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Spectral Variability of FSRQs

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Abstract. The optical variability of 29 flat spectrum radio quasars in SDSS Stripe 82 region are investigated by using DR7 released multi-epoch data. All FSRQs show variations with overall amplitude ranging from 0.24 mag to 3.46 mag in different sources. About half of FSRQs show a bluer-when-brighter trend, which is commonly observed for blazars. However, only one source shows a redder-when-brighter trend, which implies it is rare in FSRQs. In this source, the thermal emission may be responsible for the spectral behaviour.

Key words. Galaxies: active—galaxies: quasars: general—galaxies: photometry.

1. Introduction

Blazars, including BL Lac objects and flat-spectrum radio quasars (FSRQs), are the most extreme class of active galactic nuclei (AGNs), characterized by strong and rapid variability, high polarization and apparent superluminal motion. These extreme properties are generally interpreted as a consequence of non-thermal emission from a relativistic jet oriented close to the line of sight. While the jet non-thermal emissions are thought to be dominated in FSRQs, this is actually not always true. As a matter of fact, Chen *et al.* (2009) found that the thermal emission can be dominant at least in the optical bands for some FSRQs.

The color behaviours in blazars are still debated. The bluer-when-brighter trend (BWB) is commonly observed in blazars (e.g., Fan *et al.* 1998; Raiteri *et al.* 2001; Villata *et al.* 2002; Wu *et al.* 2007). But, opposite examples have also been found (e.g., Gu *et al.* 2006; Dai *et al.* 2009; Rani *et al.* 2010), such as 3C 454.3 (Gu *et al.* 2006), PKS 0736+017 (Clements *et al.* 2003; Ramírez *et al.* 2004), 3C 446 (Miller 1981), PKS 1622-297 & CTA 102 (Osterman Meyer *et al.* 2008, 2009). But still not many FSRQs were found to show redder-when-brighter trends (RWB). From a sample of FSRQs selected from SDSS, we briefly show here one more FSRQ with RWB (see Gu & Ai 2011 for details).

2. Sample

The Stripe-82 region, i.e., right ascension $\alpha = 20^{\mathrm{h}} - 4^{\mathrm{h}}$ and declination $\delta = -1.25^\circ - +1.25^\circ$, was repeatedly scanned during the SDSS-I phase (2000–2005) and also over the course of three 3-month campaigns in three successive years during 2005–2007 known as the SDSS Supernova Survey. Those quasars selected from SDSS DR7 quasars catalogue (Schneider *et al.* 2010) in the region of the Stripe 82, were cross-correlated with the faint images of the radio sky at 20-cm (FIRST) 1.4-GHz radio catalogue (Becker *et al.* 1995), the Green Bank 6-cm (GB6) survey at 4.85 GHz radio catalogue (Gregory *et al.* 1996), and the Parkes-MIT-NRAO (PMN) radio continuum survey at 4.85 GHz (Griffith & Wright 1993). A quasar is defined as a FSRQ according to the radio spectral index between 1.4 and 4.85 GHz with $\alpha < 0.5$ ($f_\nu \propto \nu^{-\alpha}$), which results in a sample of 32 FSRQs.

3. Results

We use the photometric data obtained during the SDSS-I phase from Data Release 7 (DR7; Abazajian *et al.* 2009) and the SN survey during 2005–2007. We use the point-spread function magnitudes. The spectral index α are calculated from the linear fit on $\log f_\nu - \log \nu$ after extinction correction on *ugriz* flux density.

3.1 *Variability*

Among 32 FSRQs, three sources were excluded in our analysis due to various reasons. The remaining 29 FSRQs showed large amplitude variations with overall variations in the r band, $\Delta r = 0.24$–3.46 mag, which is much larger than that of the radio quiet AGNs, 0.05−0.3 mag (e.g., Ai *et al.* 2010), which is typical for blazars (e.g., Gu *et al.* 2006). There are four sources with $\Delta r > 1$ mag, i.e., SDSS J001130.400+005751.80 − $\Delta r = 3.46$ mag; SDSS J023105.597+000843.61 − $\Delta r =$ 1.02 mag; SDSS J025515.096+003740.55−Δr=1.70 mag; SDSS J235936.817−003112.78 − $\Delta r = 1.20$ mag. In general, the variations in different bands show similar trends.

3.2 *Spectral index and brightness relation*

The correlation between the spectral index α_ν and psf r magnitude were checked for all sources using the Spearman rank correlation analysis method. We found that 15 of 29 FSRQs show a significant correlation at a confidence level of $> 99\%$, of which 14 FSRQs show positive correlations, and only one FSRQ (SDSS J001130.40+005751.7) shows a negative correlation.

The negative correlation shows that the source becomes steeper when the source is brighter, i.e., RWB, which is shown in Fig. 1 with a total 43 data points. The Spearman correlation analysis shows a significant negative correlation with a correlation coefficient of $r_{\mathrm{s}} = -0.606$ at a confidence level $> 99.99\%$. This source is included in the first Fermi Large Area Telescope AGNs catalogue with photon index of 2.51 ± 0.15 and it is classified as a low-synchrotron-peaked FSRQs with $\nu_{\mathrm{peak}} < 10^{14}$ Hz (Abdo *et al.* 2010). With the source redshift $z = 1.4934$,

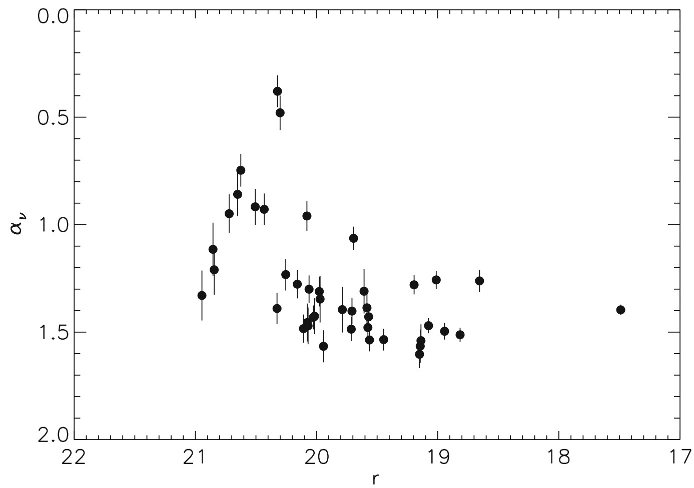

Figure 1. The relationship between the spectral index and the psf magnitude at *r* band for SDSS J001130.40+005751.7. A significant anti-correlation is present, which implies a redder-when-brighter trend.

SDSS *ugriz* wave bands correspond to the wavelength range of 1424–3582 Å in the source rest frame, which therefore is likely at the falling part of the synchrotron SED. Shang *et al.* (2005) showed that the spectral break happens at around 1100 Å, which is thought to be closely related to the big blue bump. If this spectral break also exists in SDSS J001130.40+005751.7, we would expect to observe the rising part of accretion disk thermal emission when it dominates over the nonthermal emission. Indeed, Fig. 1 qualitatively shows that the optical spectral is rising ($\alpha_\nu < 1.0$) when the source is at a low flux state; while it becomes falling ($\alpha_\nu > 1.0$) when the source is at high flux state implying that a nonthermal low peak frequency synchrotron emission starts dominating.

It is interesting to note that FSRQs are supposed to generally have redder-when-brighter trend (e.g., Dai *et al.* 2009), for example, in at least two of three, 3C 454.3 and PKS 0420-014 (Gu *et al.* 2006), and four of six, PKS 0420-014, 4C 29.45, PKS 1510-089 and 3C 454.3 (Rani *et al.* 2010), all of which are known low-synchrotron-peaked FSRQs. However, our results imply that the redder-when-brighter trend may likely to be rare in FSRQs, at least for our present sample. Although the details are unclear, it is most likely that the spectral behaviour of FSRQs is dependent on the position of the synchrotron peak frequency, the sampled optical wavelength range in the source rest frame, the positions of thermal blue bump and its strength compared to jet emission (see also Gu & Ai 2011).

4. Conclusion

For a sample of 29 FSRQs selected in the SDSS stripe 82 region, all FSRQs show large amplitude overall variations, e.g., 0.24–3.46 mag at the *r* band. We only found a significant negative correlation between the spectral index and *r* magnitude (i.e., RWB) in one FSRQ. This implies that the RWB trend is rare in FSRQs, which could be explained by the contribution of thermal accretion disk emission. In contrast, BWB is more common in FSRQs.

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