Extragalactic jets from every angle
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Extragalactic jets of broad absorption line (BAL) quasars

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Abstract. Fast outflows of the ionized plasma, probably lunched in proximity of Supermassive Black Hole, are responsible for blue-shifted Broad Absorption Lines (BALs) in quasar spectrum. Outflows together with powerful jets produced in AGN are important feedback processes. Therefore, understanding physics behind BAL outflows might be a key to comprehend Galaxy Evolution as a whole. Discovery of the existence of radio-loud BAL quasars gave us another opportunity to study the BAL phenomenon, this time on the ground on radio emission. The radio emission is an additional tool to understand the BAL quasars, their orientation and age, by the VLBI imaging (detection of radio jets and their direction, size determination), the radio-loudness parameter distribution and variability study.

1. Radio observations

In order to build a sample of compact radio-loud BAL quasars we have matched the optical positions of BAL quasars from the catalog of Trump *et al.* 2006 which is drawn from the *Sloan Digital Sky Survey (SDSS) Data Release 3* to FIRST coordinates (White *et al.* 1997) in a radius of 10 arcseconds. In the next step we have excluded from this initial sample objects with additional radio counterparts within 60 arcseconds of SDSS position as those possessing large scale structures. Finally our sample consisted of 309 objects. We have then selected 31 sources with the largest 1.4 GHz flux densities for further high resolution VLBI observations at 1.7, 5 and 8.4 GHz. Most of the compact BAL quasars have been resolved at the higher observed frequencies showing typical quasar geometries namely one-sided core-jet structures. There are few objects classified as flat spectrum radio quasars (FSRQ), others have steep spectra. These radio properties implies that the observed objects belong to the population of young compact steep spectrum (CSS) sources. Their high radio luminosities, above the FR II-FR I luminosity threshold (Fanaroff & Riley 1974), make them the most luminous representatives of the class of compact radio-loud BAL quasars (Kunert-Bajraszewska *et al.*, in preparation).

2. Statistical study

The radio-to-optical ratio of the quasar core (R) is thought to be a strong statistical measure of orientation. Objects with $\log \mathrm{R} > 2.5$ are assumed to be viewed close to the radio jet axis and quasars with $\log \mathrm{R} < 1.5$ are thought to be those with large viewing angles (Kimball *et al.* 2011). We have calculated the radio-loudness parameter R defined as the radio (1.4 GHz)-to-optical (i-band) ratio of the quasar core for all BAL quasars from the initial sample (309 objects). The peak of the $\log \mathrm{R}$ distribution of the compact BAL quasars is in the range 1 - 1.5 what probably indicates large viewing angles. The number of sources decreases with the increasing radio flux density and $\log \mathrm{R}$.

As the next step we have checked the distribution of the value of the absorption quantified by the balnicity index BI (Weyman *et al.* 1991) versus the radio-loudness parameter $\log \mathrm{R}$ for this sample. We did not found any formal correlation between these two parameters but it can be noticed that the strongest absorption is connected with the lower values of the radio-loudness parameter, $\log \mathrm{R} < 1.5$ and thus larger viewing angles. However, the large span of BI values in the each bin of the radio-loudness parameter indicates that orientation is only one of the factors that influences the measured absorption (Kunert-Bajraszewska *et al.*, in preparation).

3. Radio jet power

Majority of radio-loud BAL quasars are radio intermediate or low luminosity young objects ($\sim \mathrm{L}_{1.4\,\mathrm{GHz}} \leqslant 10^{25.5}\,\mathrm{W\,Hz^{-1}}$). Studies of the low luminosity young AGNs (Kunert-Bajraszewska *et al.* 2010, Kunert-Bajraszewska & Labiano 2010) indicate they may develop to diffuse, large-scale structures as their weak jets are disrupted before escaping their host galaxies (Cegłowski *et al.* 2013). They may undergo disrupted evolution many times, as they are able to escape the host galaxy and evolve further. Such behaviour explains the excess of compact AGNs compared to large-scale FR Is and FR IIs. We suggest that the same mechanism could also explain the low number of extended 'adult' radio sources among the BAL quasars. In this sense many of the weak compact AGNs (thereby BALQSOs) can be also considered as the re-activated objects as proposed by a few authors (Kunert-Bajraszewska *et al.* 2010, Bruni *et al.* 2013, Hayashi *et al.* 2013).

The radio luminosity of large-scale radio source is approximately proportional to the jet power (Willott *et al.* 1999). We adopted this analysis to the compact BAL quasars and then plotted the 1.4 GHz jet power versus the value of the balnicity index (BI). There is no correlation between these two parameters but it can be noticed that strongest absorption is associated with the lower jet powers in accordance to the scenario discussed above.

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