Probing the Galaxies seen in Absorption

Joshi, R.[1], Srianand, R.[1], Petitjean, P.[2], Noterdaeme, P.[2]

[1]Inter-University Centre for Astronomy and Astrophysics, Post Bag 4, Ganeshkhind, Pune 411007, India

[2]UPMC-CNRS, UMR7095, Institut d'Astrophysique de Paris, F−75014 Paris, France

Abstract

With an aim to probe the nature of absorbing gas in emission at high redshift, we perform a stacking exercise to study the average Lyα emission associated with high-z strong (log N$_{(\mathrm{H\ I})} \geq 21$) damped Ly$\alpha$ systems (DLAs). We detect the Lyα emission profile, redshifted by about $300-400$ km s^{-1} with respect to the systemic absorption redshift. Interestingly, for the first time we detect a clear signature of a double-hump Lyα profile in DLA trough.
At low-z ($0.35 < z < 1.1$), we detect the nebular emission associated with 198 strong Mg II absorbers in SDSS quasar spectra. The Mg II absorbers are found to be typical of sub-L* galaxies with derived star formation rate in the range of 0.5-20 M$_\odot$ yr^{-1}, showing a higher detection rate with increasing rest equivalent width, W_{2796}. We show that finite fibre size plays a very crucial role in the strong correlation between W_{2796} and [O II] luminosity seen in stacked spectra. Interestingly, the physical properties of absorbing gas is found to be evolving with redshift and is consistent with those of galaxies detected in deep surveys.

Introduction

- The DLAs are the highest HI column density absorbers, with log N$_{(\mathrm{H\ I})} \geq 20.3$, trace the bulk of the neutral hydrogen at $2 < z < 3$. Presence of enriched elements, measured excitation of C II fine-structure levels etc. suggest DLAs are associated in some way with star forming regions. However, we still know little about how these most significant HI overdensities relate to star formation and the nature of host galaxies.
- At low redshift, metal lines, such as Mg II$\lambda\lambda$2796,2803 doublet, provides a direct tracer of neutral hydrogen column density, $10^{16} \leq$ N$_{(\mathrm{H\ I})} \leq 10^{22}$ cm^{-2}. At present, they are the best probe of dynamic environment, i.e., gas inflows and outflows in a luminosity unbiased manner.

DLAs in Emission

- **Spectral stacking exercise:** We have stacked 704 strong DLAs (i.e., log N$_{(\mathrm{H\ I})} \geq 21$) from SDSS to detect the Lyα emission in the bottom of DLA trough.
- We find $L_{\mathrm{Ly}\alpha} < 10^{41}$ (3σ) erg s^{-1} with a 2.8σ level detection of Lyα emission in the red part of the DLA trough.

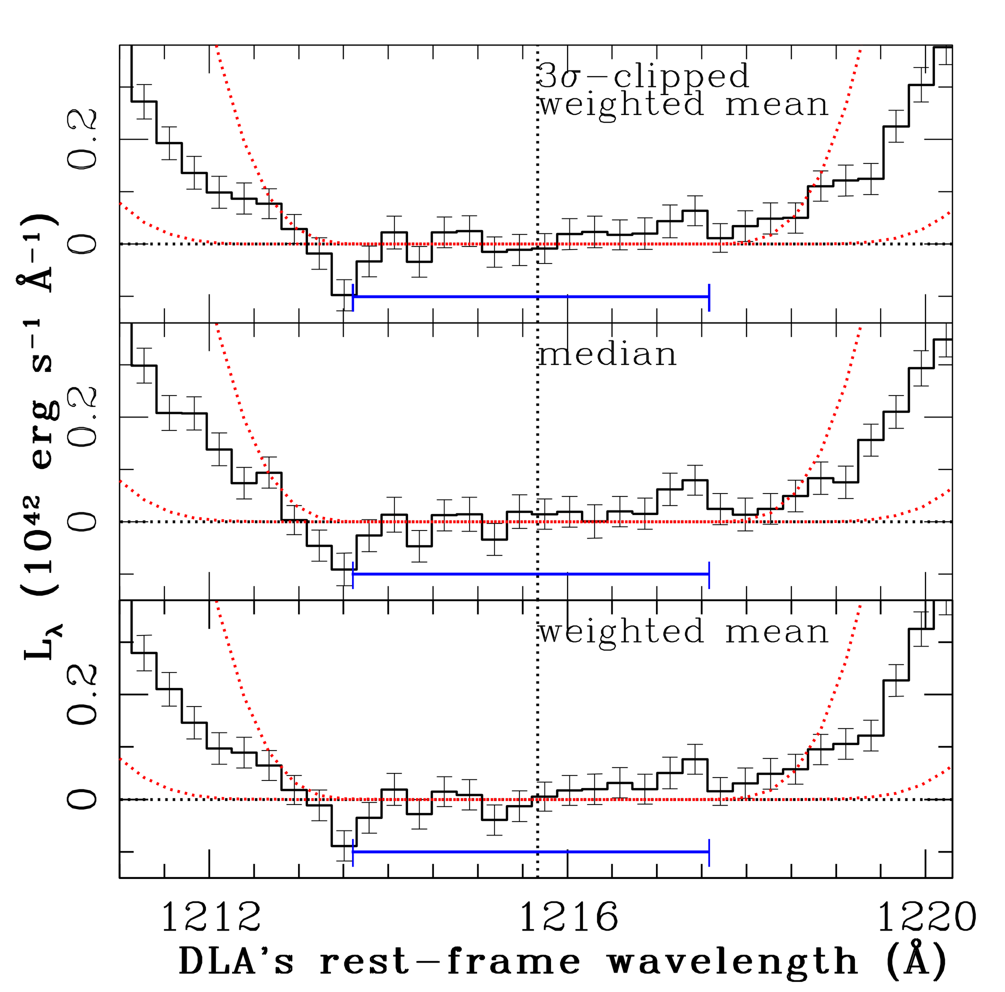

Fig. 1. The stacked spectrum for DLAs in the redshift range of $2.30 \leq z \leq 3.44$. The dashed curves show the synthetic profiles for lower (i.e., log N$_{(\mathrm{H\ I})}$= 21) and median (i.e., log N$_{(\mathrm{H\ I})}$= 21.23) column density of DLAs used to get the stacked spectrum.

Lyα emission: Dependence on W$_r$(Si IIλ1526)

- The Lyα luminosity is found to be higher for systems with higher W_{1526} with its peak, detected at $\geq 3\ \sigma$, redshifted by about 300-400 km s^{-1} with respect to the systemic absorption redshift, as seen in Lyman Break Galaxies (LBGs) and Lyα emitters.

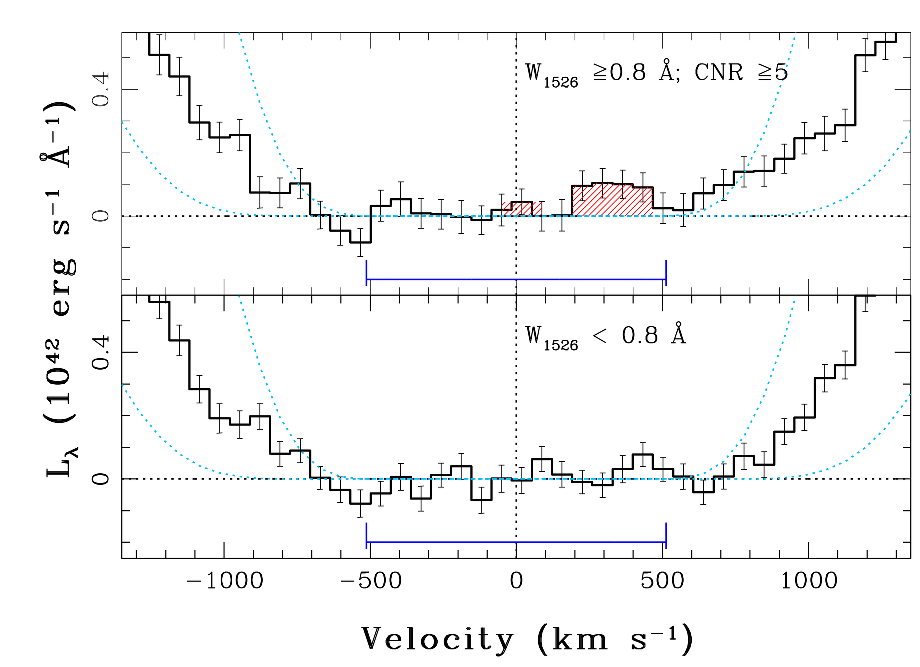

Fig. 2. Same as Fig. 1, for the subsets based on $W_{1526} \geq 0.8$ Å and $W_{1526} < 0.8$ Å.

Lyα emission: Dependence on QSO colours

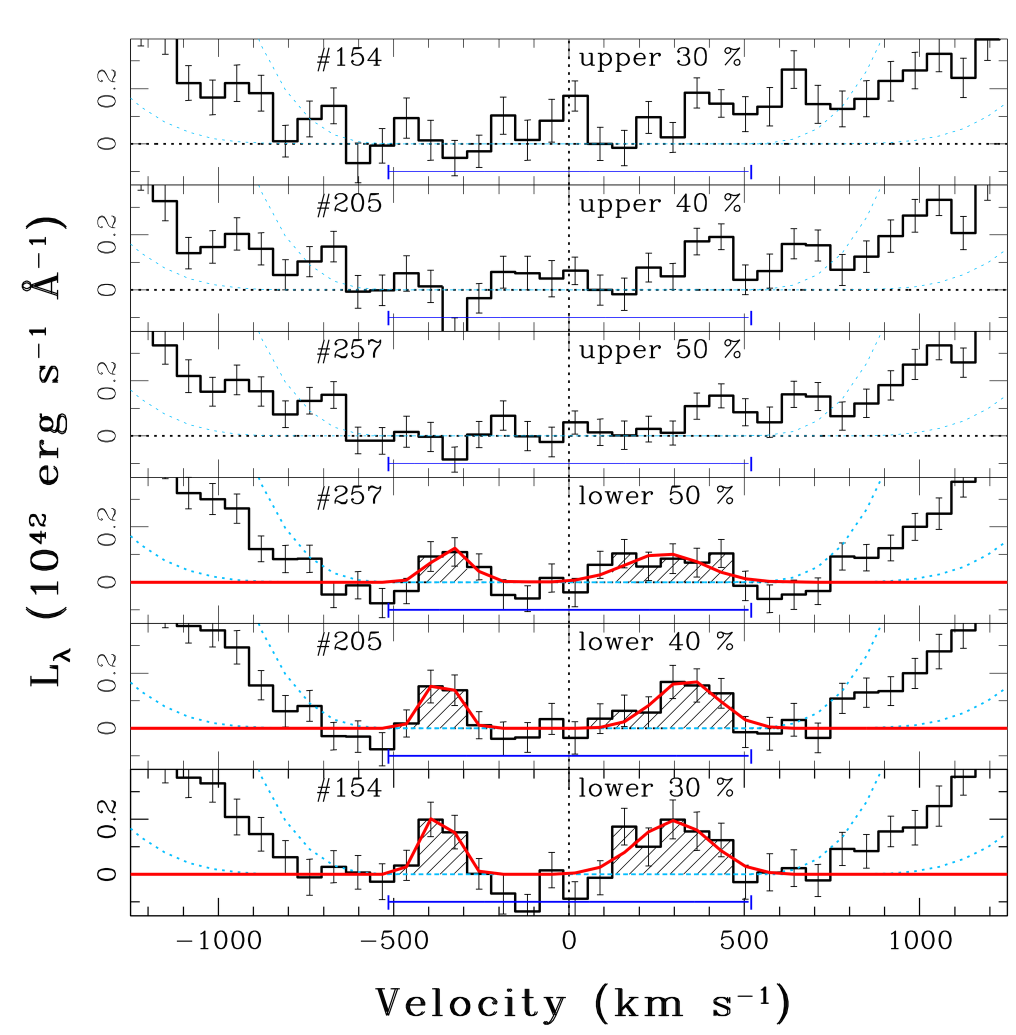

Fig. 3. The median stacked spectra for various sub-samples with $W_{1526} \geq 0.4$ Å with color selection criteria of $(r-i) < 0.05, < 0.08, < 0.11, > 0.11, > 0.13,$ and > 0.16. The **blue** segment shows the DLA core with $\tau \geq 10$ for log N$_{(\mathrm{H\ I})}$ = 21.0.

Mg II absorbers in Emission

Utilizing the fact that the fibre fed spectroscopic observations, registers photons from all the objects that happen to fall within the fibre along our line-of-sight we search for the nebular emission features from foreground Mg II systems in SDSS.

- **Sample selection criteria:**
  - Searched 11,000 and 37,000 Mg II absorbers with $W_{2796} \geq 0.1$ Å from SDSS-DR7 and DR12.
  - The z ranges from $0.35 \leq z_{abs} \leq 0.8$ and $0.32 \leq z_{abs} \leq 1.0$ for SDSS-DR7 and SDSS-DR12.

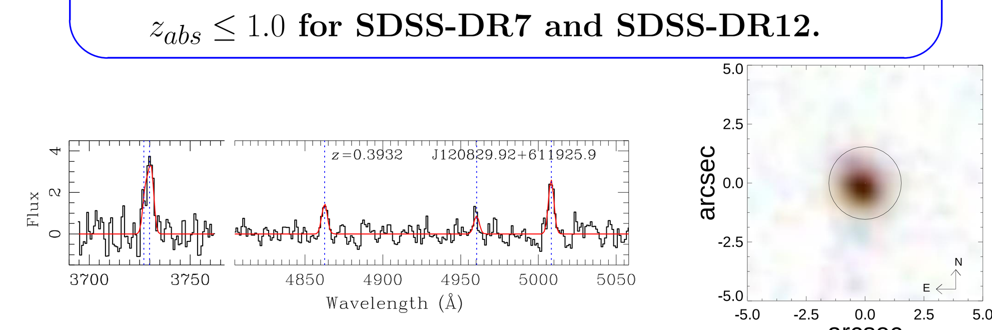

Fig. 4. Example of nebular emission lines detected in the continuum subtracted spectra from the intervening Mg II system.

Fibre size effect

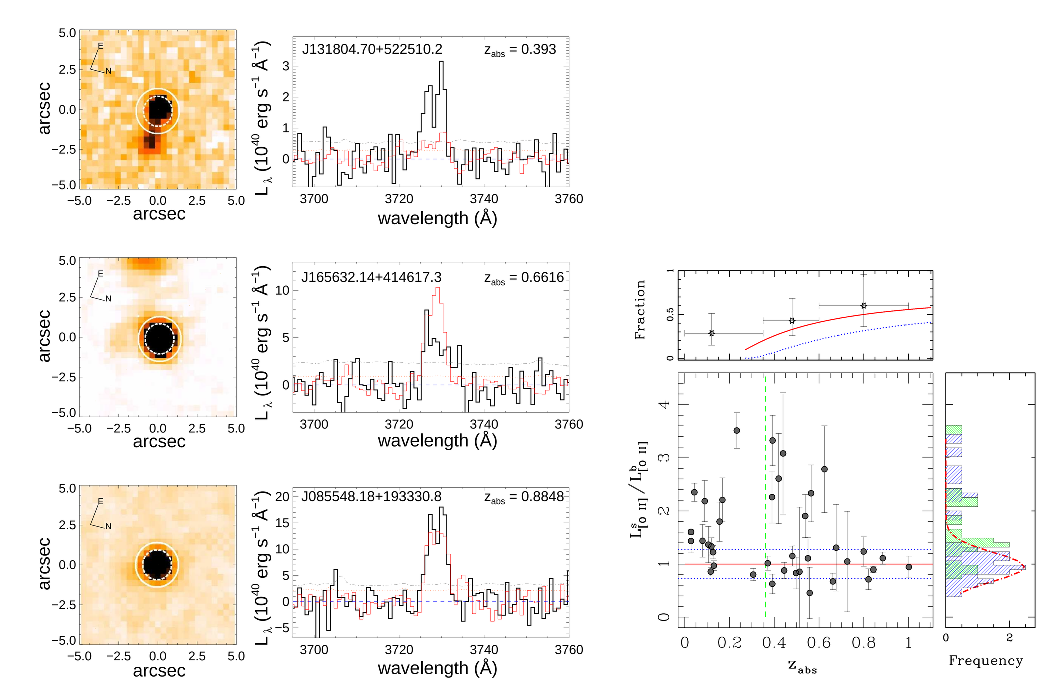

Fig. 5. In the left panel examples of variation in [O II] nebular emission line luminosity with change in fibre size from 3 to 2 arcsec in SDSS-DR7 (*thick solid line*) and DR12 (*thin solid line*) spectrum are shown. In the right panel we show the [O II] luminosity ratio measured between SDSS-DR7 and SDSS-DR12 spectra (i.e., L$^s_{[\mathrm{OII}]}$/L$^b_{[\mathrm{OII}]}$) as a function of absorber redshift.

L$_{[\mathrm{O\ II}]}$ vs W_{2796} and L$_{[\mathrm{O\ II}]}$ vs redshift

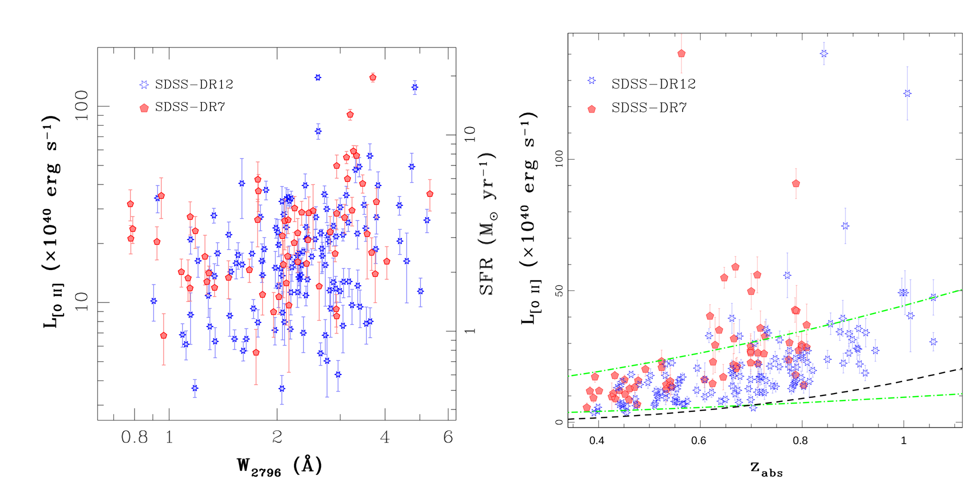

Fig. 6. *Left panel:* L$_{[\mathrm{O\ II}]}$ of Mg II absorbers as a function of W_{2796}. *Right panel:* The redshift dependence of L$_{[\mathrm{O\ II}]}$ associated with Mg II absorbers..

[O III]/[O II] and [O III]/Hβ nebular line ratio

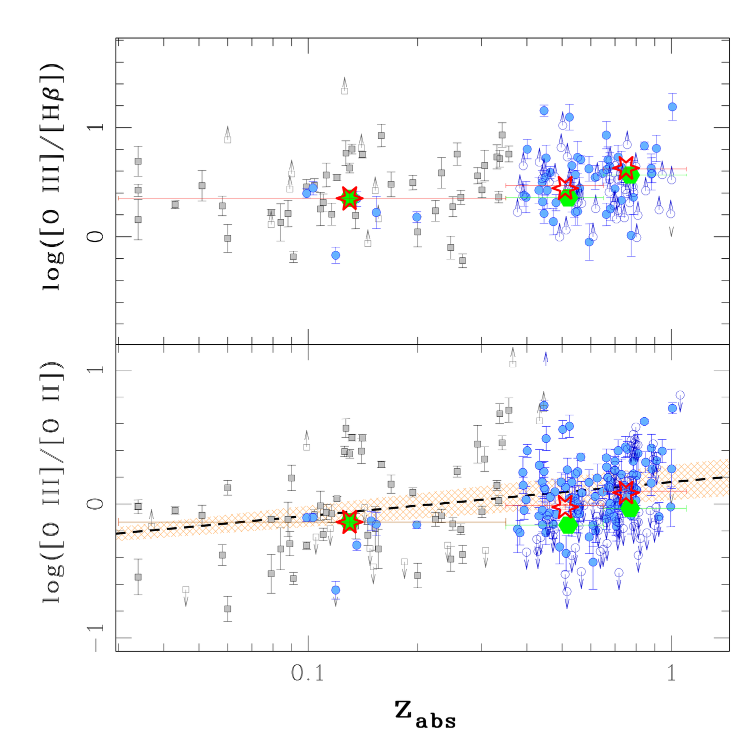

Fig. 7. The [O III]/Hβ (*top*) and [O III]/[O II] (*bottom*) line ratio as a function of z. The redshift evolution of [O III]/[O II], best described by a power-law fit by Khostovan et al. (2016 MNRAS, 463, 2363) is shown as *dashed line*.

- Based on the median stacked spectra, we infer the average metallicity (log Z $\sim$8.3), ionization parameter (log q $\sim$7.5)
- A rise of ~ 0.2 dex in the nebular emission line ratio of [O III]/[O II] is seen over a redshift range of $0.1 \leq z \leq 1$. The known stellar mass dependence on the line ratio suggest that the Mg II absorbers likely belongs to the population of low stellar mass galaxies with a typical stellar masses in the range $9.2 < \log(\mathrm{M/M_\odot}) < 9.4$.

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