MWL studies of AGN

Locating the blazar zone

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CTA Key Science Program on Active Galactic Nuclei

Key Science Project will address:

-AGN physics at Very High Energies

-gamma-ray cosmology

-ultra high energy cosmic rays and fundamental physics

Observational strategies:

1. Long-term monitoring

2. High-quality spectra

3. AGN flare programme

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Outline

1. Where does the dissipation occur, where is the blazar zone located?
   - BLR absorbs gamma-rays => signatures in gamma-ray spectra and no VHE emission
   - Multiwavelength light curves => timing of the gamma-ray flares with respect *to events for which we know the location = VLBA*
2. Optical polarization to support VHE observations, why?
   - What is the mechanism of the optical rotations?
   - What is the mechanism of the fast VHE flares?
   - Are the two connected?

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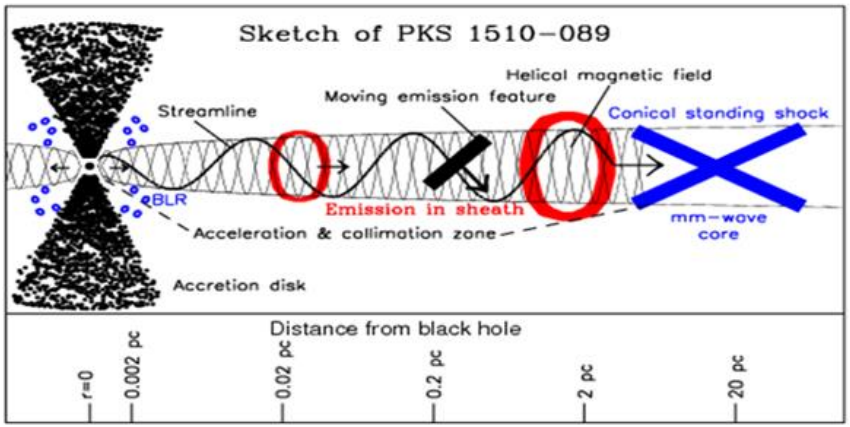
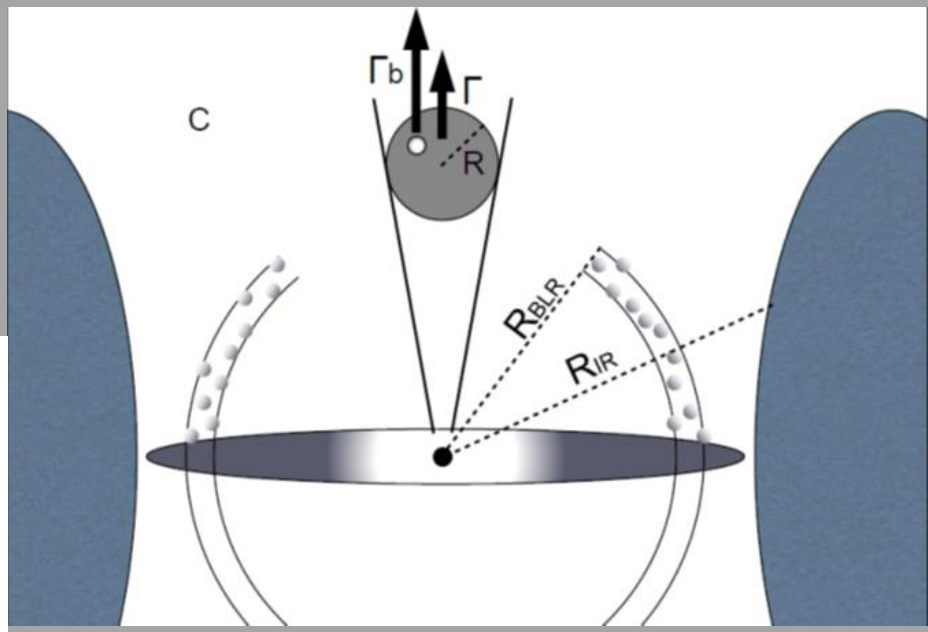
Location





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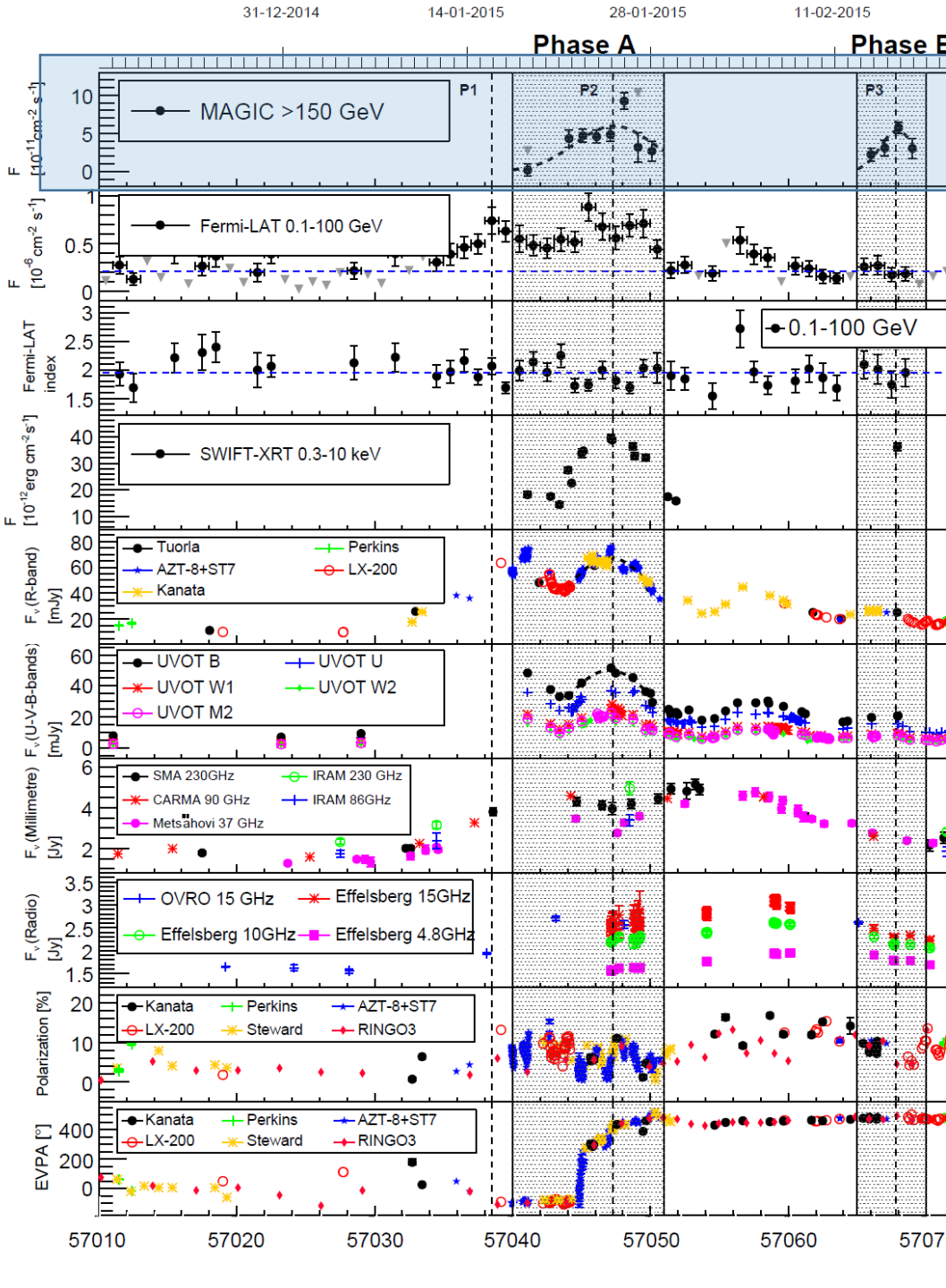
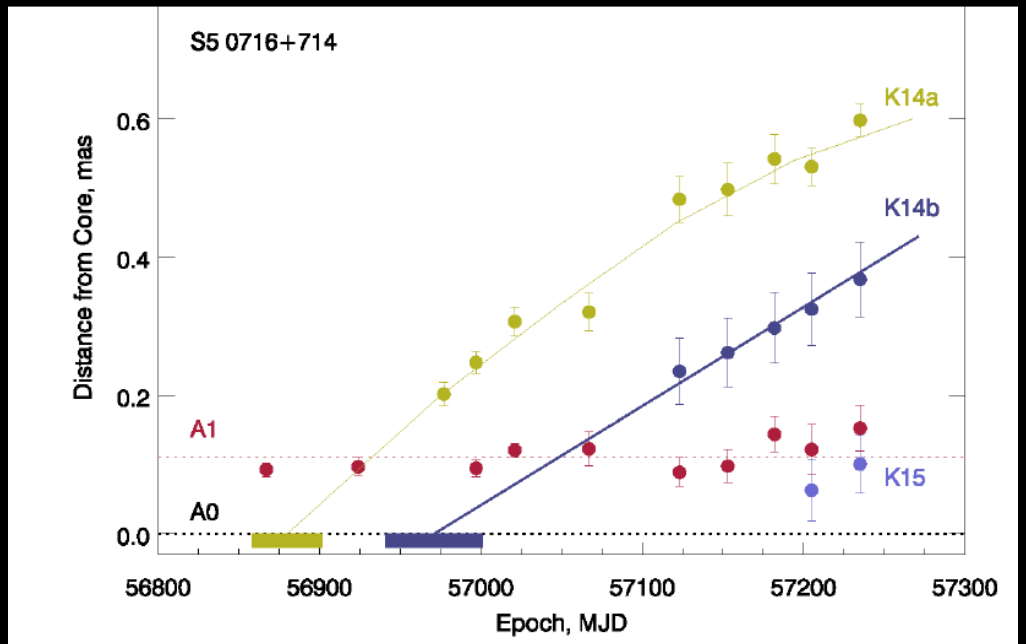
S50716+714 flaring state in January 2015

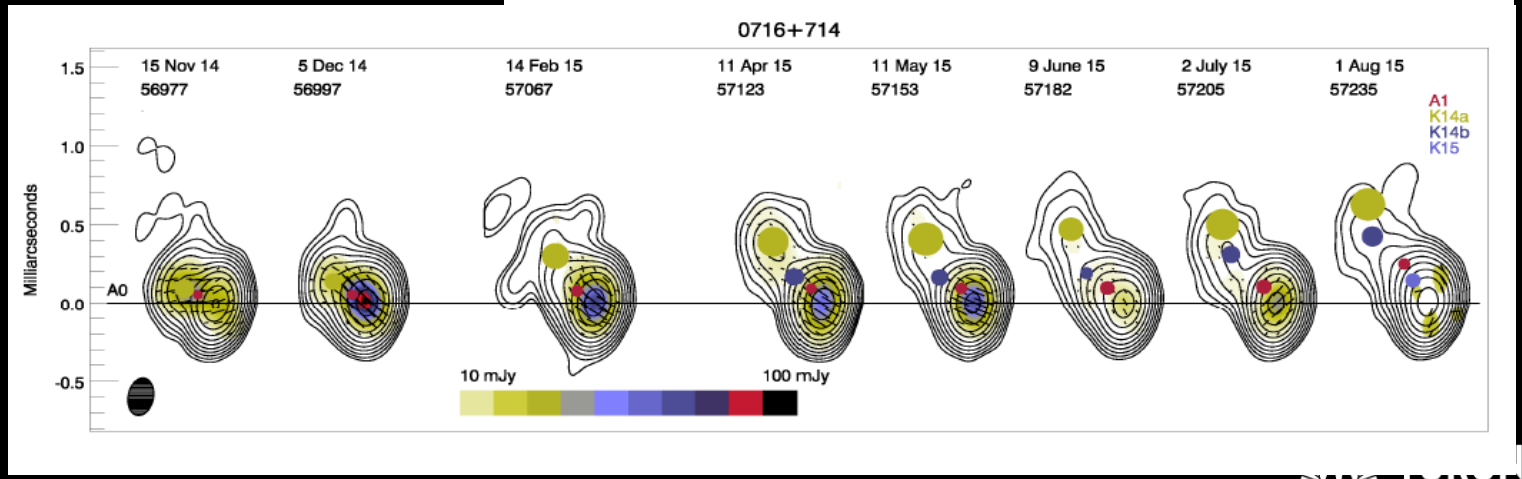
- High state (radio, optical, GeV gamma-rays) started in the beginning of January 2015
- Phase A: flare in radio, optical, X-rays, gamma-rays, VHE gamma-rays, very fast rotation of optical EVPA
- Phase B: flare in X-rays and VHE gamma-rays



What was happening in the jet?

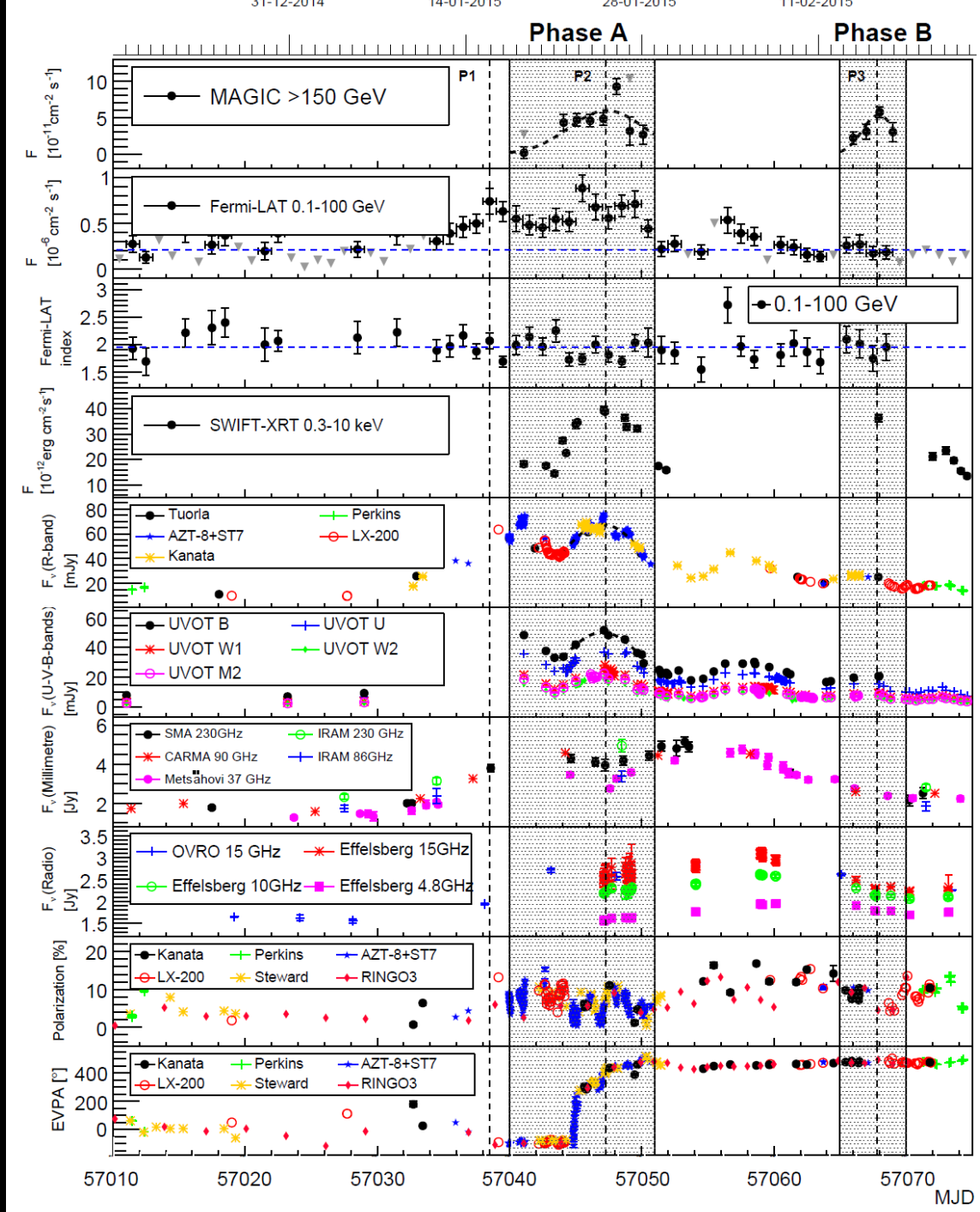
- Component K14b passes through the stationary feature A1 at MJD 57050+-30 days
- Average size of A1 is (0.049+-0.020) mas, it will take K14b (35+-13) days to pass A1





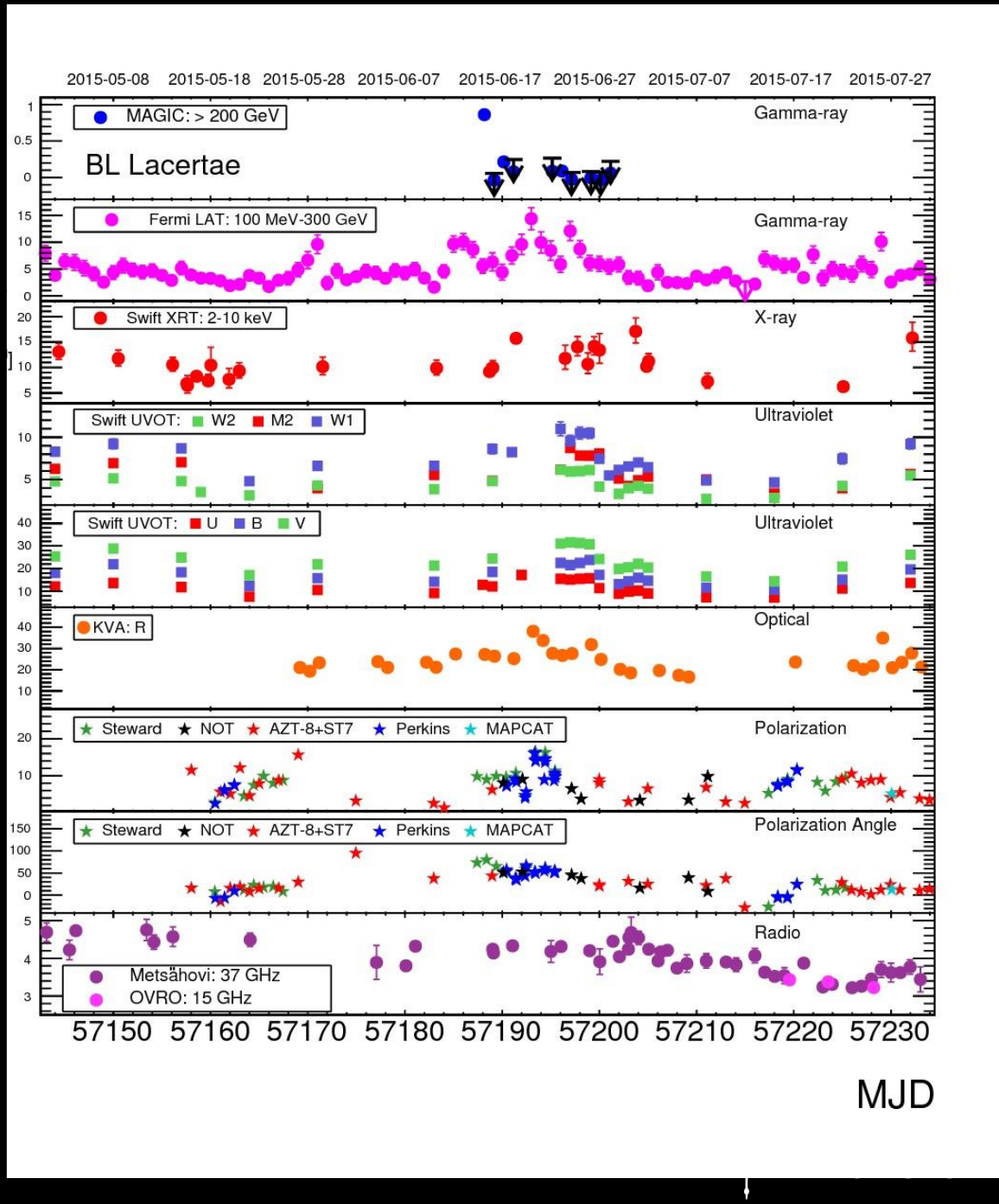
Light curves +VLBA

- The time it takes for K14b to pass A1 fits very well with the duration of 34 days of the elevated gamma-ray flux in the Fermi light curve MJD 57032 to 57066.
- In this scenario the TeV detections can be associated with the entrance and exit of the superluminal knot in and out of the recollimation shock (A1).



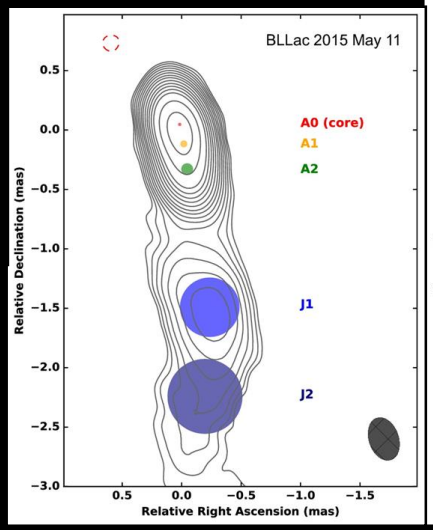
BL Lacertae flaring state in June 2015

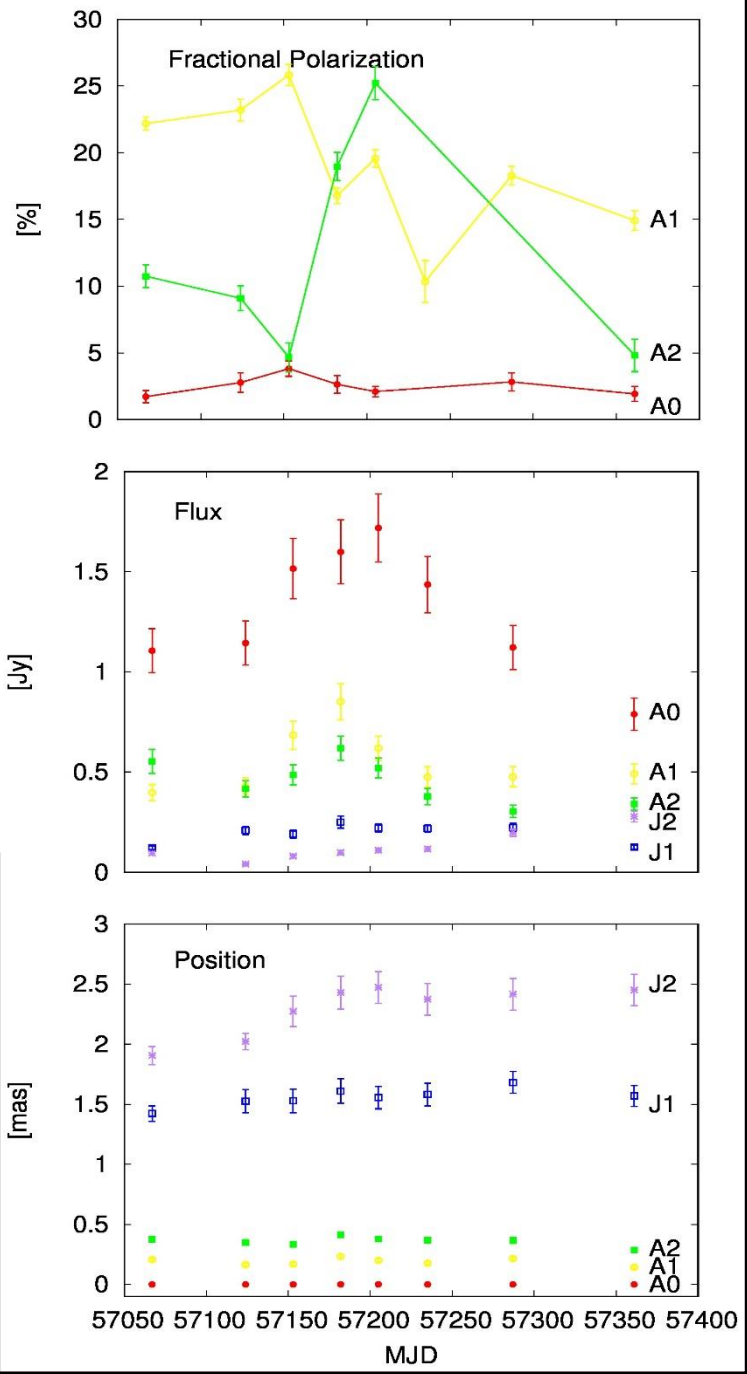
- High state (optical, GeV gamma-rays) started in the May 2015
- Radio, X-rays no major flares
- Optical polarization: rotation of EVPA with >90 degrees, starting around the night of fast VHE flare



What was happening in the jet?

- No clear ejection of new component, but the quasi-stationary components A1 and A2 make it very difficult to detect new components.
- Brightening of the core
- Increase of polarized flux density
- Maybe a new component anyhow?





Comparison with the other two fast VHE flares from BL Lacertae

	Peak flux >200GeVx10^{-10} /ph/cm2/s	Decay Timescale Minutes	Gamma+ optical	X-ray	Optical polarization	VLBA jet
VERITAS f1 2011	3.4+-0.6	13+-4	High	Low	Drop in %, rotation 90 degrees	New knot
MAGIC 2015	1.5+-0.3	26+-8	High	Low	Drop in %, rotation 90 degrees	Brightening of the core, Tentative new knot
VERITAS f2 2016	4.2+-0.6	36+-8	High	Low	Drop in %, rotation 90 degrees	Brightening of the core, Tentative new knot

Observational bias?

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Monitoring with CTA for locating the blazar zone

- Difficult to conclude on the connection, when most of the observations are during the flares
- Difficult to conclude on the connection, when VHE light curves mostly consist of upperlimits
- With CTA: unbiased monitoring with great sensitivity
- The MWL monitoring observations to support the CTA monitoring are crucial

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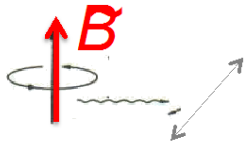
Optical polarization to support VHE gamma-ray observations, why?

Optical Polarization in Blazars

Blazars: Optical = Synchrotron : highly linearly polarized
polarization direction ? $\vec{B}$

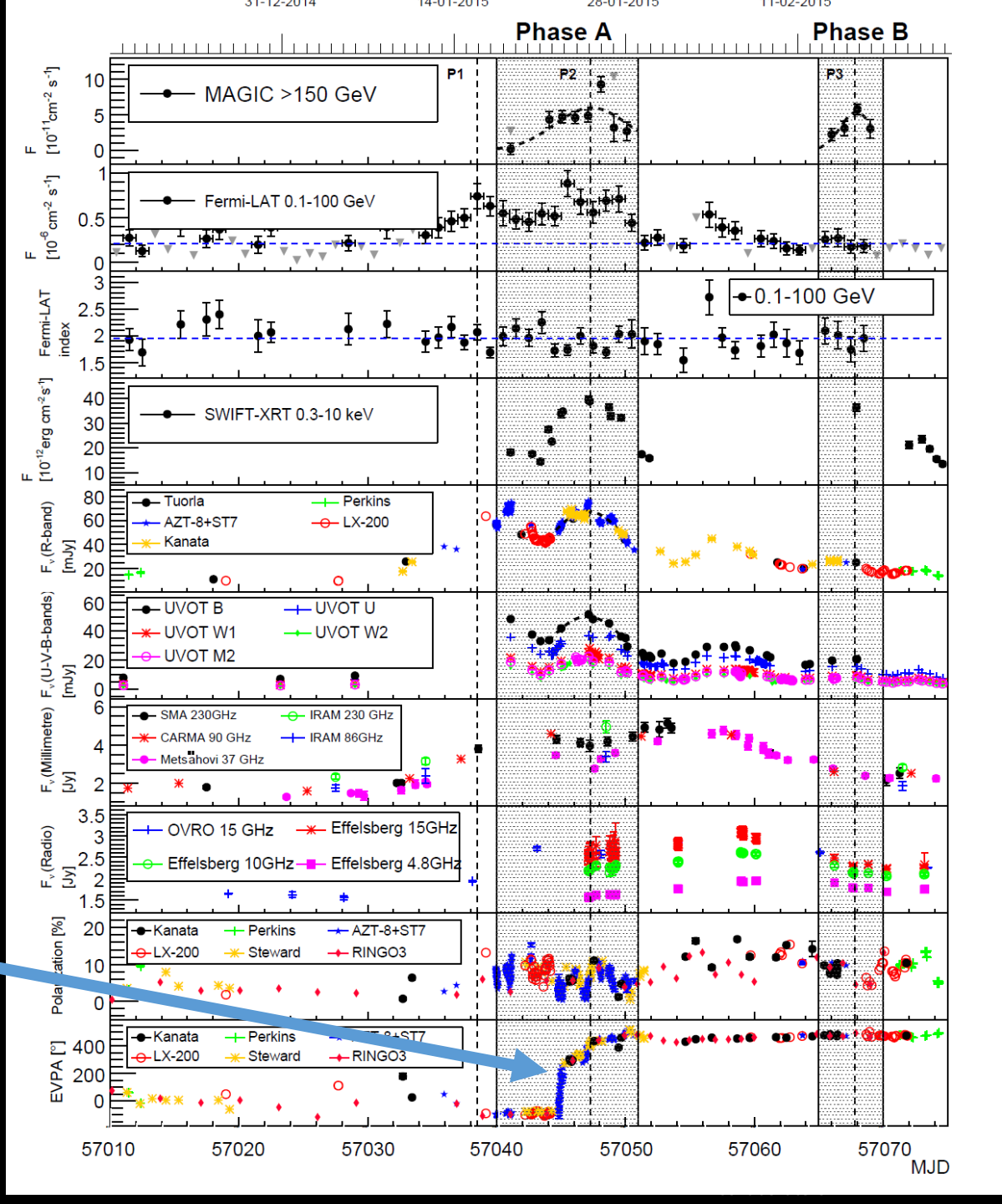


Optical polarization encodes information about:

- **geometry** of magnetic field in emission region
- **number** of emitting cells along line of sight
- degree to which magnetic field is **ordered**

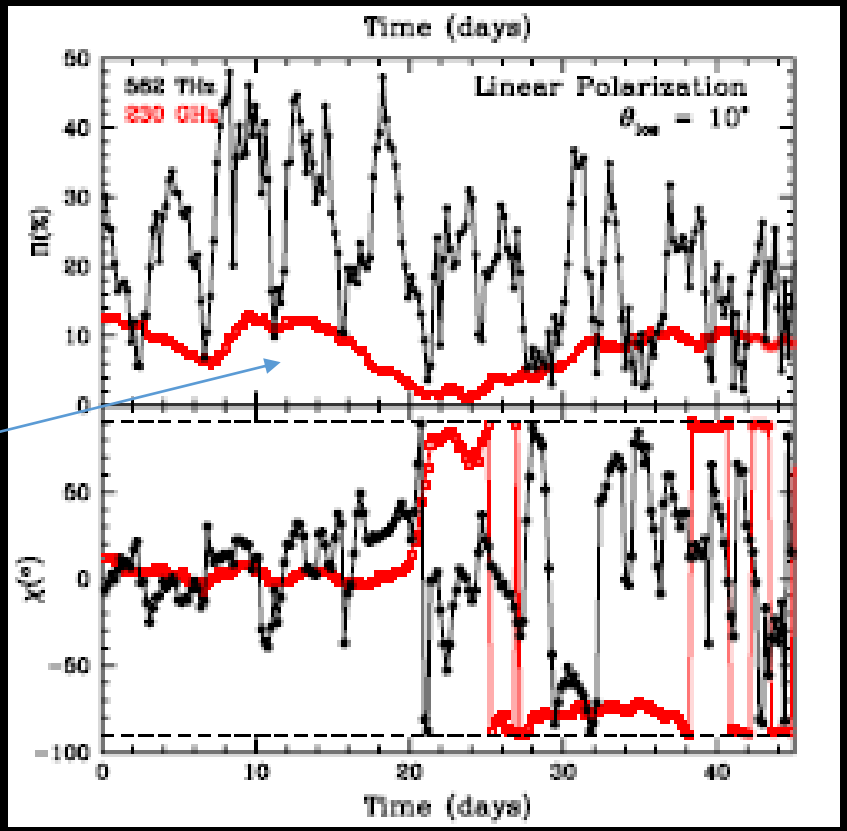
Optical polarization in blazars is ***variable***

Rotation at the time of VHE flare



Turbulent plasma crossing standing shock

- Turbulent magnetic field produces **stochastic variations** to the polarization angle and degree (Jones et al. 1985, Marscher 2014)
- **Expect**: an EVPA rotation of any length (but long rotations difficult), typically low polarization degree, rotation not smooth. **Detailed fits to data not possible**.
- Large number of objects needs to be studied to compare with the statistical properties of turbulence**.**



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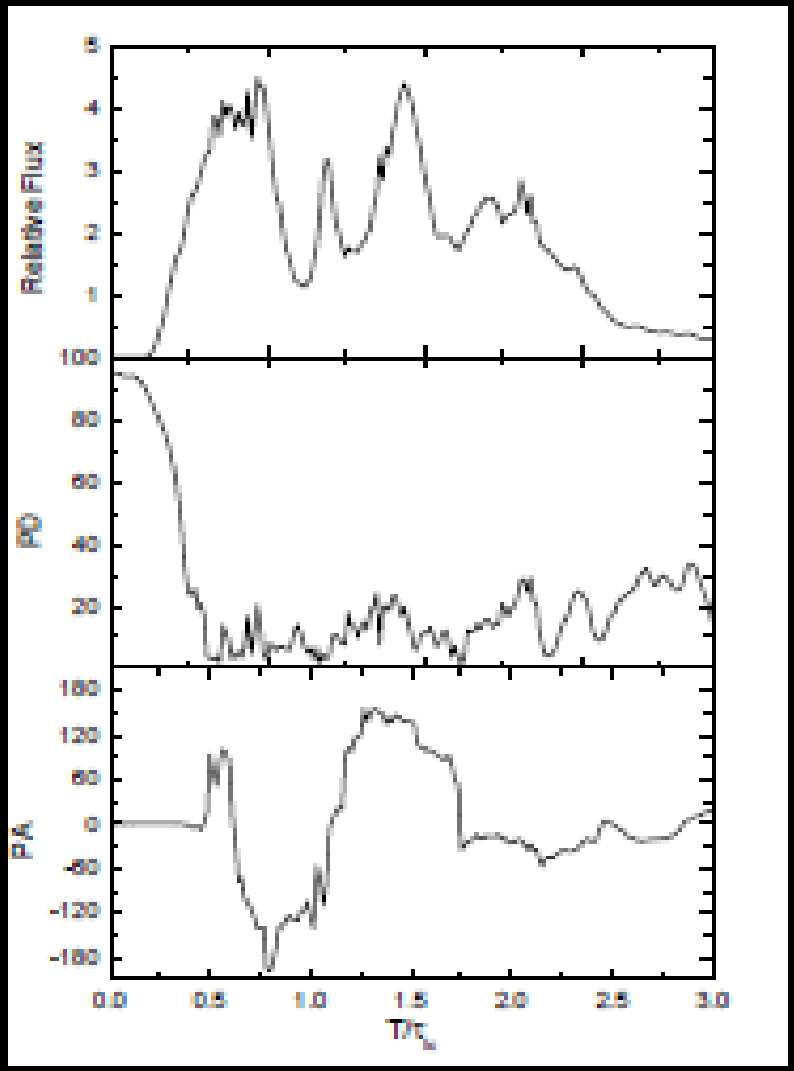
Magnetic reconnection

- ”In the magnetic reconnection scenario, while the plasmoid mergers can appear very stochastic and strongly dependent on the local plasma conditions, the polarization variations during one specific merger is quite systematic and can have a large PA shift. **Therefore, the magnetic reconnection polarization signatures possess both the smooth patterns that are dominated by one merger and the bumpy patterns that occur when a new plasmoid merger succeeds the old one.”**
- **Expect**: also long rotations (but short are also not a problem?), both smooth and bumpy patterns



Zhang, Li, Guo, Giannios, 2018, arxiv:1807.08420

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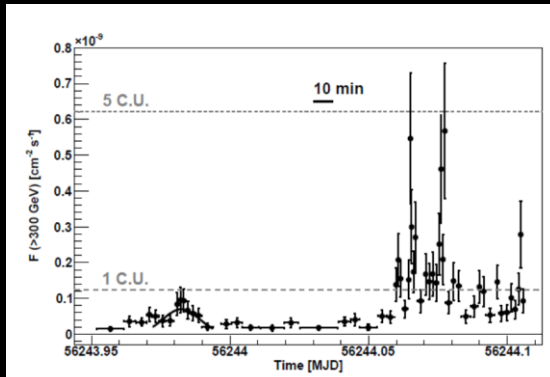
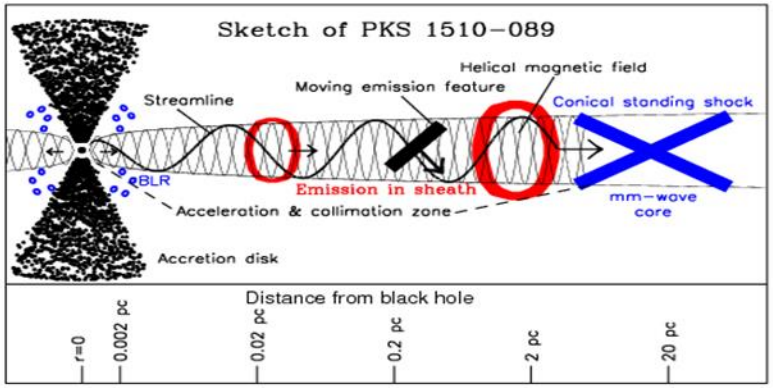
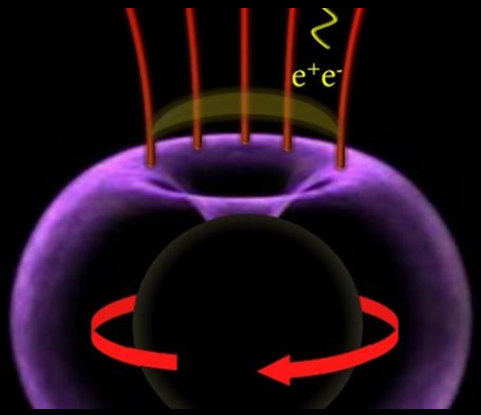
Fast VHE gamma-ray flares

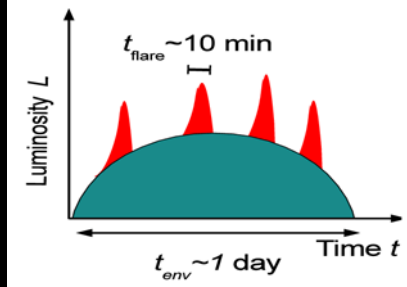
- Observed from FSRQs, BL Lacs and radio galaxies
- Variability timescales less than 30 minutes, fastest ~5 minutes
- Mechanism not known (but many suggested)

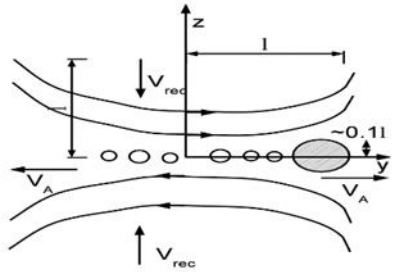


Aleksić et al. 2014. *Science*









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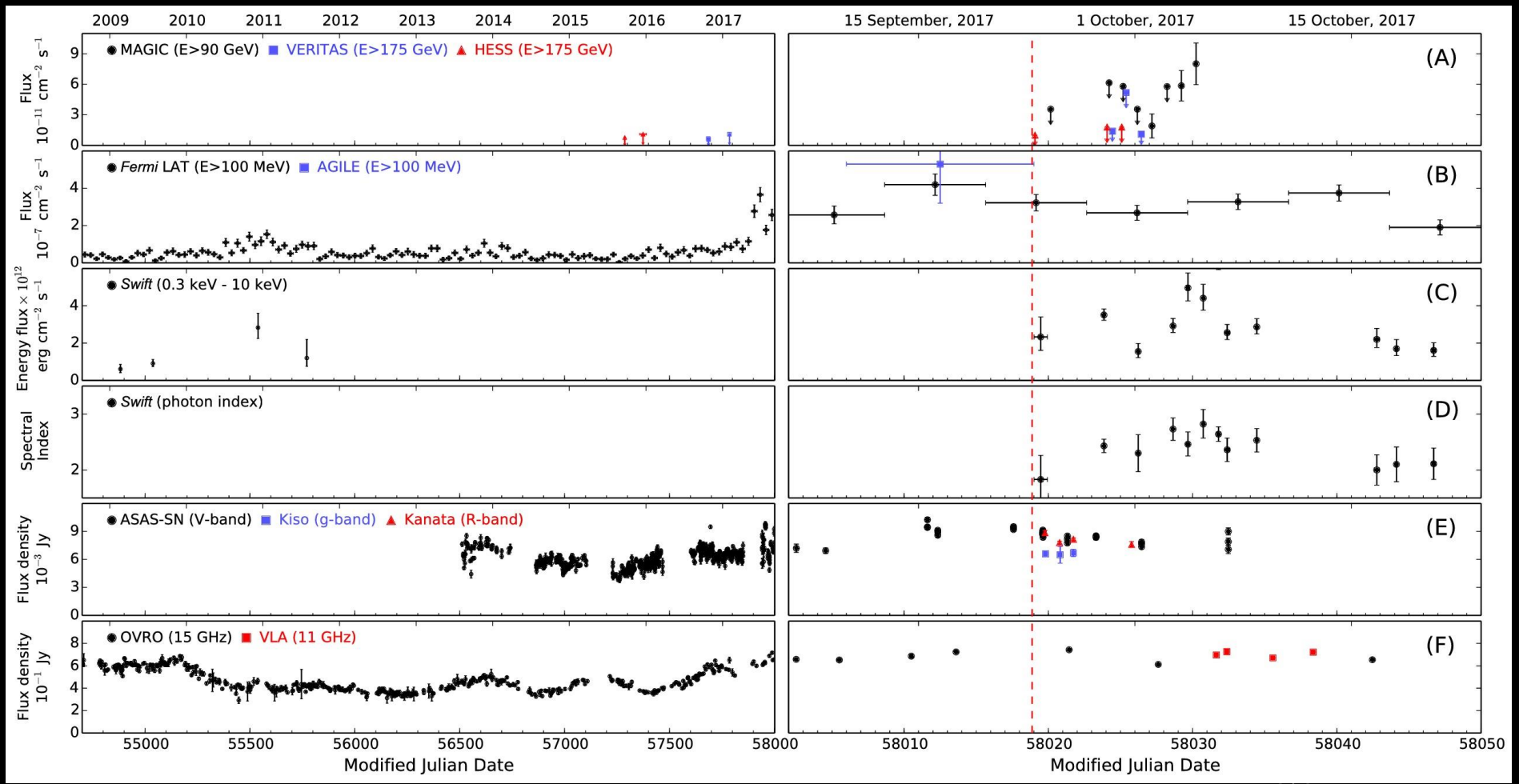
Always nice polarization data for all interesting flares? NO



TXS 0506+056 Aartsen et al. 2018

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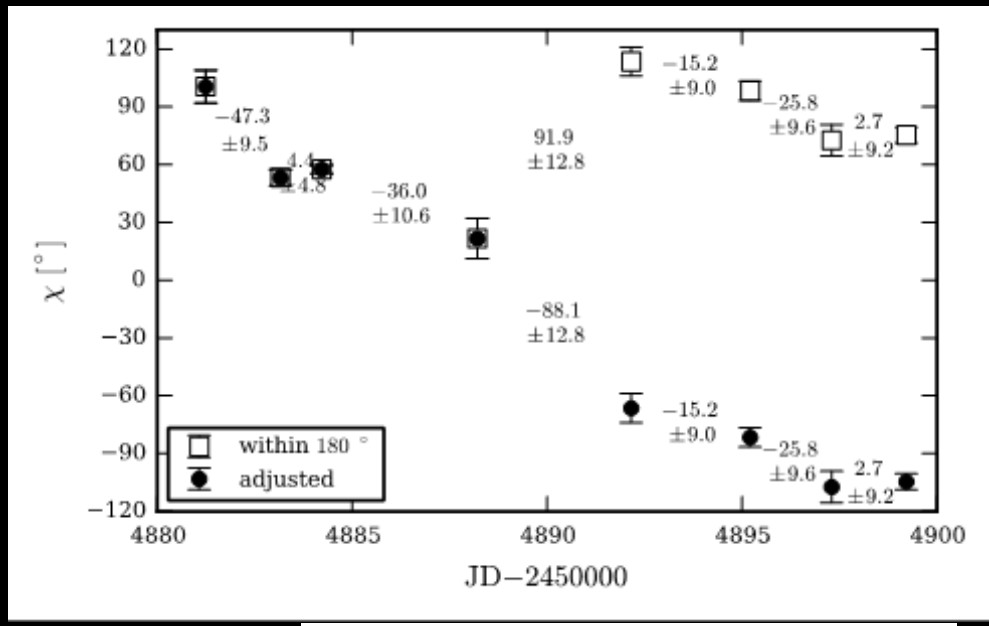
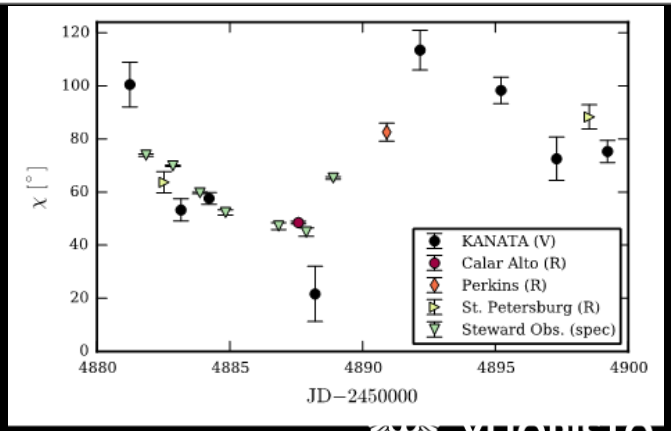
Always nice polarization data for all interesting flares with sufficient cadence?

- Observations show that polarization varies in daily scales and even intra-night variability is seen
- Moreover, poor cadence can lead to wrong conclusions





Kiehlmann et al. 2016

Optical polarization observations to support CTA

- Mechanism of the optical rotations and VHE flares unknown, could they be connected?
- To answer we need statistical approach, the complicated models are not ”one event” models. Observations of large sample of flares and rotations!
- AGN KSP needs long-term optical monitoring both in photometry and polarimetry, ~1m class onsite telescope with good polarimeter is necessary to obtain the simulatenous data. But in addition we need large network of optical telescopes to improve the cadence,

please join!

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