Calibration of the polarimeter CasPol at the Nasmyth focus: Application to two extragalactic sources

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Resumen / En este trabajo presentamos los resultados del análisis de datos fotopolarimétricos obtenidos durante una campaña observacional de tres noches durante mes de enero de 2019, utilizando el instrumento CasPol ubicado en el foco Nasmyth del telescopio de 2.15 m Jorge Sahade, en el CASLEO. También estudiamos diferentes estrellas estándares polarizadas y no polarizadas, para caracterizar este instrumento cuando está ubicado en el foco antes mencionado. Los resultados obtenidos de este análisis fueron aplicados para calibrar adecuadamente los datos observados para dos fuentes extragalácticas: PKS 0625-35 y 1RXS J084702.1-23.

Abstract / In this work we present the results of the analysis of photo-polarimetric data obtained with the instrument CasPol at the Nasmyth focus of the Jorge Sahade 2.15 m telescope, at CASLEO. We also study different polarized and unpolarized standard stars to characterize this instrument when it is used in the aforementioned focus. The results of this characterization were applied to calibrate the data from two extragalactic sources: PKS 0625-35 and 1RXS J084702.1-23.

Keywords / instrumentation: polarimeters — galaxies: active — techniques: polarimetric

1. Introduction

Optical polarization measurement is an important technique to identify and characterize objects of unknown nature. High polarization is a signature of non-thermal emission processes (Mandarakas et al., 2019). In blazar-type AGNs, the optical flux is dominated by synchrotron emission from the relativistic jet, and is thus highly polarized (e.g. Blandford & Königl, 1979). Measurements of the optical linear polarization give then information on the direction and ordering of the magnetic field, while variability studies provide clues on its geometry (Marscher, 2015).

In this work we gave a first step in the characterization of the polarimeter CasPol positioned at the Nasmyth focus of the Jorge Sahade 2.15 m telescope, at CASLEO. This was done by observing, we observed unpolarized and polarized standard stars to make a first calibration to use as reference for science targets.

We also studied two extragalactic sources: PKS 0625-35 and 1RXS J084702.1-23. The first one is an unclassified AGN (a radio-galaxy with BL Lac optical characteristics, probably due to a misaligned jet; Wills et al., 2004) detected recently by the HESS telescope at high energies (HESS Collaboration et al., 2018). The second one is an unclassified blazar detected in X rays (Shaw et al., 2013).

Within the frame of a long-term photo-polarimetric study of AGN carried on by our group, we are starting a campaign set on unclassified sources, with the aim of providing data to characterize their nature.*

2. Observations

The data presented in this work were obtained with the instrument CasPol at the Nasmyth focus of the Jorge Sahade telescope, on January 22-24th 2019. This instrument is a dual-beam polarimeter that has a filter wheel with $UBVRI$ Johnson-Cousins filters (J-C), another wheel with neutral filters, a half-wave plate (HWP) retarder and a Savart plate. The detector of this instrument is a 1024×1024 Tek CCD with a scale of $0.27''$ per pixel. The polarimeter splits the optical flux of the source into two orthogonal beams, the ordinary and the extraordinary one.

There is a previous characterization of this instrument mounted at the Cassegrain focus, by Sosa et al. (2019). However, technical and operational reasons demand the relocation of this instrument at the Nasmyth focus. Since the changes in the optical path between the different foci affect the instrumental polarization (mainly due to the extra reflection by the tertiary 45 degree mirror), a new characterization for the Nasmyth focus is needed.

The science objects were observed only on the first night, while the standard stars were systematically observed with the filter configurations along the three

*Based on data obtained at CASLEO, operated under agreement between CONICET and the National Universities of La Plata, Córdoba and San Juan.

Table 1: Polarization standard stars used in this work.

Object	Type	Filter	$N_{\rm obs}$
HD42078	unpolarized	B	4
		V	5
		R	3
		I	1
HD97689	unpolarized	B	1
		V	1
		R	2
		I	1
HD64299	unpolarized	B	1
		V	1
		R	1
		I	1
HD298383	polarized	B	3
		V	2
		R	3
		I	2
Ve6-23	polarized	B	1
		V	1
		R	2
		I	1

nights. In Table 1 we present the standard stars used in this work, with number of observations for each J-C filter. The Stokes parameters of these standards have been published by Turnshek et al. (1990), Fossati et al. (2007) and Cikota et al. (2017).

To obtain a polarization point, four exposures with the HWP in different positions (0°, 22.5°, 45° and 66.5°) are required, so the time of each polarization point is the mean of the four exposures.

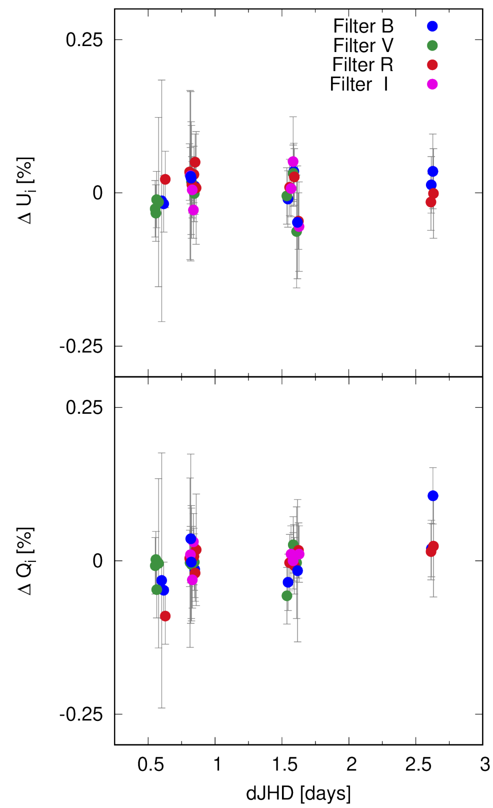

Figure 1: Differences between the instrumental Stokes parameters obtained by different reduction processes. The differential JHD started on January 22nd, 2019.

3. Methodology

3.1. Reduction

In this section we explore any possible differences between two different reduction processes. For the first one, we we used combined flat field images for each different HWP position, while in the second one we reduced the images with flats combining all of the HWP positions. In Fig. 1 we show the differences between the instrumental Stokes parameters obtained through these processes for all the standards stars. The average difference between the two ways of processing are $\langle \Delta U_i \rangle = 0.002$ and $\langle \Delta Q_i \rangle = 0.003$ while the minimum associated error of the instrumental Stokes parameters (calculated by propagating the photometric errors given by IRAF) is 0.046. Since the errors are larger than the differences between the instrumental Stokes parameters, we decided to continue this work using combined flats from all the HWP positions, and only discriminating by J-C filters.

3.2. Standard system

To obtain the linear polarization value, we need to calculate the Stokes parameters in the standard system ($Q_{\rm std}$, $U_{\rm std}$). We use the following equations to obtain these parameters:

$$Q_{\rm std} = Q_{\rm obs} - Q_{\rm ins}$$
$$U_{\rm std} = U_{\rm obs} - U_{\rm ins}$$

where $Q_{\rm ins}$ and $U_{\rm ins}$ are the instrumental parameters (due to polarization introduced by the telescope-instrument system), while $Q_{\rm obs}$ and $U_{\rm obs}$ are the observed parameters.

We observed different unpolarized stars to determine the instrumental correction to the Stokes parameters, because by assuming $Q_{\rm std} = U_{\rm std} = 0$, the observed parameters are equal to the instrumental parameters.

We used a conservative statistics, rejecting the points more than $2.5\,\sigma$ off the mean value. We show these values in Fig. 2. We can see that Q_i absolute values are high, showing significant dispersion between different filters. Instead, U_i absolute values are lower, with a milder difference between filters. These are indications of some dependence between the Stokes parameters and wavelength, but we need a larger sample to confirm that. Because of that, we decided to estimate the instrumental Stokes parameters for the scientific targets calibration as an average value for all filters.

We also studied polarized standards stars, so we could use the known polarization angles of these stars to determine the instrumental angle polarization and applied this correction to the science objects.

Finally, after applying all the corrections, we obtained the polarization results for these sources. In Fig. 3 we show the polarization percent and the angle of polarization of these extragalactic sources for each filter.

4. Summary

There are no significant differences between the reduction processes applied in this work –flats for each HWP position or flats combining all the HWP positions–.

A thorough characterization of CasPol mounted at the Nasmyth focus of the Jorge Sahade telescope will require a larger sample and a longer observation run.

However, our results provide a first estimation of basic parameters, namely the instrumental polarization. In this estimation the instrumental Stokes parameters are: $\langle U_{\rm ins}\rangle = -0.75 \pm 0.08$ and $\langle Q_{\rm ins}\rangle = -4.22 \pm 0.21$. The estimation for the correction to obtain the standard polarization angle is $\langle \theta_{\rm s}\rangle = 49.83° \pm 0.79°$.

These high values of the instrumental polarization are typical of polarimeters mounted on the Nasmyth focus (Covino et al., 2014) ; however, in CasPol the instrumental polarization is constant because there is no field rotation thanks to the equatorial mount.

The instrumental polarization might have a dependency with the wavelength, but we need a larger sample to study this in detail.

We found that PKS 0625-35 shows a polarization between $1 - 2$ % depending on wavelength. This result can be expected in radiogalaxies with misaligned jets, like this one. Non-blazar AGNs also have low polarization ($\lesssim 2$ %) due to scattering by dust/electrons (e.g., Kokubo 2017). 1RXS J084702.1-233650, in turn, has a linear polarization around 6 %. This high value of linear polarization is usual in blazars with low synchrotron peak in their spectral energy distributions (Andruchow et al., 2005). In order to be able to derive physical parameters of these sources, we need a temporal analysis of θ_s with a broad time distribution.

Acknowledgements: We acknowledge CASLEO staff support. We also thank the anonymous referee for useful suggestions that helped to improve the paper.

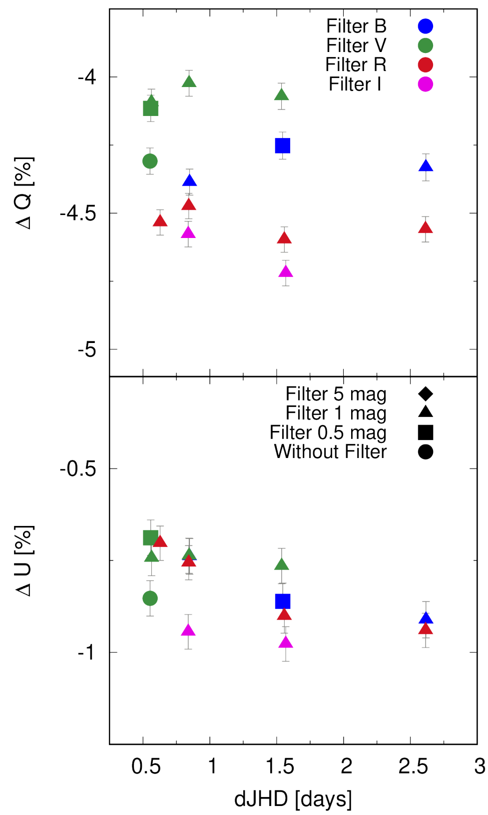

Figure 2: Instrumental Stokes parameters for unpolarized standard stars. The differential JHD started on January 22nd, 2019.

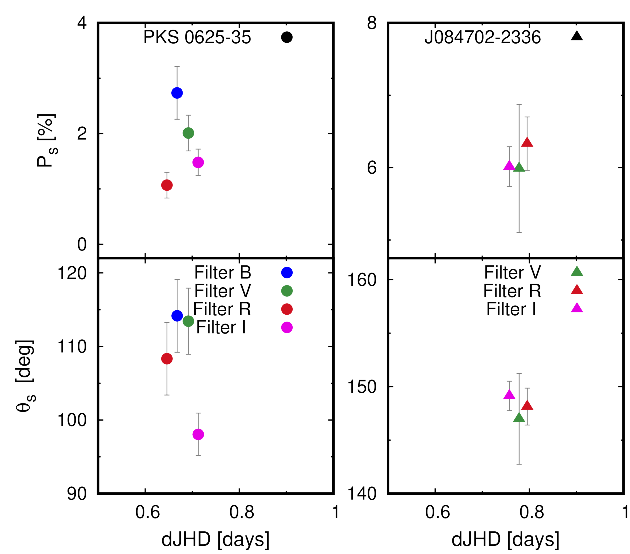

Figure 3: Standard Stokes parameters for the extragalactic sources. The differential JHD started on January 22nd, 2019.

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