Discovery of a Galaxy Responsible for a DLA System at $z = 3.15$ and a Near-Infrared Search for Primeval Galaxies

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Abstract.

We report the detection, both in line and continuum emission, of a galaxy responsible for a damped Ly$\alpha$ absorption (DLA) system at $z = 3.15$ projected $2.3''$ from QSO 2233+131. The star formation rate implied by both the Ly$\alpha$ and restframe far-UV continuum is $\sim 7 \, M_{\odot} \, yr^{-1}$. The galaxy also shows no sign of an active nucleus and has blue colors, both consistent with it being observed early in its star formation history. The Ly$\alpha$ emission is offset $\sim 200 \, km \, s^{-1}$ from the DLA velocity, which could be explained as the rotational signature of a disk galaxy.

We also report on the progress of an ongoing near-infrared narrow-band search with the Keck telescope for line emission from a population of primeval galaxies at high redshift. We have found several promising candidates which are being followed up with optical spectroscopy. Our survey is beginning to place constraints on a possible population of slightly dusty primeval galaxies at high redshift.

1. Discovery of the Galaxy Responsible for DLA 2233+131

Damped Lyman-alpha absorber (DLA) systems, detected along lines of sight to unrelated high-redshift quasars, have been proposed as possible progenitors of normal disk galaxies today. They appear to contain a substantial fraction of the baryons known to exist in normal galaxies today (Lanzetta, Wolfe, & Turnshek 1995). Several searches for the galaxies responsible for various DLA systems have resulted in a few detections of emission–line galaxies (Lowenthal et al. 1991; Macchetto et al. 1993; Møller & Warren 1993; Francis et al. 1996), but all appear either to be AGN or are at a similar redshift as the QSO, suggesting that the source of their ionization may not be a result of star formation.

We report on the detection of an object, designated DLA 2233+131, responsible for a previously known DLA system at $z_{\text{abs}} = 3.150$ (Lu et al. 1993) in the spectrum of QSO 2233+131 ($z_{\text{QSO}} = 3.295$; Crampton, Schade, & Cowley
The spectra of QSO 2233+131 [top] and DLA 2233+131 [bottom]. The DLA is seen in emission 2.3′′ projected from the QSO. The DLA shows emission from Lyα at $z = 3.153$, and no signs of higher-ionization lines that would be expected for an active nucleus.

1985). It was found serendipitously during observations of a candidate for a different DLA system in the same field. The object was also selected independently as a DLA candidate on the basis of its broad-band colors by Steidel, Pettini, & Hamilton (1995), which was unknown to us at the time. We obtained direct images of the field in the $V_C$ and $R_C$ bands, and long-slit spectra using low and moderate resolution gratings. Details can be found in Djorgovski et al. (1996). The discovery spectrum of the DLA is shown in Figure 1; the QSO spectrum is plotted for comparison.

We find the DLA in emission at a location offset 2.3′′ (17.2 kpc for $H_0 = 75$ and $\Omega_0 = 0.2$) from the QSO line–of–sight. There are no signs of any higher–ionization emission lines from the DLA, suggesting that this object does not harbor an AGN. The star formation rate implied by the Lyα line is 7.5 $M_\odot$ yr$^{-1}$, and that by the restframe far–UV continuum is 6.4 $M_\odot$ yr$^{-1}$, suggesting that there is very little dust present in this galaxy. The Lyα luminosity for this galaxy is the highest for non–AGN at these redshifts in the list of Steidel et al. (1996). This galaxy’s luminosity is similar to that of a $L^*$ galaxy today.

The emission line appears offset by $\sim 200$ km s$^{-1}$ from the damped absorption line, which could be explained by a rotating disk galaxy. DLA systems represent a significant population of high–redshift objects which have been proposed as the progenitors of normal disk galaxies (Wolfe 1993). Our observations for DLA 2233+131 are fully–consistent with that hypothesis. HST images are planned for this source (C. Steidel, private communication), which may be capable of determining if the source shows a disk–like morphology or one more similar to that of the Steidel et al. population (e.g. in Giavalisco et al. 1996).
2. A Near-Infrared Search for Line Emission from Protogalaxies

The search for primeval galaxies—a population of the progenitors of present-day spheroidal galaxies—is a central goal of modern observational cosmology. Recent optical searches for the signs of Lyα emission from such a population (e.g., Thompson, Djorgovski, & Trauger 1995) have been largely unsuccessful. Those optical searches for Lyα could be brought into agreement with the present-day space density of spheroidal systems if the primeval galaxies were, in general, enshrouded in a modest quantity of dust.

Similar searches for longer-wavelength emission lines should be much less-affected by dust obscuration. For this reason, we are pursuing a search for the O II, Hβ, [O III], and Hα lines at redshifts of $2 < z < 5$ using the near-infrared camera on the W. M. Keck Telescope. We have deliberately chosen fields centered on high redshift QSOs, DLAs, or radio galaxies, and narrow-band filters to match an emission line at that known object’s redshift. Results for the first four fields were presented by Pahre & Djorgovski (1995); to date we have surveyed nearly three times the area described in that work, and are reaching flux limits up to twice as deep. The estimated limits imposed by our survey are shown in Figure 2. Comparison is made to several other near-infrared searches: Thompson, Djorgovski, & Beckwith (1994, TDB); Parkes, Collins, & Joseph (1994, PCJ); and Mannucci, Beckwith, & McCaughrean (1994, MBM). (See Pahre & Djorgovski 1995 for further details on the comparison.) In our search we have found a few promising candidates with narrow-band excess emission of $> 3\sigma$, and are currently following these up with optical spectroscopy.

As shown in Figure 2, we are beginning to probe the relevant region of parameter space where we would expect to find a population of primeval spheroidal galaxies if they were to form during a relatively short burst ($\tau < 0.1$ Gyr) of star formation while obscured by a small quantity of dust. We note that the population of star-forming galaxies discovered by Steidel et al. (1996) should be undetected in our survey because of their low star formation rates and surface density. On the other hand, if there exists a population of highly-reddened, star-forming galaxies at these redshifts they would be missed by the blue selection criteria of Steidel et al. but should in principle be found by our search for the longer-wavelength nebular lines. Furthermore, the importance of resonant scattering of the Lyα found by Steidel et al. should not affect the nebular lines used in our near-infrared search.

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Figure 2. The estimated limits set by near-infrared narrow-band searches for emission-lines due to primeval galaxies. Regions of the figure above and left of the lines are excluded by the observations. The effects due to a simple dust screen model with $A_V = 2$ mag, which is required to explain the lack of detection of Lyα for optical searches for primeval galaxies, is shown in the right panel. The population of $z > 3$ star-forming galaxies discovered by Steidel et al. (1996, S96) is shown at the bottom of the left panel; the effects of resonant scattering on the Lyα line are shown with an arrow. Two single-burst models are shown in the right panel and labelled with their star-formation timescales.

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