The study of magnetic field direction in blazar jets by identifying optical outbursts using the l1 trend filter

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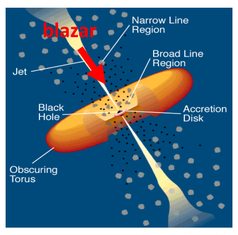
We investigated a systematic relationship between the position angle (P.A.) of optical polarization of the outburst component and that of radio jets in blazars. In the optically thin domain, P.A. is perpendicular to the direction of magnetic field. Hence, we can study the universal field structure in the jet by investigating a correlation between P.A. of the outburst component and the direction of radio jets. However, it is difficult to uniquely identify the outburst components because blazars show very irregular variations. Here, we identified optical outbursts of blazars using the l1 trend filter and the wavelet analysis. The l1 trend filter is a filtering method to estimate the turning points of time-series data. We used the optical polarimetric data observed with Kanata telescope in Hiroshima, Japan. Our targets consist of approximately 40 FSRQs and BL Lacs. The observation period is approximately six years (2008 to 2014). As a result, we identified approximately 450 outbursts and their P.A. We compared them with the position angles of radio jets which were referred from the public VLBA data. We surveyed the distribution of the angular difference between P.A. and radio jets, and found no deviation from a uniform distribution. We obtained similar results even for each individual object, for gamma-ray loudness.

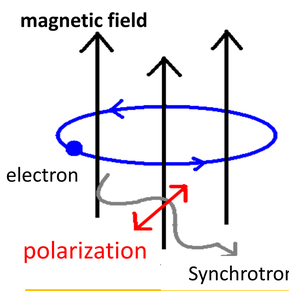
Active galactic nuclei(AGN)

There is a large mass black hole at the center of the galaxies. It has a complex structure such as an accretion disc, torus, and jet.



Urry et al.1995

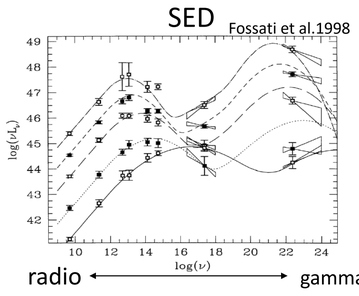
*Seyfert
*Liner
*Radio galaxy
*Quasar
*Blazar(FSRQ, BL Lac)



polarization ⊥ magnetic field

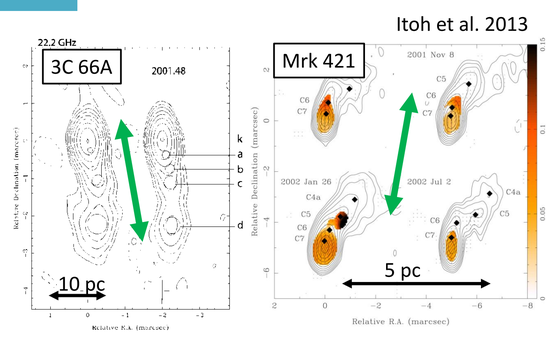
SED

Fossati et al.1998



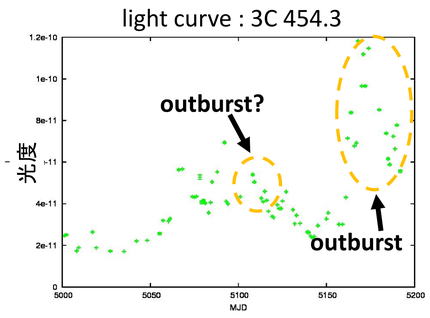
Past study & motivation

Itoh et al. 2013



The P.A. of large scale outbursts is parallel to the direction of the jets.
Demerit : Only few events.

light curve : 3C 454.3



Studying small scale outbursts
Demerit : The variation pattern is so irregular that it is difficult to identify outbursts

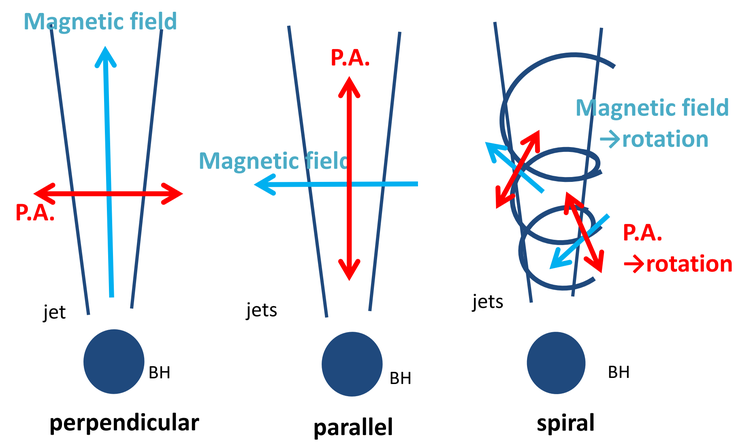
↓

We identified optical outbursts using the l1 trend filter and the wavelet.

Optical polarization & magnetic field

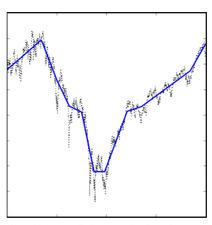
Relation between the jet and the magnetic field
Dominant magnetic field

- parallel to the jet -> PA (always) perpendicular to the jet
- perpendicular to the jet -> PA (always) parallel to the jet
- helical ->rotation or swing of PA, and random PA



L1 trend filter

*Estimate the turning points of time series data
*Taking a minimum of the following function
(the model is identical to observations with λ=0)
*We can identify flares only with a parameter, λ



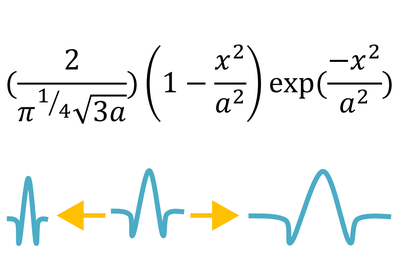
S.J.Kim,K.Koh,S.Boyd,D.Gorinvsky et al.2009

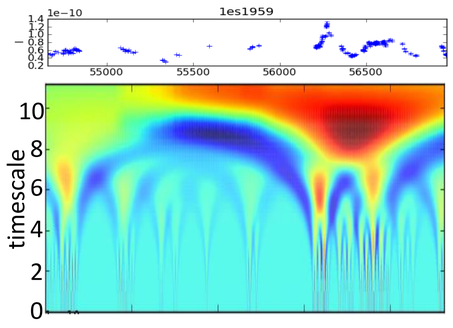
$$\sum_{i=1}^{n}(y_i - x_i)^2 + \lambda \sum_{i=2}^{n-1} |x_{i-1} - 2x_i + x_{i+1}|$$

Wavelet

*Basis: the Ricker function
*We can identify flares by assuming a time-scale

$$\left(\frac{2}{\pi^{1/4}\sqrt{3a}}\right)\left(1-\frac{x^2}{a^2}\right)\exp\left(\frac{-x^2}{a^2}\right)$$





Observation

optical *object~42 blazars

Kanata(1.5m)

- HOWPol
- TRISPEC

radio

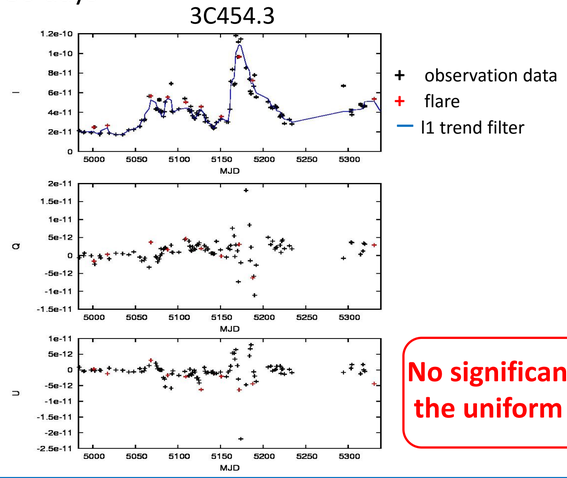
VLBA(Very Long Baseline Array)
We used public VLBI data.

Result

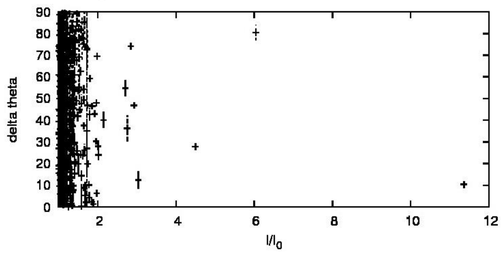
L1 trend filter

Flare(definition)
*The peaks in the filtered light-curve.
*The peaks having neighbor data points within 30 days

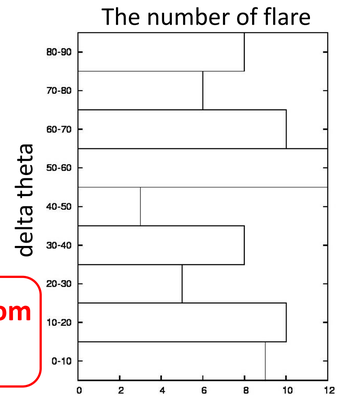
3C454.3



Fractional amplitude of the flare v.s.
Polarization angle measured from the direction of radio jets



The number of flare

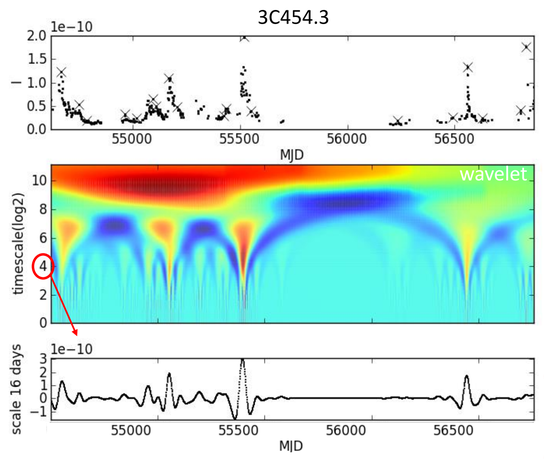


No significant deviation from the uniform distribution

Wavelet

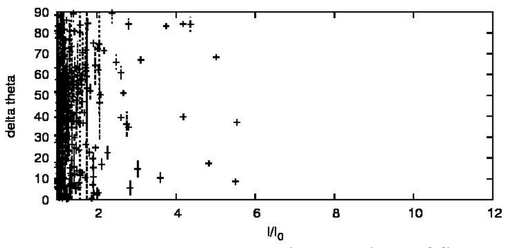
Flare(definition)
*The data points which are closest to the peaks in a time-scale of scale gram

3C454.3

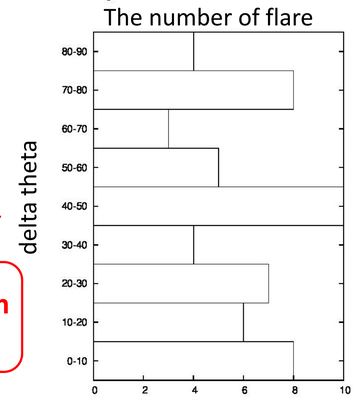


▪ observation data
× flare

Fractional amplitude of the flare v.s.
Polarization angle measured from the direction of radio jets



The number of flare

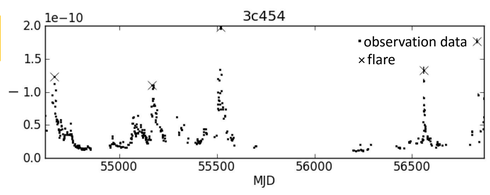


No significant deviation from the uniform distribution

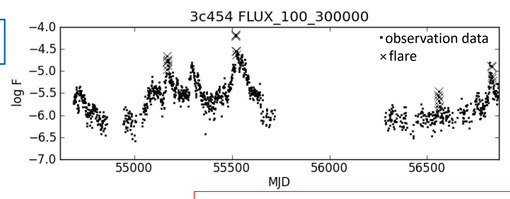
Gamma-ray loud v.s. quiet flares

*We used the public light curves obtained by Fermi.
(http://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/)
*Optical flares accompanied by gamma-rays -> gamma-ray loud flares
*Optical flares without gamma-ray counterpart -> gamma-ray quiet flares

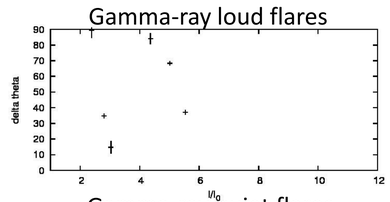
Kanata



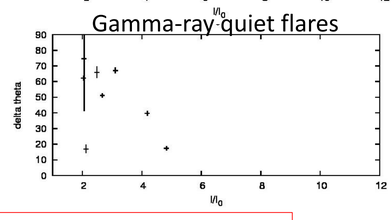
Fermi



Gamma-ray loud flares



Gamma-ray quiet flares

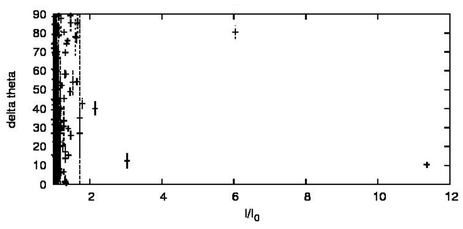


No significant deviation from the uniform distribution

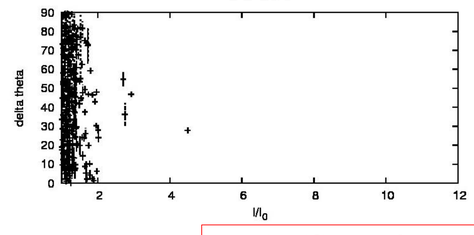
FSRQ vs BL Lac

L1 trend filter

FSRQ

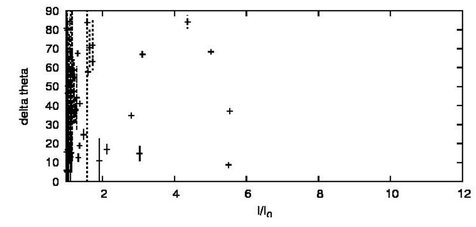


BL Lac

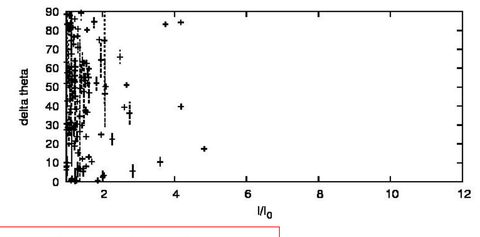


wavelet

FSRQ



BL Lac



No significant deviation from the uniform distribution

We found no universal correlation between the position angle of polarization of the outburst component and the direction of radio jet. We surveyed the distribution of the angular difference between the position angle of polarization to radio jets, and found no deviation from a uniform distribution. And we obtained similar results even for each individual object, for gamma-ray loudness.