Investigating Dynamics of Active Galactic Nuclei Jets Using FERMI and TESS Observations

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Outlook:

1- Overview of AGNs

2- Flux variability

3- Selection of AGNs

4- Fermi and TESS analysis of two AGNs

5- Summary

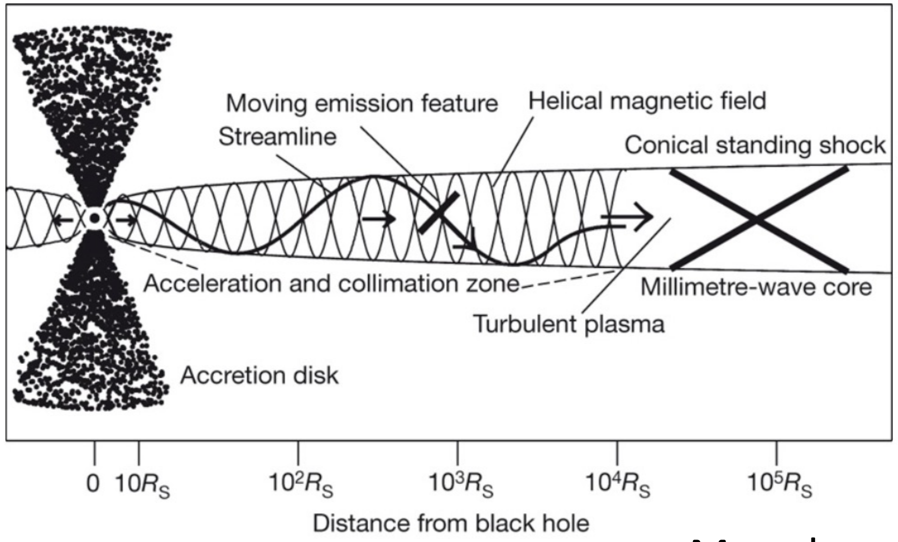
Overview of Active Galactic Nuclei (AGNs)

- AGNs: One of the most luminous objects in the universe that host supermassive black holes.
- Jets: Collimated outflows of particles and radiation.
  - Observed from radio to gamma-ray energies.
  - Flux variability in timescales of years to hours.
- Flux Variability provides one of the best insights into the emission mechanisms of jets.
- Astro2020 Decadal Survey: “Dynamics of relativistic jets is a major bottleneck in understanding the evolution of galaxies”.

Image courtesy: NASA

Research idea

- An X-ray and gamma-ray flare originates in the inner jet ➔ The passage of the feature through the millimeter-wave core stimulates a second flare ➔ an increase in the radio flux.
- A complete picture of the physics of the jet can only be achieved by multiwavelength studies of jets.
- Quantify the flux variability by combining Gamma-ray (Fermi-LAT) and optical (TESS) flux variability.



Marscher et al. (2008)

- TESS (Transiting Exoplanet Survey Satellite):
  - Surveying nearly the full sky since 2018
  - Large filed of view ➔ sensitive to large range of phenomena (transiting exoplanets, moving Solar System objects, variable AGNs, …)
  - Data is publicly available in units of sectors (approx. 25 days of observations)

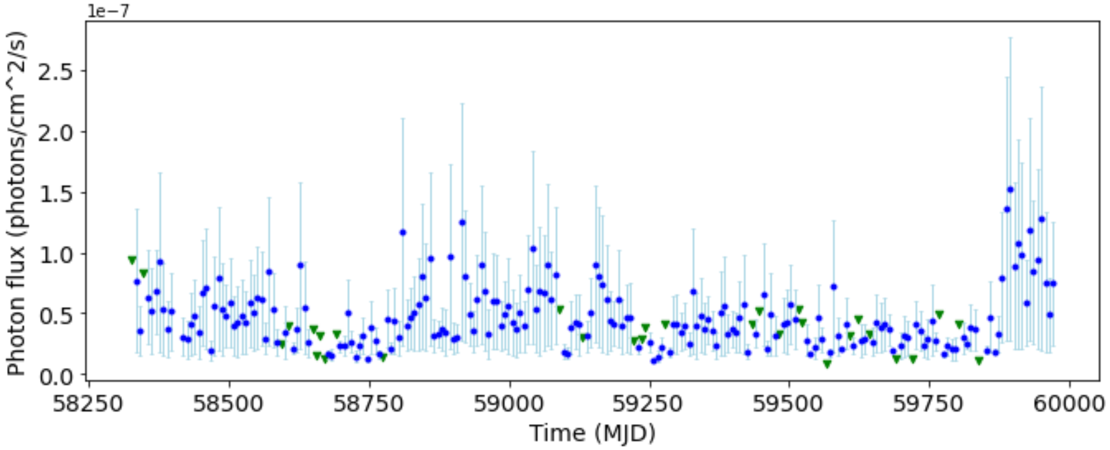
Image courtesy: NASA

- Fermi-LAT:
  - Surveying nearly the full sky since 2008
  - Gamma-ray sources (SNR, AGNS, molecular clouds,…)

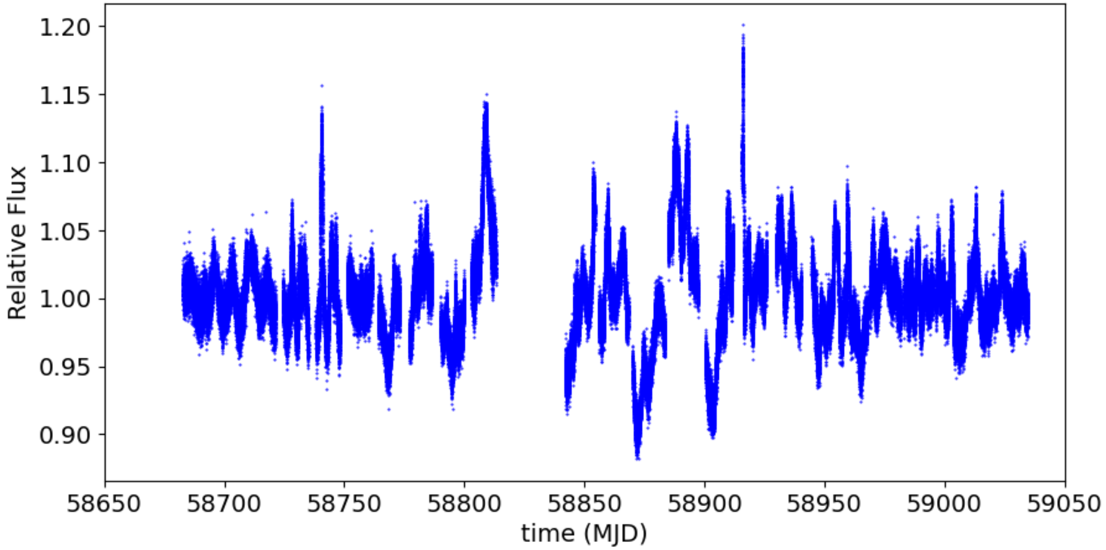
Image courtesy: NASA

Research idea

- Measure flux variability in Optical energy band (TESS) on blazar type AGNs.
- Measure average gamma-ray flux at each time sector of TESS observation.



Fermi light curve of 4FGL J1806.8+6949 (3C371)
approx. 4 years of data



TESS light curve of 4FGL J1806.8+6949 (3C371)
approx. 1 years of data

Methodology: Flux variability

- Variability in an ideal data set measures using variance:

$$\sigma^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2$$

$$\sigma_N^2 = \frac{\sigma^2}{\bar{x}^2}$$

- Flux is data points including the error ➔ excess variance (Vaughan et al. 2003):

$$\sigma_{XS}^2 = \sigma^2 - \overline{\sigma_{err}^2}$$

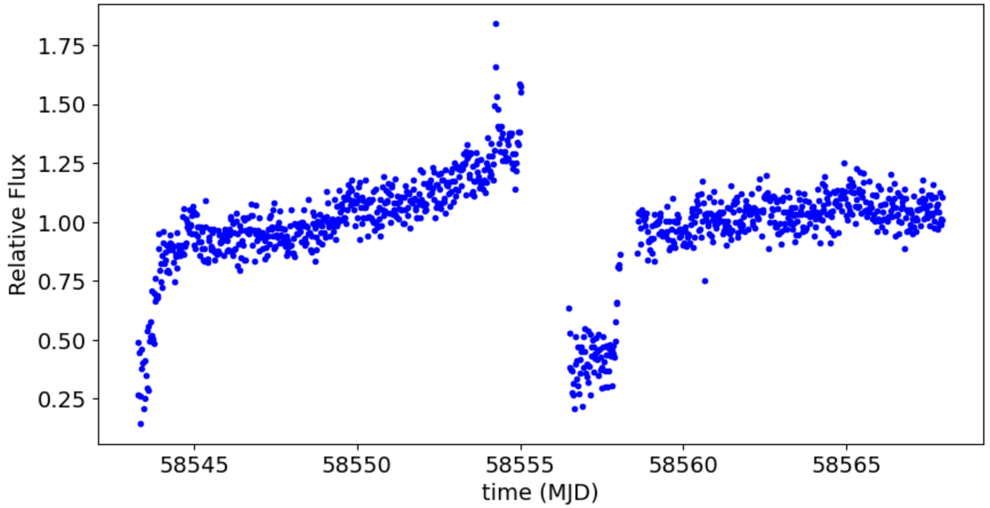
$$\sigma_{NXS}^2 = \frac{\sigma_{XS}^2}{\bar{x}^2}$$

$$err(\sigma_{NXS}^2) = \sqrt{\left(\sqrt{\frac{2}{N}} \cdot \frac{\overline{\sigma_{err}^2}}{\bar{x}^2}\right)^2 + \left(\sqrt{\frac{\overline{\sigma_{err}^2}}{N}} \cdot \frac{2\sigma_{NXS}}{\bar{x}}\right)^2}$$

Selection of AGNs

- AGNs located within ≈ 12 degrees from the northern and southern ecliptic poles
  - Maximize number of observing epochs of TESS
  - Generally, not very bright in optical
  - Need a good method of background rejection

- Looking at bright AGNs in optical but having fewer observing epochs of TESS
  - 3C371 (4FGL J1806.8+6949)
  - Mkn501 (4FGL J1653.8+3945)

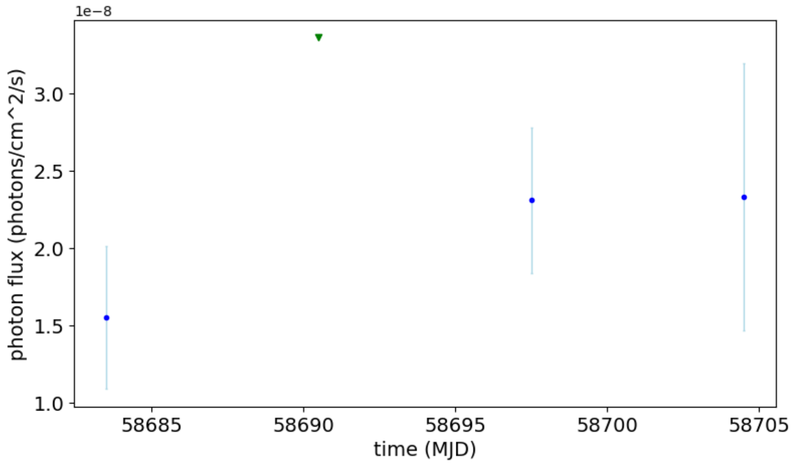


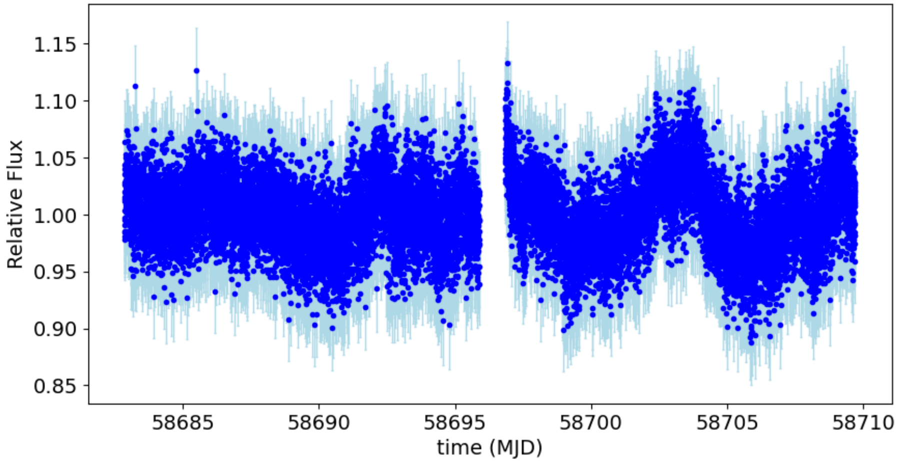
One sector of TESS light curve for 4FGL J0601.1-7035 with brightness mag of ~ 18 in optical.

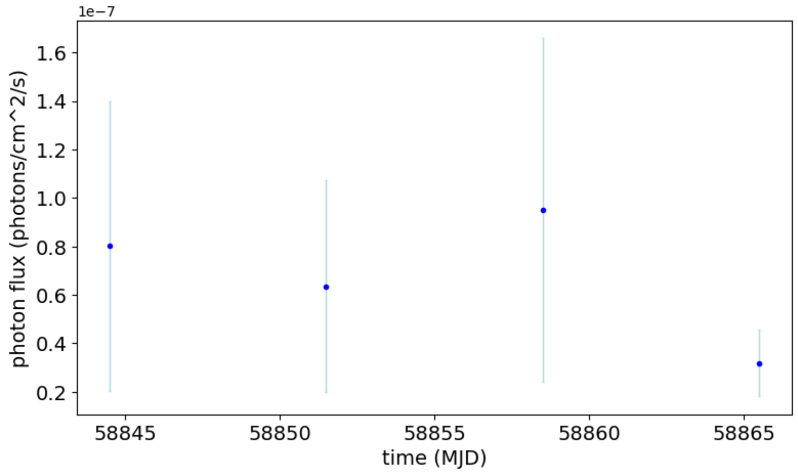
3C371 (4FGL J1806.8+6949)

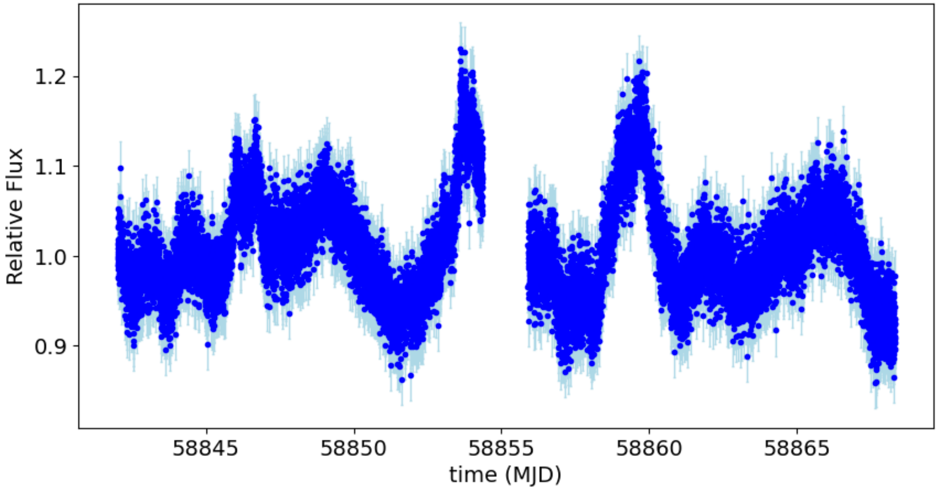
- A BL Lac type Blazar (RA: 271.71, Dec: 69.83).
- There are 21 sectors of TESS data available since 2018.

Sector 14 observation for TESS (bottom) and Fermi-LAT, LCR (top).



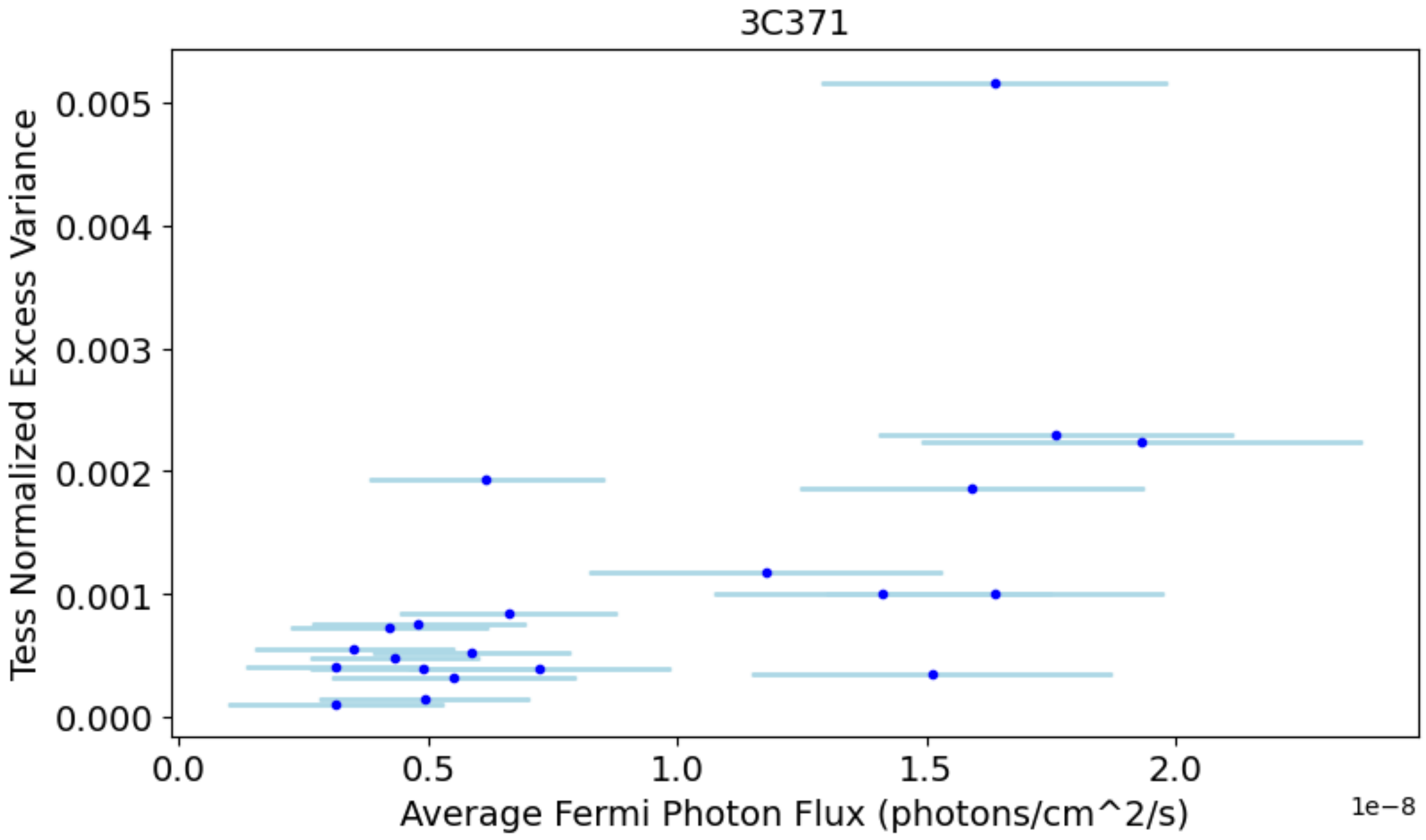






Sector 20 observation for TESS (bottom) and Fermi-LAT, LCR (top).

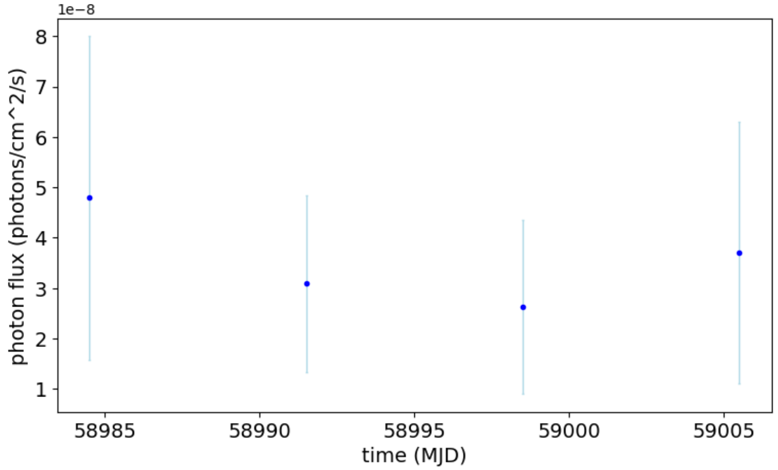
Flux variability in optical band as a function of gamma-ray flux.

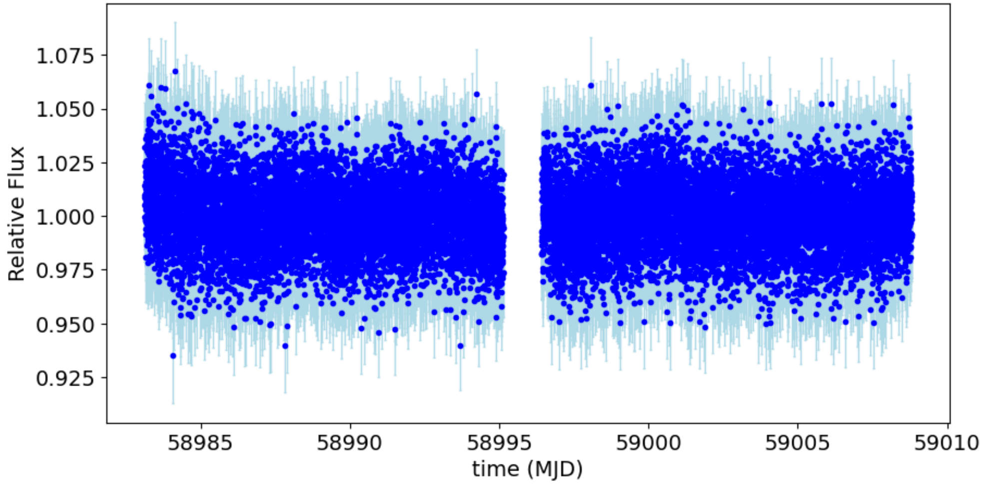


Mkn501 (4FGL J1653.8+3945)

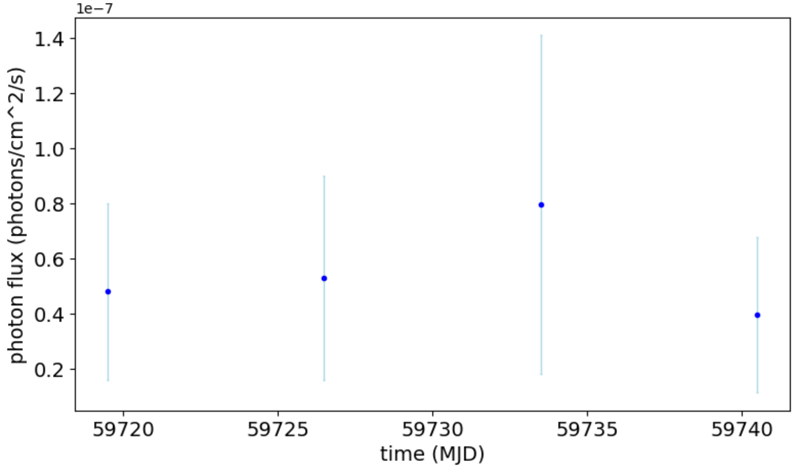
- A BL Lac type Blazar (RA: 253.47, Dec: 39.76).
- There are 4 sectors of TESS data available since 2018.

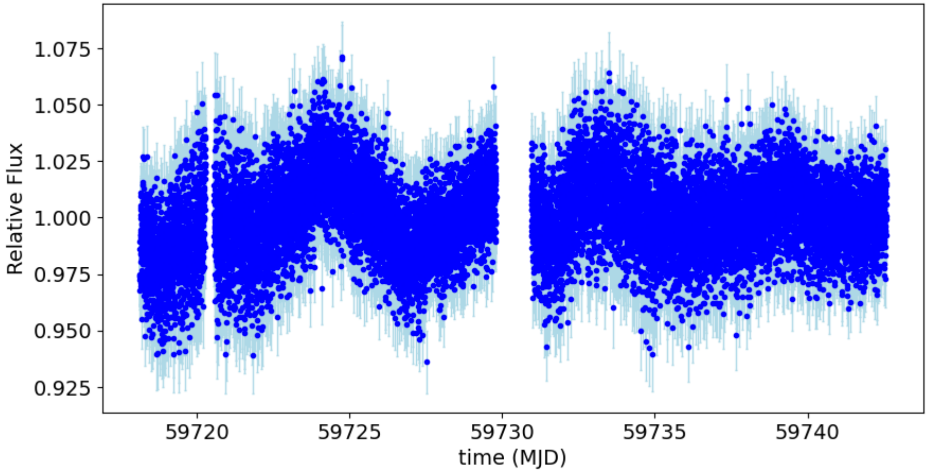
Sector 25 observation for TESS (bottom) and Fermi-LAT, LCR (top).



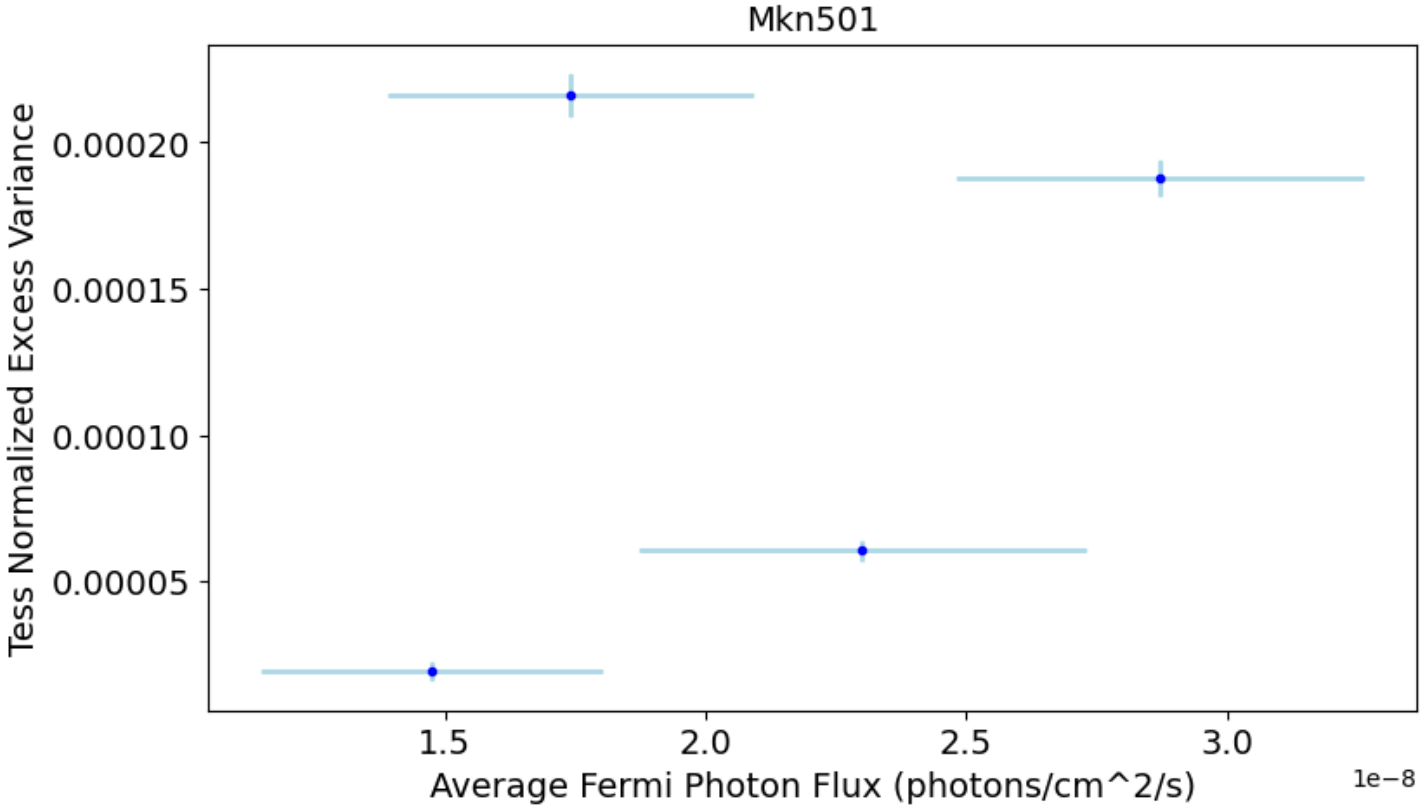


Sector 52 observation for TESS (bottom) and Fermi-LAT, LCR (top).





Flux variability in optical band as a function of gamma-ray flux.



Summary and outlook:

- We are studying jet variability using multi-wavelength observation, optical and gamma-ray.
- We are measuring the variability in optical and gamma-ray band for a sample of AGN to classify them based on their physical properties, optimize observing strategies that maximize the scientific return of time-domain AGN data, …
- Our study shows that for low bright AGNs in optical band, a background rejection method is needed to clean the target data.
- We showed the variability correlation for the two bright AGNs, but larger sample is needed for a better conclusion.