EPJ Web of Conferences **61**, 06007 (2013)
DOI: 10.1051/epjconf/20136106007


# Near infrared polarimetry of a sample of blazars*

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**Abstract.** Polarization variability is one of the most ubiquitous characteristic of blazars. Near infrared (NIR) polarization measurements of blazars are not common, contrary to the optical ones. Nonetheless, the NIR regime can be essential to understand correlated or non-correlated behaviour between the optical and radio energy ranges. In this work, we report on NIR polarimetry measurements of a sample of 28 blazars, collected with LIRIS at WHT/La Palma in several campaigns during 2011. The majority of the blazars were observed more than one epoch using two filters (J and Ks). Here we present preliminary results for few selected targets.

## 1 Introduction

Blazars appear as the most luminous objects in the gamma ray sky. Nowadays, blazar studies are living in a "golden age" thank to the advent of sensitive high-energy facilities like Fermi satellite, MAGIC telescopes. They also emit profusely along a broad range of the electromagnetic spectrum, from radio to gamma rays. Their emission is highly variable and polarized at almost any energy range and its origin is commonly attributed to a relativistic jet pointing very close to our line of sight.

The frequently observed gamma-ray and radio flares are sometimes associated with optical polarization variations (pol. degree and angle rotations) but not in other times, which indicates that the paradigm of the blazar jets should be based on multiple scenarios. In order to select the most successful models for jet acceleration and collimation, the analysis of multi-wavelengths is necessary [1, 4, 6, 7].

### 1.1 Our goals

The superb spatial resolution of VLBA (0.1 m.a.s.) and the frequent observations permit to monitorize the birth and evolution of structures propagating through the jet. The information gathered from these observations include detailed polarization maps. Despite its poorer spatial resolution, polarimetric observations at optical wavelengths would permit to "locate" optical flares assuming continuity of the electric vector polarization angle (EVPA). In this line, measuring the polarization at the near-infrared regime would permit to establish a natural bridge between optical and radio emission, in particular when non-correlation between the optical and the millimetric ranges happens. Near infrared polarization measurements of blazars are much less frequent [3, 12], contrary to optical ones. The main reason is likely that near-infrared polarimetry is not a common facility at public observatories. Furthermore simultaneous and frequent observations are difficult to obtain in fixed scheduling telescopes. Here we present preliminary results of a study in which the near-infrared polarization of a sample of 28 blazars was obtained with time gaps of few days. This work was aimed as a pilot study, observing enough number of blazars, showing the suitability of the instrument LIRIS for measuring near-infrared polarization variability.

## 2 Observations and data reduction

The sample was selected to contain the brightest millimeter and gamma-ray blazars with typical optical magnitude below 18. Objects in this sample are also being monitorized in radio by the Astronomy group of the Boston University [http://www.bu.edu/blazars/research.html] and in optical polarimetry at Calar Alto [http://www.iaa.es/ iagudo/research/MAPCAT/].

Our observations were performed using the near infrared camera/spectrograph LIRIS attached at the Cassegrain focus of the 4.2 m William Herschel Telescope. Polarization information was obtained in the J and Ks bands. Data were collected in two campaigns during 2011: March 17th & 22$^{nd}$ and September 8th+9th and

*Based on observations made with the William Herschel Telescope operated on the island of La Palma by the Isaac Newton Group in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofisica de Canarias.

13th+14th. A list containing all observations is found in Table 1.

We have compiled additional polarimetric measurements obtained in the optical range by the group of the Program Ground-based Observational Support of Fermi Telescope at the Univ. of Arizona *[http://james.as.arizona.edu/~psmith/Fermi]*. Near infrared photometry obtained in the 1.5m Carlos Sanchez Telescope at Teide observatory was also included in our analysis.

### 2.1 Instrumental setup

LIRIS is a near infrared multipurpose public instrument with imaging and spectroscopy capabilities, including polarization [5]. A WeDoWo (Wedge Double Wollaston) device [8] was used as the polarimetry analyzer, which permit to obtain simultaneous measurements of the first 3 Stokes parameters. The field of view (FoV) of LIRIS in the imaging polarimetric mode is restricted to a strip of $4 \times 1$ arcmin$^2$. The measured instrumental polarization is relatively low, around 0.5%, as expected since the instrument is located at the Cassegrain focus.

### 2.2 Data Reduction

Data were reduced using a dedicated package developed within IRAF (lirisdr). Each frame is trimmed into four strips. Each strip is processed following standard near infrared data reduction steps: flat-fielding, sky subtraction, geometric distortion and lately combined by the "shift-and-add" technique. The Stokes parameters were derived using the expressions found in [2]. The flux calibration was based on differential photometry using a reference star close by to the blazar.

## 3 Preliminary results

The polarization degree (*PD*) and the electric vector position angle (*EVPA*) observed in J and $K_s$ bands are consistent within errors in most observed blazars. Nevertheless colour effects cannot be discarded and will be explored in a future work. The observed *PD* ranges between few percent in a set of blazars to a maximum around 20%. In the group of low polarization blazars, we found the cases of 3c273 showing $PD < 1\%$; AO 0235+164 $2\% < PD < 4\%$; 3C 111 $1\% < PD < 4\%$; and 0836+710 $2\% < PD < 4\%$. In the group of high polarization (>10%) blazars we found CTA26, Pks 0420-014, and OJ 287, among others. Different types of temporal behaviours are observed: the PD varies from 10% to 20% within few days (3c345, CTA 26) with the *EVPA* being constant. In most cases, variations of the *PD* are not associated with variations of *EVPA*, but some exceptions are observed (e.g. 4C 38.41, see below). As an illustration, here we present individual results of 4 blazars. We present for each case the measured Stokes parameters in q-u plane as well as the time variation of flux, *PD* and *EVPA*.

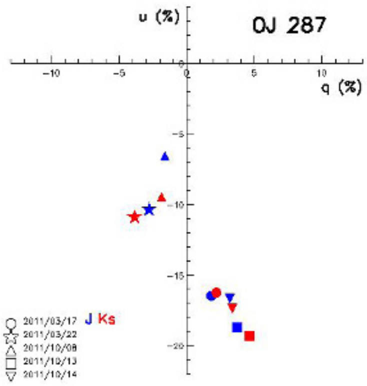


**Figure 1.** Variation of Stokes parameters in OJ 287

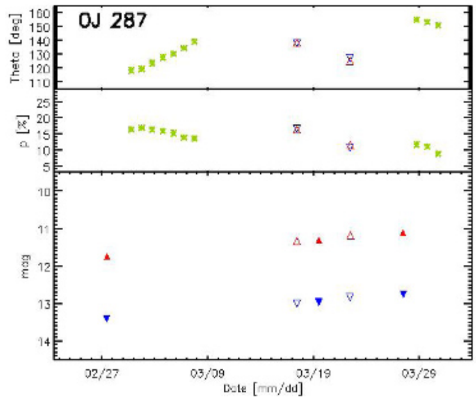


**Figure 2.** Light curve of flux and polarization degree

### 3.1 OJ 287 (0851+2020)

OJ 287 (z=0.360) is one of the best observed blazars, it has been classified as a low-energy peaked BL Lac object [9]. In the optical there is strong evidence of a period of about 12 years which is explained by a binary black hole system [13, 14] We have observed OJ 287 during the two campaigns (March and October). The variation of polarization in the q-u plane is presented in Fig. 1. It can be seen that the *PD* changes rapidly within 4 days, which was observed in the two runs, whereas the EVPA does not vary noticeably. In Fig. 2, we present the time variation of flux, *PD* and *EVPA* during the March run. There is a trend of decreasing *PD* when source brightens, a similar event was reported by [3]. The *EVPA* shows steady variation within this period, which could be part of a polarization rotation event.

### 3.2 4C 38.31 (1633+382)

4C 38.41 (z=1.814) is clasified as an optically violent variable flat-spectrum radio quasar (FSRQ). During year 2011 experienced a large outburst which was studied in detail by [10]. The variation of near-infrared polarization in the q-u plane is presented in Fig. 3. *PD* changes rapidly by several percent within few days, the *EVPA* varies between

**Table 1.** Observing log

| | 2011, March 17 | | 2011, March 22 | | 2011, Oct 8 | | 2011, Oct 9 | | 2011, Oct 13 | | 2011, Oct 14 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Object | J | $K_s$ | J | $K_s$ | J | $K_s$ | J | $K_s$ | J | $K_s$ | J | $K_s$ |
| 3C 273 | √ | √ | √ | √ | ... | ... | ... | ... | ... | ... | ... | ... |
| 3C 279 | √ | √ | √ | √ | ... | ... | ... | ... | ... | ... | ... | ... |
| 4C 38.41 | √ | √ | √ | √ | ... | ... | √ | √ | √ | √ | ... | ... |
| OJ 287 | √ | √ | √ | √ | √ | √ | ... | ... | √ | √ | √ | √ |
| B2 1308+30 | √ | √ | √ | √ | ... | ... | ... | ... | ... | ... | ... | ... |
| AO 0235+164 | ... | ... | ... | ... | √ | √ | √ | √ | ... | ... | √ | √ |
| 3C 345 | ... | ... | ... | ... | √ | √ | ... | ... | √ | ... | √ | √ |
| 3C 454 | ... | ... | ... | ... | √ | √ | √ | √ | ... | ... | √ | √ |
| ON 231 | √ | √ | √ | √ | ... | ... | ... | ... | ... | ... | ... | ... |
| PG 1222+216 | √ | √ | √ | √ | ... | ... | ... | ... | ... | ... | ... | ... |
| Pks 1510-08 | √ | √ | √ | √ | ... | ... | ... | ... | ... | ... | ... | ... |
| S4 0954+65 | √ | √ | √ | √ | ... | ... | ... | ... | ... | ... | ... | ... |
| OT 081 | ... | ... | ... | ... | ... | ... | √ | √ | ... | ... | ... | ... |

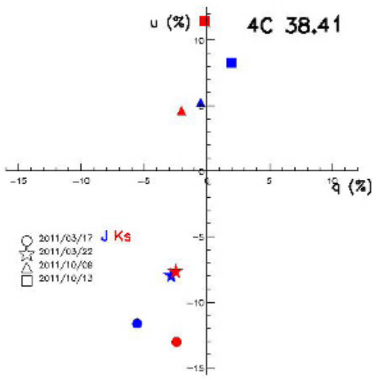


**Figure 3.** Variation of Stokes parameters in 4C 38.41

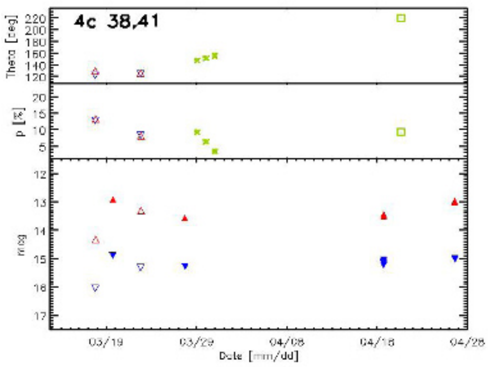


**Figure 4.** Light curve of flux, *PD* and *EVPA* in 4C 38.41

March and October runs. The time variation of flux and polarization is presented in Fig. 4 for the 2011 March period. A clear possitive correlation can be seen between the *PD* and the brightness, which was already reported by [10] . The *EVPA* also shows some variation, although sampling is not enough to identify a clear trend.

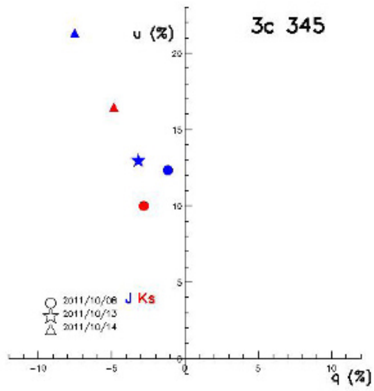


**Figure 5.** Variation of Stokes parameters in 3C 345

### 3.3 3C 345 (1641+399)

3C 345 (z=0.593) is a very extensively studied FSRQ. It shows strong variability in the optical and radio bands. Radio jet components often show bend trajectories. The variation of polarization in the q-u plane is presented in Fig. 5. We have not detected firm variation of the *EVPA*, although the *PD* changes appreciably. The light curves of flux, *PD* and *EVPA* are presented in Fig. 6. Despite the *PD* and *EVPA* variation, the infrared flux does not change by more than $\sim 20\%$ in the observations time interval.

### 3.4 BL Lac (2200+420)

BL Lac (z=0.069) is the prototype of the blazar class and has been extensively studied. The variation of polarization in the q-u plane is presented in Fig. 7, the *PD* decreases by $\sim 5\%$ within 5 days and the EVPA also changes within the same time interval. More detailed results have been reported by [11]. The ligth curve of flux and polarization is presented in Fig. 8. A negative correlation between infrared flux and PD is hinted from our observations. [3] reported a similar behaviour for a flare of this target.

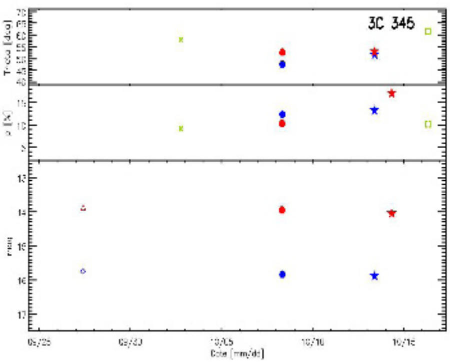


**Figure 6.** Time variation of flux, *PD* and *EVPA* in 3C 345.

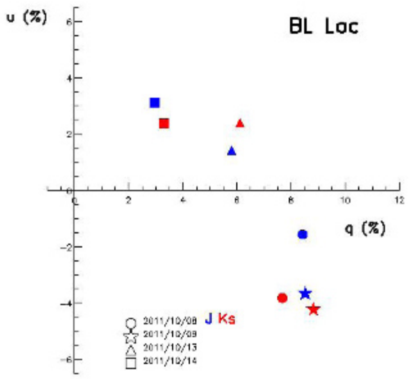


**Figure 7.** Variation of Stokes parameters in BL Lac.

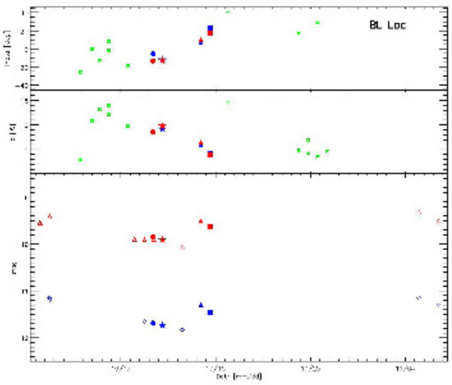


**Figure 8.** Time Variation of flux, *PD* and *EVPA* in BL Lac.

## 4 Concluding remarks

We have measured near-infrared polarization in a sample of 28 blazars, ranging from few percent to maximum values around 20%. We also found variations in *PD* in most studied blazars. Variation of *PD* is not always correlated with flux variations, although here we have shown examples of negative and possitive correlations. In this sense, [3] noticed that although correlation between *PD* and flux is weak, a significative fraction (30%) of their sample shows apparent correlations, concluding that such fraction seems to indicate that polarization variability is not as ramdon as it appears.

Further studies in the near-infrared should be carried out in order to have a more comprehensive view of blazar jet physics. The use of robotic or flexible schedule telescopes with near infrared instrumentation would be essential in order to have a better understanding of the blazar scenarios.

## Acknowledgements

Data from the Steward Observatory spectropolarimetric monitoring project were used. This program is supported by Fermi Guest Investigator grants NNX08AW56G, NNX09AU10G, and NNX12AO93G.

## 5 Addendum: blazar monitoring at Canary Islands telescopes

Photometric monitoring at optical and near-infrared using the facilities at the Izaña observatory is being carried out. Since 2011 Feb, observations take place roughly every 3-4 weeks. We are collaborating with the GASP project of the WEBT consortium (see for instance [10]). Data for potential collaborations are made available upon request.

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