Galaxies in Place of Quasars: Discovery of a Low Redshift Damped Lyman-alpha system in the Spectrum of a Star Forming Galaxy

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Overview
We have made the first discovery of a Damped Lyman-alpha (DLA) system using a star forming galaxy as a background source. Before this detection, finding a DLA required the background source to be a quasar—severely limiting the number of sightlines that could be probed. This new strategy for detecting DLAs will dramatically increase the number of sightlines available to search for intervening absorption-line systems in the universe.

Damped Lyman-alpha Systems
DLAs are clouds of neutral gas with hydrogen column densities $N(\text{H}I) \geq 2 \times 10^{20} \text{ cm}^{-2}$. The unique properties of these systems are that they are able to self-shield against photoionization. As a result, these clouds remain neutral against large ultraviolet flux. This self-shielding has implications for star formation as DLAs cool to become molecular clouds, the formation sites of new stars. Additionally, DLAs are the dominant source of neutral gas at $z \sim 3$ and are widely believed to be important for fueling cosmic star formation.

Observations
The ultraviolet spectrum of galaxy B was obtained using the Cosmic Origins Spectrograph (COS) aboard the Hubble Space Telescope (HST) as part of a low-redshift study of Lyman Break analog galaxies. A damped Ly$\alpha$ feature was found in the spectrum of galaxy B (Figures 1, 2) and upon inspection other low-ionization transitions were found associated with the same cloud (Figure 3). Using SDSS imaging we found the DLA to be associated with a second star forming galaxy in the foreground (galaxy A).

We obtained deeper ugri images of the field using the 1.8-meter Vatican Advanced Technology Telescope (VATT) on Mt. Graham (Figure 1) which uncovered a possible tail at the bottom of galaxy A. No spectroscopic redshift is available for galaxy C to confirm its location relative to galaxy A but the two could be part of an interacting system.

Results
We are probing galaxy A at an impact parameter of 36 kpc. The DLA is 237 km/s offset from the systemic velocity of galaxy A. The properties of galaxy A can be found in Table 1. Although we obtained deeper imaging of the field than SDSS, we cannot determine whether we are probing the extended disk or the circumgalactic medium (CGM) of galaxy A.

Another interesting possibility is that we are probing through a tidal tail as a result of an interaction between galaxies A and C (or a possible unseen system in the sightline of B). There is no available spectroscopic redshift for galaxy C, however the SDSS photometric redshift does place it at a similar redshift as galaxy A ($z = 0.195 \pm 0.0652$). While galaxy A is normal star forming galaxy with no active AGN[6][7], the SFRs in Table 1 do show increased star formation in the last 10 Myr. Additionally, an interaction may explain the presence of the DLA as part of a tidal structure.

References

Table 1: Galaxy A Properties

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<tr>
<th>log $M_*$</th>
<th>SFR$_{10}$</th>
<th>SFR$_{100}$</th>
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<td>(log $M_\odot$)</td>
<td>(M$_\odot$ yr$^{-1}$)</td>
<td>(M$_\odot$ yr$^{-1}$)</td>
</tr>
<tr>
<td>11.23</td>
<td>10.34</td>
<td>1.056</td>
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Figure 1: ugri false-color image of the galaxy system from VATT. The DLA was found in the spectrum of galaxy B. Based on the feature on the bottom of galaxy A (inset image), the spectral sightline might be passing through a tidal tail as a result of an interaction with galaxy C.

Figure 2: HST-COS spectrum showing the Ly$\alpha$ absorption feature. The best-fit Voigt profile is overplotted in blue. The continuum is more complicated due to using a star forming background source. As a result the centroid was fixed to the same velocity as the more well defined components below. The feature at ~1750 km/s is the Ly$\alpha$ emission from the background source (galaxy B).

Figure 3: HST-COS spectrum showing the metal-line absorption features. The best-fit Voigt profile is overplotted in blue. The continuum is more complicated due to using a star forming background source. The centroid of the strongest component is located at $z = 0.17126$.

Future Implications
With the next generation of large, 30-meter class telescopes coming online in the following decade, this method of using star forming galaxies as background sources to discover intervening absorption-line systems will be much more applicable. Steidel et al. (2010)[8] studied the CGM in high redshift ($z \sim 2 - 3$) L$^*$ galaxies using composite star forming background sources. New telescopes like GMT, ELT, and TMT will have the sensitivity and FOV needed to conduct large spectroscopic surveys of high redshift ($z \sim 1 - 5$) galaxies to search for intervening systems like the DLA presented here and to study gas accretion and outflows like Steidel et al. (2010).