Optical polarization vector IDV in BL Lac objects – a key to the jet structure

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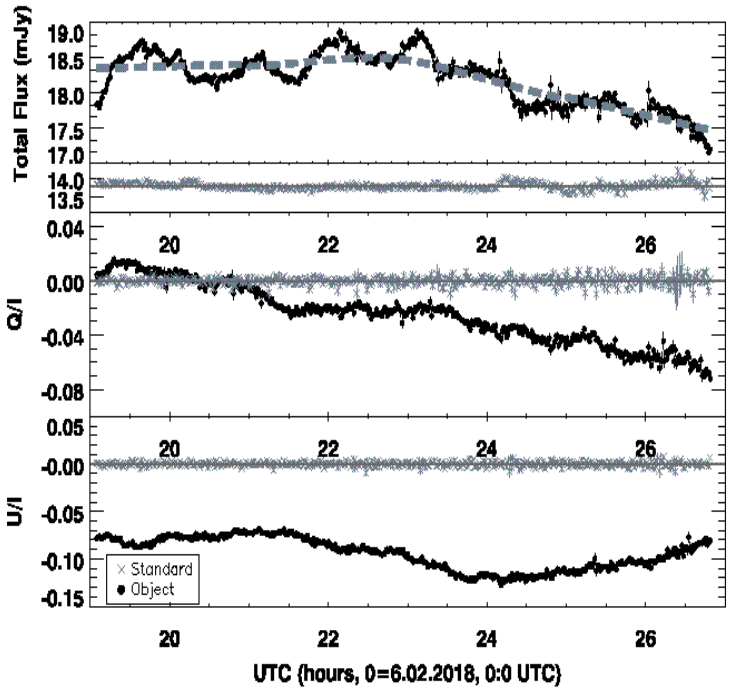
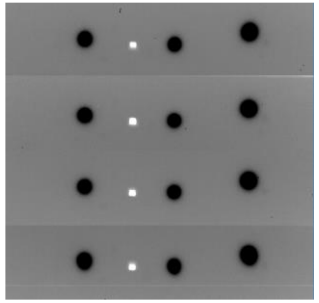
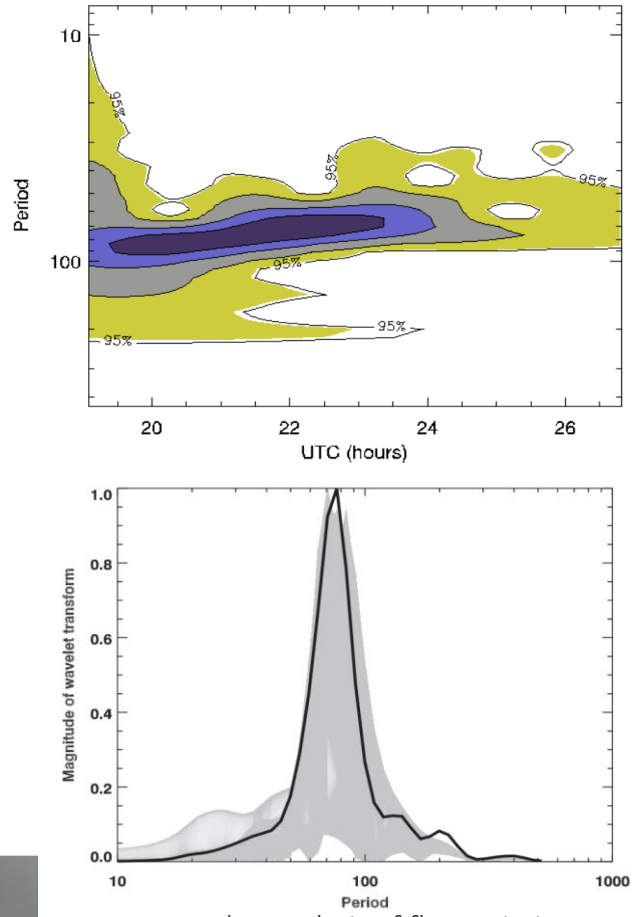
Everything started with S5 0716+714 – the bright BL Lac type object without redshift.



8-hour polarimetric monitoring at 6-m BTA+SCORPIO-2 (double Wollaston prism!)

1. The brightness variability: variation period in total flux $\sim 77 \pm 10$ min.
2. The polarization variability.





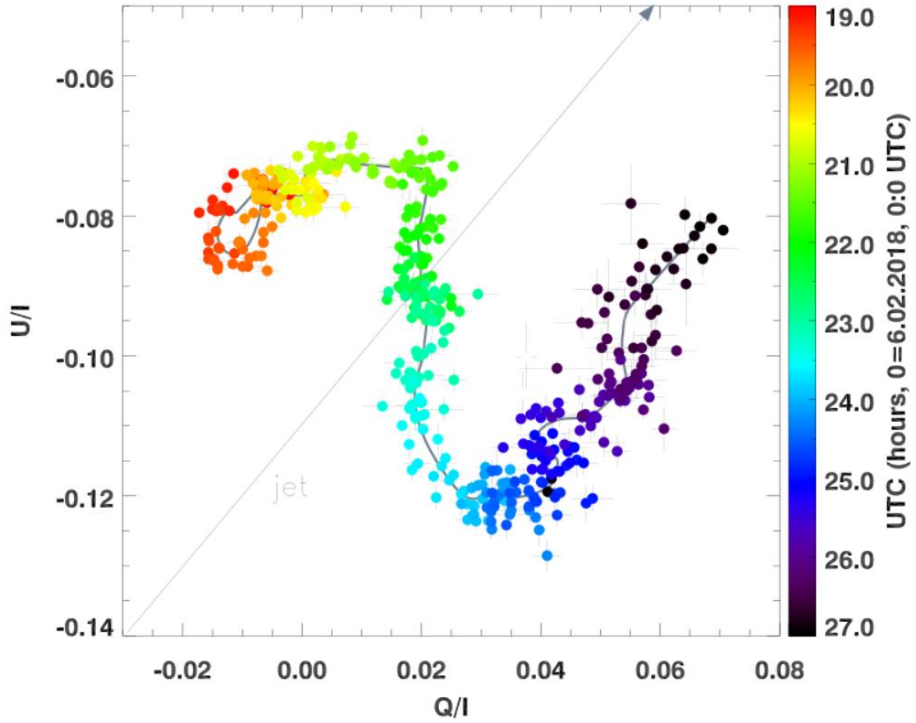
Wavelet-analysis of flux variations

The polarization vector direction switch – 1.5-3 hours.

Polarimetric accuracy – 0.1%.

↓

The linear size of the region – $1.5 \cdot 10^{-5}$ pc, or 10 a.u.

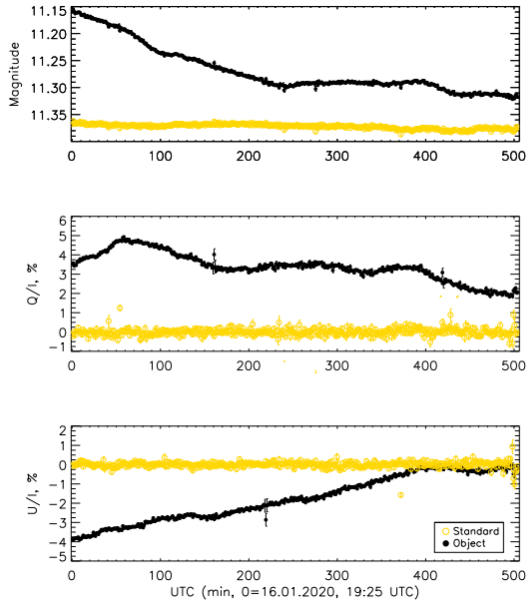


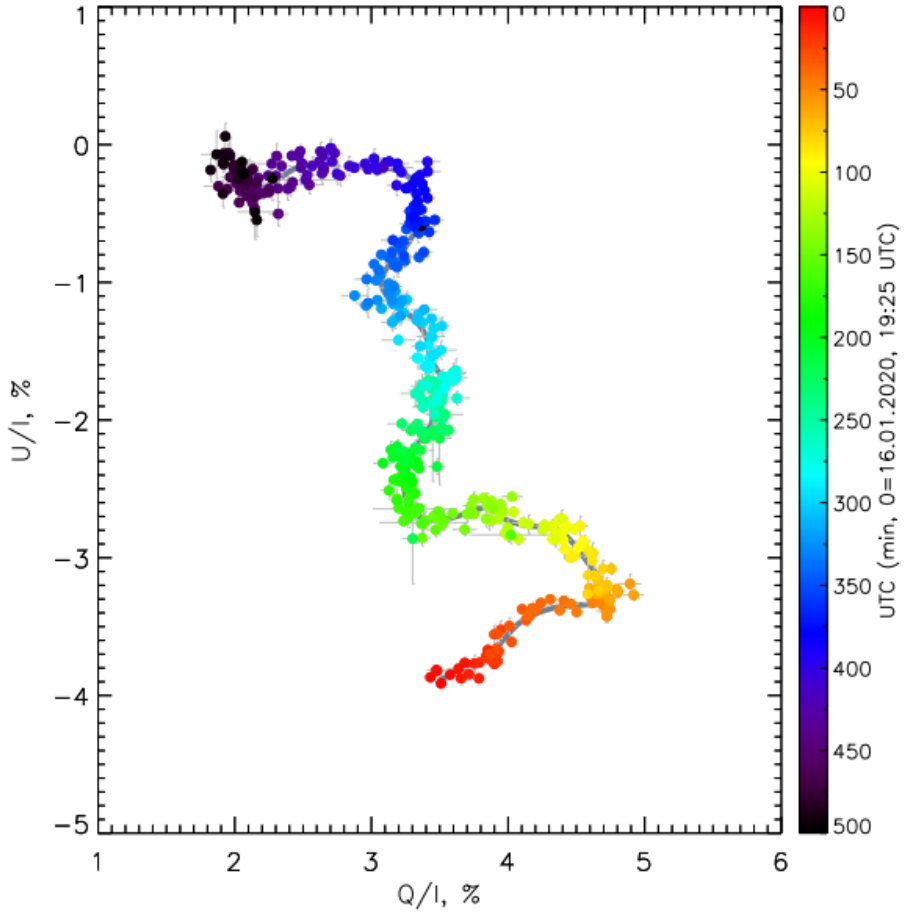
On January 16, 2020, an 8.5-hour monitoring of the S5 0716+714 blazar in polarized light was conducted at Zeiss-1000+StoP – a repeat of the 2018 observations at the BTA.

- the photometry accuracy is 0.005 mag.
- the polarimetric accuracy is 0.05%.

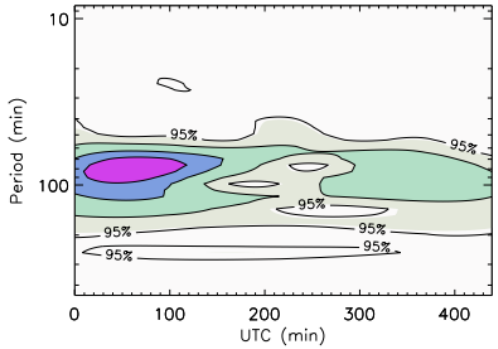
The data obtained for S5 0716+714 on Zeiss-1000 confirmed the results obtained earlier with BTA:

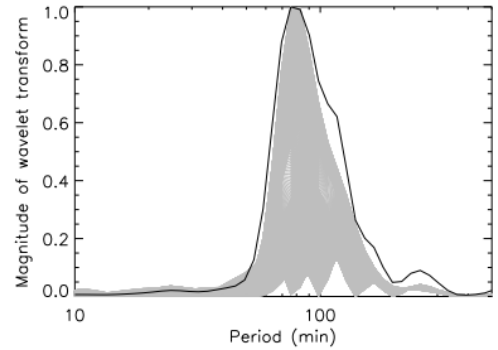
- ✓ switching the direction of the polarization vector at times of ~75 minutes;
- ✓ flux variation period 76±10 minutes





The variations of the normalized Stokes parameters Q and U during the night on the QU-diagram.





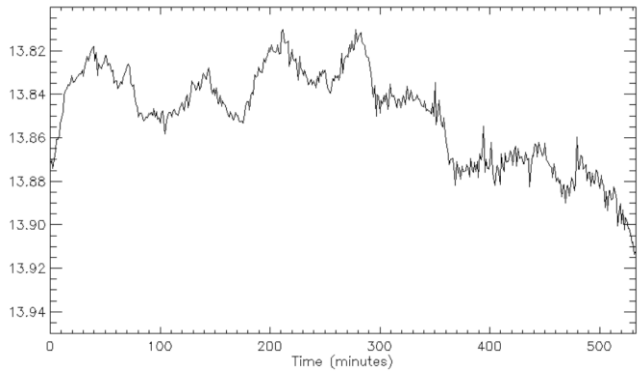
The result of wavelet analysis of the light curve of the blazar S5 0716+714. The maximum of the wavelet transform profile corresponds to a brightness change period of 76 minutes.

(Butuzova 2018,2020): magnitude variation due to the Doppler factor changes:

$$\Delta m = -2.5(3+\alpha)\log\frac{\delta_1}{\delta_2}$$

Then changes of the azimuth angle leads to:

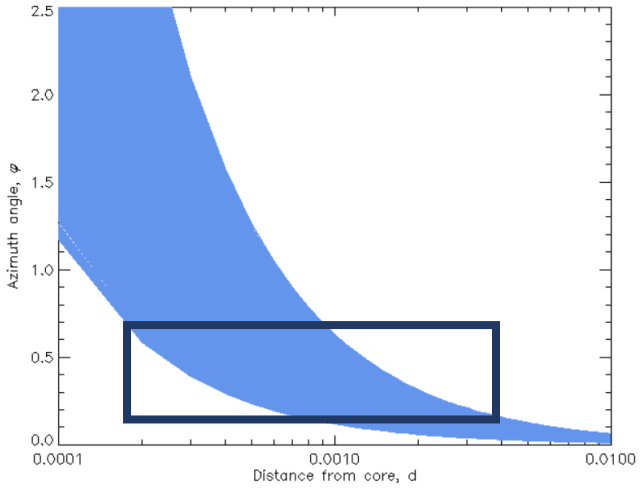
$$\Delta\varphi = 2^\circ \quad \rightarrow \Delta m \approx 0.3$$
$$\Delta\varphi = 1^\circ \quad \rightarrow \Delta m \approx 0.1$$
$$\Delta\varphi = 0.5^\circ \rightarrow \Delta m \approx 0.05$$



Could these changes appear within the observed variation period? Yes! And at the optical jet scales!

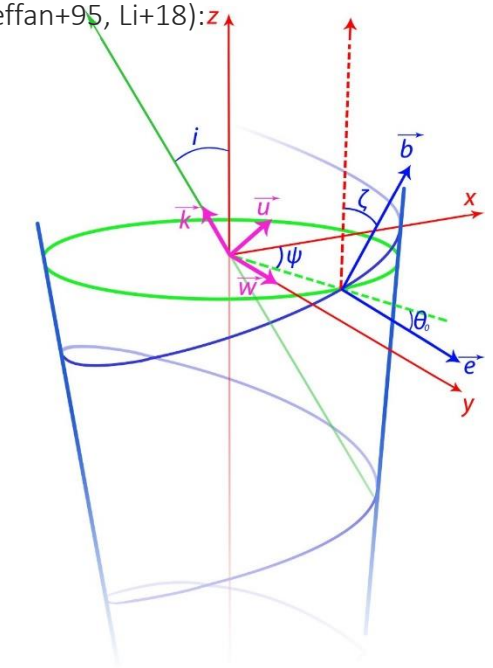
$$\Delta\varphi \approx \frac{\beta c \Delta t \sin p}{d \sin\epsilon}$$

$$t = 77 \pm 10 \text{ min}$$
$$\beta = 0.999$$
$$\epsilon \in [0.5^\circ, 1.5^\circ]$$
$$p \in [5.3^\circ, 5.5^\circ]$$



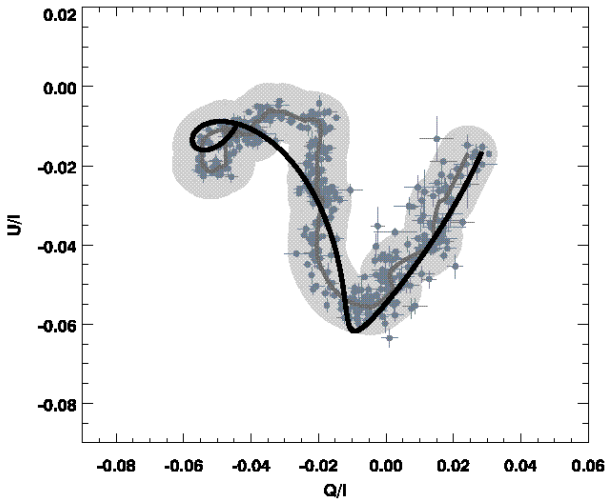
Both polarimetric and photometric variations could be explained with plasma rotation in helical magnetic field

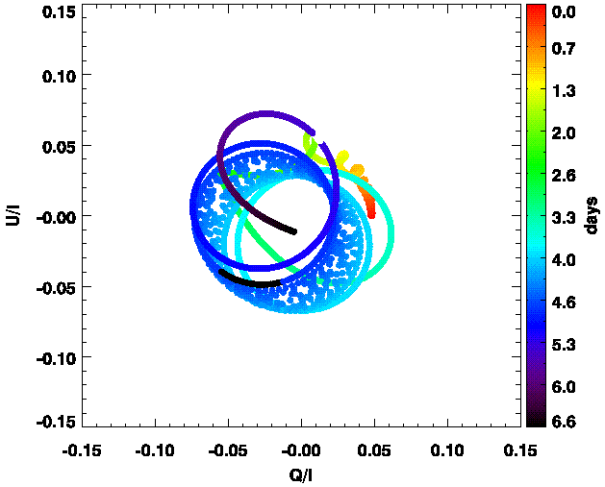
(Steffan+95, Li+18):



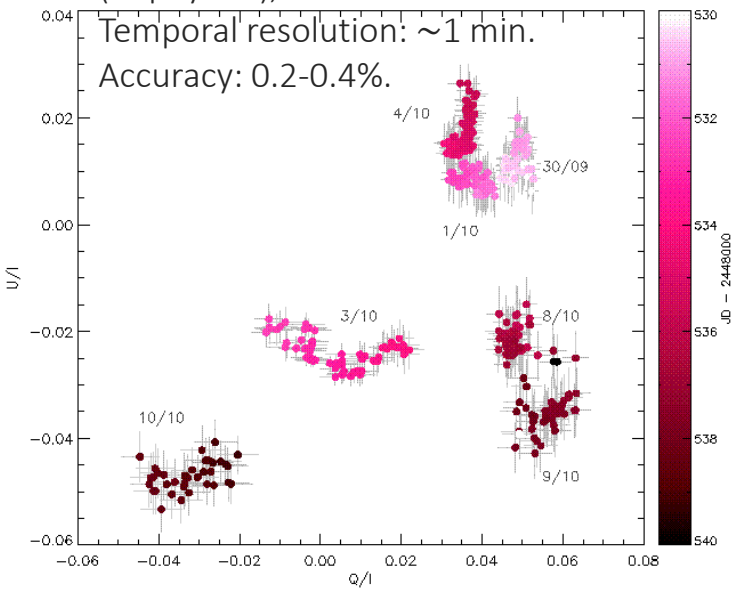
+ precession

Kinematic parameters	Value
Distance from the precession axis	$0.7 \cdot 10^{-3}$pc
Precession period	15 days

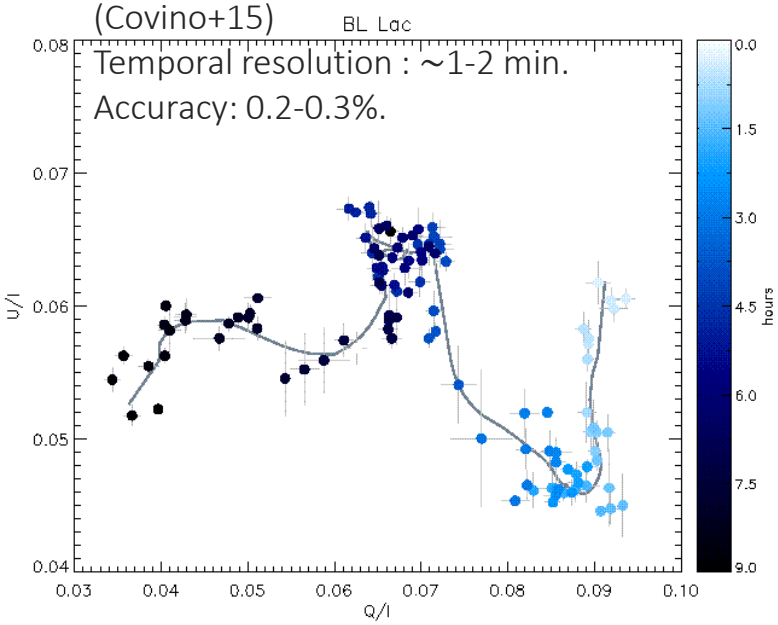




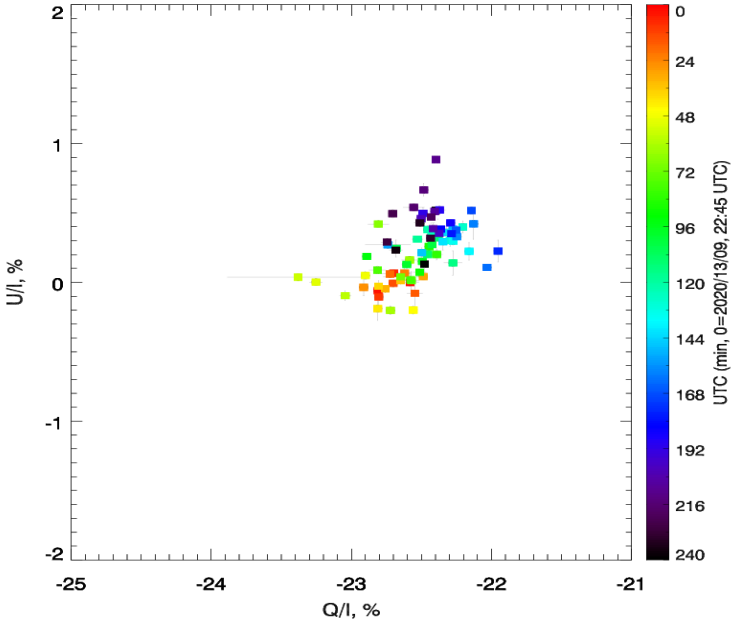
(Impey+00), S5 0716+716



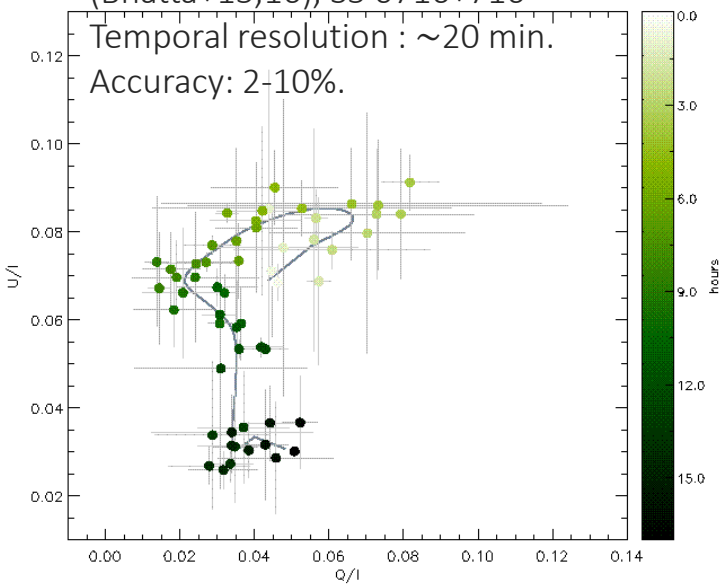
(Covino+15)



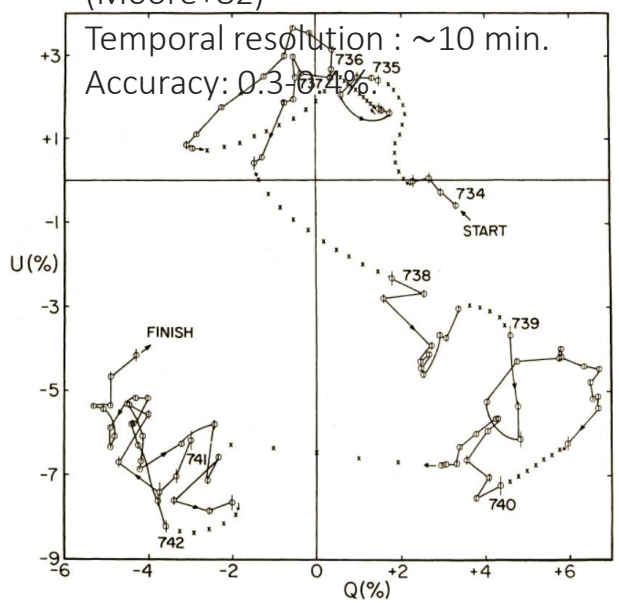
3C66A, BTA+SC-2



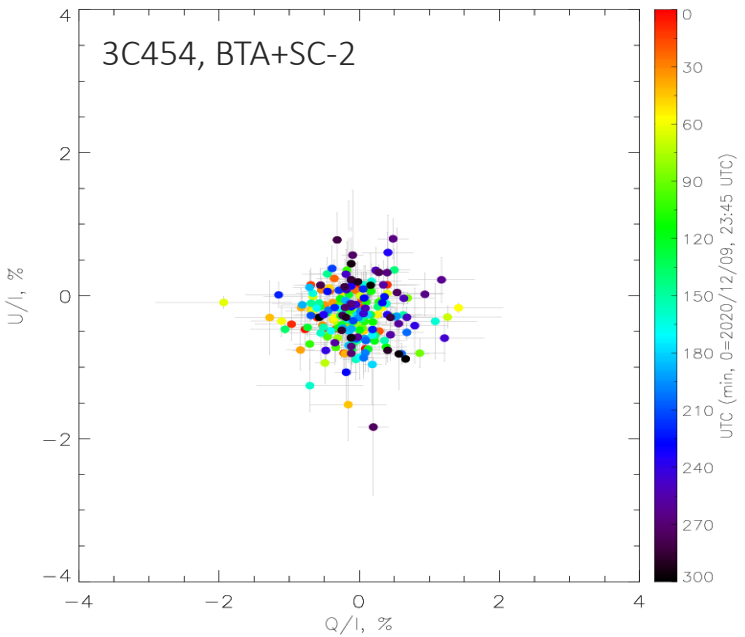
(Bhatta+15,16), S5 0716+716



(Moore+82)



3C454, BTA+SC-2



- 9-hour polarimetric monitoring of S5 0716+714 revealed the intraday variability on the time-scale ~ 1.5 hour. QU-plane discovered the pattern of polarization vector changes – ”arches” and ”loops”;
- the linear size of the emitting region - 1.5 light hour or 10 a.u. at the <0.01 pc distance from the central black hole;
- suggested model of polarization produced by geometrical effects due to relativistic plasma motion in precessing helical magnetic field fits the observational data with precession period ~ 15 days.
- The size of the emitting region is stable within years.

- Is IDV of polarization vector observed in all blazars?
- How does it correlate with the state of brightness?