Simultaneous optical flux, colour and polarization intra-night variability studies of blazars

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Abstract

The physical processes responsible for producing intra-night optical variability (INOV) of blazars continue to be debated. We present the initial results of our on-going monitoring programme to investigate the INOV of a sample of optically bright (V $\leq$ 15 mag) blazars in optical colour and polarization. We have used 130cm DOT and 104cm ST telescopes at ARIES, India (optical multi-band observations) and the 1.5m KANATA telescope (polarization observations) at Higashi-Hiroshima observatory, Japan for simultaneous measurements on intra-night timescales. Since the blazars display, besides the quiescent slowly varying emission, flares on time scales as short as minutes, we have assumed a two component model responsible for producing a long (base emission) and short (flaring) trends. Blazar OJ 287 was observed on 2 nights. On 20 February 2014, OJ 287 shows a variety of trends between optical flux, fractional polarization and the electric vector polarization angle (EVPA) of source OJ 287 observed on in a short time span of 5 hours. We deduce that the variable component has a fractional polarization of 20-40 per cent. On 27 February 2014, OJ 287 shows a steady increase in flux, polarized flux while the polarization degree remains constant. Blazar 1156+295 was observed on 30 March 2014 where it did not display INOV.

Introduction

The optical emission of blazars is known to be predominantly the synchrotron radiation of relativistic electrons in a jet while the high energy ($\gamma-$ray) emission is most widely believed to be due to the inverse-Compton emission of the same or distinct electron population (e.g.,Urry & Padovani 1995). Besides the quiescent, slowly varying emission, blazars exhibit flares and outbursts on timescales ranging from minutes to weeks, pronounced especially at higher energies (i.e., X-rays or $\gamma-$rays; Aleksić et al. 2011 and reference theirin). The origin of such dramatic flux changes, and in particular their relation to smaller-amplitude but short-timescale variability observed at lower frequencies (including INOV), is still being widely debated.

There are several competing models which have been proposed to explain the rapid ($\sim$ hour timescale) total flux and polarized flux variability of blazar sources. These includes 'extrinsic models', such as, the 'light house effect' (Gopal-Krishna & Wiita 1992) and the 'intrinsic models' which includes various plasma instabilities and development of compact shocks in relativistic jets (e.g., Marscher et al. 1985; Goyal et al. 2012) or the magnetic reconnection events (Giannios 2013). The temporal behaviour of the optical polarization is used to look for signatures of the formation and passage of the shocks through the jet flow, (Laing 1980; Abdo et al. 2010), an effective way to unravel the origin of INOV can be through multi-frequency optical flux and polarization monitoring.

Observations, analysis and results

Sample and data analysis

The sample consists of 4 flat radio spectrum quasars (FSRQs) (B $\leq$ 16 mag) and the data analysis was carried out using standard procedures in $IRAF$. Table 1 lists the observational parameters of our sample.

Table 1: Basic information on the sample

SNo.	IAU Name	RA (J2000)	Dec.(J2000)	2FGL flux (10^{-12}erg cm^{-2} s^{-1})	Γ	B (mag)	P$_{opt}$ (per cent)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	S5 0716+71*	07 21 53.3	+71 20 36	183±5.3	2.08	15.50	6
2.	OJ 287	08 54 48.8	+20 06 30	41±2.3	2.23	15.91	16
3.	4C 29.45	11 59 31.9	+29 14 45	73±2.5	2.29	14.80	28
4.	3C 279*	12 56 11.1	−05 47 21	298±4.8	2.34	16.01	26

$*$ marked are the once detected at TeV wavebands (http://tevcat.uchicago.edu/).

Columns : (1) serial number; (2) IAU name ; (3) right ascension; (4) declination ; (5) 2FGL energy flux±error for 100 MeV - 100 GeV ; (6) photon power-law index; 100 MeV - 100 GeV; (7) apparent B-magnitude; (8) typical degree of optical polarization.

Modelling - decomposition of the short flaring component

Assuming that observed emission in blazars is arising from 2 components, a slow varying background emission (long component L) and a fast varying component responsible for INOV flares (short component S). We follow the methodology used by Uemura et al. (2010), and using the scalar properties of Stokes Q and U parameters;

$$Q_{Obs} = Q_L + Q_S$$
$$U_{Obs} = U_L + U_S$$

Where Q_{obs}, U_{obs}, Q_L, U_L, Q_S, U_S are the Stokes Q and U parameters for the observed (total emission), long (slowly varying background) and short (fast flaring) components. The polarized flux (PF), polarization degree (PD) and polarization angle (PA) is given by $\sqrt{(Q^2+U^2)}$, $\frac{\sqrt{(Q^2+U^2)}}{F}$ and $\frac{1}{2}arctan(\frac{U}{Q})$.

Results

Fig. 1 (A) presents the INOV lightcurve of blazar OJ 287 obtained on 20.02.14. The total flux variation is plotted in column (a). The red crosses represents the slowly varying background emission, modelled as changing linearly within the micro flare duration. Superposed on this variation, short component can be distinguished at the beginning and towards the end of observation. The Stokes parameters for short component, Q_S and U_S are obtained by subtracting the Q_L and U_L from the total emission. The PD_S and PA_S for the short component are obtained using the standard expressions. The total spectral index is plotted in column (g) ($\alpha_I^V = \frac{log(Flux_V/Flux_I)}{log(\nu_V/\nu_I)}$). Fig. 1 (B) gives the computed values of the PD_S, PA_S and α_S, for the sort component as a function of observing time.

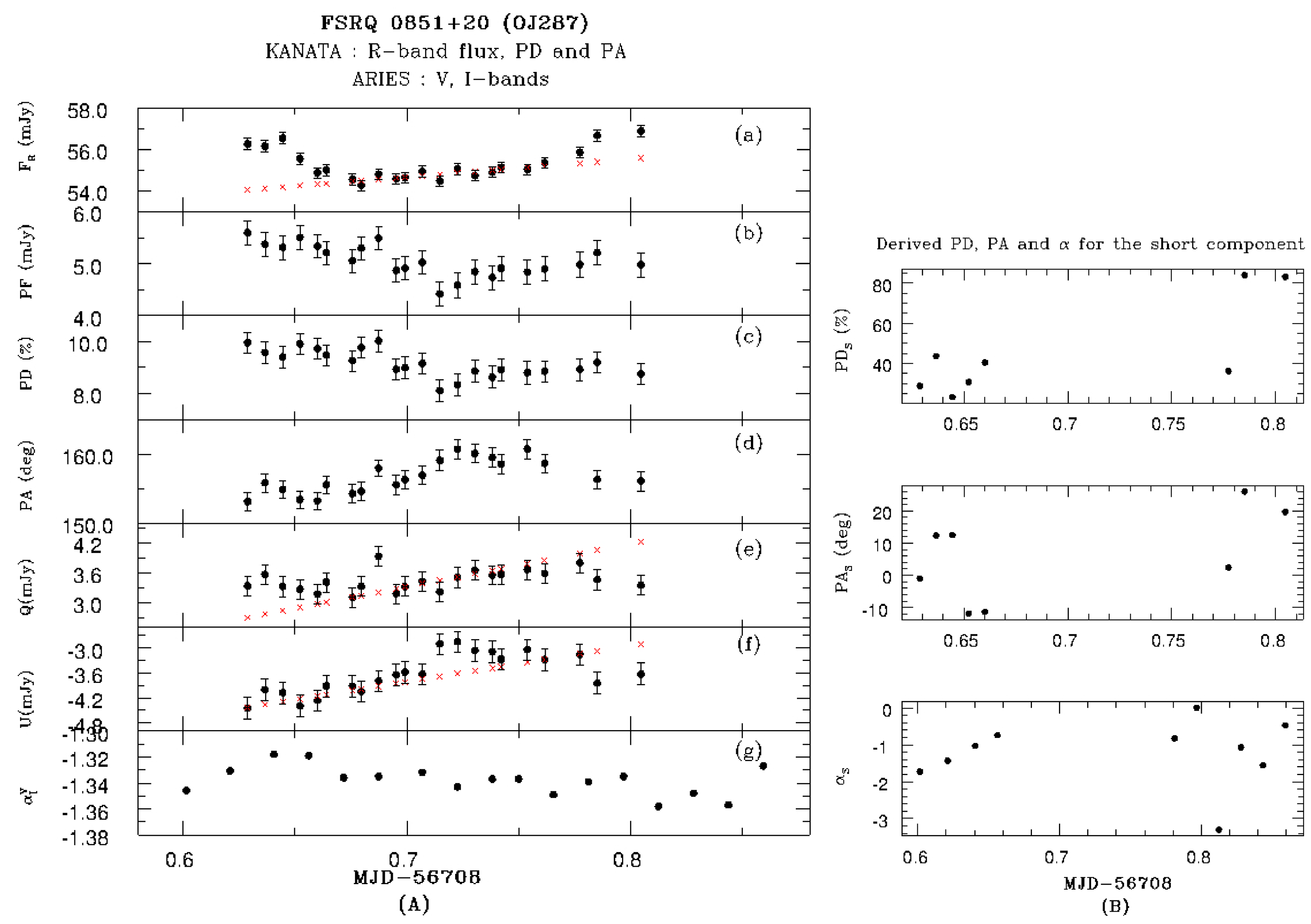

Figure 1: (A) The flux (R-band), PD, PA are obtained using the 1.5m KANATA telescope, Japan while the optical V, I band observations are obtained using 1.3m DOT telescope, India. **(B)** The computed PD and PA and optical spectral index of the short component. Note that the measurement errors in computed PD_S and PA_S are $\sim$10 per cent and about few per cent for α_S

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Conclusions

We present the results of INOV monitoring in flux and polarization for two FSRQs, namely OJ 287 and 1156+295.

- OJ 287 showed INOV of about 0.1 mag in about 6h duration on 20.02.14 (Fig. 1A). Both PD and PA varied during this time. Using the two component analysis, we subtracted the underlying long-term component and derived the PD and PA of the short term component. The computed polarization degree is $\sim$ 20 per cent and 10 deg. We deduce, (a) the short term component has a higher PD than the slowly varying background component (mean observed polarization $\sim$ 9 per cent as compared to the 20 per cent, Fig. 1B), indicating higher ordering of magnetic field in the short component emission region. (b) the PA of the short component is $\sim$ 0 deg, as compared to the mean PA of $\sim$155 deg of the total emission, indicating that the magnetic field direction of the short component is almost anti-parallel to the general direction (Fig. 1B). (c) spectral index for the short component is ranging from -1 to -3 (Fig. 1B), as compared to the spectral index of long component which remains stable at -1.34.
- OJ 287 indicates a steady rise in flux and PD on the night of 27.02.14. The PA remains unchanged. We could not identify any short flaring in these observations.
- FSRQ 1156+295 did not show INOV on the night it was observed.
- Our analysis presents a simple method to derive the parameters of the short flaring component (however, there can be more flaring components), responsible for the fluctuation on intra-night time scales that can be used to distinguish between the competing scenarios for fast flux variability.

References

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