Blazar Flares in the γ-ray Band

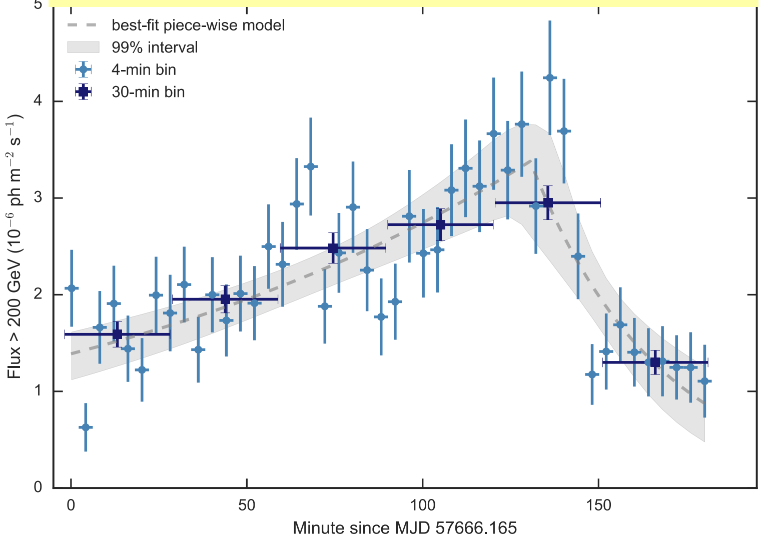
1st CDY Black Hole Workshop

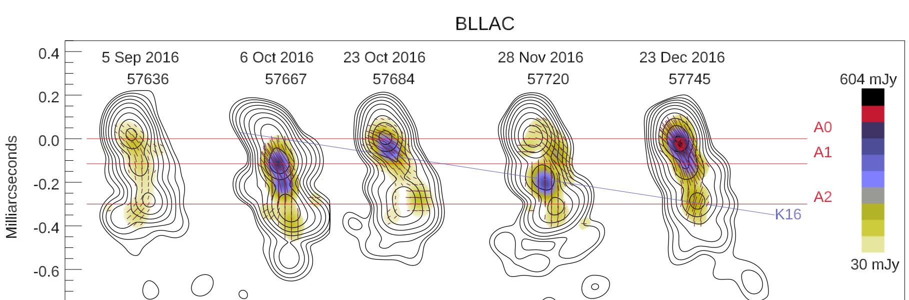
Aharonian, Coppi, Mukherjee – Discussion

15-Nov-2023

Examples in short time scale variability

Feng + VERITAS Collaboration, ApJ (2018)



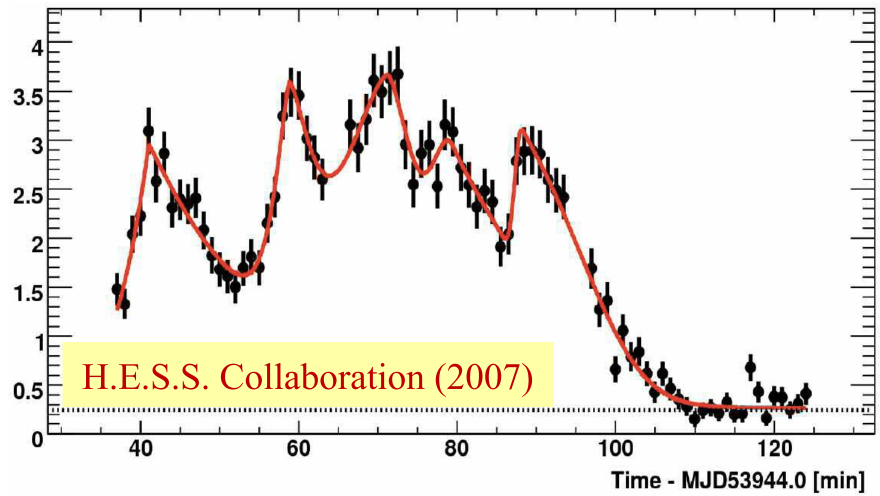


- BL Lac: Major flare in Oct 2016
- 150% Crab flux, τ ~ 36 min.
- 43 GHz VLBA imaging, coincident knots
- R < ctδ/(1+z) < 12 $R_{Sch.}$

- Locating the emission region in the jet.
- Measuring minute-scale variability.

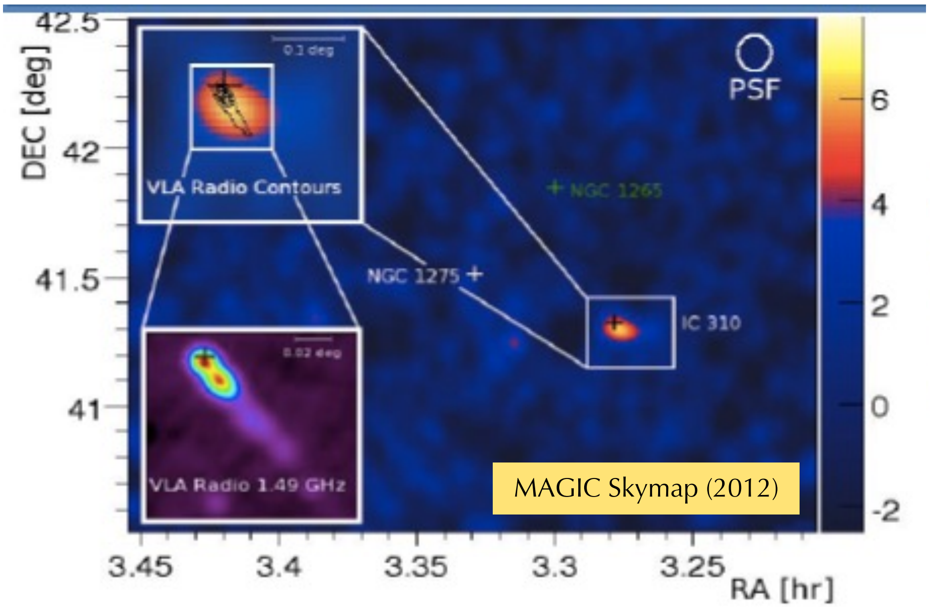
PKS 2155-304

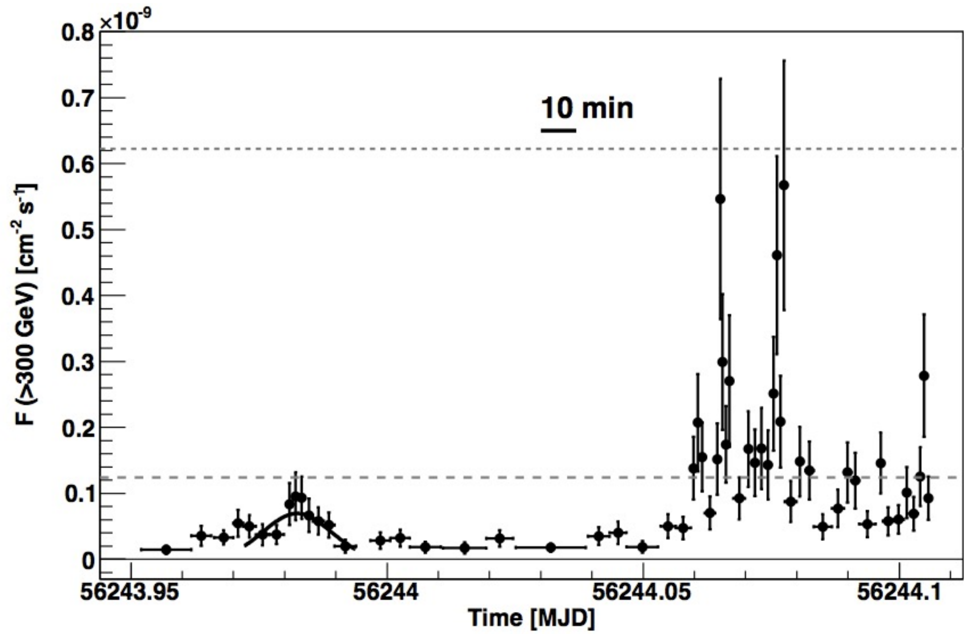
- Peak flux ~15 x Crab
- Doubling times ~ 1-2 min
- $R_{BH}/c \sim 1...2 \times 10^4$



Classic flare from PKS 2155-304, still unbeatable!

IC 310: Unexpected Discovery in the Perseus Cluster of Galaxies



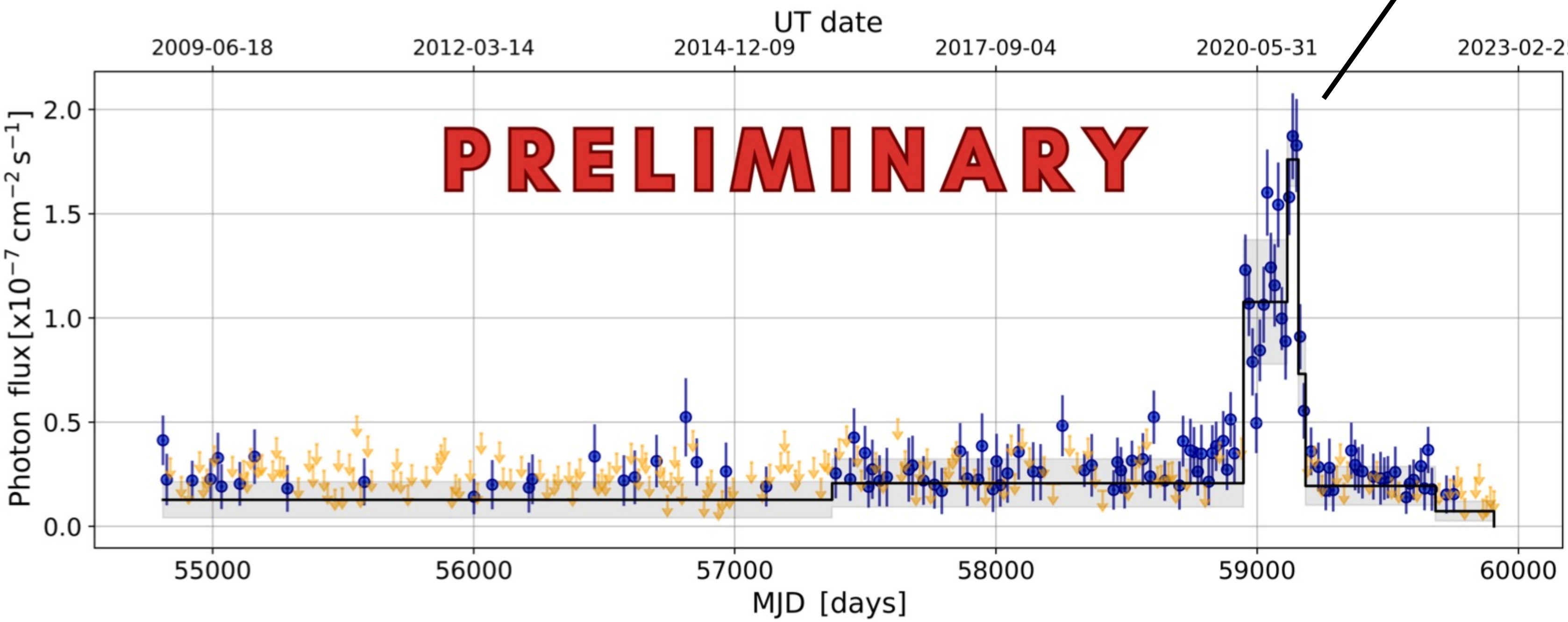


- Detection at > 260 GeV by MAGIC. MWL campaign in 2012-2013.
- VLBI reports parsec-scale blazar-like structures; $\theta \leq 38^\circ$.
- Light curve with 1-min bins shows extreme variability; unusual for a radio galaxy.
- No curvature in spectrum from 60 GeV – 10 TeV.
- Difficult to explain with current (standard) theoretical scenarios.

MAGIC Collaboration, Science, 346 (2014)

Long-term monitoring of blazars with Fermi-LAT

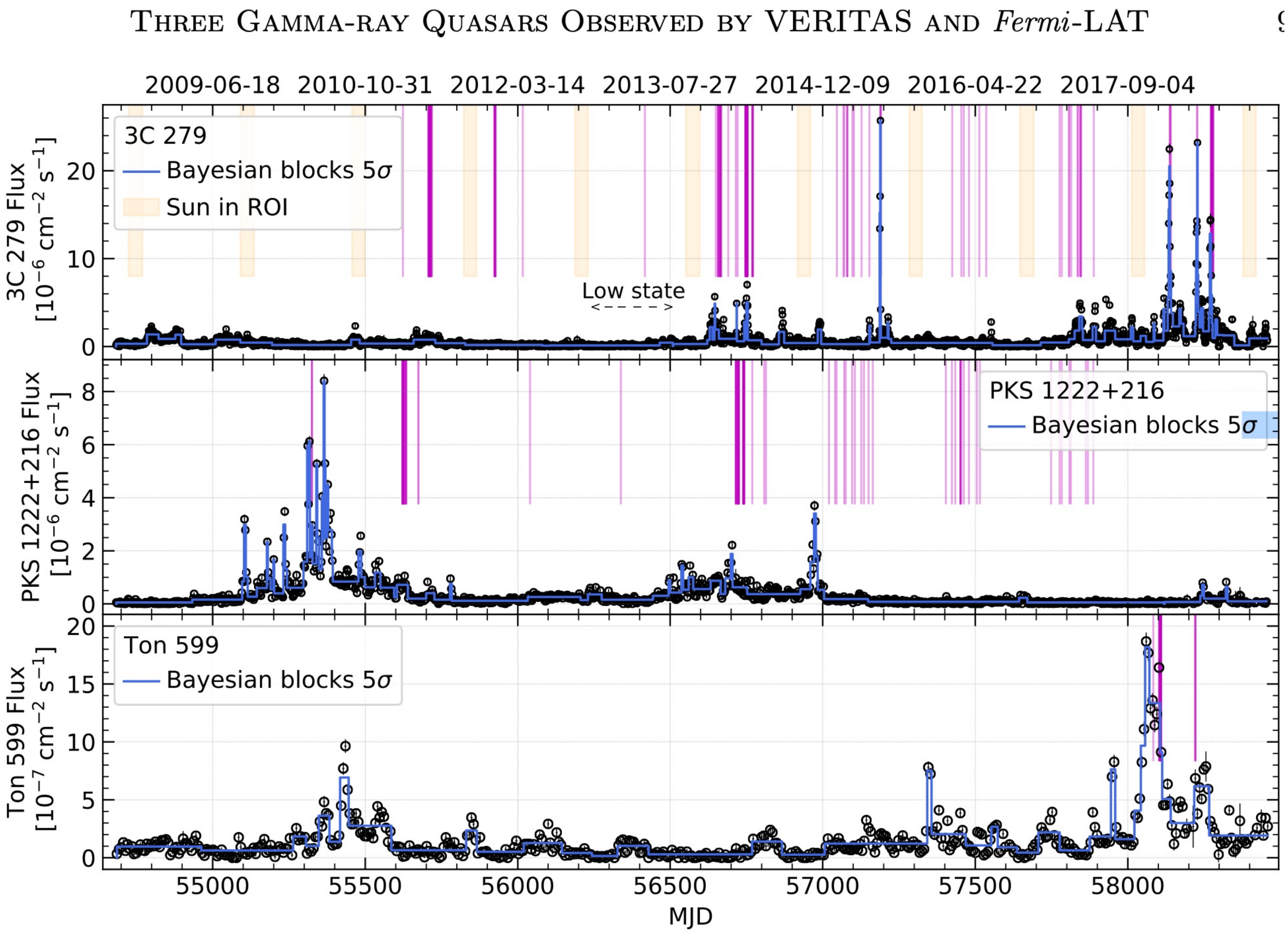
TeV flare detected by MAGIC & VERITAS



B2 1811+31: Fermi-LAT B2 1811+31 12-year full dataset light curve, with 14-day bins.

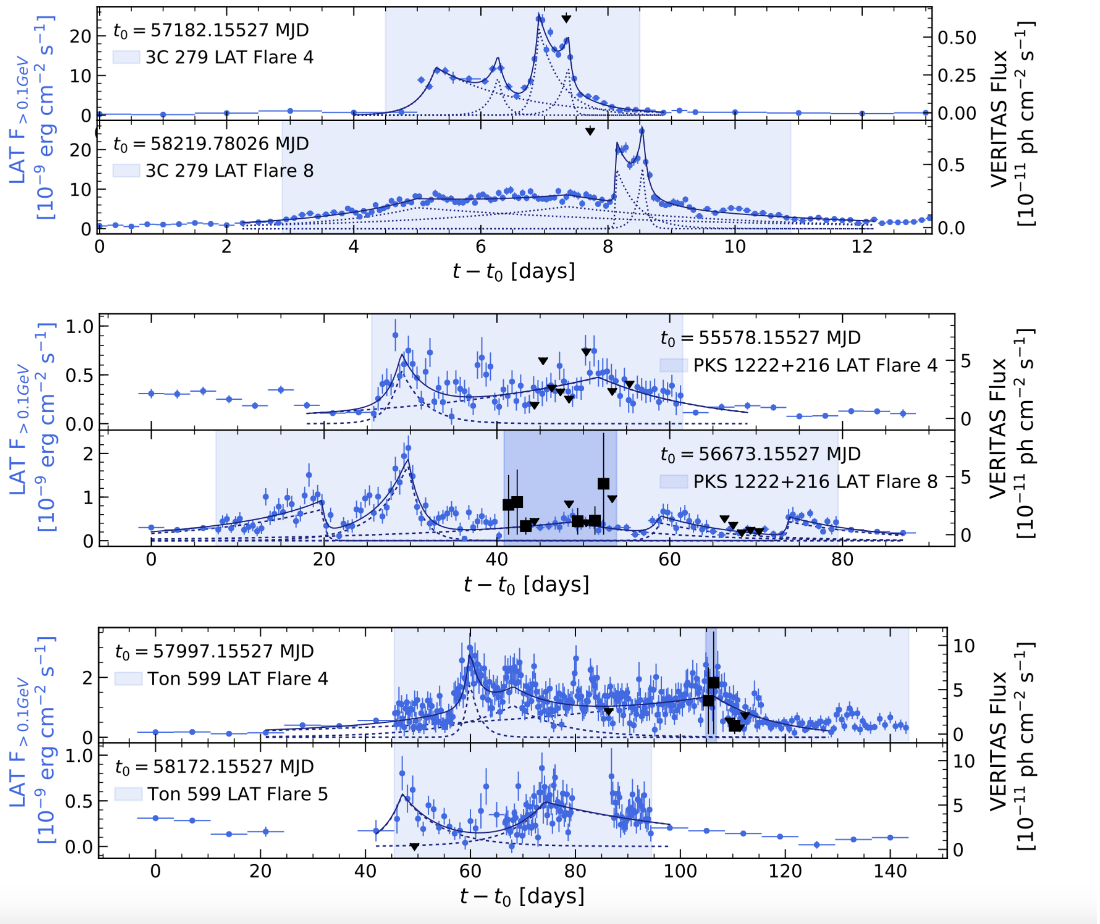
P. Drake, C. Adams, + VERITAS arXiv:2309.12920v1

Long-term monitoring of blazars with Fermi-LAT



Brill, Hervert, Valverde + VERITAS arXiv:2110.13181v1

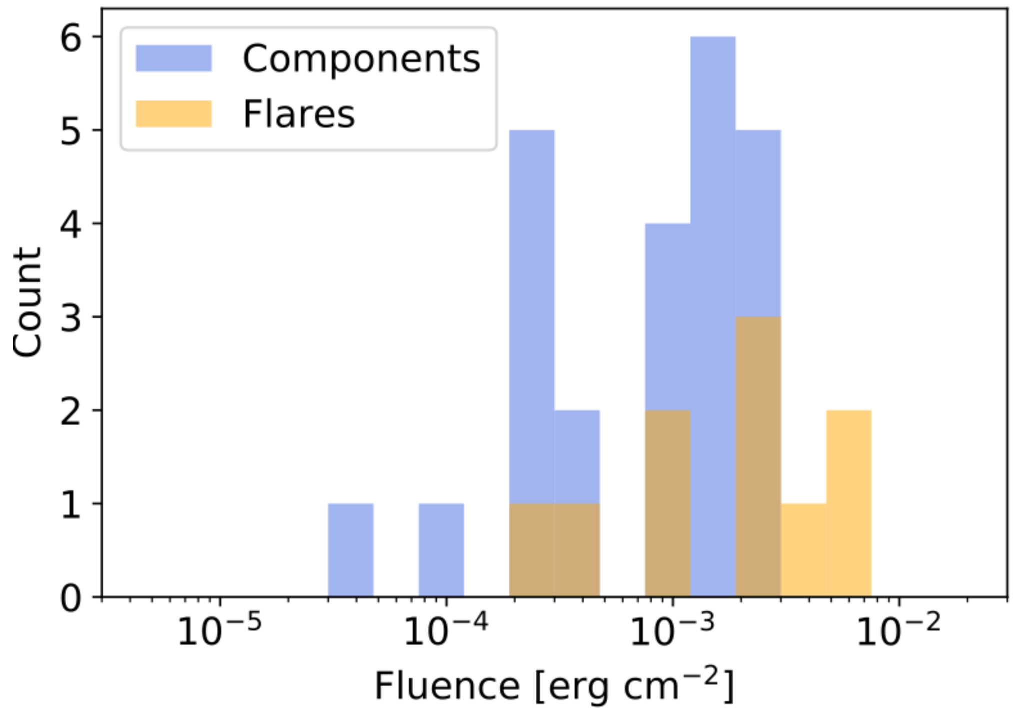
Fast variability of blazars measured with Fermi-LAT



LAT daily and sub-daily light curves (blue points). VERITAS data points and 95% upper limits are shown as black squares and downwards arrows.

Brill, Hervert, Valverde + VERITAS arXiv:2110.13181v1

Flare fluence distributions (3C 279)

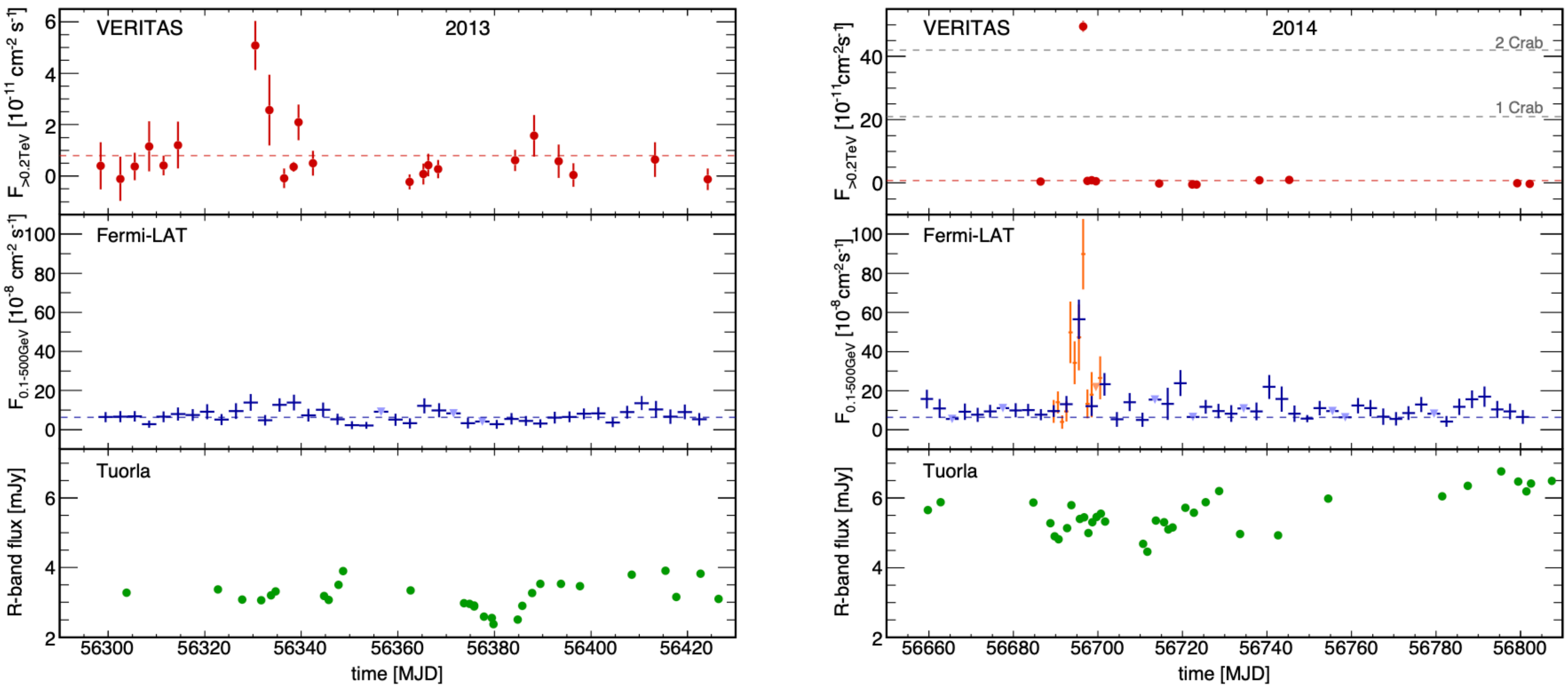


Fluence distributions of the twenty-four resolved flare components and ten flares of 3C 279

Relativistic reconnection predict that flare components produced by large, non-relativistic plasmoids should have similar fluences to components produced by small, relativistic ones, so that flare components should have similar fluence regardless of their variability timescales.

Brill, Hervert, Valverde + VERITAS + Sironi arXiv:2110.13181v1

A luminous and isolated gamma-ray flare from the blazar B2 1215+303

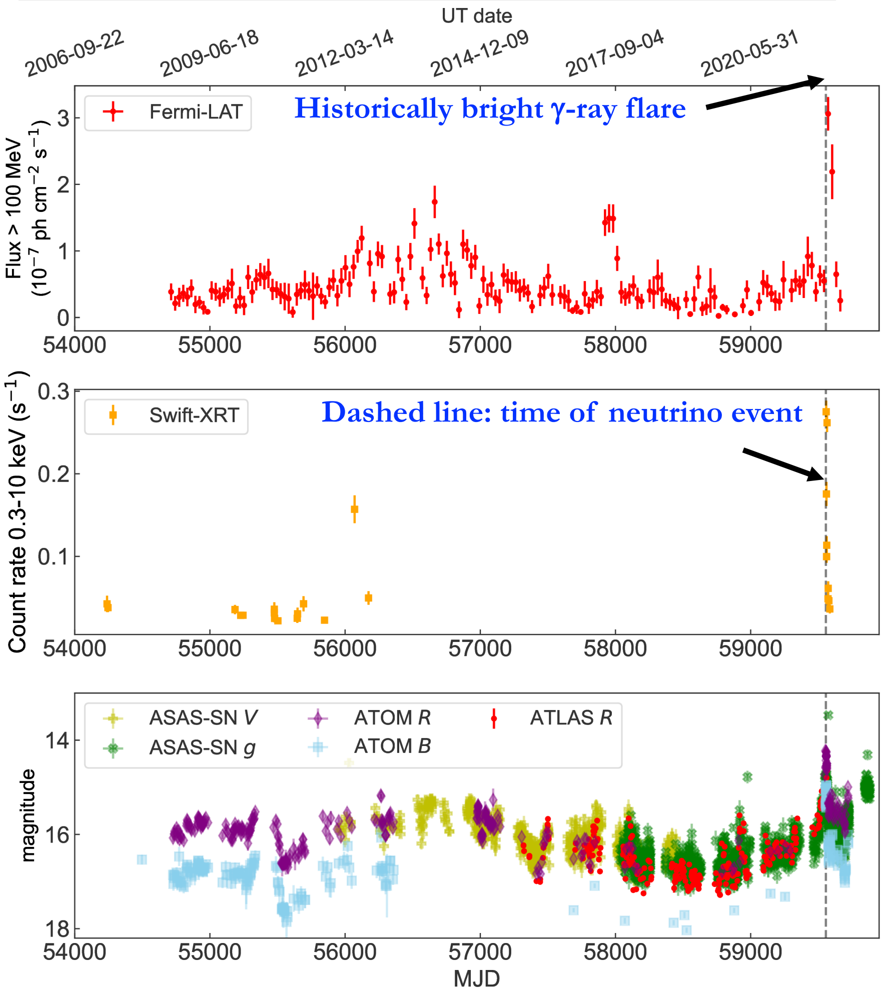


The TeV flux reached 2.4 times the Crab Nebula flux with a variability timescale of < 3.6 h. Multiwavelength observations with Fermi-LAT, Swift, and the Tuorla observatory revealed a correlated high GeV flux state and no significant optical counterpart to the flare.

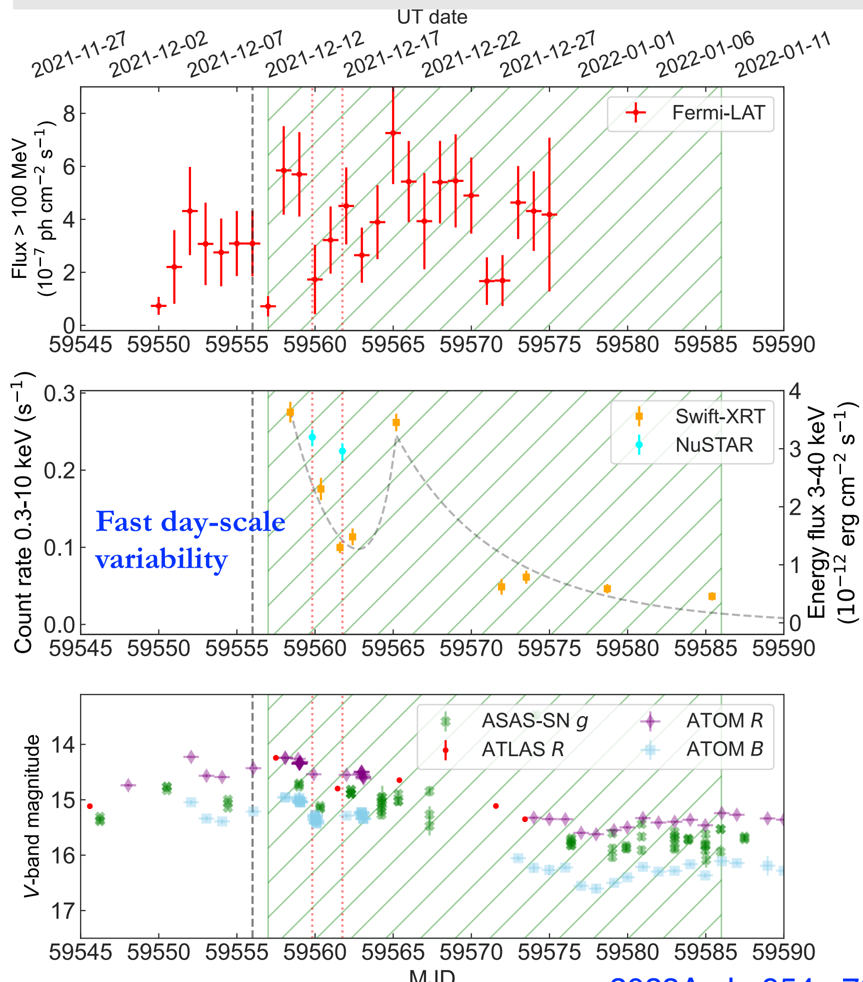
Errando + VERITAS arXiv:1701.01067

Multiwavelength flare in PKS 0735+178 during IceCube neutrino event IceCube-211208A

The long-term variability of PKS 0735+178



MMW activity 2 months after neutrino event



2023ApJ...954...70A

Highest flux during IC neutrino event at all frequencies

Q. Feng + VERITAS + H.E.S.S. arXiv:2306.17819

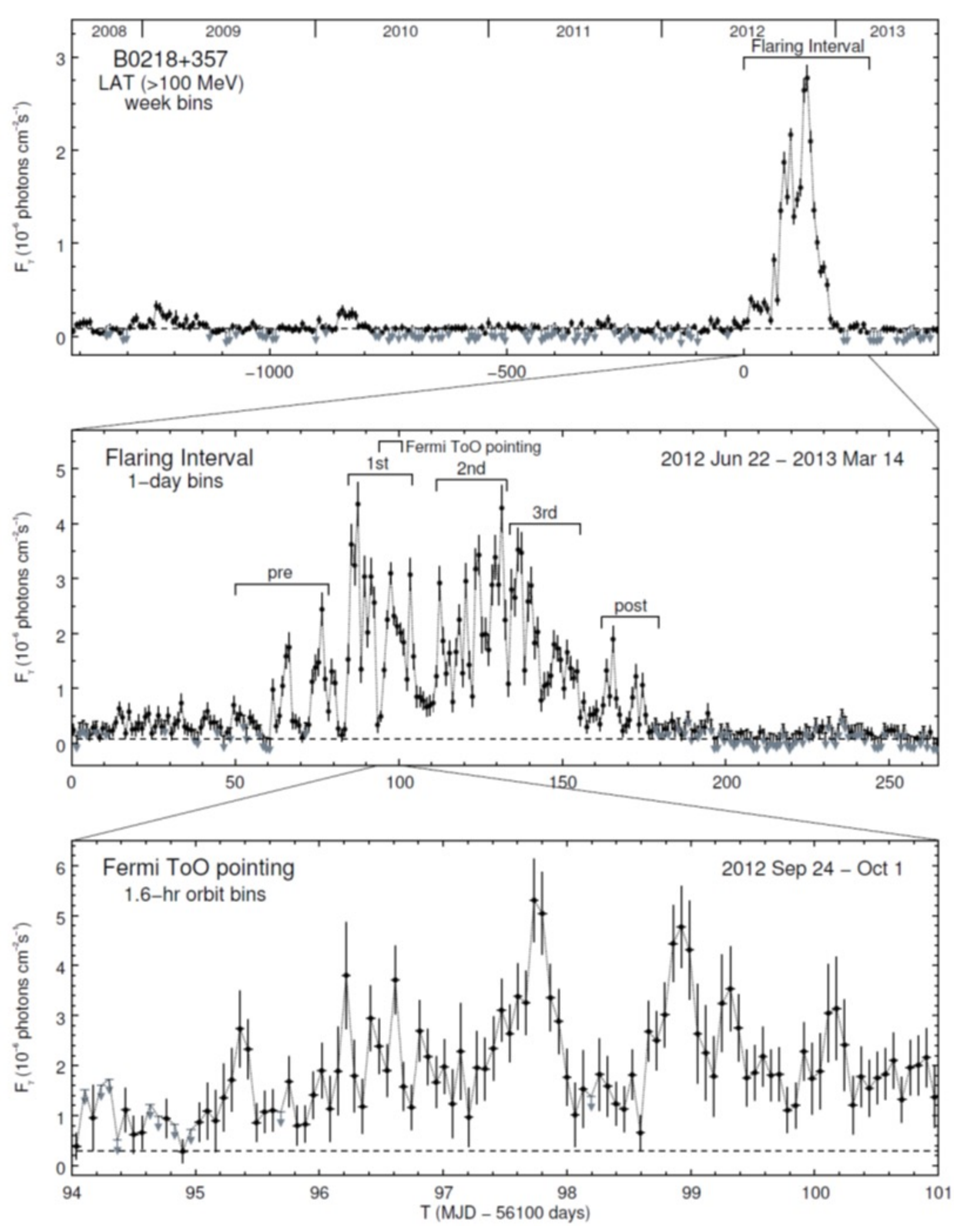
Flares inside flares

A lightcurve interpretation complication for some blazars -- fractal Gamma-Rays ?

"Flares inside flares" – when have sufficient signal to resolve a "flare" on shorter timescales, often see that it is actually superposition of shorter (higher peak flux!) flares ..

Cheung, C.C. et al., ApJL, 2014

Gravitational Lens Delayed Gamma-ray Flares in B0218+357



Aside: similar fractal behavior in XRB Cyg X-1 … good timing statistics allow you to constrain models

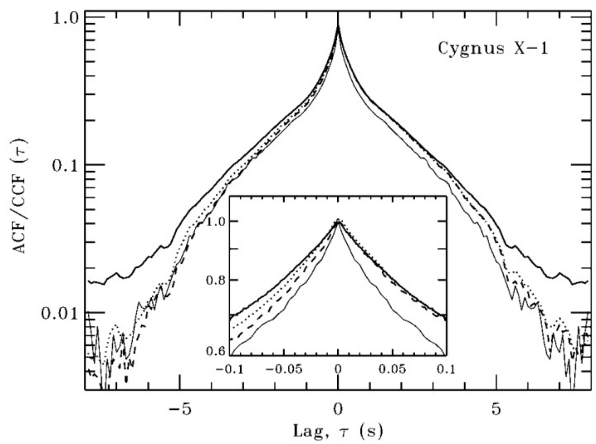
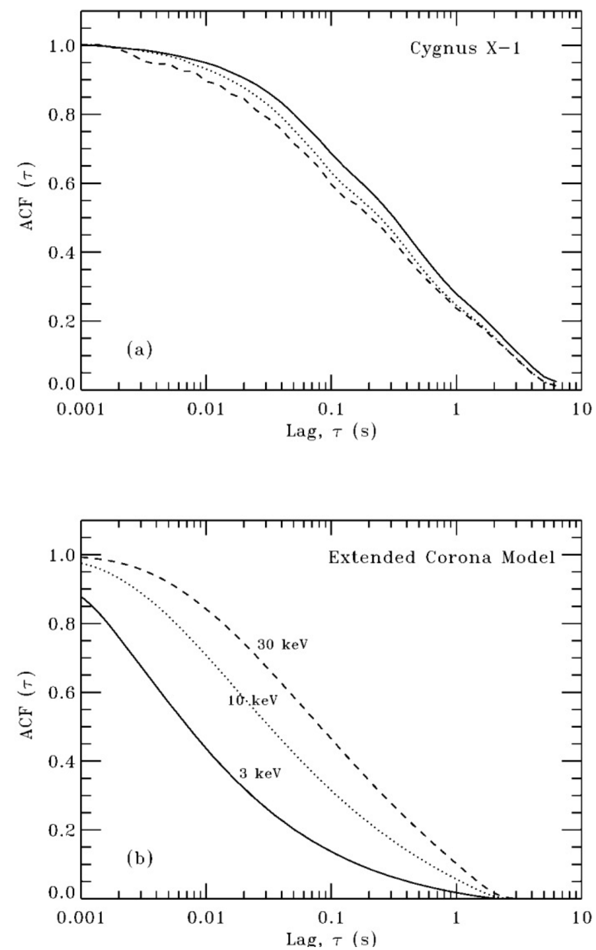


Fig. 1.—Auto- and cross-correlation functions of Cyg X-1 observed in 1997 December. Solid curves show the ACFs for the 2–5 keV energy band (*thick curves*) and the 24–40 keV band (*thin curves*). Dotted curves show the CCF between the 8–13 keV band and the 2–5 keV band, and dashed curves represent the CCF for the 24–40 keV band vs. the 2–5 keV band. The CCFs at other energies have similar shapes. The peaks all align at around zero lag. The higher energy curves are narrower. The CCFs are defined in such a way that the peak is expected to appear at a positive lag when hard photons are lagging the soft ones. The errors at small lags are roughly the same size as the line widths and are hence left unplotted for clarity. The CCF peak lag is at less than 2 ms for the 2–5 keV vs. 8–13 keV CCF.

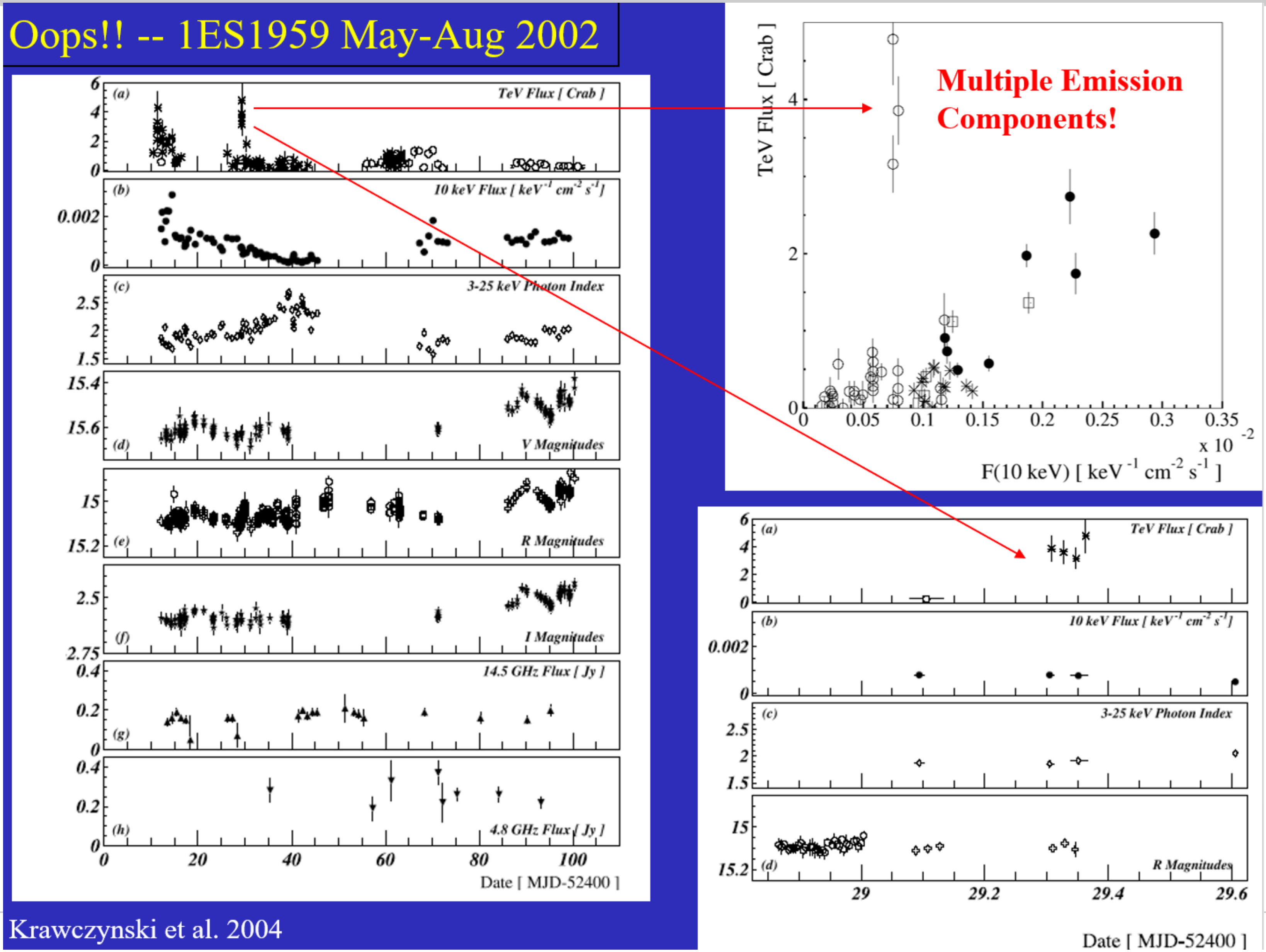
ground counts are a very small fraction of the total counts and because current background models for *RXTE* do not give estimates on timescales shorter than 16 s. *RXTE* dead time for Cygnus X-1 is about 1% and should affect only zero-lag bins in the correlation functions.

2.2. *Light Curves*



e.g., Maccarone, Coppi, Poutanen, ApJL, 2000

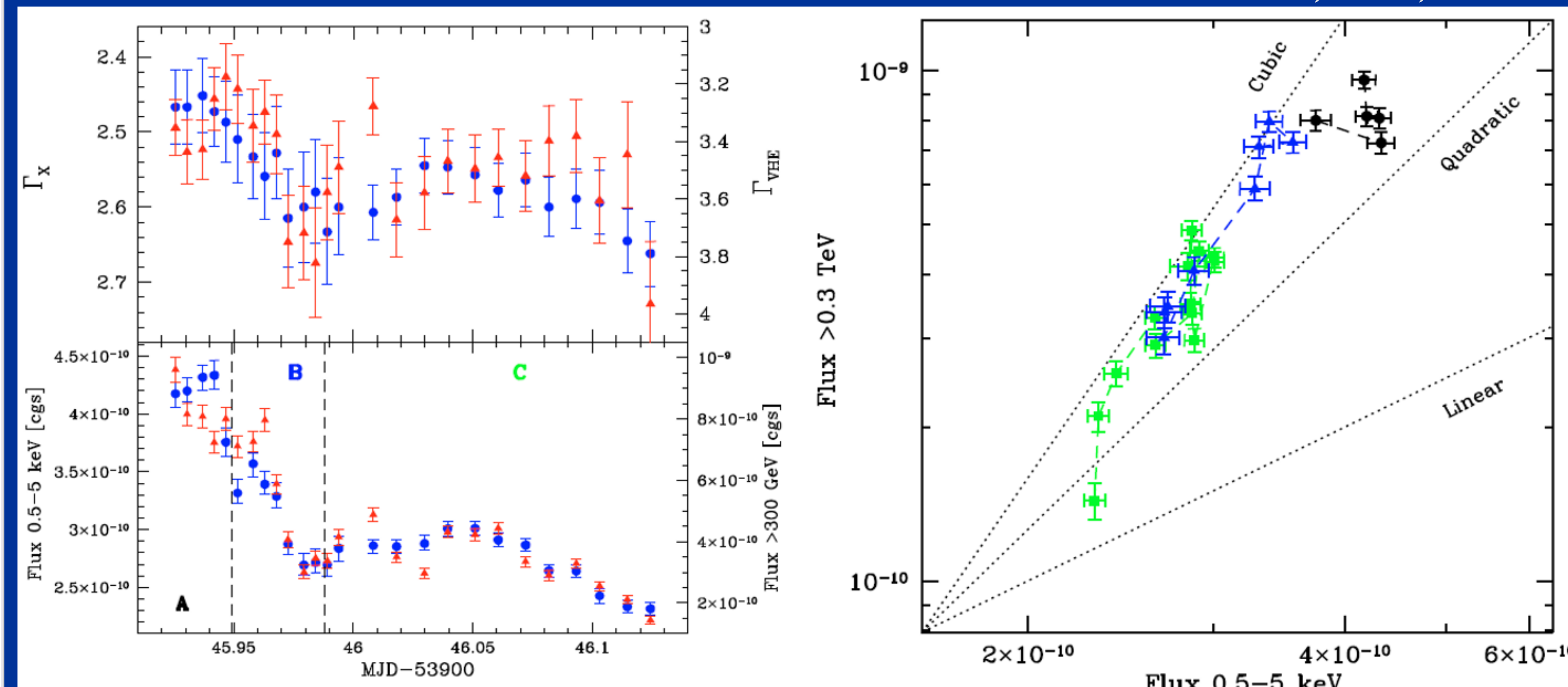
Orphan 1ES 1959+650 Flare



PKS 2155-304 Flare X-ray – TeV Correlation

Famous PKS 2155 (HESS) Flare of an “IBL”
Multiple Emission Components – Dilution!?

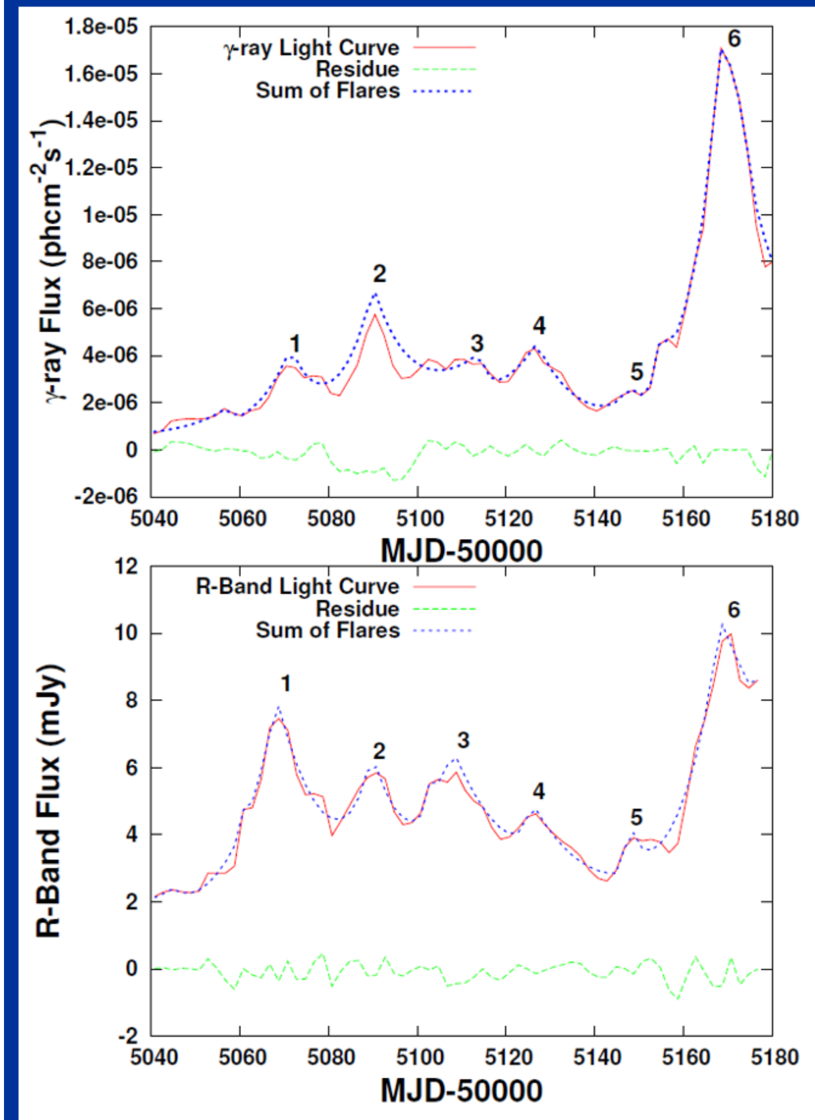
Aharonian et. al, A&A, 2009

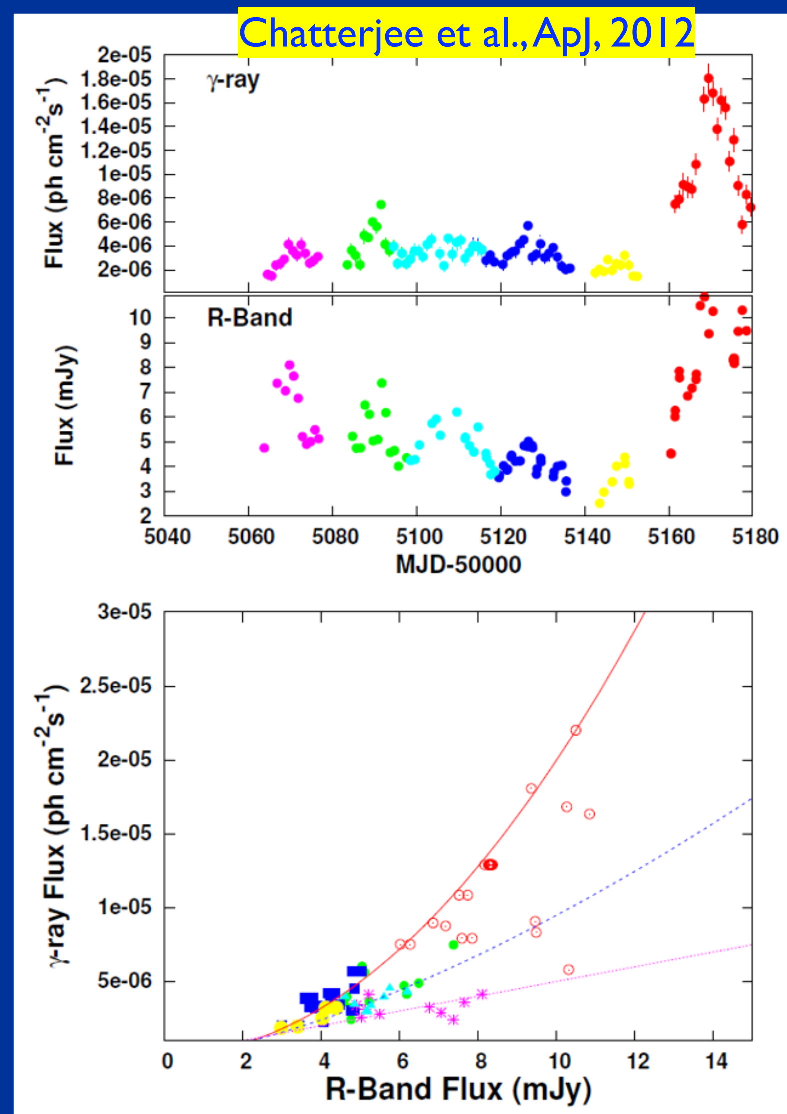


Very fast (~5min) variability! [N.B. Now also seen in 3C279, FSRQ!]

3C 454.3 2009 Flare: Optical – Gamma-Ray Correlation

3C 454.3 2009 Flare – SMARTS + Fermi (Chatterjee et al.) - “states”?

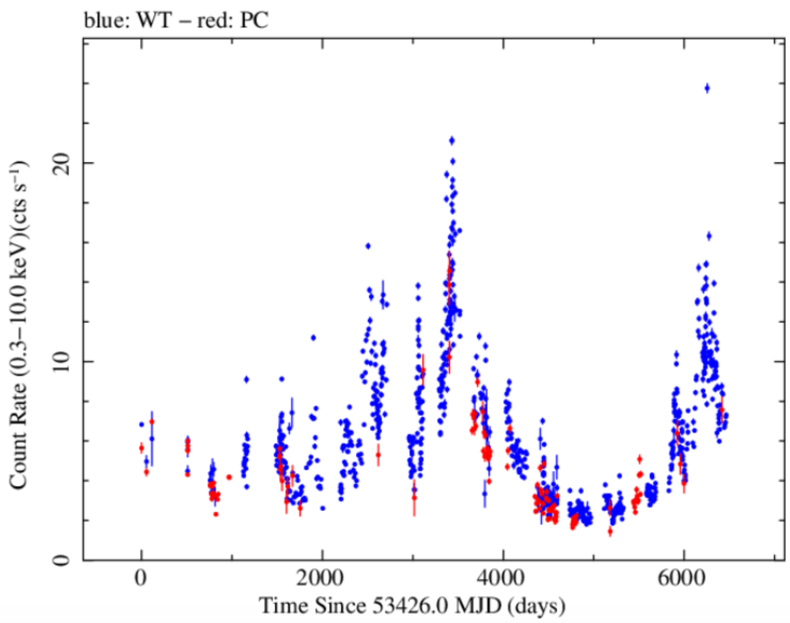




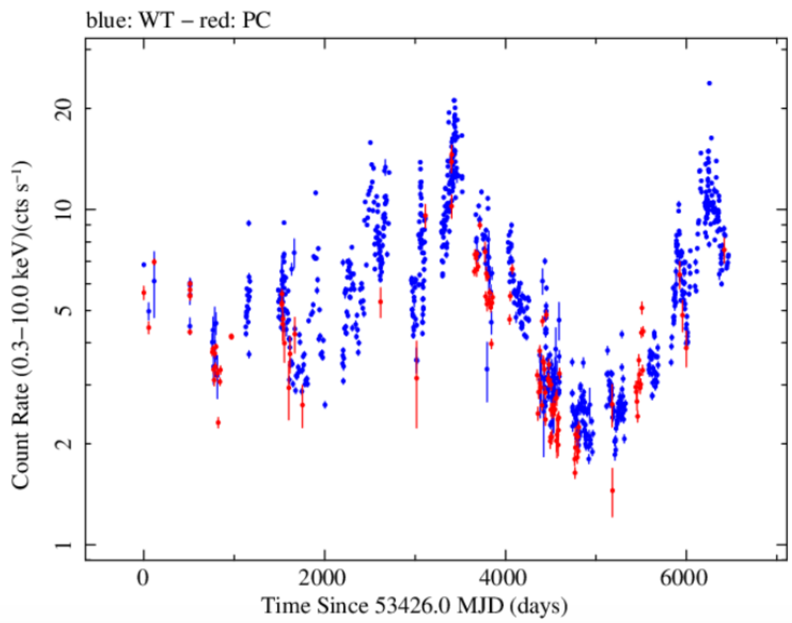
Extended Swift (X-Ray) Monitoring: Mrk 501 (HBL)

Overall Light Curves

Linear Light Curve



Log Light Curve

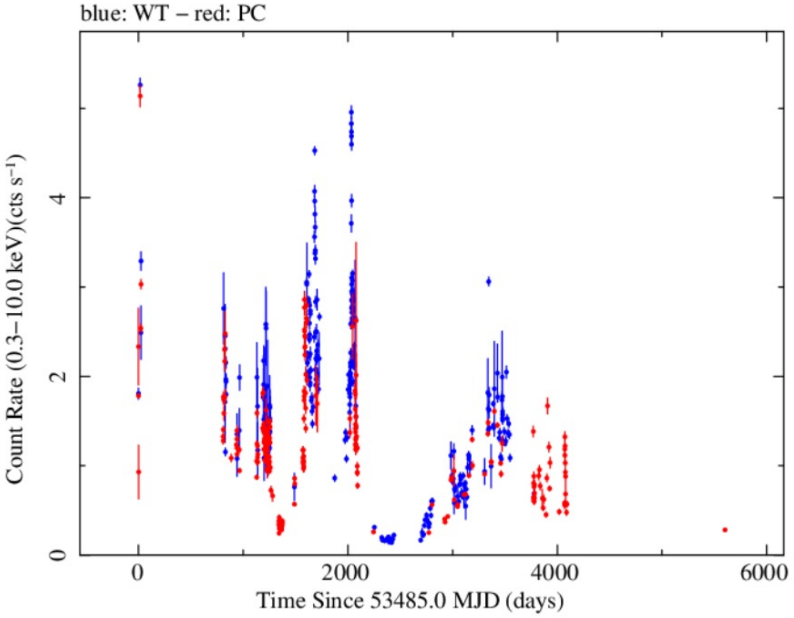


https://www.swift.psu.edu/monitoring/ (Falcone et al.)

Extended Swift (X-Ray) Monitoring: 3C 454.3 (LBL)

Overall Light Curves

Linear Light Curve



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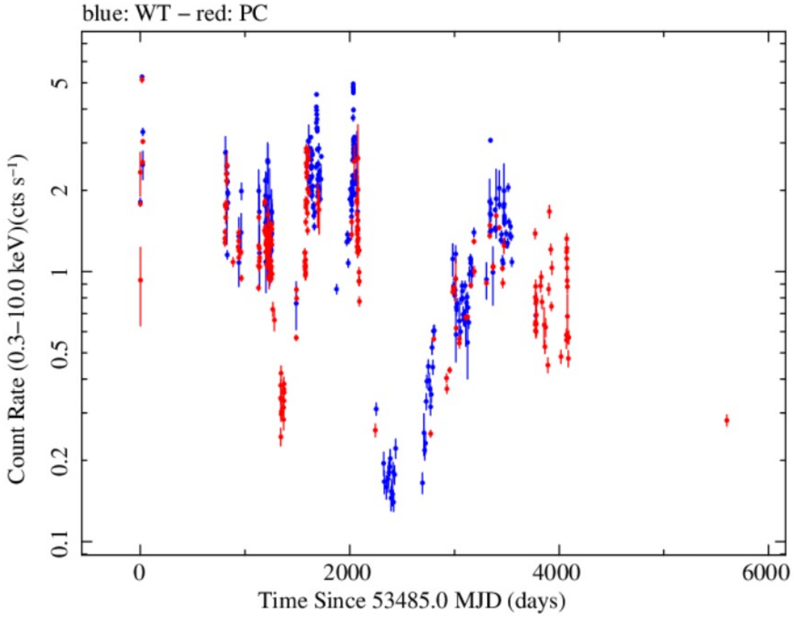

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