The intraday variations of the polarization vector direction in blazar S5 0716+714

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Introduction

The object S5 0716+714 is a bright radio source, classified as BL Lac object [1]. It is characterized with extraordinary variability: 5 mag for long-term variations and 0.5 mag within a night. According to the general model [2], the optical radiation of blazar having synchrotron origin is produced in unresolved region of the jet at the distance < 0.01 pc from the centre (Fig. 1). Therefore, **the variations of brightness and polarization vector direction is a pointer of the plasma motion on scales not resolved in optical band with modern techniques**. Here we present the results of observations of the rapid variability in total and polarized light of S5 0716+714. The obtained data were interpreted in case of model of precessing helical magnetic field.
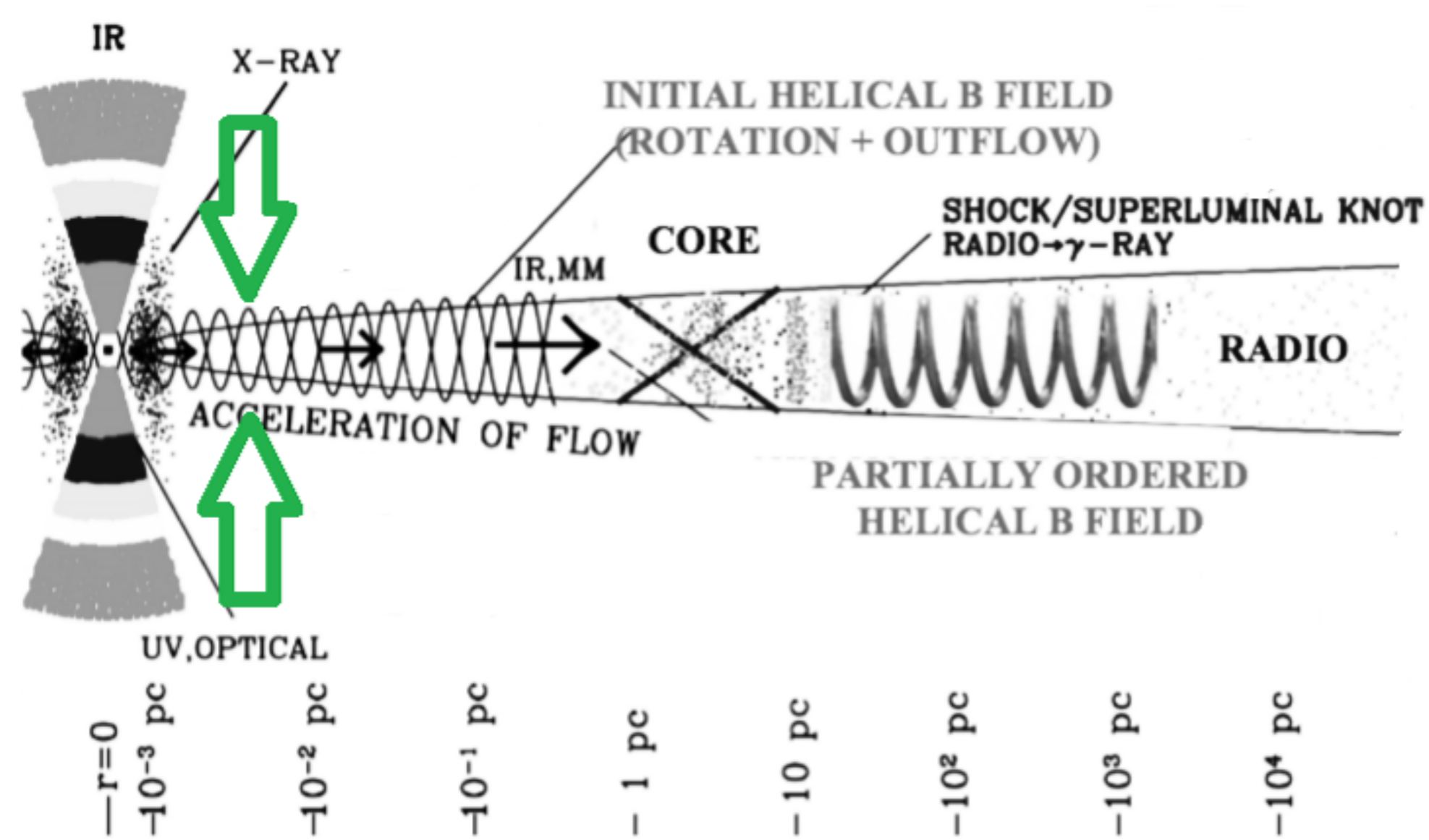

Figure 1: The model of the synchrotron radiation of the jet [2].
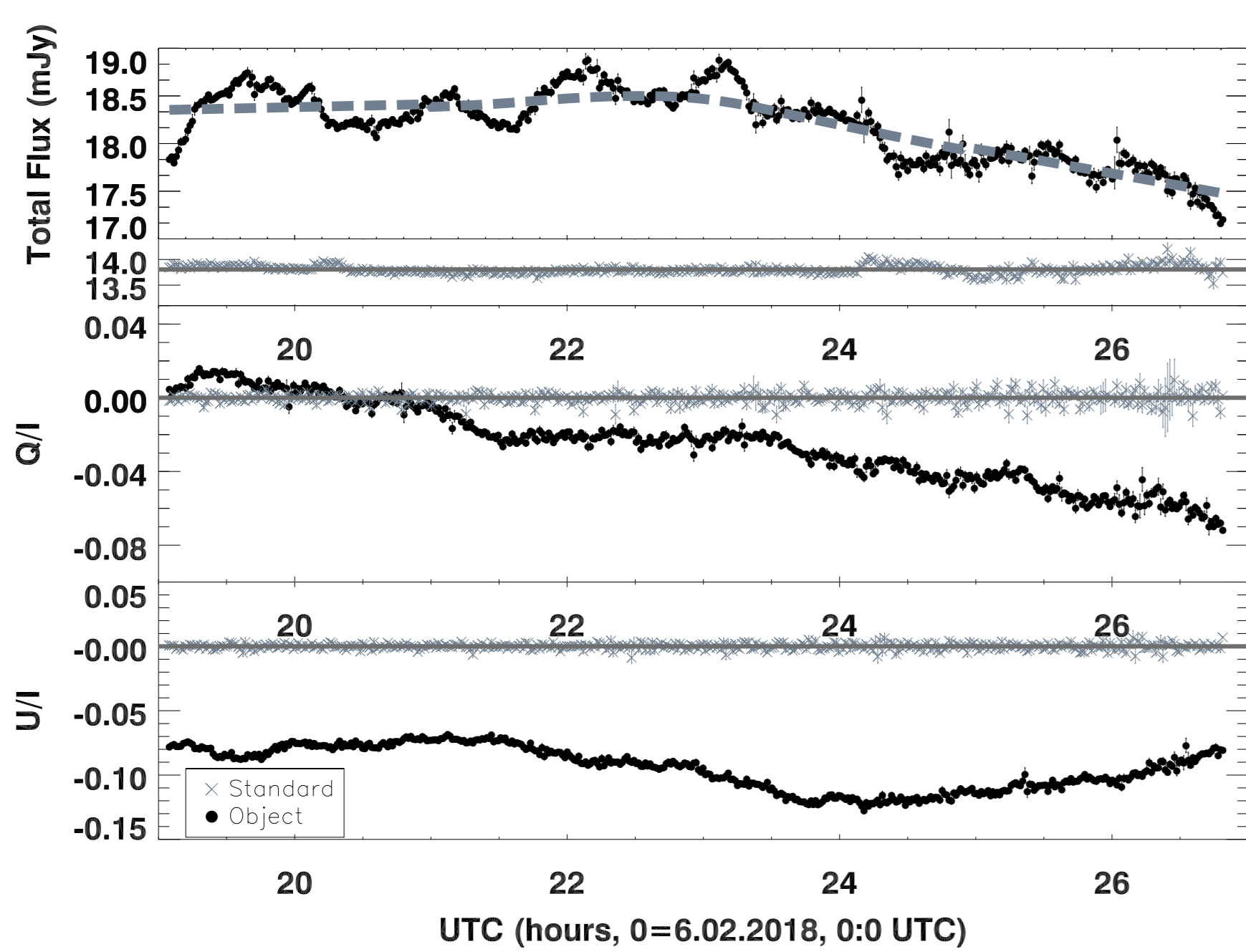
Observations

Figure 2: The variations of the total flux and the Stokes parameters Q and U during the night.

In February 2018, 8-hour polarimetric monitoring of S5 0716+714 with 70-second temporary resolution was conducted with the 6m BTA telescope with SCORPIO-2 reducer [3]. The double Wollaston prism was used as the polarization analyzer, which allows to obtain three Stokes parameters – intensity I and linear polarization parameters Q and U – simultaneously. Simultaneous observations of the object and the non-polarized standard star in the field minimize atmospheric absorption and depolarization. The Stokes parameters are calculated as:

$$\frac{Q}{I} = \frac{I_0 - I_{90}D_Q}{I_0 + I_{90}D_Q}, \ \frac{U}{I} = \frac{I_{45} - I_{135}D_U}{I_{45} + I_{135}D_U},$$

where D_Q and D_U are coefficients of polarization channel transmission. Eventually, the polarimetric accuracy is 0.1% and photometric accuracy is 0.005 mag.

References

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[2] Marscher A.P. et al., 2008, Nature, 452
[3] Afanasiev V. L., Amirkhanyan V. R., 2012, Astrophys. Bull., 67, 4
[4] Butuzova M. S., 2018, Astron. Rep., 62, 2
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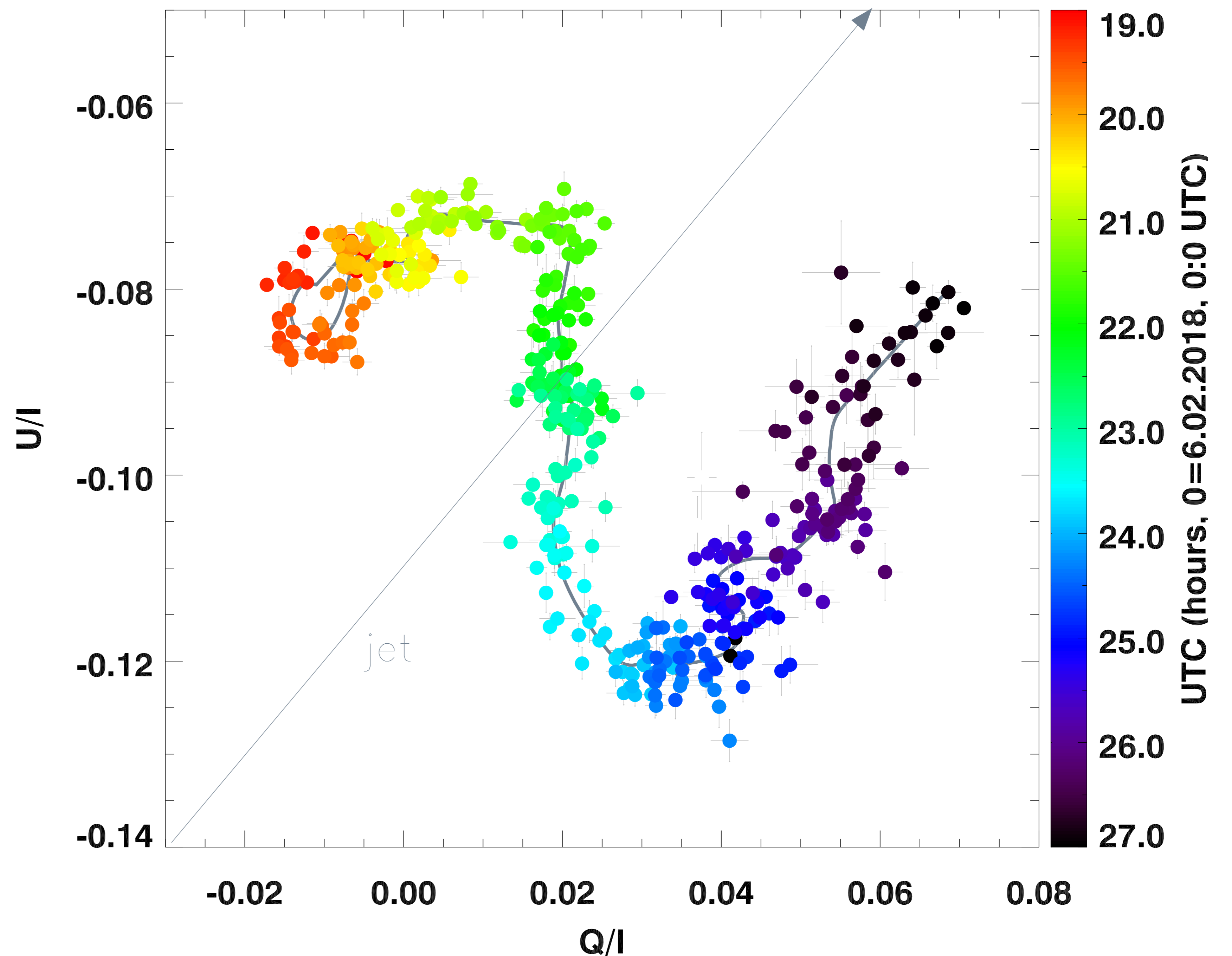
(arXiv:1810.07594).

Results

Figure 3: The variations of the normalized Stokes parameters Q and U during the night on the QU-diagram.
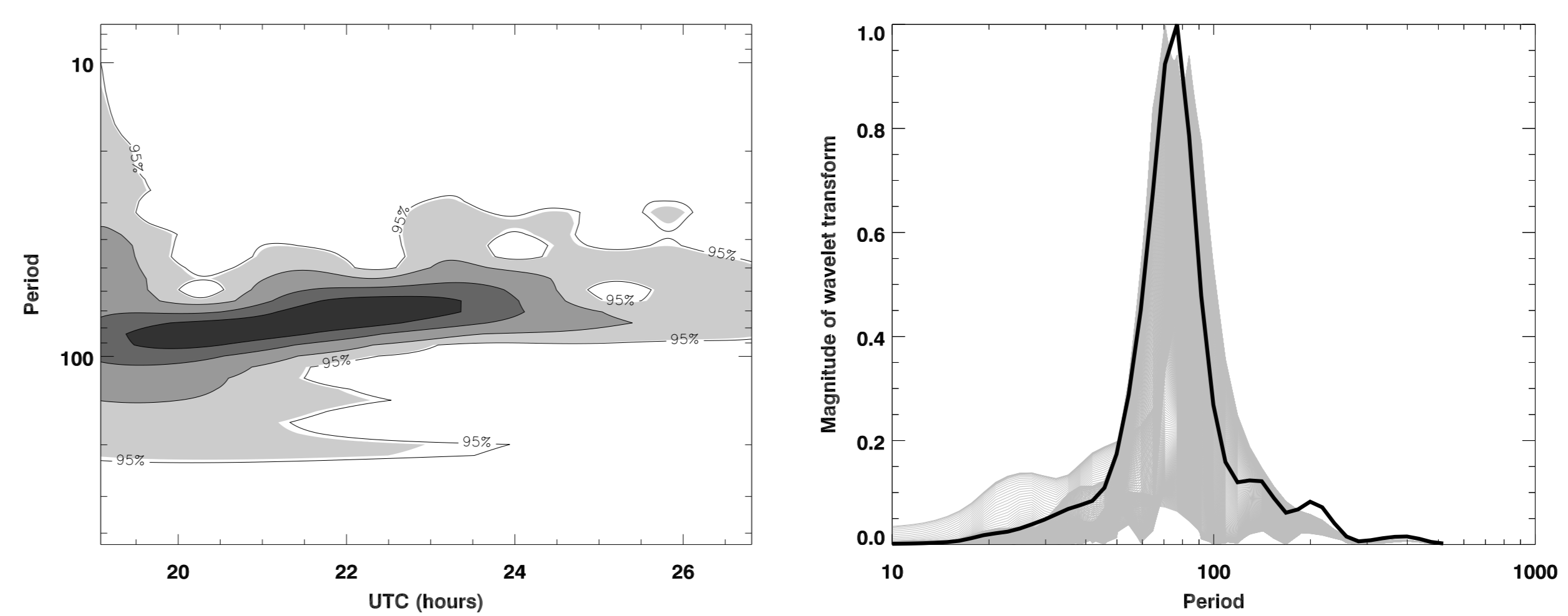

Figure 4: The magnitude (left) and profiles (right) of the wavelet transformation.

▶ Flux variations: $\Delta F \approx 1$ mJy, $\sigma = 0.079$ with the period $\sim$77 min.
▶ Polarization variations: $\Delta \mathrm{P.D.} \approx 7\%$, $\sigma_Q = 0.0038$ and $\sigma_U = 0.0023$. EVPA switch period 1.5–3 hours.

Polarization model

We considered a model of jet polarization variation due to geometric effects of the plasma motion in a helical magnetic field. The kinematic parameters are taken from [4 and ref.]. Then, on the QU-plane the polarization vector creates a smoothly unwinding spiral. However, this does not correspond to our observations, nor the observations of other authors [e.g., 5]. A fundamentally new solution was the addition of precession of the magnetic field. Approximating our data by this model indicated a precession period of ~ 15 days (Fig. 5).
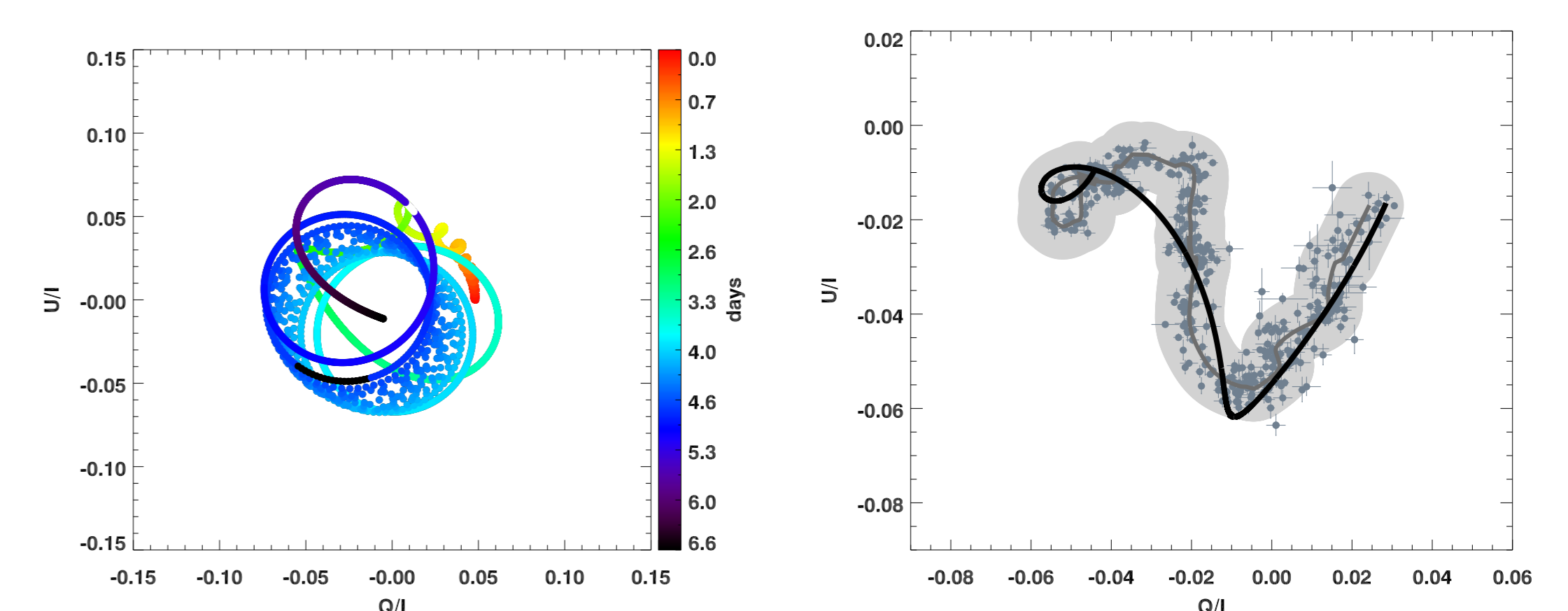

Figure 5: Results of numerical simulation of polarization in jet: characteristic motion of polarization vector (left) and approximation of observational data (right).

Conclusion

▶ 9-hour polarimetric monitoring 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 $5 \cdot 10^{-5}$ pc at the 0.001 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.