Studying the population of Radio-Loud Broad Absorption Line Quasars (BAL QSOs) from the Sloan Digital Sky Survey

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Abstract Broad Absorption Lines (BALs) seem to be the most extreme manifestations of quasar (QSO) outflows. Two main scenarios have been proposed to explain the nature of BAL QSOs. They may be a physically distinct population (e.g., newborn or recently refuelled QSOs) or present in all QSOs but intercepted by only a fraction of the lines of sight to the QSOs. Our previous observations of a sample of 15 radio BAL QSOs show that they have convex radio spectra typical of Giga-Hertz Peaked-Spectrum (GPS) sources. We have selected a well-defined sample of radio bright BAL QSOs from the Sloan Digital Sky Survey - Data Release 5. Here we present preliminary results on radio continuum observations in full polarisation of this sample, taken with the 100-m Effelsberg radiotelescope at 2.7, 4.8, 8.4 and 10.5 GHz. The aim is to describe the radio spectra and polarisation characteristics of these radio bright BAL QSOs and compare them with our previous results from the study of a radio fainter sample of BAL QSOs and with the properties of normal QSOs where the BAL phenomenon is not seen.

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1 BAL QSOs with radio emission

The Broad Absorption Lines are the most evident manifestation of QSO outflows, and are present in about 15% of the optically-selected QSOs (see e.g. Knigge et al. 2008). For a long time, radio-loud BAL QSOs were believed to be extremely rare among the population of luminous QSOs (Stocke et al. 1992). With the advent of FIRST it became clear that a substantial population of radio BAL QSOs exists (Becker et al. 2000). However, the fraction of BAL QSOs seems to vary inversely with the radio-loudness parameter, with the radio-brightest QSOs being less likely to exhibit BALs (Becker et al. 2001; Shankar et al. 2008). The explanation for this anticorrelation is, to date, not completely clear.

The nature of BAL QSOs is under debate. They can be just normal QSOs observed from a particular line of sight (see e.g. Elvis 2000) or might be newborn or recently refueled QSOs at some stage of their evolution (Becker et al. 2000; Gregg et al. 2006).

2 Previous pilot sample of 15 BAL QSOs

In a recent work we have selected from the literature a pilot sample of 15 radio-loud BAL QSOs in order to study their radio spectra, radio variability, spectral index distribution, polarisation properties, radiative ages, and radio morphology (Montenegro-Montes et al. 2008). The sample was selected using a cut in flux density at 1.4 GHz of 15 mJy and the frequency range covered was from 74 MHz up to 43 GHz. In our analysis we found that:

- most of the BAL QSOs in the sample show convex radio spectra which typically peak at about 1 to 5 GHz in the observer's frame, and flatten at MHz frequencies, probably due to synchrotron self-absorption. The normalisation frequency was chosen to be 25 GHz in the rest-frame.

- they show little or no variability at 1.4 GHz comparing the NVSS and FIRST flux densities. There are some variable objects at 8.4 GHz but variability is moderate (20-30%). This is consistent with the behaviour of CSS/ GPS sources.

- most sources are very compact being unresolved at all frequencies up to 22 GHz (HPBW=80 mas) with VLA (A configuration). The exceptions are 1053−00 and 1312+23 (see Montenegro-Montes et al. 2008).

- about two thirds of the BAL QSOs are unpolarised or weakly polarised at 8.4 GHz, finding a median polarisation degree of 1.3%, similar to the mean fractional polarisation found by Stanghellini et al. (2003), in a sample of GigaHertz-Peaked

Spectrum (GPS) QSOs.

- there was no significant difference between the distribution of spectral indices in our sample of BAL QSOs, and the comparison sample of compact non-BAL QSOs extracted from the complete B3-VLA QSO sample (Vigotti et al. 1997).

3 Exploiting the SDSS database

The Sloan Digital Sky Survey (SDSS) Data Release 5 contains spectroscopic data for 5,740 deg of sky, and catalogues about 80,000 QSOs. We used as a starting point the fourth edition of the SDSS QSO Catalogue (Schneider et al. 2007), which includes photometric information about the QSOs and also the associations with the 1.4-GHz radio sources of the FIRST catalogue. Among all the radio QSOs satisfying the same criterion applied to the pilot sample, S(1.4GHz) $>$ 15 mJy (see Figure 1), we selected two lists of objects:

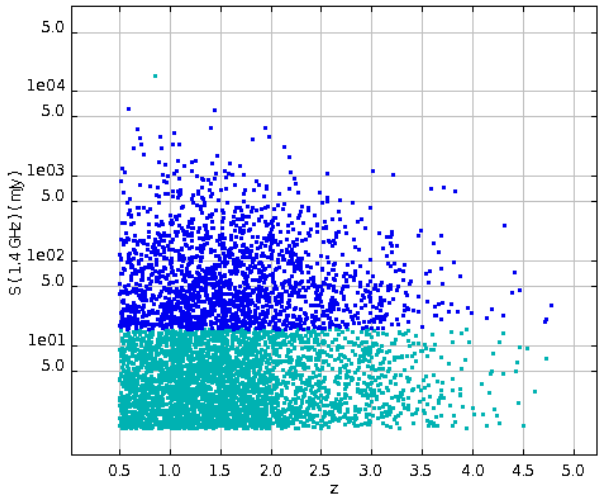

Fig. 1 Plot of radio flux density versus redshift for all QSOs with $0.5 < z < 4.8$ in the SDSS-DR5. In light-blue all radio QSOs; in dark-blue all with similar criterion as the pilot-sample: S(1.4GHz) $>$ 15 mJy.

- a sample of BAL QSOs with the presence of BAL troughs in C IV or Mg II. We used as a selection criterion for the presence of BALs the Balnicity Index (BI, Weymann et al. 1991) instead of the less reliable Absorption Index (AI, Hall et al. 2002).

- a comparison sample of non-BAL QSOs with otherwise similar characteristics to the sample of BAL QSOs (e.g., redshift distribution, absolute magnitude). This sample will be used to statistically compare some radio properties of BAL and non-BAL QSOs.

We have already observed about 40 SDSS QSOs with the 100-m Effelsberg radiotelescope at 2.6, 4.8, 8.4 and 10.5 GHz, including both BAL QSOs and non-BAL QSOs. Our preliminary results show that a high percentage BAL QSOs are unpolarised at 8.4 GHz, in agreement with our previous results. However, a few BAL QSOs show polarisation higher than 5%. These could be beamed flat-spectrum QSOs and not genuine young GPS QSOs.

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