Multi-frequency polarisation monitoring: **physical conditions and processes in relativistic jets**

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We present two examples which demonstrate the potential of multi-band, multi-frequency polarisation monitoring:

1. **OJ287**: we analyse radio and optical polarisation data trains to reveal simultaneously the small and large scale topologies of the magnetic field and compute mechanical properties of the flow and physical conditions *(Myserlis, Komossa, Angelakis et al. 2018A&A...619A..88M)*.
2. **Narrow line Seyfert 1 galaxies**: we use optical polarisation monitoring to examine the potential occurrence of long polarisation plane rotations and validate the assumption that physical processes as those in blazar jets occur also in NLSy1s *(Angelakis, Kiehlmann, Myserlis, et al. 2018A&A…618A.92A)*.

They are conducted in the framework of the **QUIVER** which is among the most comprehensive, multi-frequency, all-Stokes radio monitoring program presented by **Ioannis Myserlis** (**Thursday June 17** at **12:50**) ; and the **RoboPol** program which is among the most systematic optical polarisation monitoring.

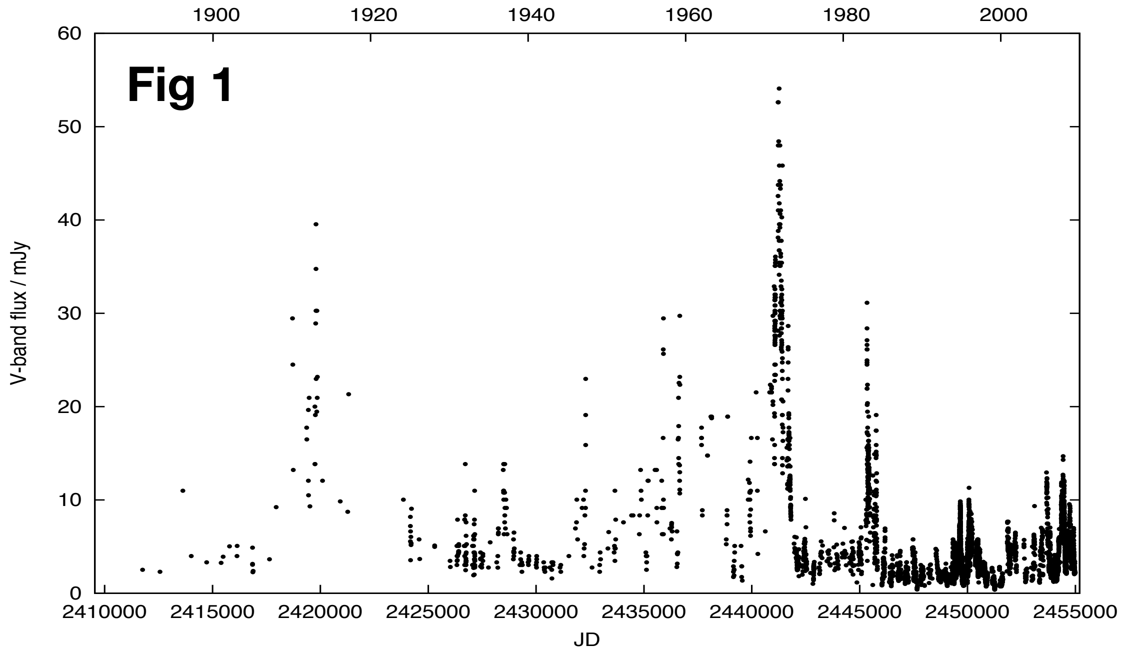
Following are 2 pages, one for each case

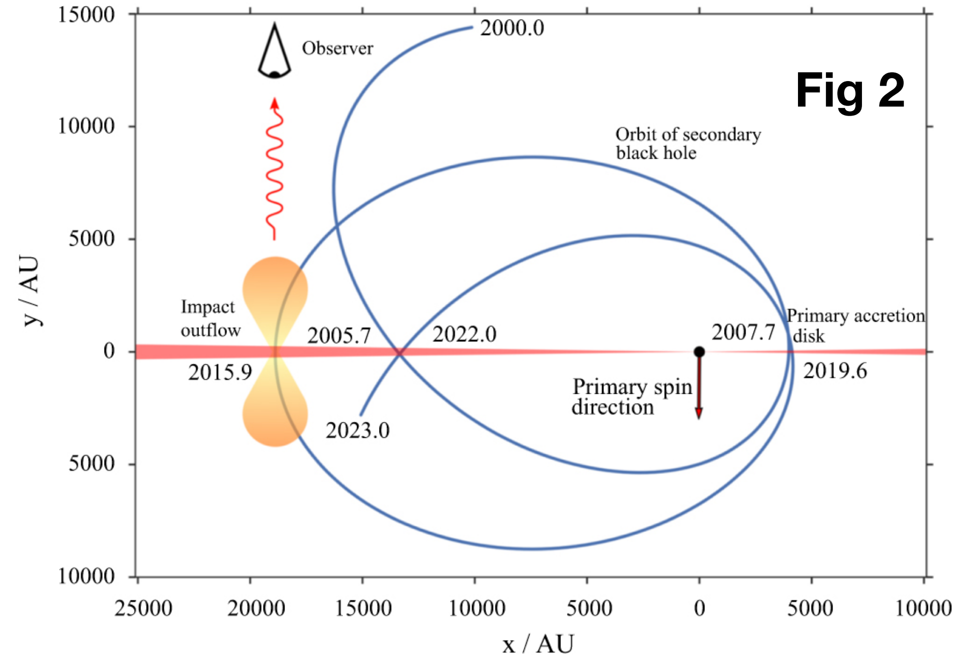
OJ287: **Helical magnetic field in a bent jet**

Myserlis, Komossa, Angelakis et al. 2018A&A...619A..88M

1. Background

Historical optical light curve of OJ287 shows double peaks every ~12 years (Fig 1)





Valtonen et al. (2008, Nature, 452, 851 and 2016, ApJ, 819, L37) suggested:

- binary black hole system (Fig 2)
- a secondary BH (1.46x10^8 M⊙) crossing the accretion disk of a primary BH (1.8x10^{10} M⊙)

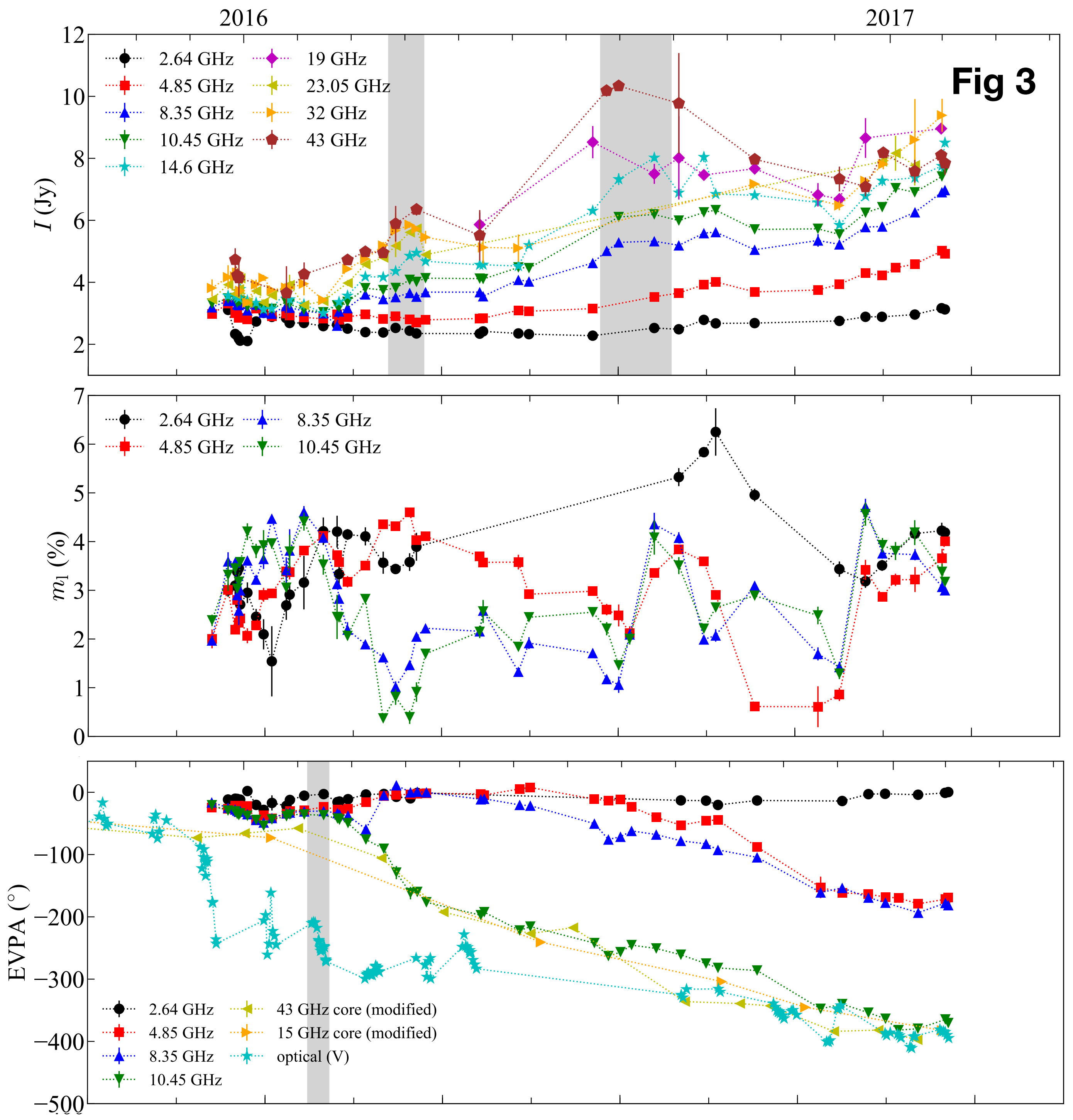
2. Our dataset

To study the decadal maximum of December 2015 predicted by *Valtonen et al. (2015, 2016)* we initiated a dense monitoring with the Effelsberg 100-m radio telescope and obtained **total intensity** at **9** frequencies between **2.64 — 43 GHz** and **polarisation** at **4** frequencies between **2.64 — 10.45 GHz.** We also analyse archival **VLBA polarisation** data at **15** and **43 GHz** and R-band **optical** polarisation.

3. Our findings

Our main findings — shown in Fig 3 — can be summarised as follows:

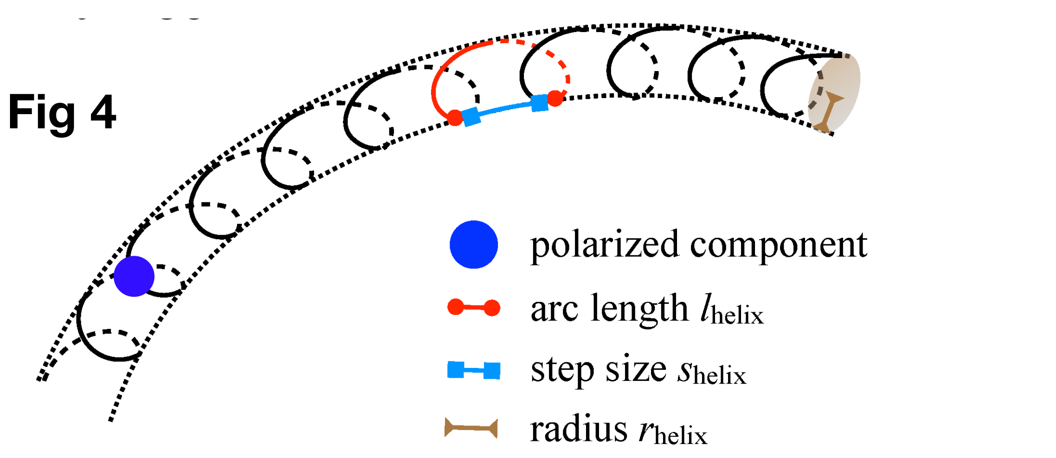
- The **radio total intensity** shows extreme coloured variability (top) which appears as a dynamically evolving radio SED.
- The **radio linear polarisation** also displays intense variability both in degree (middle) and angle (bottom).
- In radio there appears a **long EVPA rotation** with magnitude Δχ~340º with a rate of -1.04º/day.
- In the optical we identify a **slow rotation** with a rate of -1.1º/day populated by **fast rotation** events with a mean rate of -7.8º/day (bottom).



4. Our assumptions

The interpretation of our data relies on (Fig 4):

- a polarised component moving on a **helical path** (determined by the magnetic field configuration) that undergoes
- a **large scale bending** (e.g. due to the mechanical behaviour of the flow), and
- a **stable polarised component** which becomes dominant at larger scales.



5. Our scenario: the large and small scale topology of the magnetic field

The emission element radiates both the low (radio) and high energy (optical) photons. However,

- radio photons are **partially absorbed**. As a result:
  - ➡ The radio emission originates mainly from an **outer jet layer**. As the element moves in its helical path its polarisation orientation is observed for almost half of the circle. Thus, seemingly tracing **only** the **slow** rotation of the **bent.**
- The optical photons on the other hand are **unabsorbed** and subsequently:
  - ➡ The optical polarisation of the element is seen constantly tracing both the **helical motion** and the turning due to the **bend**. This why we observe both the **slow** (**bent**) and **fast** (**helix**) rotation modes.

We find that the rotation happens in VLBI core at a de-projected size of ~12.8 pc i.e. 7.4 × 10^3 R_S which corresponds to the Acceleration and Collimating Zone expected *Marscher et al. (2008)* to be ≤10^4 R_S.

- ➡ suggesting that the inner jet contains a **helical magnetic field component**
- ➡ the stable polarised component with EVPA orientation is –10º, perpendicular to the large scale jet
- ➡ indicates dominance of the **poloidal** magnetic **field in the jet**

In the publication we also compute physical parameters of the flow otherwise completely inaccessible.

The QR code at the top links the relevant publication.

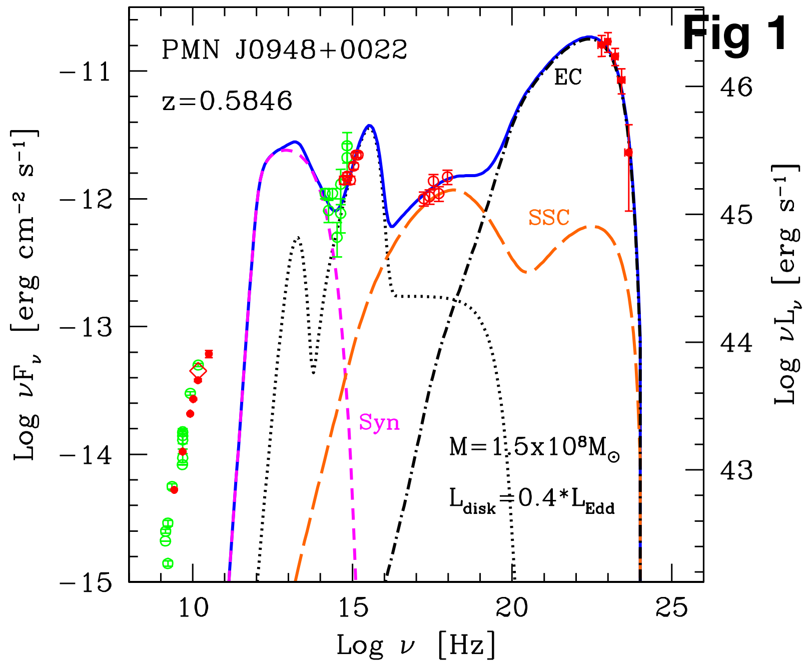
NLSY1s: **long optical EVPA rotations**

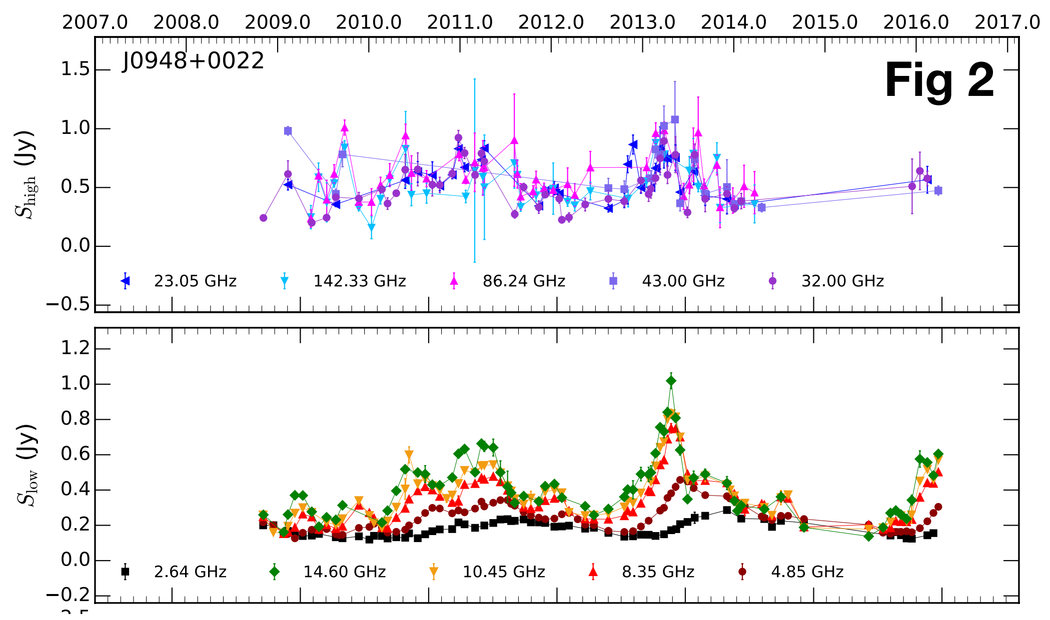
Angelakis, Kiehlmann, Myserlis, et al. 2018A&A...618A..92A

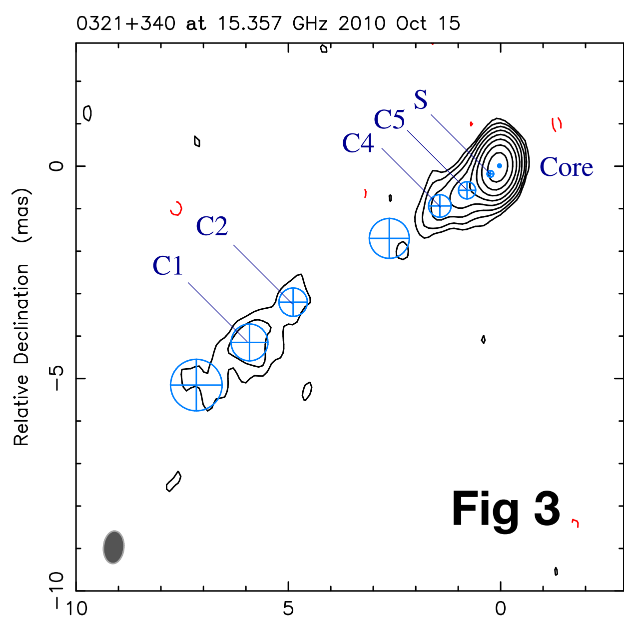
1. Background

Narrow line Seyfert 1 galaxies (NLSy1) are associated with **smaller black hole masses** (10^6–10^8 M⊙, *Komossa et al. 2006*). Their detection in gamma rays in 2009 *(Abdo et al.2009a, Foschini et al. 2010)* was the first of a series of indications that these systems **posses relativistic jets** qualitatively **similar to the most powerful quasars** making them **a control population in understanding the jet emergence mechanism**. Generally:

- Their SED resembles that of a blazar-like source (Fig 1).
- They show typical blazar phenomenology in radio bands (Fig 2, *Angelakis et al., 2015, A&A, 575, A55*).
- Their Doppler factors are below 10: indicating moderately relativistic jets.
- They display intense spectral evolution: particle acceleration events (e.g. shocks) (Fig 2).
- In the rare cases where jets morphology can observed, they show apparent speeds ranging 0.93— 6.92 c and small viewing angle mimicking the blazar phenomenon (Fig 3, *Fuhrmann, et al., 2016, RAA,16,176F*).







2. Motivation and dataset

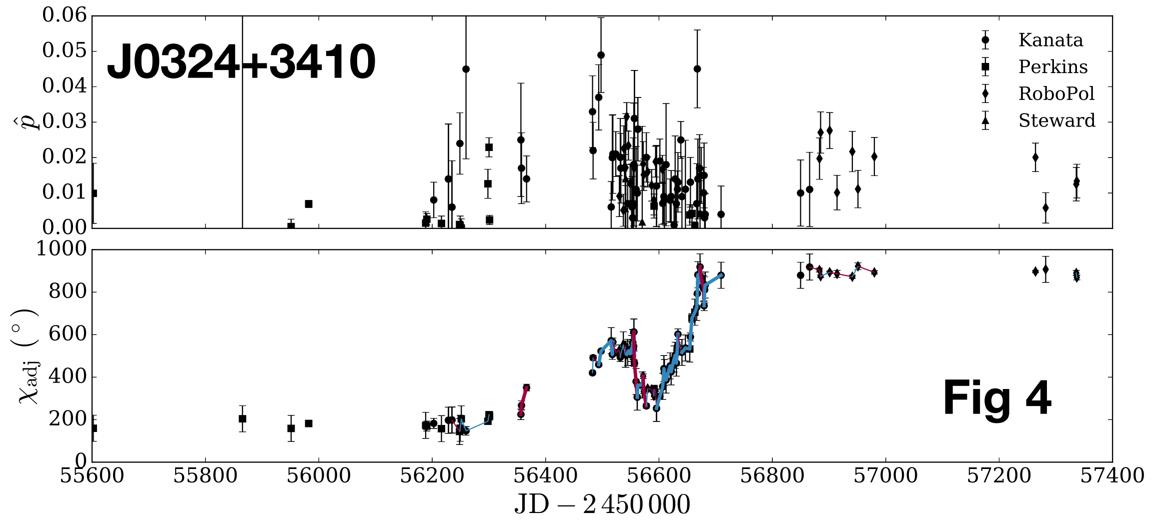
In order to validate the hypothesis that **the physical processes that occur in blazar jets are relevant also for jetted NLSy1** (especially those emitting gamma rays), we investigated the occurrence of long, smooth rotations of the EVPA. Such events are seen associated with activity in gamma rays (*Blinov et al. 2018MNRAS.474.1296B*).

The sample we studied includes **10 Radio Loud NLSy1s, 5 of which detected by Fermi** in the GeV energy regime. Our dataset contains RoboPol, KANATA, Perkins & Steward optical datasets.

The QR code at the top links the relevant publication.

3. Our main findings

In Fig 4 we show an example dataset which happens to be the best sampled case.

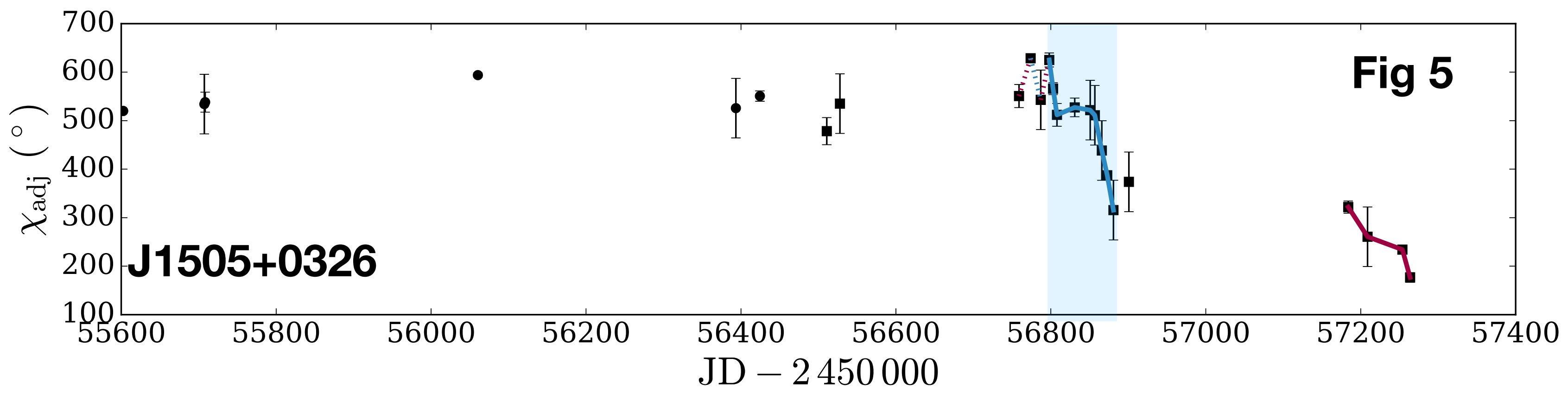


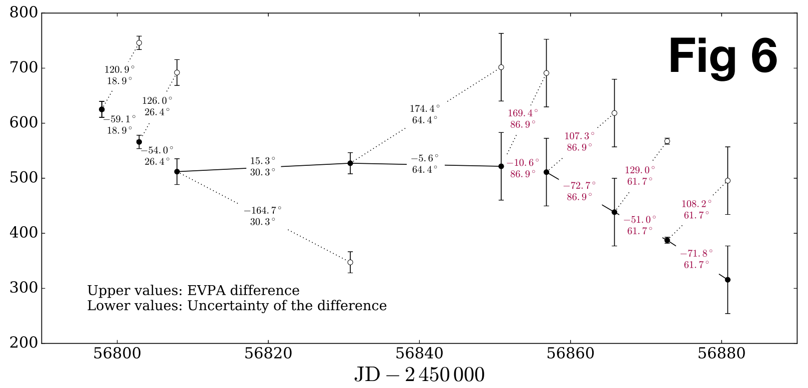
Our main observational facts can be summarised as follows:

- 7 of 10 RL NLSy1s show phases of significant polarisation Of those 7, 3 have maximum polarisation below 5%, 1 is larger than 5 but less 10% and **3** have maximum polarisation **above 10%.**
- The polarisation is generally variable.
- 5 sources show periods of significant continuous variability (coloured connecting lines in Fig 4) and 2 of those 5 are **long rotations i.e.** consist of **more than three points** and **exceed 90º**.

4. The best candidate rotation

In Fig 5 we show the dataset that showed the most significant rotation (blue shaded area). In Fig 6 we zoom in the rotation of **length Δχ ~ -309.5º** and **rate Δχ/t ~ -3.7º/day**.





5. Is the rotation reliable?

If it happens that the sum of the absolute difference |Δχ| between two consecutive data points and the uncertainty in that difference σΔχ exceeds 90◦ the direction of **the rotation becomes uncertain** as both solutions χ and χ + π could be valid (Fig 6). So **sparse sampling** and **large angle uncertainties** make **the direction uncertain** hence: **the rotation is uncertain** (see also **Sebastian Kiehlmann's** talk on **Monday at 13:45)**.

We carried out exhaustive simulations and conclude

- Concerning the effector **measurement uncertainties**: the probability of rotation over angle within 1.0 sigma of observed value as a result of the uncertainties in Stokes parameters is ~23%.
- Concerning the scenario that **noise in Stoke** Q and U **creates the rotation** in **the absence of intrinsic variability**: we find P (full rotation; |Δχintr| ≥ 309.5○| dχintr/dt = 0) = 6 × 10^{-4} · Thus hence **there must be intrinsic variability.**

6. Conclusion

It is **realistic that an intrinsic EVPA rotation is causing the observed event.** This is the first detection of a candidate rotation of the optical EVPA in NLSy1s indicating that similar physical processes occur in these systems just as they do in blazer jets.