High Redshift Lyman Break Galaxies

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Abstract. Two of the most outstanding issues in modern astrophysics are what reionized the Universe and how did the first objects form. Observations of galaxies selected through the Lyman-Break technique indicate that UV photon output at the end of reionization was dominated by relatively faint low mass galaxies and not AGN.

1 Background

Galaxies at the highest redshifts, z>5, are the key to our developing understanding of how galaxies have formed and evolved, and how the Universe was reionized. The recent results from the Wilkinson Microwave Anisotropy Probe (Kogut et al. 2003) combined with the fact that the Universe appears to be opaque to Lyman continuum photons at z≈6 (Becker et al. 2001; but see Songaila 2004), suggests that the Universe had a very complex reionization history.

Probing the re-ionization epoch directly will be exceedingly difficult with the current generation of telescopes and instrumentation. On physical grounds, observing Ly-α emission may be difficult. An optical depth of a few in the Lyman continuum is reached at very low neutral fraction in the IGM ($\approx 10^{-5}$). Thus damping wings of the neutral material will effectively eat into the galaxies Lyα emission even at relatively low neutral fractions. Although sources will create their own HII regions, observability of Lyα will depend on the star-formation rate, lifetime, local galaxy and halo gas density, and kinematics of neutral halo gas. Although lines like HeIIλ1640 or CIVλ1549 could be used, they are likely to be much weaker except at low metallicities. On technical and functional grounds, obtaining robust compete samples of z- or J-band drop outs (6.5<z<10.3) will be difficult. Current near-infrared imagers on 8m class telescopes have small fields of view (<20 arcmin^2) and the source density of (even bright) sources is likely to be very small (few tenth per arcmin^2 at most). Moreover, the "spectral filling factor" of the night sky lines is 40-50% even at moderate resolutions (R=4000) and Nyquist sampling implying that many line emitters will be missed. Perhaps more importantly, it will be challenging and time consuming to detect these faint objects in two band longward of Lyman continuum break. Having a two band detection is important to eliminating spurious or contaminating sources like stars or lower redshift red galaxies.

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2 Survey for High Redshift LBGs

However, large samples of high redshift galaxies are required in order to carry out detailed studies of their properties and to ensure that conclusions drawn are not subject to cosmic variance. In addition, the selection techniques must be varied so that biases do not hamper us in obtaining a broad understanding of early galaxy evolution. Thus large areas need to be surveyed and both continuum break techniques and narrow-band imaging should be used. The later of these is particularly important. Galaxy selected using the Lyman break technique are sensitive to the brightness of the rest-frame UV continuum and would be generally expected to be sensitive to galaxies which have low equivalent width Lyα lines. On the other hand, narrow-band selection favors galaxies with high equivalent width emission lines – typically greater than a significant fraction of the filter width and will discover galaxies with faint rest-frame continua. In addition, narrow band selection allows one to pick a region with few night sky lines and thus make spectroscopic follow-up that much easier (see contributions by Tanaguichi and Cowie). However, the disadvantage of narrow-band selection is that wide areas need to be surveyed since the volume contributed by the redshift coverage is small.

Until now, we have been in the exciting "discovery phase", showing that it is indeed possible to detect high redshift galaxies with current instrumentation on 8-m class telescopes. To create such large samples, we have an on-going program to obtain deep R-, I-, and z-band images with FORS2 on the VLT. This 3 color technique relies on the fact that the continuum opacity in the Lyman continuum is high at redshifts above about 5 giving galaxies at these redshifts very red R-I or I-z colors. Galaxies selected in this manner have redshifts between 4.8 and 6.4 (using R-I and I-z color selection technique with the FORS2 filters and CCD response).

We identified a field of about 200 arcmin^2 with extremely low galactic extinction and infrared cirrus emission that was well-placed in RA for ease of service observing. The field was chosen to have a declination of -35, so that it went roughly overhead at Paranal but meant that the telescope faced south, out of the prevailing wind, minimising the time the field was unobservable due to weather conditions. In 2002 we imaged 40 arcmin^2 to a depth of R_{AB}=27.8, I_{AB}=26.5 and z_{AB}=26. In 2003 we deepened this field in z to z_{AB}=26.5 and imaged a further 40 arcmin^2 to the same depths in the 3 filters. Two more similarly-sized regions should be imaged in 2004, leading to complete imaging of a 160 arcmin^2 region of sky.

Sources that appear to have spectral breaks can be selected from the imaging data. Starting with a flux-limited sample in the I-band (to I_{AB}=26.3) we can identify such sources by requiring R-I>1.5. To-date we have followed up spectroscopically the sources identified in the 80 arcmin^2 of imaging data we have obtained so far (see Lehnert & Bremer 2003 for details of the first 40 arcmin^2). All of these sources meeting the flux and colour criteria, except one, have been observed with FORS2 using the MXU mode.