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Quasar Metal Abundance and FIR Luminosity

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**Abstract.** We compare the metallicities in high-redshift quasars to the star formation rates (SFR) in their host galaxies using measurements of broad emission lines and far-infrared (FIR) luminosities. The FIR emission indicates the level of ongoing massive starbursts in the galaxy, whereas the abundance of metals in the gas surrounding the quasar indicates the amount of star formation which occurred before the visible quasar phase began. The results of this study can be used to constrain the late stages of starburst-quasar evolution. We detect high metallicities throughout the sample, up to several times solar, confirming that star formation must have begun before the visible quasar phase. However, we do not detect a trend in metallicity versus current SFR.

1. **Introduction**

High redshift quasars are thought to represent an early stage of galaxy evolution, where major mergers trigger violent star formation and the rapid growth of a central super-massive black hole. However, the timing of the quasar phase during a galaxy’s evolution is not well understood. For example, the quasar could trigger a massive burst of star formation in the host galaxy, quench star formation in the host, or have no direct effect on star formation whatsoever.

The gas-phase abundance of the near-quasar environment has been probed out to high redshifts, particularly through the use of quasar broad emission lines, and has consistently shown metal abundances near or above the solar value. This result suggests that there is always significant star formation enriching the surrounding gas before the black hole becomes a luminous quasar.

One possible indicator of ongoing star formation is emission at far-infrared (FIR) wavelengths, where FIR emission is caused by dust heated by ultraviolet (UV) emission from massive starbursts (Kenricutt 1998, and references therein). A recent analysis by Hao et al. (2008) of FIR data from the literature indicates that high-redshift quasars can have star formation rates (SFR) up to $>1000 \ M_\odot \ yr^{-1}$ for the brightest $L_{FIR}$ quasars.

We look for signs of age progression in various stages of the quasar lifecycle by measuring the metallicity of the quasar emission line gas at different increments of $L_{FIR}$, i.e., ongoing star formation. Presumably the later stages of evolution are older and therefore show more metal enrichment than earlier, younger stages. To smooth over variations in individual quasars, we make composite spectra of quasars in each of three $L_{FIR}$ increments.

We measure metallicites using the N V $\lambda$1240 and C IV $\lambda$1549 UV emission line strengths. The ratio of N V to C IV increases with metallicity (and age), due to the secondary enrichment of nitrogen (Hamann et al. 2002). Thus, a
trend in the N V/C IV ratio over the three L_{FIR} increments could indicate a progression from one evolutionary phase to the next.

2. Method

We compile a sample of 30 optical spectra from SDSS of known optically bright FIR-observed quasars with a redshift range of 2 < z < 5. This redshift range shifts the UV region of the quasar spectrum into the optical region observed by SDSS. We use the L_{FIR} from Hao et al. (2008), who compile a list of optically selected quasars observed at FIR wavelengths, and we use the optical (B) magnitudes from Omont et al. (2001, 2003) and Carilli et al. (2001) who actually observed these sources in the FIR using MAMBO and SCUBA respectively. We sort the SDSS spectra by L_{FIR} into three non-overlapping categories of ∼10 spectra each with the brightest category containing spectra with log(L_{60\mu m}/L_\odot) > 13.2, the faint category containing spectra with 12.8 < log(L_{60\mu m}/L_\odot) < 13.15 and the category not detected in the FIR with log(L_{60\mu m}/L_\odot) < 12.8 upper limits. The range of M_B is -26.5 to -28.9. All three categories span this range, but the FIR bright category is dominated by M_B > -28, whereas the other two categories are clustered near M_B -27.4.

We create average combined spectra of each sample, removing strong absorption by hand before combining. We normalize the combined spectra using power law fits to regions relatively free of emission or absorption; rest-frame 1447-1473 Å, 1757-1783 Å and 1987-2013 Å for the non-detected in FIR composite. We intend to use gaussian profiles to fit N V, C IV and Lyα emission in each composite spectrum.

3. Results

Based on preliminary analysis, the N V/C IV line ratios in all three composites indicate that the quasar environments are metal rich, with approximately a few times solar metallicities. A weak trend also appears for increasing metallicity (i.e., increasing N V/C IV line ratio) in the sources with larger L_{FIR} (Figure 1). However, these sources also tend to have larger accretion luminosities, L_{UV}, and their slightly higher metallicities can be attributed to a known correlation between metallicity, L_{UV} and central black hole mass among quasars generally (Warner, Hamann, & Dietrich, 2004). Thus, we find no clear evidence for evolutionary (enrichment) differences between quasars sorted by the presumed SFR indicator, L_{FIR}. Instead, we find simply an affirmation of previous work showing that quasar broad emission line regions are generically metal rich, with the highest metallicities occurring in the most luminous and most massive quasar environments.

These results can be understood in the context of galaxy evolution and black hole growth by noting that the SMBHs that power these quasars have masses of order 10^9 M_\odot or higher. The metal rich gas suggests vigorous previous star formation, as is expected along the way toward making these massive SMBHs. The lack of an obvious trend in line strengths with L_{FIR} may indicate that ongoing star formation in quasar hosts is not a significant source of enrichment.
Figure 1. Composite SDSS quasar spectra grouped by $L_{FIR}$, shifted to rest-UV wavelengths. The solid curve represents the composite of upper-limit non-detections in FIR, the dashed curve represents the composite of faint FIR quasars and the dotted curve represents the composite of bright FIR quasars. Prominent emission lines are labeled. All composite spectra are normalized using a power law fit to feature-free regions as described in the text.

This result is still consistent with current models where quasars are preceded by massive starbursts in their hosts (Hopkins et al. 2008).

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