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Optical polarization variability in TeV blazars*

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Blazars are characterized by the existence of brightness variability in all observed wavelengths occurring in very short time scales. The origin of the extreme activity is probably related to a relativistic jet that lies very close to the line of sight. Since the radio to X-rays emission in blazars can be associated with synchrotron radiation, multiband polarimetric data are an important tool to investigate the nature of the components associated with the brightness variability. In this work, we present a study of the optical polarization variability in the TeV BL Lacs PKS 2005-489 and PKS 2155-304. The data were taken between 2003 and 2006 with time resolution from a few hours to a few years, complemented with data obtained in the literature, when available. For both sources we analyzed the incidence of variability at different time scales; the existence of correlations between total and polarized flux and the existence of preferential values of polarization. The combination of results favours a scenario in which the origin of the variability is associated with shock evolution along a quiescent jet, which changes its of orientation in time scales of decades.

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1.Introduction

Extreme brightness variations across the entire electromagnetic spectrum occurring at several time scales are known properties of blazars. Their Spectral Energy Distribution (SED) is characterized by two broad bumps. The first, related to emission from radio to X-rays, is probably produced by incoherent synchrotron radiation, while the Compton emission is believed to be responsible for the hard X- to gamma-rays associated to the second peak.

Constraints provided by the polarimetric variability in these sources are crucial to understand the magnetic field structure of the relativistic jets. These jets are believed to be oriented very close to the line of sight and in most cases they cannot be resolved even with the highest available spatial resolution. Although the simplest model for the origin of the polarized flux is a single homogeneous synchrotron source, the observation of spectral dependence in the polarization degree (*P*) and, more rarely, also in the position angle (θ), requires more complex scenarios as an inhomogeneous synchrotron source, or the assumption of several components with different spectral indices and magnetic field orientation (Brindle et al. 1986, Valtaoja et al. 1991, Björnsson 1985).

The analysis of contemporaneous multiwavelength observations of the polarized emission should help to improve the understanding of the phenomena occurring in these objects. For this reason, we carried out, between 2003 and 2006, a program to monitor the optical polarization of a sample of blazars. In this work we present some of the results concerning two TeV BL Lacs: PKS 2005-489 and PKS 2155-304. The observations were planned to:

- verify the incidence of variability in different time scales;
- analyze the relationship between the total and polarized flux density;
- search for preferential values of polarization, which are indicative of the existence of a stable magnetic field component in the relativistic jet;
- look for spectral dependence in the position angle (θ) and polarization degree (*P*);
- compare the optical polarization and the total flux density with contemporaneous data obtained at higher energies.

2. Observations and data analysis

The observations were made with the B&C 60 cm telescope at the Pico dos Dias Observatory (LNA-MCT/CNPq, Brazópolis, Brazil) using the imaging polarimeter IAGPOL. Three optical filters were used (V, R and I). The data reduction was made with PCCDPACK, a package for IRAF environment, developed by the IAG/USP polarimetry group (see Pereyra 2000, for example).

The data were corrected for interstellar polarization (ISP), using observations of field stars. The light from the host galaxy can affect the polarization measurement, decreasing its value (Andruchow, Cellone & Romero, 2008). For this reason, the host flux contribution was

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subtracted, based on the data of Urry et al. (2000) and Kotilainen & Ward (1994) for PKS 2005-489 and PKS 2155-304, respectively. Total magnitude information was obtained from the polarimetric measurements and calibrated using field stars (Smith, Jannuzi & Elston 1991, Rector & Perlman 2003). The main results for each source are described in the next Sections. The complete analysis of the data will be presented in a next opportunity (Dominici et al. 2008ab, in preparation).

2.1 PKS 2005-489

The bright and nearby BL Lac PKS 2005-489 (z = 0.071, Véron-Cetty & Véron 1998) was detected at energies larger than 200 GeV by the H.E.S.S. telescope (Aharonian et al. 2005a). Previously, it was mainly known for its X-ray variability (e.g. Perlman et al. 1999), although optical continuum variability was also found at several time scales (Heidt & Wagner 1996, Rector & Perlman 2003, Dominici et al. 2004, 2006). However, few measurements of its optical polarization are found in the literature (Tommasi et al. 2001, Andruchow, Cellone & Romero, 2005).

The data presented here were taken during 13 nights between March 2003 and July 2004. Figure 1 shows the observed variability in P, θ and in the total flux density. Variability was detected in all time scales covered by the observations (few hours to several months) and the maximum value observed for P was 11.12% in the V band.

The largest values of the polarization were obtained when the source was brightest. However, analyzing a subset of the data obtained between 4 August and 4 September, 2003, representing the daily time scale variability, we found an anti-correlation between flux density and polarization degree, which can indicate the existence of an additional short-lived (i.e., weeks) source of polarized emission.

The distribution of the values of P and θ did not show evidences of preferred values. However, the values of the Stokes parameters seem to be concentrated in the second quadrant of the Q × U plane, as can be seen in Figure 1. Despite the suggestion of a preferential behaviour, observations with larger time coverage are necessary to confirm its existence.

2.2 PKS 2155-304

The optical and near-infrared polarization variability of the TeV BL Lac PKS 2155-304 (z=0.116, Falomo, Pesce & Treves 1993) has been studied intensively (e.g. Brindle et al. 1986, Mead et al. 1990, Smith & Sitko 1991, Smith et al. 1992, Jannuzi et al. 1993, Allen et al. 1993, Courvoisier et al. 1995, Pesce et al. 1997, Tommasi et al. 2001, Andruchow et al. 2005). Despite of all available data, our understanding of this source is still poor, mainly because of the limitations in time resolution and coverage, and the lack of contemporaneous multiwavelength data. The recently available TeV measurements (Chadwick et al. 1999, Aharonian et al. 2005b, Aharonian et al. 2007) reinforced the necessity of continuous monitoring of this source to allow

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a better understanding of the relationship between the lower energy synchrotron emission and on the high energy Compton component.

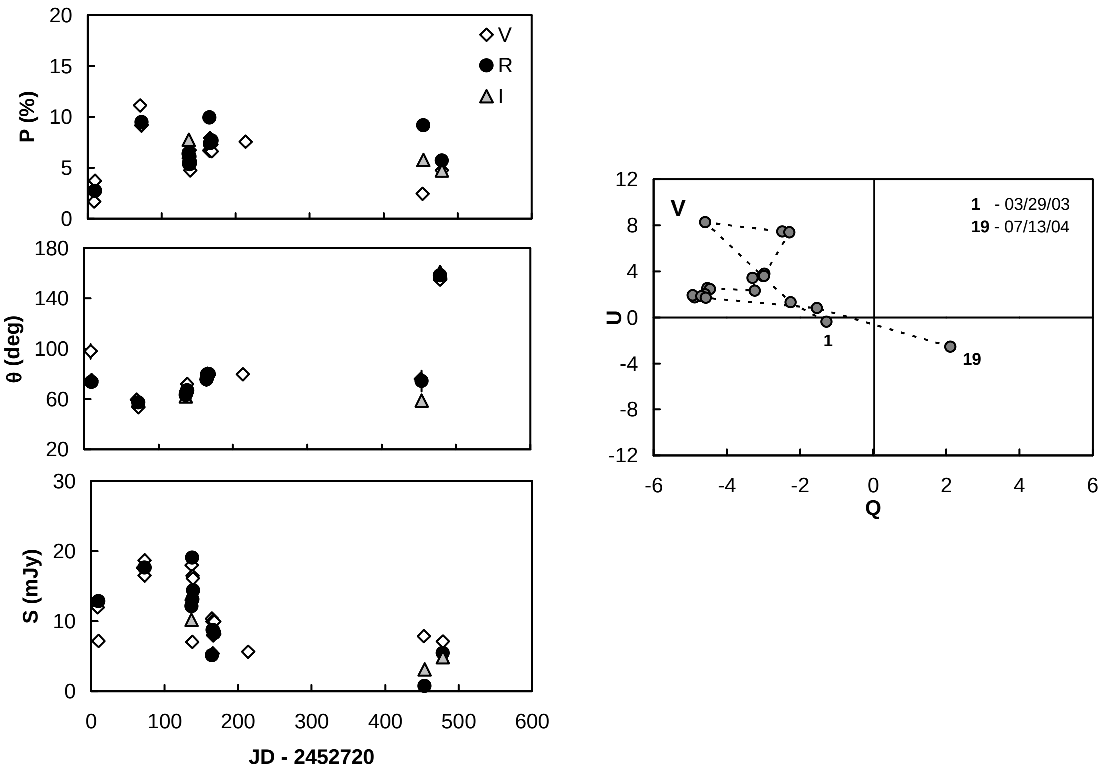

Figure 1: Left: variability of the polarization degree (P), position angle (θ) *and total flux density (S) in PKS 2005-489, observed between 2003 and 2004. Right: Distribution of the Stokes parameters in the V band. The measurements are concentrated in the second quadrant of the* Q × U *plane, as a hint for the existence of preferential values of polarization.*

Our data were obtained during 19 nights in 2003, 2004 and 2006. In particular, a dedicated monitoring was implemented during three nights in August 2006, about 20 days after the last TeV flare (Benbow et al. 2006, Aharonian et al. 2007). Figure 2 shows the main results of the monitoring. Variability was detected in all time scales covered by the observations (several minutes until few years) and the maximum value observed for *P* was 11.86% in the V band. The data allowed the analysis of the difference in the polarization during epochs of low and high level of flux density. We found evidences of a positive linear correlation between *P* and the total flux density using daily averaged values. However, the slope of the correlation seems to be smaller during the low flux density phase (2003-2004) than on high flux density phase (2006).

We investigated the existence of preferential values of polarization combining our data with observations collected in the literature and obtained during more than 25 years. Instead of a preferential value, as claimed before (Tommasi et al. 2001), the polarization angle seems to have a variable component at large time scales, as θ has been systematically decreasing during the last decades. This long-term behaviour can be caused by global geometric changes in the direction of the relativistic jet.

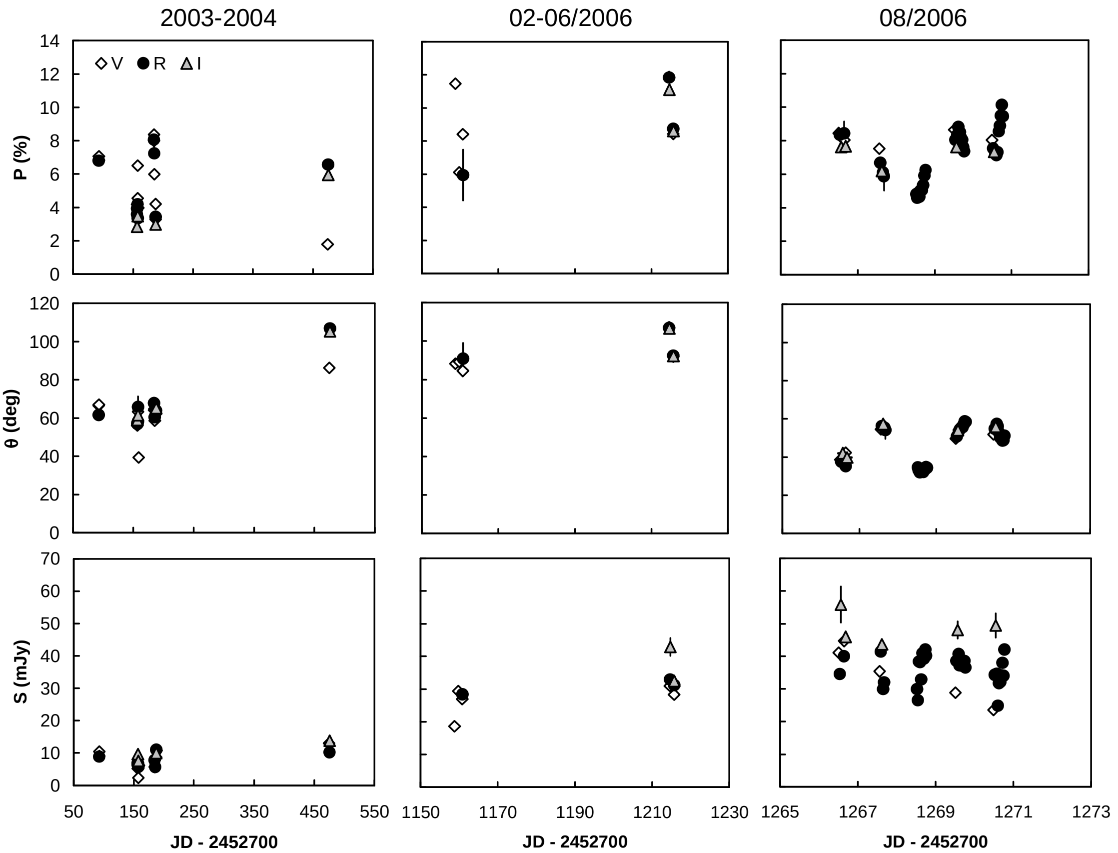

Figure 2: Variability in the polarization degree (P), position angle (θ) *and total flux density (S) in PKS 2155-304, observed between 2003 and 2006.*

3. Final remarks

PKS 2005-489 and PKS 2155-304 are similar sources according with their SED and the existence and characteristics of variability from radio to X-rays. The duty cycle of polarization, defined as the fraction of the time in which an AGN presents P > 3% (Angel & Stockman 1980), was 84.2% and 91.3% for PKS 2005-489 and PKS 2155-304, respectively, based only on data obtained during our V band monitoring. Also the observed maximum value of polarization was similar (~ 11%.). Spectral dependence was found for both sources and it is larger in *P* than in θ. The lack of historical polarization data for PKS 2005-489 did not allow to study the existence of preferential values or long-term variability, as observed for PKS 2155-304.

However, the combination of the results is compatible with a scenario in which the origin of the variability is associated with the shocks evolution along of the quiescent jet, which may suffer changes of orientations in time scales of decades.

Although both blazars are observed in TeV energies, much more intense activity has been observed in PKS 2155-304 than in PKS 2005-489. For this last source, the maximum observed flux above 200 GeV was I = 6.9 x 10^{-12} $cm^{-2}s^{-1}$, and there are indications of variability in time scales of years (Aharonian et al. 2005a). In contrast, PKS 2155-304 was detected with I (> 200 GeV) = 1.72 x 10^{-9} $cm^{-2}s^{-1}$ and varying in time scales from about 3 minutes to years (Benbow et al. 2007, Aharonian et al. 2005b). Continuous polarization monitoring of those and another TeV blazars are essential to investigate the relationship between synchrotron and TeV emission in epochs of high flux density level and also during quiescence.

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