Absorption Line Study of JWST Galaxies

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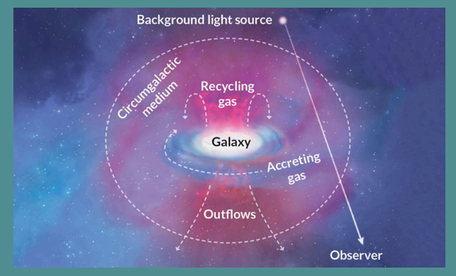


Fig 1. Schematic diagram of the circumgalactic medium and kinemattics within

Objective

This work aims at understanding the Circumgalactic Media (CGM) associated with three high-redshift galaxies observed in the GOODS-South field as part of the JWST (James Webb Space Telescope) Advanced Deep Extragalactic Survey (JADES).

Introduction

Galaxies continuously evolve over cosmic time through interactions with the surrounding circumgalactic media (CGM). Here, we present an absorption-line study of the CGM associated with three high-redshift galaxies with emission redshift in the range 1.9-3. Analysis of absorption spectra provides insight into the kinematics, depletion patterns, and gas conditions in these galaxy environments, with a focus on key metal lines such as Ca II, Mg II, and Na I.

Methodology

We surveyed and identified spectra with aborption features from the Data Release (DR) 3 catalog of NIRSpec/MSA spectroscopy for 4,000 galaxies (D'Eugenio et al., (2025)), observed within the Great Observatories Origins Deep Survey (GOODS) South Deep and Ultradeep field in the g140 grating wavelength range (0.6 - 2.0 microns).

Analysing absorption profiles can help calculate the column density N (abundance) (Fig 2.) through the total optical depth and observed intensity equations. Fitting a voigt profile enables us to find the best N parameter that succesfully equates them, implying a 'good fit'.

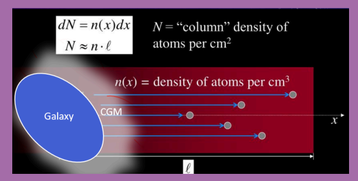
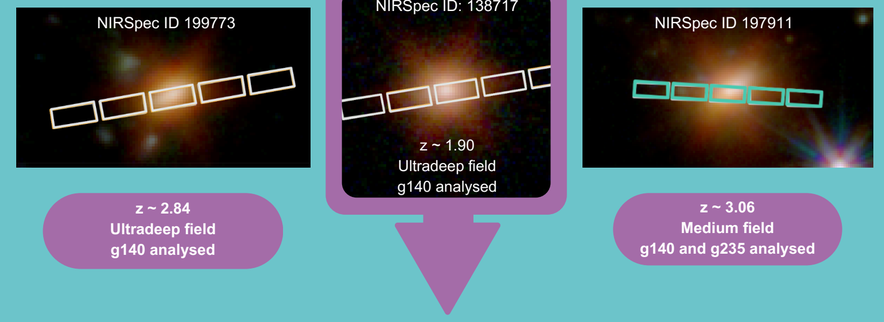


Fig 2. Column density implying the abundance of an element in the host galaxy

Previous studies featuring similiar high velocity widths in absorption as well as emission lean toward turbulent winds, inflows and outflows caused mainly due to star formation and/or active galactic nuclei (AGN) activity as the primary driving agent.

Analysis and Results

- We proceeded with laying metal absorption lines: CaII, NaI, MgII along with the Hydrogen Balmer lines on top of the spectra in the observer's frame of referennce (Fig.3), for the three shortlisted sources. Atomic transition data was referred to from the NIST Atomic Database.
- Next we employed the Python package VoigtFit (Krogager, J.-K. 2018) to fit single-component voigt profiles to our aborption features (Fig.4) in the spectra and obtain the column density (Table 1) for each element, to understand their abundamce in the CGM of the galaxy.
- Lastly we computed the depletion patterns (Table 2) using a volatile element: NaI and a non-volatile element: CaII or MgII depending on the wavelength range and good fit for each.
- The kinematic analysis reveals significant velocity widths in the galaxies, ranging from 400 to 2000 km/s, with absorption features indicating large-scale gas motions possibly linked to strong outflows, turbulent CGM dynamics, or AGN-driven winds.



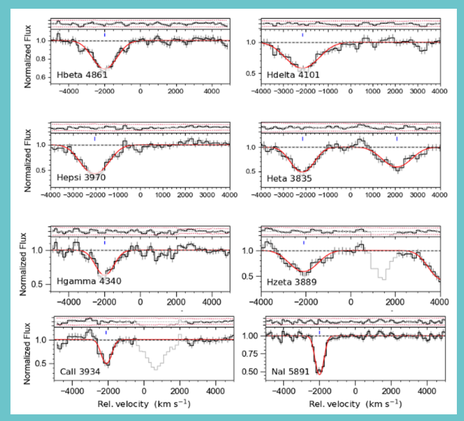


Fig. 4. Voigt profiles fit to absorption features in the galaxy spectra of NIRSpec ID 138717

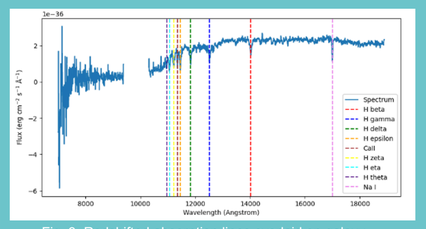


Fig. 3. Redshifted absorption lines overlaid on galaxy spectra of NIRSpec ID 138717

Element	v (km s^{-1})	b (km s^{-1})	log N
Ca II 3934	-1459.80 ± 23.70	367.38 ± 37.05	13.54 ± 0.04
Hβ 4861	-1327.40 ± 56.20	925.24 ± 101.15	14.53 ± 0.07
Hγ 4340	-1394.90 ± 27.60	650.64 ± 43.41	15.04 ± 0.03
Hδ 4101	-1348.70 ± 24.00	650.67 ± 37.84	15.43 ± 0.03
Hϵ 3970	-1330.20 ± 16.30	723.66 ± 23.38	15.93 ± 0.01
Hη 3835	-1351.70 ± 22.10	636.66 ± 32.96	16.14 ± 0.02
Hθ 3797	-1354.80 ± 23.80	591.10 ± 40.00	16.18 ± 0.03
Hζ 3889	-1314.90 ± 20.80	730.79 ± 32.34	16.00 ± 0.02

Table 1. Velocity offset v from prism redshift repoerted in DR3 catalog, Doppler parameter b and log of column density N computed from voigt profile fitting

Conclusion

NIRSpec ID	X	Y	[Y/X]
138717	Na	Ca	0.119 ± 0.074
197911	Na	Ca	0.342 ± 0.086

Table 2. Depletion [Y/X] calculated from volatile element Na and non-volaitle element Ca

Elemental abundance and depletion patterns in these environments appear to be quite different from the local interstellar medium.

These results, which are part of an ongoing study, shed more light on the role of galactic feedback, AGN activity, and dust processing in shaping the CGM at high redshifts. Probing more such sightlines, both from the JADES recent DR 4 and 5 release and the Nancy Grace Roman Space Telescope could enable a richer understanding of CGM-galaxy interactions across the history of the Universe.

Related literature
- **Keck absorption-line spectroscopy of galactic winds in ultra luminous infrared galaxies (David S. Rupke et al. 2002)**
- **A fast-rotator post-starburst galaxy quenched by supermassive black-hole feedback at z = 3 (Francesco D. Eugenio et al. 2025)**
- **Mapping the "invisible" circumgalactic medium around a z ˜ 4.5 radio galaxy with muse (Wuji Wang et al. 2021)**

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