Optimizing Multi-Wavelength Blazar Studies Through *Fermi*-LAT and *Swift* Synergy

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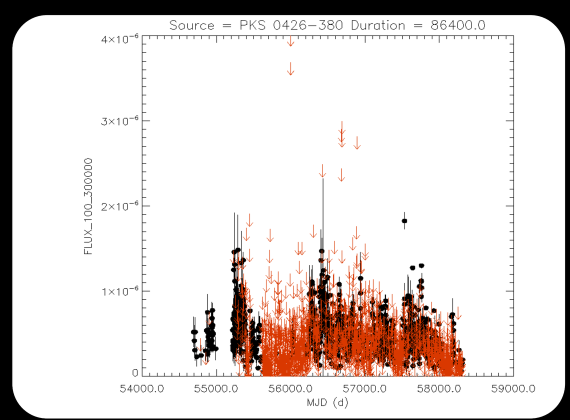
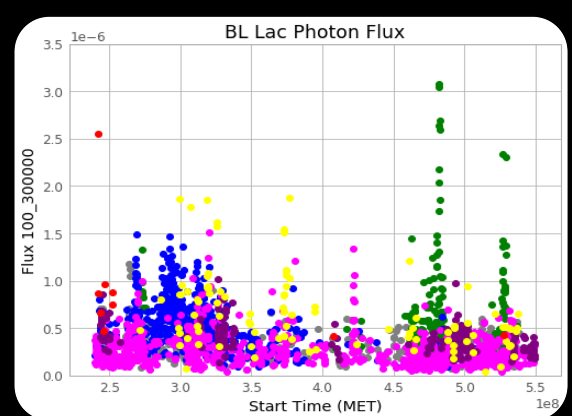
Methods

1. Sort through *Fermi* LAT's Monitored Source List (fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/) with a photon flux , $\Phi \geq 1.0 \times 10^{-6} \frac{(E>100MeV) photons}{cm^2 s}$, picking out sources that flared prior to 2017 and had significant and visually interesting activity. We found that 110/158 were of interest.



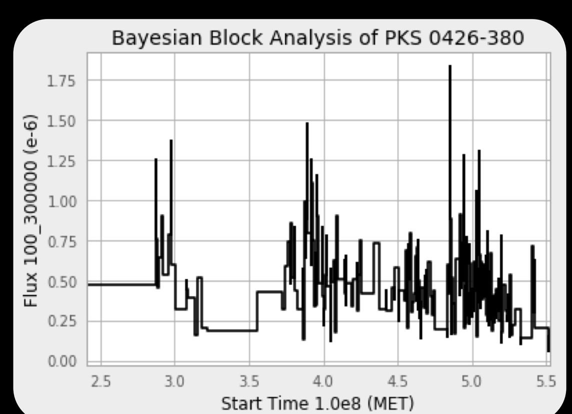
Fermi-LAT light curve example of PKS 0426-380
(red arrows represent upper limits)

2. Determine if *Fermi* sources had *Swift* ToO follow ups by searching in online *Swift* ToO archive (https://www.swift.psu.edu/secure/toop/summary.php).
3. Analyze fits file data with one another. Over-plot light curves to compare with one another



Published BL Lac sources plotted in python for comparison analysis

4. Perform Bayesian Block analysis to determine flare durations in each source



Bayesian Block analysis of PKS 0426-380
helping to provide insight into flare duration

5. Determine which blazar classifications, FSRQs or BL Lacs, are most abundantly published (using info from *Fermi* LAT 4 year Catalog)
6. Determine which type of flaring sources are more likely to result in publications by searching for publications in the SAO/NASA ADS Astronomy Query (http://adsabs.harvard.edu/abstract_service.html).

Summary

Swift ToO observations of flaring *Fermi*-LAT blazars are likely to result in publications for historically active sources and high-photon-flux sources.

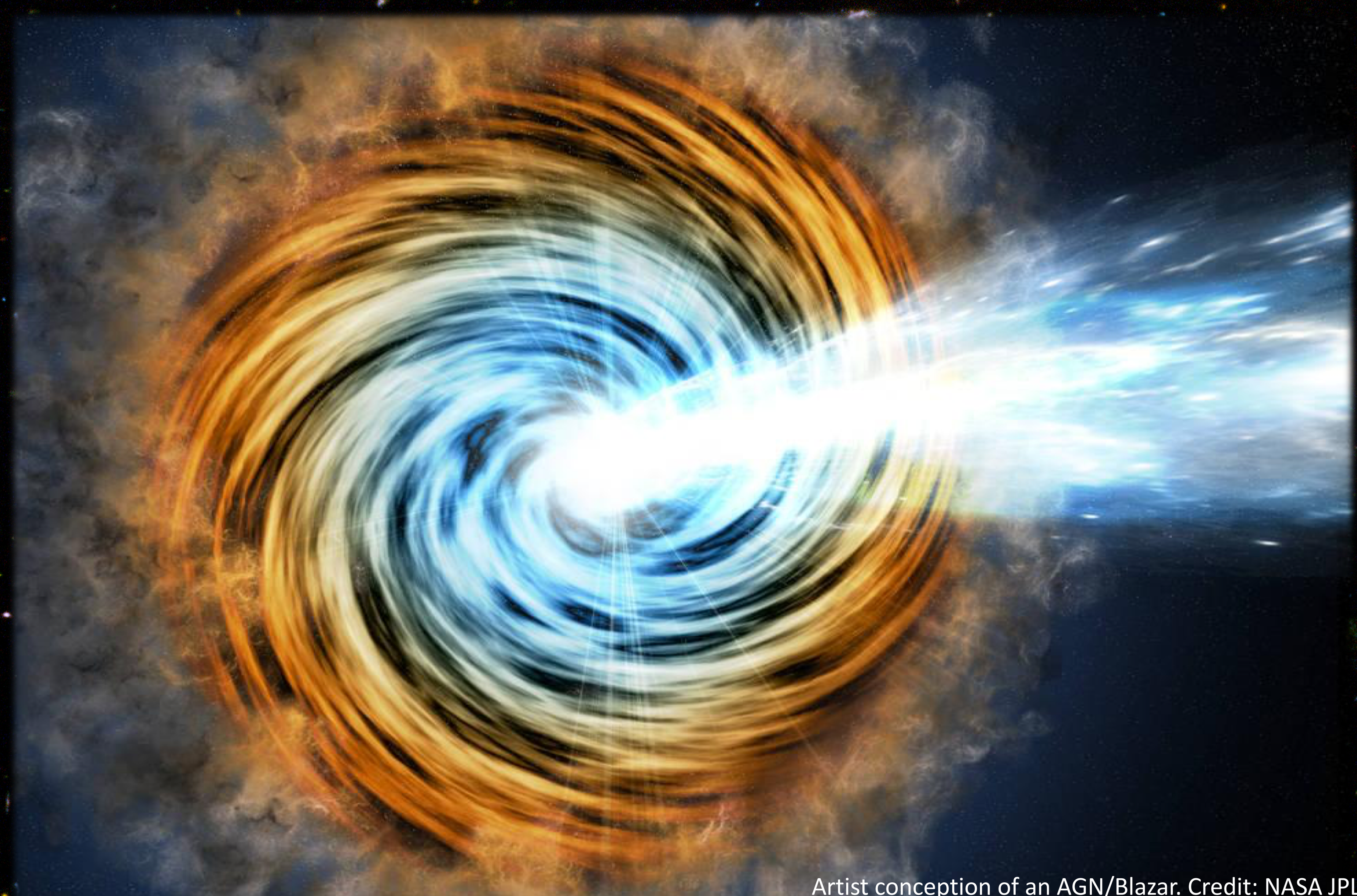
Abstract

Blazar flares seen by the *Fermi Gamma-Ray Space Telescope* Large Area Telescope (*Fermi* LAT) are often followed up by Target of Opportunity (ToO) requests to the *Neil Gehrels Swift Observatory (Swift)*. Using flares identified in the daily light curves of *Fermi* LAT Monitored Sources, we investigated which follow-up *Swift* ToO requests resulted in refereed publications. The goal was to create criteria of what *Swift* should look for in following up a *Fermi*-LAT gamma-ray flare. Parameters tested were peak gamma-ray flux, flare duration (based on a Bayesian Block analysis), type of AGN (BL Lac or FSRQ), and pattern of activity (single flare or extensive activity). We found that historically active sources and high-photon-flux sources result in more publications, deeming these successful *Swift* ToOs, while flare duration and type of AGN had no impact on whether or not a ToO led to a publication.

83% of interesting *Fermi* observations have *Swift* counterparts (91/110)

35% of *Fermi-Swift* sources have general publications (32/91)

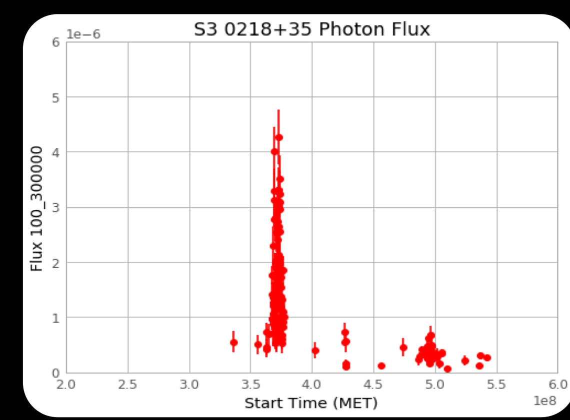
19% of original *Fermi* observations have publications with specified *Swift* ToOs. (21/110)



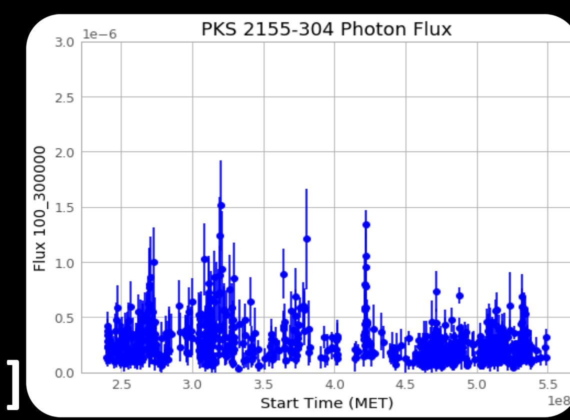
Artist conception of an AGN/Blazar. Credit: NASA JPL

Hypothesis vs. Results

- The **left** graph represents a *Fermi*-LAT light curve hypothesized to produce publications: single bright flare.



FSRQ S3 0218+35, showing one steep, single spike in flux

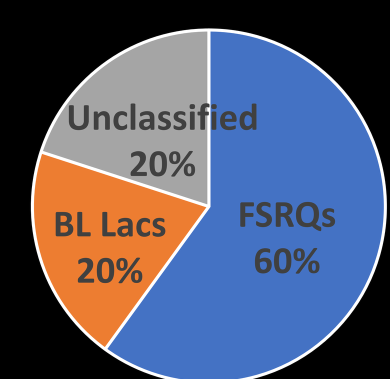


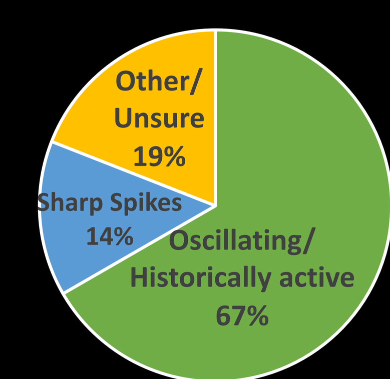
BL Lac PKS 2155-304, showing historic and oscillating activity

- The **right** graph represents a standard *Fermi* light curve that actually produced publications.

Conclusions

1. Higher flux flares were published more than lower flux flares
   A. $\bar{\Phi} = 8.6 \times 10^{-6} \frac{photons}{cm^2}/s$ for published *Fermi-Swift* sources. Median value = 2.4(e-6)
   B. $\bar{\Phi} = 2.2 \times 10^{-6} \frac{photons}{cm^2}/s$ for non-published *Fermi-Swift* sources. Median value= 2.0(e-6)
   C. $\bar{\Phi} = 1.2 \times 10^{-6} \frac{photons}{cm^2}/s$ for *Fermi*-LAT sources that did not have a *Swift* follow-up. Median value = 1.1(e-6)
2. 87.5% (7/8) of *Fermi*-LAT sources with flux $\geq 8.0 \times 10^{-6} \frac{photons}{cm^2}/s$ had publications with *Swift* ToO observations (In the 8th case, a ToO was not possible due to a *Swift* sun angle constraint).
3. 18.4% (14/76) of sources with a max flux between 1.0-3.0 (e-6) had publications with *Swift* ToO observations.
4. Unlike the initial hypothesis, historically active and or oscillating sources resulted in more publications rather than one single, steep spike in the flux.
5. 4 BL Lacs, 12 FSRQs, and 4 uncertain blazars published.





6. 14 sources were oscillating/historically active, 2 sources had sharp spikes (both FSRQs), and 3 were somewhat hybrids.
7. Published sources had a higher average number of flares at 2.6 than non-published sources at 1.7.
8. Durations of flares were highly variable, meaning that flare duration should not necessarily matter when accepting a ToO.