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A SURVEY FOR FE II EMISSION TOWARD A LARGE QUASAR GROUP AT $Z \sim 1.2$

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Abstract. We present 14 quasars which show evidence of strong and ultra-strong UV Fe II emission. The quasars are all within an area of two deg^2 covering a portion of the Clowes-Campusano Large Quasar Group (CCLQG) ($\langle z \rangle = 1.28$). This area is noteworthy for the high densities of quasars at several redshifts, spanning a redshift range of $1.11 < z < 1.67$. The distribution of Fe II emission has been compared to a control sample and there is a highly significant relative excess at higher emission levels. This indicates either a special environment within a LQG or suggests that a large number of quasars within a LQG are in a particular stage of their evolution.

Keywords: quasars, large quasar groups, iron emission

1 Introduction

Iron emission can be seen in Active Galactic Nuclei (AGN) and quasars in the optical and ultra-violet at varying levels. Few quasars in the literature have been measured to be strong or ultra-strong UV Fe II emitters, suggesting this strength of emission is rare. All of these show ultra-strong Fe II emission in the rest-frame region between 2255 Å and 2650 Å. The most notable ultra-strong UV Fe II emitters are:

- IZw1, a Seyfert galaxy (Bruhweiler & Verner 2008; Vestergaard & Wilkes 2001),
- 2226-3905 (Graham et al. 1996),
- 0335-336 from Weymann et al. (1991), and
- Mrk 376 and Mrk 486 (Seyfert galaxies) (e.g. Osterbrock 1976).

It is important to gain accurate measurements of the Fe abundance as a function of cosmic time, especially for high redshift quasars, as this will provide constraints on and verify cosmological parameters (e.g. Hamann & Ferland 1993). Simulations of Fe II emitting regions 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 & Pradhan 2003; Baldwin et al. 2004). The observed UV Fe II emission is most likely caused by the interplay of different mechanisms (Elitzur & Netzer 1985; Sigut et al. 2004; Osterbrock & Ferland 2006). Collisional excitation can excite the Fe II to a few eV above ground level, whereas resonance fluorescence (from both the continuum and Lyα) can excite Fe II to 5–10 eV above ground level.

2 The Clowes-Campusano Large Quasar Group

Large Quasar Groups (LQGs) are some of the largest structures seen in the Universe and can span 50–200 h^{-1} rest-frame Mpc. These clusters of quasars exist at high redshifts, presumably trace the mass distribution, and are potentially the precursors of the large structures seen at the present epoch, such as super-clusters (Komberg et al. 1996; Wray et al. 2006). The Clowes-Campusano Large Quasar Group (CCLQG, Fig. 1) contains 34 quasars at $1.18 < z < 1.43$ (Clowes et al. 2012, and references therein). The field covers ~ 20 deg^2 (1° is ~ 30 local Mpc at $z \sim 1.3$) The CCLQG is associated with an overdensity of strong Mg II absorbers which are likely produced by galaxy haloes (Williger et al. 2002).

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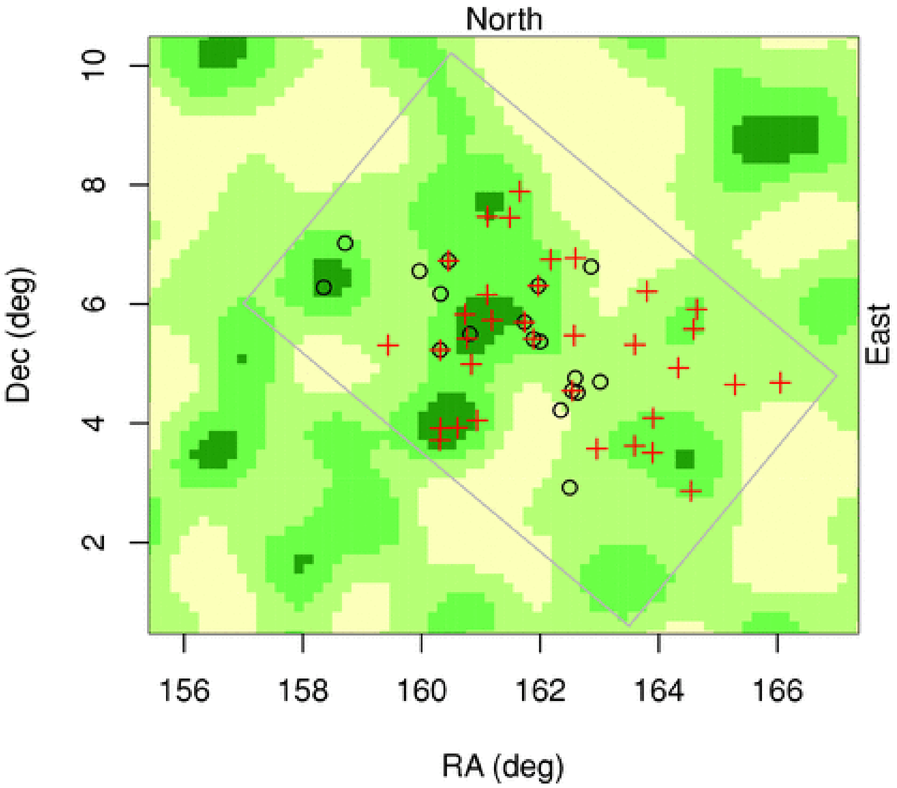

Fig. 1. From Clowes et al. (2012). Sky distribution of 34 quasars at $\langle z \rangle = 1.28$ (crosses) connected with original 18 LQG members (circles). Superimposed on these distributions is a kernel-smoothed intensity map of all quasars at $1.18 < z < 1.42$.

3 Observations/Data

We took data from the 6.5m MMT+Hectospec, supplemented with Sloan Digital Sky Survey (SDSS) spectra.

Hectospec: We observed 17 quasars over Feb–Apr 2010, taken from the SDSS DR6 photo-z catalogue (Richards et al. 2009), selecting for $r < 20.1$, covering 3900–9100 Å (see Fig. 2 for an example), targeting quasars with redshifts $1.1 < z < 1.6$. Our observations had ~ 4 Å resolution and 1.2 Å/pixel dispersion.

SDSS: We took data from 30 quasars in CCLQG field, from the DR7 spectroscopic catalogue (Schneider et al. 2010), selecting for $i < 19.1$, with resolution $R \sim 2000$, and covering 3800–9200 Å.

Controls: We also selected as a control sample ~ 400 quasars from Stripe 82 of the SDSS DR7 catalogue, which have higher signal to noise ratio (SNR) than the general SDSS data set.

4 Fe II Equivalent Widths and Discussion

We used the Fe II measurement convention of Weymann et al. (1991) for both the CCLQG field sample and the Stripe 82 control sample. The Fe II 2400 Å rest equivalent width (EW) distribution (W2400) is shown in Fig. 3, with Poissonian errors for illustration. We divide the sample into 3 categories: WEAK: W2400 < 30 Å, STRONG: 30 Å $<$ W2400 < 45 Å, and ULTRA-STRONG: W2400 > 45 Å. Typical W2400 errors are ± 5 Å for spectra with SNR > 5/pixel, and ± 3 Å for SNR > 10/pixel.

A one-sided Mann-Whitney test was used, with a confidence level of 95%, to estimate the p-value as 4.7×10^{-5} and a shift in median compared to the control as 10.4 Å. The alternative hypothesis for this test was that the distribution of the LQG field quasars is shifted to greater W2400 values than the control sample. The errors on

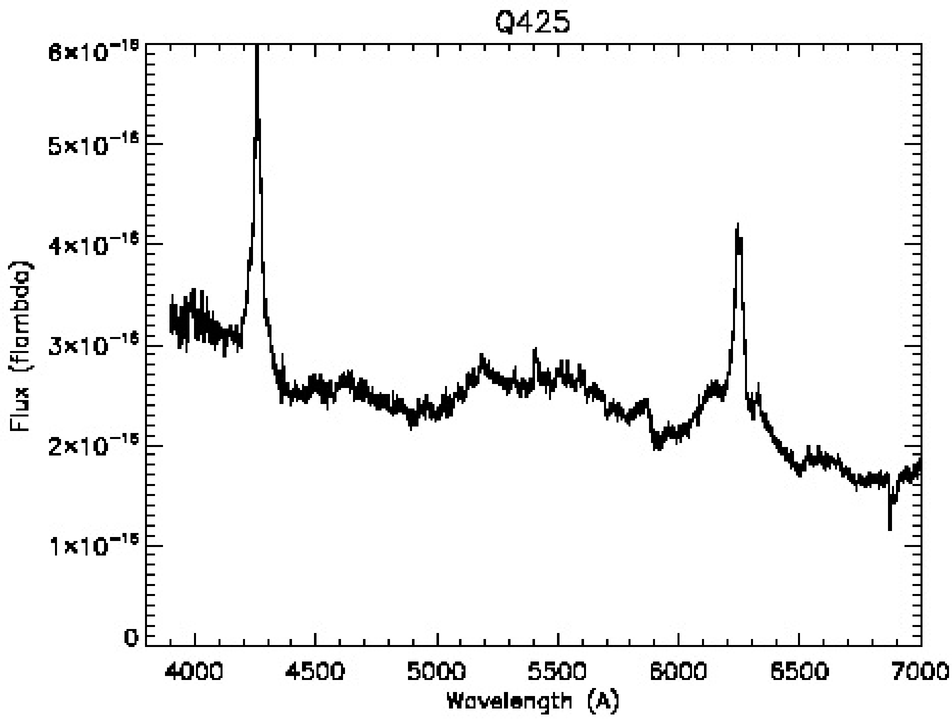

Fig. 2. Quasar 425 in our sample (1048+0522, $z_Q = 1.230$). The redshifted broad FeII emission bump is clearly visible at 5200–5800 Å (ultra-strong, rest EW = 56 Å).

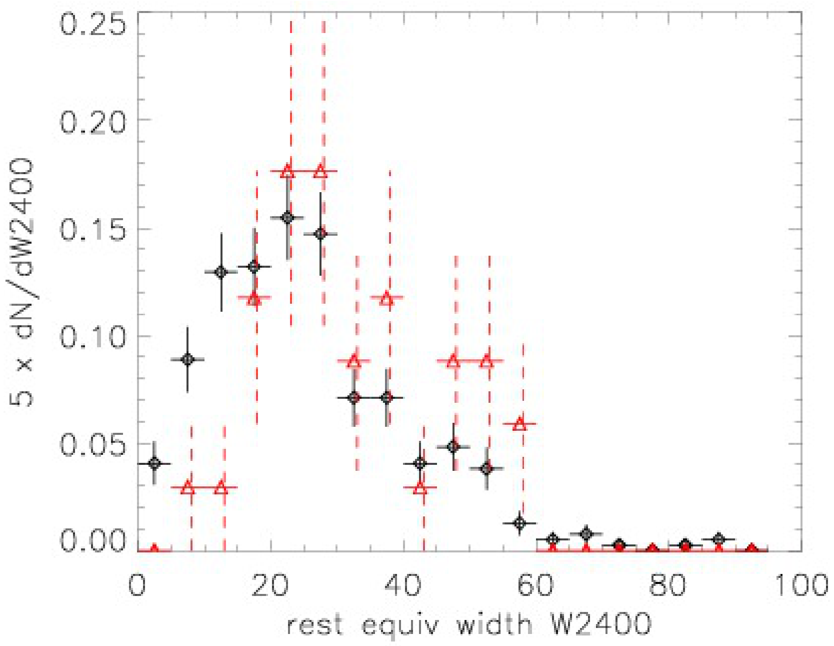

Fig. 3. Fe II 2400 Å rest equivalent width distribution for CCLQG field sample (red) and SDSS Stripe 82 control sample (black). Errors are Poissonian.

the W2400 measurements were estimated using repeat measurements of the EW, and the Mann-Whitney test was repeated to create a range of p-values. We obtain a range for the p-value of $4.8 \times 10^{-9} - 6.3 \times 10^{-4}$. Even taking the largest p-value, the null hypothesis (that the distributions are the same) can be discarded in favour of the alternative hypothesis, with an increase in the general emission strength of W2400 for the LQG sample of ~ 9 Å compared to the controls.

Further details are in Harris et al. (2012, MNRAS, submitted).

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