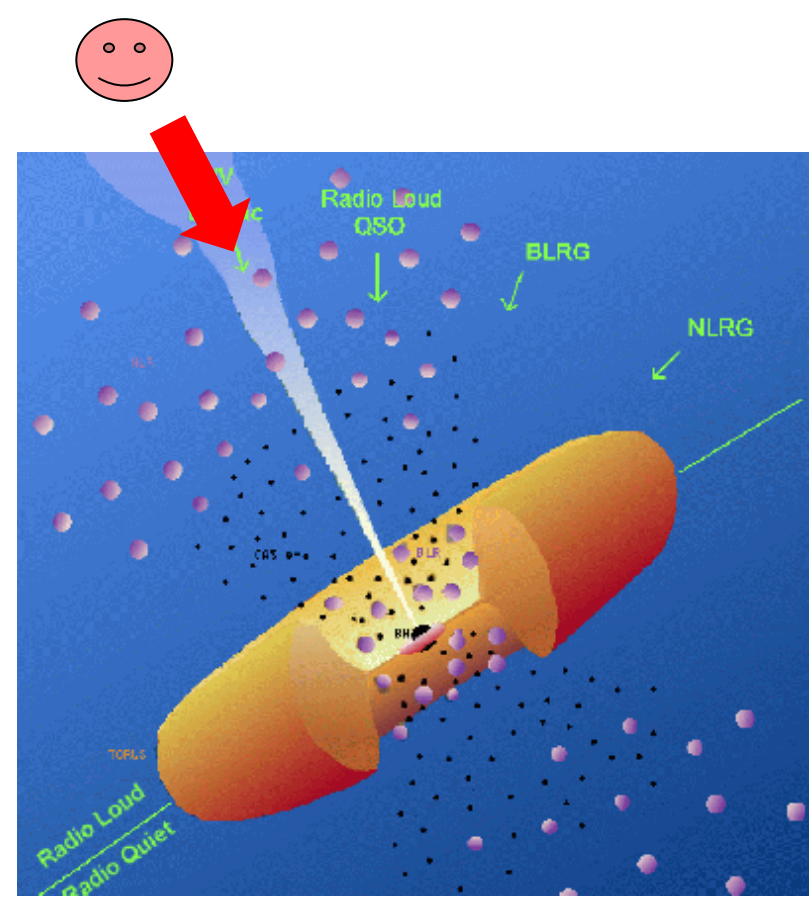# 4-year optical-infrared photometric and polarimetric behaviors of a gamma-ray blazar 3C 454.3

M. Sasada (Kyoto Univ.), Makoto Uemura, Yasushi Fukazawa, Ryosuke Itoh,
Koji Kawabata, Michitoshi Yoshida (Hiroshima Univ.)

sasada@kusastro.kyoto-u.ac.jp

1. Introduction

Properties of blazar

1. Broad band radiation
2. Rapid and violent variability
3. High polarization

Blazar :
A subclass of AGNs. A relativistic jet is viewed at a small angle to the line of sight.
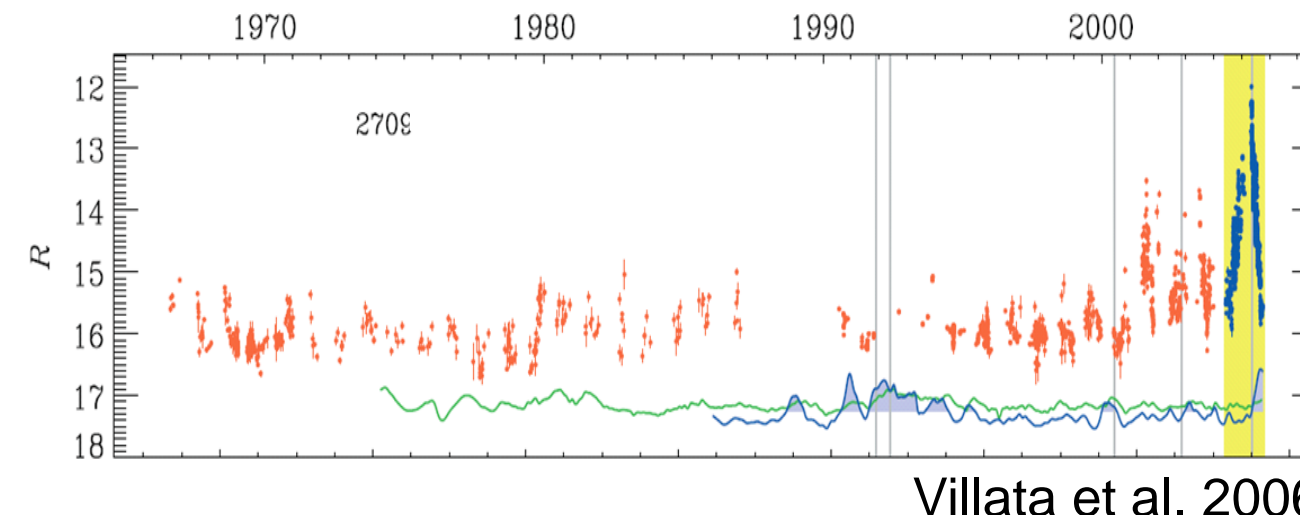
Radiation in the optical band
- Synchrotron radiation
  → High polarization

The polarization observations allow us to probe the magnetic field in the jet.

3C 454.3
- One of the most famous blazars
- Redshift z = 0.859
- Several large-amplitude outbursts were reported in 2005, 2007, 2008, 2009 and 2010.

Villata et al. 2006

2. Observation

Advantages of Kanata/TRISPEC
- TRISPEC has imaging-polarimetry mode.
- Simultaneous three-color (one optical and two near-infrared bands) observation.
- Long term and high density monitoring.
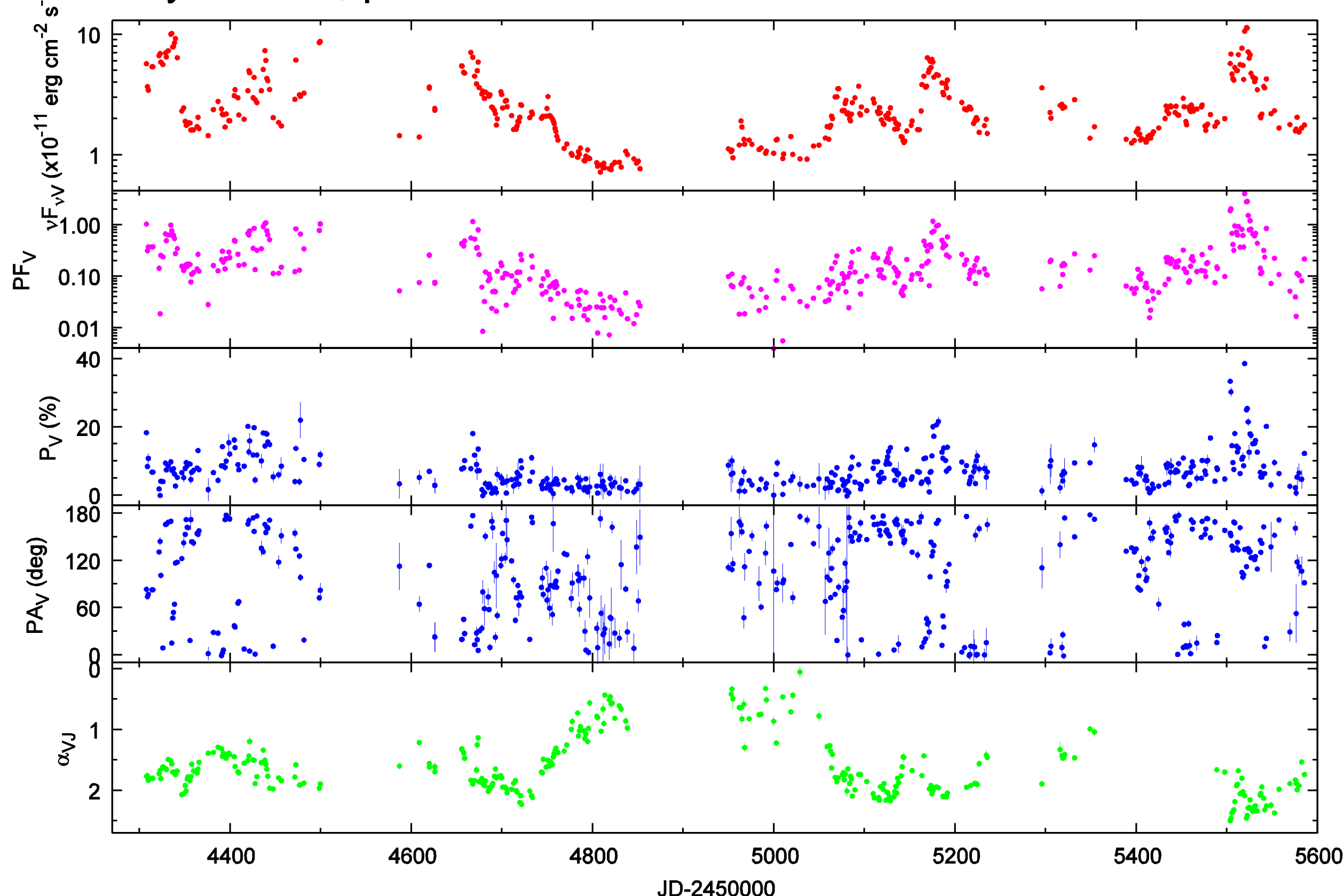
Kanata telescope (1.5-m)

@Higashi-Hiroshima Observatory, Japan

We have monitored 3C 454.3 in photopolarimetric mode since 2007. Then, we detected the several outbursts.

3. Results of 4-year Monitoring of 3C 454.3

4-year flux, polarization and color variations of 3C 454.3

Observational Feature
- Both flux and polarization show violent variations.
- There are four apparent outbursts in 2007, 2008, 2009 and 2010.
- The peak flux is 20 times larger than the quiescent level.
- The polarized flux also shows a rapid variation.
- During the outbursts, degrees of polarization became high (P_{max}>40%).
- Rotations of the polarization vector during the outbursts were observed several times.
- The object became bluer in its faint state probably because of the contribution of the accretion disk UV bump emission.

Structure Function

- Definition of the structure function (SF) about the flux variation $F(t)$ is;

$$SF^{(1)}_F(\Delta\tau) = \frac{1}{N}\sum_{i=1}^{N}[F(t_i) - F(t_i + \Delta\tau)]^2.$$

- We define the moving distance of the polarization vector, l, which is represented as;

$$l_i(\Delta\tau) = \sqrt{\{Q(t_i) - Q(t_i + \Delta\tau)\}^2 + \{U(t_i) - U(t_i + \Delta\tau)\}^2},$$

where Q and U are the Stokes parameters.
- The SF of the polarization is defined as;

$$SF^{(1)}_P(\Delta\tau) = \frac{1}{N}\sum_{i=1}^{N}[l_i(\Delta\tau)]^2.$$

Error Estimation of the SF

➢ Systematic error
- We estimate the σ_{sys} by the Monte Carlo method (Iyomoto+ 2001).
1. Assume the power spectrum density (PSD).
2. Generate a light curve from the assumed PSD (Timmer+ 1995).
3. Select a simulated light curve same as the time series of the observed data, and estimate the simulated SF.
4. We regard the σ_{sys} as the standard deviation of 1000 simulated SFs.

1. Assumed PSD   2. Simulated light curve   3-1. Select data   3-2. Calculate SF
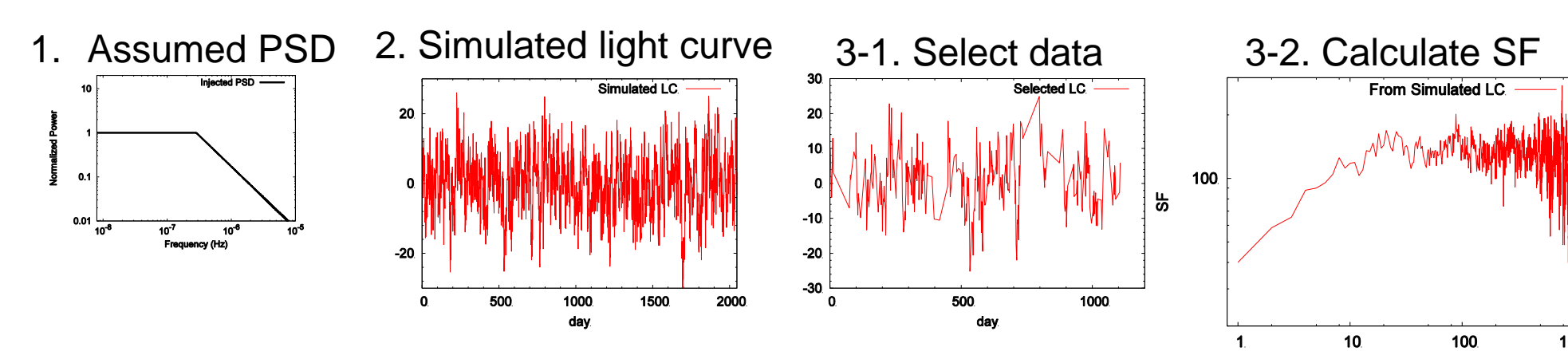
➢ Statistical error
- We estimate the σ_{sta} using a bootstrap method.

◆ The total error σ of the SF is the sum of σ_{sys} and σ_{sta}

$$\sigma = \sigma_{sys} + \sigma_{sta}$$

SFs of the Flux and Polarization
- The break time scale of the SF should be the typical variation time scale.
- We estimate the break time scales of the flux $\tau_{br,F}$ and polarization $\tau_{br,P}$ by fitting a knee model using a MCMC method.

$$SF_{F/P}(\Delta\tau) = \frac{A}{\left[1 + \left(\Delta\tau / \tau_{br,F/P}\right)^{-b}\right]^{\alpha_{F/P}/b}}$$

The SF of the flux

3C 454.3 Flux
$b = 2$
Best fitted model
$\tau_{br,F}$

The SF of the polarization

3C 454.3 Pol
$b = 4$
$\tau_{br,P}$

Different break time scales!!
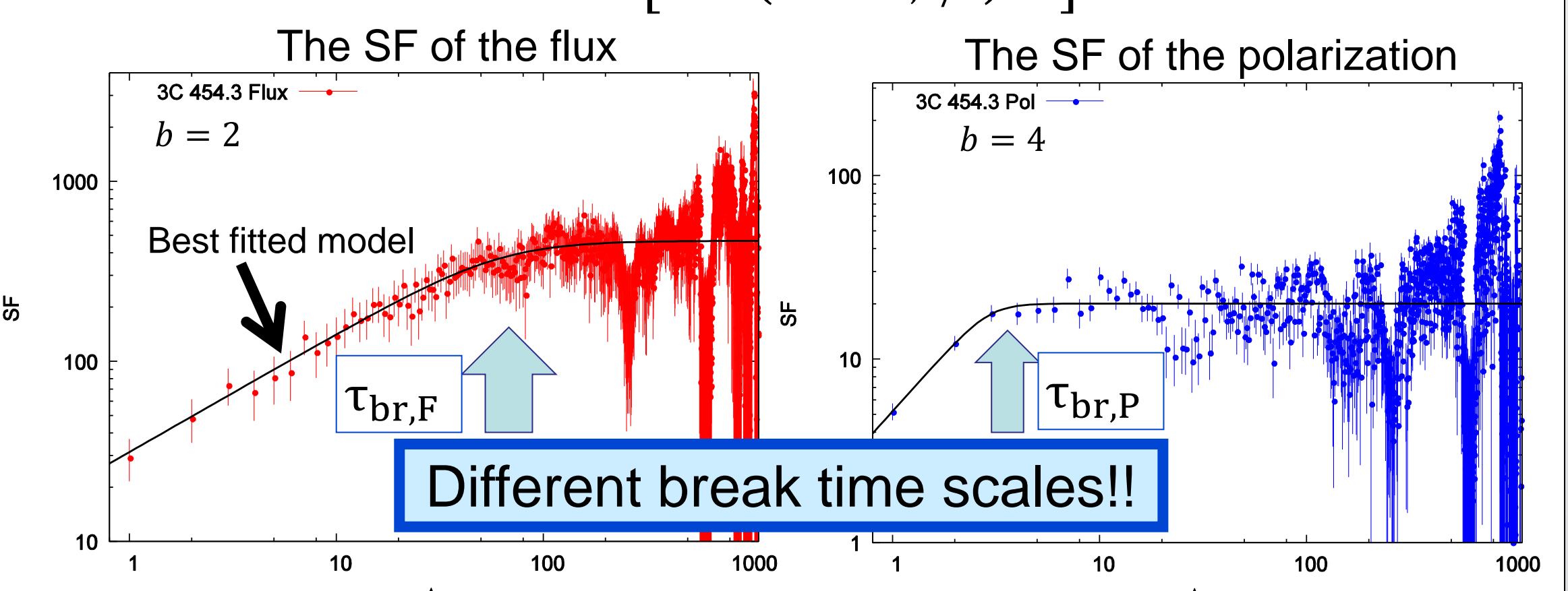
- The $\tau_{br,F}$ and $\tau_{br,P}$ are 61^{+9}_{-8} days and 2.9 ± 0.2 days.
- The $\tau_{br,F}$ is longer than $\tau_{br,P}$.
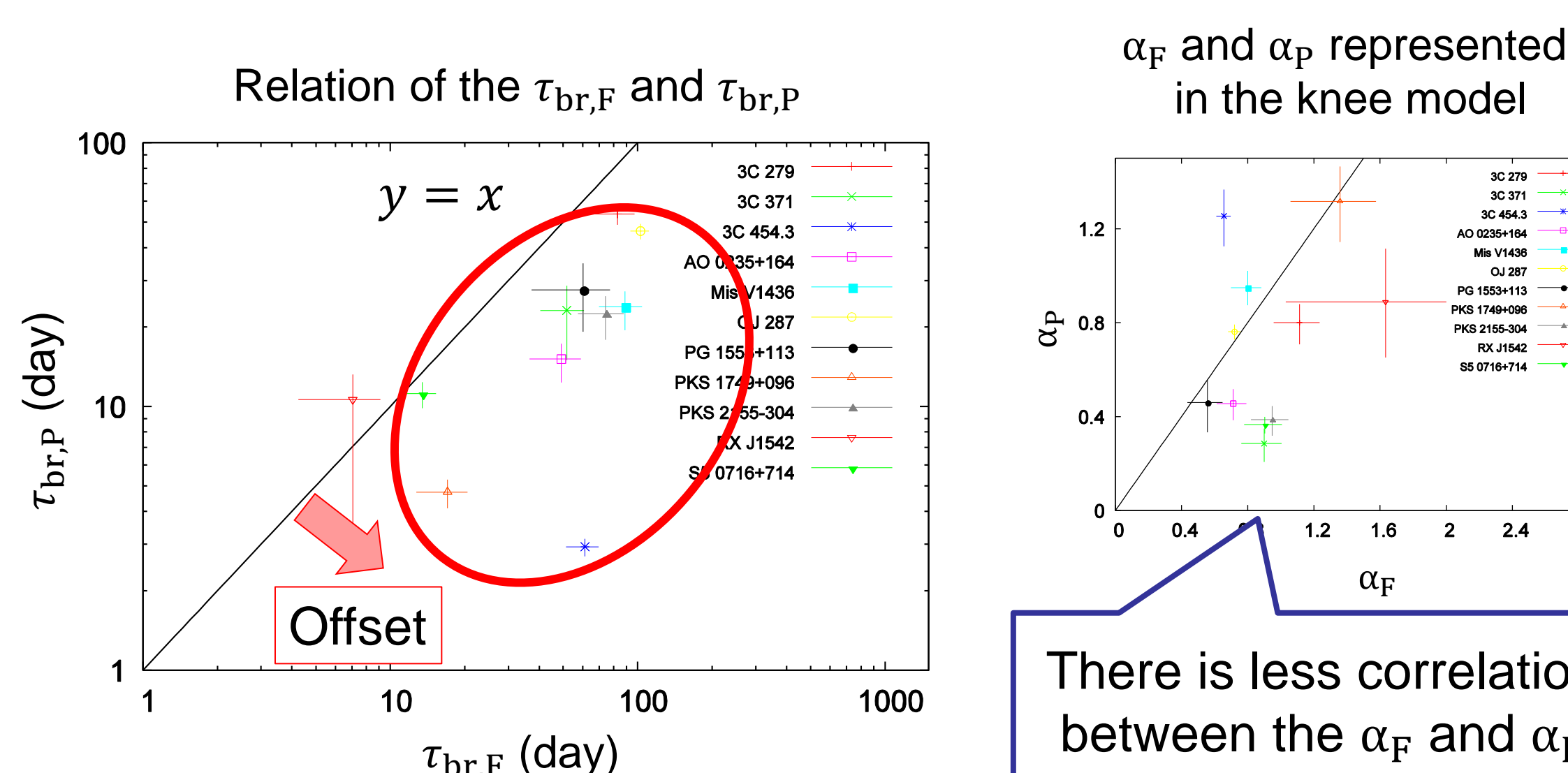- The α_F and α_P, which are gradients at shorter sides of SFs, are also different.

4. Other Blazars

- We have monitored 45 blazars for more than 1 year.
- We estimate the $\tau_{br,F}$ and $\tau_{br,P}$ for the high-frequency monitored 15 blazars.

|			
3C 279	AO 0235+164	PG 1553+113	RX J1542.8+6129
3C 371	BL Lacertae	PKS 1502+106	S2 0109+224
3C 454.3	Mis V1436	PKS 1749+096	S5 0716+714
3C 66A	OJ 287	PKS 2155-304	

- 11 blazars can estimate the $\tau_{br,F}$ and $\tau_{br,P}$ (4 blazars did not converge by the MCMC method).

➢ In general, the $\tau_{br,F}$ is systematically longer than the $\tau_{br,P}$ for each blazar.
➢ The indices of the flux and polarization did not correlated.

Relation of the $\tau_{br,F}$ and $\tau_{br,P}$

$y = x$

Offset

α_F and α_P represented in the knee model

There is less correlation between the α_F and α_P.

Flux

Additional →Longer

Polarization

Difference →Shorter or equal

Interpretation
- If there are two emission regions, the flux is additional, but the polarization is subtracting.
- The timescale of the flux should be longer and that of the polarization should be shorter or equal to a physical time scale.
- These time scales should be different.
- The time scale of polarization seems to be reflected to the physical time scale of the emitting region.
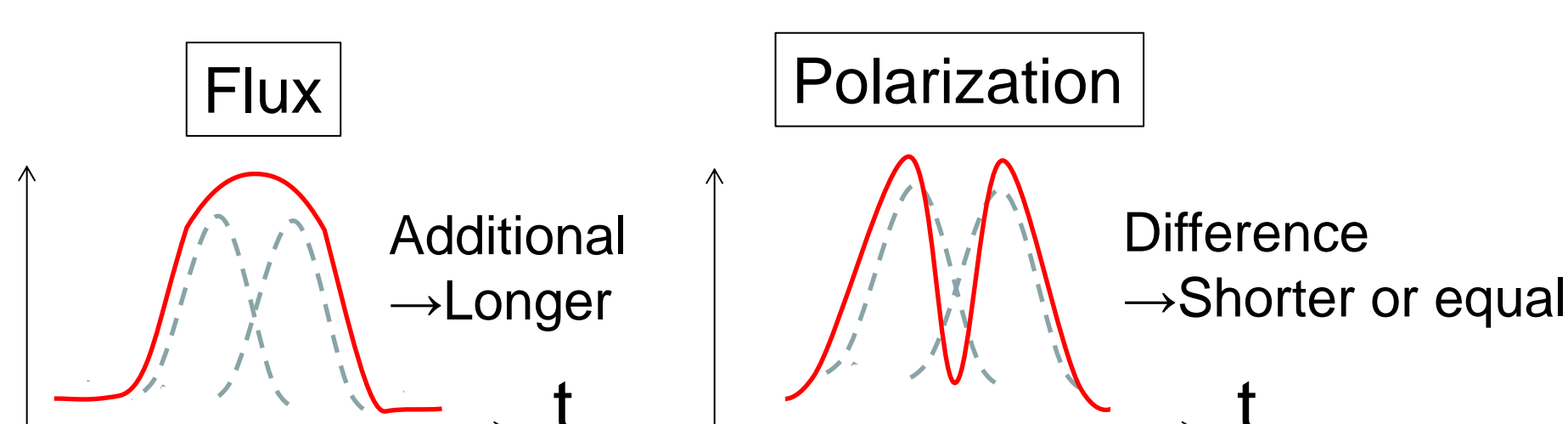
5. Conclusion

- 3C 454.3 has large-amplitude outbursts in all wavelength.
- The peak flux is more than 20 times larger than the quiescent level.
- The degree of polarization became high (>40%) during the outburst.
- We estimate the SFs of the flux and polarization of 3C 454.3.
- The typical variation time scale of the total flux ($\tau_{br,F}$) is longer than that of the polarization ($\tau_{br,P}$) in 3C 454.3.
- Eleven other high-cadence monitored blazars also show the same trend; the $\tau_{br,F}$ is systematically longer than the $\tau_{br,P}$.