Abstract

We calculate the median far-ultraviolet (FUV) minus near-ultraviolet (NUV) colors for \(\approx 137,000\) SDSS quasars observed with the GALEX satellite out to a cosmological redshift \((z)\) of 3. The sample is divided into various \(z\) ranges wide enough to include 15,000-20,000 quasars, centered particularly on \(z = 0.44, 1.5\), and 2.4, which are optimal for studying the continuum spectra and extreme ultraviolet properties (EUV) of quasars. Each sub-sample is further divided by bolometric luminosity (L) and central blackhole mass (M) into as many as 100 bins, and the median color calculated in each bin. We find a moderate reddening of the population (corresponding to lower EUV flux) with increasing luminosity and black hole mass. The amount of reddening is about half a magnitude for \(z < 1.5\) and gradually increases to 2 or more magnitudes at \(z > 2\).

Redshift and EUV Flux

2020 Vandenberk et. al. showed the EUV flux of quasars at \(z > 1\) to be far lower than previously observed. This could have profound physical implications for a quasar’s central engine; an accretion disk falling onto a supermassive black hole. Our study seeks to correlate trends in UV reddening (lower EUV flux), with quasars’ intrinsic properties of blackhole mass and total luminosity. We do this by dividing the sample into successively smaller regions, increasing “spatial” resolution with the price of higher error margins in each bin.

Figure 1: Distribution in LMZ space of \(\approx 137,000\) quasars.

The sample is shown divided into 9 bins of dimensions luminosity (green) by blackhole mass (blue). The red rectangles show the redshift bands we explore.

Figures 2, 4, 6 (left); 3, 5, 7 (right); 8, 9 (bottom): Color magnitude trends for \(z\) centered on 0.44 (bottom), 1.5 (left), and 2.4 (right), in 9, 36, and 81 bins respectively. Colors are not calculated for bins with fewer than five detections (gray).

At \(z = 1.5\) the prominent Lyman alpha transition line falls between the FUV and NUV sensitivity of the GALEX satellite, the effect being that colors observed here are more representative of the quasar’s central engine itself. At \(z > 2\), significant features of the rest frame EUV shift into the FUV. At both redshifts, we see a mild reddening with increasing blackhole mass and luminosity, with the effect becoming more pronounced with higher \(z\). Compare with the colors at \(z = 0.44\) below, where there is considerably less or even no reddening.

Figures 10 and 11: Representative uncertainties for middle and high redshift ranges taken from 10 runs of bootstrap resampling. Scale colors represent the width of the 95% confidence interval in each bin in color magnitude units (positive numbers correspond to redder colors, as in the previous figures)

The uncertainties given above are preliminary, and more rigorous statistical analysis of the sample is ongoing, including up to 1,000 bootstrap resampling runs for each figure, and Monte Carlo analysis. As expected, we see significantly more variation, up to several orders of magnitude, at higher redshifts where the population size is much lower. Larger bin sizes afford better statistics at the cost of resolution in the parameter space.

Conclusions and Further Research

While more analysis is clearly needed, our results do show at least a mild correlation between both blackhole mass and luminosity with lower EUV flux (redder ultraviolet colors). This counterintuitive result could possibly be explained by disk wind models, in which strong outflows of material and energy from near the center of the disk reduce the accretion rate onto the central blackhole, and with it, EUV emission.

We also take into account the fact that blackhole masses are not directly measured and are actually derived spectral line widths and luminosity, which likely explains the apparent dual correlation. Using partial correlation statistics it may be possible to separate the effects of these parameters, in addition to comparing objects with similar properties, but differing significantly with blackhole mass.

References