OPTICAL POLARIMETRY & RADIO OBSERVATIONS OF PKS1510-089

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Polarised Emission from Astrophysical Jets
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Introduction

• Monthly Basis Observations:
  – (OPD) Optical Polarimetric campaign: between 2009 and 2013
  – (ROI) Radio Monitoring: between 2011 and 2013

• Multi wavelength flaring Activity:
  – before 2008, a weak radio source 6 Jy at 37 GHz (Teräsranta et al. 2005)

• Activity of 2 Polarization Degree (PD) and Polarization Angle(PA) variability (Marscher et al. 2010, Sasada et al. 2011, Jermak et al. 2016)

• Activity of 2011 was follow by a radio increase reported in many telegrams (Beaklini et al. 2011, Nestoras et al. 2011, Orienti et al. 2011, 2013).
2009

Marscher et al. 2010

Sasada et al. 2011

2011

Radio observations of PKS 1510-089 at 43 GHz during July 2011

Detected of an increase in the flux density at 43 GHz from blazar PKS 1510-089 since August, 2011

Jermak et al. 2016

Orienti et al. 2013
SMARTS: Small and Moderate Aperture Research Telescope System (Bonning et al. 2012)
Fermi/LAT: Large Area telescope (Atwood et al. 2009, Abdo et al. 2010)
2011 Activity
Radio Variability

VLBA data from the VLBA-BU Blazar Monitoring Program (VLBA-BU-BLAZAR)
http://www.bu.edu/blazars/VLBAproject.html
Time Delay – Radio-Gamma:1510-089

2011 Event

Delay of $\approx 55$ days

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Evidences of a new jet component

(a) Our data (black dot) superposed with the Aleksic et al. (2014) data
(b) Our data (black dot) superposed with the Orienti et al. (2013) data

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2009 Activity
Polarimetry: 1510-089

2009 Event

60° rotation of PA in 2 days interval
Depolarization at same time of rotation

<table>
<thead>
<tr>
<th>Day</th>
<th>MJD</th>
<th>Q/I</th>
<th>U/I</th>
<th>Flux (mJy)</th>
<th>Error</th>
<th>PolFlux</th>
<th>Error</th>
<th>PD (%)</th>
<th>Error</th>
<th>Theta (deg)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/04/09 4942.65</td>
<td>-0.0430</td>
<td>0.0640</td>
<td>2.29771</td>
<td>0.68931</td>
<td>0.17722</td>
<td>0.05886</td>
<td>7.713</td>
<td>0.248</td>
<td>120.8</td>
<td>0.9212</td>
<td></td>
</tr>
<tr>
<td>22/04/09 4944.63</td>
<td>0.0420</td>
<td>-0.0074</td>
<td>1.67956</td>
<td>0.50387</td>
<td>0.07172</td>
<td>0.02559</td>
<td>4.27</td>
<td>0.243</td>
<td>185.1</td>
<td>1.6304</td>
<td></td>
</tr>
</tbody>
</table>

On a 2 days interval, PA change for 65 ° while PD decrease from 7.7% to 4.2%

How could an ejection of a new jet component produce such effects?
New Component

\[
Q_{\text{final}} = Q_{\text{jet}} + Q_{\text{new}} \\
U_{\text{final}} = U_{\text{jet}} + U_{\text{new}} \\
I_{0(\text{final})} = \sqrt{Q_{\text{final}}^2 + U_{\text{final}}^2} \\
\cos 2\theta_{\text{final}} = (I_{0(\text{jet})} \cos 2\theta_{\text{jet}} + I_{0(\text{new})} \cos 2\theta_{\text{new}})/I_{0(\text{final})} \\
\sin 2\theta_{\text{final}} = (I_{0(\text{jet})} \sin 2\theta_{\text{jet}} + I_{0(\text{new})} \sin 2\theta_{\text{new}})/I_{0(\text{final})} \\
I_{0(\text{final})}^2 = I_{0(\text{jet})}^2 + I_{0(\text{new})}^2 + 2I_{0(\text{jet})}I_{0(\text{new})}\cos 2(\theta_{\text{new}} - \theta_{\text{jet}})
\]

Can we obtain information about the new jet component using the Stokes Parameters before and after start the flare activity?
Depolarization

We investigate the possibility that $I_{0(final)} < I_{0(jet)}$ simultaneously with a large change in $PA$, as detected during the $\gamma$-ray flare of 2009 April, in which $I_{0(jet)} = (0.18 \pm 0.07)\,\text{mJy}$ and $\theta_{jet} = -59^\circ \pm 2^\circ$ in April 20, and $I_{0(final)} = (0.08 \pm 0.02)\,\text{mJy}$ and $\theta_{final} = +11^\circ \pm 2^\circ$ in April 22. From equation 8, this condition is satisfied if:

$$I_{0(new)} < -2I_{0(jet)} \cos 2(\theta_{new} - \theta_{jet}),$$

or

$$| (\theta_{new} - \theta_{jet}) | > 45^\circ.$$  

We used equations 6 to 8 to estimate the polarimetric properties of the ejected component and found $\theta_{new} = 23^\circ 7^{+2\circ 8}_{-3\circ 3}$ and $I_{0(new)} = (0.23 \pm 0.10)\,\text{mJy}$, resulting in $(\theta_{new} - \theta_{jet}) = 83^\circ \pm 4^\circ$, in agreement with the requirement of equation 10.
How often a depolarization induced by a new component occurs?

Flux: 7mJy
PA: 0-180
PD: 0-100

10000 combinations
Combining

• Marscher et al. (2010)

• Sasada et al. (2011)

• Jemark et al. (2016)

• Our data
180° Multiplicity

Observation Day 1: 45° or 225° or...n x 180°

Observation Day 2: 95° or 275° or...n x 180°

Difference: 40° or 140°

Let’s do the simplest assumption?
PA variability

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Acknowledgements

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• This paper has made use of up-to-date SMARTS optical/near-infrared light curves that are available www.astro.yale.edu/smarts/glast/home.php.

• This research has made use of data from the MOJAVE database that is maintained by the MOJAVE team (Lister et al., 2009, AJ, 137, 3718).

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