

# Search for rotations of the polarization position angle of quasars

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# Introduction

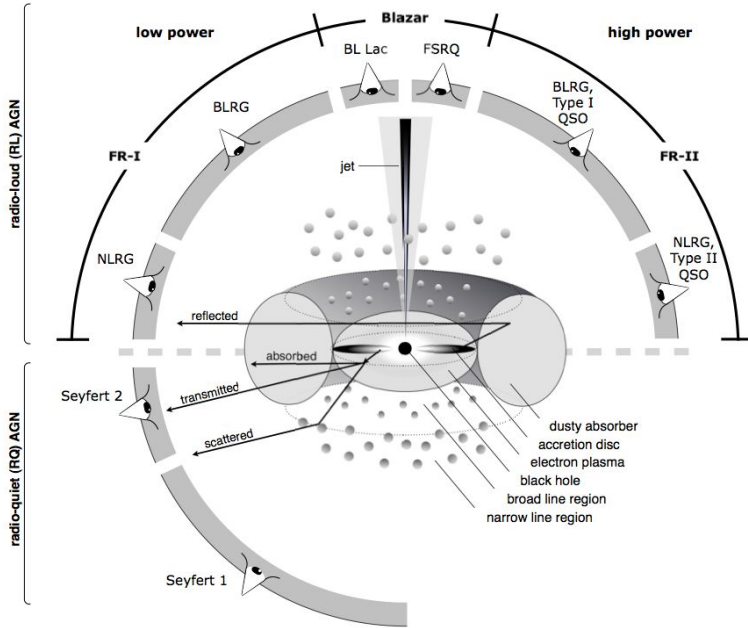


Fig. 1. Unified model of AGN.

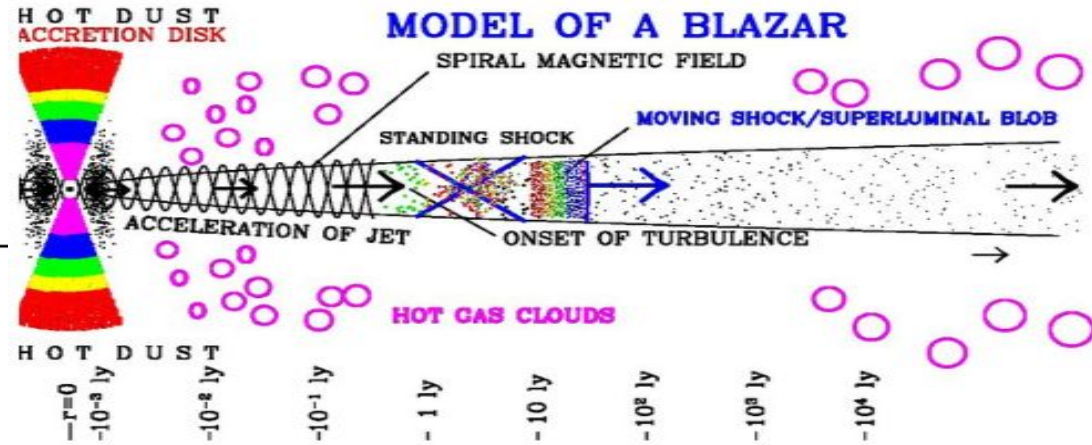


Fig. 2. Model of a blazar(Marscher 2018).

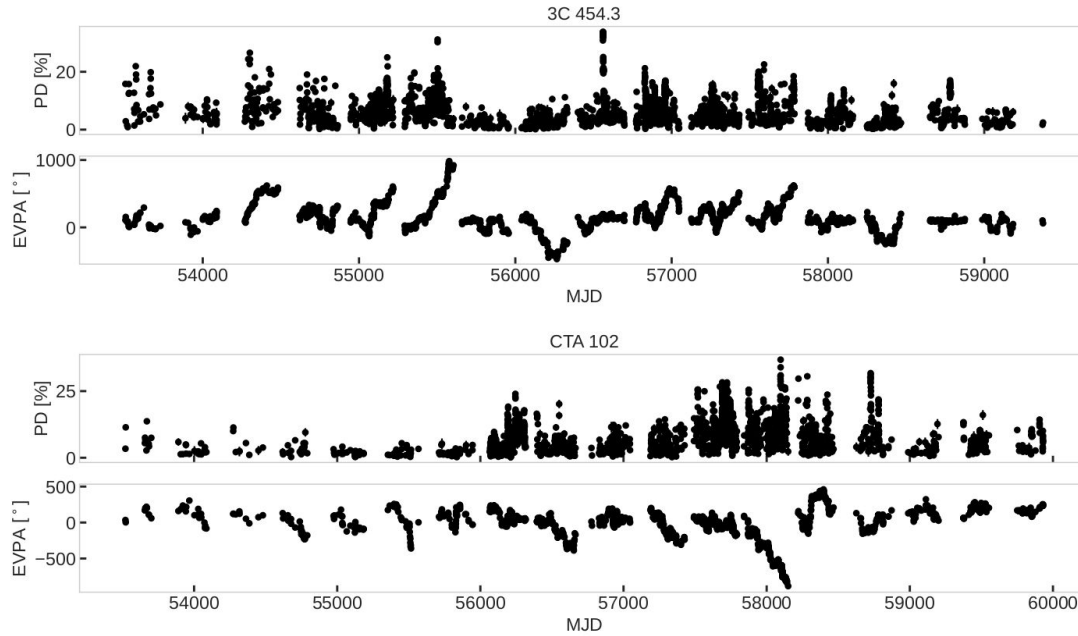


Fig. 3. The top and bottom panels show curves of the degree (PD) and angle (PA) of polarization versus time (in Modified Julian Date) for 3C 454.3 and CTA 102.

The observational data (R band) was obtained by employees of the Laboratory of Observational Astrophysics of St. Petersburg State University as a part of a program for monitoring a sample of blazars bright in the gamma-ray range.

# New method for searching EVPA rotations

The method is based on two statistical tests: the binomial test and the T-test based test, and applied to the EVPA curve smoothed using the Bayesian blocks algorithm.

- One-sided binomial test allows us to estimate the probability that several consecutive EVPA changes occurred by chance.
- The Student's T-test is used to test the significance of the difference between the mean rate of the rotation and zero.

Fig. 4. Examples of rotations selected using the proposed criteria (according to Robopol, Blinov et al., 2020). Circles with error bars are observational data, lines are data smoothed using Bayesian blocks. Filled circles and a dark continuous line show the area of the selected rotation, open circles and a dotted line show areas outside the rotations. The numbers are the p-values of rotations determined by the binomial test ( $p_{\text{binom}}$ ) and the T-test ( $p_{\text{T-test}}$ ).

For comparison, crosses indicate points assigned to rotations based on criterion of the strict monotonicity of changes of the EVPA in the work of Blinov et al. (2016a).

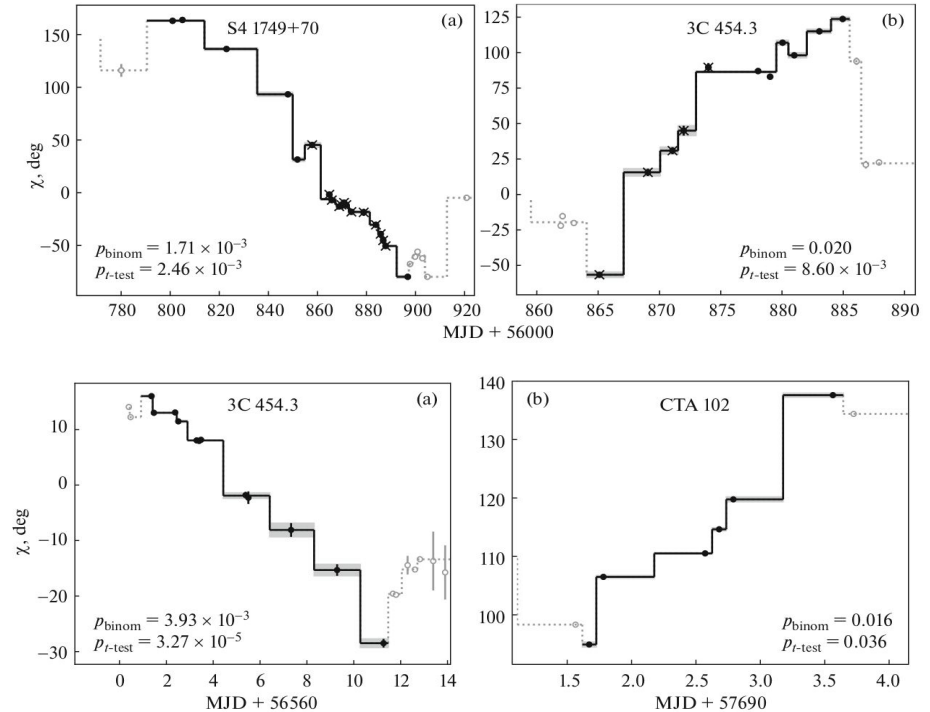
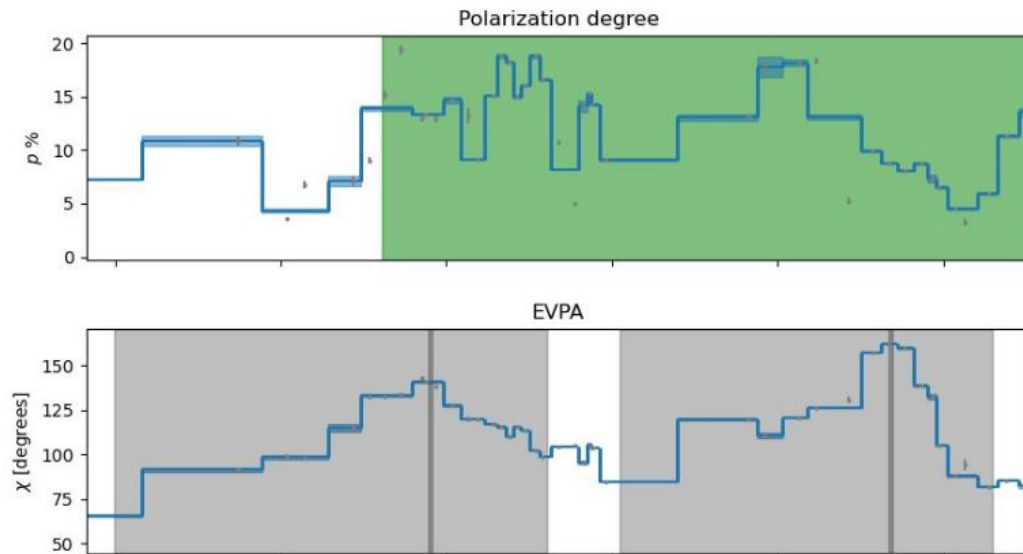


Fig. 5. Curves of the degree (upper panel) and angle (lower panel) of polarization versus time (MJD) for the blazar OJ 287 in the time interval from MJD 57080 to MJD 57130. Gray areas show the EVPA rotations selected by our method. The green area on the upper panel indicates that a new radio component was ejected in this region.

Note that in this case, a chain of successive EVPA rotations is observed.



OJ 287  
MJD 57080 - MJD 57130

# Results

Tab. 1. Total amount of clockwise (CW) and counterclockwise (CCW) rotations selected in EVPA curves of blazars of our sample.

Source	N	Nccw	Ncw
<u>OJ 287</u>	84	30	54
<u>S5 0716</u>	77	47	30
<u>BL Lac</u>	60	33	27
<u>3C 454</u>	50	33	17
<u>3C 279</u>	48	28	20
<u>MKN 421</u>	44	26	18
<u>PKS 1510</u>	33	17	16
<u>Q 1156</u>	32	11	21
<u>CTA 102</u>	31	9	22
<u>S4 0954</u>	28	15	13

Source	N	Nccw	Ncw
<u>3C 66a</u>	26	17	9
<u>PKS 1222</u>	23	10	13
<u>W Com</u>	18	8	10
<u>Q 1633</u>	18	6	12
<u>AO 0235</u>	15	5	10
<u>OT 081</u>	14	5	9
<u>PG 1553</u>	14	12	2
<u>MKN 501</u>	11	7	4
<u>PKS 0420</u>	7	1	6
<u>3C 273</u>	7	3	4

Source	N	Nccw	Ncw
<u>OJ 248</u>	6	5	1
<u>Q 0836</u>	6	3	3
<u>CTA 26</u>	6	3	3
<u>PKS 0735</u>	6	2	4
<u>Q 1959</u>	5	3	2
<u>3C 345</u>	5	4	1
<u>OJ 49</u>	3	0	3
<u>PKS 0528</u>	2	1	1
<u>B2 1308</u>	2	1	1
<u>Q 1611</u>	1	1	0
<u>3C 84</u>	1	0	1

# Discussion

- EVPA rotations are observed in each of 31 blazars of our sample.
- 18 sources demonstrate a large amount of rotations (more than 10).
- Total amount of selected rotations: 683.
- In the same source, rotations can occur in different directions (CW and CCW) and at different rates.
- 5 blazars (OJ 287, S5 0716+71, 3C 454.3, CTA 102 и PG 1553+113) tend to have preferred direction of EVPA rotations, they are highlighted in green in the Tab. 1.
- 18 sources demonstrate chains of rotations (see Fig. 5), such blazars are underlined in the Tab. 1.
- Both BL Lacs and FSRQs demonstrate EVPA rotations.

Source	N	N <sub>ccw</sub>	N <sub>cw</sub>	$\sigma$
<u>OJ 287</u>	84	30	54	2.75
<u>S5 0716</u>	77	47	30	2.12
<u>3C 454</u>	50	33	17	2.41
<u>CTA 102</u>	31	9	22	2.43
<u>PG 1553</u>	14	12	2	2.75
Q 1156	32	11	21	
<u>3C 66a</u>	26	17	9	
<u>PKS 0420</u>	7	1	6	

# Discussion

- A significant proportion of selected rotations have low amplitudes and occur with low rates. They are often called “swings” in the literature and are usually considered as insignificant.
- The presence of EVPA rotations could be explained by the helical structure of the magnetic field in the jet (for example, shock waves moving along a jet, Marscher et al., 2008). In this case, the observed preferred direction of rotations reflects the global structure of the magnetic field, which is related to the direction of rotation of the black hole ergosphere or accretion disk.
- The existence of a preferred direction of EVPA rotations in five blazars rules out their pure random walk origin, even for low-amplitude ones, that are usually considered as insignificant. The existence of rotations in the opposite direction, suggests that there is a turbulent components in addition to the ordered magnetic field, while the ratio of  $N_{\text{dom}}$  to  $N_{\text{obs}}$  can reflect the contribution of the ordered component in the total magnetic field geometry.
- Since the presence of the EVPA rotations in CW and CCW directions may imply the action of different production mechanisms, in further works we plan to investigate the mean properties of selected rotations, as well as the mean polarization properties of our objects out of the rotations.
- The origin of chains of rotations also need to be explained.

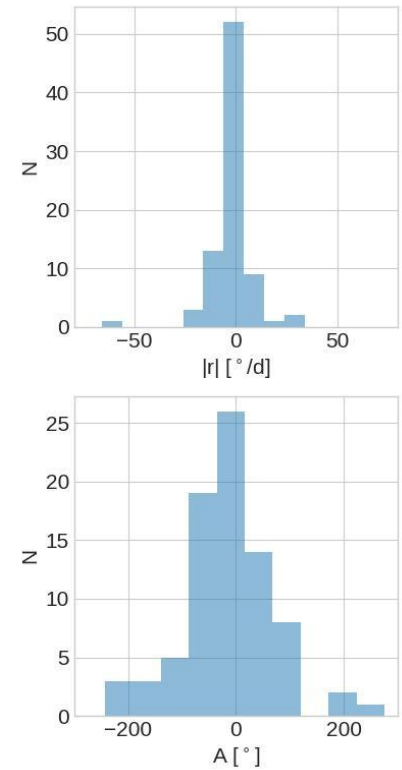


Fig. 6. Distribution of rates (top panel) and amplitudes (bottom panel) of rotations of the positional polarization angle for OJ 287.

**Thank you for your attention!**