Optical polarisation of NLSy1s. Searching for long rotations of the polarisation plane

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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Narrow line Seyfert 1 galaxies

Osterbrock & Pogge 1985; Goodrich 1989; Zhou et al. 2006

- narrow broad Balmer emission line and weak forbidden lines[O iii]λ5007/Hβ < 3
- associated with black hole masses: 10^6–10^8 M⊙ *(Komossa et al. 2006)*
- accrete close to the Eddington rate *(Boroson & Green 1992)*
- 2009 first gamma-ray detection from J0948+0022 *(Abdo et al.2009a, Foschini et al. 2010)*
- SED resembles that of a blazar-like source
- essential in understanding the jet emergence mechanism

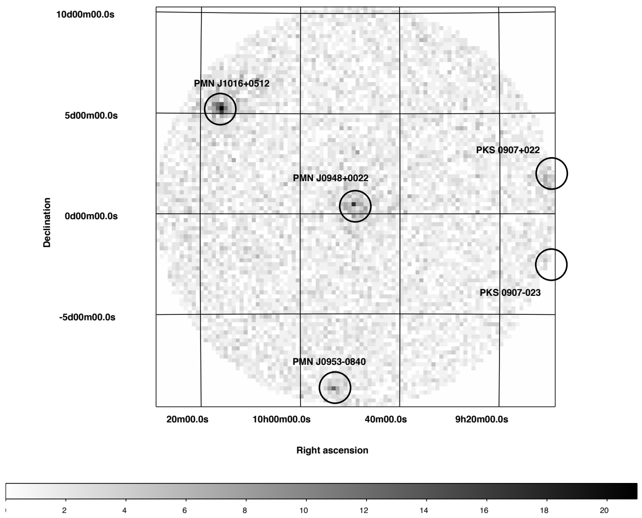


FIG. 1.— *Fermi*/LAT counts map ($E > 200$ MeV) of the region centered on PKS J0948+0022 with radius 10°. The pixel size is 0°.2. The gray scale bar is in units of LAT counts integrated in the 5-month period. Epoch of coordinates is J2000. Nearby sources included in the likelihood analysis are also indicated.

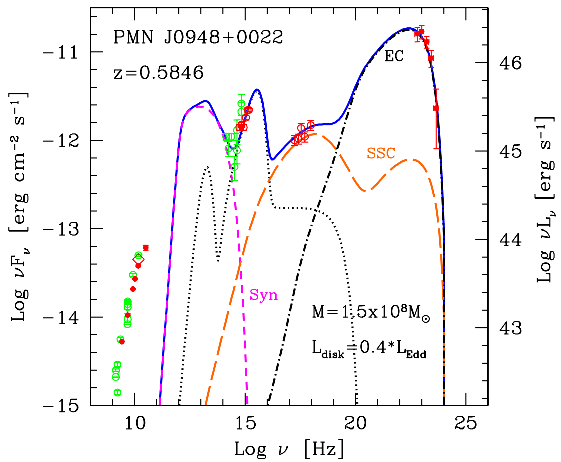


FIG. 4.— Spectral Energy Distribution of PMN J0948+0022. *Fermi*/LAT (5-months data); *Swift* XRT and UVOT (5 December 2008); Effelsberg (24 January 2009) and OVRO (average in the 5-months of LAT data, indicated with a red diamond) are indicated with red symbols. Archival data are marked with green symbols. Radio data: from 1.4 to 15 GHz from Bennett et al. (1986), Becker et al. (1991), Gregory & Condon (1991), White & Becker (1992), Griffith et al. (1995), Doi et al. (2006). Optical/IR: USNO B1, *B*, *R*, *I* filters (Monet et al. 2003); 2MASS *J*, *H*, *K* filters (Cutri et al. 2003). The dotted line indicates the contributions from the infrared torus, the accretion disk and the X-ray corona. The synchrotron (self-absorbed) is shown with a small dash line. The SSC and EC components are displayed with dashed and dot-dashed lines, respectively. The continuous line indicates the sum of all the contributions.

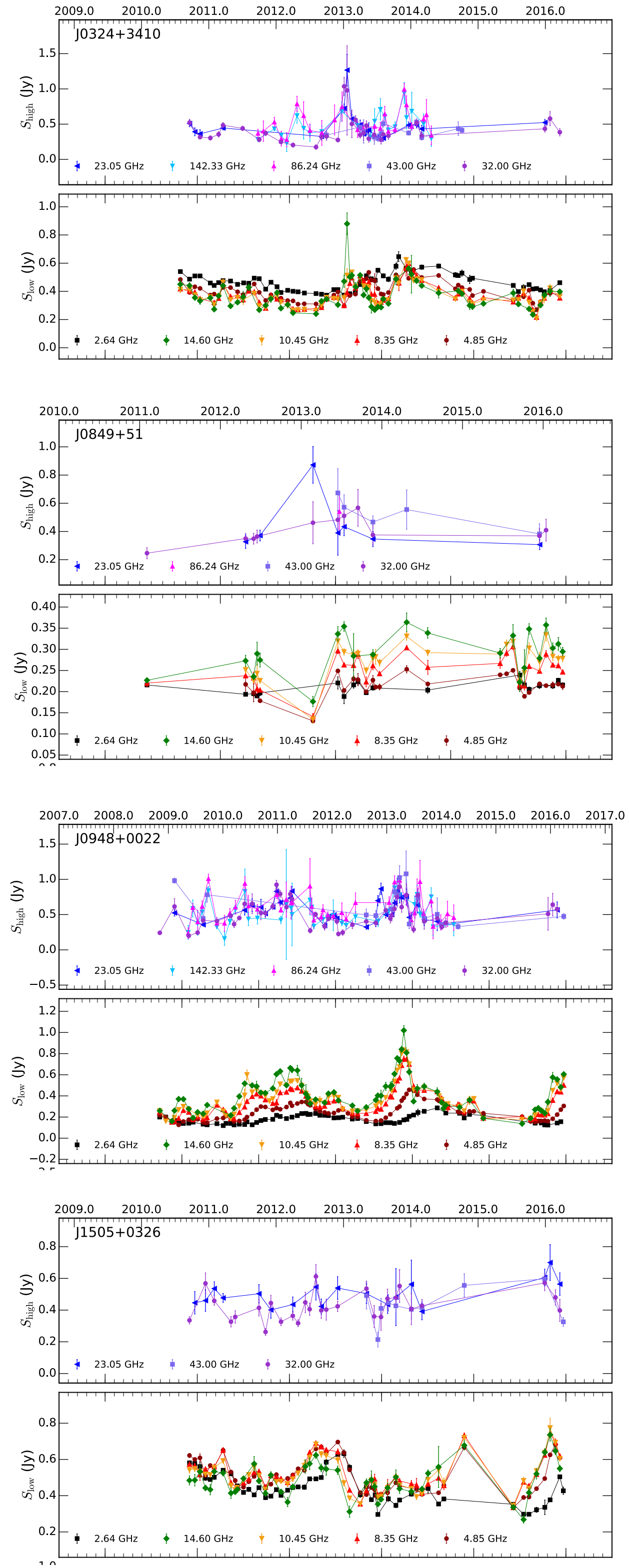
Abdo et al. 2009, ApJ, 699, 976

radio jet emission

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

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

- 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)



radio jet emission

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

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- typical blazar phenomenology but **lower flux densities**
- Doppler factors below 10: **moderately relativistic** jets
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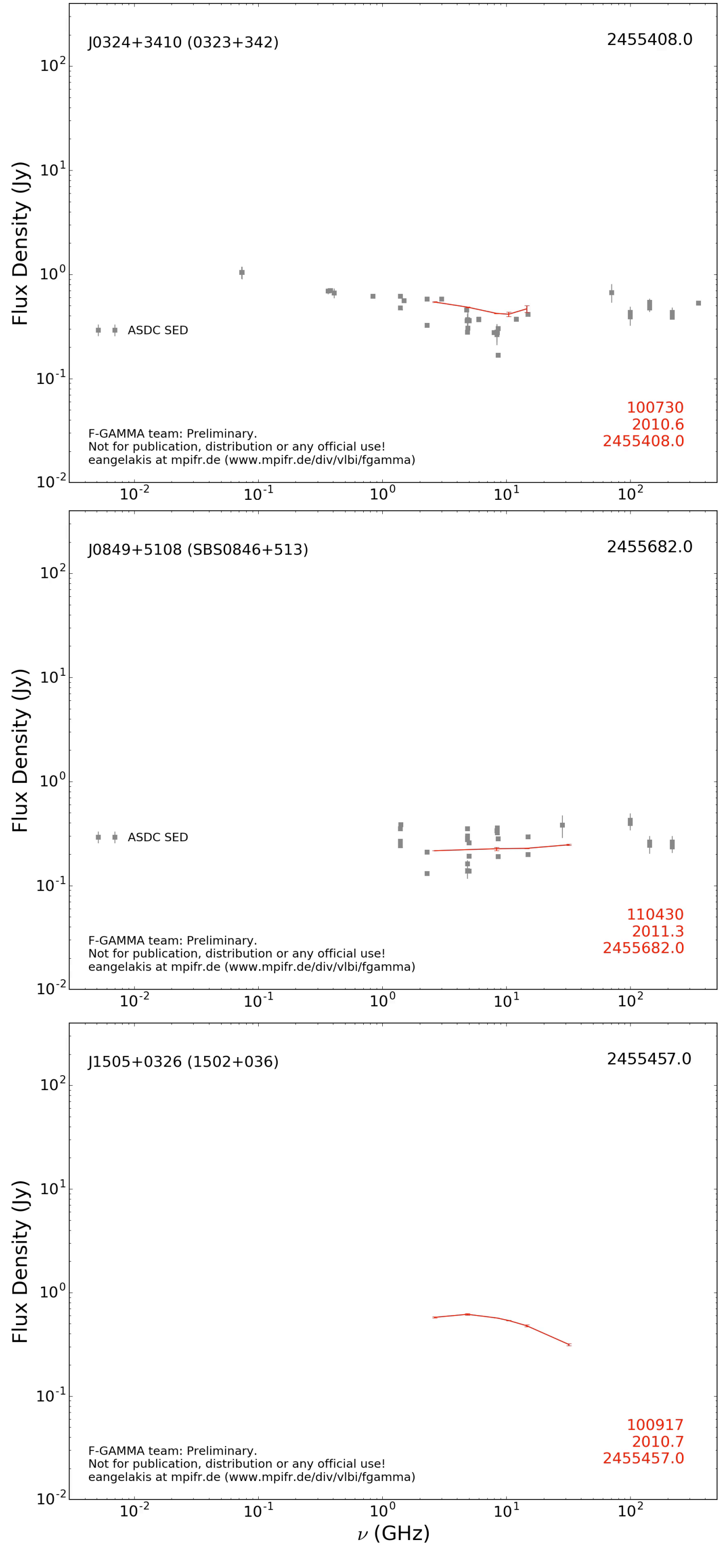
- **intense spectral evolution:** particle acceleration events (e.g. shocks)

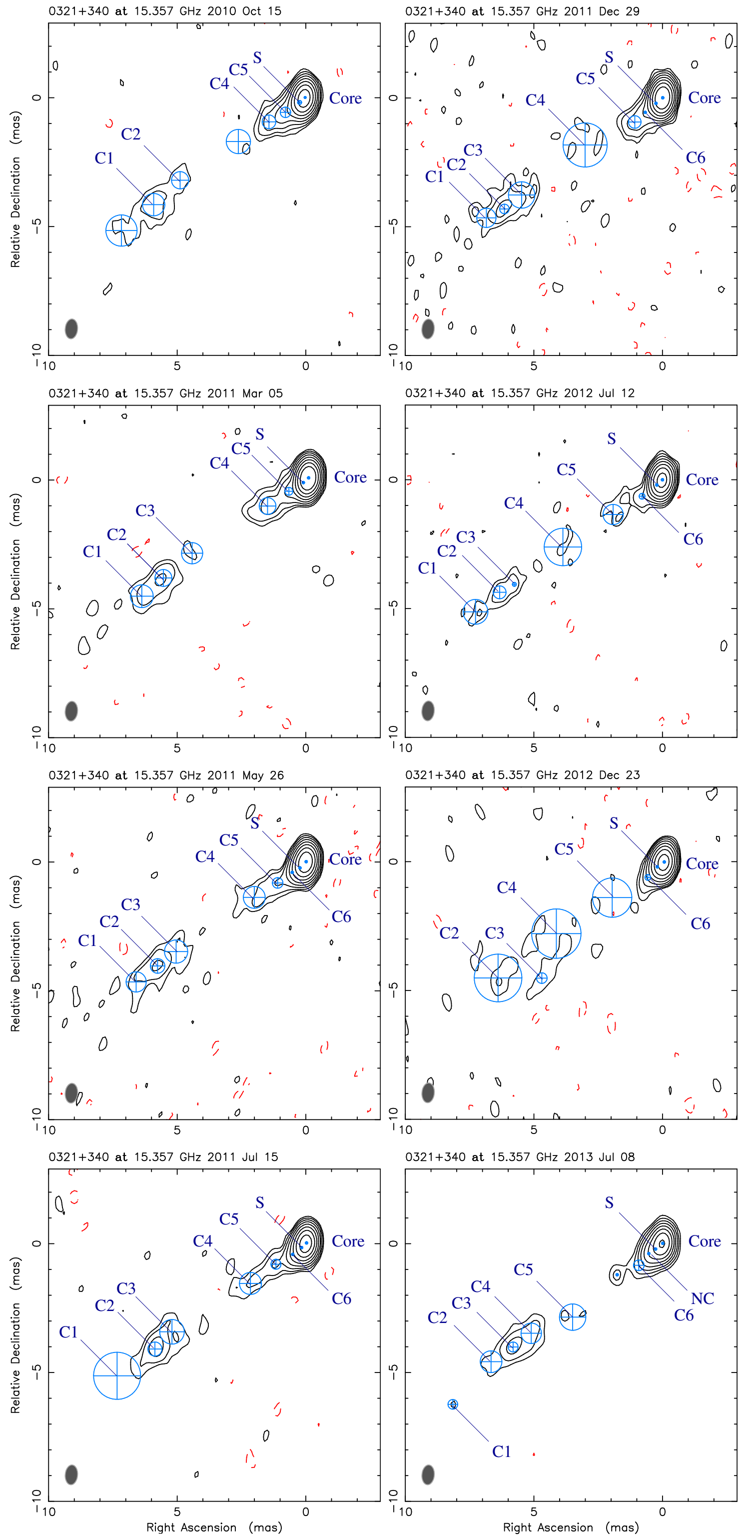


jet kinematics: 1H 0323+342

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

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

- ➡ apparent speeds ranging 0.93— 6.92 c
- ➡ viewing angle towards 1H 0323+342: $\theta_{var} \leq 4^{\circ}$–$13^{\circ}$: validating the **aligned geometry scenario**



optical polarisation variability

Angelakis et al., submitted to A&A

scope:

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

dataset:

- ➡ RoboPol, KANATA, Perkins & Steward

sample:

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

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]	$0.8 - 9.8\times10^{7}$ [B,C,D]	1445 [J]	Fermi detected[6]
J0948+0022	PMN J0948+0022	0.585102 [2]	$0.4 - 8.1\times10^{8}$ [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]	$0.04 - 2\times10^{8}$ [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

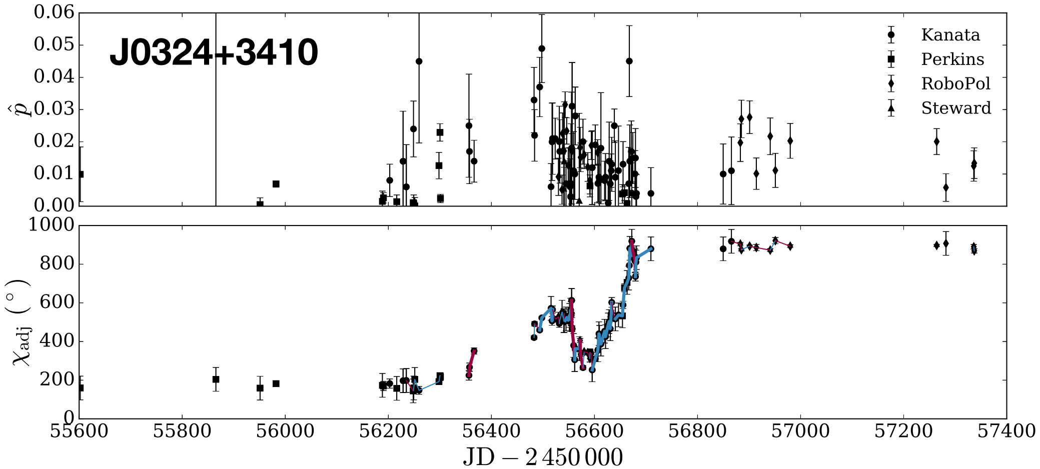
Angelakis et al., submitted to A&A

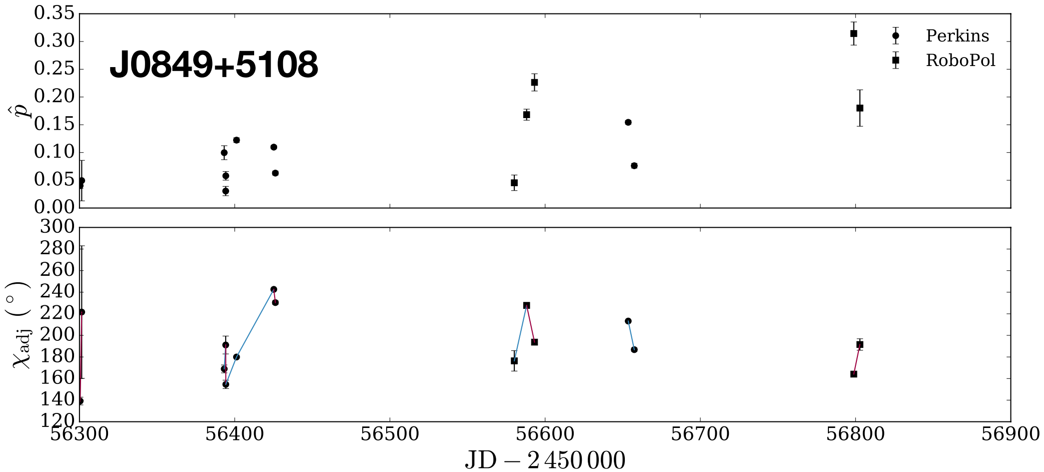
Rice distribution:

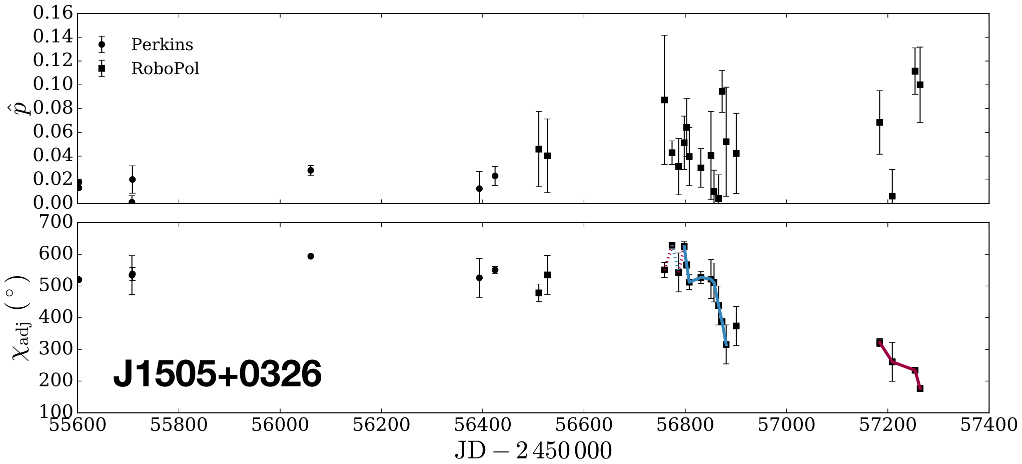
$$F(p \mid p_0)dp = \frac{p}{\sigma_p} \exp\left[-\frac{p^2 + p_0^2}{2\sigma_p^2}\right] I_0\left(\frac{p p_0}{\sigma_p^2}\right) \frac{dp}{\sigma_p}$$

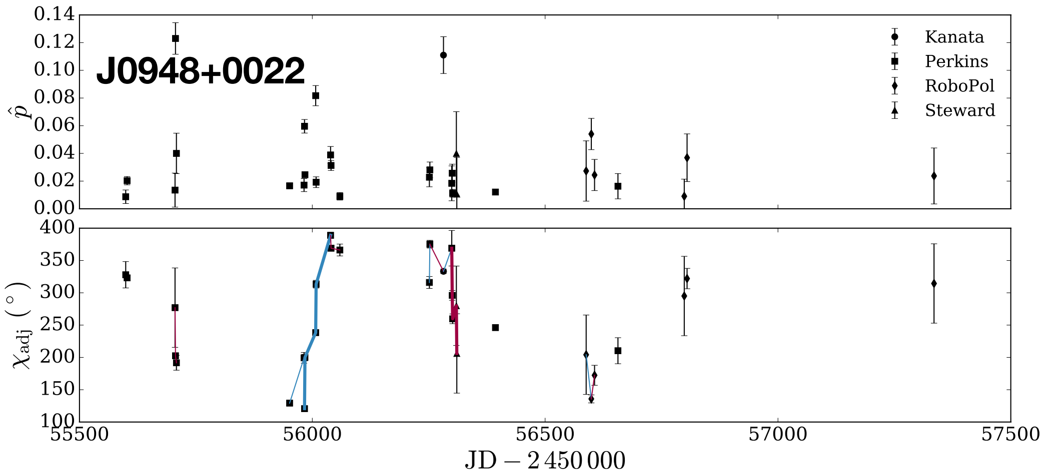
de-biassing recipe:

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





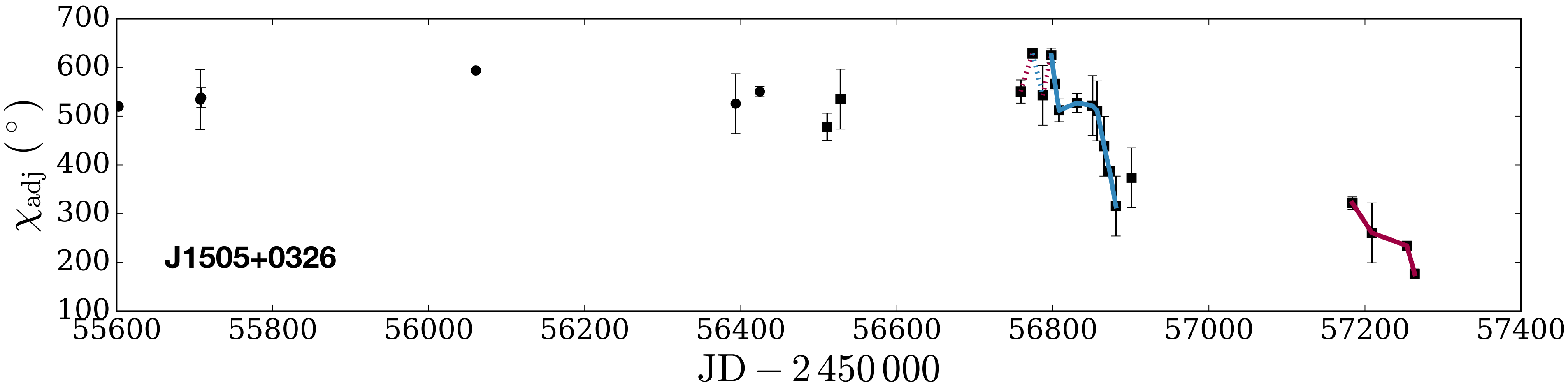




polarisation angle of J1505+0326

Angelakis et al., submitted to A&A

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

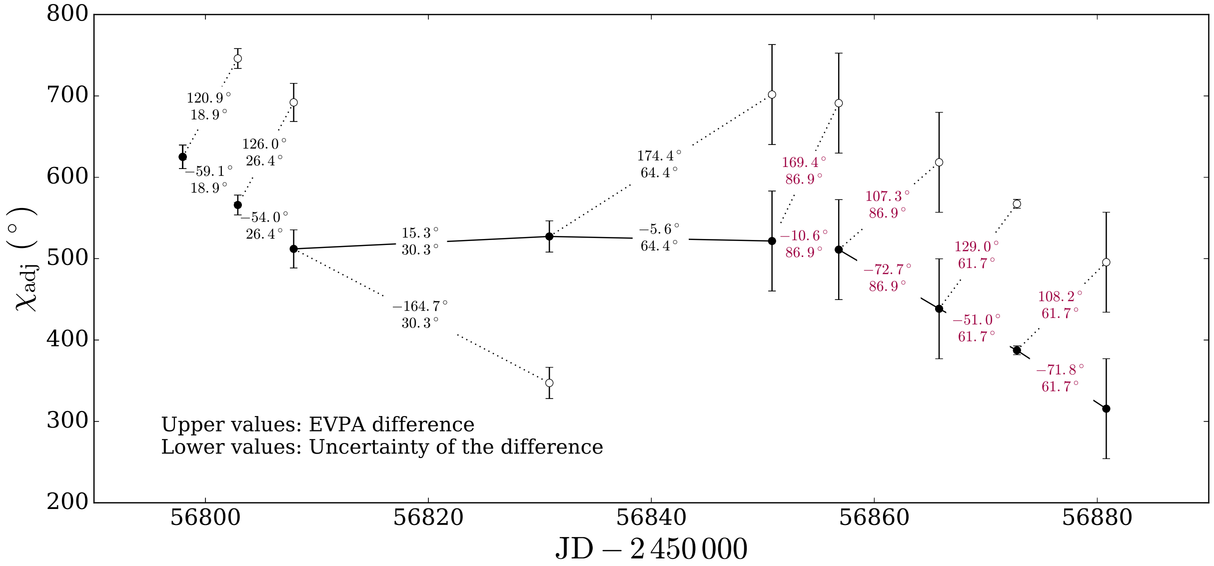


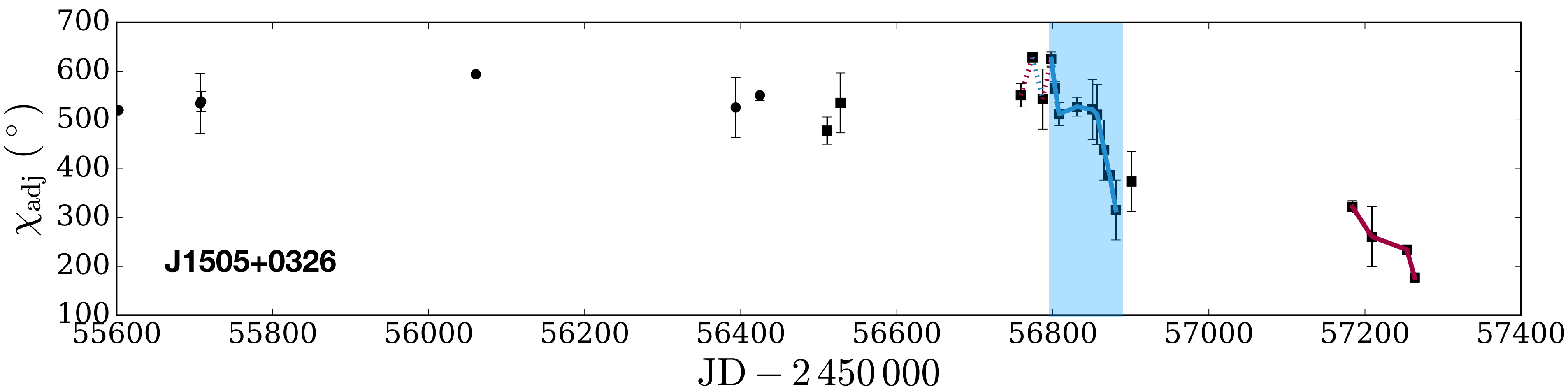
the “long” rotation of J1505+0326

Angelakis et al., submitted to A&A

observed parameters:

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



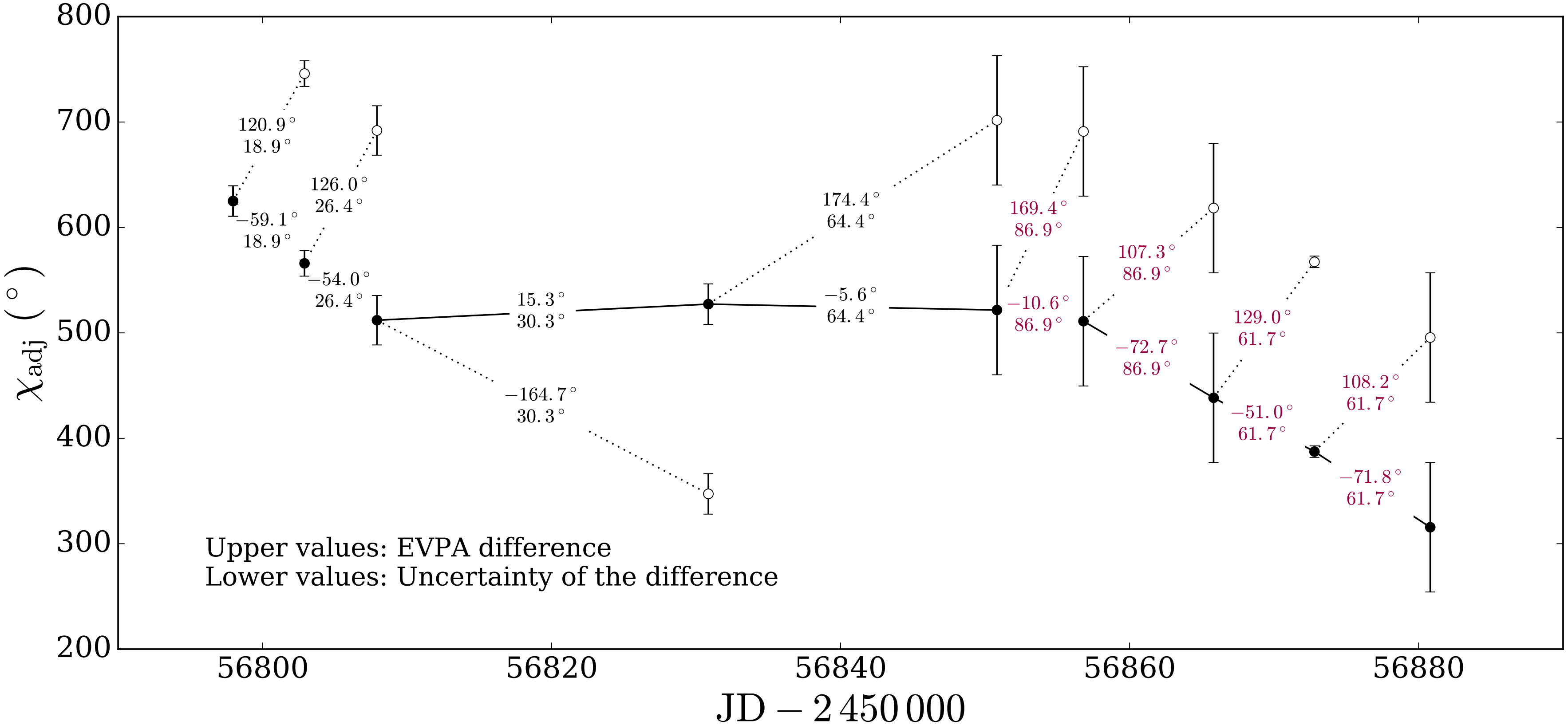


the “long” rotation of J1505+0326

Angelakis et al., submitted to A&A

is the rotation **reliable**?

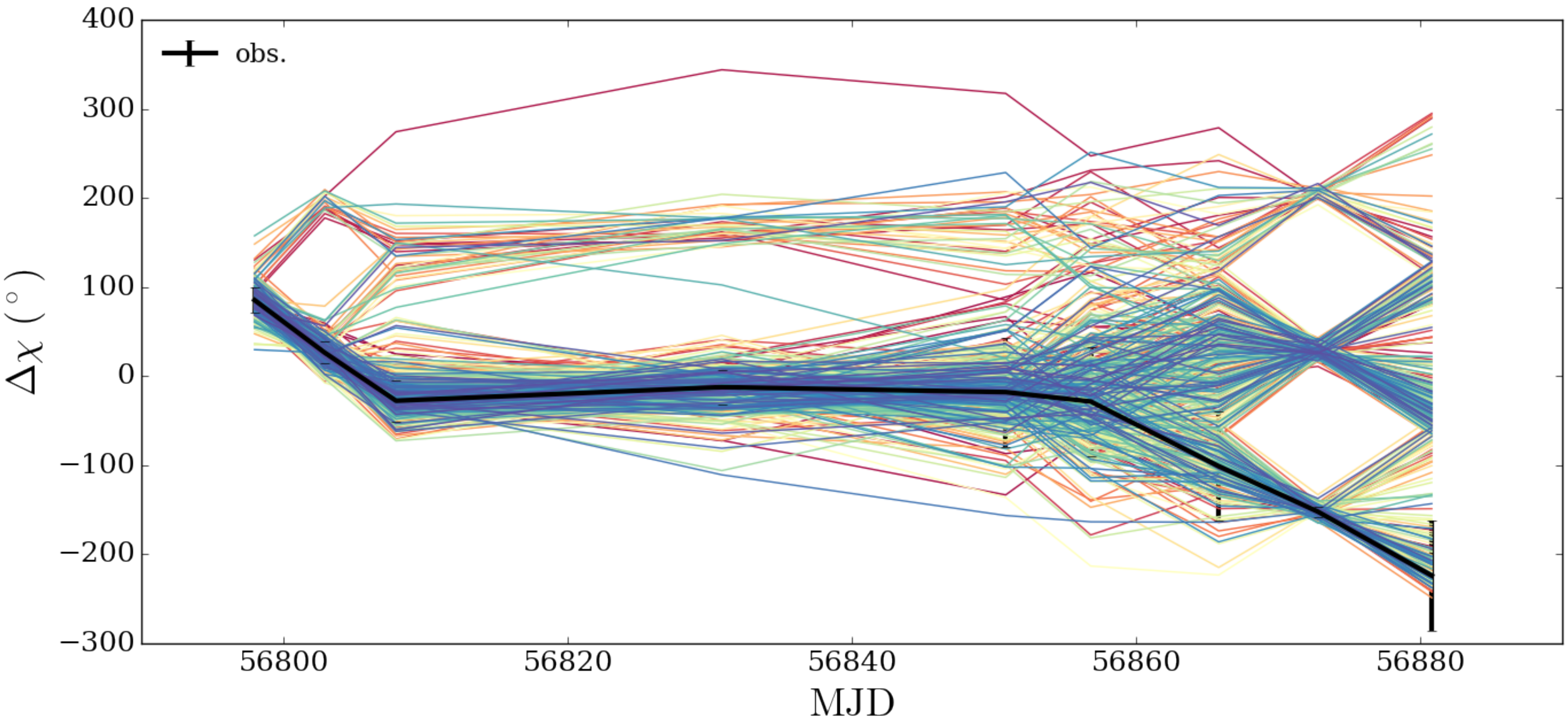
- ➡ sparse sampling and large **angle uncertainties** make the **direction uncertain**
- ➡ hence: the rotation is **uncertain**



the “long” rotation of J1505+0326

Angelakis et al., submitted to A&A

is the rotation **reliable**?

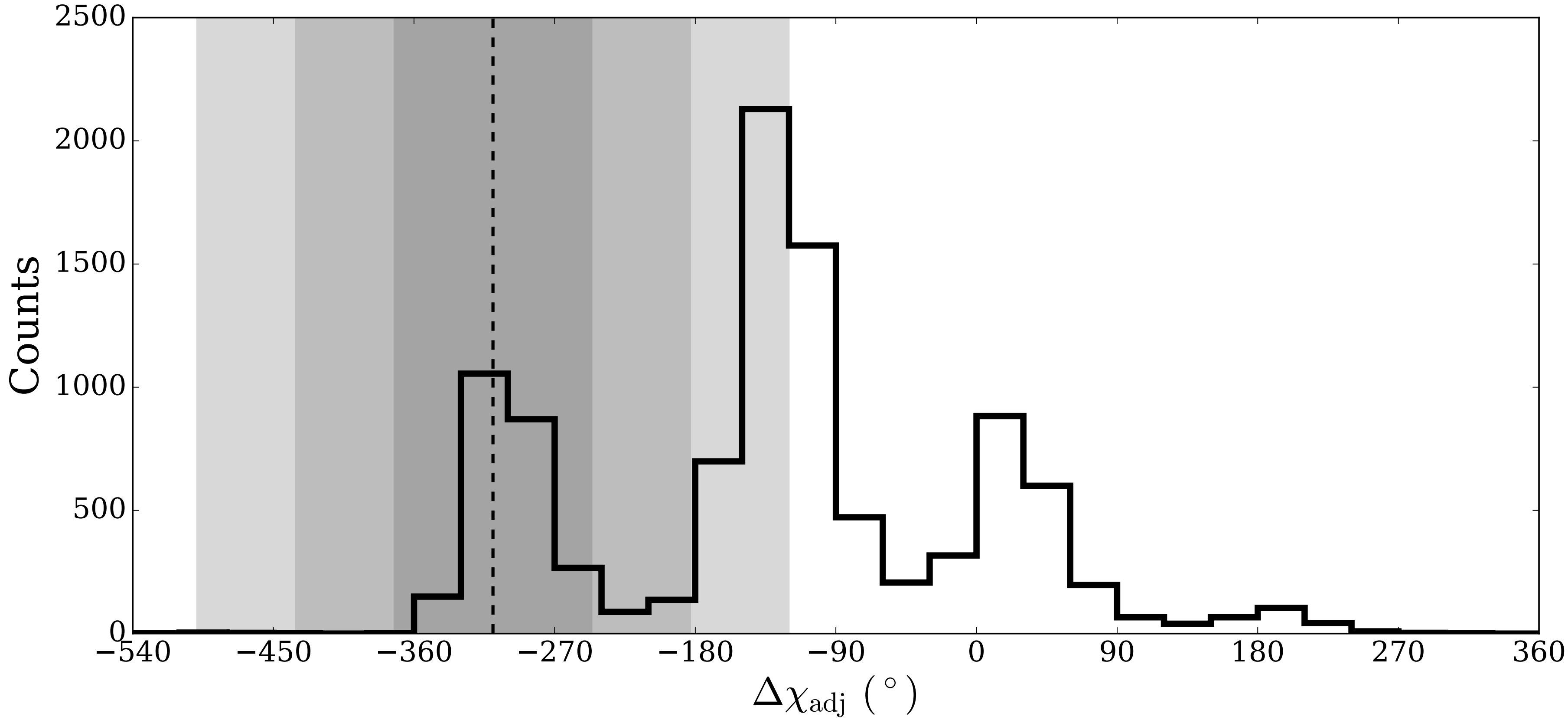


the “long” rotation of J1505+0326

Angelakis et al., submitted to A&A

is the rotation **reliable**?

➡ yet, probability of rotation over angle within **1.0 sigma of observed value: ~23%**

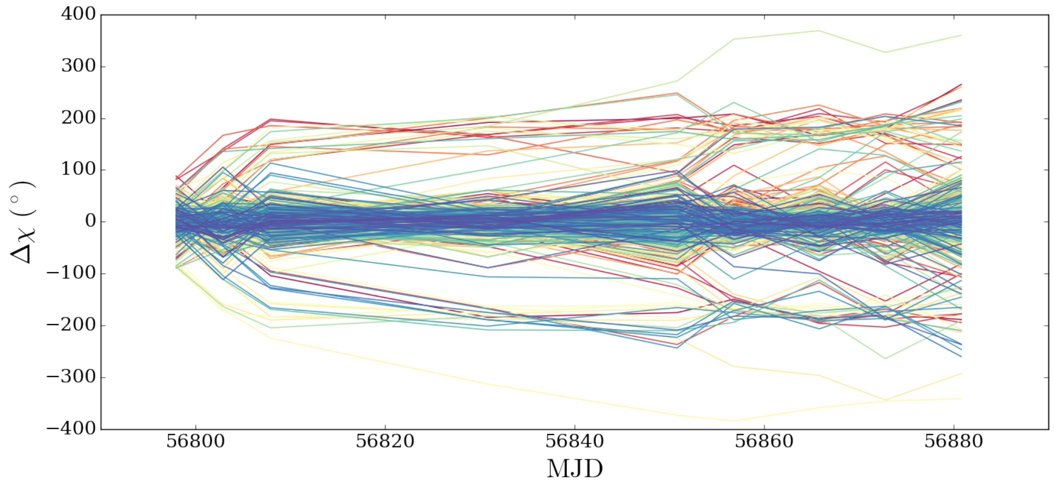


the “long” rotation of J1505+0326

Angelakis et al., submitted to A&A

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

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



- ➡ for simplicity we assume

$$
\begin{aligned}
q &= \overline{p_{\rm rot}} + \mathcal{N}(0, \sigma_q) \\
u &= \mathcal{N}(0, \sigma_u).
\end{aligned}
$$

the “long” rotation of J1505+0326

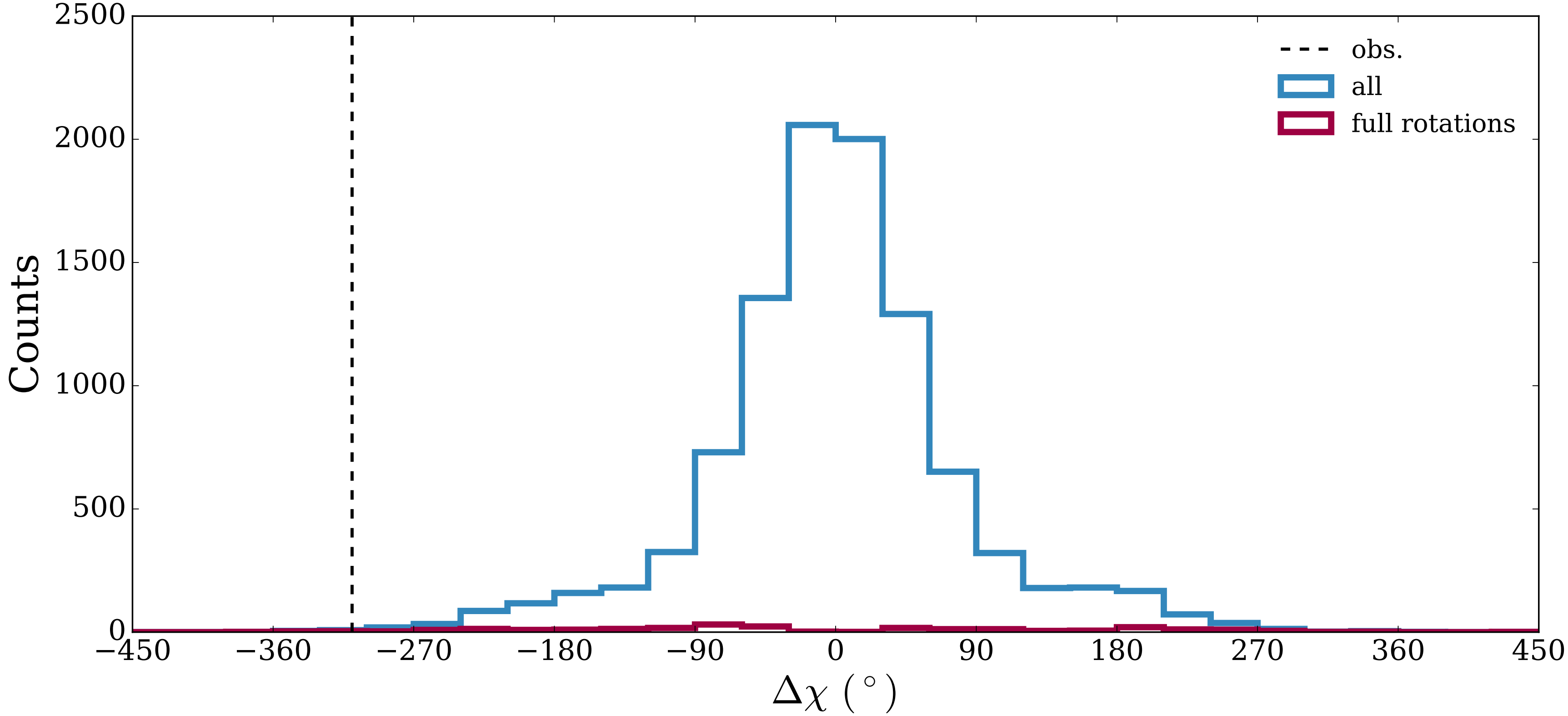
Angelakis et al., submitted to A&A

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**

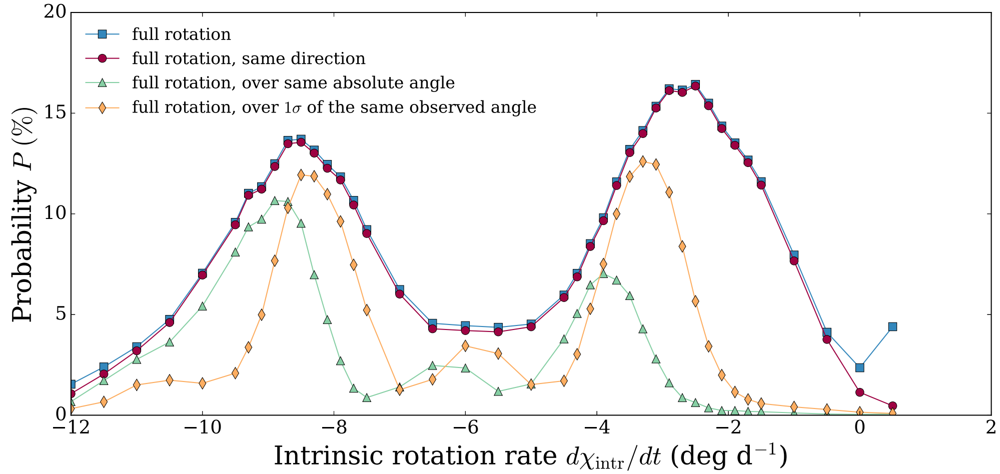


the “long” rotation of J1505+0326

Angelakis et al., submitted to A&A

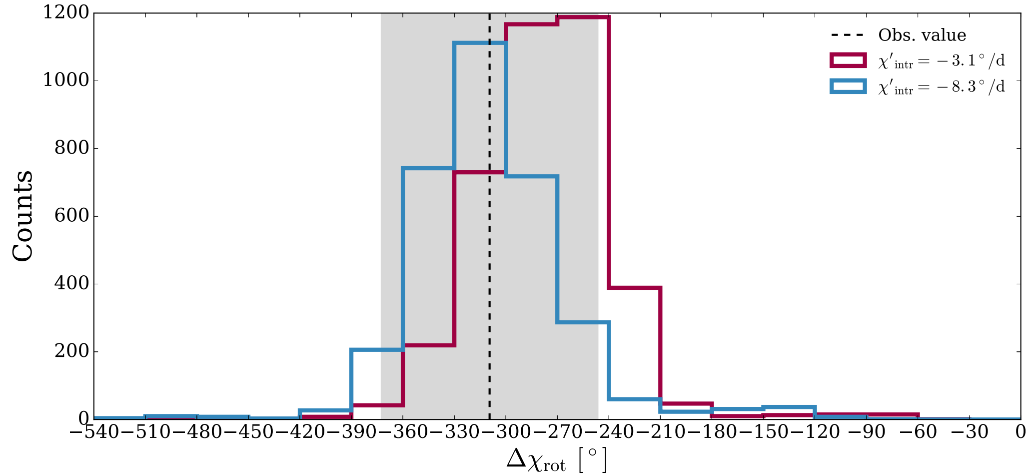
most probable intrinsic parameters:

- ➡ 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%



- ➡ the observed angle is **consistent** with an **constant rate**

- ➡ conclusion: it is **realistic** that an **intrinsic EVPA rotation** (with pseudo-variability from uncertainties) **is causing the observed event**

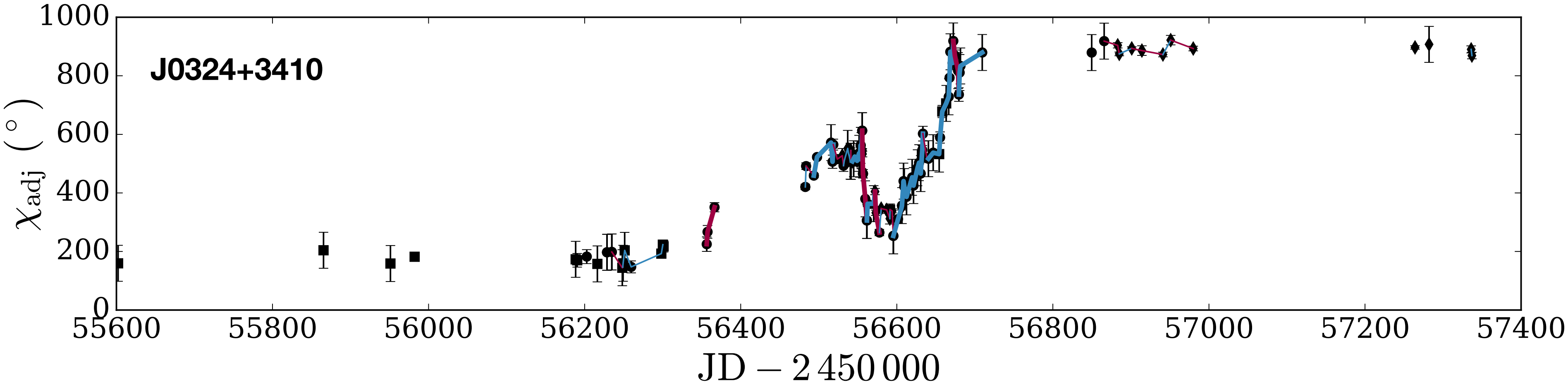


optical polarisation: angle

Angelakis et al., submitted to A&A

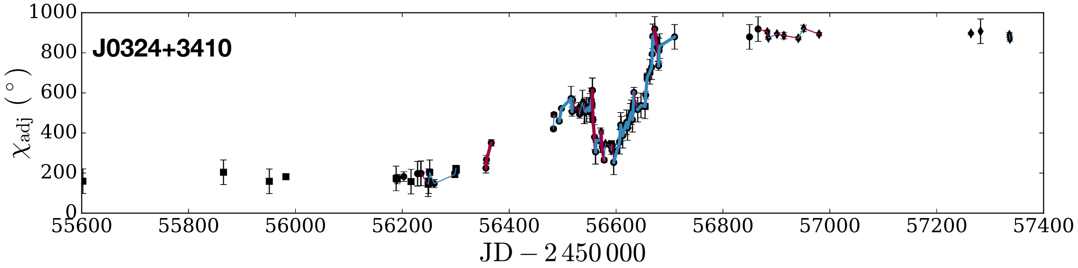
polarisation angle:

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

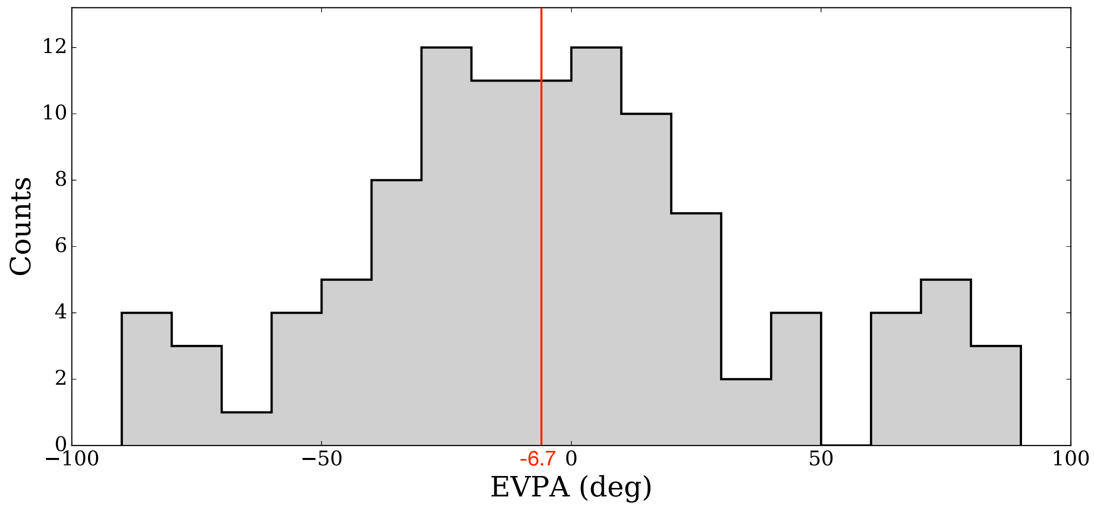


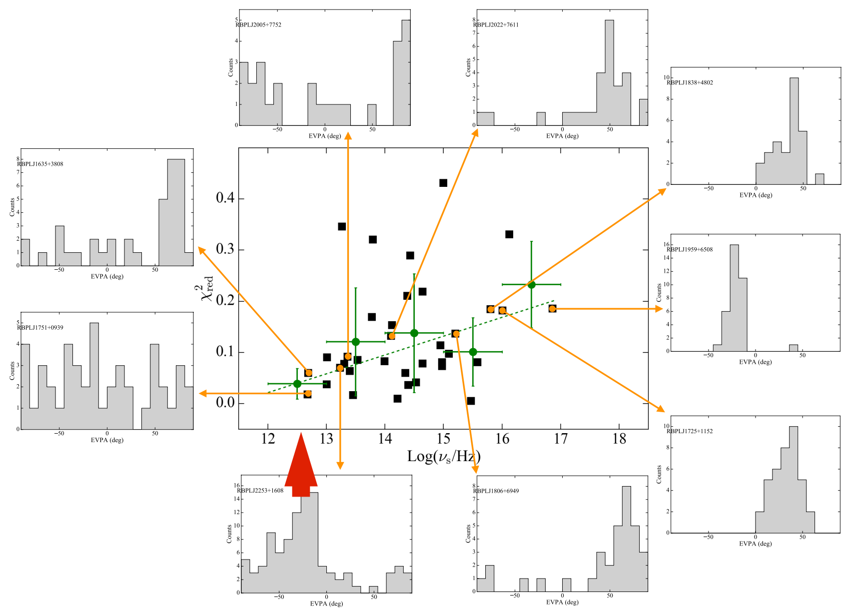
polarisation angle of J0324+3410

Angelakis et al., submitted to A&A



- the angle in the [-90,90] range centres around -6.7 (sigma ~40)
- log(ν_{synch}) ~12.5
  Kynoch et al, 2018MNRAS.475..404K
- **NOT** uniform
  Angelakis et al., 2016, MNRAS, 463, 3365



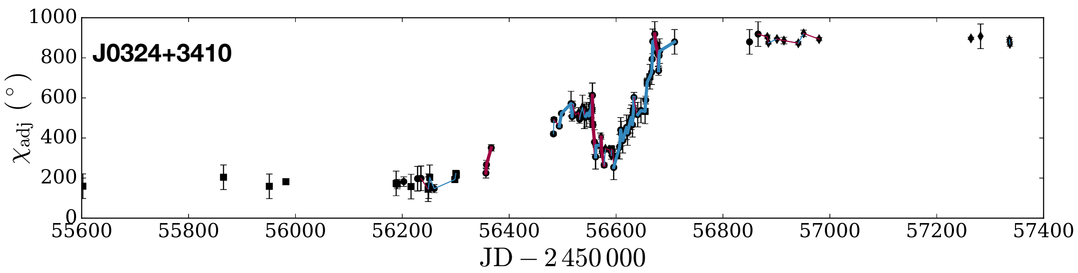


Angelakis et al., 2016, MNRAS, 463, 3365
Angelakis et al., 2017, PoS
Hovatta et a l.2016, A&A, 596A, 78H5

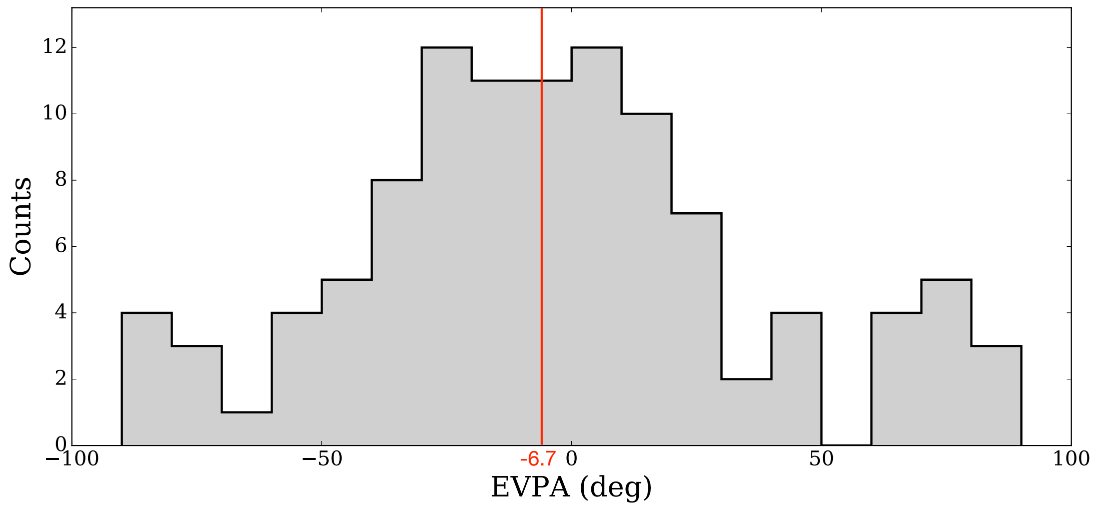
polarisation angle of J0324+3410

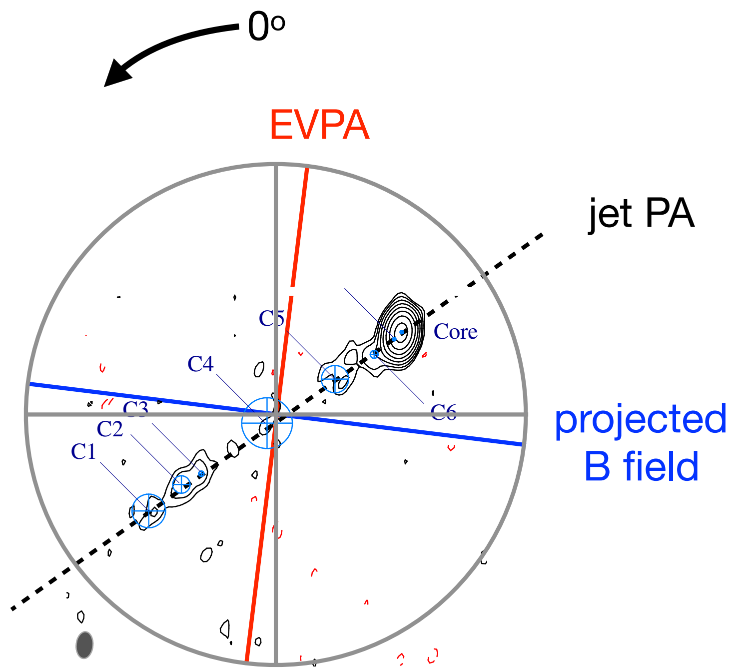
Angelakis et al., submitted to A&A

- the angle in the [-90,90] range centres around -6.7 (sigma ~40)
- The radio jet is at PA ~124



- **inconclusive** whether **parallel** or **perpendicular** to the radio jet *(see Hovatta et a l.2016, A&A, 596A, 78H5)*



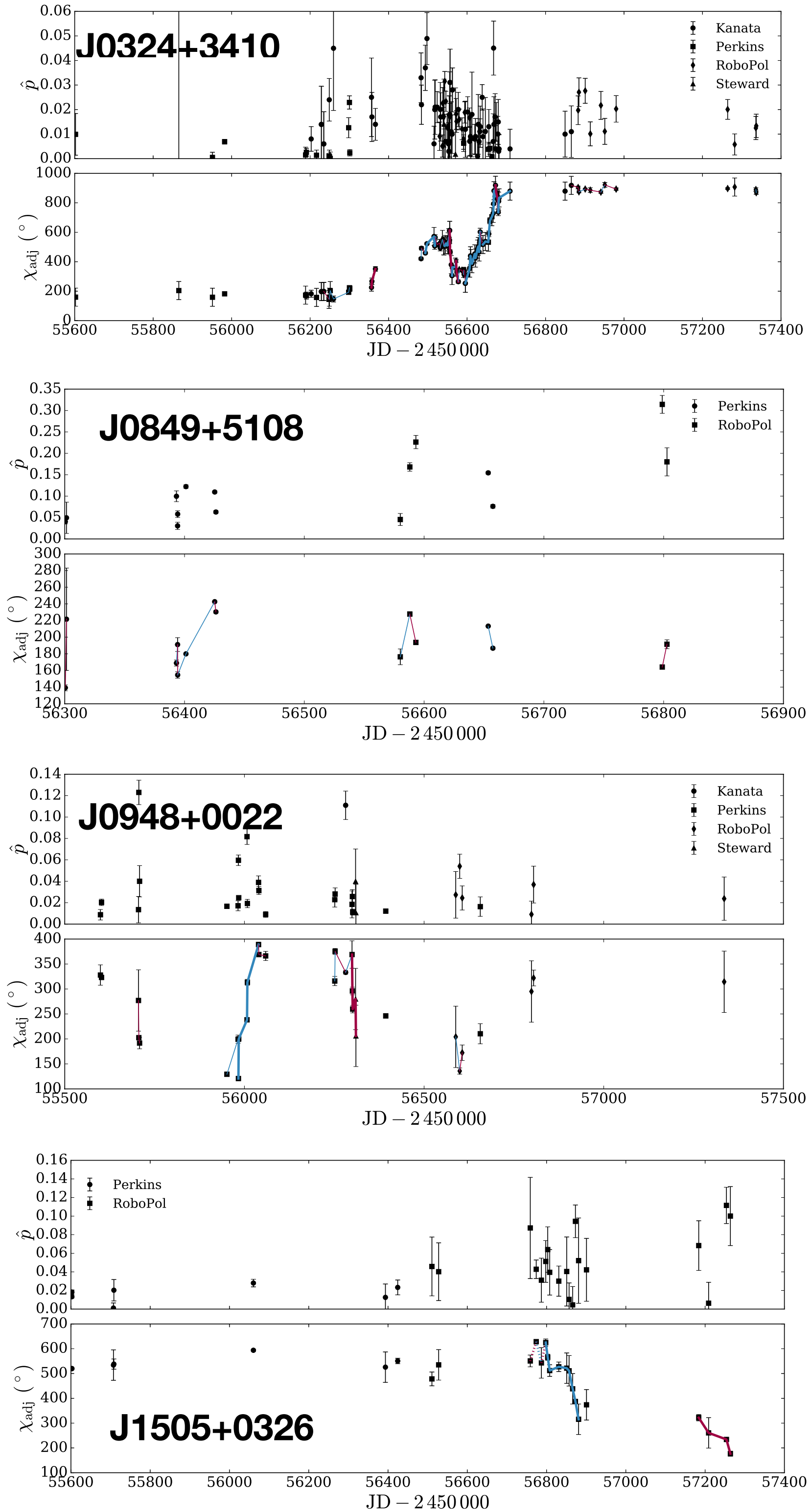


optical polarisation variability

Angelakis et al., submitted to A&A

main conclusions

- ➡ significant **angle and polarisation variability**
- ➡ **long rotation candidates** detected
- ➡ **poor sampling** and **measurement uncertainties** make the events uncertain
- ➡ **pure noise** can induce rotations but **very improbable**
- ➡ **much more likely** that are **intrinsic events drive the observed behaviour**
- ➡ polarisation **tends to increase** during rotations : urges for systematic study



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