A MOSAIC Search for Lyman Alpha Emitting Galaxies at z~2.1

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Introduction

The study of galaxy formation and evolution is one of the most active areas of research in astrophysics. Due to the finite speed of light, observations of very distant galaxies provide us with historical snapshots of the early Universe. In studying these high redshift galaxies, astrophysicists can model how the homogeneous Universe as seen in the Cosmic Microwave Background evolved into the heterogeneous and galaxy-filled Universe that we observe locally.

Lyman Alpha Emitters (LAEs) are high redshift galaxies that emit Lyman alpha radiation. This emission of Lyman alpha radiation is thought to be indicative of outbursts of star formation in galaxies (Partridge & Peebles 1967). Due to their compact size and starburst nature, they are believed to be the building blocks of most galaxies that we see in the local Universe (e.g., Gawiser et al. 2007). In addition, the specific redshifts of observed LAEs provide crucial insight into the formation of dark matter halos and hence the evolution of matter distribution in the Universe.

We present narrow-band imaging from the Mayall 4-meter at KPNO and the Blanco 4-meter at CTIO consisting of three data sets obtained over a three year period. Using this data, we attempt to select LAEs at an intermediate redshift of z~2.1 to probe the evolution of the Lyman alpha luminosity function (LF) and the characteristic number density. Although the LF does not evolve much between z = 3.1- 6 (e.g., Dawson et al. 2007, Ouchi et al. 2008), observations at z ~ 0.3 show changes in the LF and number density corresponding to a fainter and rarer sample of LAEs (e.g., Deharveng et al. 2008). In addition, our sample at z ~2.1 will allow us to investigate the age, stellar mass, dust, and dark matter halo mass evolution in LAEs down to z ~ 2.1.
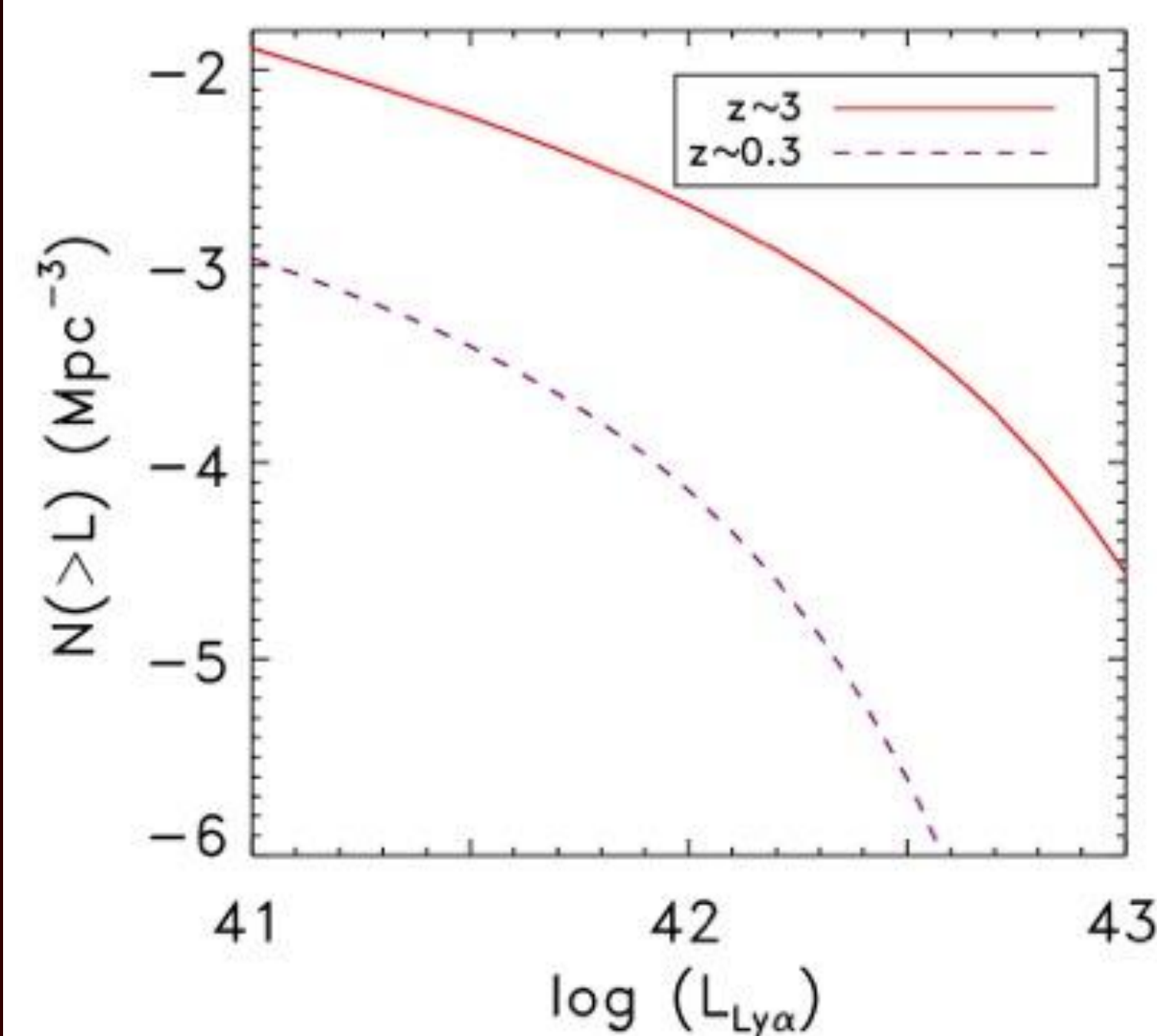
Figure 1
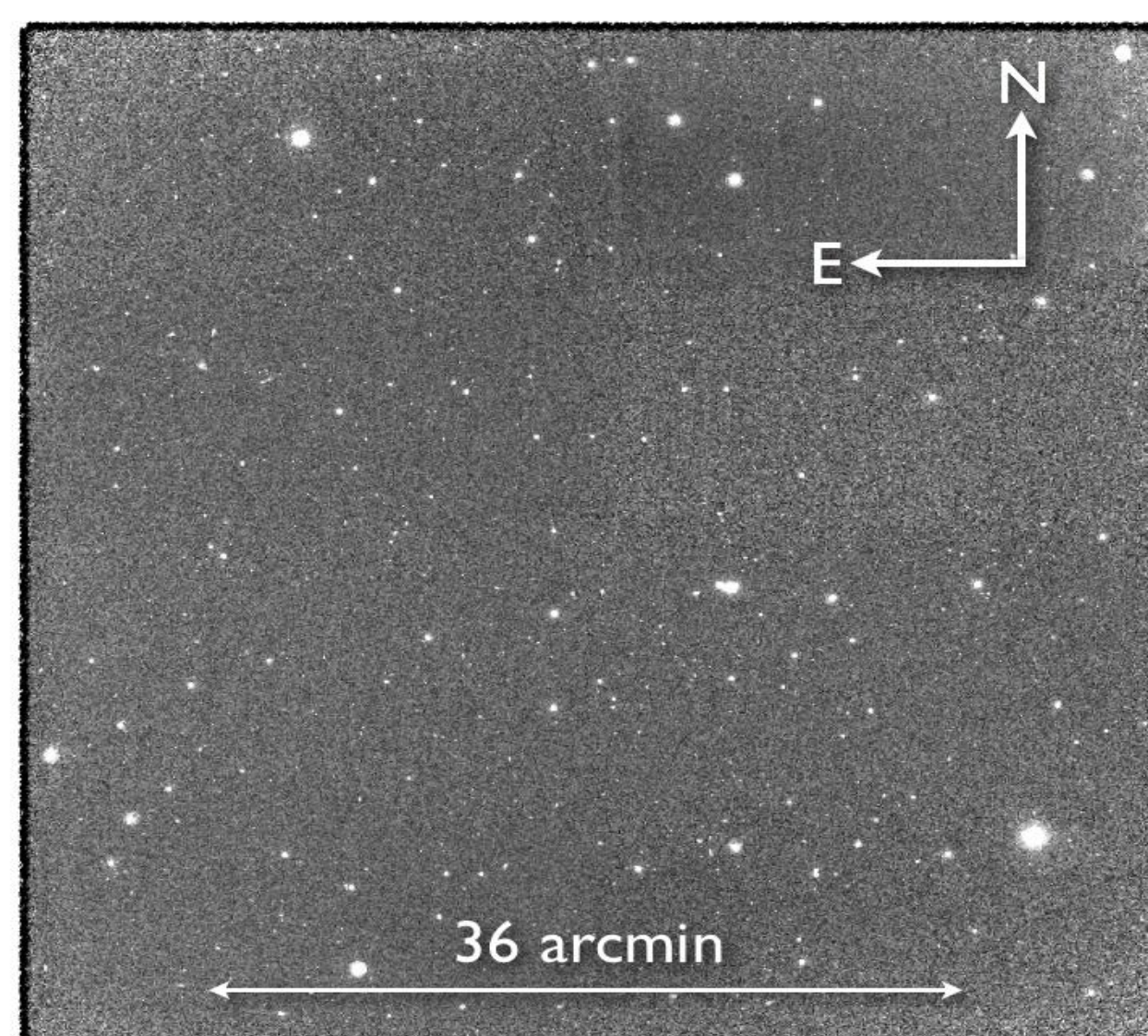

To the left we see the luminosity functions of z~3 LAEs (Gronwall et al. 2007) compared to that of a sample at z~.3 LAEs (Deharveng et al. 2008). The difference in look-back time between these two curves corresponds to about 10 billion years.
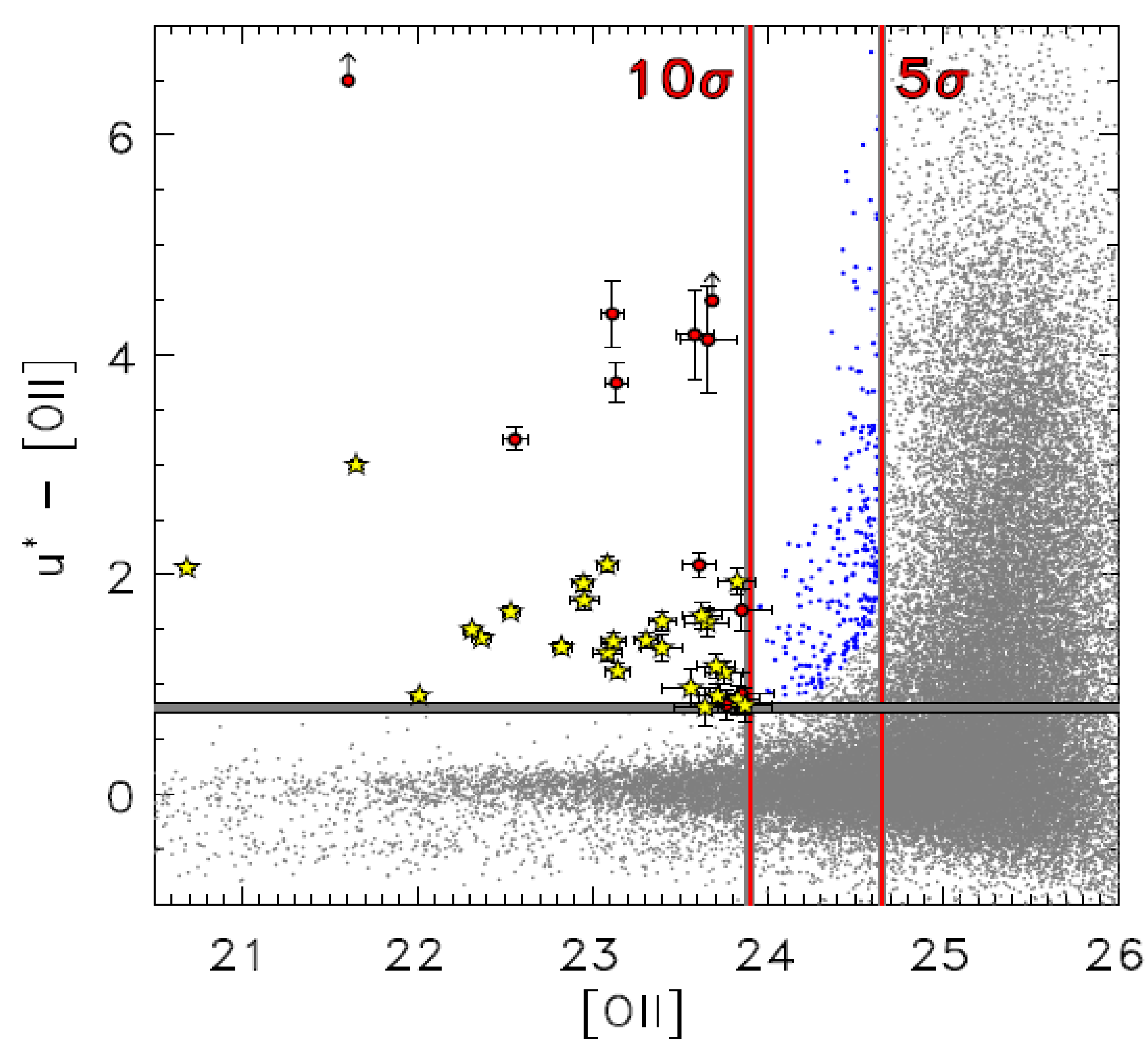
Figure 2

To the right is our final reduced [OII] narrowband image of the central region of the COSMOS field. Reductions consisted of crosstalk, overscan, and trim corrections in addition to cosmic ray rejection, and world coordinate system (WCS) fitting. We then resampled the 8-extension object and bad pixel mask frames into single images with a simple WCS. With our reconstructed MOSAIC image, we next matched the intensity scales of the image. Lastly, we performed a stacking procedure which incorporates the WCS and combines multiple reconstructed MOSAIC images. Due to the dithering of the images, the gaps between the separate chips were replaced by useable data. The data set with the best seeing from 2009 (KPNO) was finally stacked into the image above which increased the effective depth of the field in order to better detect the LAE candidates.

Abstract

Lyman Alpha Emitting Galaxies (LAEs) are extremely important in the study of galaxy evolution as their clustering indicates that they are the likely progenitors of Milky-Way size galaxies in the local Universe. Although observations of LAEs at 3.1 < z < 6 indicate very little evolution of the luminosity function (LF), separate observations at z~0.3 indicate that low-redshift LAEs are both rarer and fainter. We use narrow-band imaging to select LAEs at an intermediate redshift of z~2.1 to search for evolution in the range of 0.3 < z < 3.1. The data sets consisted of images gathered from three separate observing runs spanning three years at the Kitt Peak National Observatory (KPNO) and Cerro Tololo Inter-American Observatory (CTIO). In addition to standard reduction techniques, we used specifically designed reduction tasks for the MOSAIC camera at KPNO and CTIO in order to combine our final reduced images into a single stacked image. This deep, stacked image will aid us in detecting LAEs at our chosen redshift of z~2.1. Using this sample at z~2.1, we hope to investigate certain evolutionary properties of LAEs including age, stellar mass, dust and dark matter halo mass. We will present a status update on this project, including our initial sample of z~2.1 LAEs.

Figure 3

Using the narrowband image as the detection image, we performed aperture photometry on the narrowband image, as well as on broadband u* (CFHT/Megacam) and BVgriz (Subaru/SuprimeCam) images from the COSMOS survey. Using the fluxes in 2.4" diameter apertures (~2X the seeing disk), we selected candidate LAEs with the following criteria: > 10-sigma detection in the narrowband, a narrowband excess (i.e., narrow/broad flux ratio) > 2.1 (which is equivalent to a rest-frame Lya equivalent width [EW] > 20 A) at a > 4-sigma significance. The figure above shows our selection plane. The 37 objects above the gray line (the narrowband excess cut), and to the left of the 10-sigma line composed our initial sample. These objects were visually inspected to eliminate bad pixels and other non-real sources. The 26 candidate LAEs which passed our visual inspection are shown as the yellow stars. The red circles shown to the left of the 10 sigma cutoff represent LAE candidates that were visually inspected and did not appear to be genuine LAE sources. Upon inspecting these non-genuine sources, we witnessed bad pixels and nearby bright sources that may have caused these to be initially selected as LAE candidates. Further analysis of these samples will be done in the future, specifically in determining a more reasonable sigma cutoff.
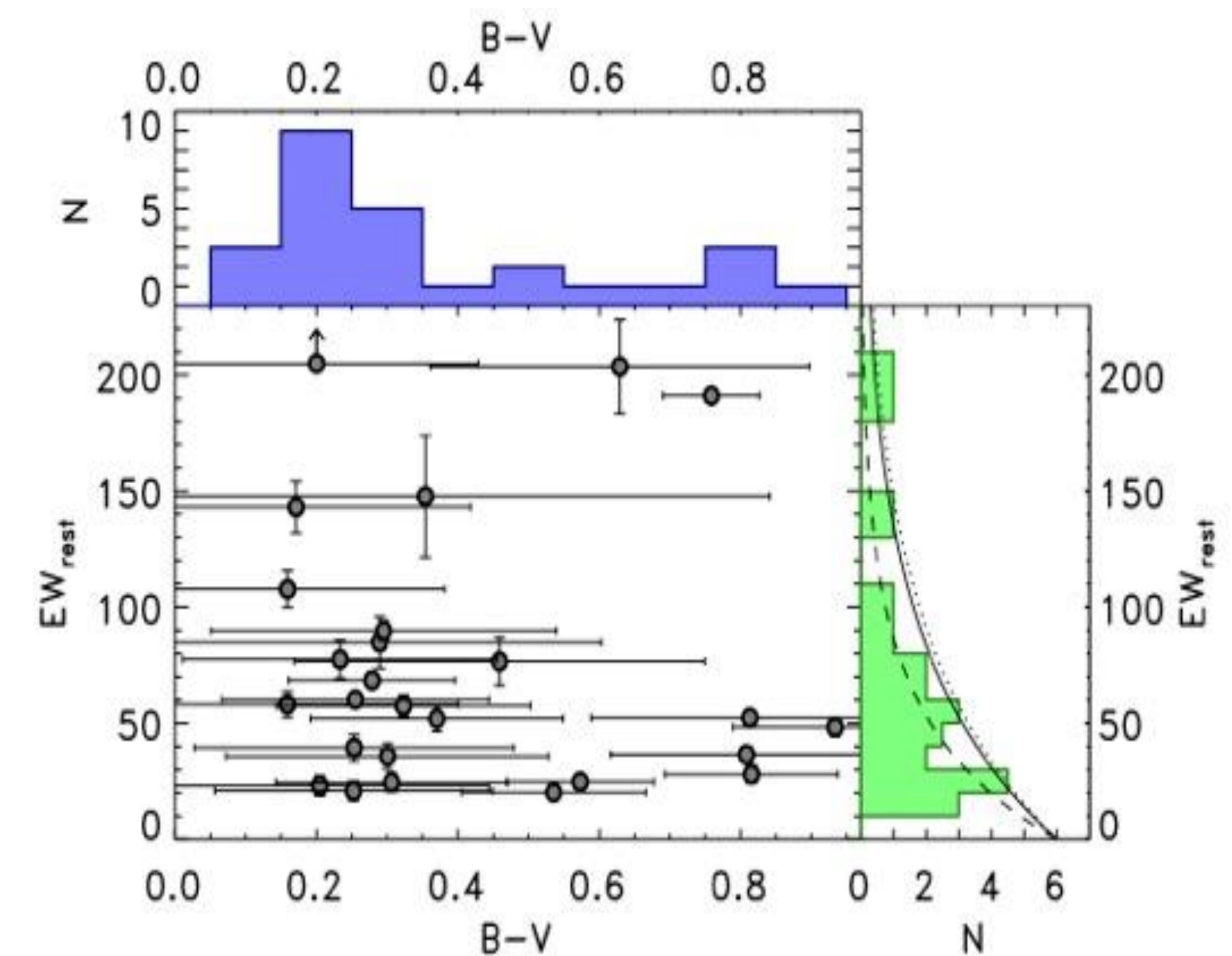
Figure 4

The above figure shows our initial analysis of this conservative LAE sample. In it we plot the rest-frame EW as measured by the narrow-to-broad-band flux ratio, versus the B-V color, which is a measure of the rest-frame ultraviolet (UV) color. The blue and green histograms show the distribution of colors and EWs, respectively. The majority of LAEs appear relatively blue (i.e., B-V ~ 0.2), though the average is somewhat redder than at higher redshift (e.g., Finkelstein et al. 2009), and there is a tail toward redder colors. The UV color is dominated by the dust extinction (c.f., Bouwens et al. 2009), thus on average our sample of LAEs appears at least a little dustier than typical samples at higher redshift, with a small fraction of galaxies that appear significantly dusty. A few of our LAEs have EWs > 100 A, though all have EW < 240 A, thus appearing consistent with "normal" star formation. We overplot on our EW distribution the published EW distributions from Gronwall et al. (2007) at z~3.1 (solid line), Guaita et al. (2010) at z~2.1 (dotted line) and Nilsson et al. (2010) at z~2.25 (dashed line). Our EW distribution, specifically the high-EW tail, appears more consistent with the previous work by Guaita et al. at z~2.1, thus implying little evolution in the EW distribution from z ~ 3 to 2. Finally, there is a rough correlation between color and EW, where the higher EW galaxies tend to have bluer colors, though there are a couple red, high-EW galaxies. The latter could be explained by a patchy interstellar medium which facilitates the escape of Lya photons (e.g., Neufeld 1991; Finkelstein et al. 2009).

Future Work

In the immediate future we plan to refine our selection criteria by using simulations to see how far we can reliably push our signal-to-noise cut in the narrowband image. Once our sample is finalized, we will apply for follow-up optical spectroscopy to confirm the redshifts of our sources. We can then pursue our study of the Lya luminosity function, to see whether it has begun its decline in the Gyr from z=3 to 2.

References

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