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New quasar surveys with WIRO: Searching for high redshift (z~6) quasar candidates

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Abstract

High redshift quasars (z ~> 6) are of great interest to fundamental astronomy due to the information they hold regarding the reionization epoch of the universe, growth rates of black holes in the early universe, and intervening neutral hydrogen. With their low number density in the sky, however, they are elusive objects. Reported here is our search for these high re6dshift quasars using the Wyoming Infrared Observatory (WIRO) 2.3m telescope. We search for potential candidates that were originally detected by the Dark Energy Camera Legacy Survey (DECaLS) which were later refined by other surveys such as the Wide-field Infrared Survey Explorer (WISE) and the United Kingdom Infrared Telescope Deep Sky Survey (UKIDSS). The main emission feature of these quasars (the Lyman-Alpha (Lyα) line at ~1215 Å rest-frame) would be redshifted to the z-band or beyond. Light that is blueward of 1215Å will be absorbed and scattered by neutral hydrogen, meaning that the quasars should have very low or no levels of i-band flux. These objects are known as i-dropouts. By imaging the quasars in the i-band and running photometric analysis on the fields, candidates can be identified as red point sources that are faint in the i-band. An analysis of the colors of the candidate high-redshift quasars are presented.

Introduction

High Redshift Quasars (high-z quasars) (z ~> 6) existed during the tail end of the reionization epoch ~1 billion years after the big bang. Since the objects formed close to the end of this epoch, they can be used to assess the state of the intergalactic medium (IGM) at the time [1][2]. The state of the IGM can be assessed by the absorption spectra of the high-z quasars. By looking at the Lymanα forest in their spectra (Fig. 1), abundances of intervening neutral hydrogen in the IGM can be quantified. This becomes pivotal in the constraining of cosmological models that describe conditions in the early universe [3]. One such model describes the formation of massive black holes during the end of the reionization epoch. The amount of time in which massive black holes must have formed can be deduced by observing the number density of high-z quasars[1]. Since there was less than 1Gyr that the high-z quasars had to form, there could be different mechanisms that are behind massive black hole formation to account for this time discrepancy with current models. This then constrains models of quasar and galaxy evolution given their dependence on massive black holes [2].

The main emission feature of these high-z quasars, the Lyα emission line (rest wavelength of ~1215 Å), is shifted from the ultraviolet to the near-infrared. This puts these quasars near the visible spectrum where they can be studied using photometry. In this survey, they are imaged in the i-band, which is expected to have very low-levels of flux, which is why they are given the name “i-dropouts”. The images taken will be reduced, calibrated and plotted by color.

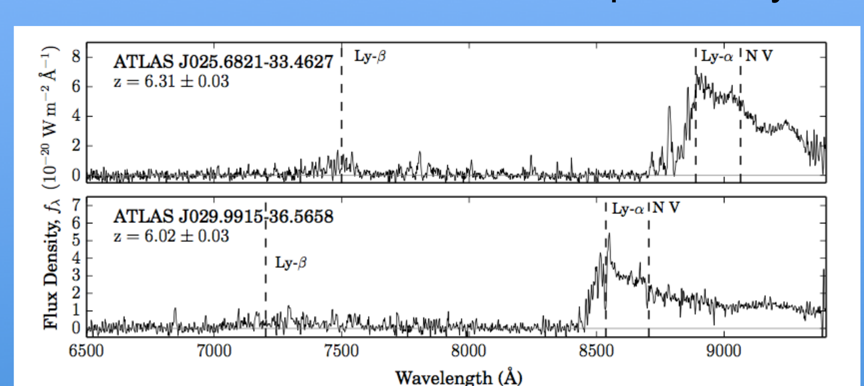


Figure 1. The spectra of two newly discovered high-z quasars that show the distinct Lyα emission line and Lyα absorption forest [3].

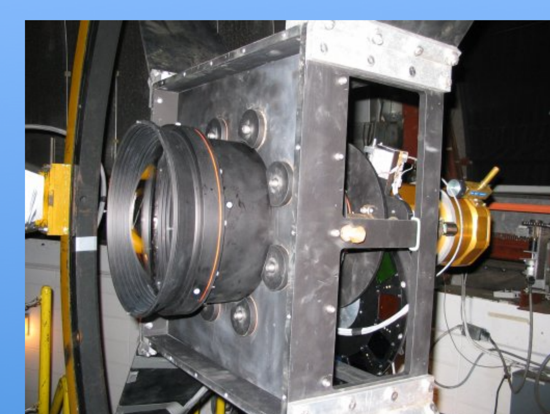
Data Acquisition and Calibration

The University of Wyoming owned Wyoming Infrared Observatory (WIRO) 2.3 meter telescope (Fig. 2) was used to acquire the data for the survey. The custom 4096x4096 UV sensitive DoublePrime CCD imager was used to capture all of the photometric data for the survey. WIRO is equipped with a Sloan Digital Sky Survey (SDSS) like u, g, r, i, z filter set.

We imaged exclusively in the i-band due to the nature of high-z quasars as discussed earlier. The exposures were 300 seconds which gave a depth of ~24.0 at 5-sigma. Each field was taken three separate times with two corresponding 200’’ shifts, north and south to get three independent measures of each of the quasar candidates. These were then stacked to reach the desired depth. This is all in effort to further increase the confidence of the detection of the i-dropouts.

The reduction of fields taken with WIRO consisted of standard procedures ran through a custom Python pipeline and other packages including Imaging Reduction and Analysis Facility (IRAF), astrometry.net, and the Astromatic.net software suite. The fully reduced, registered and stacked images were calibrated to SDSS standard stars.

WIRO dome facing west [4].



WIRO corrector plate (past) and SDSS like filter wheel (current) [5].

Candidates

The candidates for this survey were originally detected by the Dark Energy Camera Legacy Survey (DECaLS). Supplemental refinement has been done by Wide-field Infrared Survey Explorer (WISE) and the United Kingdom Infrared Telescope Deep Sky Survey (UKIDSS). This gives a wide range of bands for each of the candidates.

Using the calibrated WIRO data and data from the aforementioned infrared surveys, the colors of the quasars can be plotted. Each plot has three different elements. Simulated quasars are plotted to give a reference to standard quasars; Cool M, L and T-type dwarf stars (MLT) are plotted since they have colors that are very similar to the high-z quasars; then the candidates colors from the respective surveys.

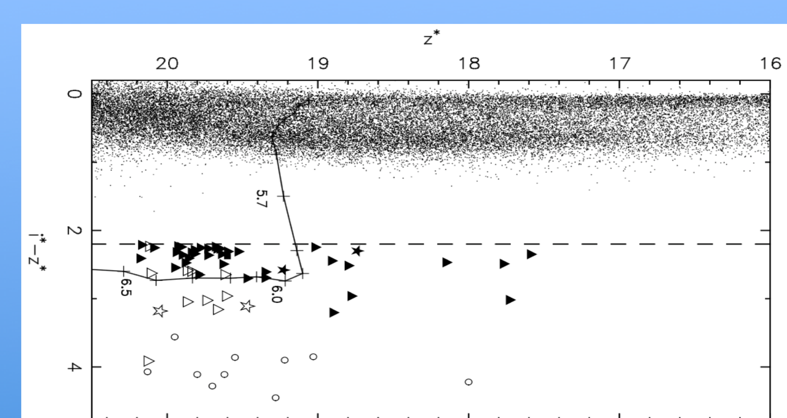


Figure 2. Sample color-magnitude plot of high redshift quasars (black triangles).

Results

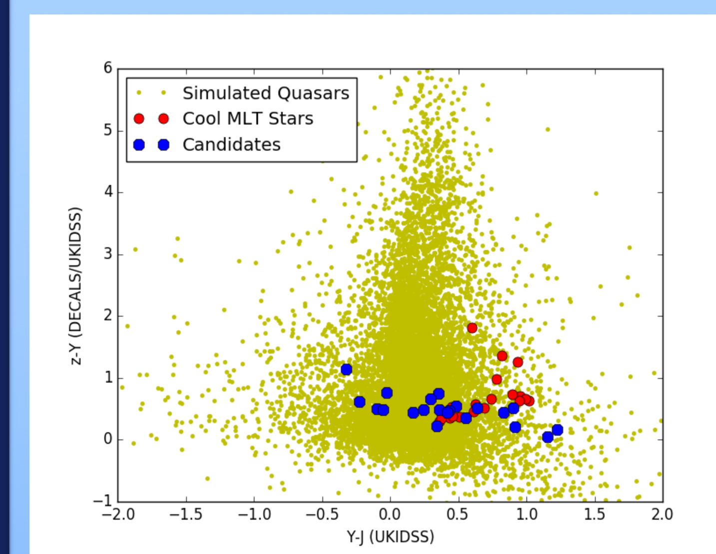


Figure 3. Y-J, z-Y

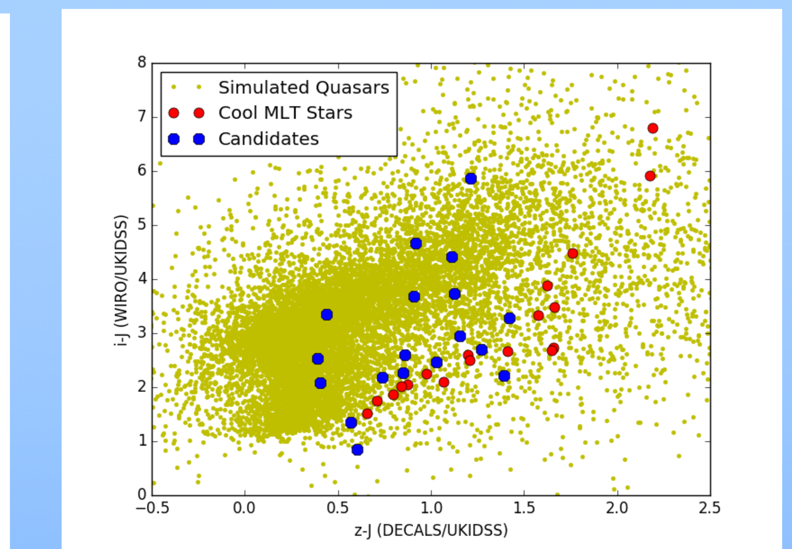


Figure 4. z-J, i-J

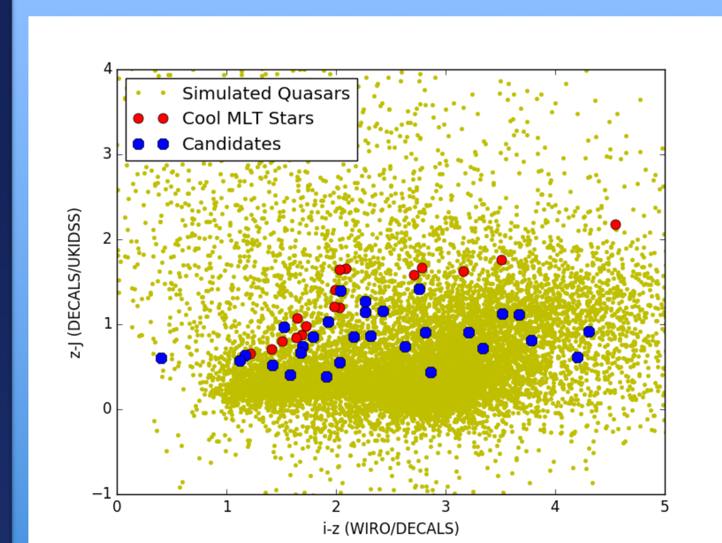


Figure 5. i-z, z-J

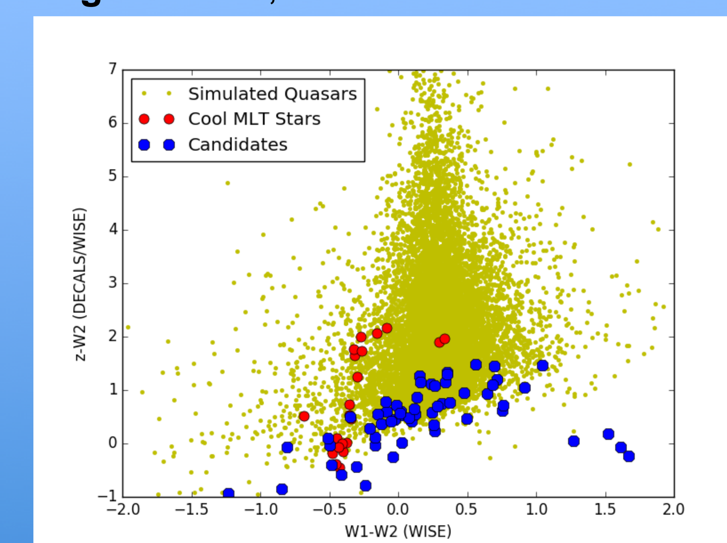


Figure 6. W1-W2, z-W2

Conclusion

Figures 3, 4, 5, and 6 are accurate replications of color-color plots presented from several similar and smaller surveys [1][2][3]. A few discrepancies arose with Figure 6 where the high-z candidates did not lie in a heavily populated region of the simulated quasar space. The plotting of the MLT stars showcase the contamination that dwarf stars cause when photometrically observing high-z candidates. The project is still on going. There are still more plots that can be made to further assess the certainty of the candidate detections.

The candidates would now have their spectra obtained to further asses their candidacy as a high-z quasar. After this, all of the aforementioned science will begin. The early universe will become more clear as the candidates become confirmed.

References

1. “DISCOVERY OF THREE Z > 6.5 QUASARS IN THE VISTA KILO-DEGREE INFRARED GALAXY (VIKING) SURVEY,” B.P Venemans, J. R. Findlay et al. 2013.
2. “A Survey of z > 5.8 Quasars in the Sloan Digital Sky Survey I: Discovery of Three New Quasars and the Spatial Density of Luminous Quasars at z ~ 6,” Xiaohui Fan, Vijay K. Narayanan, et al. 2001.
3. “Two bright z > 6 quasars from VST ATLAS and a new method of optical plus mid-infra-red colour selection,” A. C. Carnall, T. Shanks et al. 2015.
4. “WIRO dome.” Evan Haze Nunez. 2016.
5. “Corrector PF Box.” Matt Bryan. 2014.

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