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Probing the Gas Distribution of Lyα Emitting Galaxies through their Spectrally Resolved Lyα Emission

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We present the preliminary results of Magellan/IMACS deep, multi-object spectroscopic observations of 25 Lyα emitting galaxies (LAEs) at $2 \lesssim z \lesssim 3.5$ that were drawn primarily from the HETDEX Pilot Survey in the COSMOS field. With a spectral resolution of 150 km s^{-1} FWHM, we resolve the Lyα emission line profiles of these galaxies and observe an assortment of velocity and spatial structure due to the resonant scattering of Lyα photons in the H I gas of the galaxies' interstellar and circumgalactic media. The spectral structure includes varying degrees of asymmetry, a range of line widths, and a varying number of emission peaks with different velocity separations. Through parametric fitting of the Lyα line profiles, we quantify the observed structure and find evidence of a correlation between parameters describing the shape of the strongest emission line component and its velocity offset from z_{sys}, the galaxy's systemic redshift. Recent simulations have predicted a similar trend that is driven by the neutral hydrogen column density $N_{\rm HI}$ as a general property of Lyα radiative transfer in various H I distributions and kinematic configurations.

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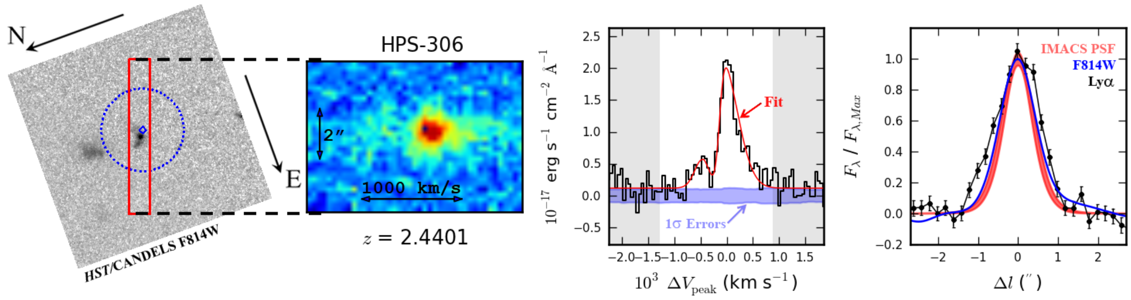

Figure 1: IMACS spectra of HPS-306, a double-peaked and extended LAE. ***Left***: *HST* F814W image. The IMACS slit is shown in red. The blue diamond (circle) is the Lyα centroid (positional error) from [2]. ***Middle Left***: IMACS 2D spectrum. ***Middle Right***: IMACS 1D spectrum plotted in velocity relative to the peak Lyα emission $\Delta V_{\rm peak}$. Note the "asymmetric Gaussian" fit in red. ***Right***: Spatial profiles plotted along the length of the slit Δl for the Lyα and continuum emission relative to the IMACS PSF.

1. Background and Observations

Lyα photons (1215 Å) are produced in the H II regions of star-forming galaxies due to hydrogen recombination after ionization by the UV radiation of young stars. The resonant scattering nature of the Lyα transition in H I results in frequency and spatial diffusion as photons random-walk out of the galaxy. This makes Lyα radiative transfer dependent on the distribution and kinematics of the H I gas, as well as the galaxy's dust content. The shape of the emergent Lyα spectrum thus encodes the physics of the scattering gas in a non-trivial way (e.g., [1]). We attempt to obtain a global perspective of the processes governing the escape of Lyα by comparing observed trends among the Lyα emission properties for a large sample of LAEs. We have obtained multi-slit Lyα spectra with Magellan/IMACS of 25 LAEs at $2 \lesssim z \lesssim 3.5$ in COSMOS, drawn from the HETDEX Pilot Survey [2, 3] and a narrowband survey for LAEs at $z \approx 2.25$ [4]. The spectra have 150 km s^{-1} FWHM spectral resolution, 0.9″ FWHM spatial resolution along the slit (7.3 kpc at $z = 2.75$), and a 1D 5σ line flux limit of 2×10^{-18} erg s^{-1} cm^{-2} in 5.25 hours of exposure at 4500 Å.

2. Lyα Classification and Spectral Line Profile Fitting

Fig. 1 shows an example of our IMACS data. Excluding two broad-line AGN, we classify the remaining 23 LAEs into three categories based on the 1D Lyα spectral line profiles: single peaks (48% of the sample), double peaks (43%), and LAEs with greater than two Lyα peaks (9%). These results are consistent with previous work [5]. The Lyα spectra are also collapsed spectrally to yield a spatial profile along the slit. To compare the spatial Lyα extent to that of the continuum, we convolve COSMOS F814W *HST* images ($\sim$ 2200 Å in the rest-frame) with the IMACS PSF and collapse the resulting image along the width of the slit. We find five LAEs with Lyα emission that is extended significantly beyond that of the continuum. Six LAEs are resolved in Lyα *and* continuum, while the majority (11 LAEs) are completely unresolved. Although our sample is small when subdivided in this way, we find no significant connection between the Lyα spectral classification and whether or not an LAE displays extended Lyα emission.

To quantify the spectral morphology of the Lyα line, we fit an "asymmetric Gaussian" function [6] to the 1D data, including an instrumental correction. For the double-peaked Lyα subsample,

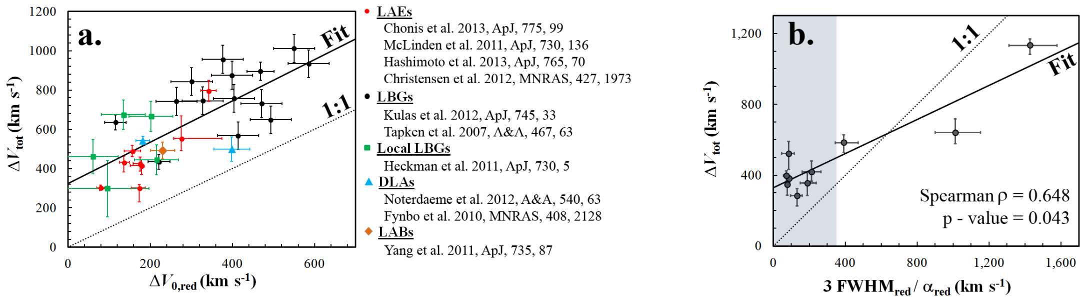

Figure 2: ***a***) The relation between $\Delta V_{\rm tot}$ and $\Delta V_{\rm 0,red}$ for double-peaked Lyα showing that $\Delta V_{\rm tot}$ scales with $\Delta V_{\rm 0,red}$ on average (but is offset from the unity relation). The data was compiled from the sources listed to the right of the plot. ***b***) The correlation between $\Delta V_{\rm tot}$ and $3{\rm FWHM_{red}}/\alpha_{\rm red}$, as derived from our Ly$\alpha$ line profile fitting for the double-peaked subsample, similar to the theoretical result shown in Fig. 16 of [7]. The blue region corresponds to the range of $3{\rm FWHM_{red}}/\alpha_{\rm red}$ covered in that work. Measurements of $z_{\rm sys}$ may result in a reduction of the scatter in the ordinate axis by allowing us to plot $\Delta V_{\rm 0,red}$ directly rather than $\Delta V_{\rm tot}$.

the measured parameters that are relevant here are the peak-to-peak velocity separation $\Delta V_{\rm tot}$, and the width ($\rm FWHM_{red}$) and asymmetry ($\alpha_{\rm red}$; defined in [6]) of the strongest emission component (i.e., the red peak for our sample). Currently, we do not have measurements of $z_{\rm sys}$ for these LAEs, so the Lyα velocity zero-point is unknown. However, data compiled from the literature shows that $\Delta V_{\rm tot}$ scales with the absolute velocity offset of the red Lyα peak $\Delta V_{\rm 0,red}$ (see Fig. 2*a*), albeit with significant scatter. With this in mind, we find a correlation between $\Delta V_{\rm tot}$ and $3{\rm FWHM_{red}}/\alpha_{\rm red}$, a parameter defined by [7] that describes the shape of the strongest Lyα emission peak (see Fig. 2*b*).

According to radiative transfer simulations by [7], LAEs with large $\Delta V_{\rm 0,red}$ (here, $\Delta V_{\rm tot}$) and large $3{\rm FWHM_{red}}/\alpha_{\rm red}$ have high $N_{\rm H\,I}$. Deviations from this correlation can indicate different kinematic/spatial configurations of the H I gas. If the observed relation between $3{\rm FWHM_{red}}/\alpha_{\rm red}$ and $\Delta V_{\rm 0,red}$ is sufficiently tight, it can also be used to predict $z_{\rm sys}$ based on observations of only Lyα. This could be powerful for studies that employ spectral stacking techniques to probe the UV continuum of LAEs. To properly explore this, we plan to obtain $z_{\rm sys}$ for our sample by observing their non-resonant nebular emission lines (e.g., [O III]λ5007), which may reduce the scatter in Fig. 2*b* by allowing us to plot $\Delta V_{\rm 0,red}$ directly. Additional observations of Lyα, particularly for LAEs with large $\Delta V_{\rm tot}$ (i.e., $\Delta V_{\rm 0,red}$) and $3{\rm FWHM_{red}}/\alpha_{\rm red}$, will also help to increase the statistical significance of the correlation shown in Fig. 2*b*. This work will be featured in a future unabridged publication.

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