

Polarimetry and Photometric observation of the gamma-ray brightening Blazar OP 313 with KANATA telescope

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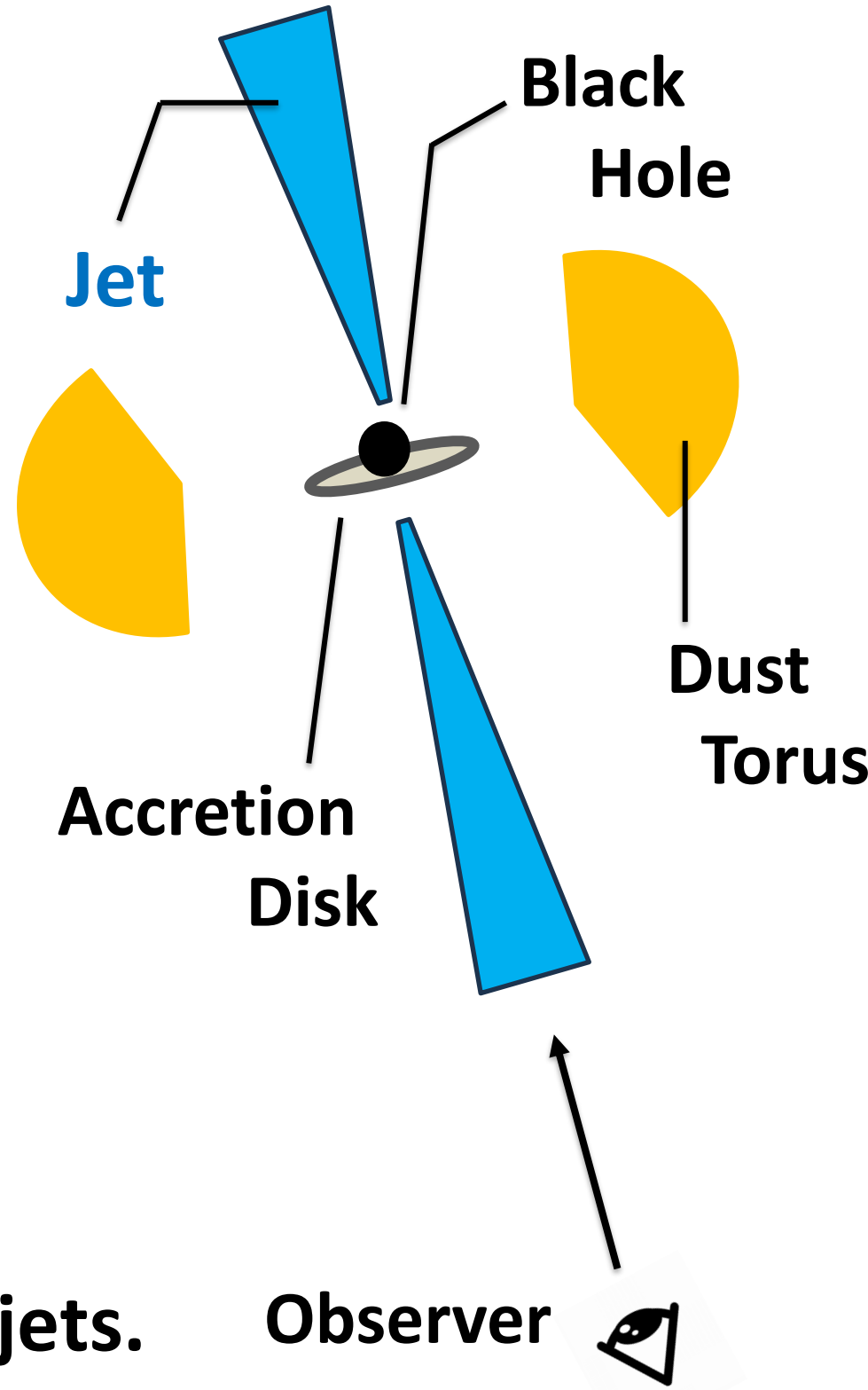


Abstract

The central core of a galaxy, which emits energy comparable to that of the entire parent galaxy from a narrow region, is called an Active Galactic Nucleus (AGN). Some AGNs possess relativistic plasma jets, but the mechanisms behind their emission and acceleration remain unclear. An AGN with its jet pointed towards the observer is called a blazar. Blazars are among the AGNs that exhibit significant luminosity variations, with radiation dominated by synchrotron emission. Since synchrotron radiation is polarized in a direction perpendicular to the magnetic field, we can gain insights into the magnetic field structure and radiation mechanisms of the jets through polarimetry of blazars. OP 313 is a blazar that exhibited its largest gamma-ray flare observed by the Fermi Gamma-ray Space Telescope in November 2023 and February 2024. As a result of the observations, luminosity variations correlated with gamma rays were detected. Furthermore, both the polarization degree and the polarization angle showed variations, and a sharp increase in the polarization degree exceeding 10% was also observed. The variations in the polarization angle indicate that the magnetic field within the jet is rotating. In this presentation, I will report on the behavior of OP 313 in the optical and near-infrared bands since the end of last year and provide insights into the jet's radiation and magnetic field.

I. Introduction ~Blazars~

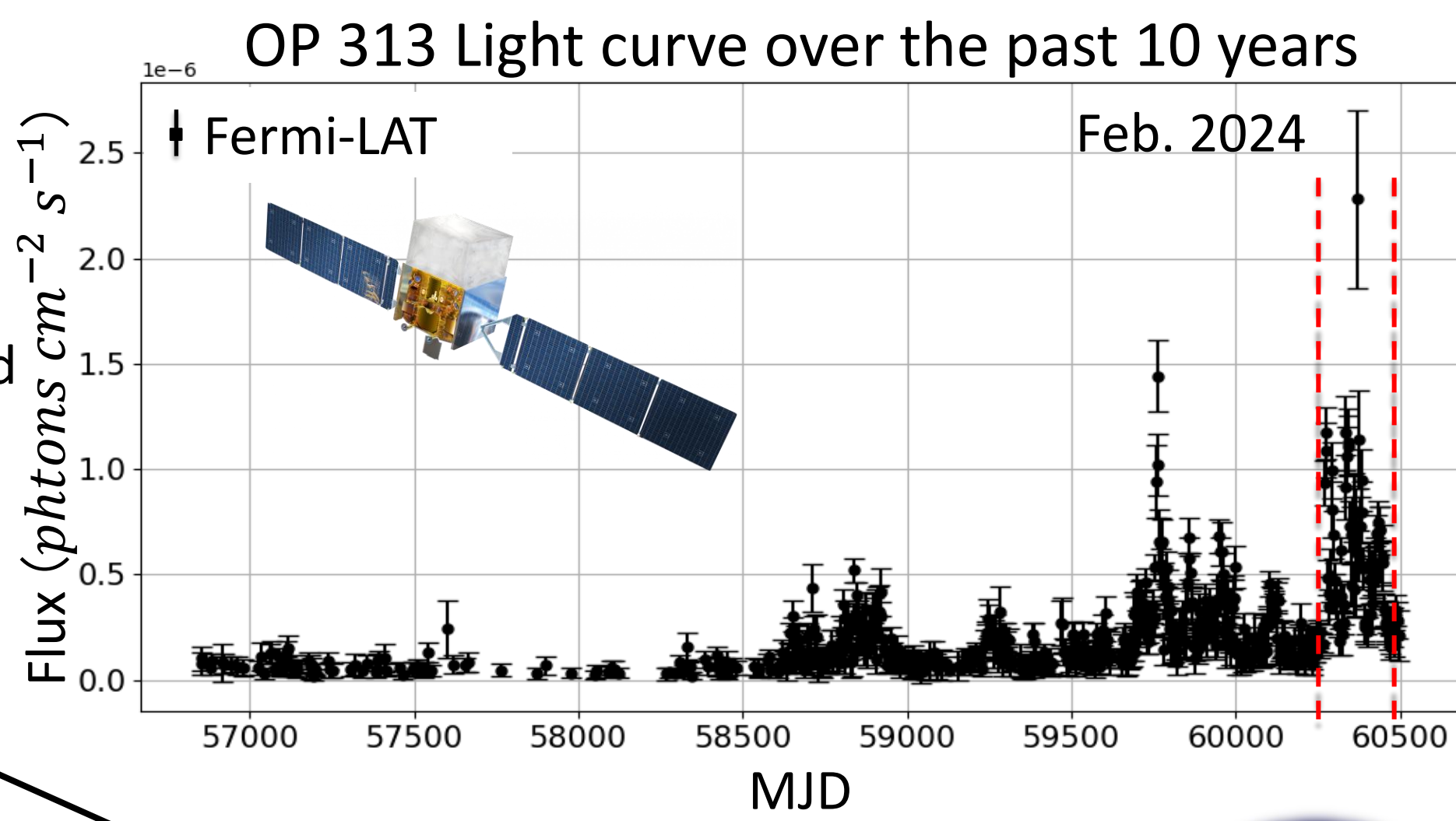
- A blazar is a type of active galactic nuclei; the jet of an AGN points in the direction of the observer.
- The mechanisms of jet formation and particle acceleration remain unclear.
- Blazars are also candidate sources of **high-energy cosmic neutrinos**.
- Blazars have several distinctive observational features;
 - Intense luminosity fluctuations
 - High polarization degree
 - The contamination from the radiation of the accretion disk and torus is small.



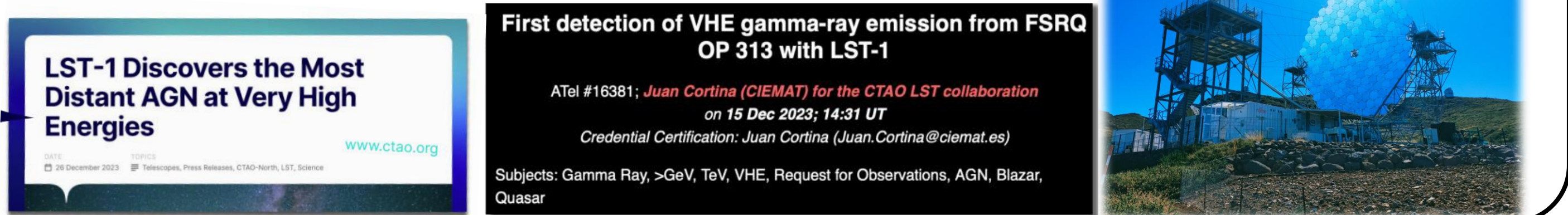
Blazars are ideal objects for probing the structure and physical conditions of jets.

II. Target Object "OP 313"

- OP 313 is a Flat-Spectrum Radio Quasar.
- In February 2024, the brightest flare ever observed was detected by Fermi-LAT.
- The redshift is 0.997.



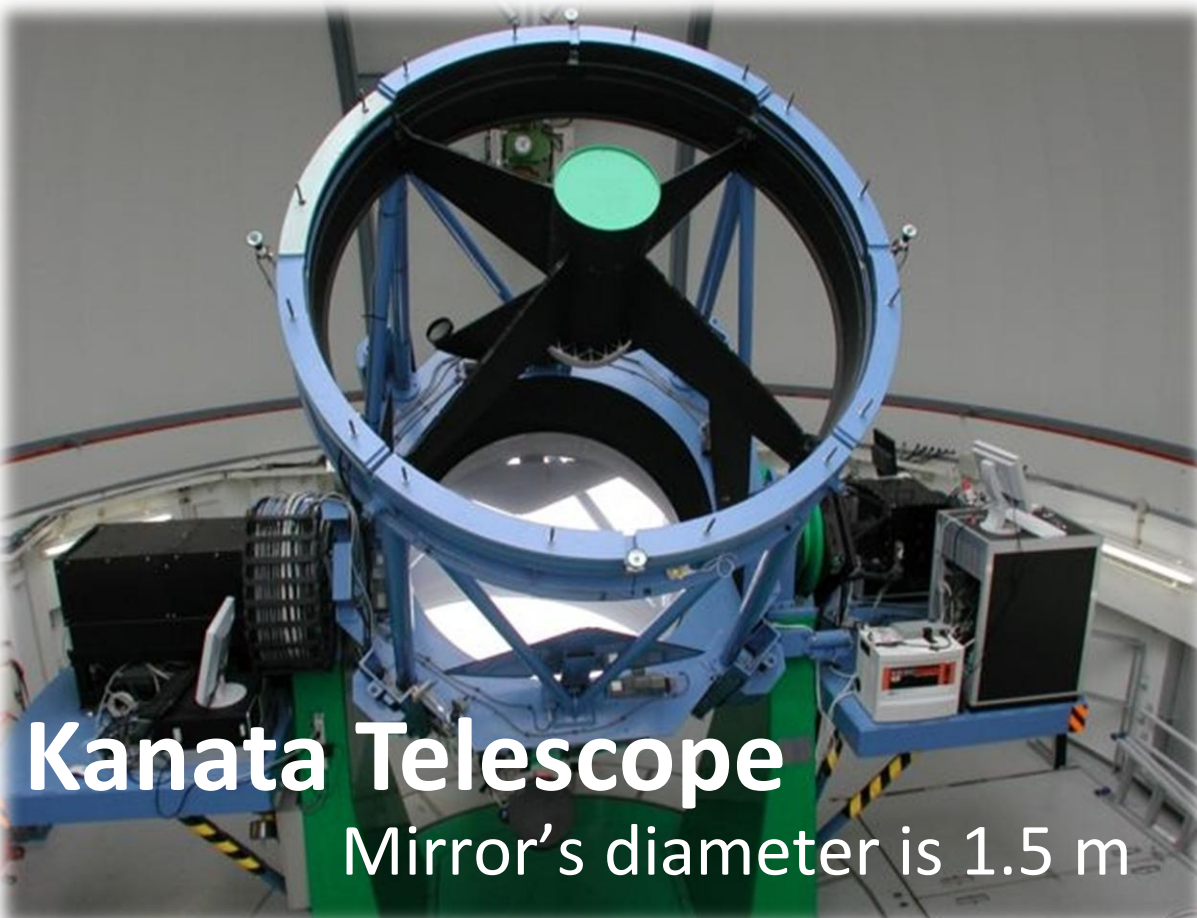
OP 313 is the most distant blazar among those in which **TeV gamma-rays** have been detected.



This Study

We conducted optical and near-infrared polarization imaging observations of OP 313 and discuss the particle acceleration mechanisms and magnetic field structure of the blazar.

III. Observation



Photometry (R-band)

Polarimetry (R-band)

OP 313

HONIR (on Cassegrain focus)

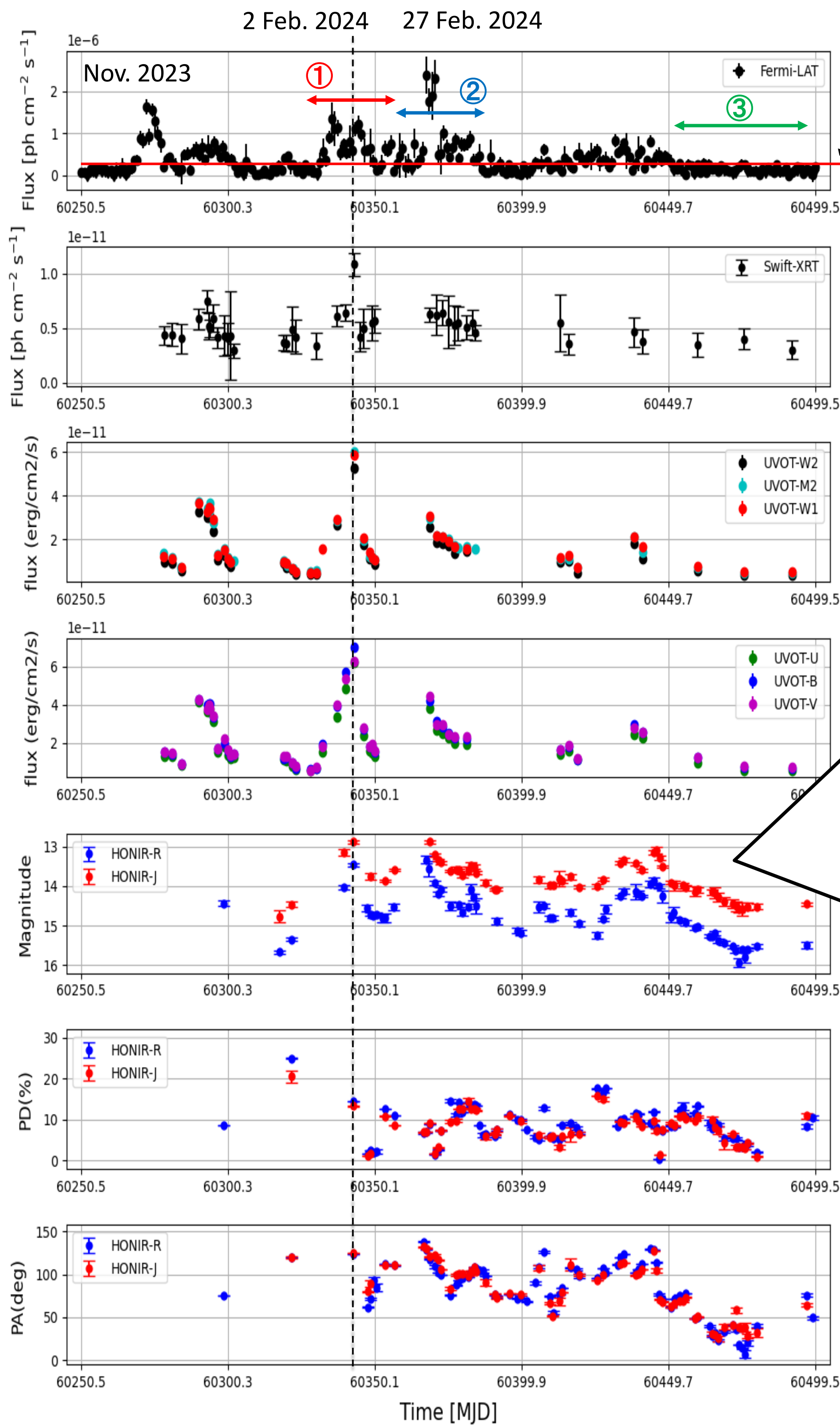
	Optical	Near-infrared
Detector	CCD	HgCdTe VIRGO (Raytheon)
Filter	(Hamamatsu Photonics) B, V, R, I, Y	Y, J, H, Ks
Wavelength range (μm)	0.5 - 1.0	1.15 - 2.40
Field of view	10' × 10'	10' × 10'
Pixel scale	0.294"/pixel	0.295"/pixel
Number of pixels	2048 × 4096	2048 × 2048

Credit: H. Akitaya et al. 2014

- Using the Kanata-HONIR, we can perform simultaneous imaging and polarization observations in two bands: optical and near-infrared.
- In this study, we conducted observations of OP 313 in the R and J bands.
- Exposure time : 45 s (R band), 30 s (J band)

IV. Result and Discussion

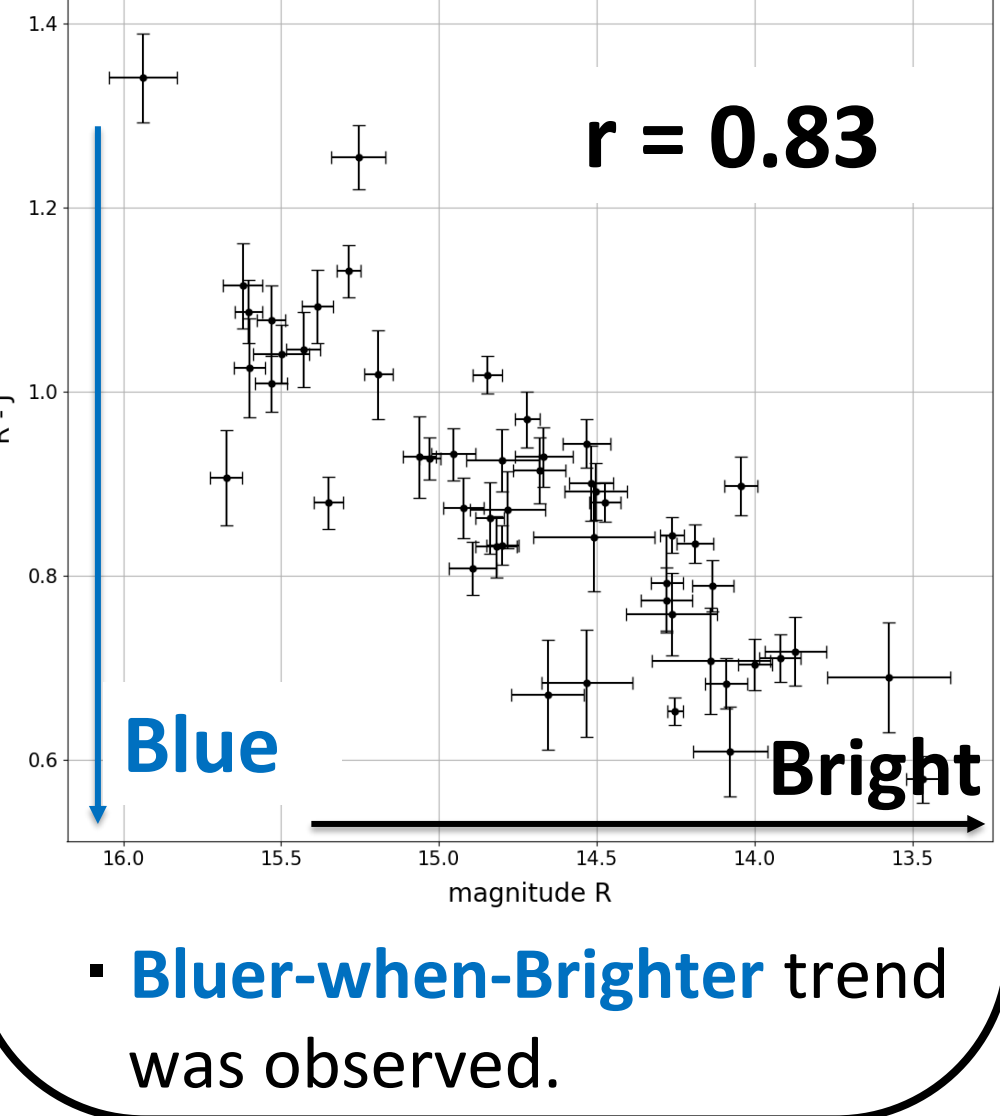
Light Curve



Base line + 1 sigma

- We focused on three epochs;
 - Epoch 1:** first flare mjd: 60335 – 60360
 - Epoch 2:** second flare mjd: 60360 – 60385
 - Epoch 3:** quiescent period mjd: 60452 – 60480

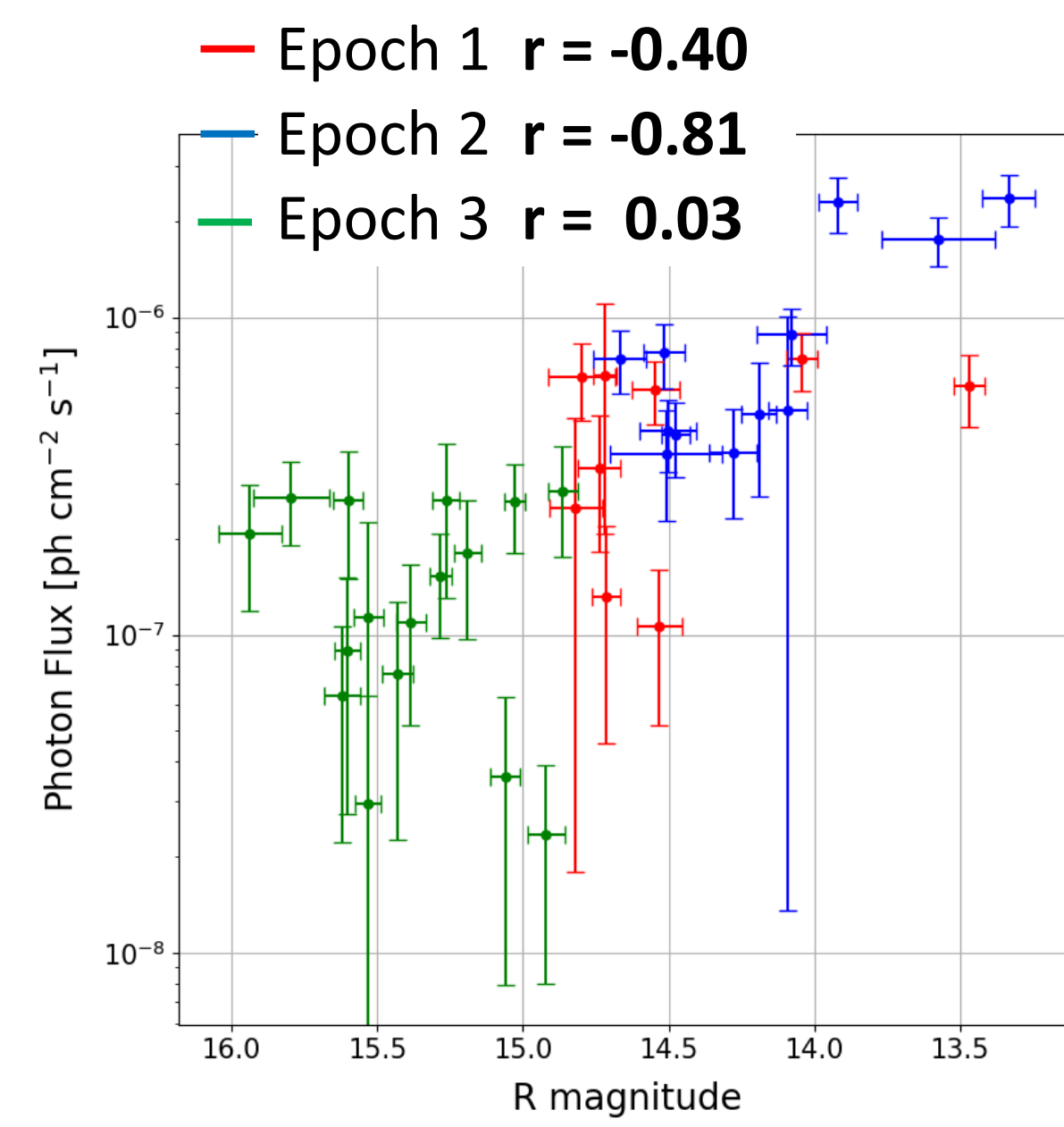
R-band Magnitude vs Color Index



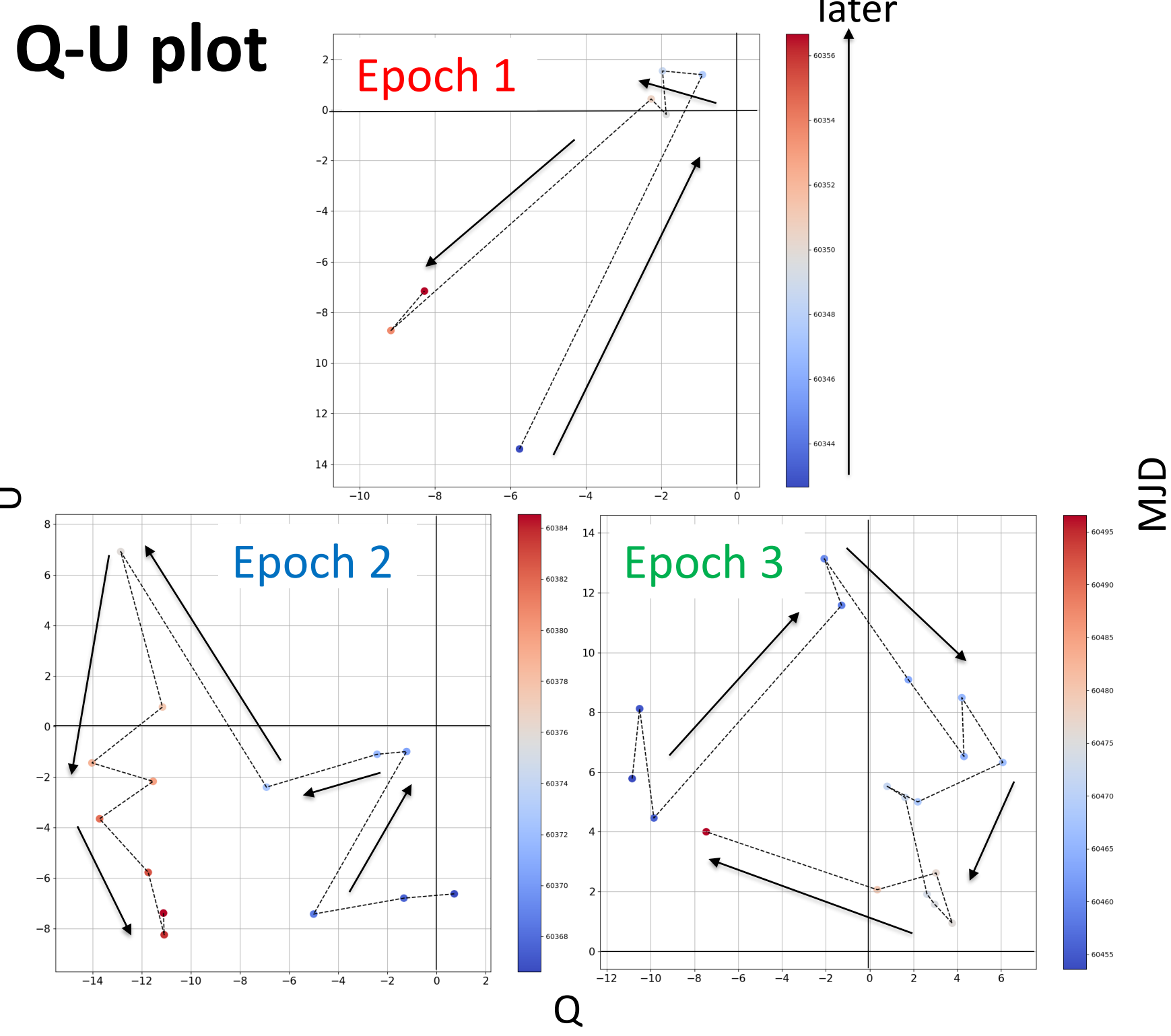
Bluer-when-Brighter trend was observed.

- 1-day binned
- PD_{max} ~ 25 %**
- The emission from OP 313 is highly polarized.
- The timing of the flare did not coincide with the increase in polarization degree.

R-band magnitude vs Gamma photon flux



Q-U plot

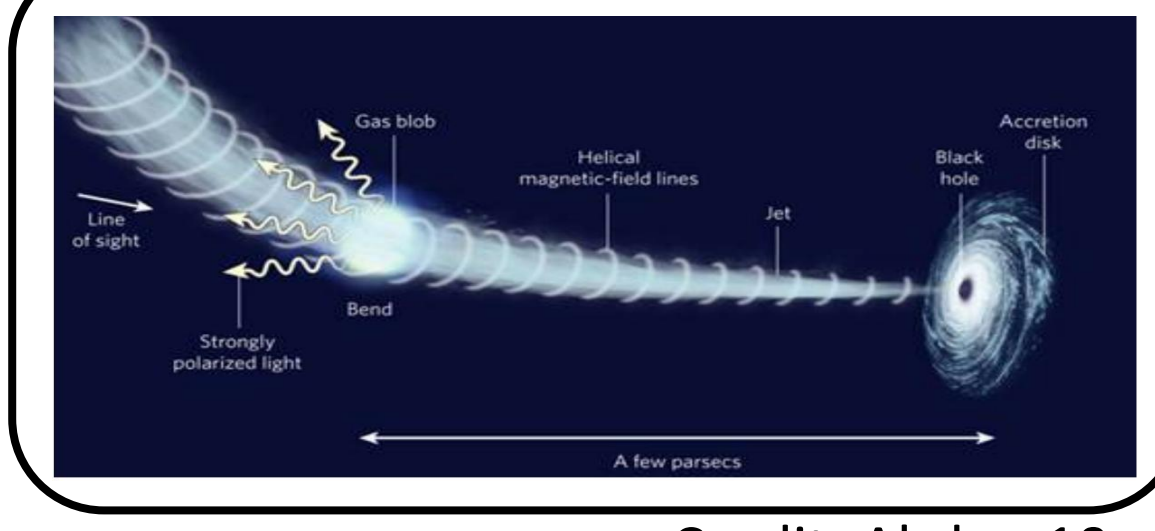


- The brighter in gamma rays, the more strongly it correlates with the optical magnitude.

- During the flare phase, the magnetic field in the jet rotates counterclockwise, while during the quiescent phase, it rotates clockwise. → **The regions we observe in optical are different.**
- Rotating magnetic field → The magnetic field could be spiral-shaped.

- During the dimming, the rotation direction was opposite. → The jet itself is curved...?

Bent-Jet model



Credit: Abdo +10

V. Summary and Future work

Photometric Observation

- Bluer-when-Brighter trend was observed.
- The brighter in gamma rays, the more strongly it correlates with the optical magnitude.

Polarimetry

- PD_{max} ~ 25 %** The emission from OP 313 is highly polarized.
- During the flare phase, the magnetic field in the jet rotates counterclockwise, while during the quiescent phase, it rotates clockwise. → The regions we observe in optical are different.

Future work

- We will discuss the results in multi-wavelengths, including X-rays and TeV gamma-rays.
- SED modeling
- We will investigate the relationship between polarization and other physical parameters.