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Connection between optical polarization plane rotations and gamma-ray flares in blazars

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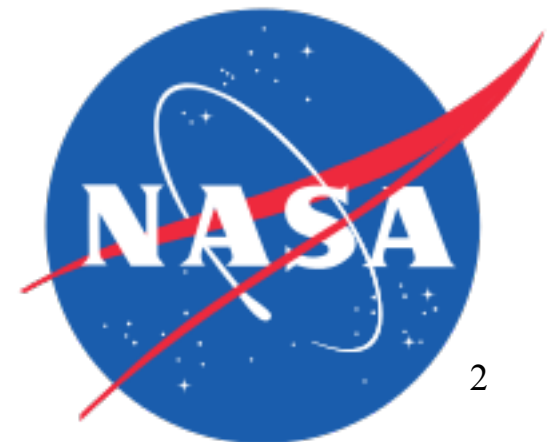
on behalf of the RoboPol Collaboration
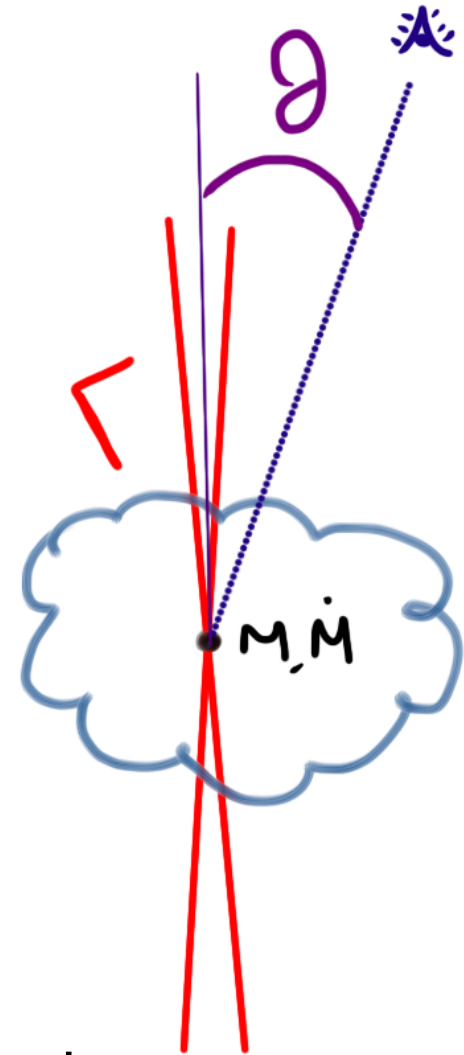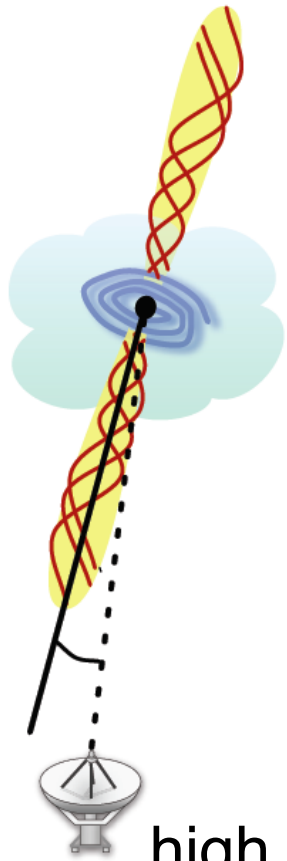U. Crete/FORTH-MPIfR-Caltech-IUCAA-NCU

TeV Particle Astrophysics Conference, Columbus, OH 2017

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS

NSRF 2007-2013
programme for development

NATIONAL SCIENCE CENTRE POLAND

FORTH
Foundation for Research & Technology - Hellas

Max-Planck-Institut für Radioastronomie

ΑΣΤΕΡΟΣΚΟΠΕΙΟ ΣΚΙΝΑΚΑ
SKINAKAS STERNWARTE

CALIFORNIA INSTITUTE OF TECHNOLOGY
1891

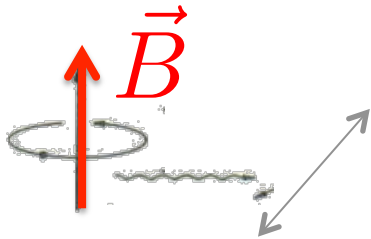IUCAA

NASA

2

Blazars

beamed & boosted

fast variability

superluminal motions

high apparent luminosity

high-energy emission

Blazars: Optical = optically thin Synchrotron:

highly linearly polarized
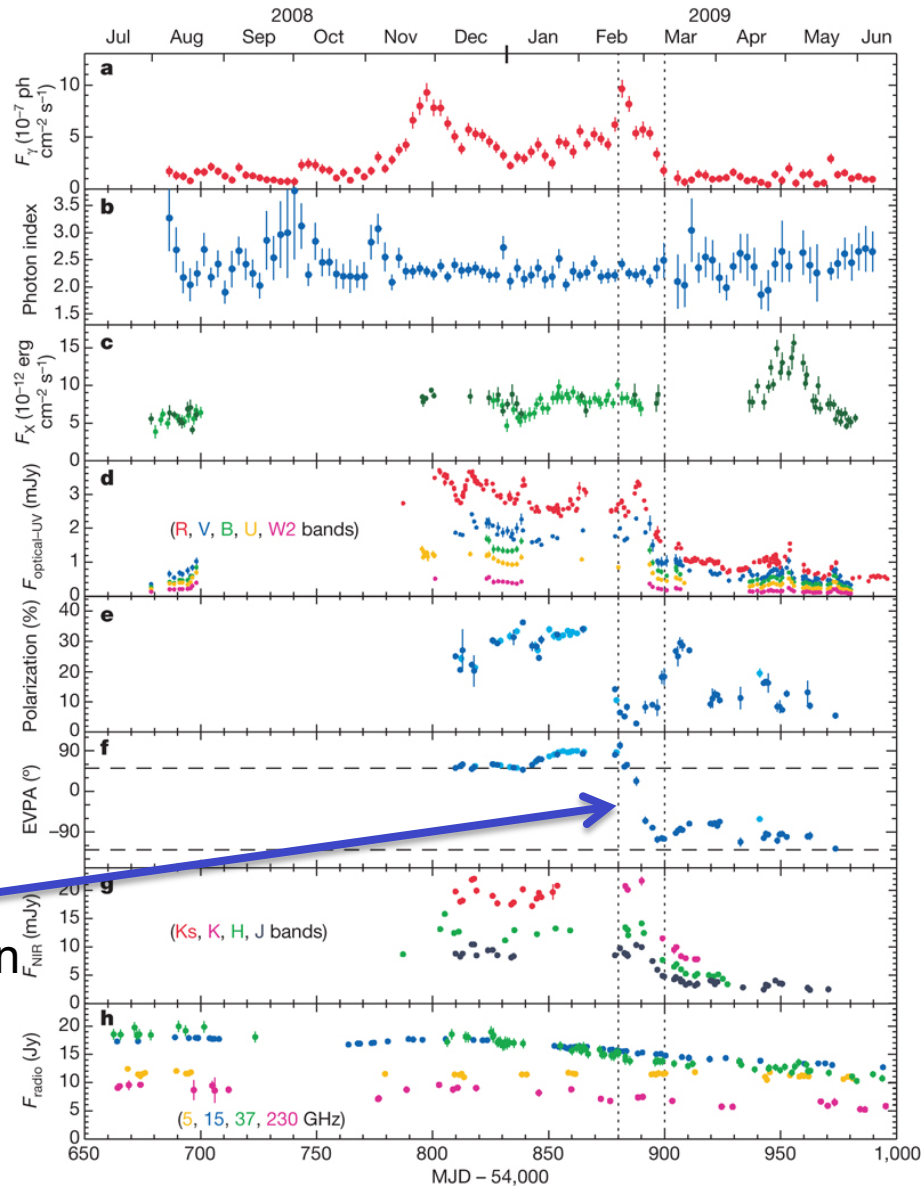polarization direction $\perp$ $\vec{B}$

$\vec{B}$

contribution from all emitting regions
along line of sight

Optical polarization encodes information about:
- ❑ **geometry** of magnetic field in emission region
- ❑ **number** of emitting cells along line of sight
- ❑ degree to which magnetic field is **ordered**

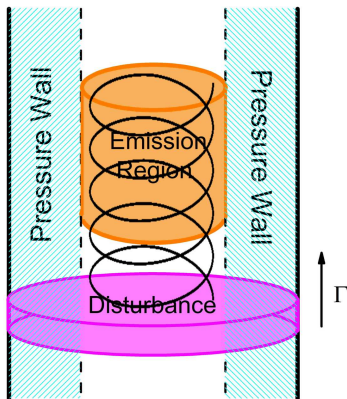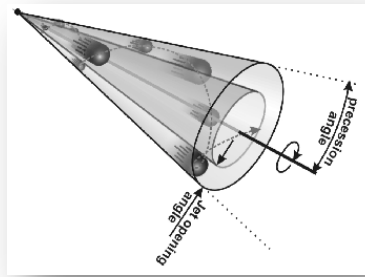Optical polarization in blazars is *variable*

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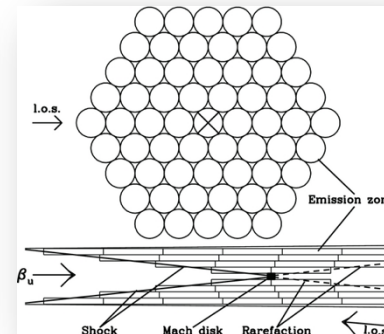Polarization rotation

. Abdo et al. (2010)
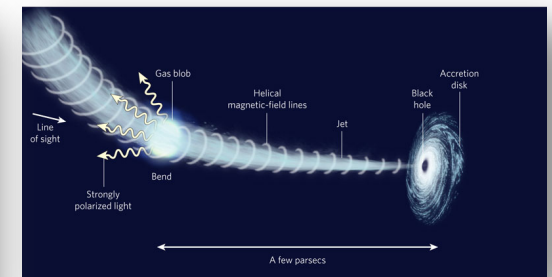
- A wealth of theoretical ideas:

Propagation of shock along jet B-field
cartoon from Zhang, Deng, Li & Boettcher 2016

Precessing jet
Blandford et al.
cartoon from Heinz & Sunyaev 2002

Turbulent plasma crossing standing shock
Marscher et al.
cartoon from Marscher 2014

Propagation through jet bend
Nalewajko et al.
cartoon from Young 2010

- A multitude of phenomenological possibilities.
  - ✓ large rotations, small rotations, rotations of all sizes
  - ✓ all blazars, many blazars, only few blazars do it
 - ✓ happens only during flares, happens all the time

The RoboPol Program

✓ Observe large, well-defined sample of blazars in optical linear polarization with high cadence

✓ Identify rotations with uniform criteria

✓ Systematically answer questions regarding optopolarimetric properties of blazars:

-- **Are γ-ray—loud and γ-ray—quiet blazars different in optical polarization?**

-- **Do all blazars exhibit polarization rotations?**

-- **Are polarization rotations related to γ-ray flares?**
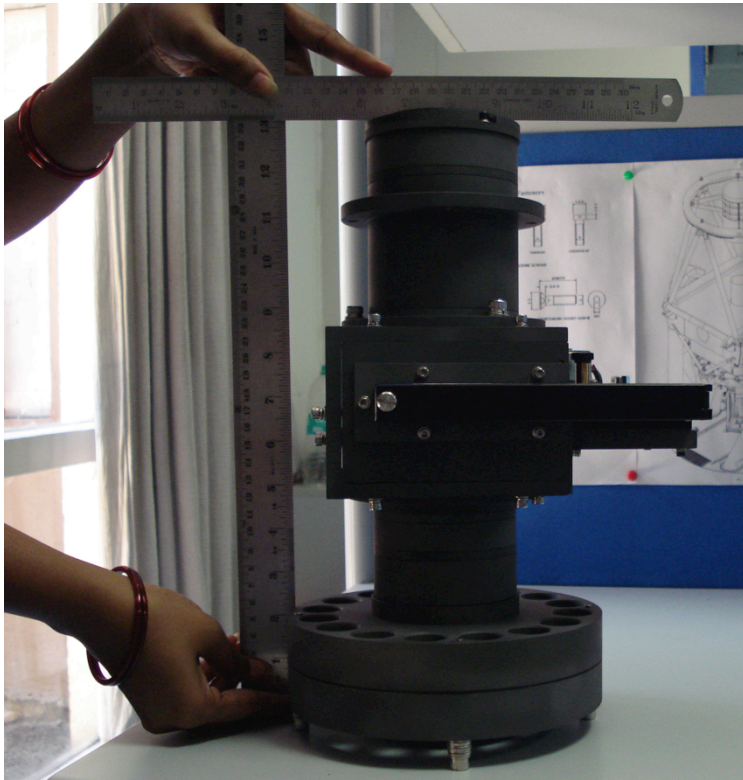
No moving parts,
low systematics,
high sensitivity

Program Features
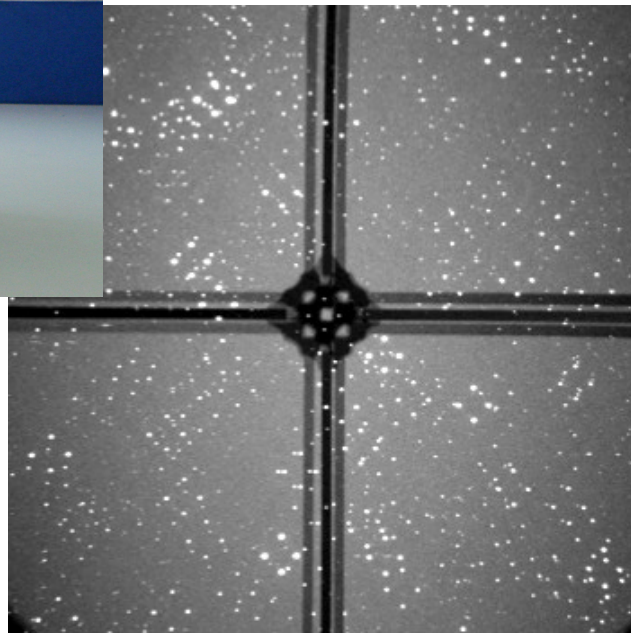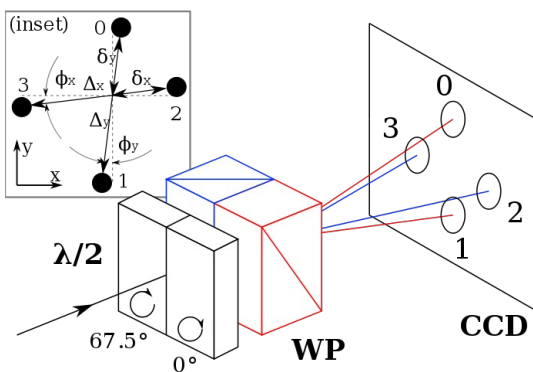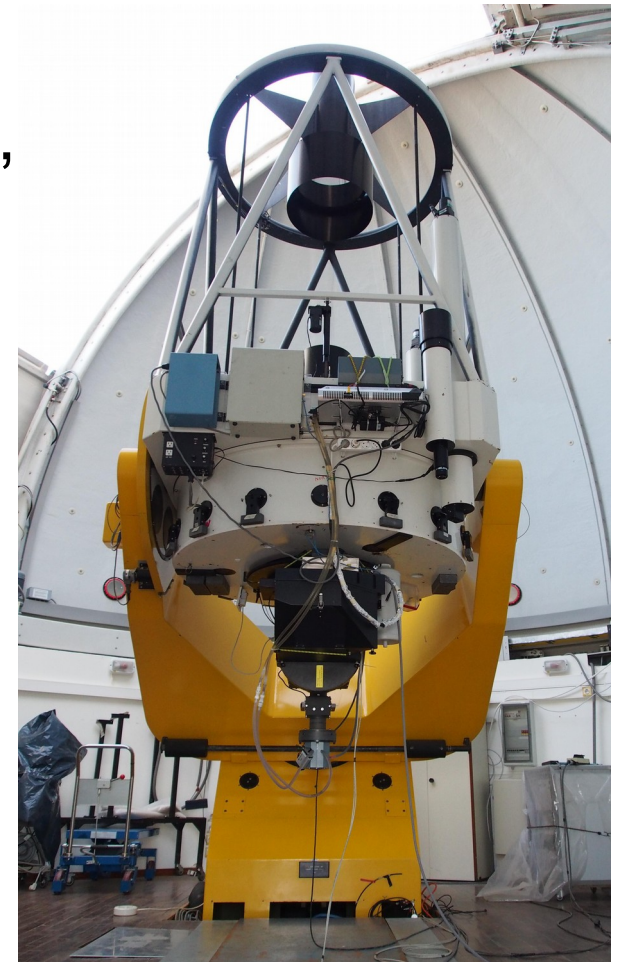
- ✓ **Low-systematics, high-sensitivity polarimeter**

- ✓ **Ample telescope time:** 4 nighs/week for 3 years at Skinakas 1.3 m telescope
  (1750m, median seeing 0.6 arcsec)

- ✓ **Statistically robust sample**

- ✓ **Unbiased observing strategy**

The Sample

✓ **Main:** 62 γ-ray – loud blazars, R<17.5^m

✓ **Control**: 15 γ-ray – quiet blazars, similar in radio flux, spectra, variability with main
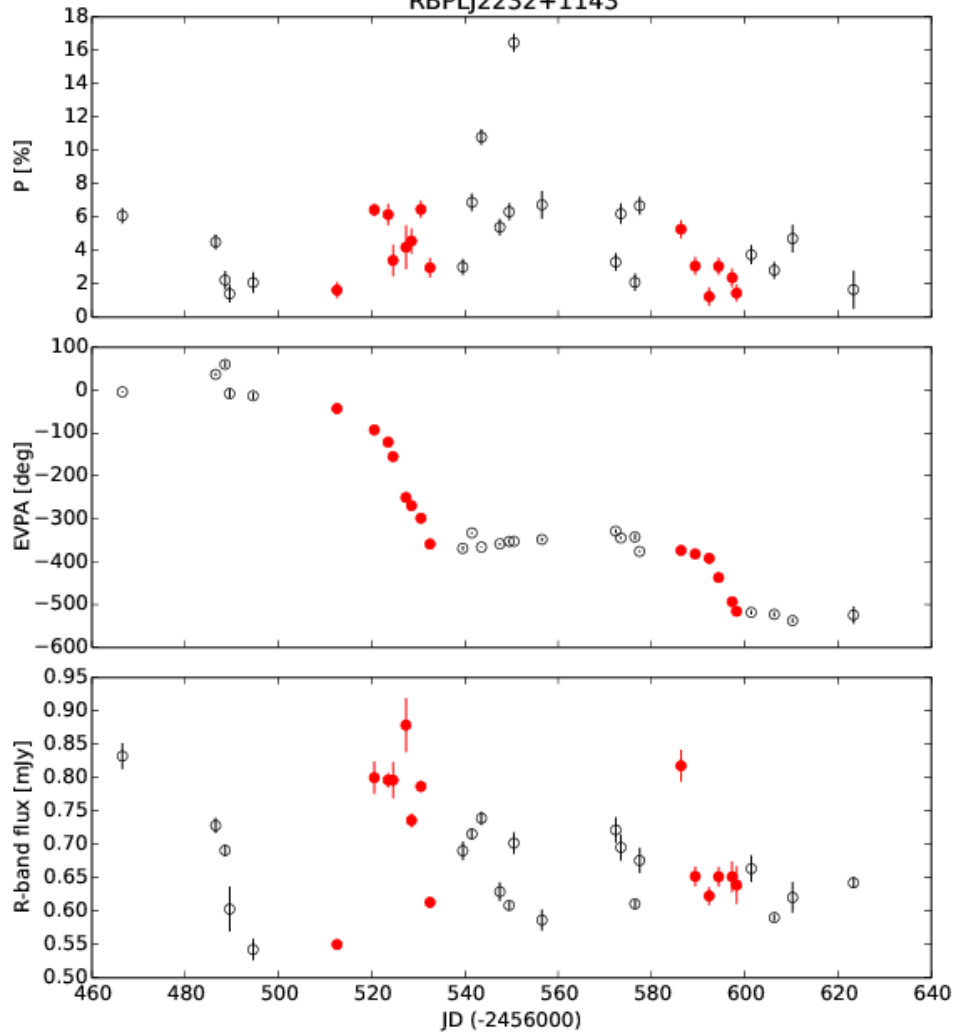
Pavlidou et al. 2014

- ✓ **Continuous EVPA change > 90°**

- ✓ **Comprised by ≥ 4 measurements with significant swings between them**

- ✓ **Start/End points defined by x5 change in slope OR change in slope sign**
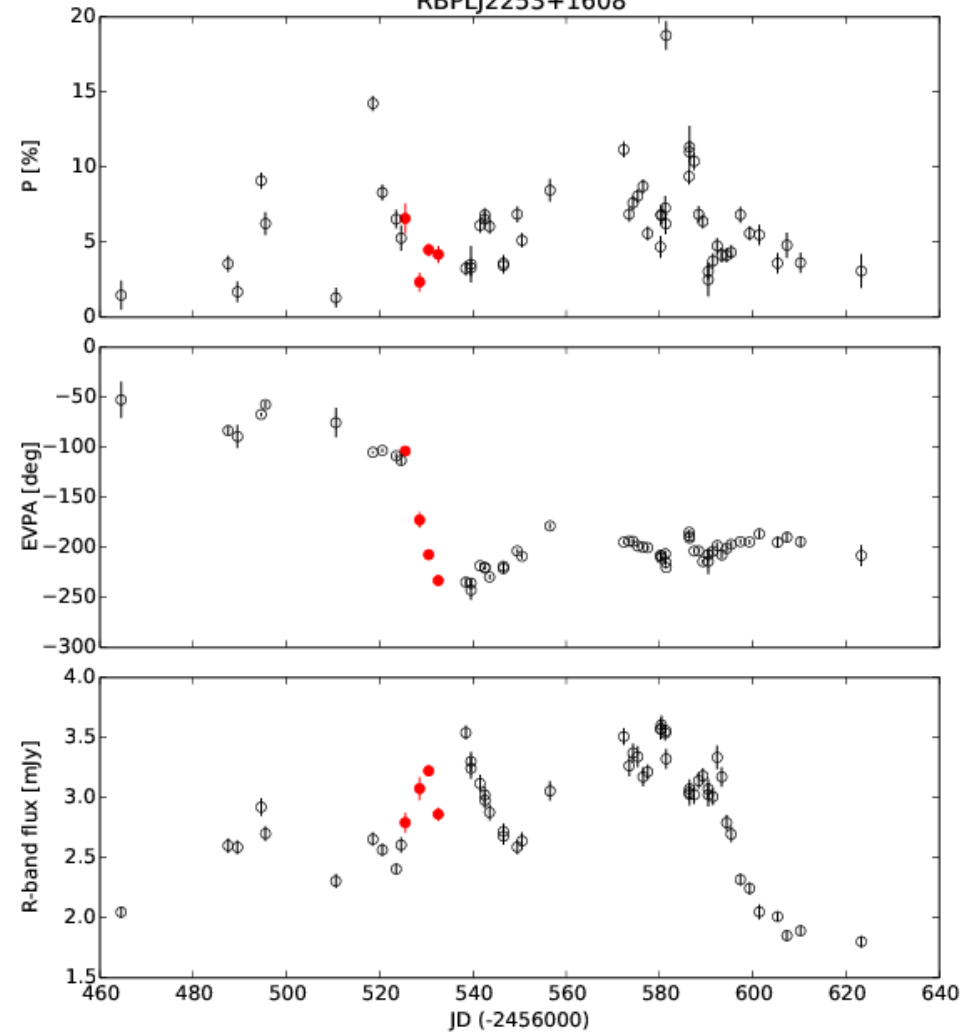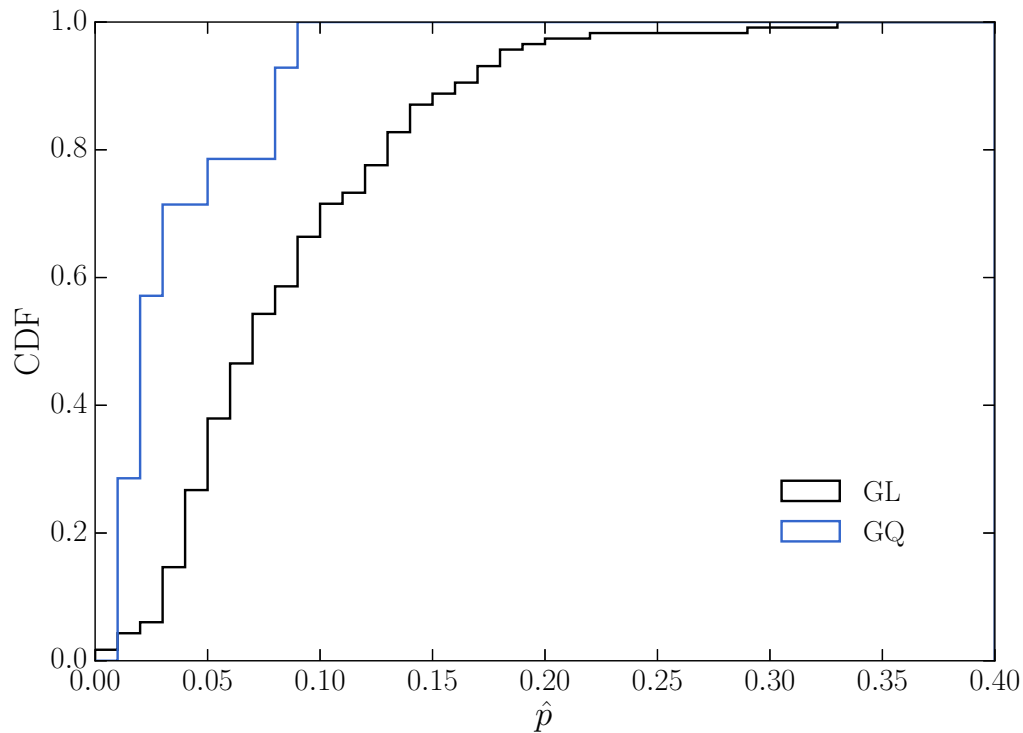
Blinov et al. 2015

CTA 102

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Median p of γ-loud blazars almost **x3** median p of γ-quiet blazars

Median p, γ-loud: 0.074
Median p, γ-quiet: 0.025

different at >4σ

Angelakis et al. 2016

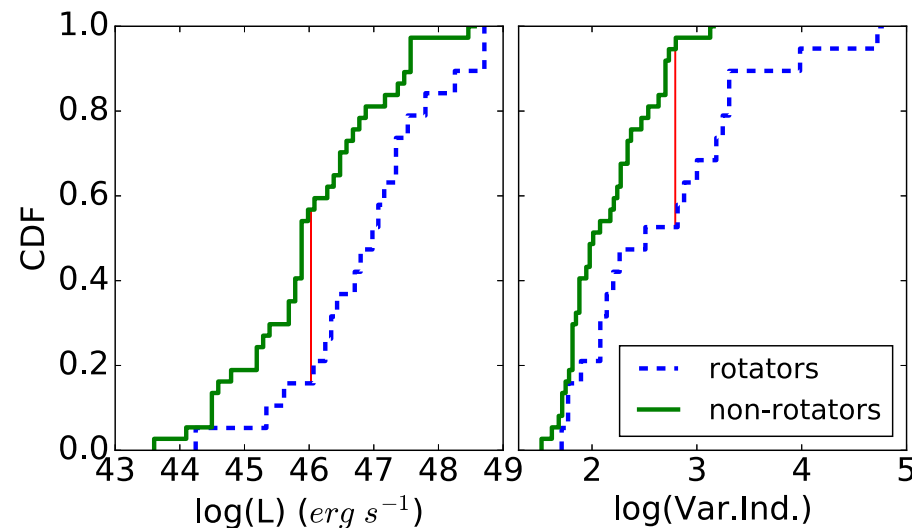# Do all blazars rotate?

Prior to RoboPol: 16 rotations in 10 blazars
3 years of RoboPol: + 40 rotations in 24 blazars

1. Avg. frequency of rotations slower than 7° per day:
   0.32/blazar-yr
   Chance to find rotations of that avg frequency only
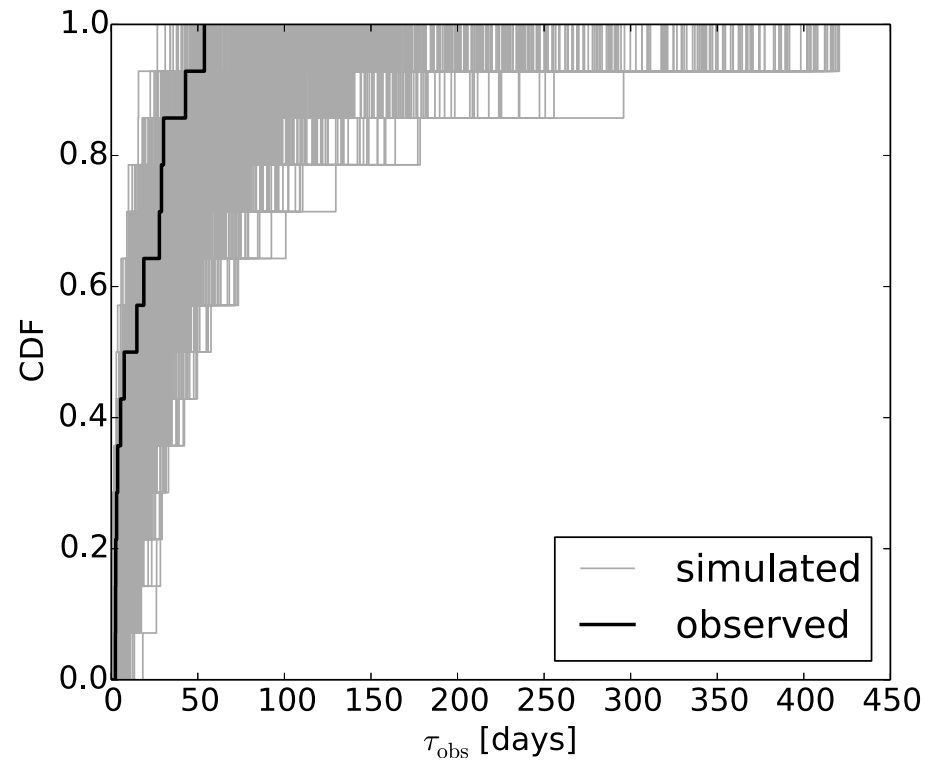   in those blazars that did rotate: **10^{-7}**

2. Rotators have different γ-ray properties than non-rotators

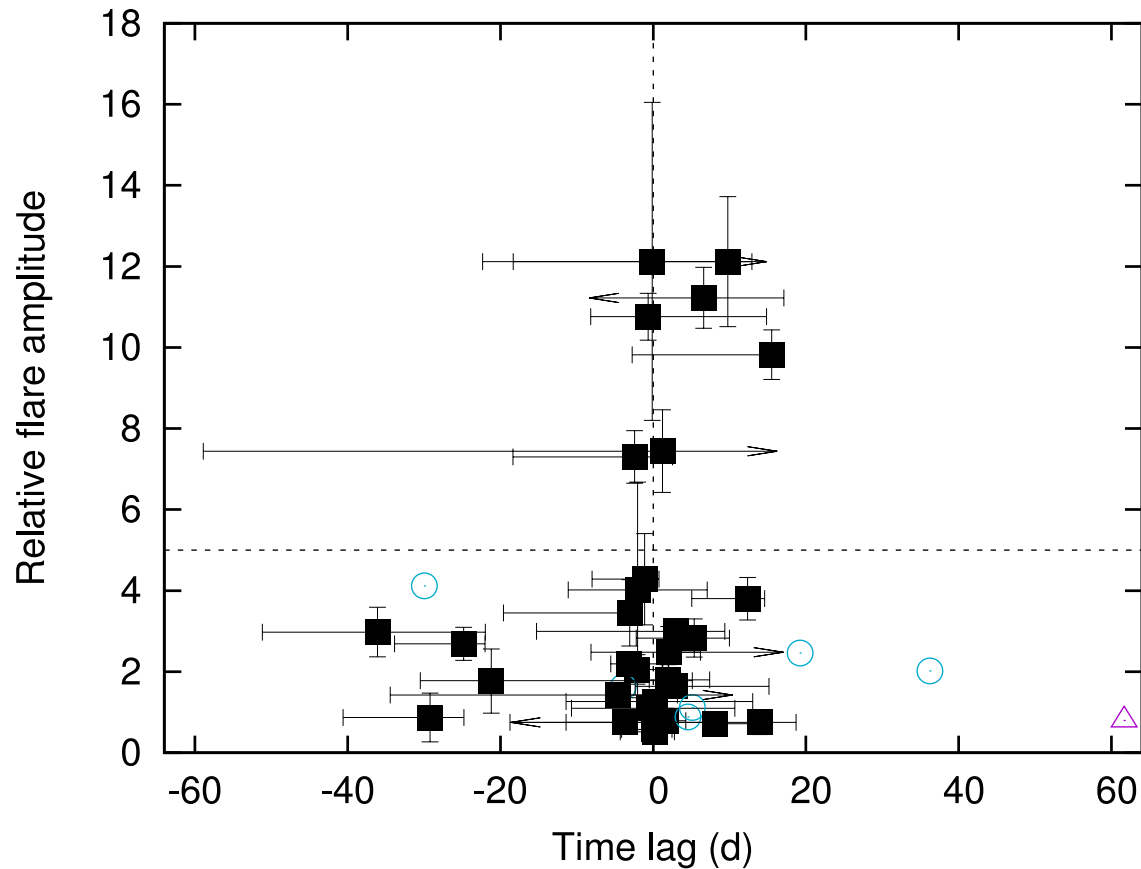Blinov et al. 2016

rotators are: **more luminous more variable**

P=2x10⁻⁴

Blinov 2016   **Lags too small to be random**

Blinov 2017

all lags consistent with zero

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Blinov 2017

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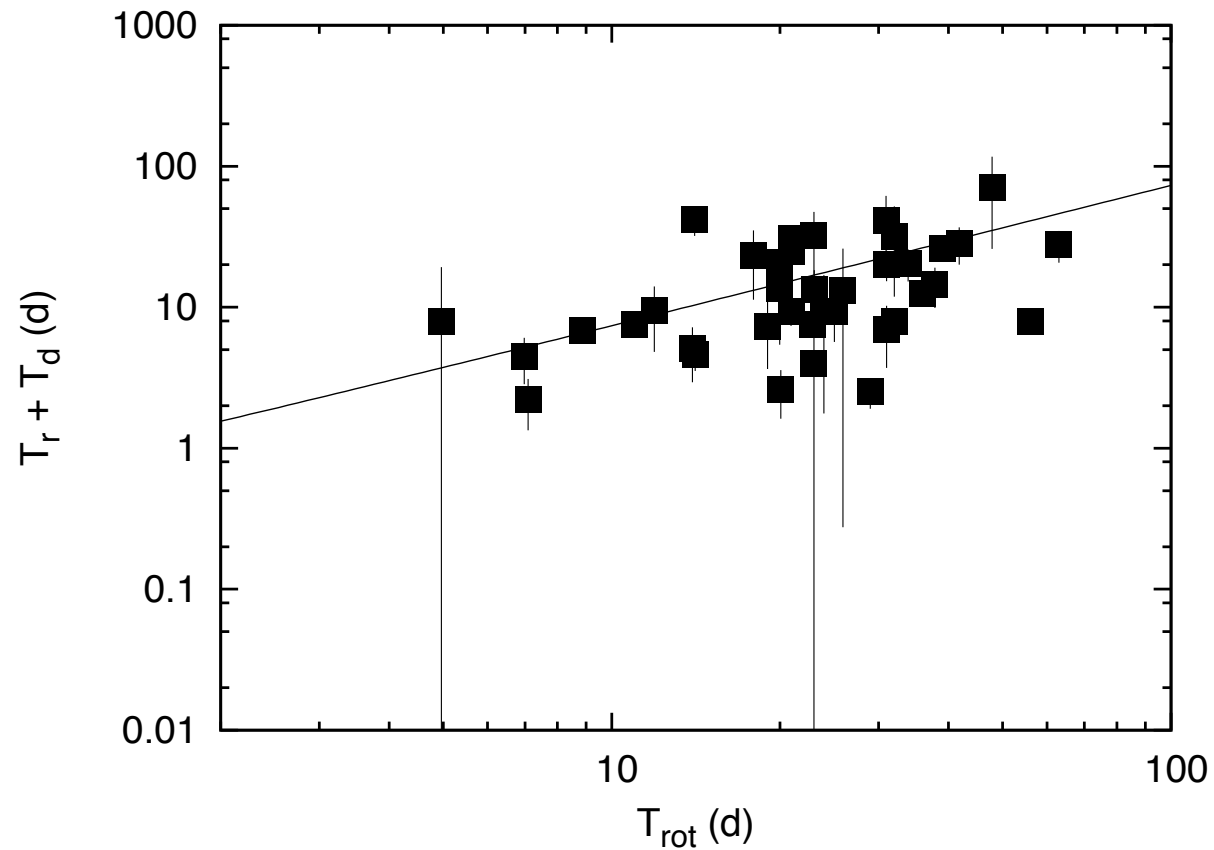
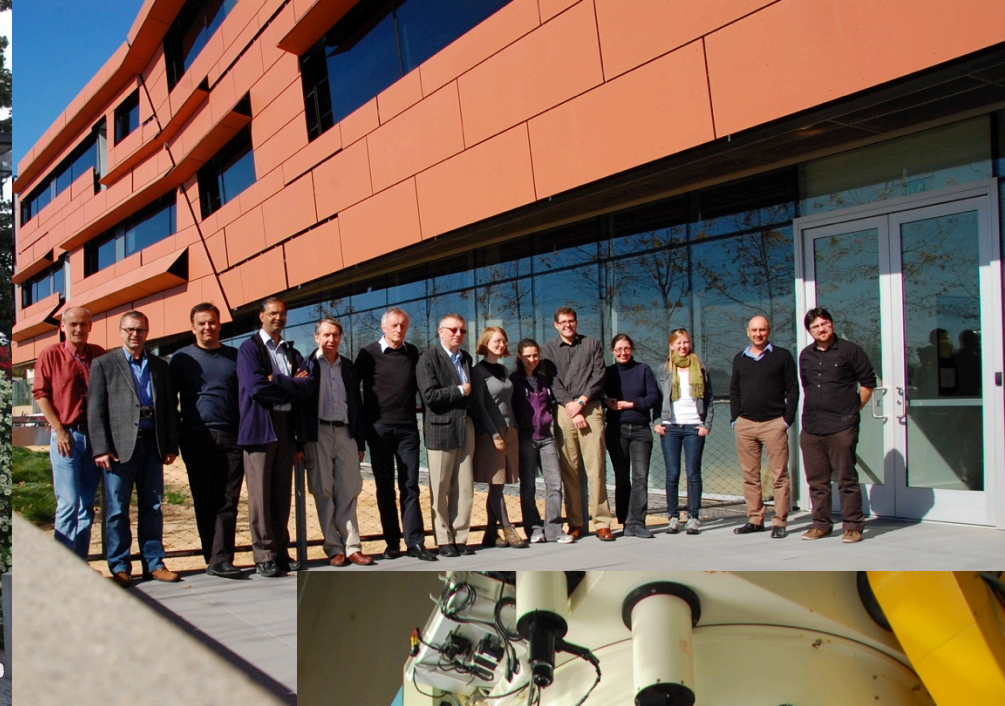Are γ-ray—loud and γ-ray quiet blazars different in optical polarization?
YES. γ-loud blazars are significantly more polarized

Do all blazars exhibit polarization rotations**?**
NO. Introducing the "rotator class of blazars":
rotates its polarization plane, brighter in γ-rays, more variable

Are polarization rotations related to γ-ray flares?
YES. Time lags with γ-flares too small for random associations.
Durations of rotations and nearest gamma-flares are correlated.

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