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Host Galaxies of Young Dust-Reddened Quasars

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Abstract. We present results on a multiwavelength campaign to identify the nature of dust-reddened Type 1 quasars. These quasars were selected by matching FIRST, 2MASS and very red optical counterparts with $r' - K > 5$. We find a very high fraction of Low Ionization Broad Absorption Line Quasars (LoBALs) among AGN selected with this method, perhaps a sign of quasar feedback. From X-ray observations and Balmer decrement measurements, the obscuring dust is most likely located in a cold absorber such as the host galaxy, rather than from a torus near the AGN. Hubble ACS imaging of a sub-sample of these sources showed a very high fraction of interacting and merging systems. The quasars appear to be very young in which dust from the merging galaxies is still settling in. Spitzer IRS and MIPS data show star formation signatures and deep Silicate absorption features in these objects, but overall the quasar is the dominant source in the Mid-infrared.

1. Introduction

Using a combination of the FIRST radio survey, the 2MASS near infrared survey and a very red ($r' - K > 5$) color, we constructed a sample of potential quasar candidates that are missed in optical surveys. Spectroscopic follow up of these objects have confirmed well over 140 intrinsically luminous dust-reddened Type 1 quasars ($E(B - V) \sim 0.7$), with a better than 50% success rate (Glikman et al. 2004, 2007; Urrutia et al. 2008b). Dust-obscured quasars are not rare and make up about 30% of the total quasar population (Lacy et al. 2007). Example spectra of red quasars are shown in Figure 1.

2. Discussion and Results

2.1. X-ray Properties

From the Chandra X-ray spectra and hardness ratios, we can gather that the red quasars are indeed also obscured in the X-rays, but not with column densities typically associated with Type 2 objects. Rather they show an average of $2.5 \times 10^{22}\,cm^{-2}$ columns, i.e. "Compton-thin" absorption. Their gas:dust ratios are lower than for typical Type 1 quasars (near Galactic). This is perhaps a hint

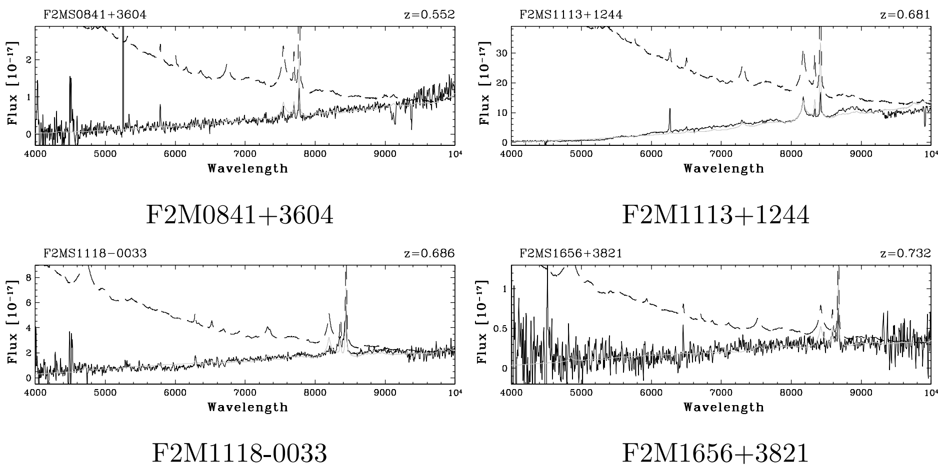


Figure 1. Four examples of spectra of dust-reddened Type 1 quasars. The upper dotted line is the normalized FBQS composite and the grey dotted line (not always visible) is the best fit SMC reddening law.

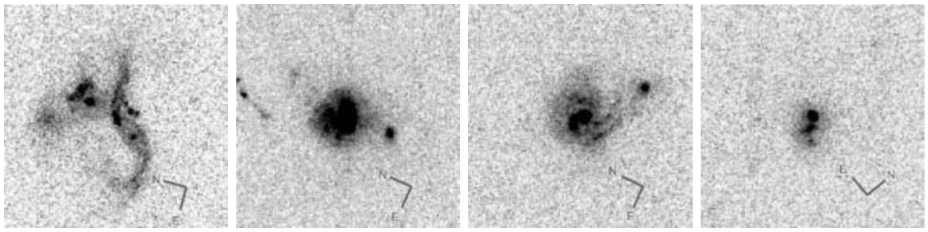
for a cold absorber, as only material far away from the nucleus not affected by sublimation can have such gas:dust ratios (Urrutia et al. 2005).

2.2. ACS Observations

We have also observed 13 moderate redshift red quasars (z $\sim$ 0.7) with HST. Example ACS images for the objects we presented the spectra are shown in Figure 2, displaying the disturbed nature of these objects. The images show significant merger activity in 85% of the objects even before subtracting the bright point-source-like quasar. This fraction of quasars showing interaction is significantly higher than the 30% seen in samples of host galaxies of normal, unobscured quasars (Guyon et al. 2006). There are hints for a correlation between the degree of the merger as measured by the Gini coefficient and the reddening of the objects (Urrutia et al. 2008a). Therefore we imply that the high merger fraction for red quasars is related to their obscured nature and that the reddenening is occuring in the host galaxy, still disturbed by the interaction. This might be further indication of a link between AGN and starburst galaxies (Sanders et al. 1988; Hopkins et al. 2008).

2.3. An Anomalously Large Fraction of LoBALs among Red Quasars

At high redshift we identify a large fraction ($\sim$75%) of LoBAL quasars among the red quasars using the SDSS Absorption Index to identify a BAL. Even using the more conservative Balnicity Index we have 33% of quasars being identified as LoBALs, a two order of magnitude discrepancy with SDSS quasars! Most of the LoBALs also belong to the rare FeLoBAL population that also shows absorption in the blueward of the FeII complex in their spectrum (Urrutia et al. 2008b). If we extrapolate the HST results to the high redshift LoBAL population, these special objects could also be explained as young quasars, which have just ignited and are still undergoing the quasar feedback phase with their host galaxy through



F2M0841+3604 F2M1113+1244 F2M1118-0033 F2M1656+3821

Figure 2. Example ACS images for the 4 quasars in Figure 1. The images are $7'' \times 7''$, with 1 arcsecond representing about 7kpc. Notice signs of previous interactions and disturbances in the host galaxies.

these BAL winds, which will eventually suppress star formation in the host galaxy.

2.4. Spitzer Data

The 13 quasars observed with HST, were also followed up in the Mid-IR with Spitzer IRS and MIPS. There are hints of star formation (PAH, warm Mid-IR excesses) on many objects observed with Spitzer IRS, but not all of them display these features and the sample is not homogeneous in its infrared properties. However, overall the quasar dominates in the infrared $L_{QSO} \sim 12L_{\odot}$ over the starburst component $L_{SB} \sim 11L_{\odot}$. In the IRS spectra, which show deep Silicate absorption, it is consistent with the amount of dust reddening seen in optical.

3. Outlook

In the future, observations of these objects is planned with OSIRIS. Furthermore, we are currently observing these high redshift LoBALs using AO imaging and are also in the process of analyzing Spitzer MIPS and IRS data of LoBALs to test their evolutionary nature. We also are exploring the lower intrinsic luminosity regime of the red quasars. If dust reddened quasars are young objects, do they have the same quasar luminosity function as "normal" quasars? We have not reached completeness over a significant redshift range yet, so we are obtaining near-IR spectra on fainter red quasar candidates obtained with UKIDSS.

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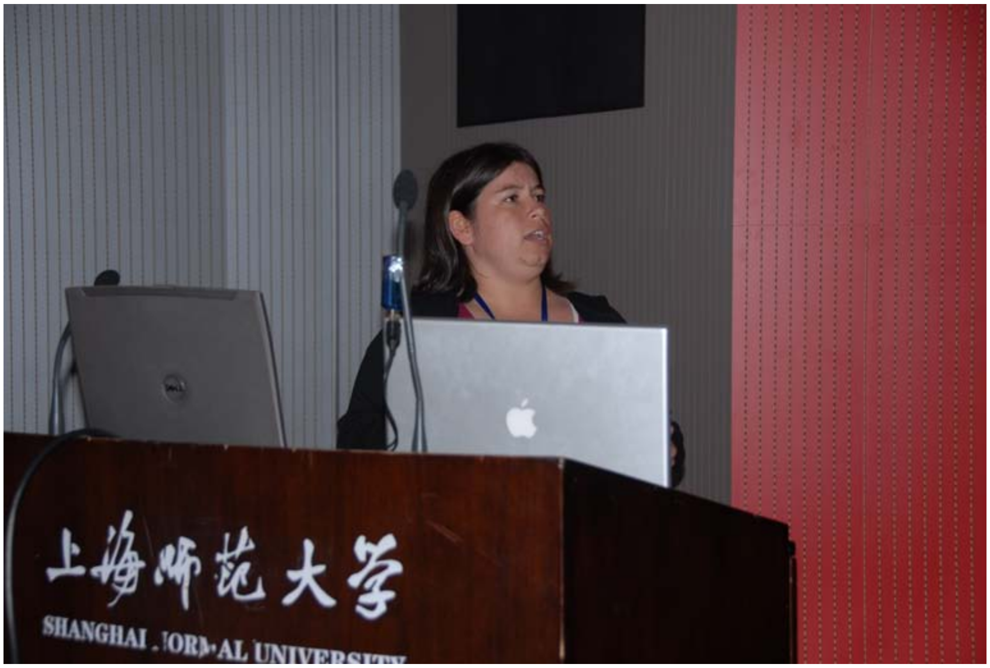

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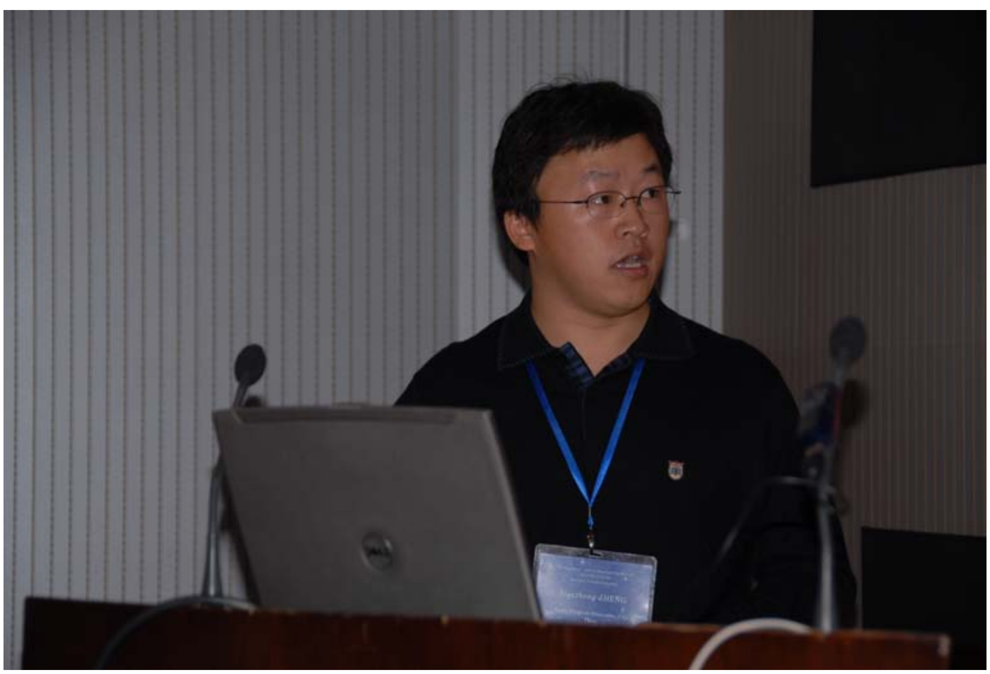

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