Jets at all Scales
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Radio variability of blazars

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Abstract. In this work, we present the analysis results using UMRAO preliminary data base. We used the light curves 1) to get the shortest timescales and then to get the brightness temperature so that we can estimate the Doppler factors; 2) to investigate the periodicity and discuss the variability index. We also used the data base to discuss the polarization properties of blazars. We found that the periodicity distribution in BL Lacs and that in the flat spectrum radio quasars should be from the same distribution. The Doppler factor in FSRQs is higher than that in BL. The polarization in BLs are higher than that in the flat spectrum radio quasars

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1. Introduction

Blazar is a special subclass of active galactic nuclei (AGNs). It consists of two subclasses, namely BL Lacertae objects–BLs and flat spectrum radio quasars-FSRQs. In this sense, the properties of BLs and FSRQs can be concluded as the properties of a blazar. Therefore, a blazar shows high and variable luminosity, high and variable polarization, superluminal motions in their radio components, high gamma-ray emission, has strong emission lines or has no emission line feature at all (e.g. Fan *et al.* 2005, 2009, 2010 and references therein). Variability is one of the most interesting properties, that is studied in the whole wavebands, particularly in the optical band (see Bai *et al.* 1998, Boettcher *et al.* 2009, Cellone *et al.* 2007, Dai 2010, de Vries *et al.* 2006, Efimov 2010, Fan *et al.* 1998, 2002, 2007, 2009a, 2009b, Fidelis *et al.* 2009, Gupta *et al.* 2008a, 2008b, 2008c, Kurtanidze *et al.* 2008, Liu 2010, Poon *et al.* 2009, Pyatunina *et al.* 2004, Qian *et al.* 2003, Qian *et al.* 2004, Raiteri *et al.* 2003, Romero *et al.* 2000, Romero *et al.* 2002, Sillanpaa *et al.* 1996, Takalo *et al.* 2010, Villata *et al.* 2004, Wagner *et al.* 1995, Webb *et al.* 1998, Wu *et al.* 2010, Xie *et al.* 1999, Xie *et al.* 2004, Zhang *et al.* 2010 etc. and reference therein).

In the radio bands, some monitoring programs provide data base for one to analyze the radio variability properties, from which we can discuss the emission mechanism and even the relationship between BLs and FSRQs. Based on the UMRAO data base, Aller *et al.* (1992) and Aller *et al.* (2003) investigated the statistical behavior of the flux and the linear polarization of AGNs, and the relation between different radio bands for the Pearson-Readhead sample. In the present paper, we will show our work in the radio variabilities based on the preliminary data base. In the 2nd section, we will show the Doppler factors estimated for the sources, in the 3rd section, we will show the periodicity and the variability index analysis, in the 4th section, we will show the polarization properties.

2. Time scale and Doppler factor

Variability is one of the most extremely properties of blazars. The variabilities were detected on different time scales. Different time scales bring us different information of the emitting source. The short-time scale perhaps sheds some lights on the emission size. If we assume the time scale as the measure of the size of the source, then the observed flux variation may be converted into a brightness temperature (Wagner *et al.* 1995)

$$\mathrm{T_B} = (4.5 \times 10^{10}\mathrm{K})\Delta\mathrm{F}[\frac{\lambda \mathrm{d_L}}{\mathrm{t_{obs}}(1+\mathrm{z})}]^2, \tag{2.1}$$

here ΔF is the variability of flux density in Jy, λ the wavelength in cm, d_L the distance in Mpc, and $\mathrm{t_{obs}}$ the time scale in days, z is redshift of the source.

The time scales can be determined using the shortest time scale at the three frequencies (4.8 GHz, 8 GHz, and 14.5 GHz). The detailed process is as follows. For each frequency, we calculated the time scales corresponding to large variation. If the variation is larger than 5 times of the uncertainty, $\Delta S \geqslant 5\sigma$, the timescale can be taken as a true one, and then we take the shortest time scale as the timescale at the frequency, so we have 3 times scales. Finally, we take the shortest time scale of the three timescales as the timescale of the source (Fan *et al.* 2009c). When the timescale, the variation, and the corresponding wavelength ($\lambda = c/\nu$) are used to relation (2.1), we can get the brightness temperature. When the brightness temperature is higher than 10^{12}K, then the Doppler factor is can be estimated using $\delta = (T_B/10^{12})^{1/3}$, or $\delta = (T_B/10^{12})^{1/5}$.

From the UMRAO data base, we get the Doppler factors, δ's are in the range of 1.02 to 25.82 for all considered blazars. If we considered the BLs and FSRQs separately, we have $\delta = 1.02$ to 19.89 with an average value of $< \delta >= 8.5 \pm 5.3$ for BLs, and $\delta = 1.34$ to 25.82 with an average value of $< \delta >= 12.29 \pm 6.45$ for FSRQs. Doppler factor in FSRQs is, on average, higher than that in BLs(Fan *et al.* 2009c).

3. Variability and periodicity

Blazars are variable in the whole electromagnetic wavebands. It is interesting to investigate the periodicity and the variability violence.

3.1. *Variability Parameter*

The variability violence can be indicated using a variability parameter(see Romero *et al.* 1999). In radio bands, there are three kinds of variability parameters (variability index (VI), the normalized variability amplitude(NVA), and the root mean square dispersion($RMSD$)) (Fan *et al.* 2007).

Variability index measuring the peak-to-trough variations, can be calculated

$$VI = \frac{(S_{max} - \sigma_{S_{max}}) - (S_{min} + \sigma_{S_{min}})}{(S_{max} - \sigma_{S_{max}}) + (S_{min} + \sigma_{S_{min}})},$$

here, S_{max} and S_{min} are the highest and the lowest flux densities with $\sigma_{\mathrm{S_{max}}}$ and $\sigma_{\mathrm{S_{min}}}$ being the corresponding uncertainties of the fluxes.

Normalized variability amplitude (NVA) can be calculated using the mean $\langle S \rangle$ and standard deviation σ_{tot} of the flux points and the mean error level σ_{err}(see Edelson *et al.* 1996).

$$NVA = \sqrt{\frac{\sigma_{\mathrm{tot}}^2 - \sigma_{\mathrm{err}}^2}{\langle S \rangle^2}}$$

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Root mean square dispersion (RMSD) can be determined by

$$\sigma_{RMSD} = \frac{1}{\langle S \rangle} \sqrt{\frac{1}{N-1} \sum_{i=1}^{n} (S_i - \langle S \rangle)^2},$$

where S_i's are the measured fluxes, $\langle S \rangle = \frac{1}{N} \sum_{i=1}^{n} S_i$ is the mean flux (see Kembhavi & Narlika 1999).

From the relevant data, we found that NVA is correlated with σ_{RMSD}, however the two parameters are not correlated with V.I.. That perhaps suggests NVA and σ_{RMSD} be good variability violence indicators.

3.2. *Periodicity*

Periodic variations are claimed in the optical bands (see Sillanpaa *et al.* 1988, Fan *et al.* 1997, 1998, 2002, Fan 2005). In the radio bands, there is no much work. For the periodicity analysis, the unevenly sampled data make periodicity investigation hard since this sampling will cause false periods. Recently there are some methods to deal with the period determination, such as Jurkevich method, DCF method, and Power spectral (Fourier) analysis (see Fan *et al.* 2002, Fan *et al.* 2007).

When the methods are used to the preliminary data base of UMRAO, we have got the periods at 8GHz for a sample of blazars. The period obtained is in the range of 2.2 to 20.8 years. If we consider FSRQs and BLs separately, we found that the physically significant periodicity at 8GHz are in the range of 2.2 to 20.8 years with an averaged value of 8.9±4.0 years for FSRQs, and 2.5 to 18.0 years with an averaged value of 8.1±3.4 years for BLs. A K-S test shows that the probability for the two distributions to be from the same distribution is 68.2% (Fan *et al.* 2007).

4. Polarization

From the UMRAO data base, we found that on average, the polarization in higher frequency tends to be higher in the radio range from 4.8GHz to 14.5GHz for all blazars. When we only considered the maximum polarization, similar behavior has been shown clearly. If we considered BLs and FSRQs separately, we found that BLs have higher maximum polarization than FSRQs on average. $\langle P^{\max}_{4.80\mathrm{GHz}}(\%)\rangle = 17\pm13$, $\langle P^{\max}_{8.00\mathrm{GHz}}(\%)\rangle = 26\pm21$, $\langle P^{\max}_{14.5\mathrm{GHz}}(\%)\rangle = 29\pm21$, for BLs, and $\langle P^{\max}_{4.80\mathrm{GHz}}(\%)\rangle = 9\pm10$ $\langle P^{\max}_{8.00\mathrm{GHz}}(\%)\rangle = 15\pm14$, and $\langle P^{\max}_{14.5\mathrm{GHz}}(\%)\rangle = 15\pm13$ for FSRQS (Fan *et al.* 2008). In fact, in the optical band, the polarization in BLs is also higher than that in FSRQs(see Wills *et al.* 1992, Fan 2002).

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