OPTICAL POLARIZATION VARIABILITY OF THE BLAZAR 1 ES 1959+650

Marco Sorcia [1], Erika Benítez [1], David Hiriart [2], José M. López[2], José I. Cabrera[1], Raúl Mújica[3], Jochen Heidt[4], Iván Agudo[5], Kari Nilsson[6], and Michael Mommert[4,7]

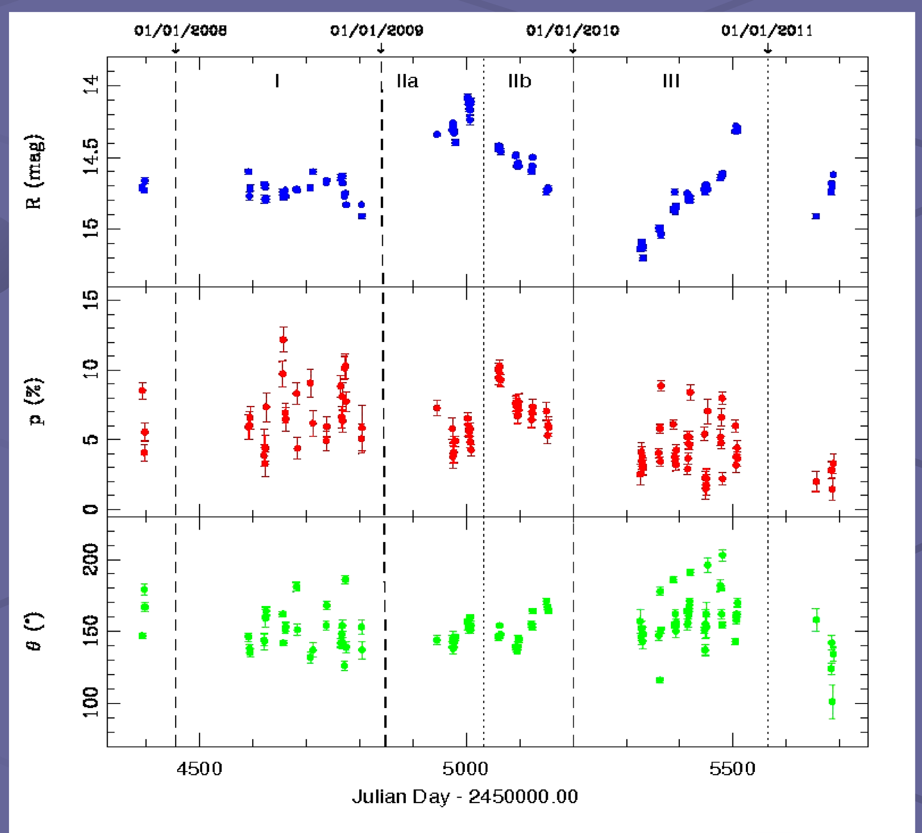
(1) Instituto de Astronomía, Universidad Nacional Autónoma de México; msorcia@astro.unam.mx . (2) Instituto de Astronomía, Universidad Nacional Autónoma de México, Ensenada B. C., México. (3) Instituto Nacional de Astrofísica, Óptica y Electrónica, Tonantzintla, Puebla, México. (4) ZAH, Landessternwarte Heidelberg, Königstuhl, Heidelberg, Germany. (5) Instituto Nacional de Astrofísica de Andalucía, CSIC, Granada, Spain. (6) Finnish Centre for Astronomy with ESO (FINCA), University of Turku, Väisäläntie 20, Piikkiö, Finland. (7) Deutsches Zentrum für Luft- und Raumfahrt e. V., Institut für Planetenforschung, Berlin-Adlershof, Germany.

ABSTRACT

In this work we presented an analysis of the optical polarimetric variability of the TeV-blazar 1ES 1959+650 from 2007 October to 2011 May. The source showed a maximum variation of 1.2 mag in *R*-band, and a maximum polarization degree of 12.2 %. The blazar presented a preferential position angle of the optical polarization of ~153°, with variations of 10°-50°, which is in agreement with the projected position angle of the parsec-scale jet found at 43 GHz. We infer the existence of the two optically thin synchrotron components that contribute to the polarized flux, consistent with the spine-sheath model. Assuming a stationary shock, we stimated some parameters associated with the physics of the relativistic jet. From polarimetric data, we infer the value for the Doppler factor δ_D (t) and the viewing angle of the jet Φ(t), as funtions of the time.

1ES 1959+650

The TeV-blazar 1ES~1959+650 was discovered in the radio band as part of a 4.85GHz survey performed with the 91 m NRAO Green Bank telescope (Beker et al.1991). Polarimetric and 43 GHz VLBA observations revealed a electric spine-sheath structures that consists of a compact core with milli-arcsecond jet, extending to the southeast at a position angle of about 150° (Piner et al. 2010). The source is known to be hosted by an elliptical galaxy at z = 0.047. The spectral energy distrubution shows its first synchrotron peak at UV-X-ray frequencies (Krawczynski et al. 2004). This object is classified as high-peaked BL Lac object (HBL). The synchrotron peak is in the range of 0.1-0.7 keV, and the overall optical and X-ray spectrum is due to synchrotron emission with the peak moving towards high energy frequencies when the flux is high. Also, the first γ-ray signal at very high energies was reported in 1998 by the Seven Telescope Array in Utah (Nishiyama 1999). In 2002 this object showed two TeV flares without simultaneous X-ray flares, a behavior sometimes referred to as orphan flares (Daniel et al. 2005). This blazar is listed in The First Catalog of AGN detected with Fermi Large Area Telescope (Abdo et al. 2010).



In Figure 1. R-band light curve (top panel), the polarization degree (middle panel), and position angle of polarization (bottom panel), where the preferential position angle θ ~153°, with variations of Δθ~±50° in quicent phase, and Δθ~±10° in active phase. The maximum brifthness is 14.08 mag at JD 2455002, and the minimum of 15.20 mag at JD 2455331. The maximum polarization degree is ~12%, observed during the quicent phase (Cycle I).

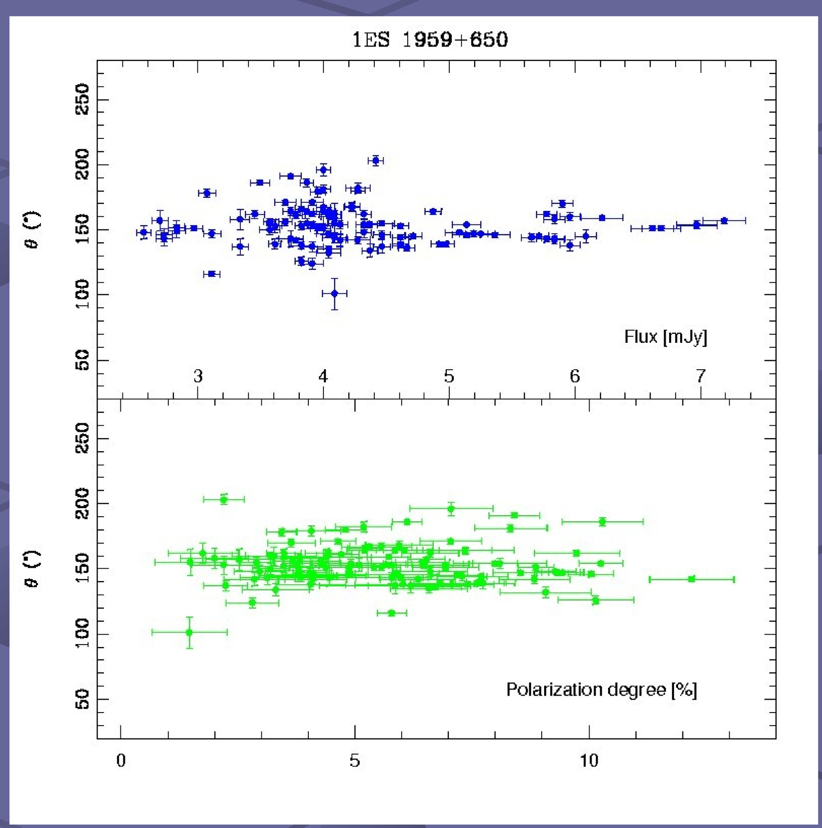


Figure 2. correlation between position angle and flux (top panel), position angle and polarization degree (bottom panel). In both panels, one can see a preferential tendency of the position angle to be ~150°.

RESULTS

The observations were carried out from 2007 October to 2011 May. We calculated the normalized Stokes parameters q and u as:

$$q = (f_0-f_{90})/(f_0+f_{90}); \quad u = (f_{45}-f_{135})/(f_{45}+f_{135}).$$

The degree of linear polarization and the position angle of polarization are defined by:

$$P = (q^2+u^2)^{1/2} ; \quad \Theta = (1/2) \arctan (u/q) ,$$

where f_0, f_{45}, f_{90}, and f_{135}, are the fluxes at the position angle of the polarimeter: 0°, 45°, 90°, 135°, respectively. The results are show en Figure 1, where we can see two flares ocrrured in 2009 and 2010. The data were corrected by the host-galaxy contribution. Following the methodology by Sorcia et al. 2013, in general we do not find a correlation between the R-band flux and the polarization degree. However, the position angle show a tendence to a constant value of ~150° (Figure 2) . From the analysis of the Stokes parameters we infered the existence of two polarized components, one with variable polarization, an the other with constant polarization of 4% and with a position angle of ~150°. In figure 3, we show the results obtained after using a two-component model to explain the variability of the active phase (JD 2454944-2455154). In this figure we can also note that the variable component (solid dots) dominates over the constant component (dashed lines). The source showed a maximum value of the linear polarization degree of 12.2°. Using the model of stationary shock, and the minimum variability time-scale, we estimated the intensity of the magnetic field of B=0.06 G. From our polarimetric data, we estimated some physical parameters associated with the relativistic jet in function of the time, as Doppler factor δ, viewing angle of the jet Φ, viewing angle of the shock Ψ, and the compression factor of the shocked and unshocked plasma η, see Figure 4.

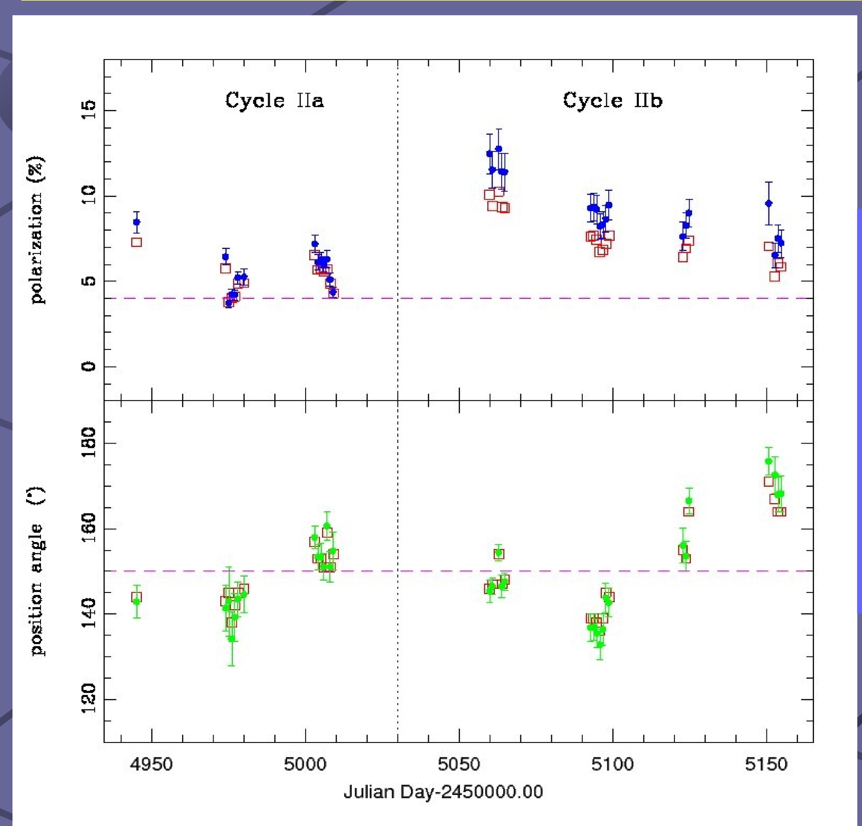


Figure 3. Results obtained with the two-component model. Red squares show the superposition of a constant (dashed lines) and a variable polarized component (blue and green dots). The polarization degree for the constant component is Pc~4%.

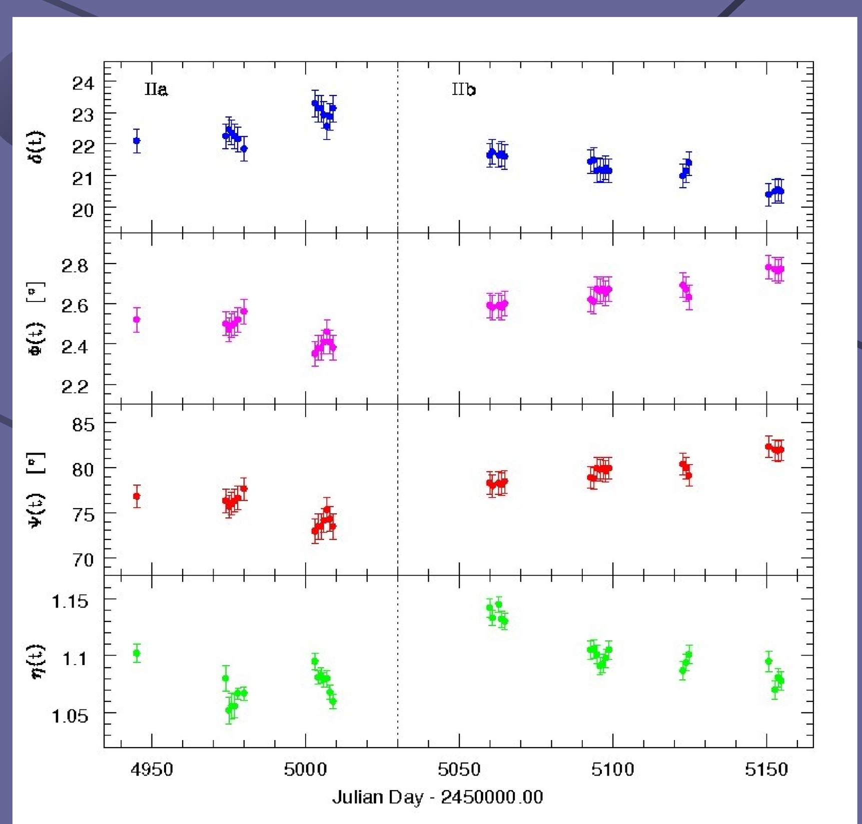


Figure 4. Variability of the physical parameters as a function of time: Doppler factor δ, viewing angle of jet Φ, viewing angle of the shock Ψ, and the compression factor η. In this figure, it can be seen that when the source shows its maximum brightness (14.08 mag, JD 2455002), the Doppler factor reaches a value of δ~23, and the viewing angle of the jet a minimum value of Φ~2.3°.

CONCLUSIONS

During the optical polarimetric observations, the blazar showed mainly a period of low-activity (2008), and two active phases (2009, 2010). In this work we have found the following results: a variability timescale of ~10 days; a preferential position angle of polarization ~153°, that is in agreement with the observations at 43 GHz reported by Piner et al. (2010). This result suggests that there is a common magnetic field component for both the optical and radio bands. From the polarimetric data we estimated a Doppler factor of δ_D~23 when the flux show a maximum value; a viewing angle of the jet of Φ~2°.35; and magnetic field intensity of B=0.06 G. The analysis done with the Stoke´s parameters, revealed the existence of two opticaly-thin syhncrotron components, one variable and the other stable with a polarization degree of 4%. In this context, the polarimetric behavior observved is consistent with a spine-sheath structure for the jet. The results of this work are reported in Sorcia et al. (2013).

(1) Hiriart, D. et al. "POLIMA *Manual del usuario*",MU-2005_08, Instituto de Astronomía, UNAM, México.
(2) http://www.astrossp.unam.mx/blazars.

References

Abdo, A. A. et al. 2010, ApJ, 716, 30.
Beker, R. H., White, R. L., & Edwards, A. L. 1991, ApJS, 75, 1
Daniel, M. K., Badran, H. M., Bond, I.H., et al. 2005, ApJ, 621, 181
Krawczynski, H., Hughes, S. B., Horan, D., et al. 2004, ApJ, 601, 151
Nishiyama, T. 1999, in Proc. 26th Int. Cosmic Ray Conf., ed. B. L. Dingus, D. B. Kieda, & M. H. Salamon (Melville, NY: AIP), 370
Piner, B. G., Pant, N., & Edwards, P. G. 2010, ApJ, 723, 1150
Sorcia, M., Benítez E., Heidt, J., et al. 2011, RMxAC, 40 131
Sorcia, M., et al. 2013, ApJS, 206, 11