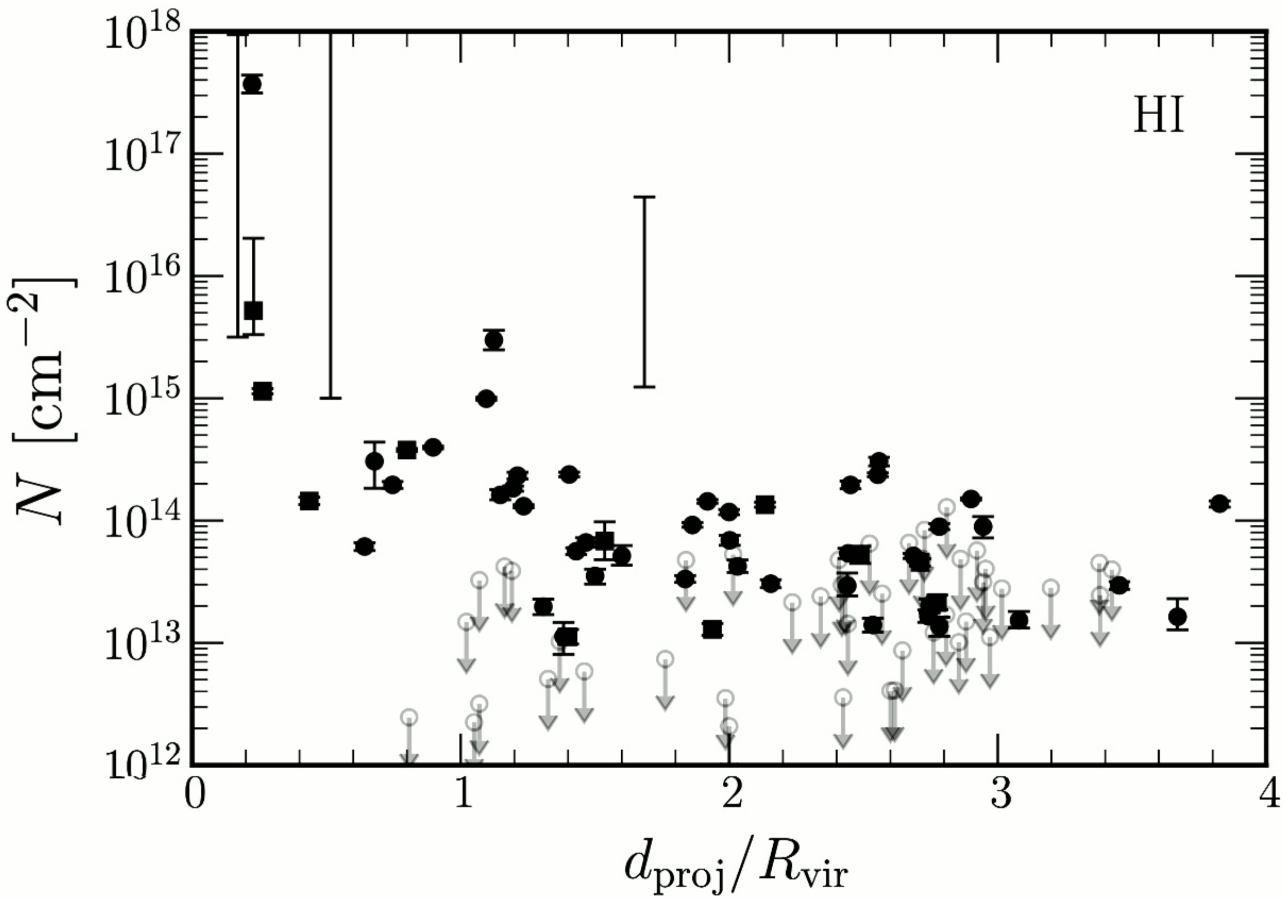


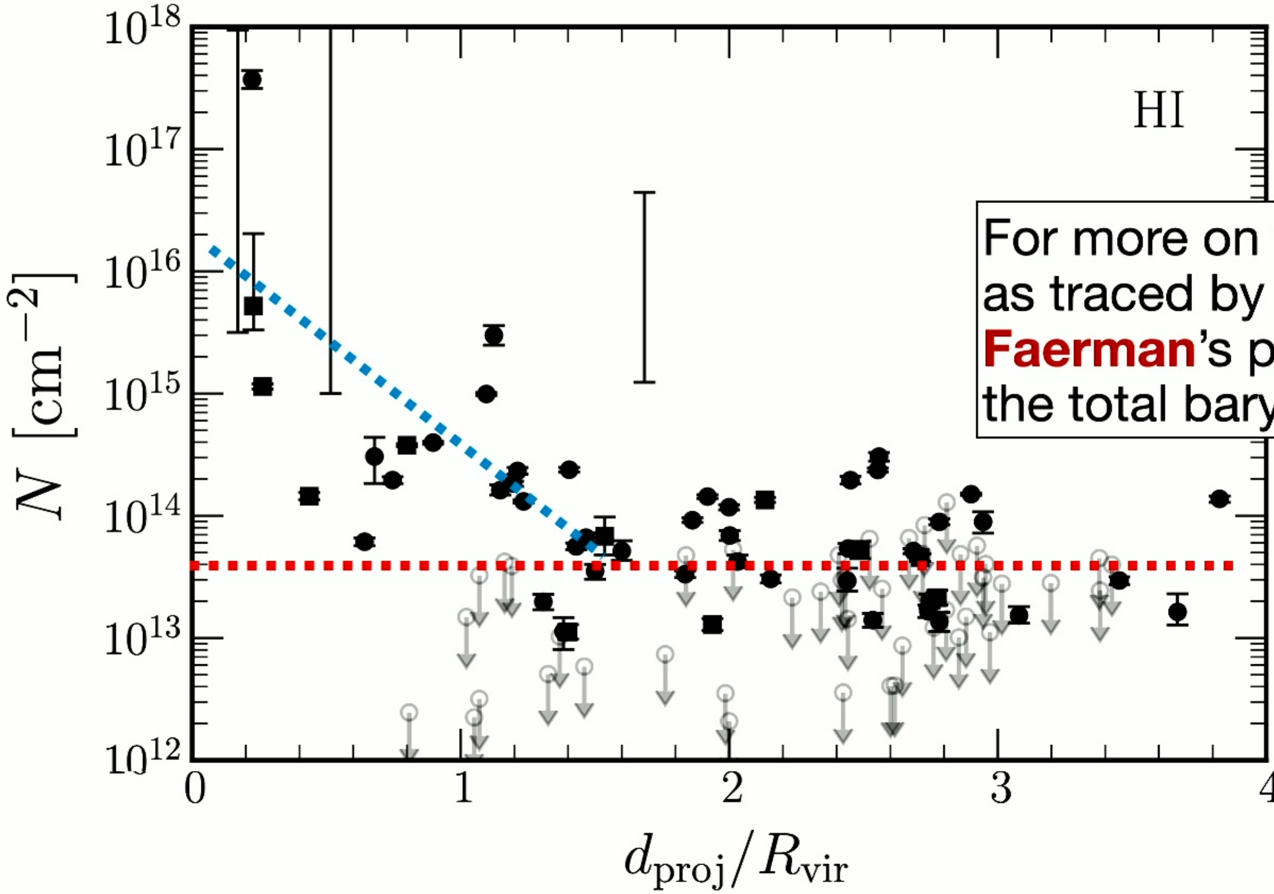
Voigt profile fitting constrains the column densities and kinematics of absorbers



Strong H I absorption in the inner CGM

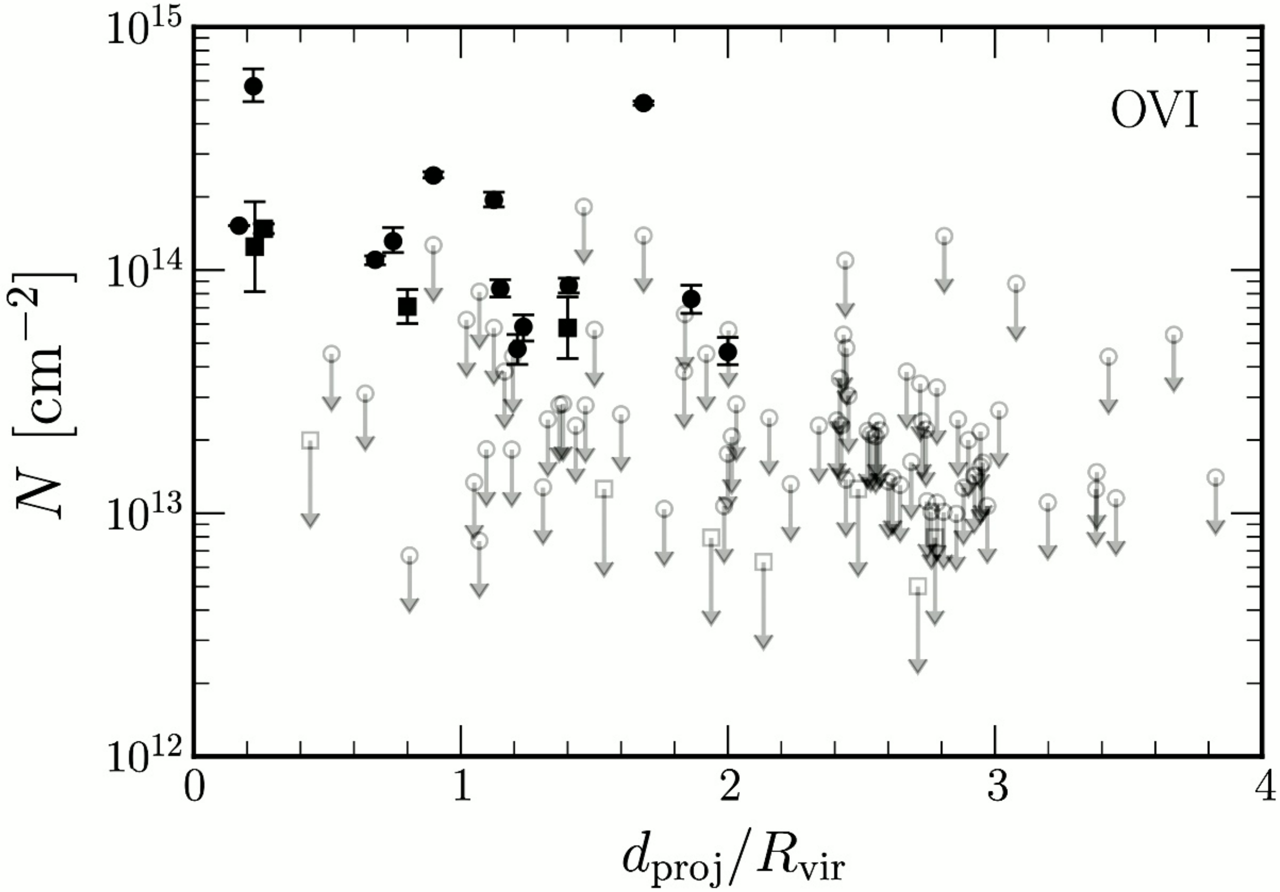


Strong H I absorption in the inner CGM

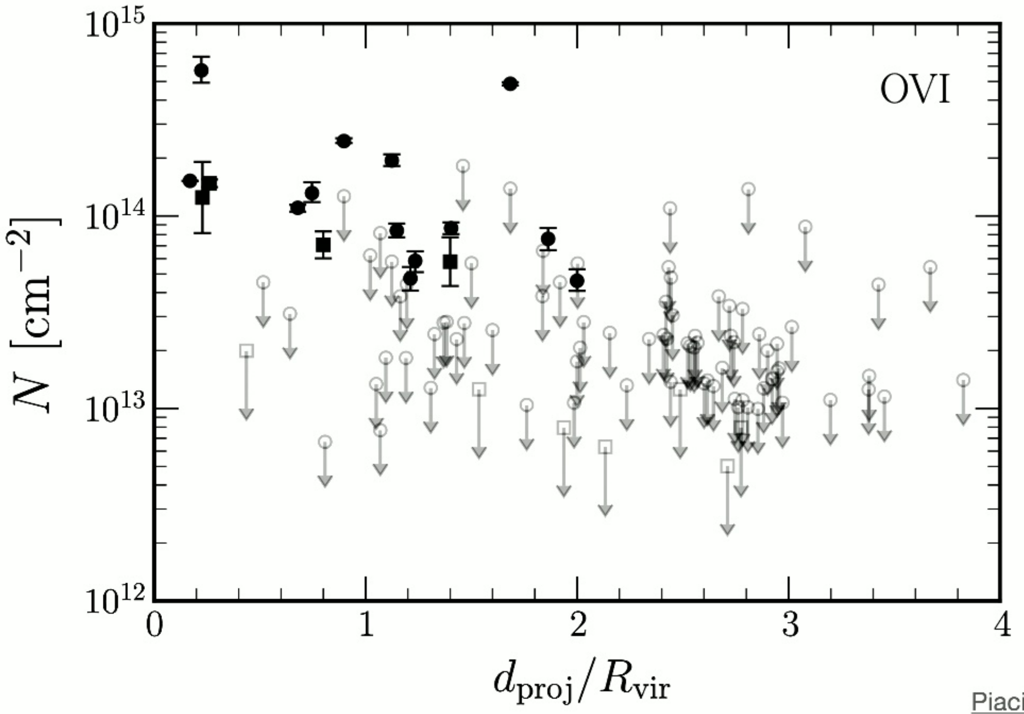


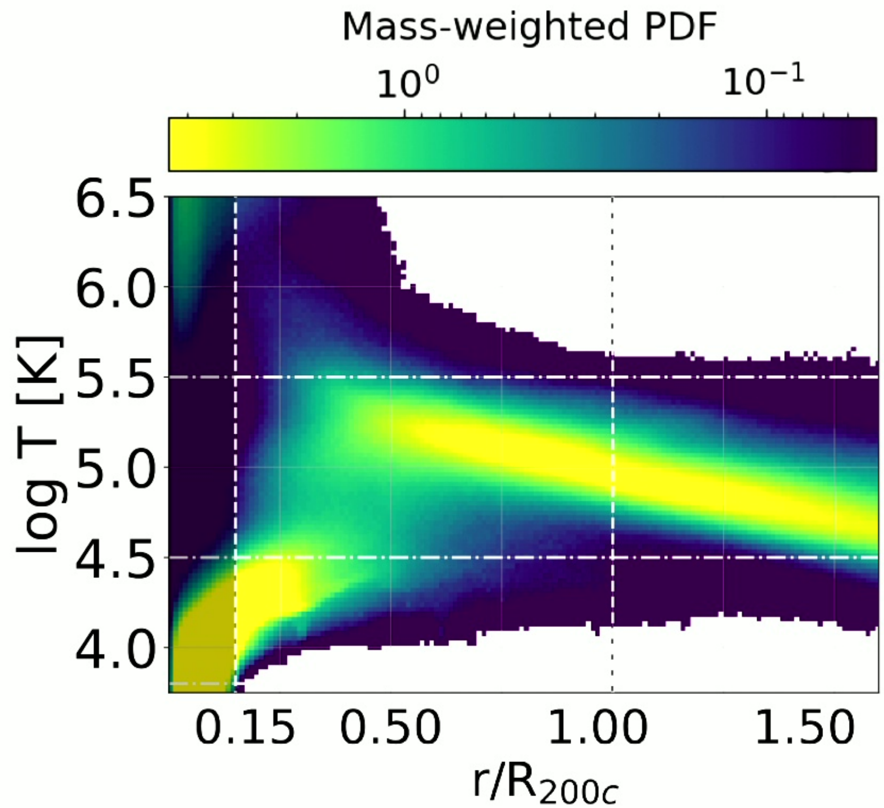
For more on the cooler phase as traced by H I, see **Yakov Faerman**'s poster! (<15% of the total baryon budget)

O VI is the most common ion and extends beyond the virial radius



Simulations predict a phase transition in the outer CGM





Piacitelli et al. (2025)

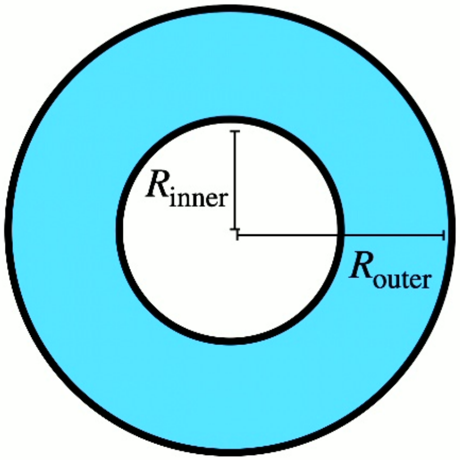
Average detected column density

Area of an annulus around the dwarf galaxy

$$M_{\rm ion} \approx \pi(R^2_{\rm outer} - R^2_{\rm inner}) m_{\rm ion} \kappa_{\rm ion} \langle N_{\rm ion} \rangle$$

Ion mass

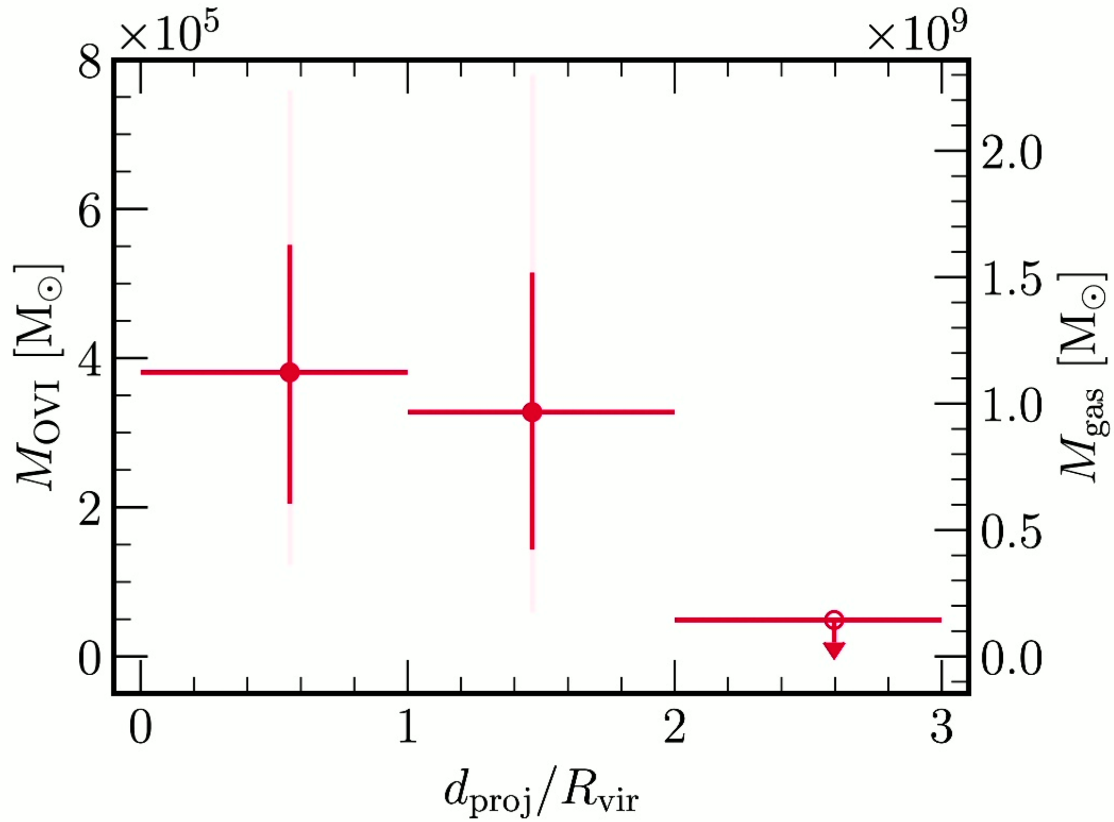
Covering fraction (detection rate)



Significant O VI mass outside the virial radius

$$M_{\rm ion} \approx \pi(R_{\rm outer}^2 - R_{\rm inner}^2) m_{\rm ion} \kappa_{\rm ion} \langle N_{\rm ion} \rangle$$

$$M_{\rm gas} = 2.1^{+0.7}_{-0.7} \times 10^9 \,{\rm M_\odot} \left(\frac{0.3\,{\rm Z_\odot}}{Z}\right)\left(\frac{0.2}{f}\right)$$



O VI CGM mass exceeds H I ISM mass

$$M_{\rm ion} \approx \pi(R^2_{\rm outer} - R^2_{\rm inner}) m_{\rm ion} \kappa_{\rm ion} \langle N_{\rm ion} \rangle$$

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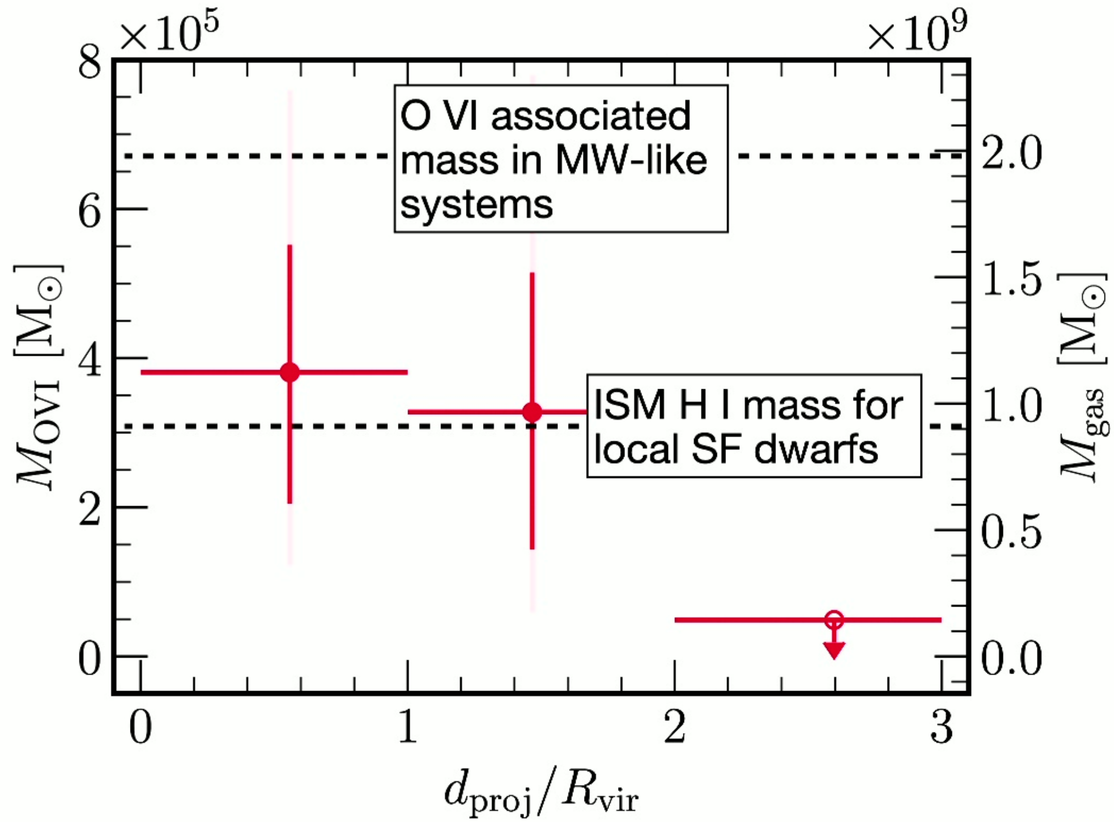
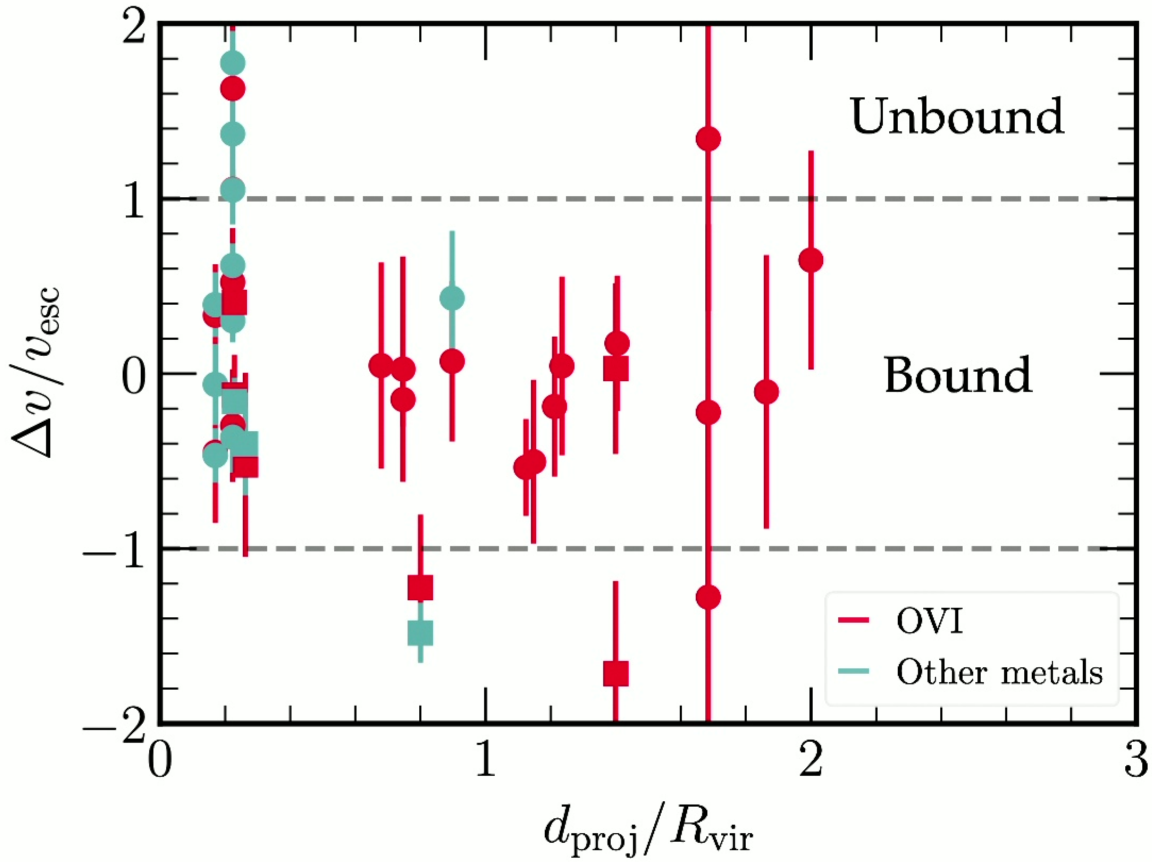


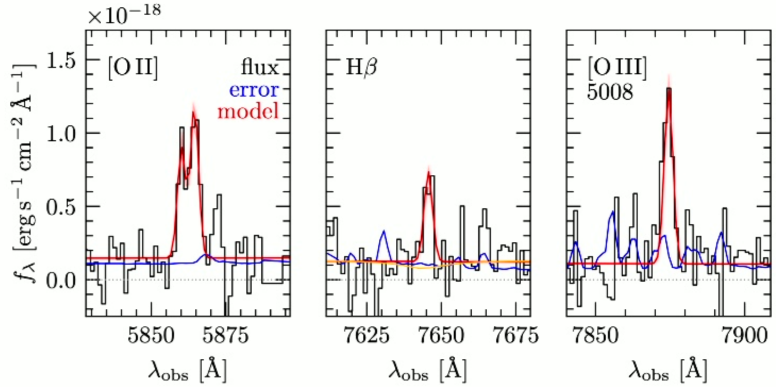
Most CGM metals are bound!

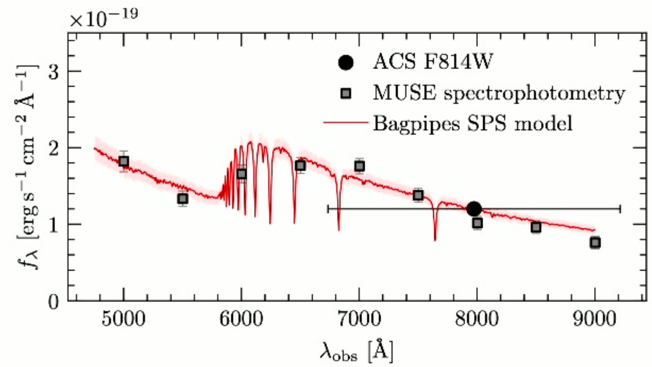
Only (~15%) of galaxies have absorbers are formally unbound (comparable to MW mass systems)

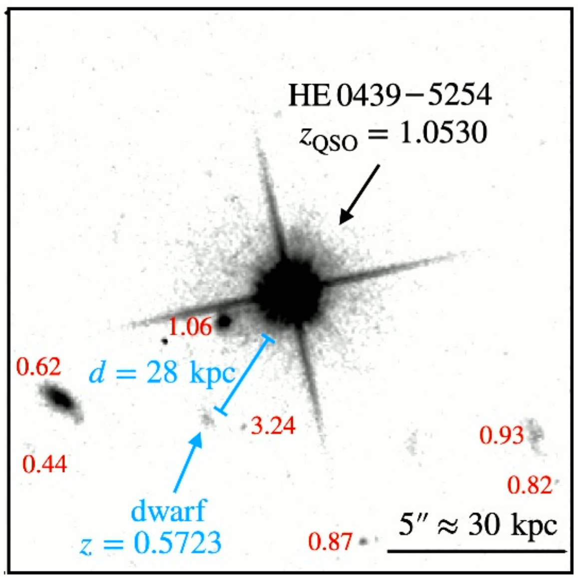


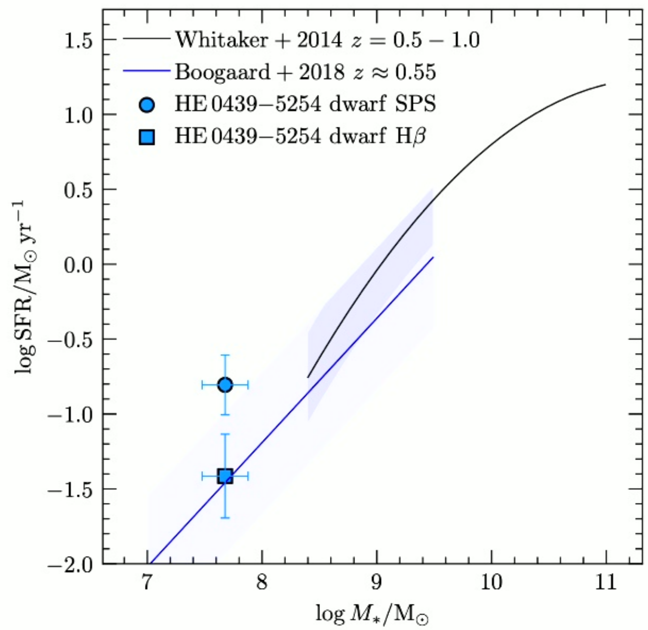
Beyond absorption line measurements

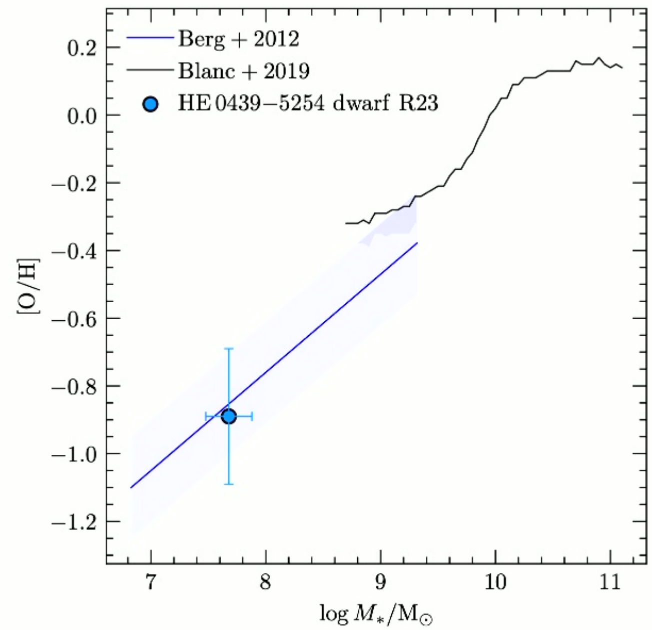
CGM around isolated dwarfs: unique constraints on metallicity and relative abundances





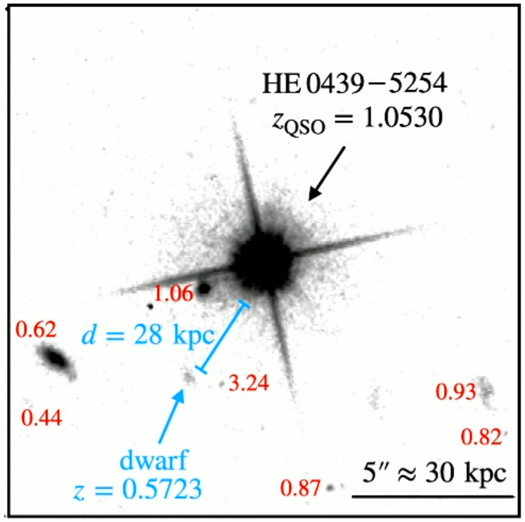


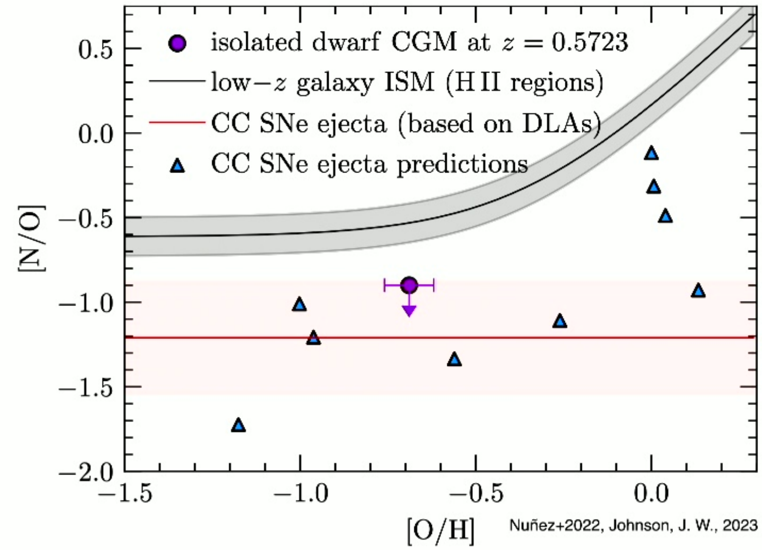




Johnson, NM+ in prep

CGM around isolated dwarfs: unique constraints on metallicity and relative abundances





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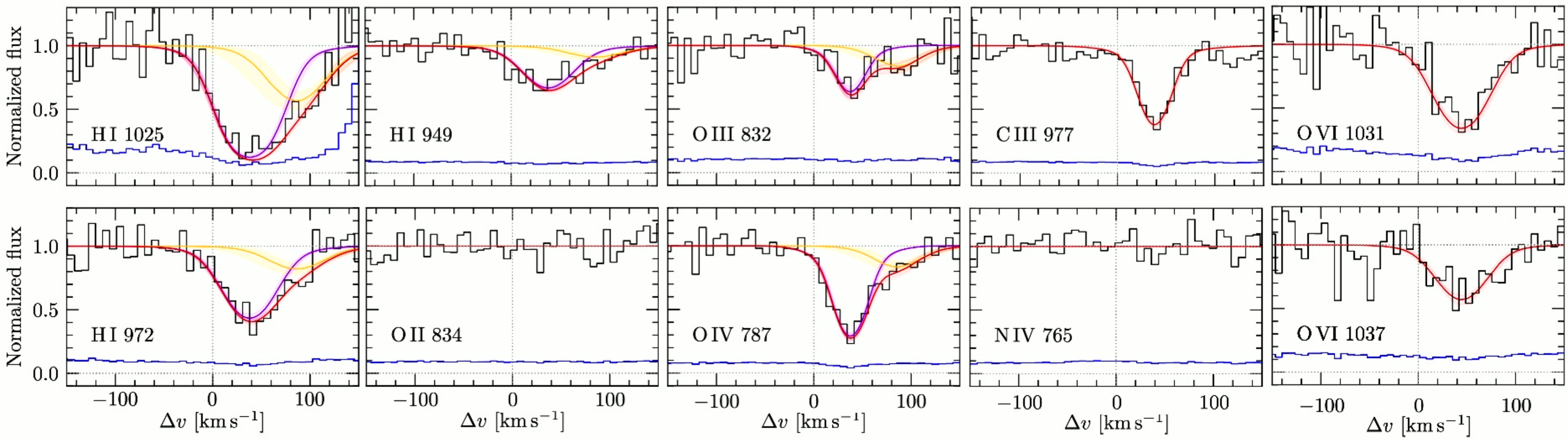
Nuñez+2022, Johnson, J. W., 2023



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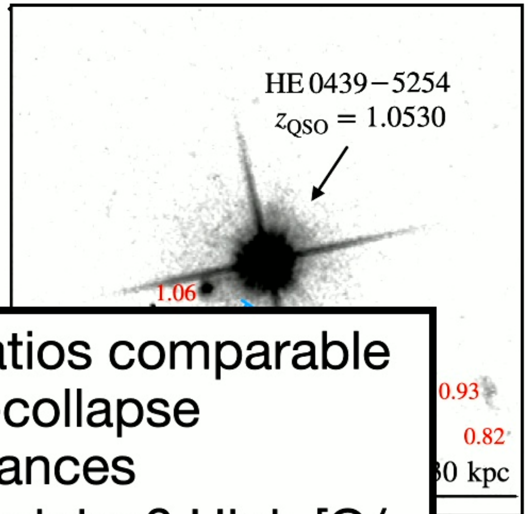
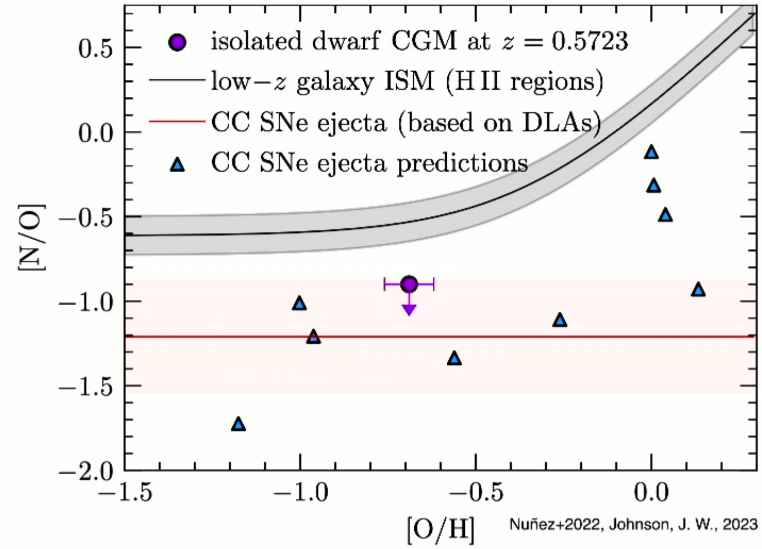
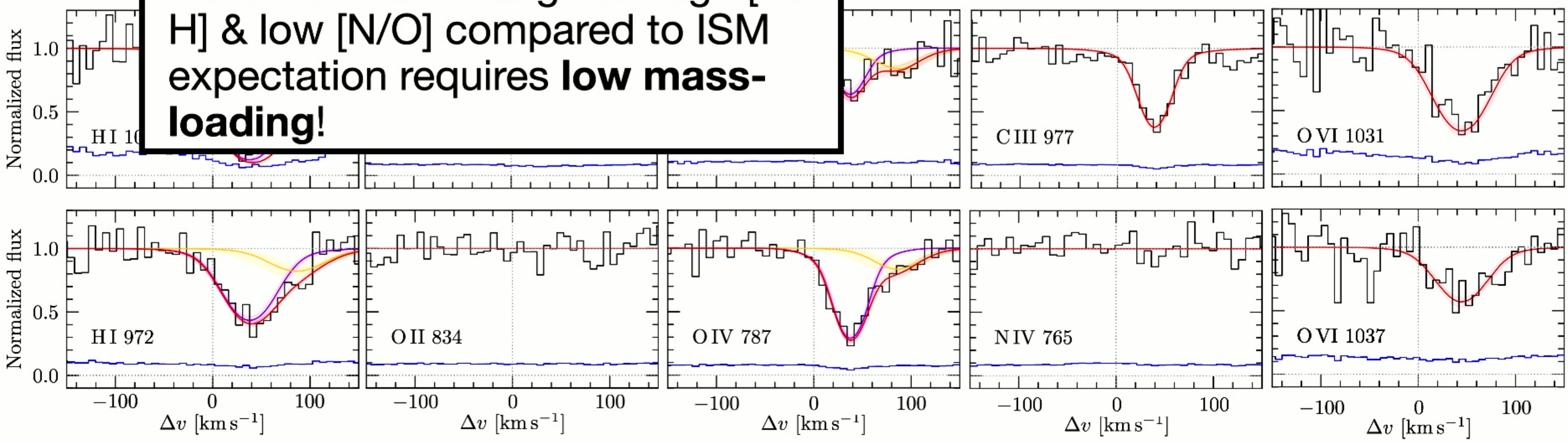




Nuñez+2022, Johnson, J. W., 2023

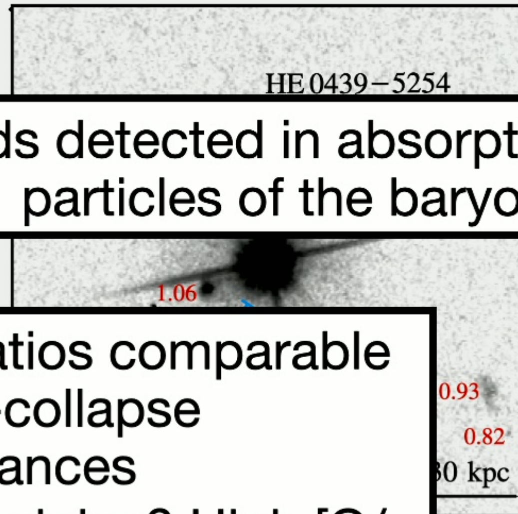
- [N/O] and [C/O] ratios comparable to expected core-collapse supernova abundances
- Possible outflow origins? High [O/H] & low [N/O] compared to ISM expectation requires **low mass-loading**!

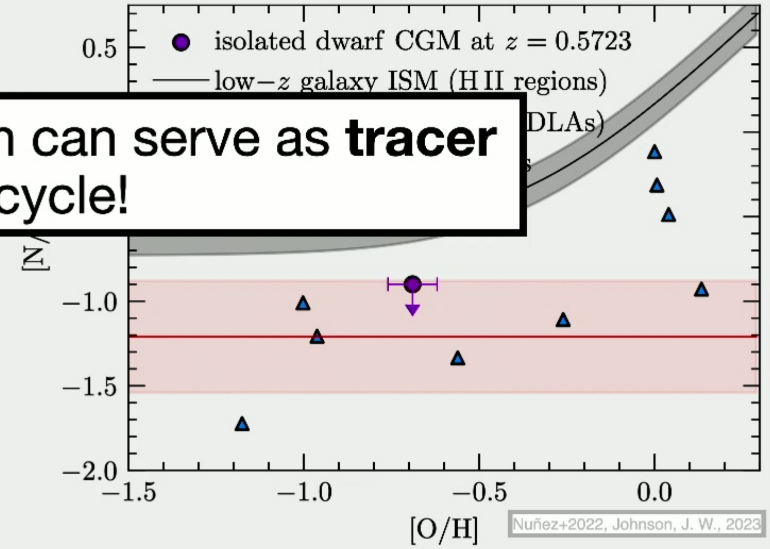
Johnson



CGM around isolated … unique c… on metallicity and relativ… abund…

Johnson…





Cold gas clouds detected in absorption can serve as **tracer** particles of the baryon cycle!

- [N/O] and [C/O] ratios comparable to expected core-collapse supernova abundances
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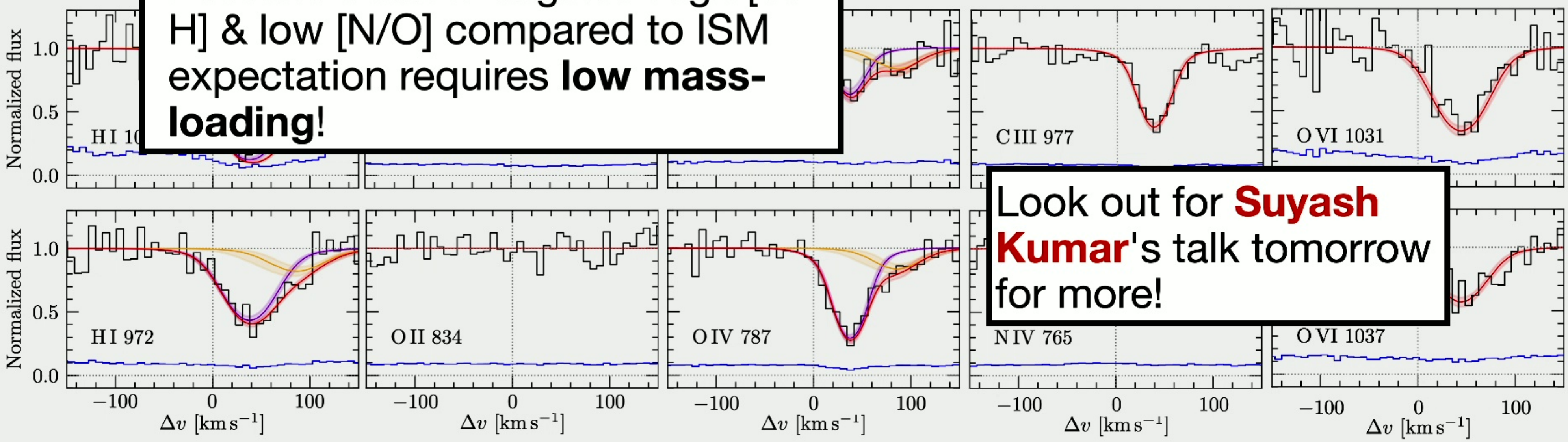
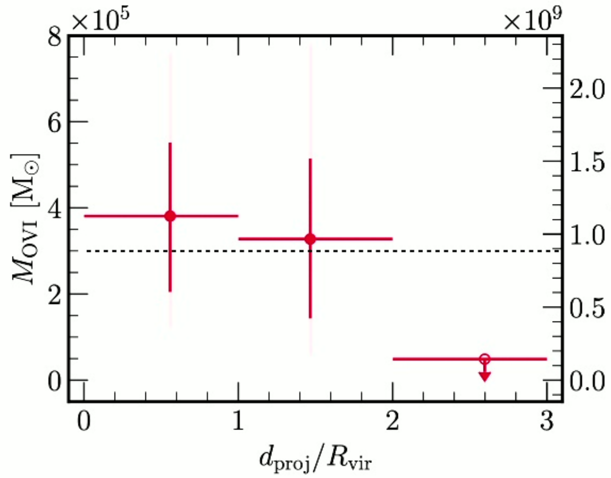
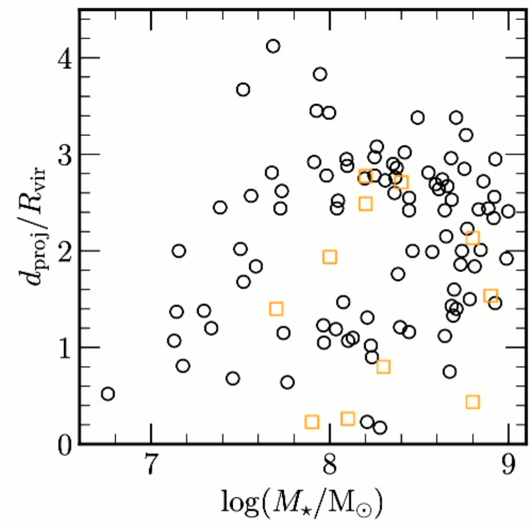


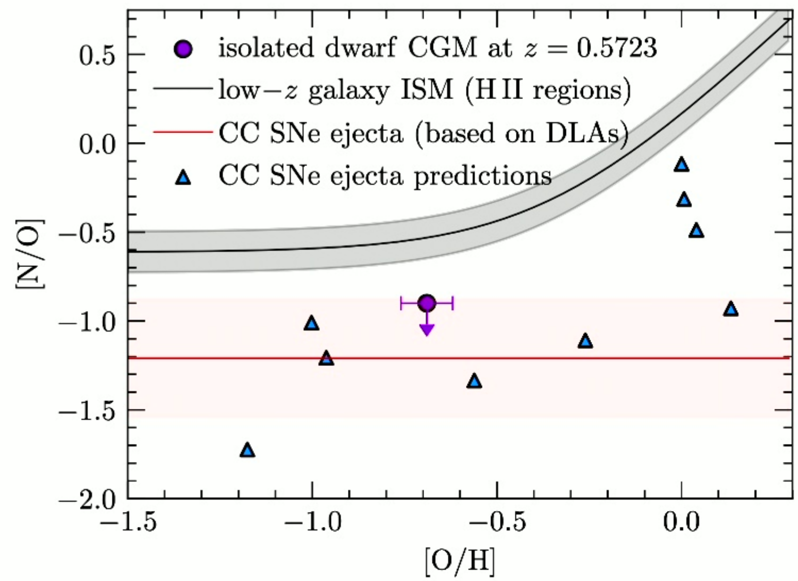
Look out for **Suyash Kumar**'s talk tomorrow for more!

Takeaways

- We studied isolated, star-forming dwarf galaxies $\log M_\star/\mathrm{M}_\odot \approx 6.7 - 9$
- We commonly observe HI and OVI at a range of projected distances
- The inferred CGM gas mass in dwarfs exceeds the stellar mass and expected 21-cm HI ISM mass
- The kinematic distribution of metal absorbers is similar to that of Milky Way mass galaxies at z<0.5
- More detailed modeling of absorption associated with dwarf galaxies reveals insights into feedback processes+outflows







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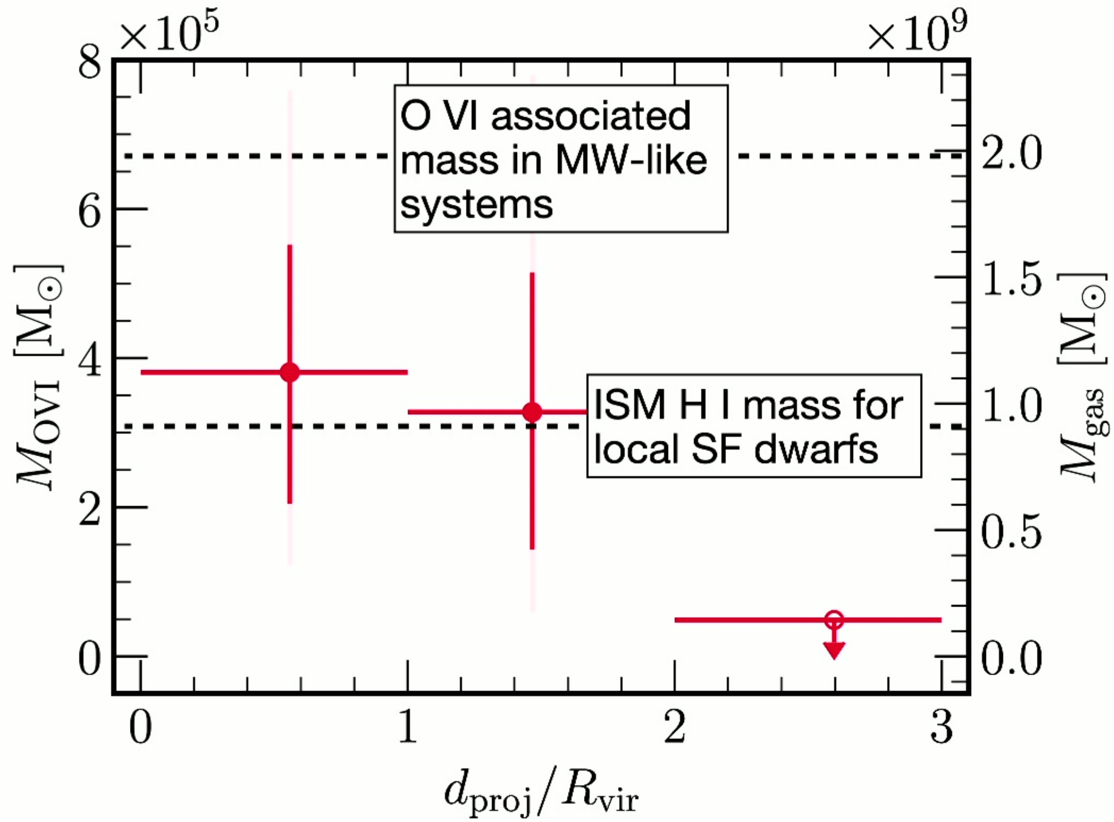

Is this metal mass bound? Unbound? Outflows?