Optical (and radio) polarisation of NLSy1s and rotation candidates in gamma-ray emitting ones

E. Angelakis
Max-Planck-Institut für Radioastronomie, Auf dem Huegel 69, Bonn 53121, Germany

S. Kiehlmann, I. Myserlis, V. Karamanavis, D. Blinov, J. Eggen, R. Itoh, S. Komossa, N. Marchili, J. A. Zensus

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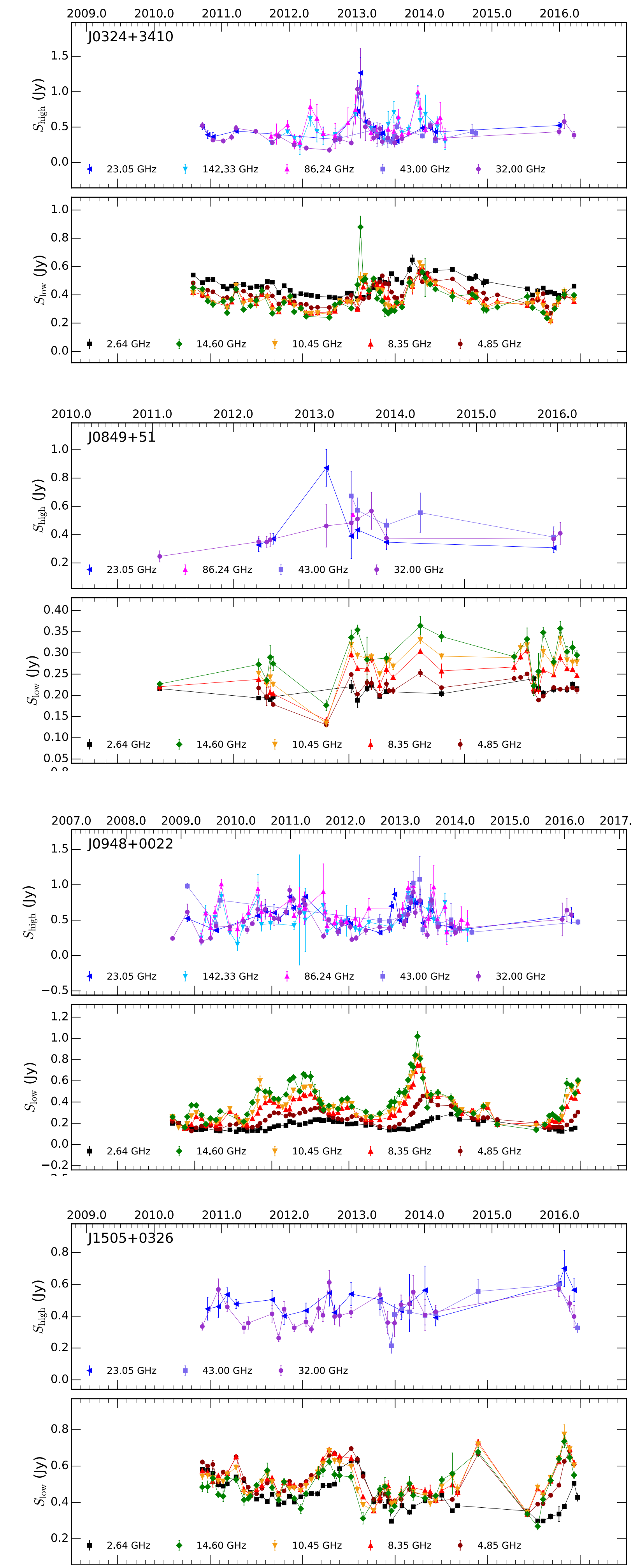
radio jet emission

Angelakis et al., 2015, A&A, 575, A55

- 10 radio frequencies 2.6 — 143 GHz
- ~1-month cadence, over ~5 years
- radio monitoring of **the 4** NLSy1s **detected by Fermi at** the time

- typical blazar phenomenology but **lower flux densities**
- Doppler factors below 10: **moderately relativistic** jets
- jet power comparable to the **least energetic blazars** (BL Lac objects)



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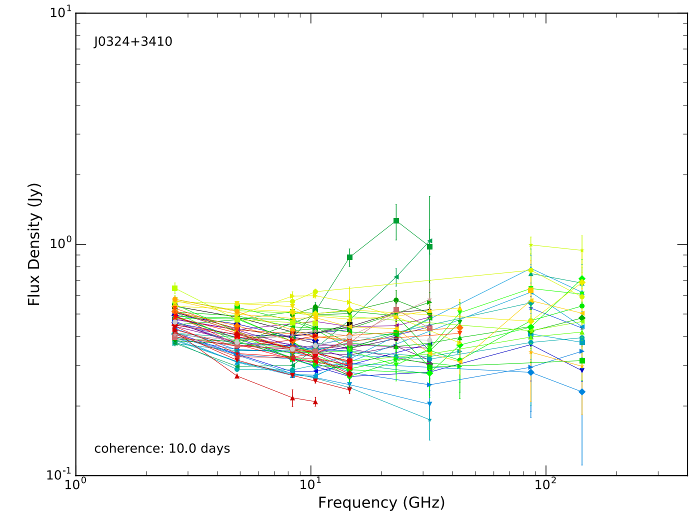
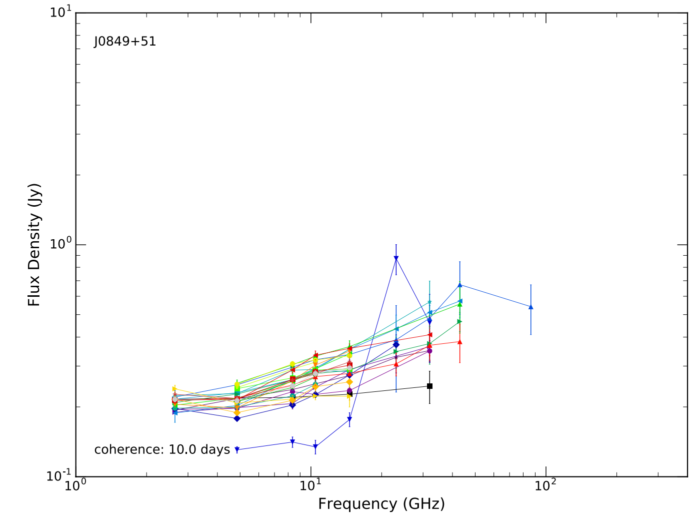
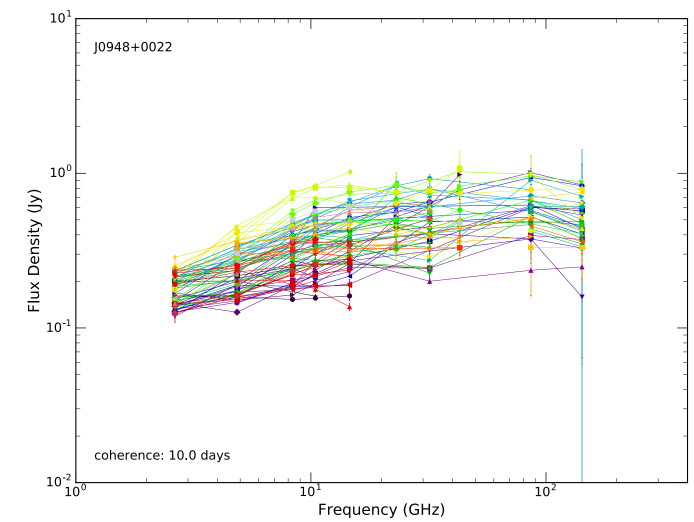
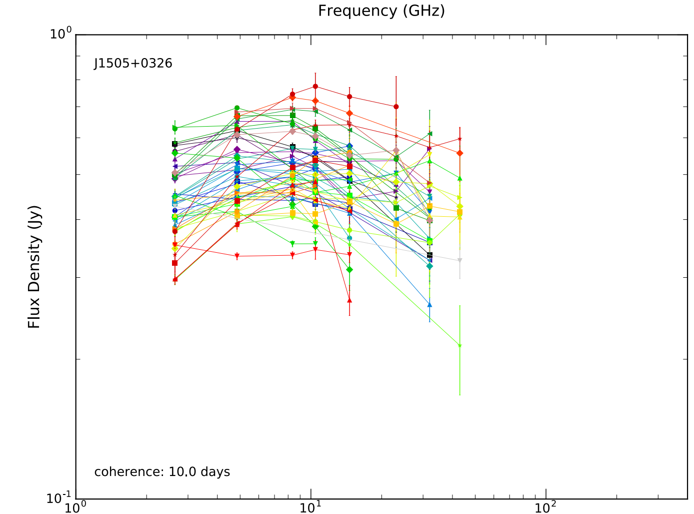
- typical blazar phenomenology but **lower flux densities**
- Doppler factors below 10: **moderately relativistic** jets
- jet power comparable to the **least energetic blazars** (BL Lac objects)
- **intense spectral evolution:** particle acceleration events (e.g. shocks)







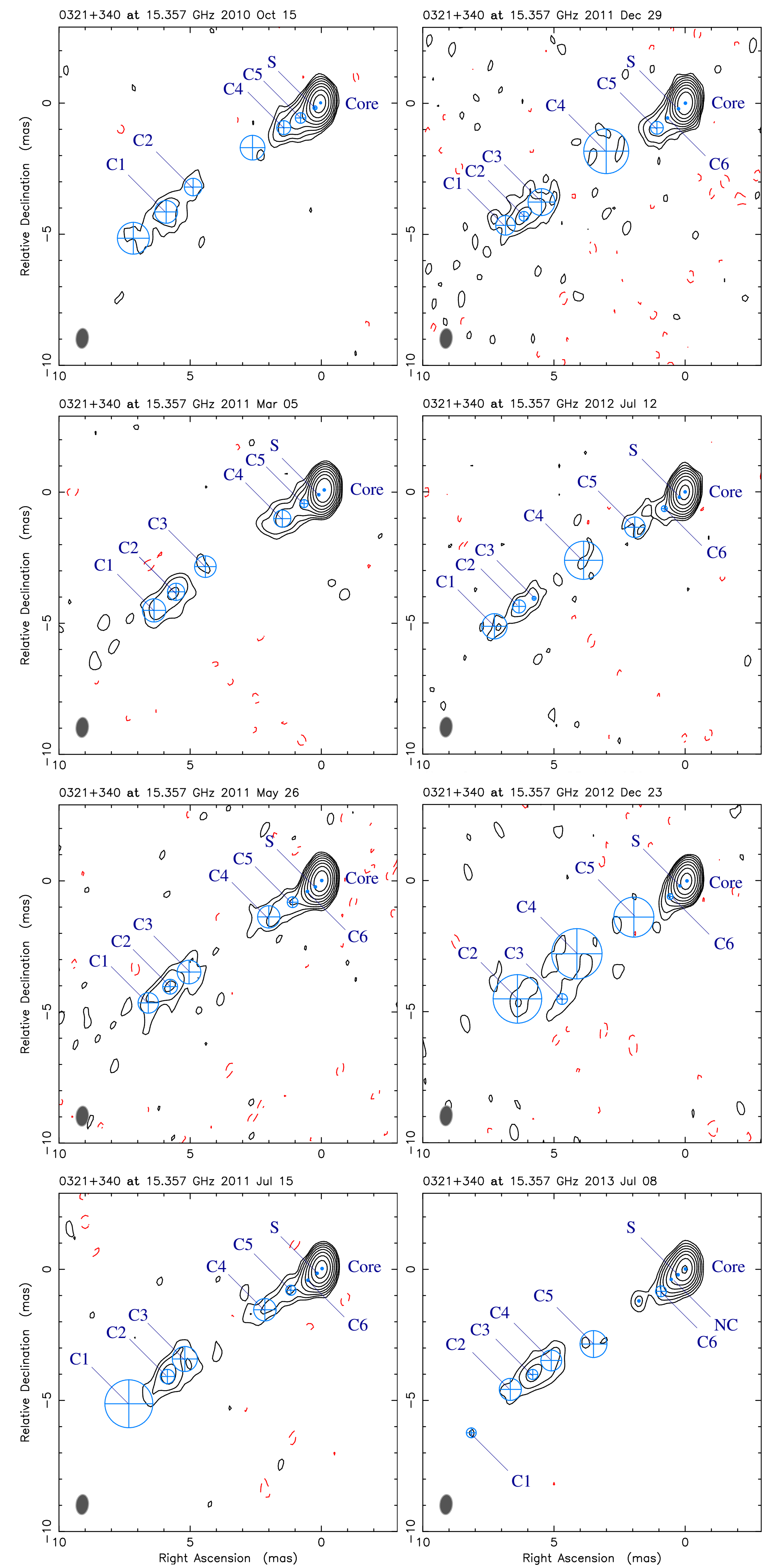


jet kinematics: 1H 0323+342

Fuhrmann et al., 2016, RAA,16,176F

multi-epoch 15 GHz VLBA images (MOJAVE) & F-GAMMA data:

- ➡ 6 moving components and one quasi-stationary feature
- ➡ apparent speeds ranging 0.93— 6.92 c
- ➡ δ_{var} ~ 5.2
- ➡ viewing angle towards 1H 0323+342: $\theta_{var} \leq 4^{\circ}–13^{\circ}$: validating the **aligned geometry scenario**



optical polarisation variability

Angelakis et al., in prep.

scope:

- study the polarisation variability
- search for rotations of the PA

sample:

- 10 Radio Loud NLSy1s
- 5 detected by *Fermi*

dataset:

- RoboPol, KANATA, Perkins & Steward

ID	Survey ID	Redshift	M_{BH}	R	Notes
J0324+3410	1H 0323+342	0.062900 [1]	2×10^{7} [A]	318 [O]	Fermi detected[5]
J0849+5108	SBS 0846+513	0.584701 [2]	0.8 - 9.8×10^{7} [B,C,D]	1445 [J]	Fermi detected[6]
J0948+0022	PMN J0948+0022	0.585102 [2]	0.4 - 8.1×10^{8} [E,F]	355 [J]	Fermi detected[7]
J1305+5116	WISE J130522.75+511640.3	0.787552 [2]	3.2×10^{8} [J]	223 [J]	Optical spec. indicates strong outflow.
J1505+0326	PKS 1502+036	0.407882 [2]	0.04 - 2×10^{8} [G,H,5,I]	1549 [J]	Fermi detected[5]
J1548+3511	HB89 1546+353	0.479014 [2]	7.9×10^{7} [J]	692 [J]	Evidence for past radio variability.
J1628+4007	RX J16290+4007	0.272486 [2]	3.5×10^{7} [L]	29 [N]	Optically variable.
J1633+4718	RX J1633.3+4718	0.116030 [4]	3×10^{6} [K]	166 [J]	Evidence for past radio variability.
J1644+2619	FBQS J1644+2619	0.145000 [3]	2.1×10^{8} [M]	447 [N]	Fermi detected[8]
J1722+5654	SDSS J172206.02+565451.6	0.425967 [2]	2.5×10^{7} [J]	234 [J]	Evidence for high-amplitude optical variability.

optical polarisation: fraction

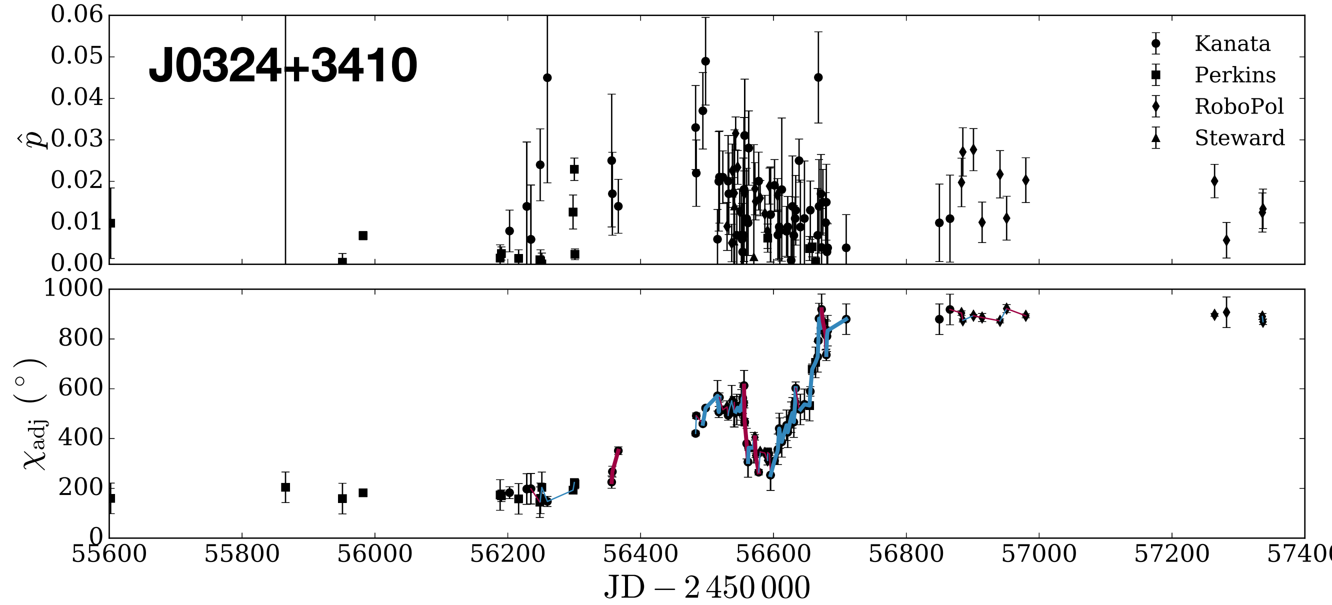
Angelakis et al., in prep.

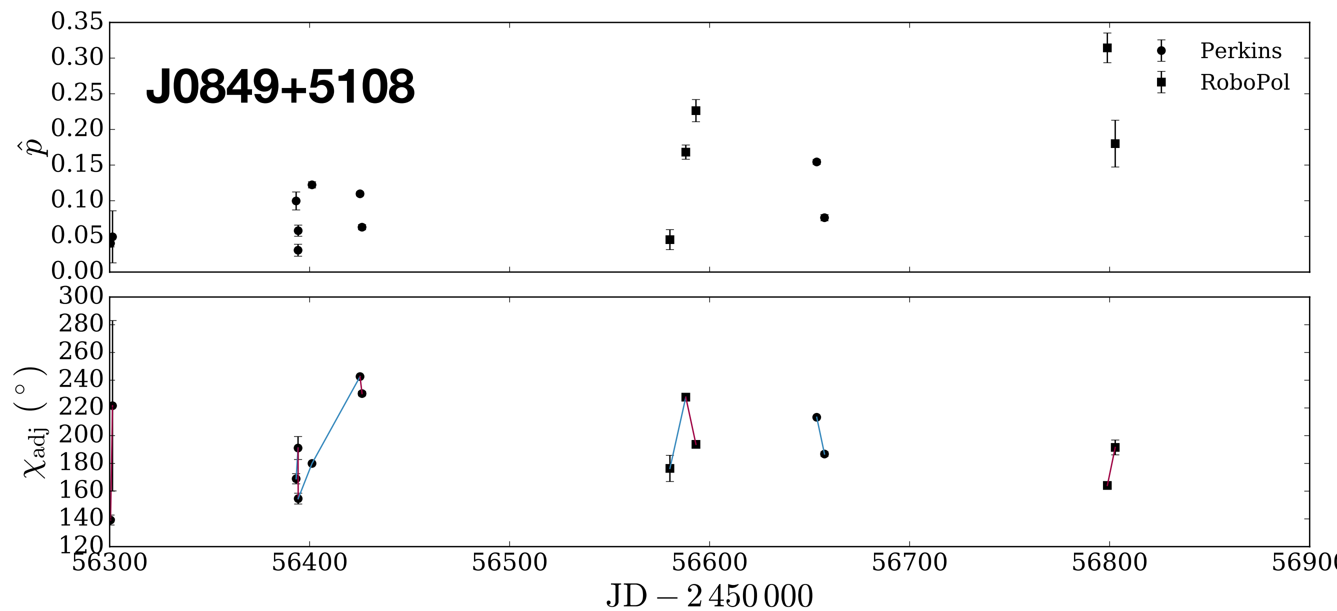
Rice distribution:

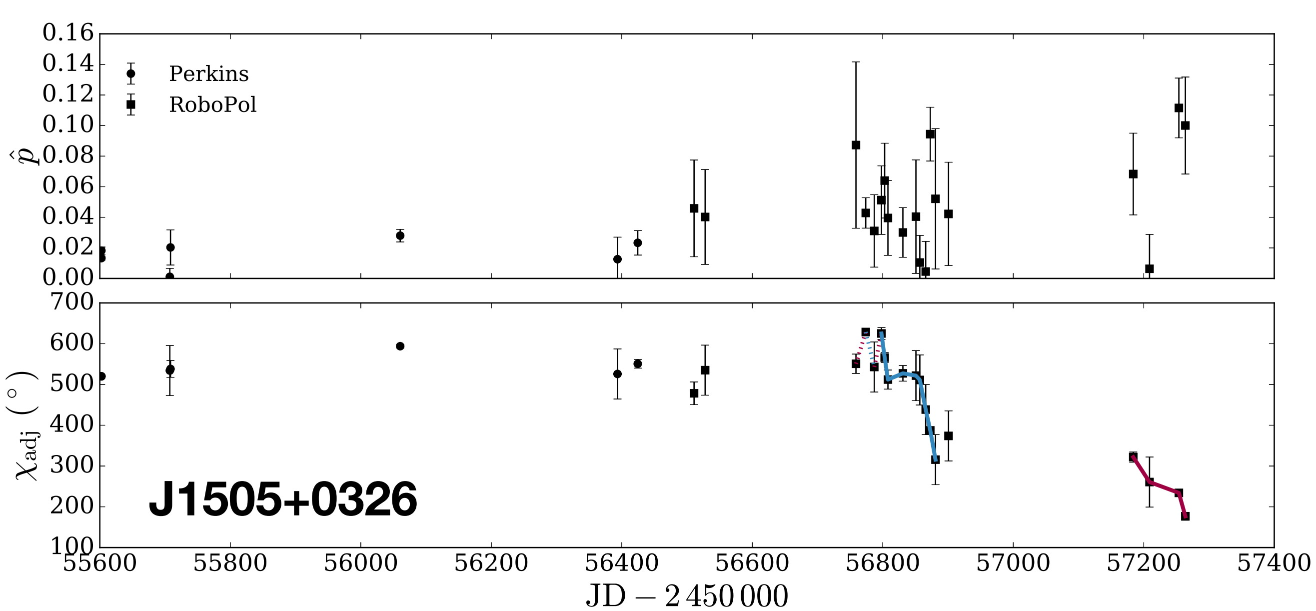
$$F(p \mid p_0)dp = \frac{p}{\sigma_p} \exp\left[-\frac{p^2 + p_0^2}{2\sigma_p^2}\right] I_0\left(\frac{p p_0}{\sigma_p^2}\right) \frac{dp}{\sigma_p}$$

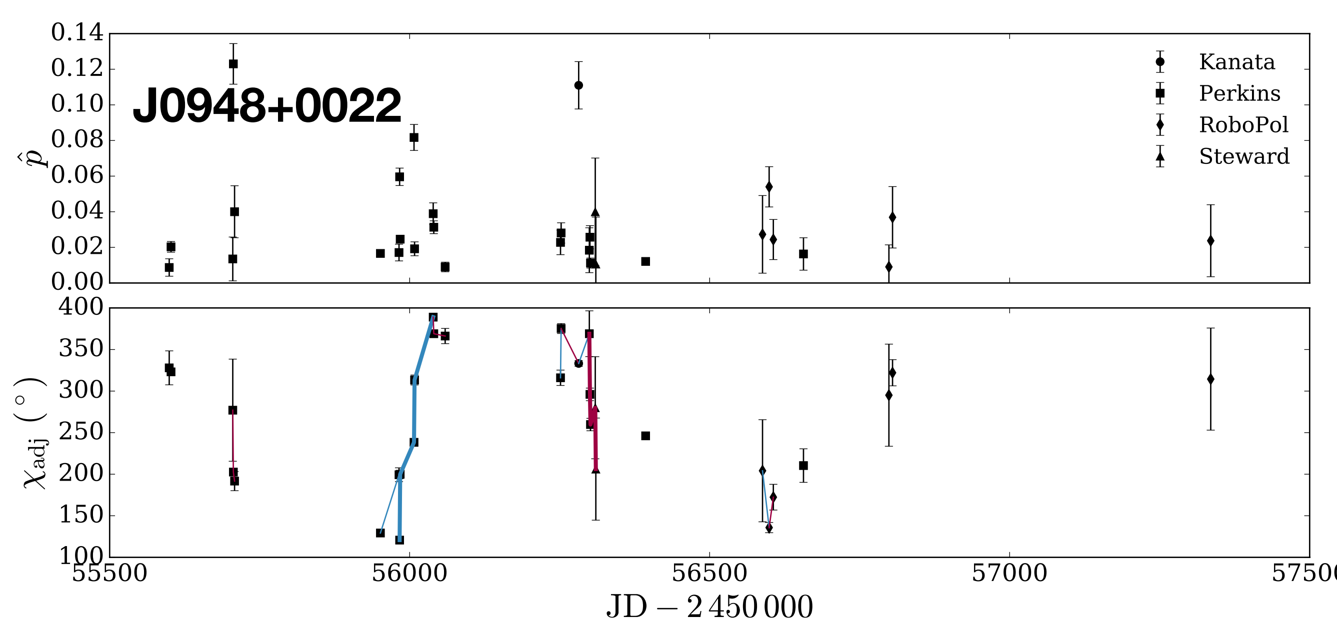
de-biassing recipe:

$$\hat{p} = \begin{cases} 0 & \text{for } p/\sigma_p < \sqrt{2} \\ \sqrt{p^2 - \sigma_p^2} & \text{for } p/\sigma_p \geq \sqrt{2} \end{cases}$$







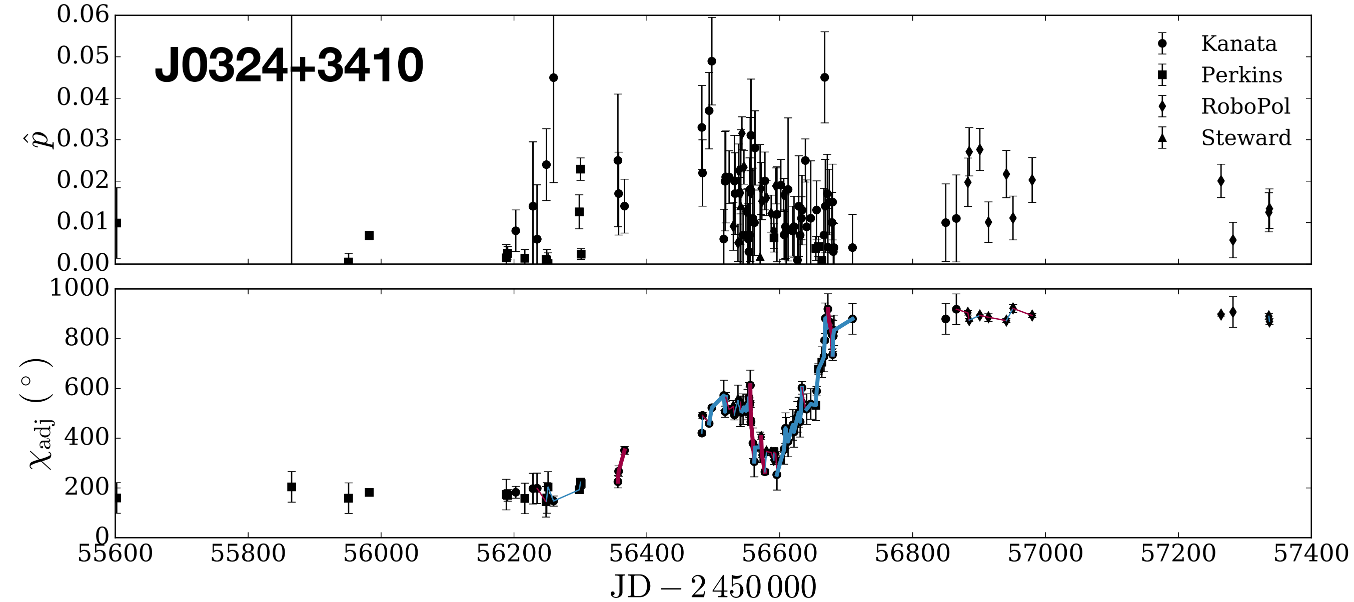


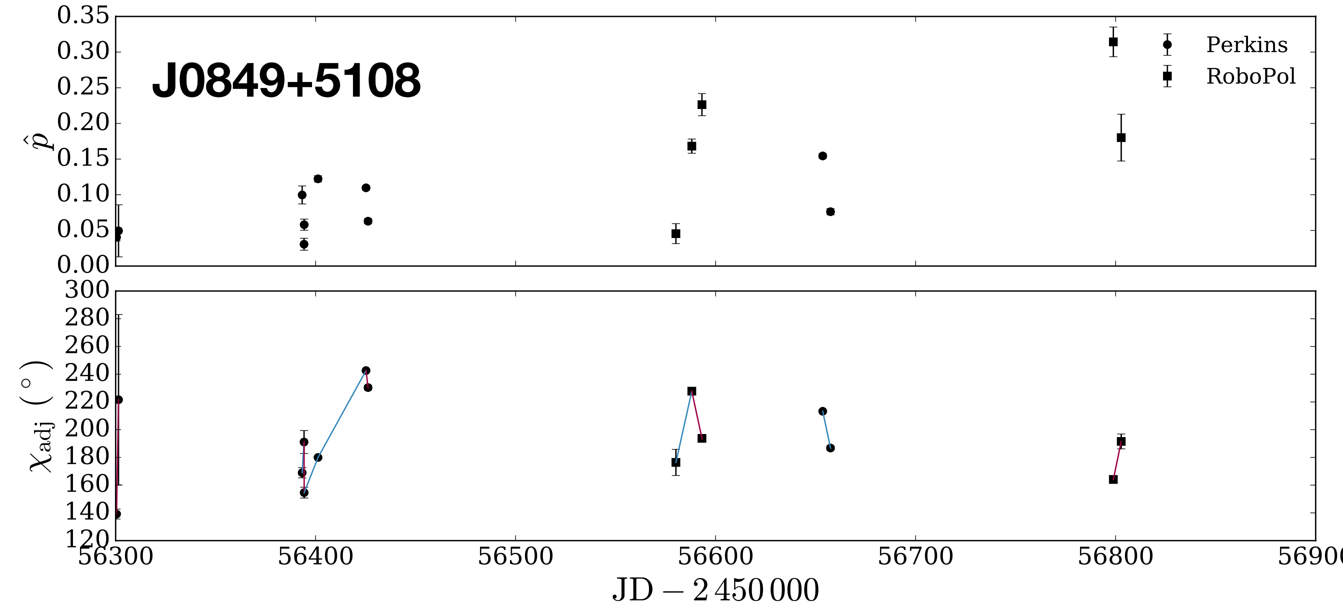
optical polarisation: fraction

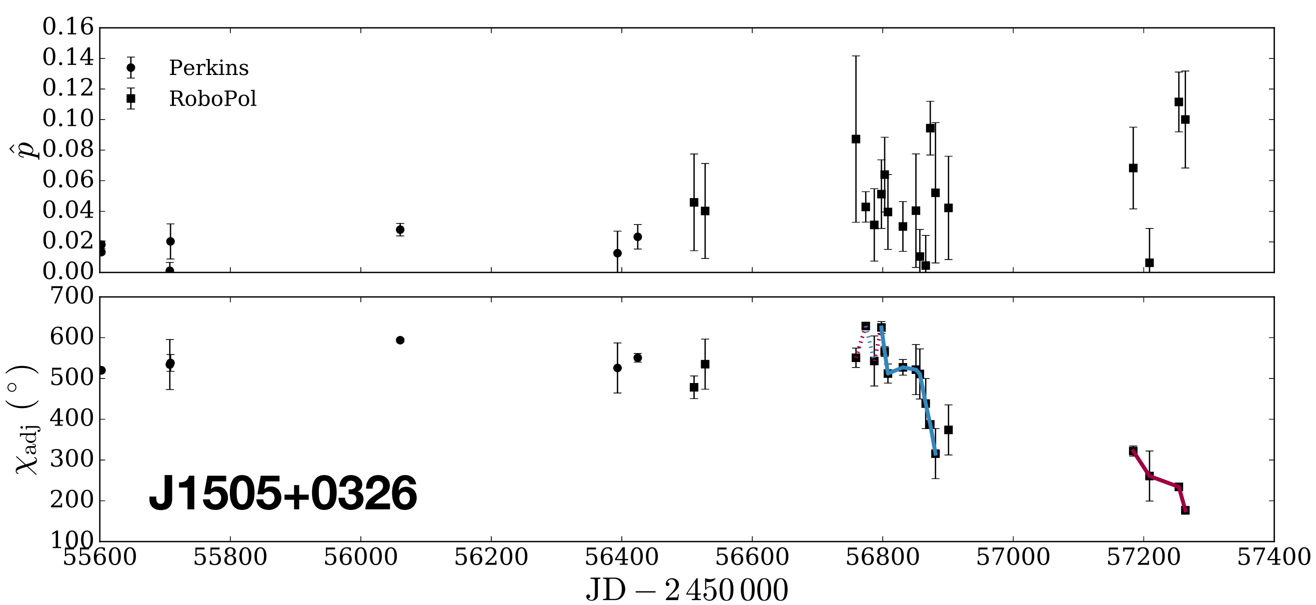
Angelakis et al., in prep.

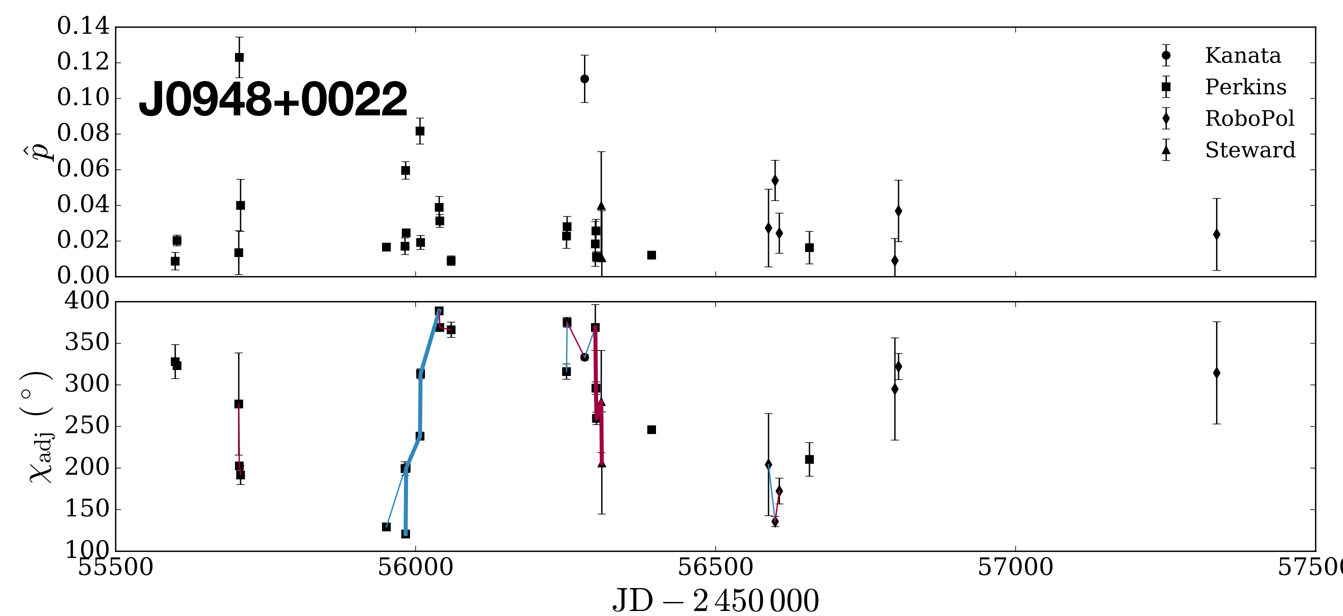
polarisation fraction:

- ➡ 7 of 10 RL NLSy1s show phases of significant polarisation ($\hat{p}/\sigma_p \geq 3$)
  - 3 of 7 have maximum: $\hat{p} \leq 0.05$
  - 1 of 7 has maximum : $5 < \hat{p} \leq 0.1$
  - 3 of 7 have maximum: $0.1 < \hat{p}$









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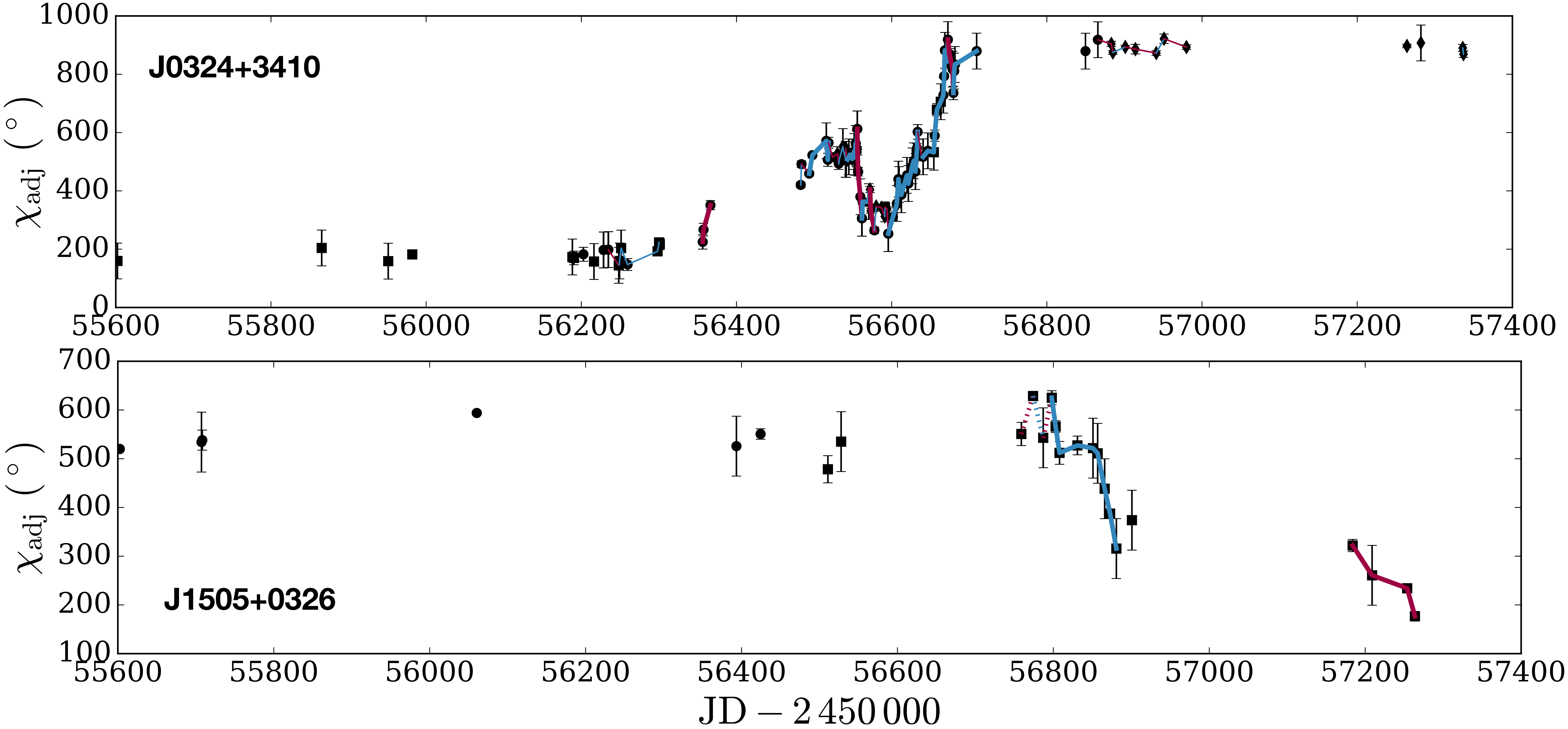
JD	$\hat{p}$	σ_p	χ (°)	σ_χ (°)
		J1305+5116		
2457209.285	0.011	0.008	-29.6	21.2
2457240.322	0.008	0.007	-8.9	23.7
		J1548+3511		
2457209.367	0.000	0.013	47.9	61.4
2457240.364	0.021	0.011	-10.8	16.5
2457264.291	0.058	0.016	-32.9	8.0
		J1628+4007		
2457209.405	0.000	0.008	-25.0	61.4
2457254.323	0.000	0.009	-45.3	61.4
		J1633+4718		
2457209.425	0.021	0.005	-8.1	7.0
2457228.395	0.030	0.005	-5.6	5.2
2457240.384	0.019	0.006	3.7	9.2
2457254.345	0.027	0.005	-3.1	5.0
		J1644+2619		
2457209.445	0.039	0.008	-24.2	5.8
2457230.387	0.000	0.011	-32.5	61.4
2457240.404	0.031	0.006	-16.8	6.0
2457254.358	0.012	0.012	-34.8	28.8
		J1722+5654		
2457228.434	0.000	0.014	-33.2	61.4
2457240.429	0.000	0.015	-37.7	61.4

optical polarisation: angle

Angelakis et al., in prep.

polarisation angle:

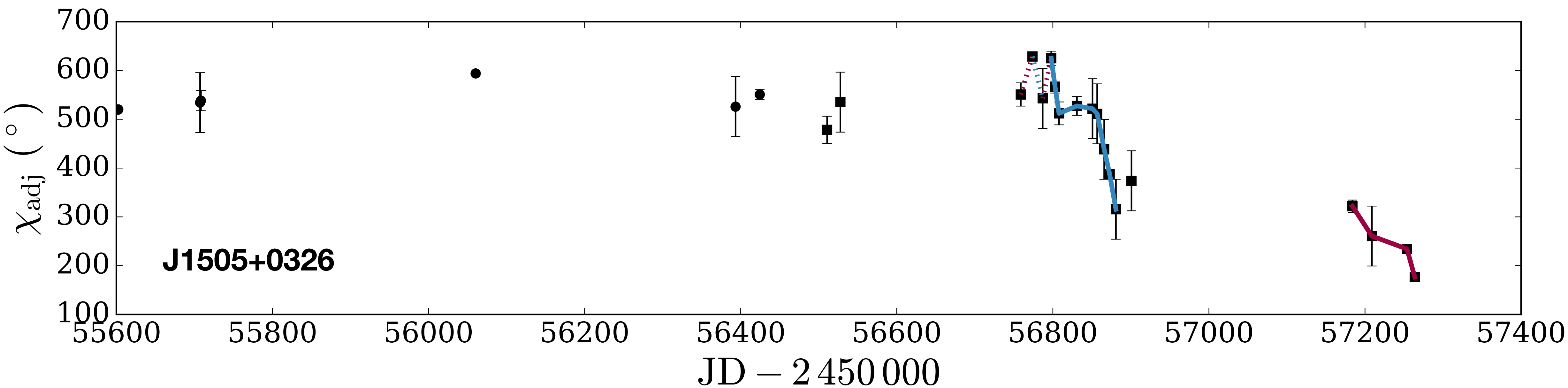
- significant variability
- possible angle **rotations** similar to those in blazars



polarisation angle of J1505+0326

Angelakis et al., in prep.

- 5 periods of significant continuous variability (coloured connecting lines)
- 2 of 5 are **long rotations** because:
  - include **more than three** points
  - exceed **90°**

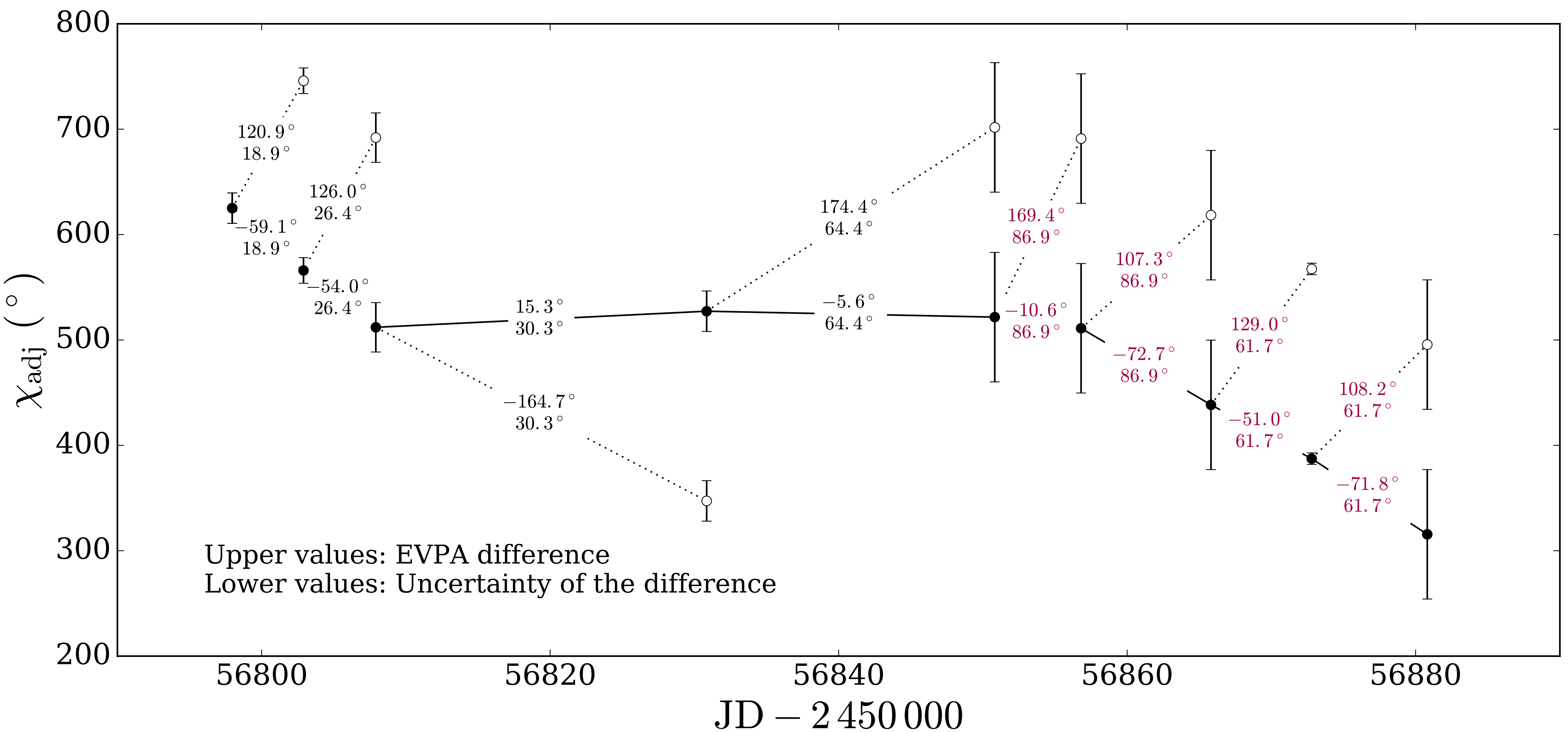


the "long" rotation of J1505+0326

Angelakis et al., in prep.

observed parameters:

- length: $\Delta\chi \approx -309.5^\circ$
- rate: $\Delta\chi/\tau \approx -3.7\ \mathrm{deg/d}$

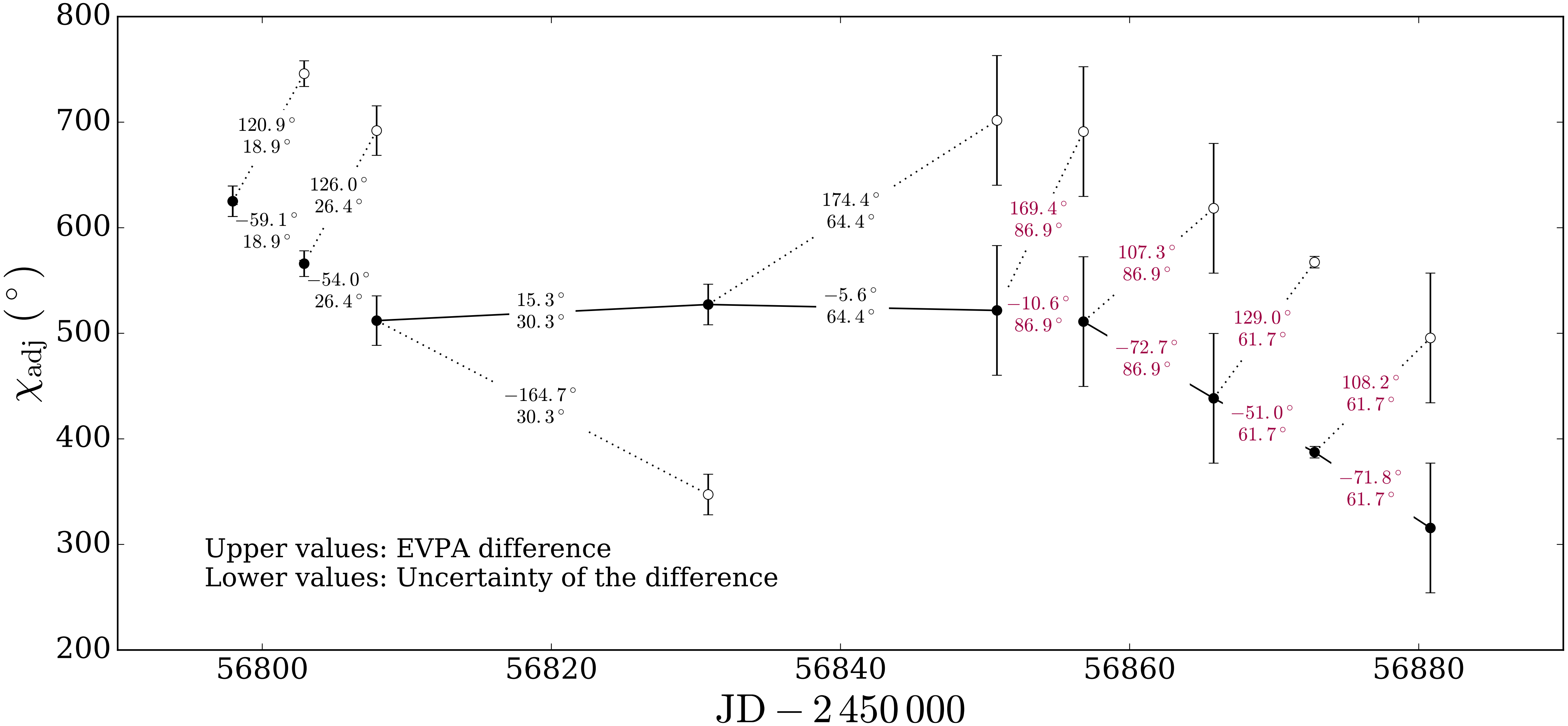


the “long” rotation of J1505+0326

Angelakis et al., in prep.

is the rotation **reliable**?

- sparse sampling and large angle uncertainties make the **direction uncertain**
- very **large number** of uncertain points (red), hence: the rotation is **uncertain**

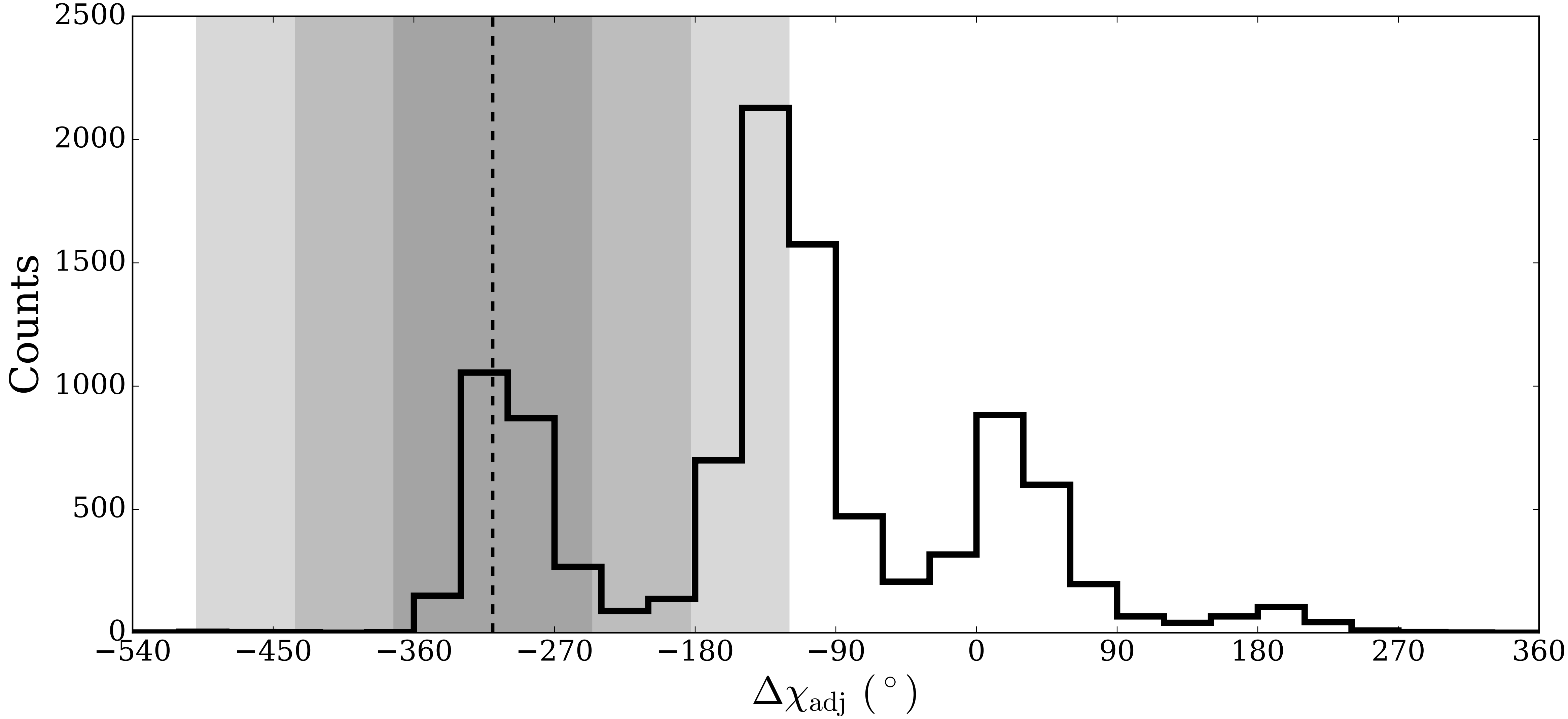


the “long” rotation of J1505+0326

Angelakis et al., in prep.

is the rotation **reliable**?

- **uncertainties** in **measured Stokes** *q* and *u* make the **rotation uncertain**
- yet, probability of rotation over angle within **1.0 sigma of observed value: ~23%**



the “long” rotation of J1505+0326

Angelakis et al., in prep.

can measurement **uncertainties fake** a **rotation**?

- ➡ assume no intrinsic rotation $d\chi/dt = 0$
- ➡ we count “**full rotations**” (i.e. cover the entire dataset)

the “long” rotation of J1505+0326

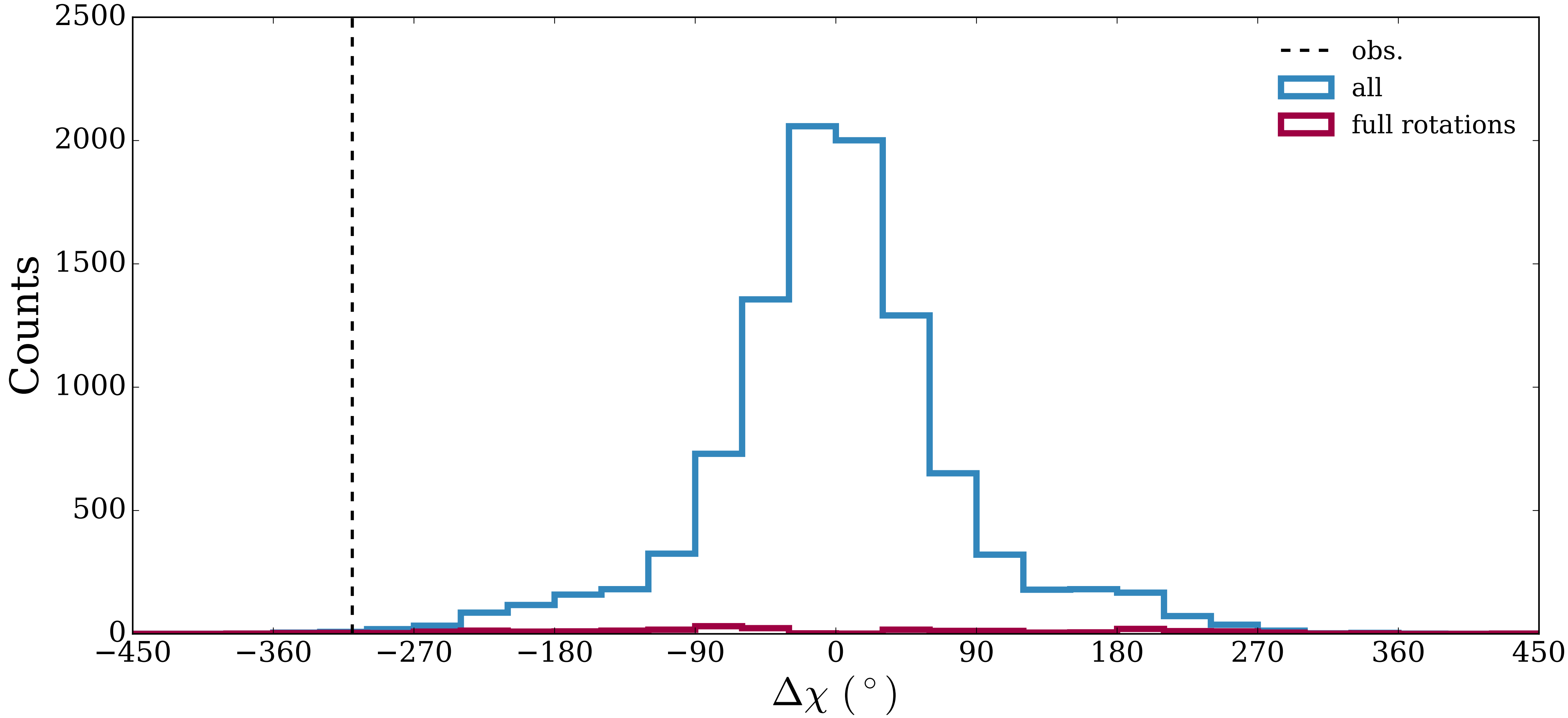
Angelakis et al., in prep.

can measurement **uncertainties fake** a **rotation**?

- we find:

$$P\,(\text{full rotation};\, |\Delta\chi_{\text{intr}}| \geq 309.5^{\circ} |\, d\chi_{\text{intr}}/dt = 0) = 6 \times 10^{-4}$$

- **fairly improbable**: hence there **must be intrinsic variability**

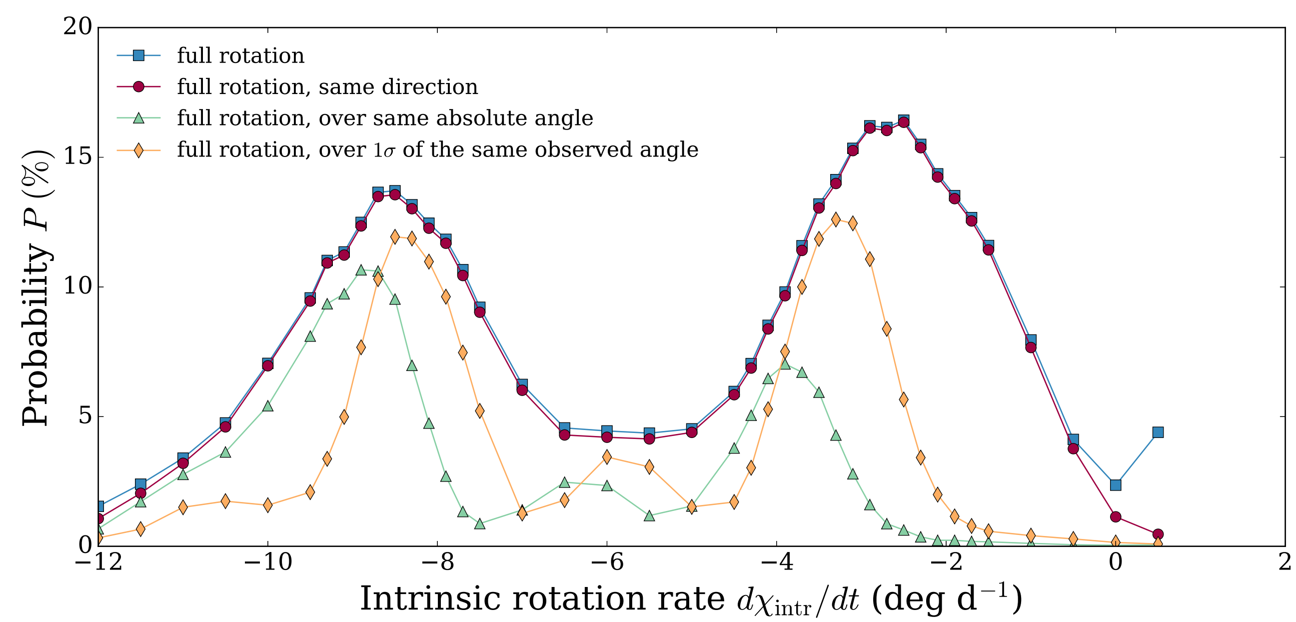


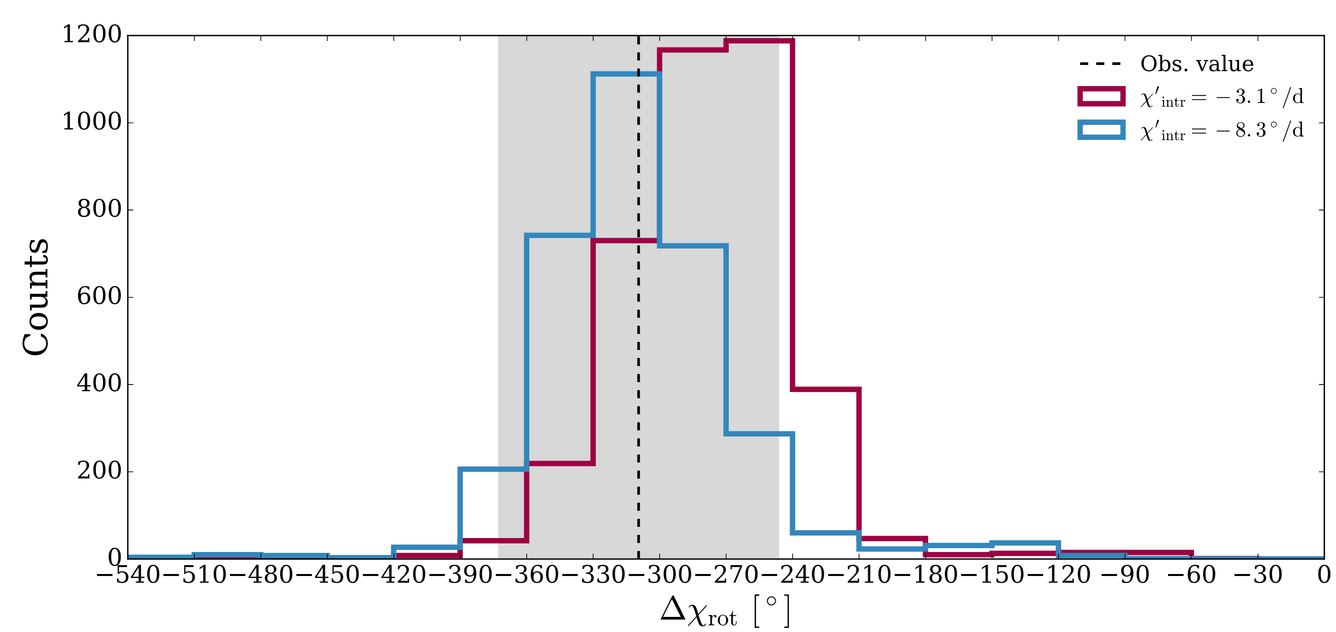
the “long” rotation of J1505+0326

Angelakis et al., in prep.

most probable intrinsic parameters:

- assume constant rate ($d\chi_{intr}dt=const$)
- for a **full rotation** over **an angle within 1σ** of the observed one:
  - most probable rate: –3.1±0.1 deg d^{-1} probability ~ 13%
- hence: the **observed** angle is **consistent** with an **intrinsically constant rotation**
- conclusion: it is **much more likely** that an **intrinsic EVPA rotation** (with pseudo-variability from uncertainties) **is causing the observed event**





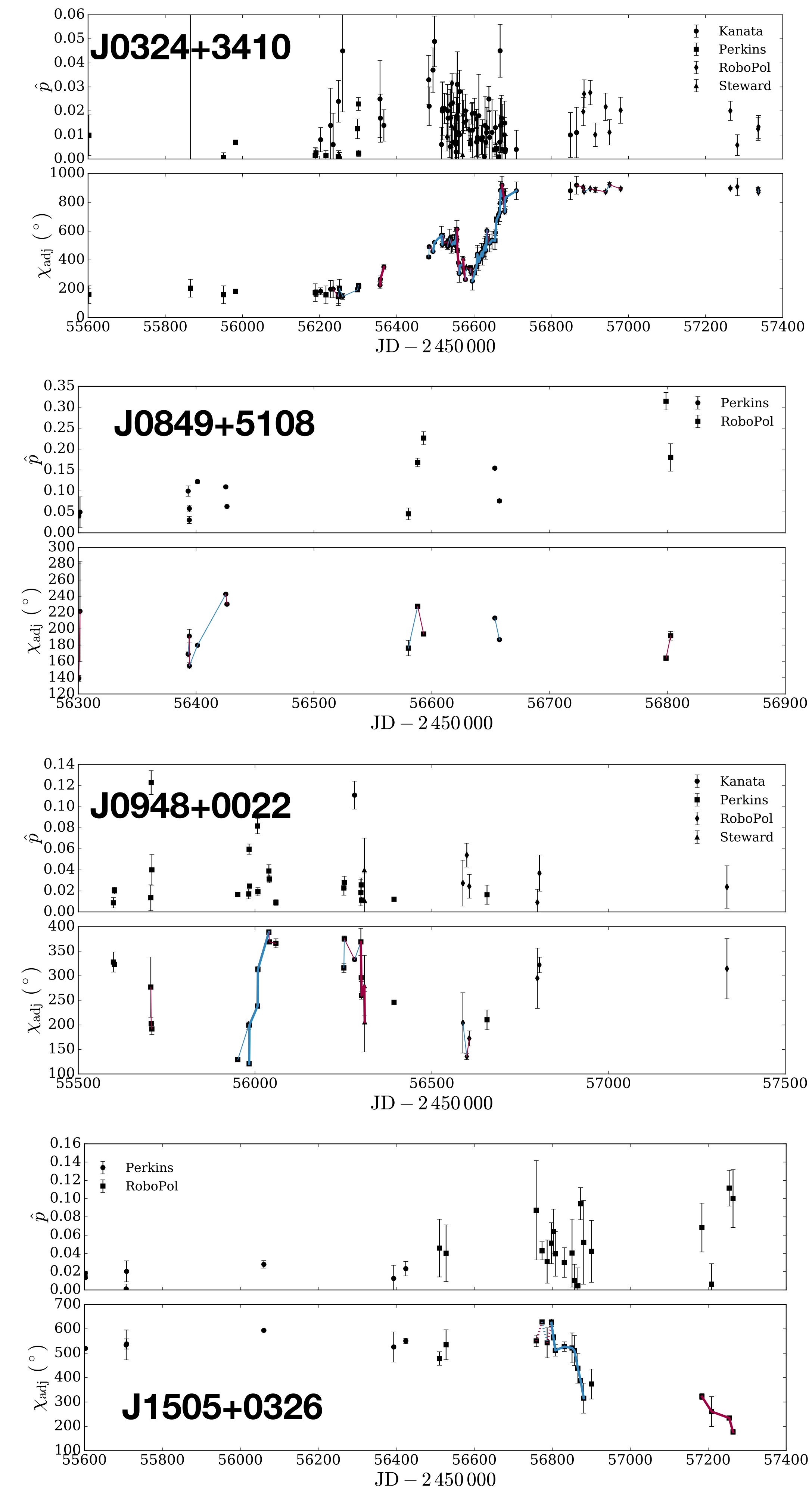
optical polarisation variability

Angelakis et al., in prep.

main conclusions

- ➡ significant **angle variability**
- ➡ **long rotation candidates** detected
- ➡ **poor sampling** and **measurement uncertainties** make the events uncertain

- ➡ **pure noise** can induce rotations but **very improbable**
- ➡ most likely there are **intrinsic events happening**

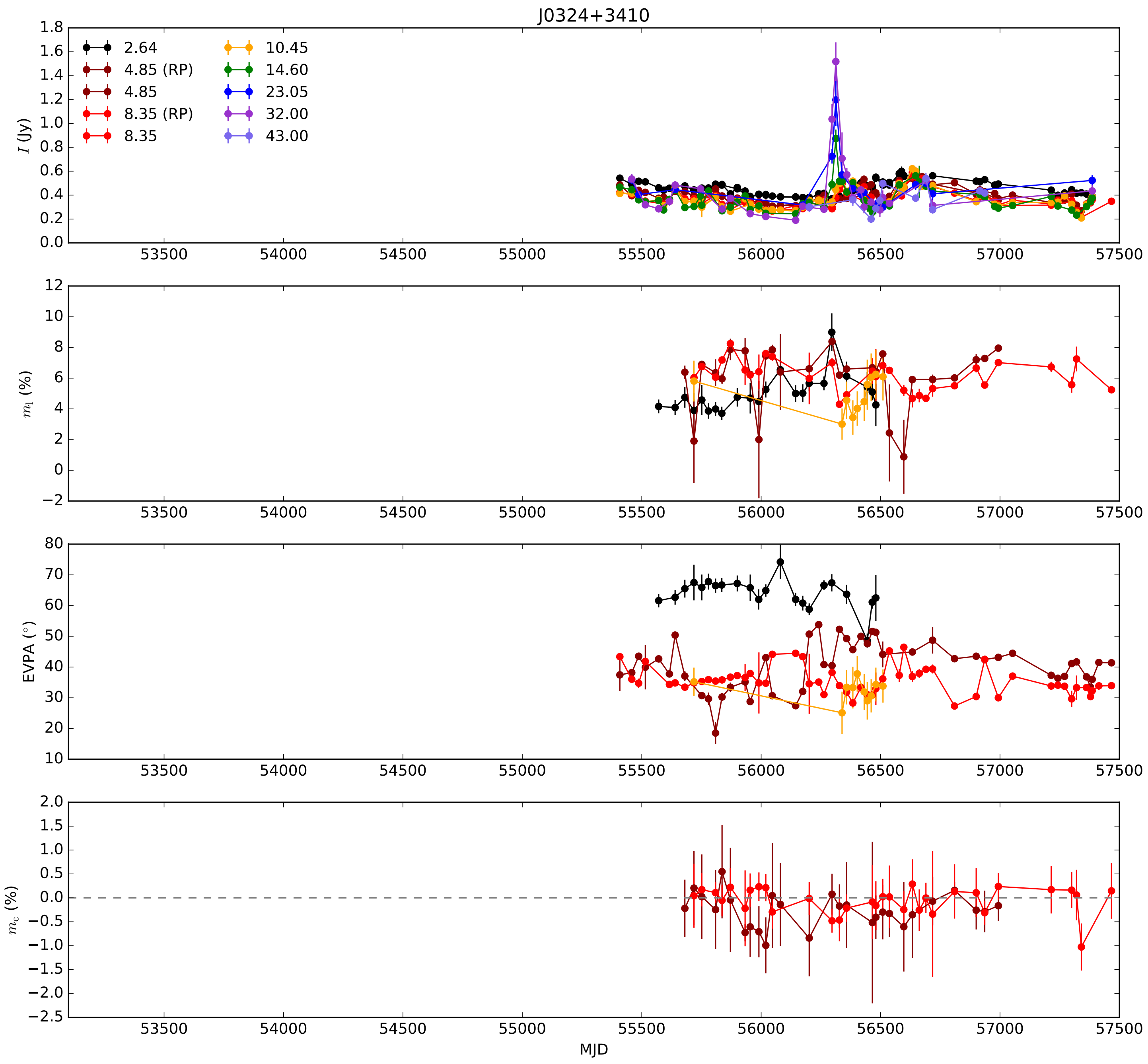


radio polarisation

Myserlis et al., in prep.

Very Preliminary

- ➡ likely below our detection limit
- ➡ multi-band polarisation
- ➡ indications for long EVPA rotations
- ➡ periods of significant Circular Polarisation
- ➡ more to come …



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