Ultra-strong UV Fe II Emission in a Large Quasar Group

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Abstract

We present a region containing an excess of strong and Ultra-strong UV Fe II emitting quasars, twice the number of previously published similar objects. These 15 quasars are spread over a redshift range 1.1<1.6 and an area of 2 sq. deg, in the direction of two Large Quasar Groups (LQGs), including the Clowes-Campusano Large Quasar Group (CCLQG), and a quasar overdensity. This is the first indication that there may be a unique environment within a Large Quasar Group. The high level of iron emission indicates a difference in environment, for example an excess of star-forming galaxies within this region or an excess of star formation within the quasar host galaxies of quasars within a LQG. This result will have implications the environments of quasars, and for star forming galaxies within large scale structures.

Introduction

Iron emission can be seen in Active Galactic Nuclei (AGN) and quasars in the optical and ultra-violet at varying levels. Few quasars have been found to have strong or ultra-strong ***UV*** Fe II emission in the range 2255-2650Å, suggesting this strength of emission is rare (e.g. Graham et al. 1996). An example of Ultra-strong Fe II emission can be seen in Figure 1. Fe II is believed to originate from the intermediate line region (e.g, Brotherton et al. 1994) , which shows the strongest trends in the ultra-violet emission line properties (Brotherton et al. 1999), characterised by the variation in emissions from different objects. Simulations of Fe II emitting regions have suggested that the Fe II emission comes from a variety of mechanisms (Sigut et al. 2003, Baldwin et al. 2004) such as Lyα excitation (or fluorescence) (e.g., Sigut et al. 2003), microturbulence around the AGN (e.g., Vestergaard et al. 2001) and iron abundance. Simulations have suggested that the Fe II abundance alone, though still important, may not be the main factor influencing the strength of the ***UV*** Fe II emission (Sigut et al. 2003, Baldwin et al. 2004). The emission strength of Fe II cannot be explained by standard photoionization cloud models (e.g., Collin 2000). There are several non-abundance factors such as the gas density in the emitting region and the strength of the radiation field (Sameshima et al. 2009).

Large Quasar Groups

Large Quasar Groups (LQGs) are some of the largest structures seen in the Universe, can span 50-200 h^{-1} Mpc, and are potentially the precursors of the large structures seen at the present epoch, such as super-clusters (Komberg 1996). The Clowes-Campusano LQG (CCLQG) (e.g., Clowes et al. 1991) lies at a redshift of $z \sim 1.3$, and spans ~100-200h^{-1} Mpc. Two LQGs and an additional quasar set have been found in this area. The overdensity was estimated using $(\rho - <\rho>)/<\rho>$ (Clowes et al. 2012).

- The CCLQG lies at z=[1.187,1.423], contains 34 members, and has an estimated overdensity of 0.83 and a statistical significance of 3.57σ (Clowes et al. 2012).
- There is a another LQG at z=[1.004,1.201], which has recently been found and contains 38 members (Clowes et al. 2012). This group has an estimated overdensity of 0.55 and a statistical significance of 2.95σ.
- There is another set of quasars with 21 members at z=[1.477,1.614]. This group has an overdensity of 0.49, a statistical significance of 1.75σ, which though suggestive, is not high enough to be statistically significant for a large structure (Newman 1999, Clowes et al. 2012).

Observations and Reductions

The spectra were taken using Hectospec, a multi-object optical spectrograph, mounted at the 6.5m MMT on Mount Hopkins, Arizona. Hectospec observations, taken over nine nights, include 30 quasars taken from the Sloan Digital Sky Survey (SDSS) photometric catalogue (Richards et al. 2009), and objects selected from a set of previous observations on the Anglo-Australian Telescope (AAT) where the data had insufficient signal-to-noise ratio. The quasars were selected to have magnitudes brighter than r ~20.1 and photometric redshifts between 0.6 and 1.8. The Fe II emission is measured using the method described in Weymann et al. (1991) and shown in Figure 2.

Control Samples

Control samples were taken from the quasars in Stripe 82, in areas which do not contain any previously known LQGs and with a similar limiting magnitude as our control samples. 13 samples of 2 deg^2 each were taken, containing in total 394 quasars within the redshift range $1.1 < z < 1.7$. The Fe II 2400 bumps on the spectra were measured with the Weymann method, as was used to measure our LQG measurements. Table 1 shows the average number of quasars with various Fe II strengths in the CCLQG fields and the control samples.

Table 1 -The number of quasars per deg^2 for the different Fe II strengths for quasars in the control fields compared to the Hectospec field.

Strength	Control field	LQG field
Weak	10.5 (69.3%)	9 (54.5%)
Strong	2.77 (18.3%)	3.5 (21.2%)
Ultra-strong	1.88 (12.4%)	4 (24.2%)

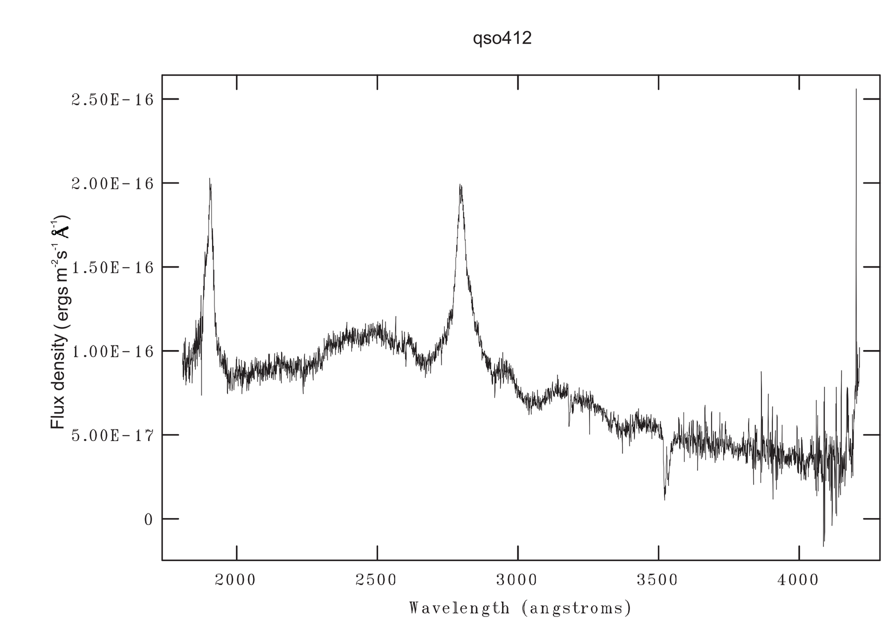

Figure 1 - An example of Ultra-Strong Fe II emission in a quasar spectra. The emission occurs between 2255 and 2650 Å.

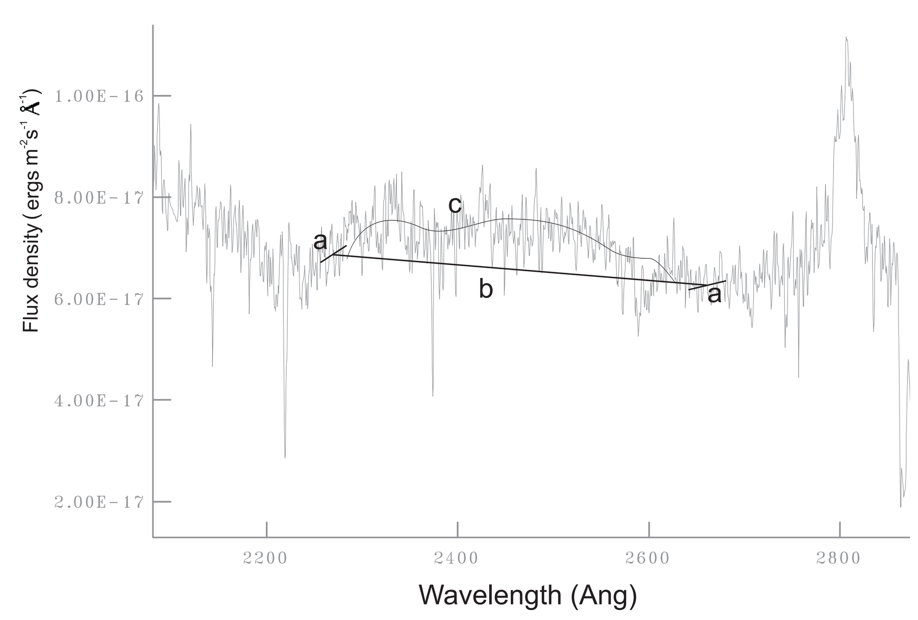

Figure 2 - Demonstration of the method used by Weymann et al. (1991).

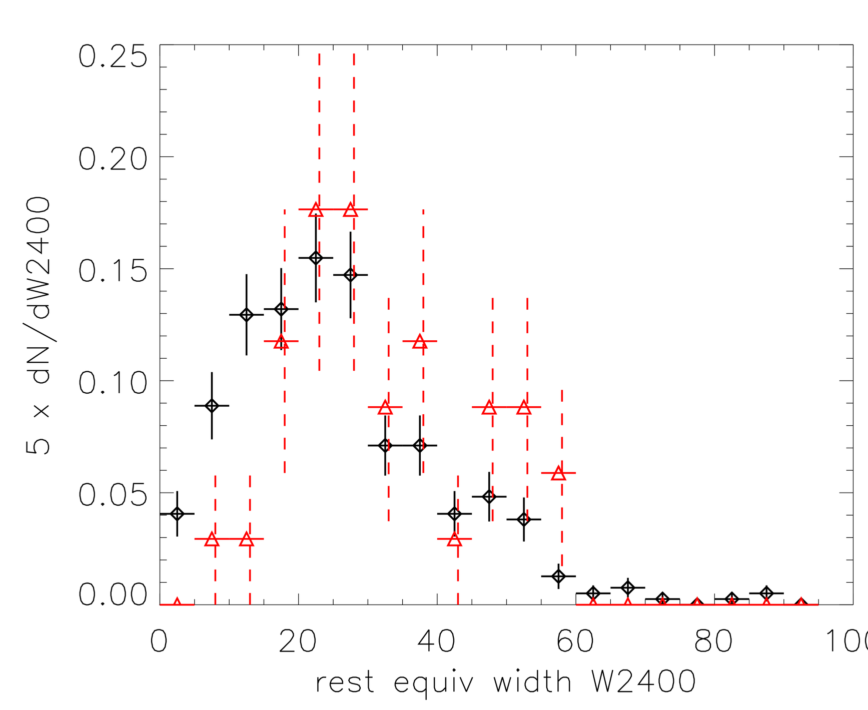

Figure 3 - The distribution of equivalent widths of Fe II for the control sample (black diamonds) and quasars in the direction of the LQGs (red triangles). The errors shown are Poissonian.

W2400 Distribution

We present the W2400 distribution for the CCLQG and the control sample in Figure 3, showing Poissonian errors. There is an apparent deficit of emitters at $W2400 < 15$ Å, with 102 of 394 control emitters (25.9 ± 2.6%) *vs.* 2 of 34 CCLQG emitters (5.9 ± 4.2)%, a reduction of 77±22% for a significance of roughly 4σ. This could be explained by a lower sensitivity in the CCLQG spectra, for which half (18 of 34) the sample comes from Hectospec data, and the other half from SDSS data. The control sample and CCLQG quasars have similar magnitudes, with $\langle g \rangle = 20.0 \pm 0.7$ and $\langle r \rangle = 19.7 \pm 0.7$ for the control, and $\langle g \rangle = 20.1 \pm 0.8$ and $\langle r \rangle = 19.8 \pm 0.8$ for the CCLQG sample. The CCLQG SDSS spectra have roughly half the SNR of the Hectospec spectra. We therefore conclude that the deficit of low equivalent width emitters is due to relatively low SNR in the CCLQG SDSS spectra. We consider whether there is an overabundance of strong+ultrastrong Fe II emitters at 30 Å $\leq W2400 < 60$ Å, with 111 of 394 control emitters (28.2 ± 2.7%) *vs.* 15 of 34 CCLQG emitters (47.1 ± 11.8)%. The excess is 1.5σ. For the ultrastrong emitters at rest equivalent width 45–60 Å, the observed sample contains 8 emitters (23.5 ± 8.3%) and the control 40 (10.1 ± 1.6%), for an excess of 1.6σ. Therefore, there is no significant overabundance of strong, ultrastrong or strong+ultrastrong (combined) emitters.

Lyα Emission

Nine of the quasars have GALEX *UV* spectra. Of these nine quasars, six are the redshift needed for Ly-α emission to be seen. Figure 4 shows the correlation between the Fe II EW measurements and the equivalent widths of the Ly-α emission line. The line drawn is the least squares best fit. There is a possible trend for quasars with higher Ly-α emission to have stronger Fe II emission. The errors are estimated by taking multiple measurements of the equivalent width, with the Ly-α value for the EW taken as the average of these values. The correlation coefficient between the Ly-α and the Fe II is 0.830, suggesting a reasonable correlation between the measurements, though the errors are large on some measurements. Ly-α pumping is one of the mechanisms suggested for increasing the Fe II strength (Sigut et al. 2003; Sigut et al. 1998). However, there are only six spectra with Lyα emission. A larger number of *UV* spectra would be needed to confirm this.

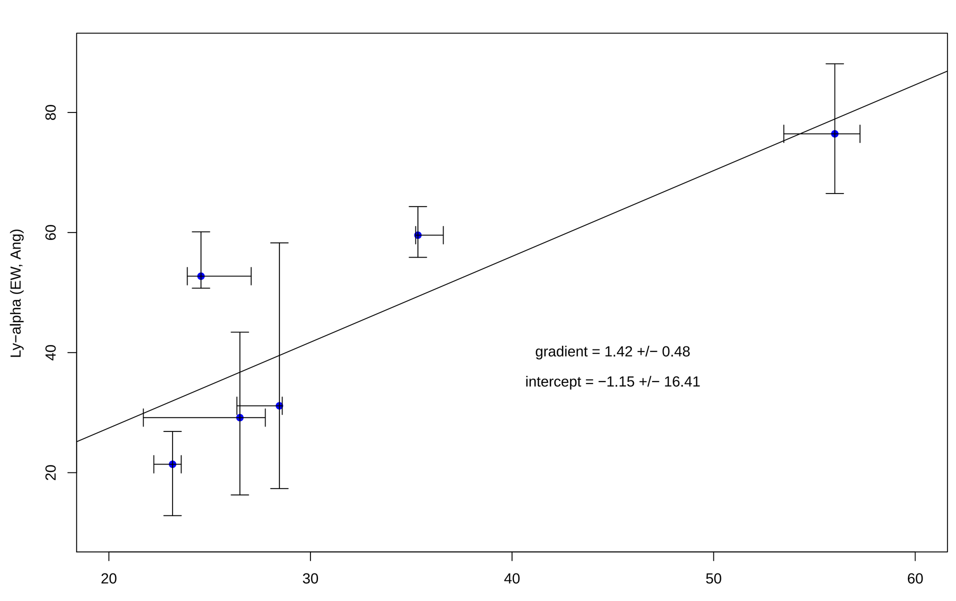

Figure 4 - Comparing the equivalent widths for the Fe II emission from the optical spectra and the Ly-α emission from GALEX UV spectra. The line fitted shows Ly-α_EW = FeII_EW, fit using least squares regression.

Conclusions

Though there appears to be an excess of Ultra-strong and strong Fe II emitting quasars in the direction of the CCLQG, this overdensity is not significant. However, there does appear to be a correlation between the amount of Ly-α emission of the Fe II emission. This needs further study with a larger sample of *UV spectra.*

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