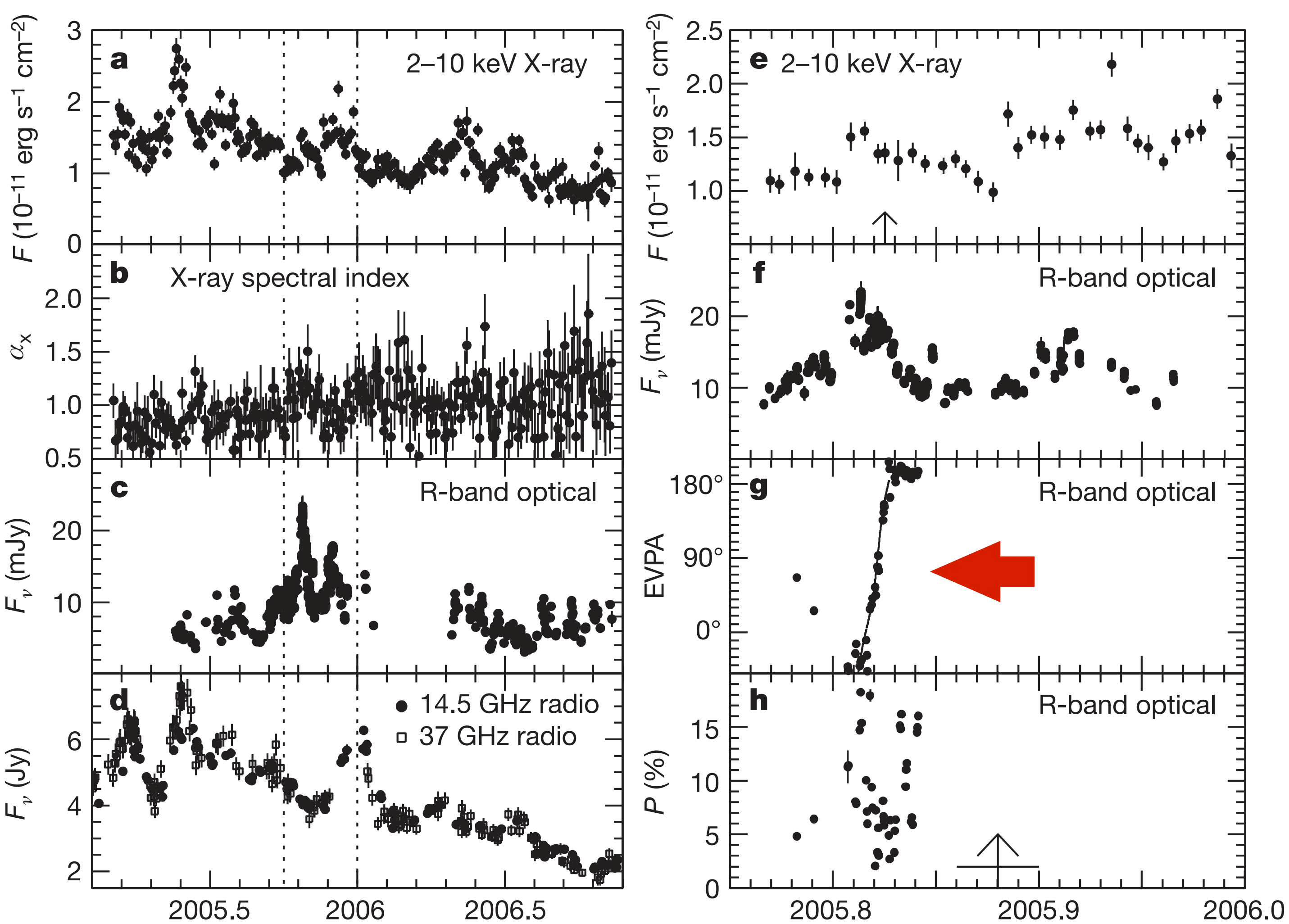
RoboPol: the optical polarisation of gamma-ray-loud and gamma-ray-quiet blazars

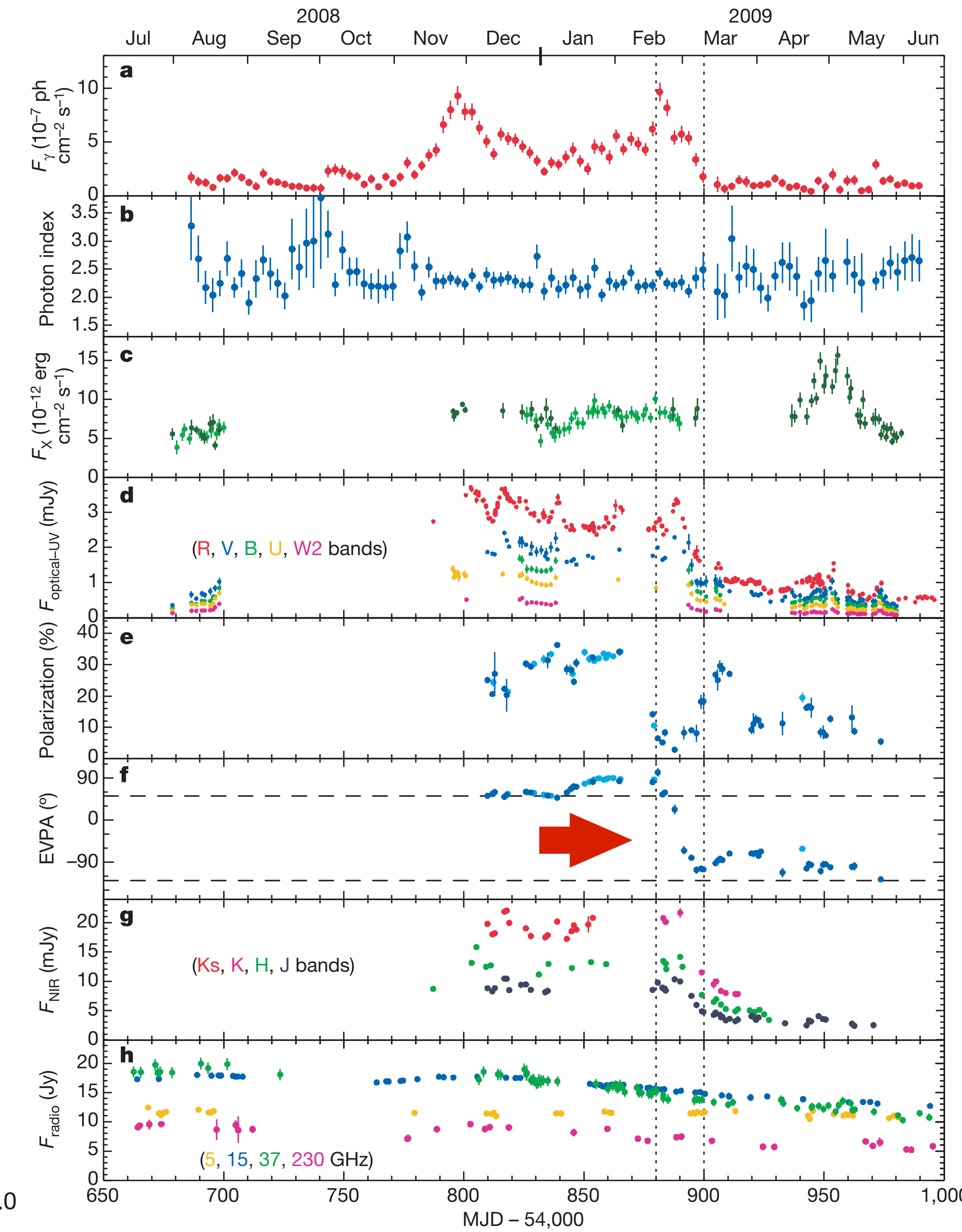
Emmanouil Angelakis
Max-Planck-Institut für Radioastronomie, Auf dem Huegel 69, Bonn 53121, Germany

T. Hovatta, D. Blinov. V. Pavlidou, S. Kiehlmann, I. Myserlis, M. Böttcher
and the RoboPol collaboration

EVPA rotations and high energy activity



Marscher et al. 2008, Nature 452, 966



Abdo et al. 2010, Nature 463, 919

the RoboPol approach:

- ➡ 4 nights / week for 3 years (2013-2015)
- ➡ cadence: 3 — 0.3 nights
- ➡ p uncertainty < 0.01, χ uncertainty: 1-2 deg

- ➡ select and unbiased sample:
  - **62** gamma-ray loud “**GL”** from 2FGL
    $F\,(> 100\ \mathrm{MeV}) > 2 \times 10^{-8}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$
  - **15** gamma-ray quiet “**GQ”**: from OVRO

Caltech, USA: M. Baloković, O. G. King, A. Mahabal, T. J. Pearson, A. C. S. Readhead,
Uni. of Crete/FORTH, Greece: D. Blinov, N. Kyla s, I. Liodakis, G. V. Panopoulou, I. Papadakis, I. Papamastorakis, V. Pavlidou, P. Reig, K. Tassis
IUCAA, India: V. Joshi, S. Prabhudesai, A. Ramaprakash
MPIfR, Germany: E. Angelakis, C. Casadio, I. Myserlis, J. A. Zensus
N.C.U., Poland: A. Kus, A. Marecki, E. Pazderska
T. Hovatta, S. Kiehlmann (Aalto University, Metsähovi Radio Observatory, Finland

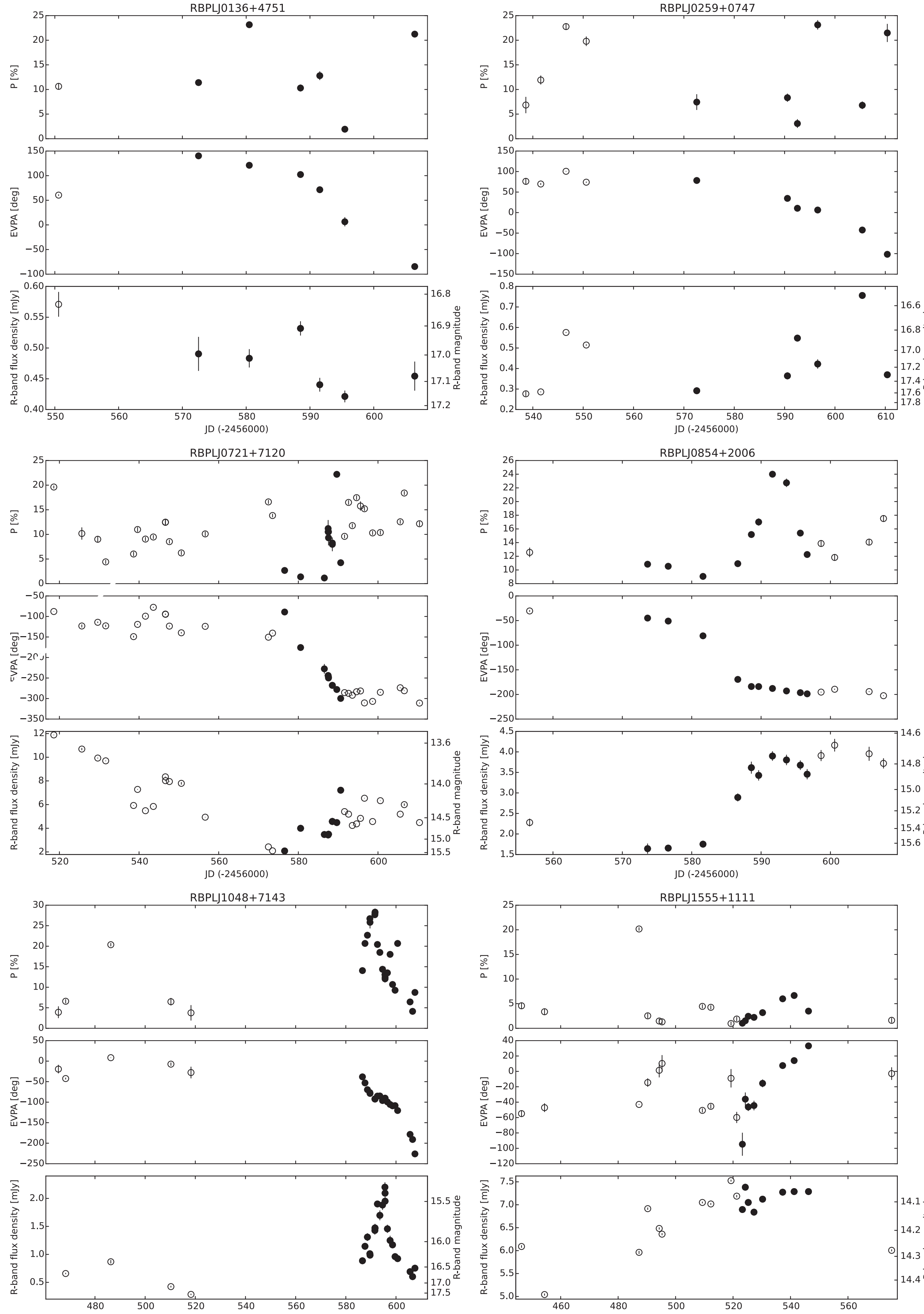
RoboPol EVPA rotations:

- 2013-2015: 40 rotations in 24 blazars
  (before RoboPol: 16 rotations in 10 blazars)
  Blinov et al. 2015, MNRAS.453.1669B;
  Blinov et al. 2016, MNRAS 457, 2252

- any class can “rotate” (HSP/LSP, FSRQs/ BL Lacs, TeV/non-TeV)

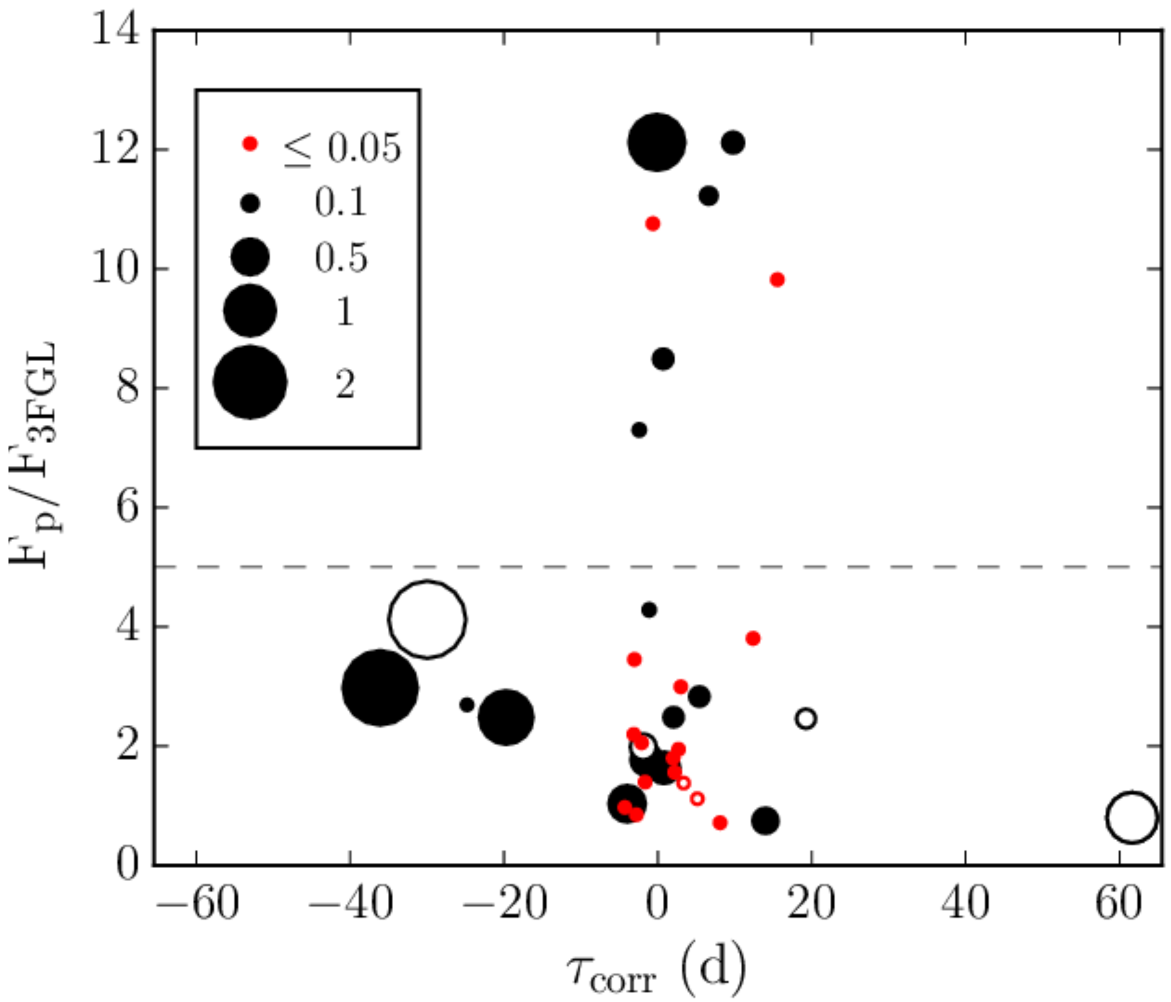
- rotation rate can vary a lot in the same source

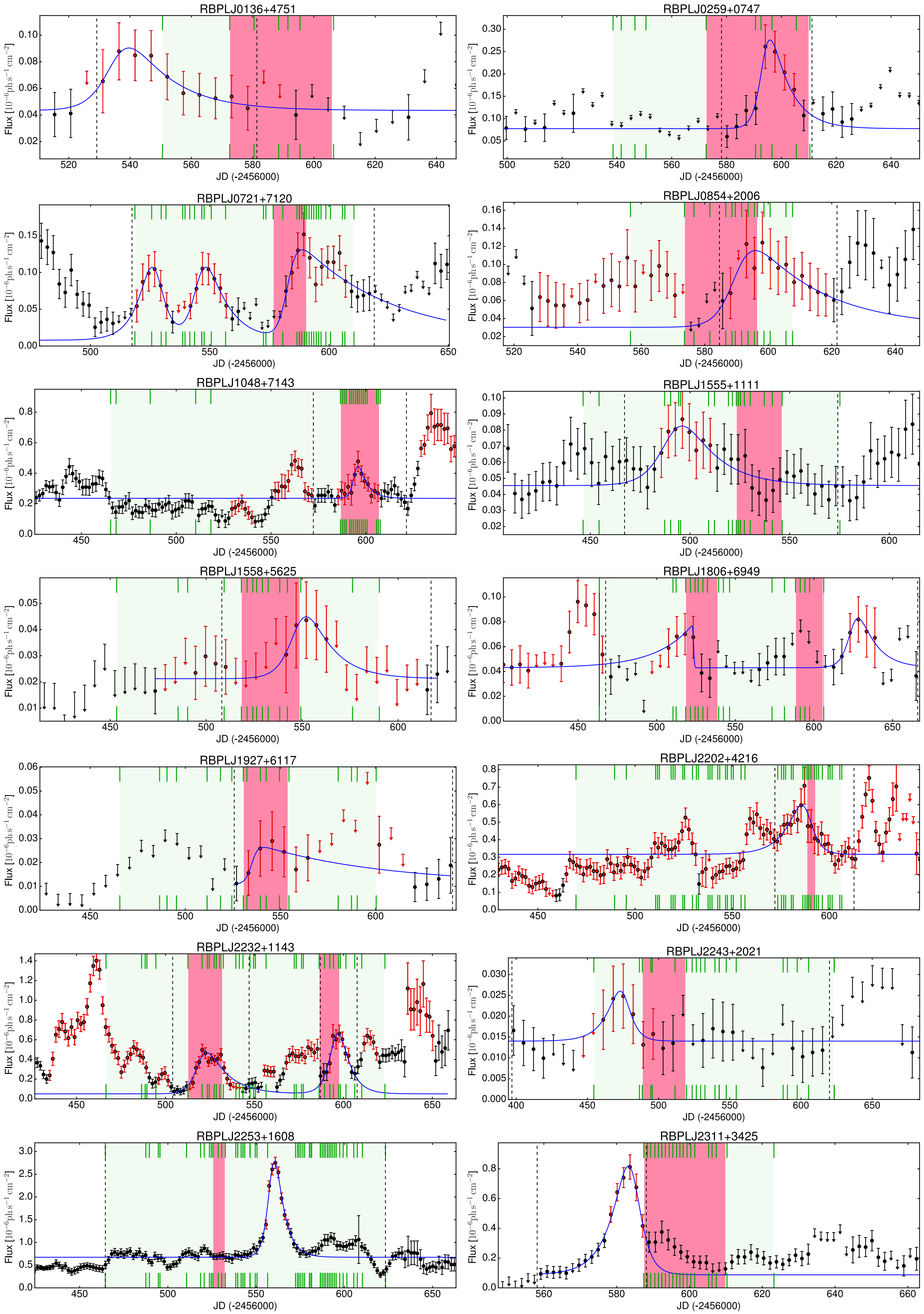
- both senses allowed in the same source



EVPA rotations and γ-ray activity:

- data suggest:
  - **all "rotators" are GL**: physical relation between γ-ray loudness and optical polarisation
  - we find no rotation that is not associate with **a gamma-ray flare within the uncertainties**
  - **all lags consistent with zero**

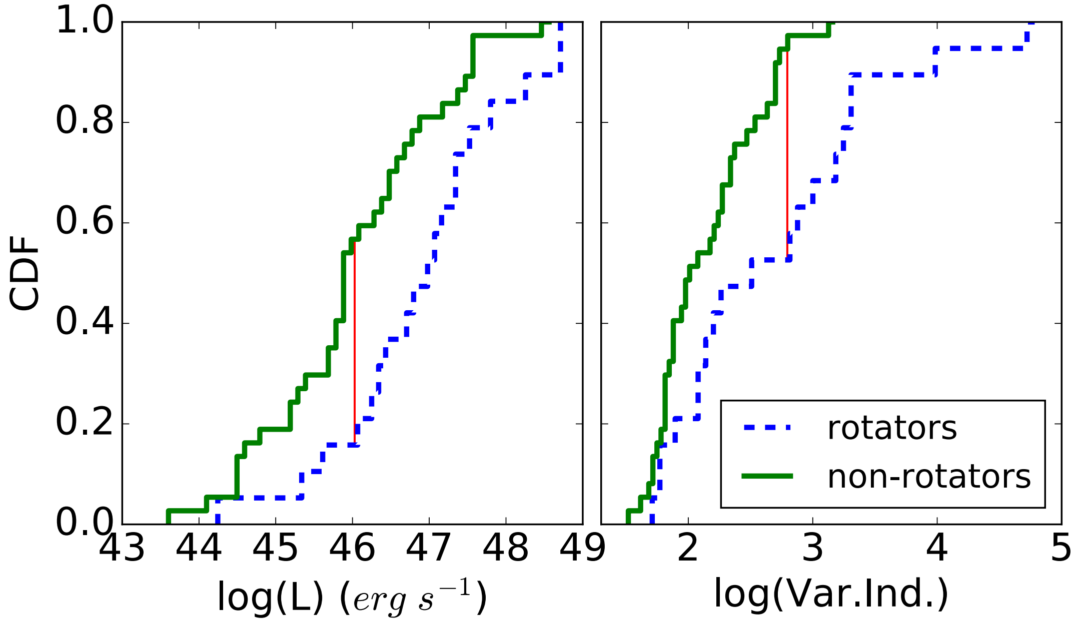




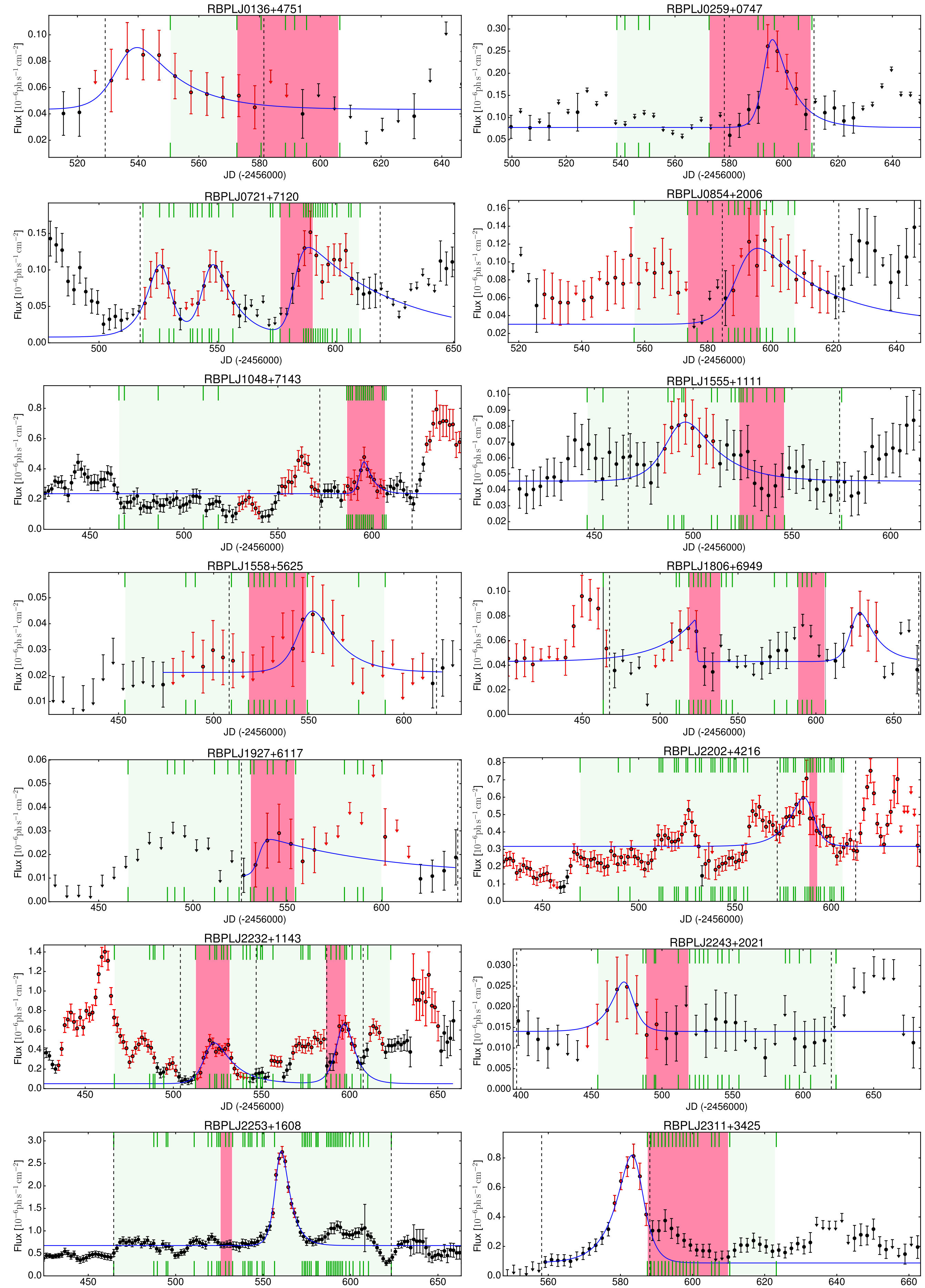
Blinov et al. 2015, MNRAS.453.1669B

EVPA rotations and γ-ray activity:

➡ rotators are more **luminous** and more **variable** in γ rays



Blinov et al. 2016



Blinov et al. 2015, MNRAS.453.1669B

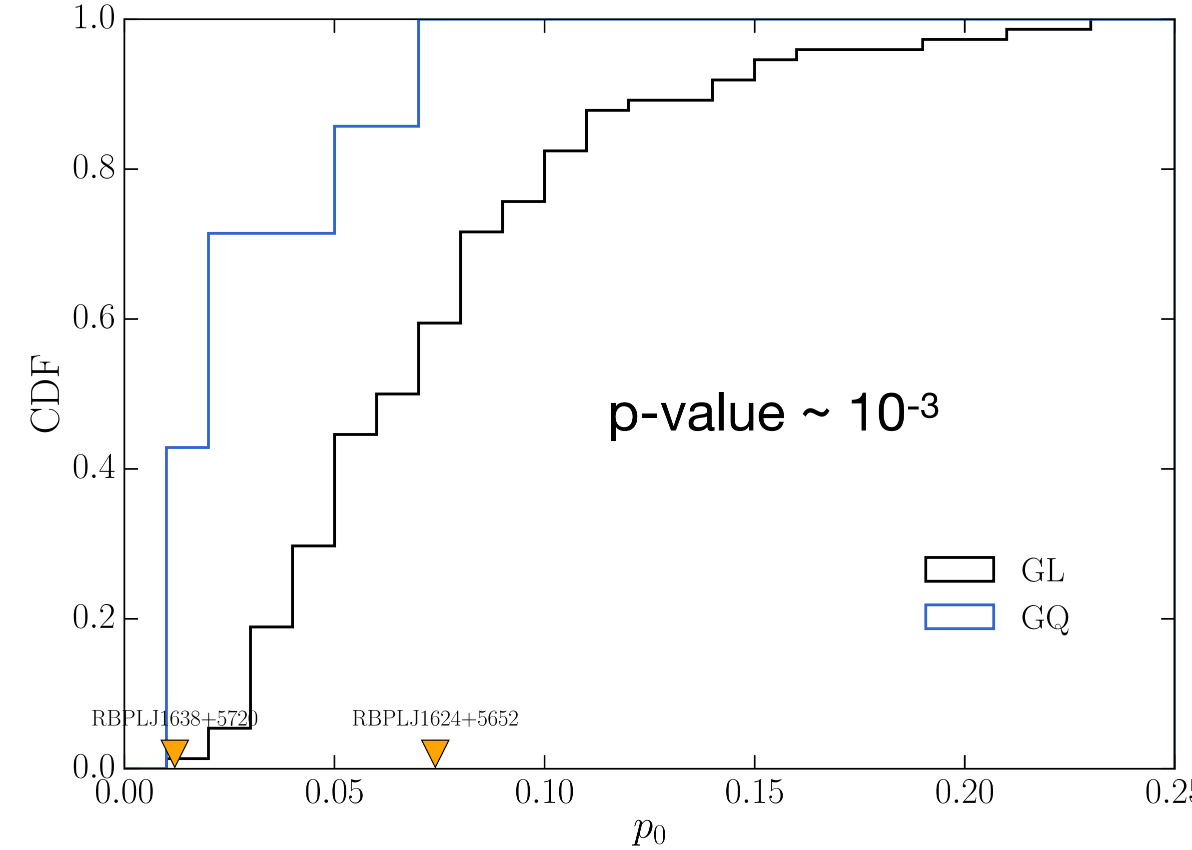
optical polarisation and γ-ray loudness:

➡ **"GL" more polarised** than **"GQ".**

assuming a power law distribution:

- **GL**: $\langle p_0 \rangle$ ~ 0.092 ± 0.008
- **GQ**: $\langle p_0 \rangle$ ~ 0.031 ± 0.008

Angelakis et al. 2016, MNRAS.463.3365A
Pavlidou et al. 2014, MNRAS.442.1693P

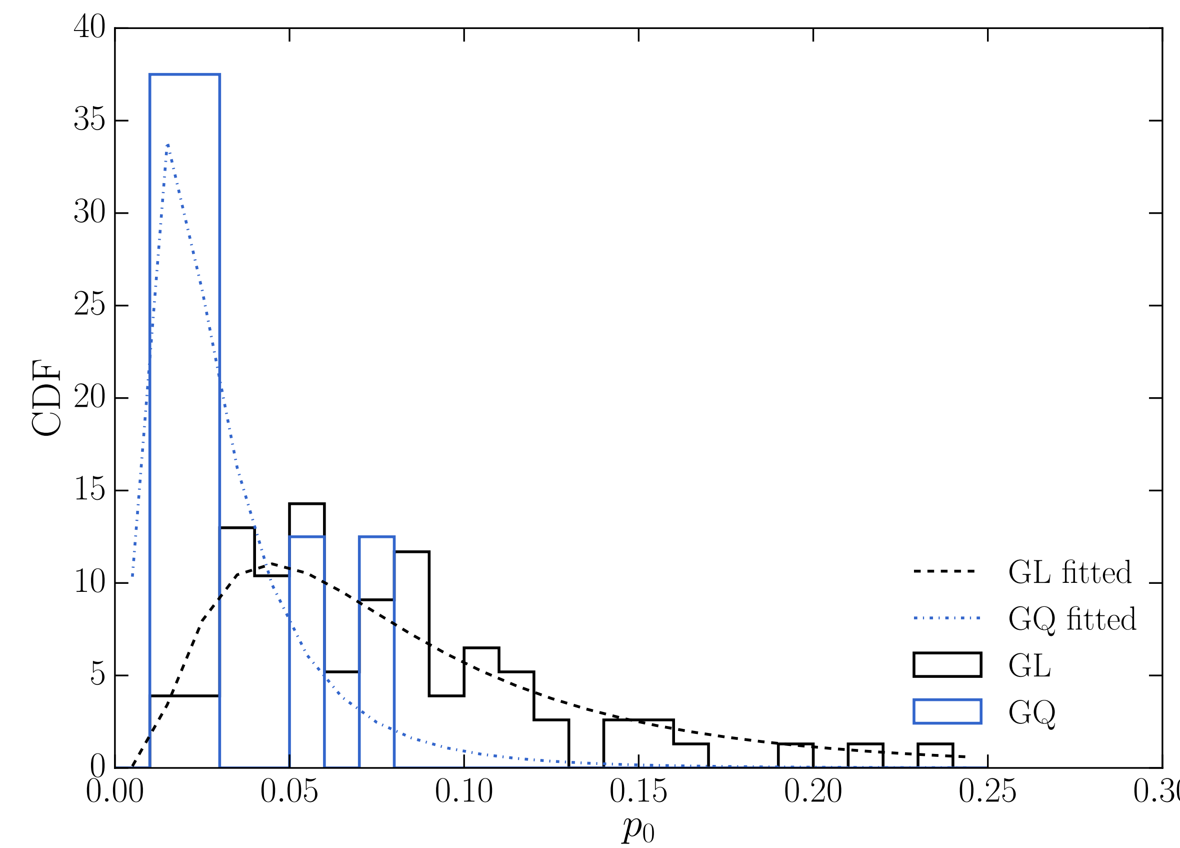


$$\mathrm{PDF}\,(p;\alpha,\beta) = \frac{p^{\alpha-1}\,(1-p)^{\beta-1}}{B\,(\alpha,\beta)}$$

$$p_0 = \frac{\alpha}{\alpha+\beta}$$

and

$$m_p = \frac{\sqrt{\mathrm{Var}}}{p_0} = \frac{\alpha+\beta}{\alpha} \cdot \sqrt{\frac{\alpha\beta}{(\alpha+\beta)^2\,(\alpha+\beta+1)}}.$$



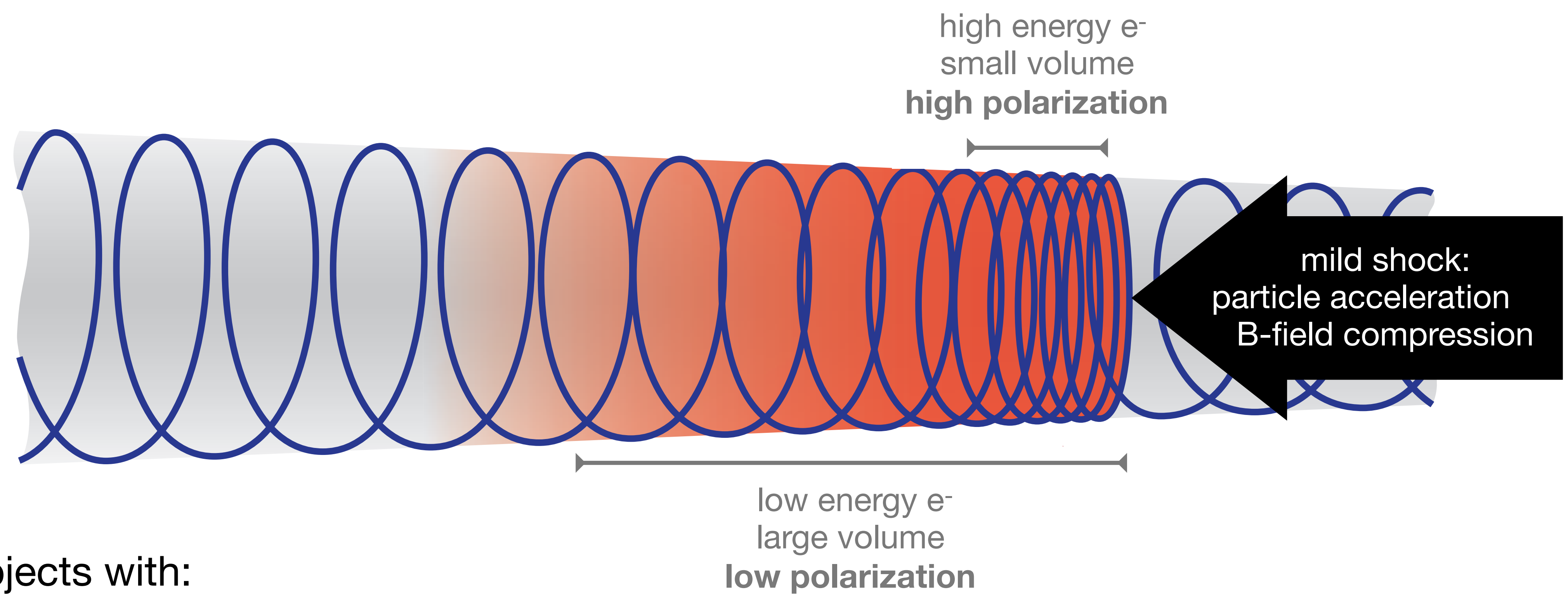
Angelakis et al. 2016, MNRAS.463.3365A

explaining the dichotomy between “GL” and “GQ”:

GL: highly variable, strong jet dominance due to **high degree of Doppler boosting**
(*e.g. Savolainen et al. 2010, A&A, 512, A24; Lister et al. 2015, ApJ, 810, L9*)

➡ frequent impulsive events of particle acceleration

➡ optical from **smaller volumes** hence **higher polarisation**



GQ: objects with:

- less extreme Doppler boosting or
- less efficient impulsive episodes,

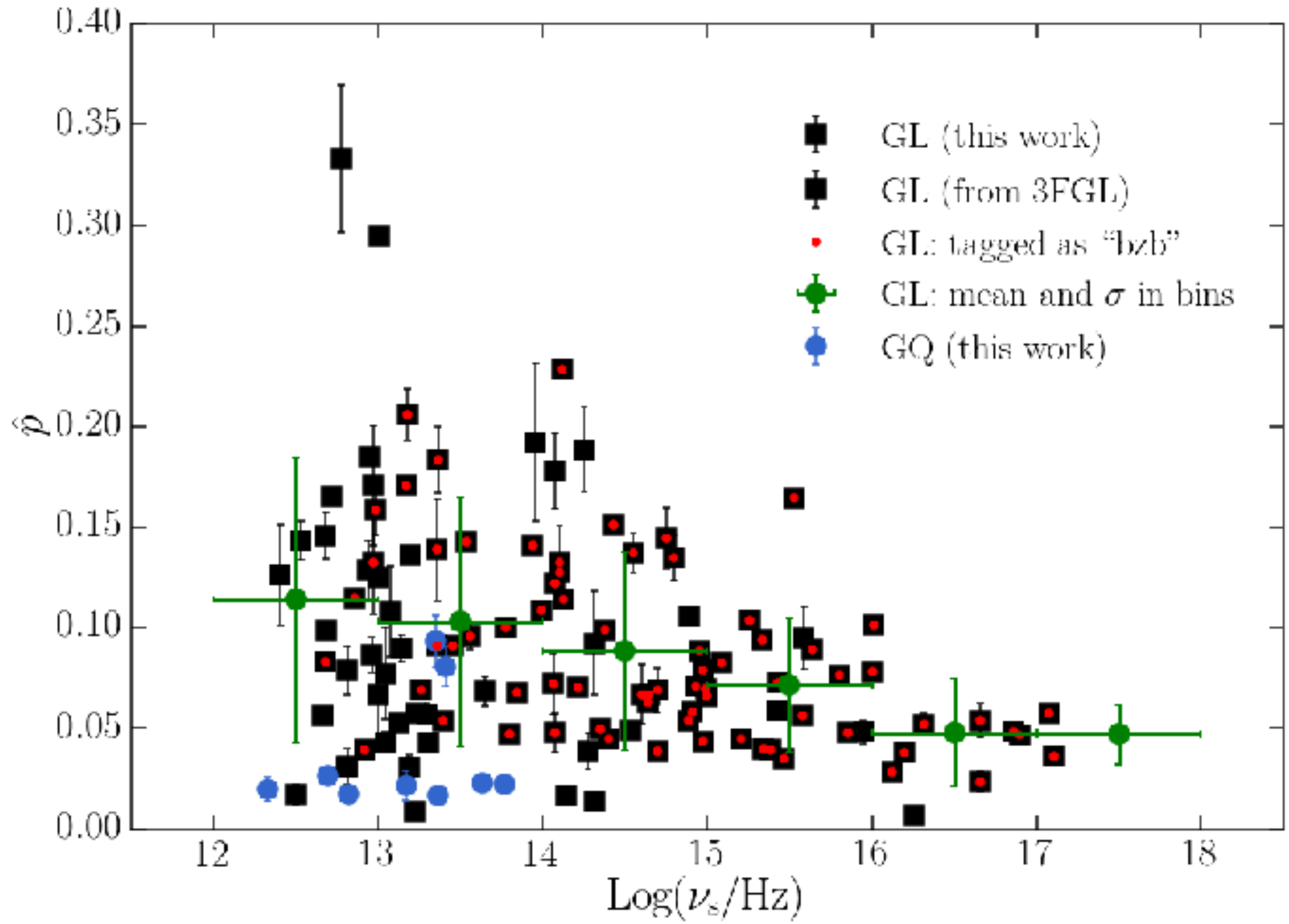
➡ not accelerating particles to energies needed for γ-ray production at **measurable levels**

➡ optical from **larger volumes** hence **lower polarisation**

Angelakis et al. 2016, MNRAS.463.3365A

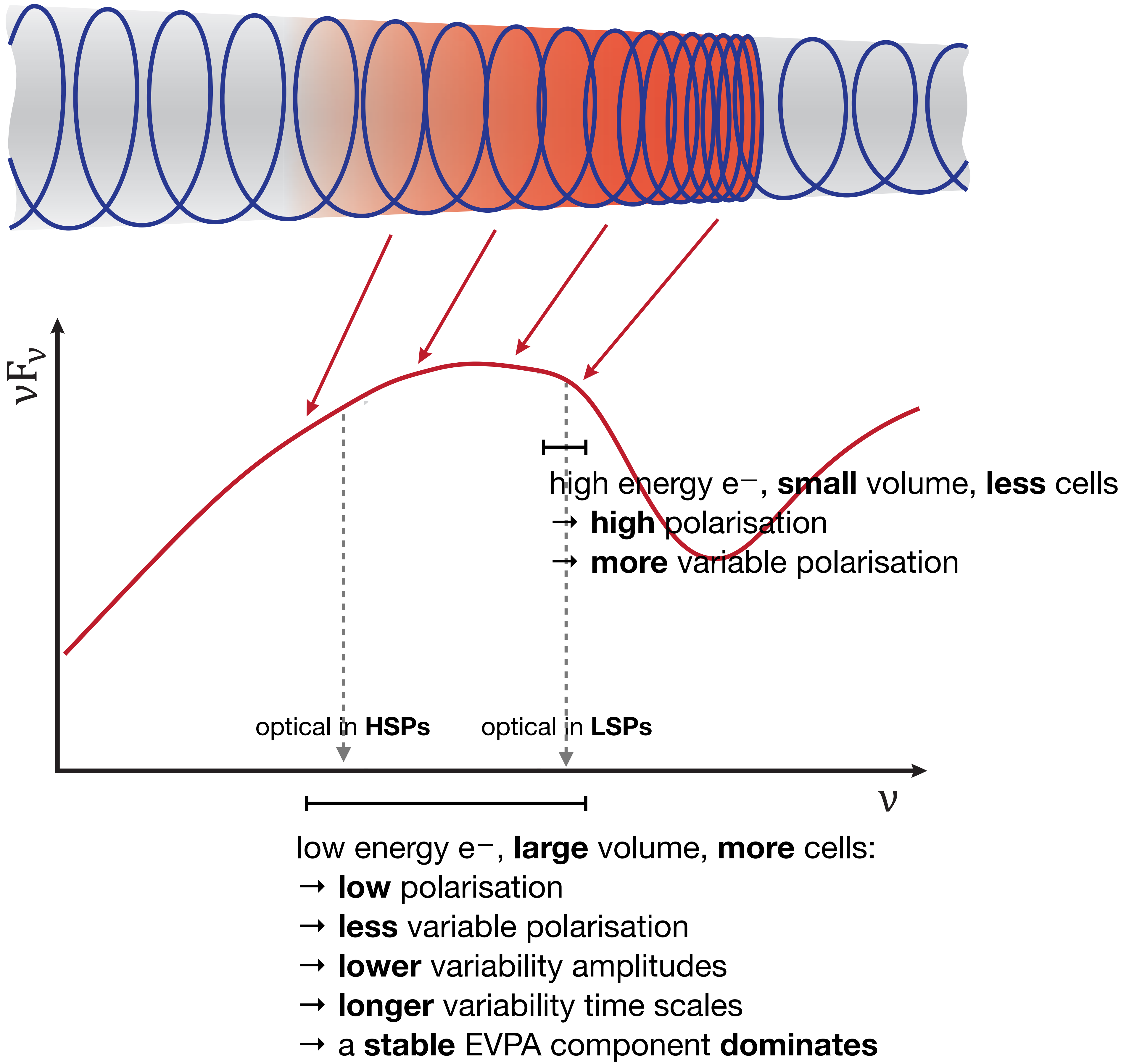
polarisation vs synchrotron peak frequency:

➡ **mean** polarisation and its **spread decreases** with **synchrotron peak** frequency

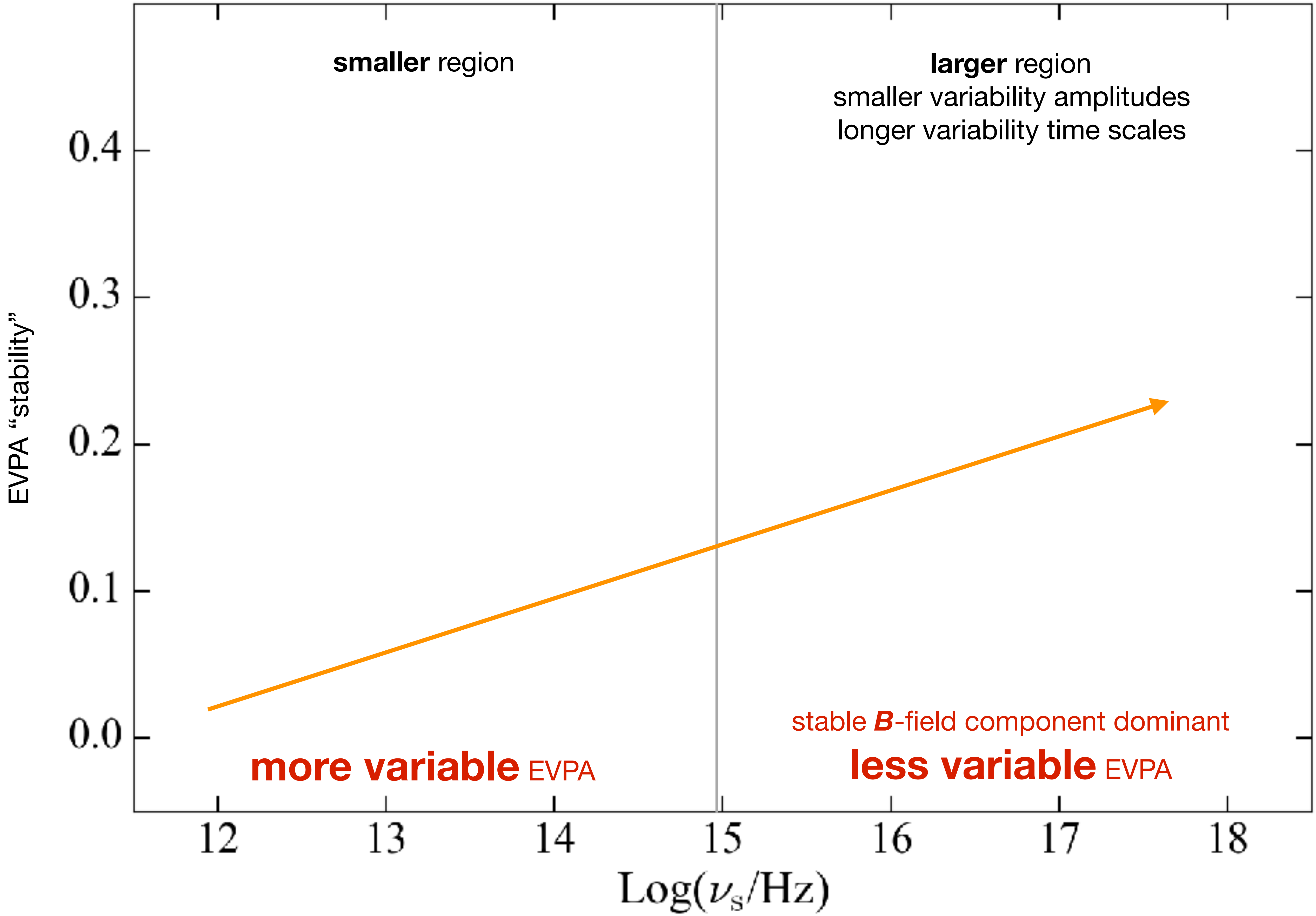


for BL Lac GL only : $\varrho = -0.5$ (p-value: $7*10^{-6}$)

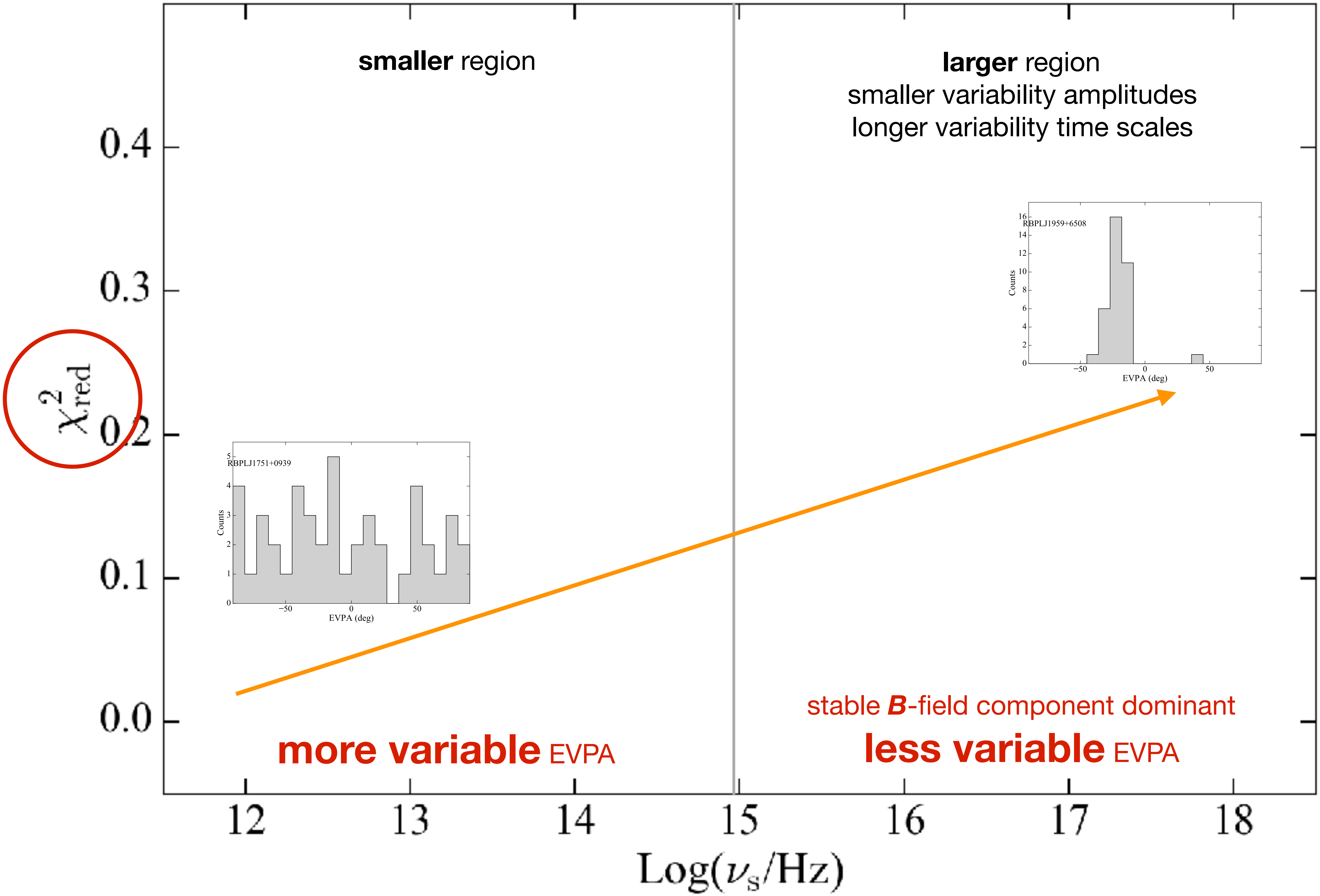
Angelakis et al. 2016, MNRAS.463.3365A



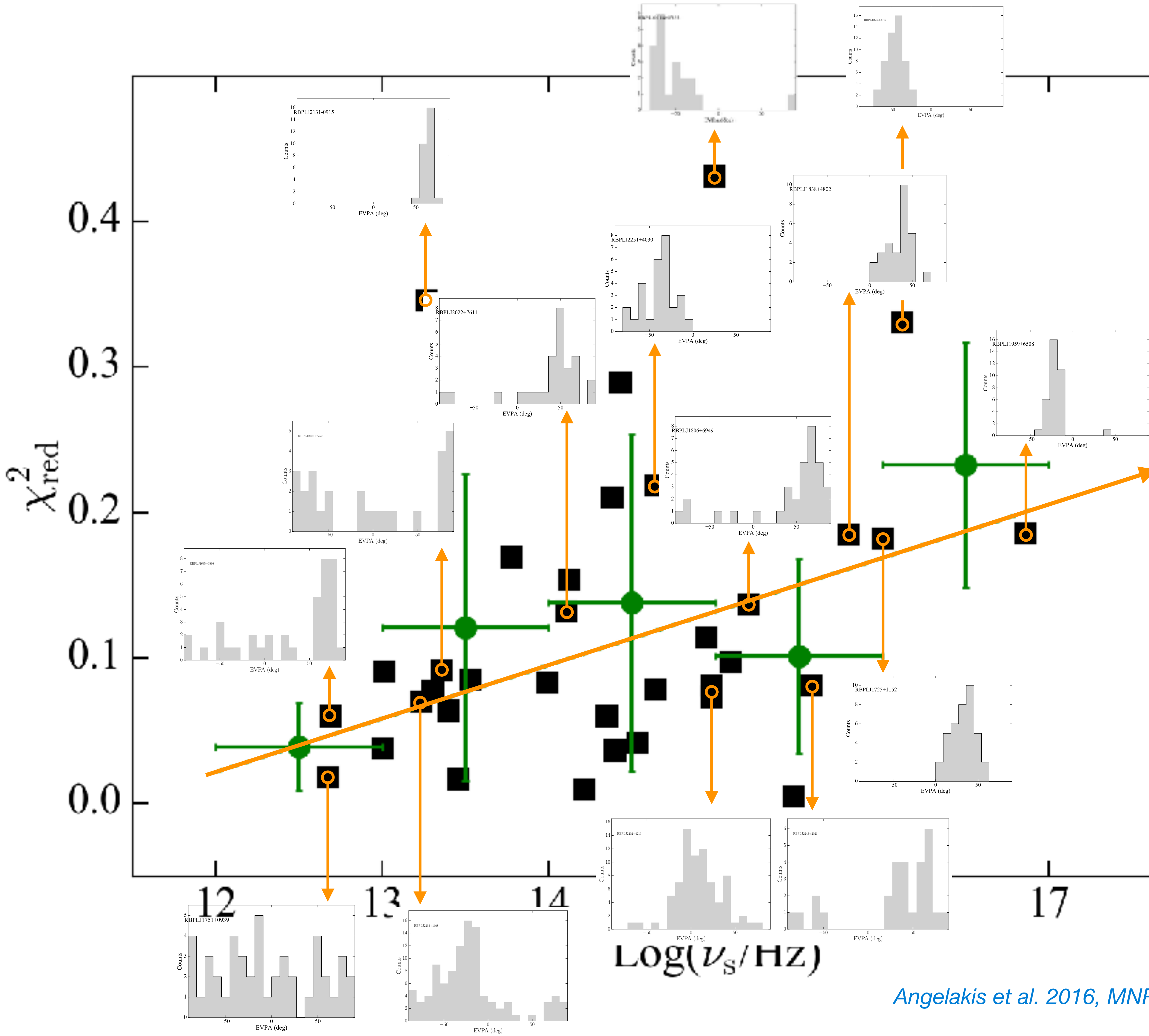
Angelakis et al. 2016, MNRAS.463.3365A



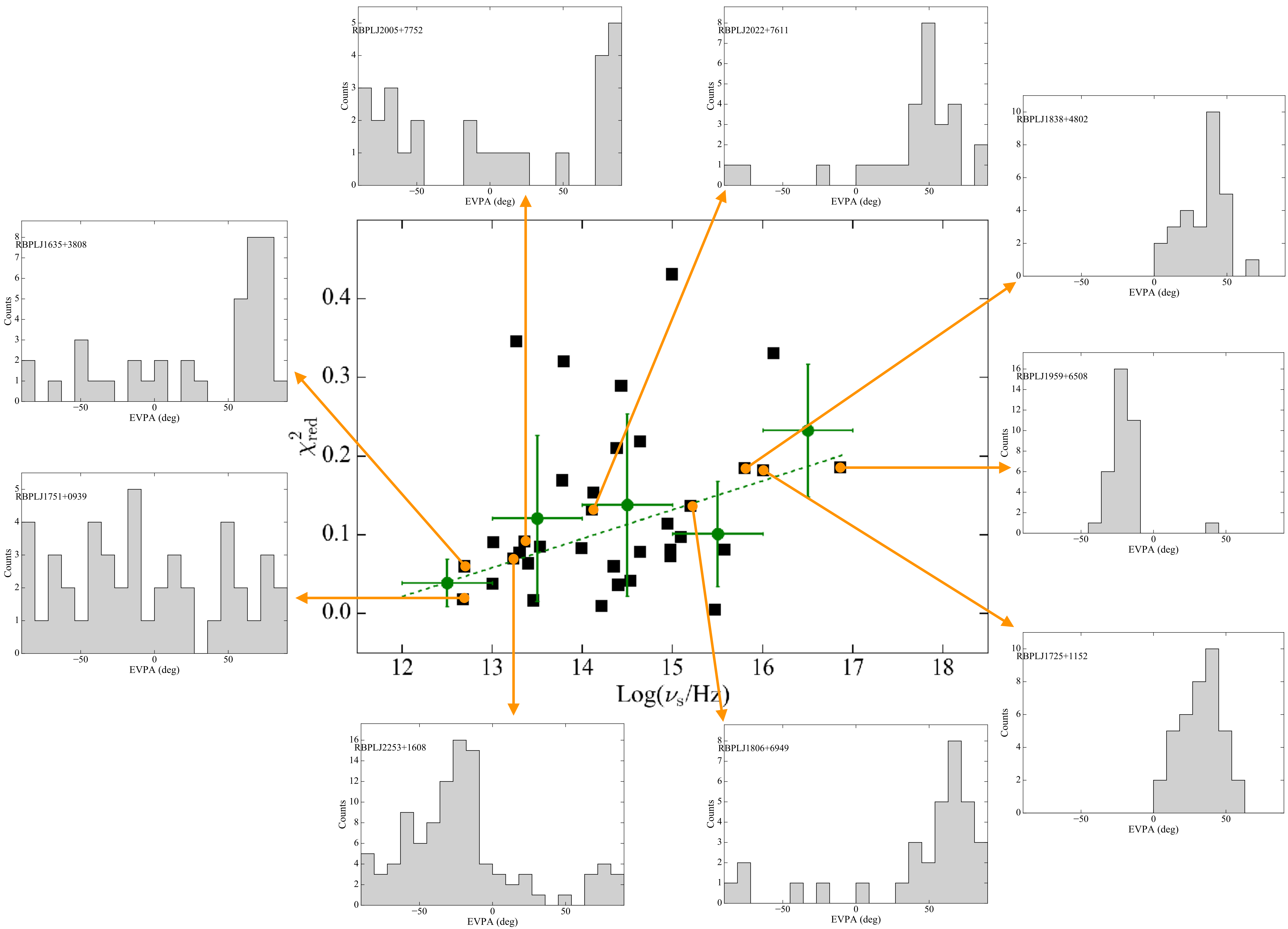
Angelakis et al. 2016, MNRAS.463.3365A



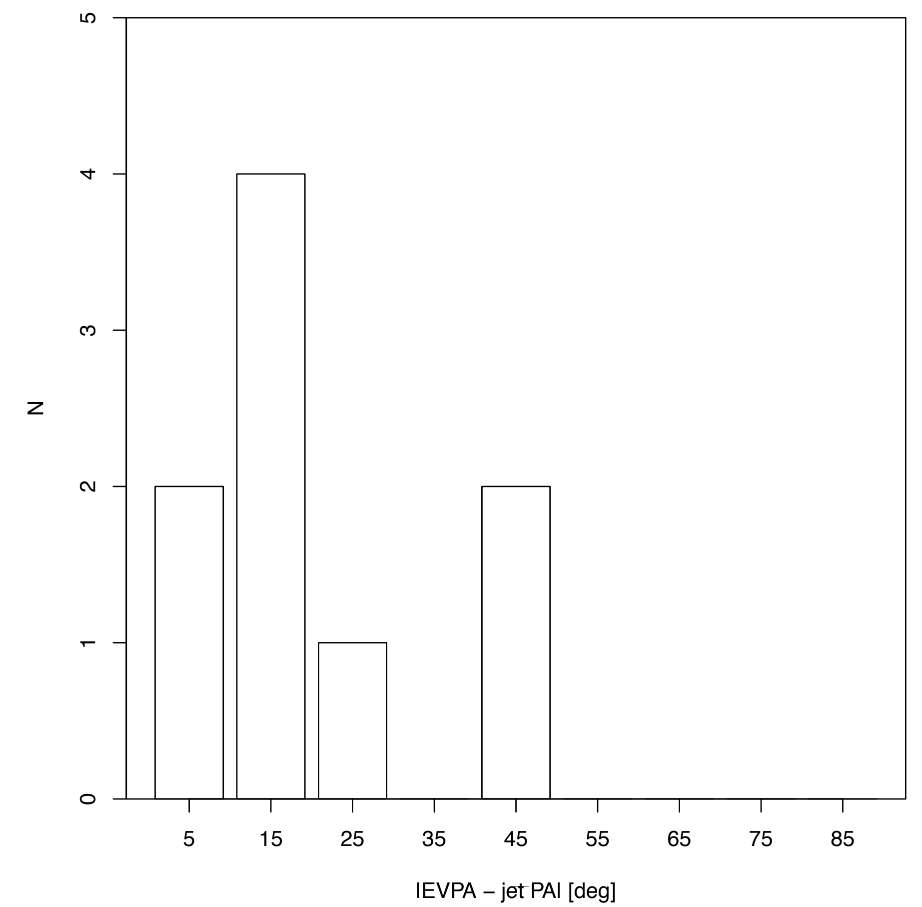
Angelakis et al. 2016, MNRAS.463.3365A



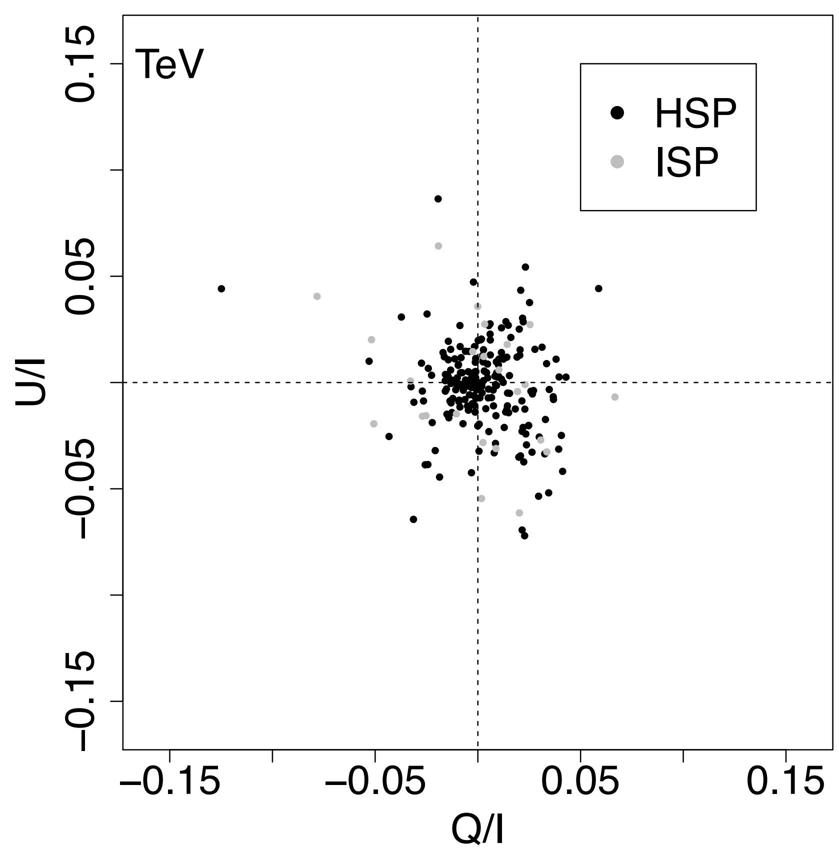
Angelakis et al. 2016, MNRAS.463.3365A

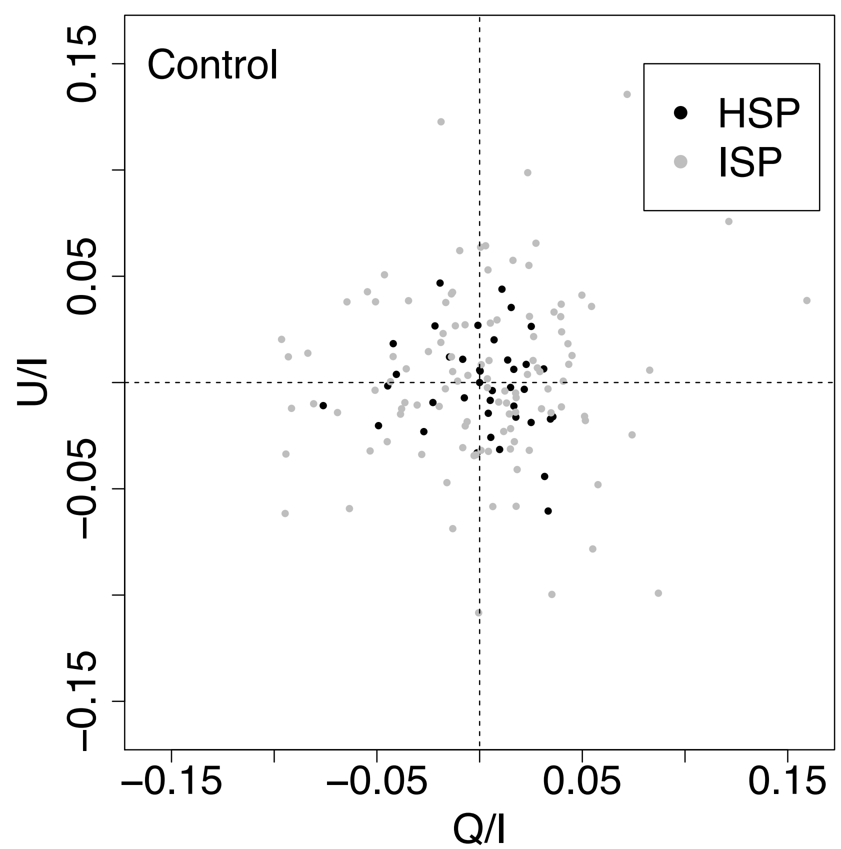

RBPLJ2005+7752
RBPLJ2022+7611
RBPLJ1838+4802
RBPLJ1635+3808
RBPLJ1959+6508
RBPLJ1751+0939
RBPLJ1725+1152
RBPLJ2253+1608
RBPLJ1806+6949
Counts
EVPA (deg)
$\chi^2_{\rm red}$
$\mathrm{Log}(\nu_s/\mathrm{Hz})$

alignment of the EVPA and jet in high-energy BL Lac objects (TeV):



- sample: **32 TeV** and **19 non-TeV**
- **TeV** show preferred orientations of the EVPA
- for most sources the EVPA and jet are aligned to less than **20º** implying a ***B*-filed perpendicular to the jet direction**





Hovatta et al. 2016, A&A, 596, A78

conclusions:

- ➡ all classes rotate; different sense allowed; rates can vary
- ➡ non all blazars rotate; there are **rotators** are more luminous and more variable in gamma-rays than **non-rotators**
- ➡ no evidence that rotations are not associate with gamma-ray flares

- ➡ GL are more polarised than GQ sources
- ➡ the dichotomy disappears fro the polarisation variability amplitude
- ➡ the mean p and its spread depend on the synchrotron peak
- ➡ the EVPA clearly shows a preferred direction for HSP sources

- ➡ A jet
  - populated by a helical field
  - impulsive events of particle acceleration (e.g. Diffusive Shock Acceleration)
- ➡ can provide a natural explanation of all the above

Angelakis et al. 2016, MNRAS.463.3365A
Hovatta et al. 2016, A&A, 596, A78
Pavlidou et al. 2014, MNRAS.442.1693P
Blinov et al. 2015, MNRAS.453.1669B;
Blinov et al. 2016, MNRAS 457, 2252

http://robopol.org

Thank you!

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