Radio variability for OJ287 and 3C279

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Based on the new data from the database of the University of Michigan Radio Astronomy Observatory (UMRAO), we analyze the spectral index and optical variability of OJ287 and 3C279. The main results show that 1) the time delay among three radio bands (4.8, 8, and 14.5 GHz) shows: \( \tau_{8-14.5} = 31 \) d, \( \tau_{4.8-8} = 41 \) d for OJ287, but no time delay lying in 3C279; 2) strong correlation lies in the polarization and flux density at 8 GHz for OJ287 and at 8, 14.5 GHz for 3C279; 3) the logarithmic brightness temperature \( \log(T_B) = 14.1 \) K for OJ287 is 14.1 K, \( \log(T_B) = 15.1 \) K for 3C279.

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Blazars are special Active Galactic Nuclei (AGNs), containing some special properties, including high and variable luminosity, high polarization, superluminal motions in their radio components, etc. [1–7]. Blazars contain two sub-classes, BL Lac objects (BLs) and flat spectrum radio quasars (FSRQs). Generally speaking, BLs only contain weak emission or no emission lines, etc.

OJ287 (VRO 20.08.1) is a typical and best studied BL Lac object, which was firstly monitored in radio observation by ref. [8] and in optical band by ref. [9]. Through spectroscopic observations, ref. [10] used a weak [OIII] spectral feature to find that the redshift was 0.306, which also can be seen from refs. [11,12]. OJ287 was found containing a one-sided jet with complex structure on parsec [13] and kiloparsec [14]. Ref. [15] analyzed the radio, millimeter and submillimeter spectra of 22 BL Lac objects and 24 optical violently variable quasars (OVV), and attributed the effect to an intrinsic difference between the underlying jets in the two types of object. Radio spectral index (\( \alpha \)) of OJ287 has been investigated by many papers [15–19].

3C279 (PKS1253-055) is a typical optical violently variable quasar, and exhibits some characteristic properties of BLs [20]. Ref. [21] used the Mg II \( \lambda 2798 \) at 4308 Å to find that the redshift was 0.538. This source exhibits relative ‘slow’ super-luminal speeds [22] and has been monitored covering the entire electromagnetic spectrum variability [23]. 3C279 was firstly monitored to be a radio source by ref. [24] and the radio jet had been known to extend out to kilo-parsec scales for \( \sim 5\" \) [25–27]. The radio polarization was firstly monitored by ref. [28] and the circular polarization had been detected in the parsec-scale jet, possibly implying an electron-positron composition [29–31].

Ref. [19] obtained that the flux density and polarization of OJ 287 in both optical and 43 GHz band increased in the late 2005, and gave a model to explain the radio variability in flux and polarization. This model corresponds to the rapid fluctuations in the direction of the flow of the emitting plasma within the core. If the direction of the spine is dominant to an instability which can cause the spatial oscillation, the changing core position can give birth to a swing in the direction of the fast spine. The variation in angle between the flow velocity vector and the line of sight can be responsible for the variability in flux and polarization that can be observed.

The paper is arranged as follows: Sect. 1 gives the sam-
samples; sect. 2 gives the method and the results; sect. 3 gives the discussion and makes the conclusion.

1 Samples

The samples about OJ287 and 3C279 come from UMRAO (University of Michigan Radio Astronomy observatory), and are directly downloaded from the UMRAO web.

For OJ287, there are 137 observations, ranging from JD 2455082.2 to JD 2455384.3, among which, there are 93 observations lying in both flux density and polarization, but the other 44 observations only have flux density. For flux density, at 4.8 GHz, there are 38 observations, which range from 2.04 Jy to 4.21 Jy, using 191 d, and lie an outburst at JD 2455305.5 (Figure 1), with the averaged value (3.29 ± 0.64) Jy. At 8 GHz, there are 47 observations, which range from 3.43 Jy to 6.23 Jy using 116 d, and lie an outburst at JD 2455211.8 (Figure 1), with the averaged value (5.02 ± 0.89) Jy. At 14.5 GHz, there are 52 observations, which range from 4.66 Jy to 9.97 Jy, using 176 d, and lie an outburst at JD 2455199.8 (Figure 1), with the averaged value (7.37 ± 1.59) Jy.

For the polarization of OJ287, at 4.8 GHz, there are 10 observations, which range from 1.32% to 5.02% (Figure 1), with the averaged value (2.71 ± 1.18%). At 8 GHz, there are 35 observations, which range from 1.04 Jy to 4.05 Jy, see Figure 1, with the averaged value (2.49% ± 0.83%). At 14.5 GHz, there are 48 observations (Figure 1), which range from 0.83% to 7.33%, with the averaged value (4.19% ± 1.83%).

For 3C279, there are 123 observations, ranging from JD 2455081.3 to JD 2455384.5, among which, there are 93 observations lying in both flux density and polarization, but the other 44 observations only have flux density. For flux density, at 4.8 GHz, there are 36 observations, which range from 8.73 Jy to 9.46 Jy using 78 d (Figure 2), with the averaged value (9.08 ± 0.21) Jy. At 8 GHz, there are 44 observations, which range from 9.16 Jy to 10.95 Jy using 208 d (Figure 2), with the averaged value (10.04 ± 0.38) Jy. At 14.5 GHz, there are 42 observations, which range from 10.52 Jy to 12.96 Jy using 72 d (Figure 2), with the averaged value (11.46 ± 0.67) Jy.

For polarization of 3C279, at 4.8 GHz, there are 33 observations, which range from 2.08% to 4.07% (Figure 2), with the averaged value (3.20% ± 0.52%). At 8 GHz, there are 44 observations, which range from 1.05 Jy to 3.71 Jy (Figure 2) with the averaged value (2.29% ± 0.69%). At 14.5 GHz, there are 42 observations (Figure 2), which range from 0.9% to 3.35%, with the averaged value (1.92% ± 0.56%).

2 Methods and results

2.1 Time delay among radio bands

Time delay among different bands can directly connect to the travelling time of a relativistic electron parcel between the two regions in the model of a shock running along the jet or particle cooling time scale [32–35]. This special phenomenon has been studied by many work [36–38].

We use the discrete correlation function (DCF) method [39] to analyze the time delay among the three radio bands of OJ287 and 3C279. DCF method can be defined in the following manner [39].

For two discrete data trains, \((t_i, y_i)\) and \((t_j, y_j)\), we obtain the set of unbinned discrete correlations

\[
UDCF_{ij} = \frac{(a_i - \langle a \rangle) \times (b_j - \langle b \rangle)}{\sqrt{\sigma_a^2 \times \sigma_b^2}},
\]

\[(1)\]

Figure 1: The observations of OJ287 in three radio bands. The left three subplots stand for flux density and the right three subplots stand for polarization.

Figure 2: The observations of 3C279 in three radio bands. The left three subplots stand for flux density and the right three subplots stand for polarization.