

Nature of Blazar Outbursts at GeV and Optical Wavebands

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Fermi-LAT Revolutionized High Energy Astrophysics

- 3rd source catalog (3FGL; Acero et al. 2015) --- based on 48 months of data --- contains 3033 sources above 4σ .
 - source location regions
 - spectral properties
 - monthly light curves
- More than 1500 AGN, 98% blazars (3LAC; Ackermann+ 2015)
- 1100 identified or associated blazars

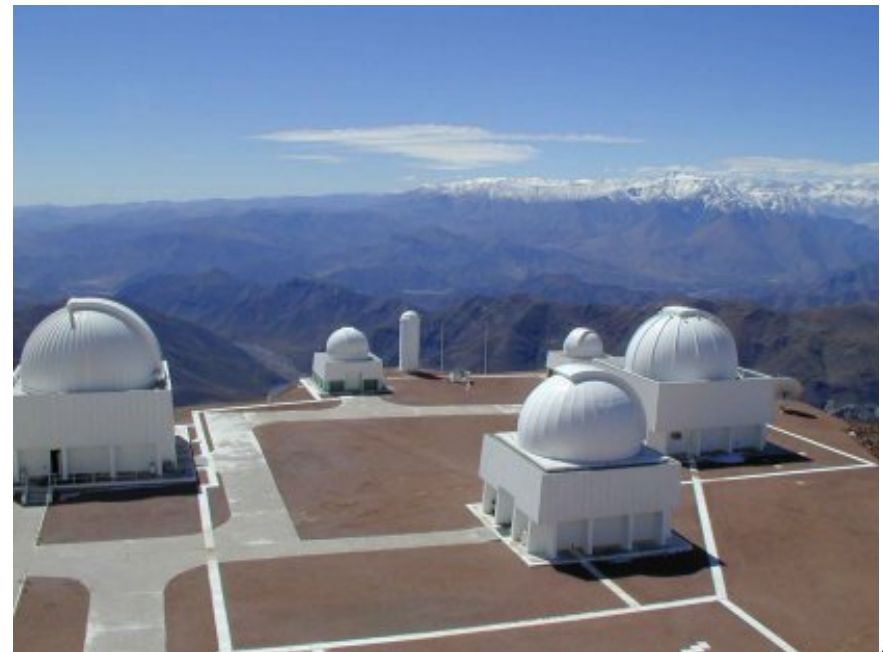


Multi-Wavelength Monitoring Initiatives Supporting Fermi

- A multitude of monitoring program all over the globe
- Cover a broad range of wave bands including (TeV), X-ray, Optical-near IR, Radio.

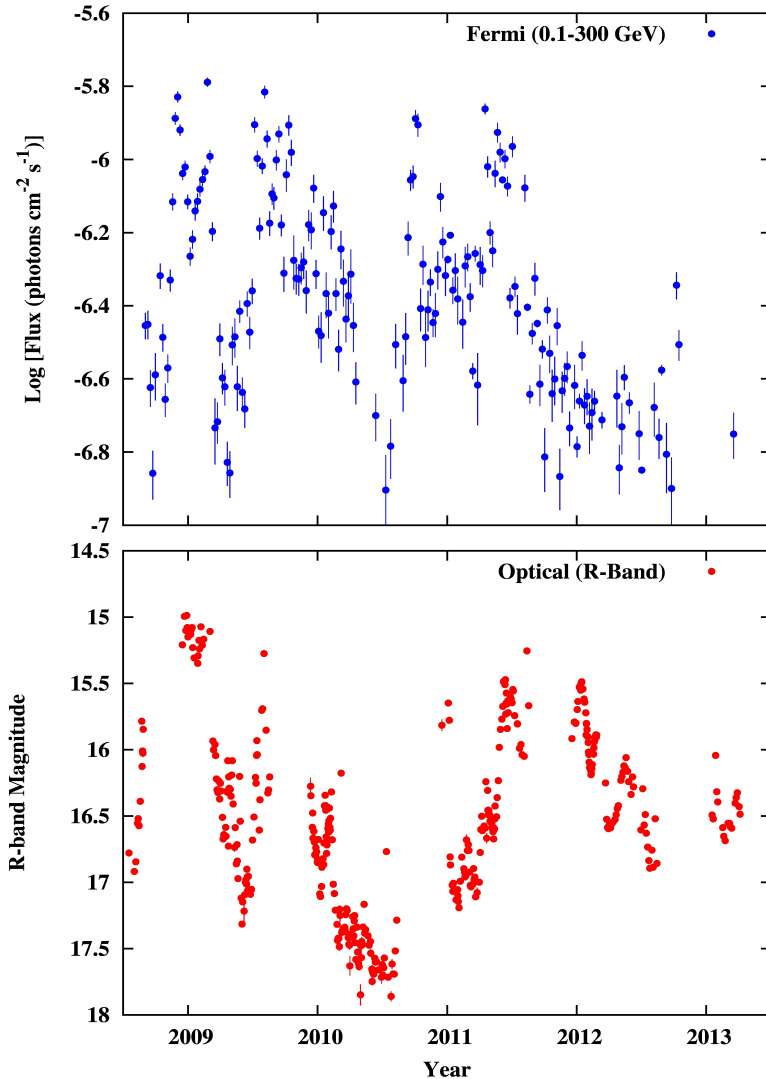
- Monitoring of “Fermi-blazars” with the SMARTS at Cerro Tololo, Chile
- Logarithmic cadence based on activity at the GeV band
- Simultaneous data from 0.4 to 2.2 microns (BVRJK).
- Data are public within a week.
- ~80 targets with varied sampling.

SMARTS: **S**mall and **M**oderate **A**pe**R**ture **T**elescope **S**ystem



Multi-waveband light curves of blazars

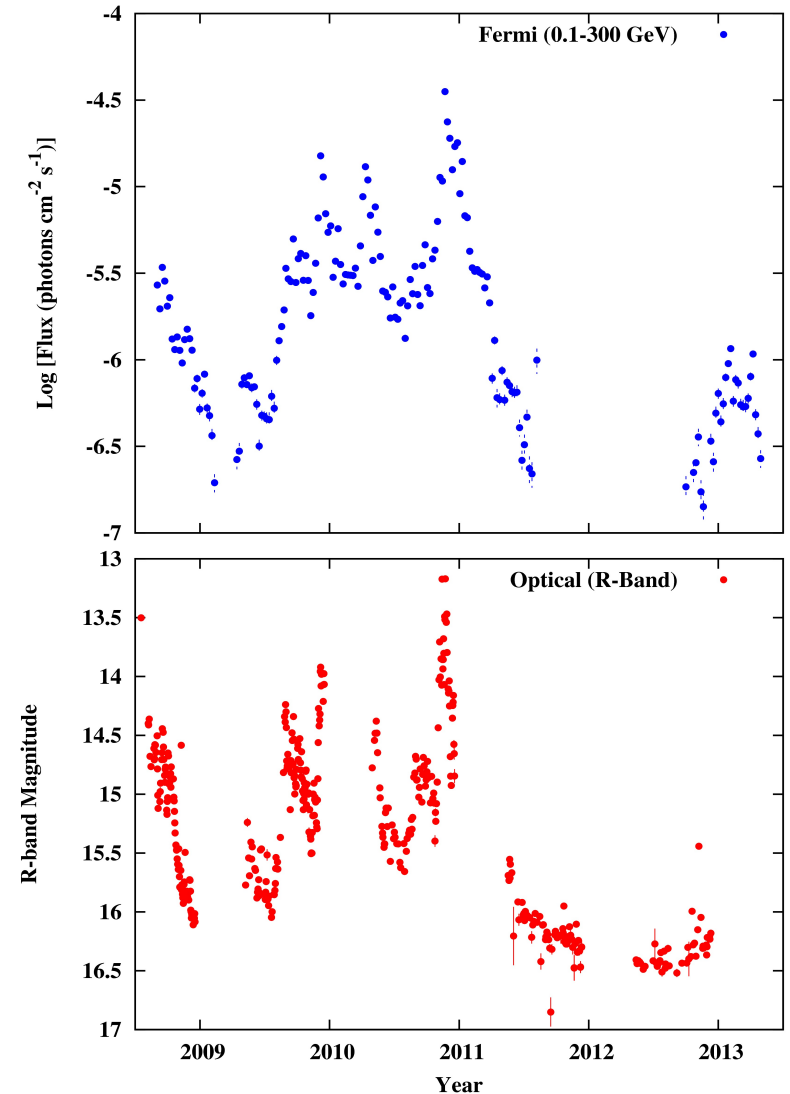
3C 279



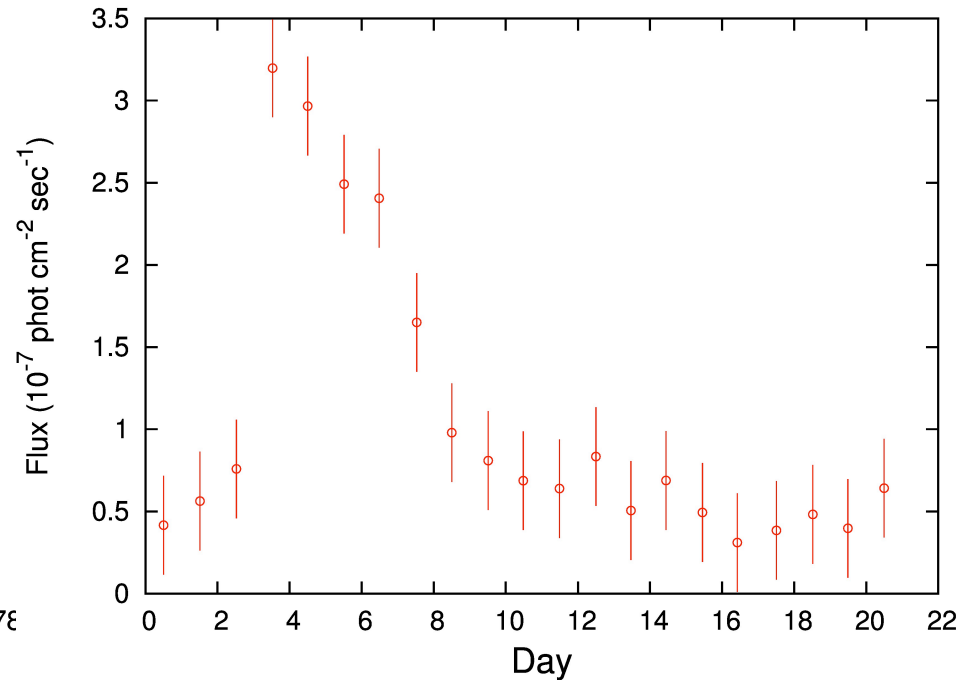
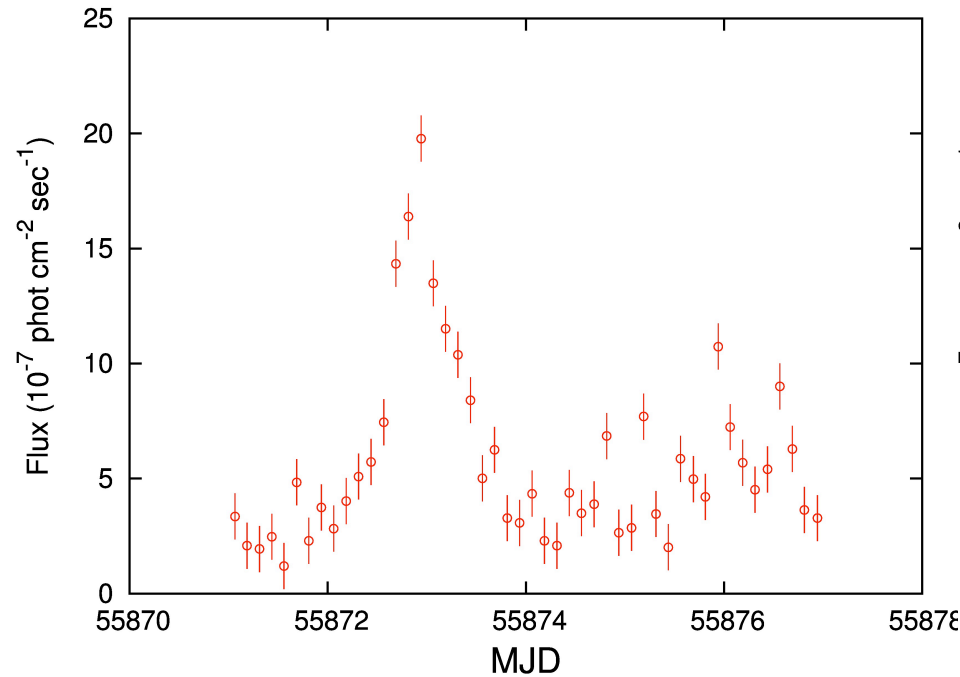
γ -ray

Optical

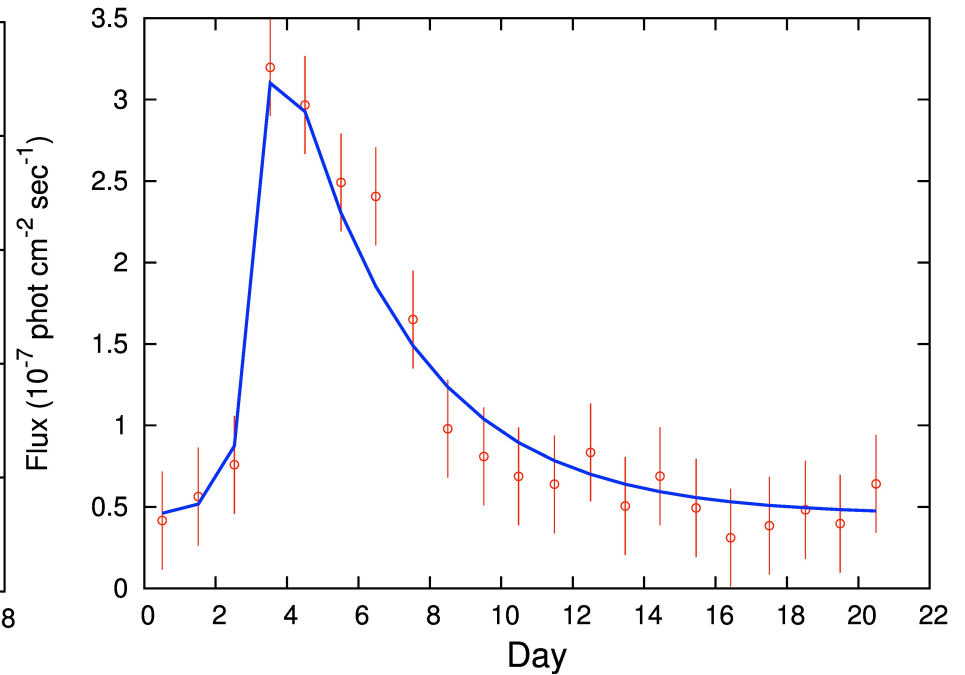
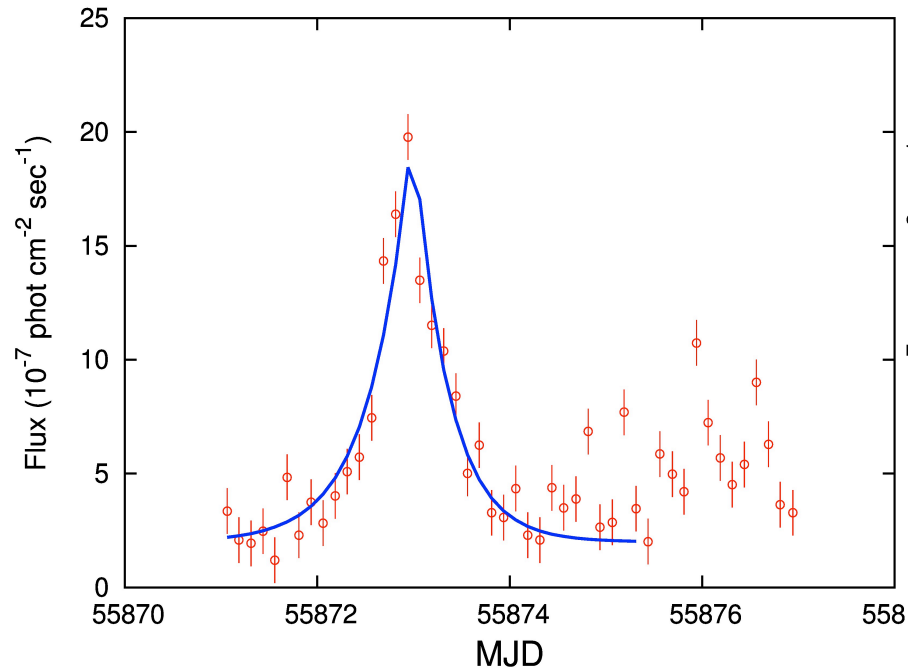
3C 454.3



Are Outbursts Symmetric or Asymmetric?



Are Outbursts Symmetric or Asymmetric?



$$f(t) = f_0 + f_{\text{max}} * \exp[(t - t_0)/T_r] \text{ for } t < t_0$$

$$= f_0 + f_{\text{max}} * \exp[-(t - t_0)/T_d] \text{ for } t > t_0$$

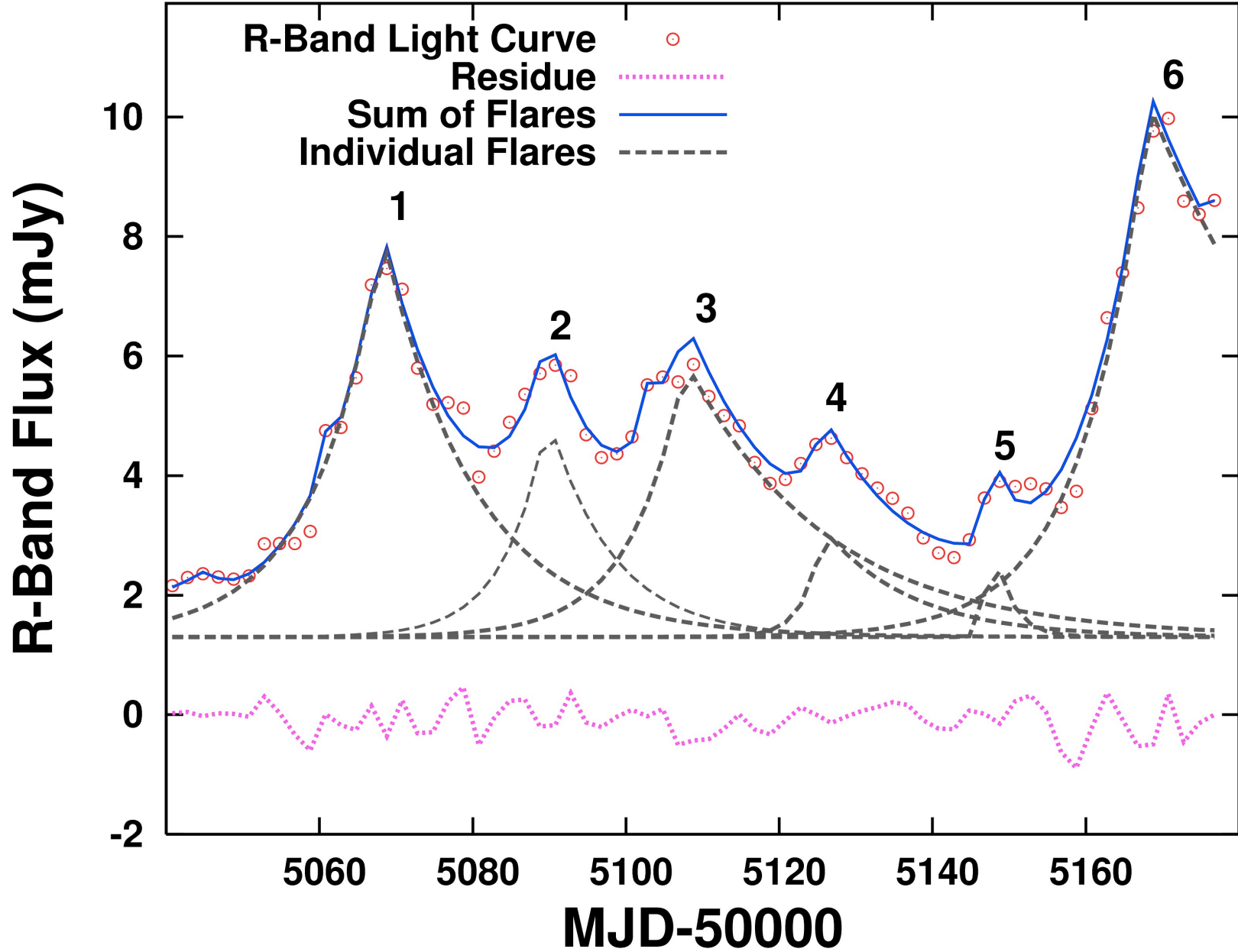
$$\xi = (T_d - T_r)/(T_d + T_r)$$

$$\xi = 0$$

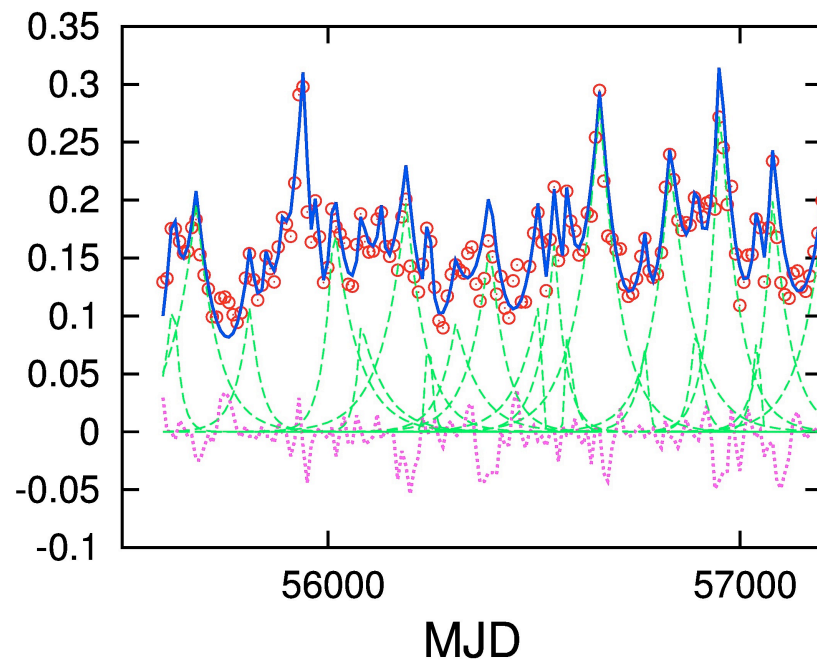
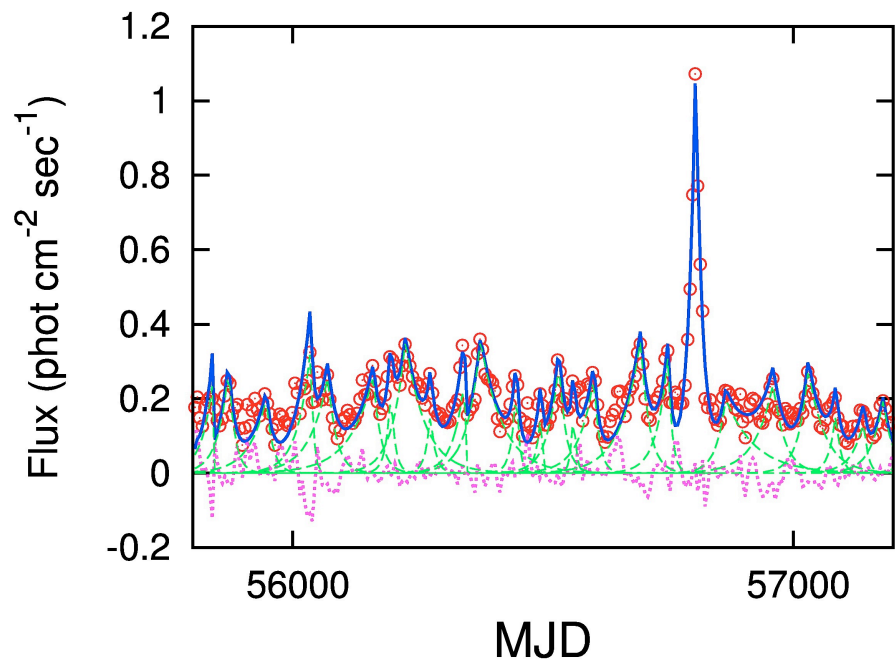
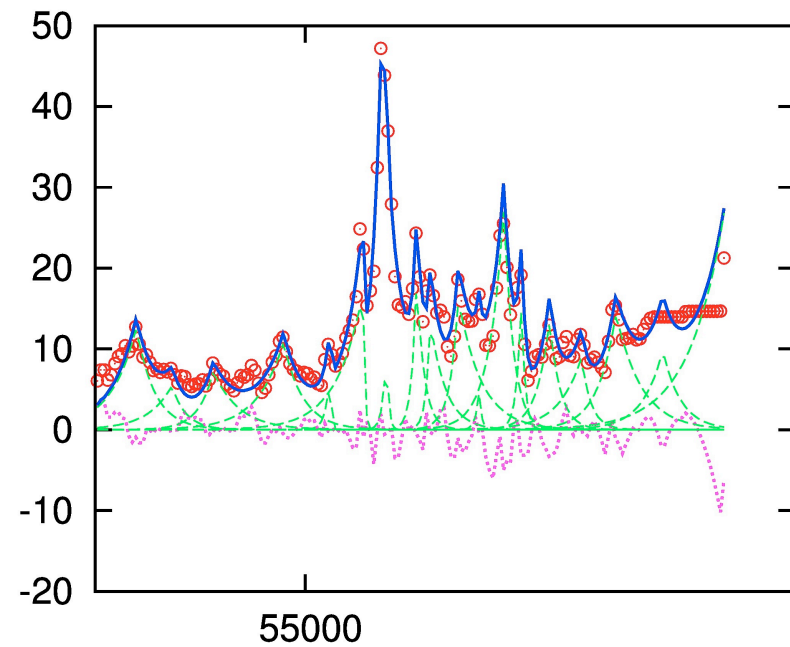
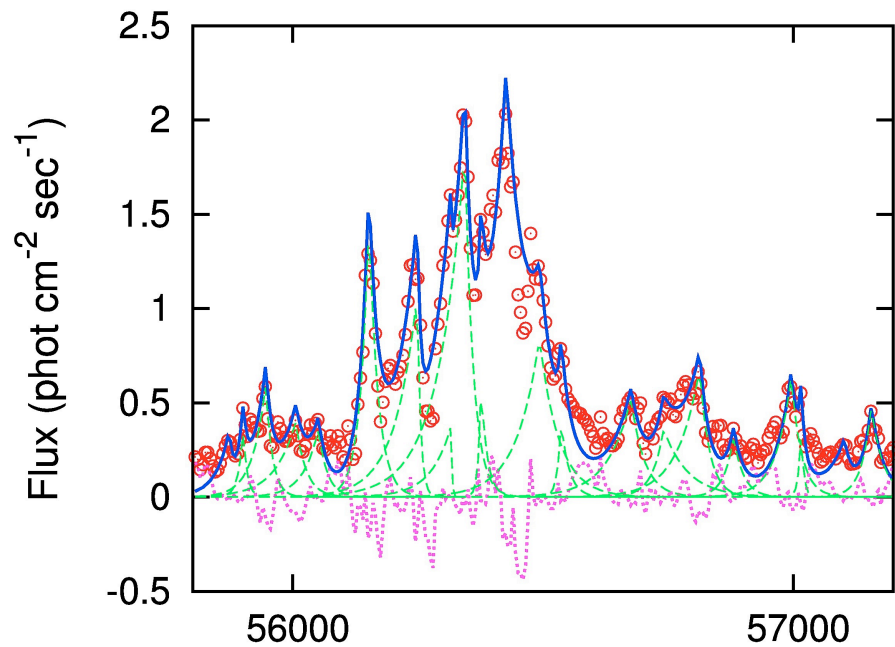
$\Rightarrow$ Perfectly symmetric

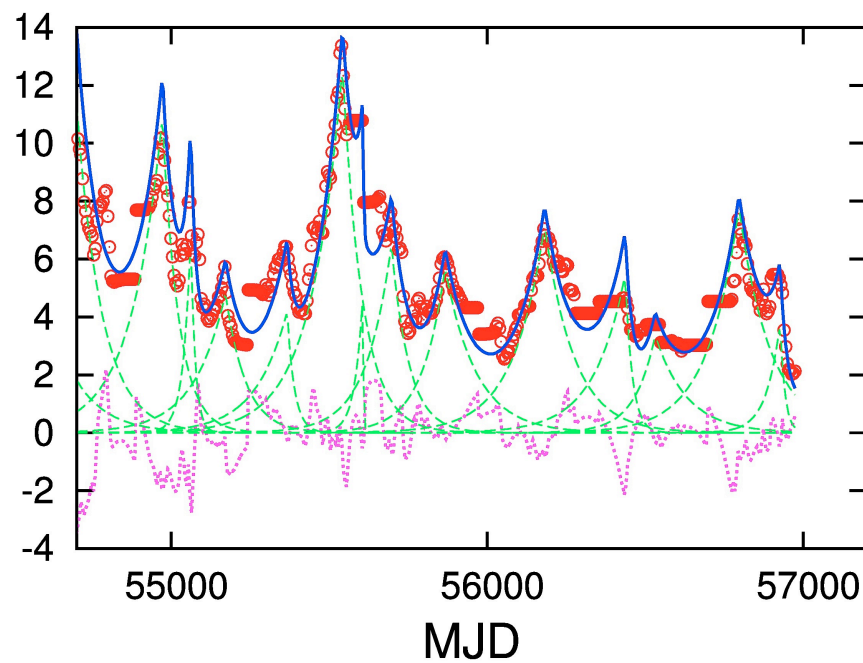
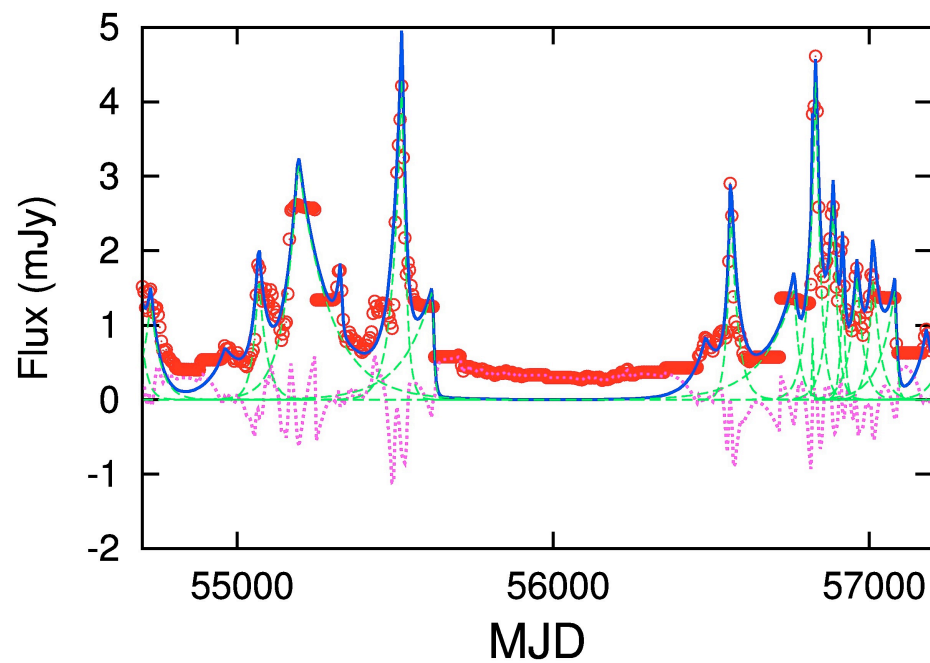
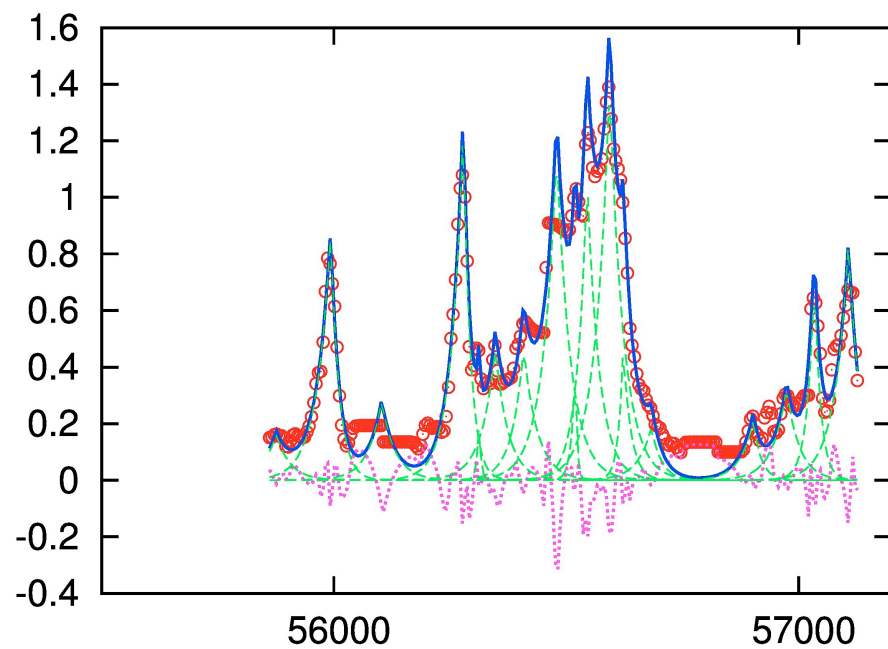
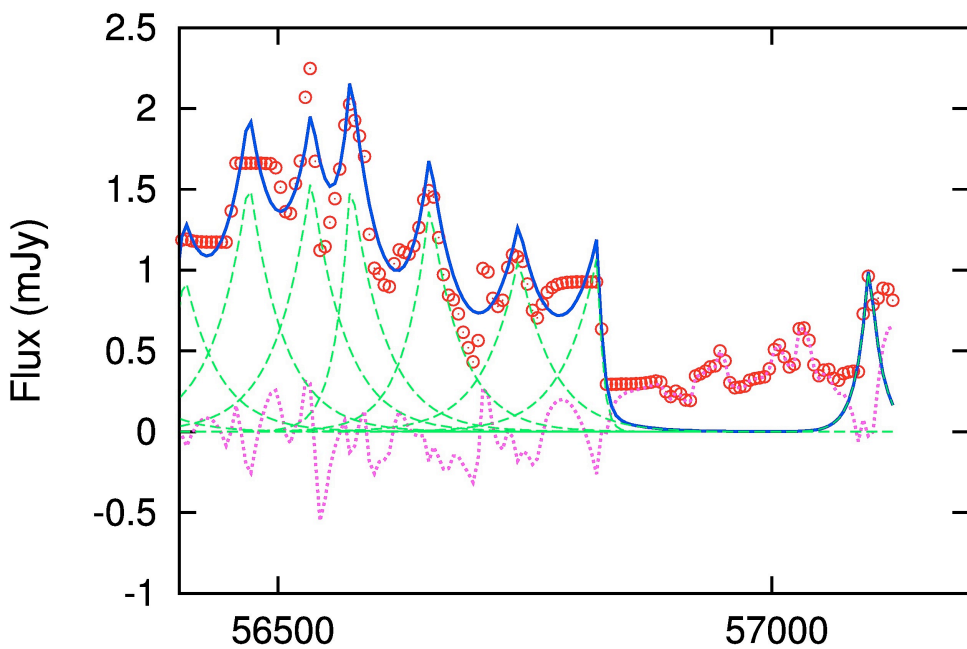
$$\xi = 1, -1$$

$\Rightarrow$ Strongly asymmetric

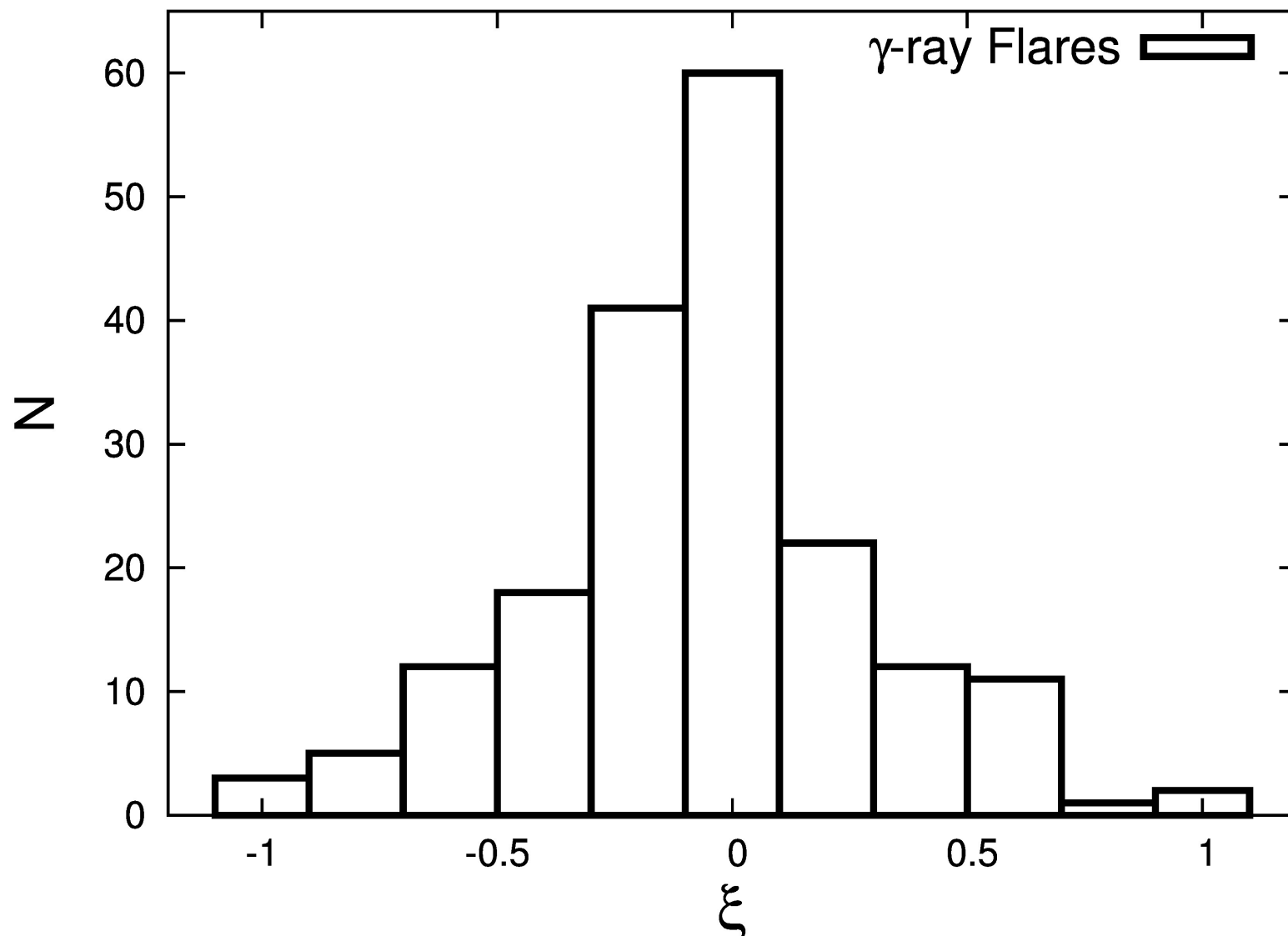


Valtaoja+ (1999), RC+ (2008), Abdo+ (2010), Kushwaha+ (2014)

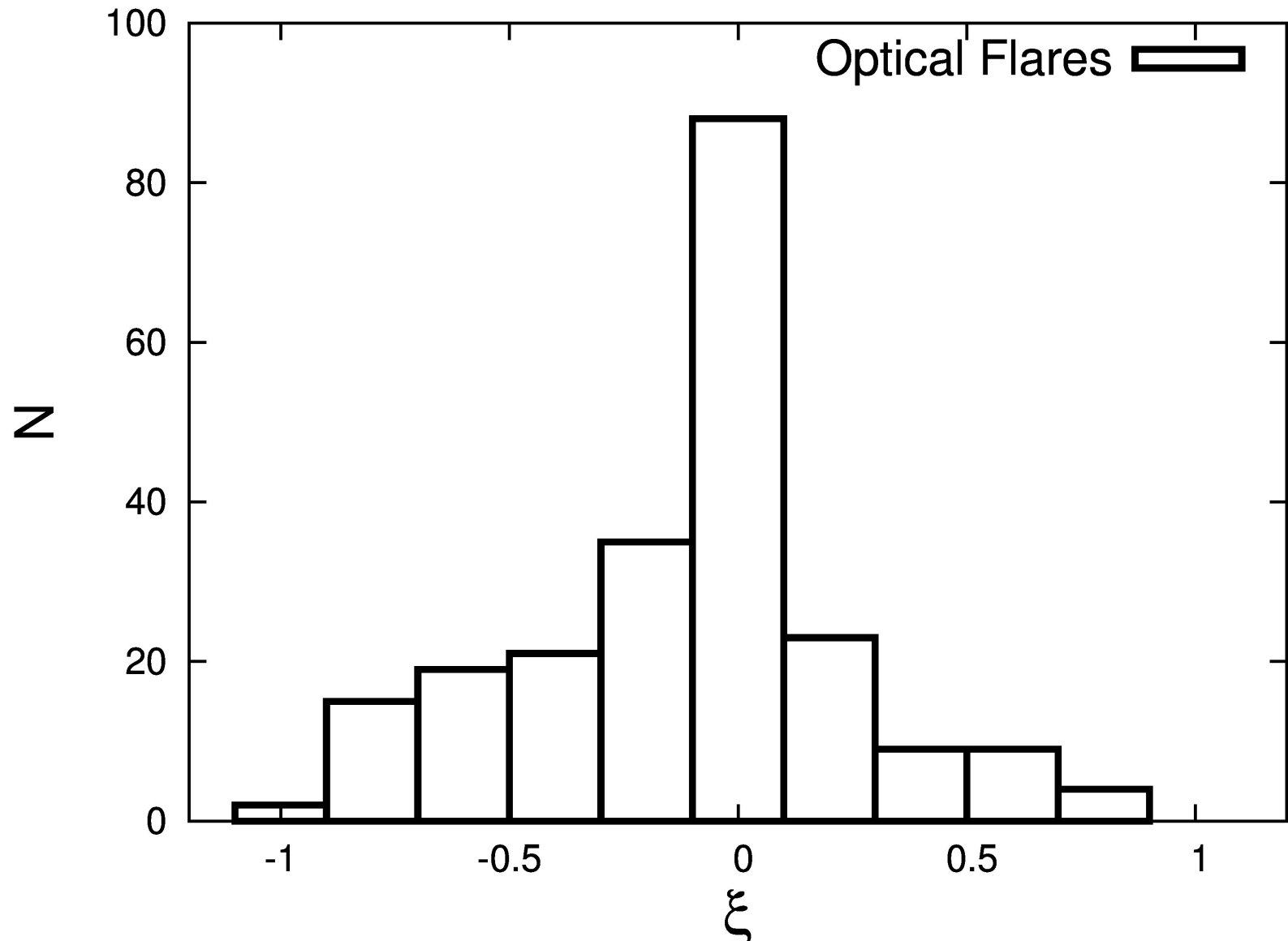




Long-Term GeV Flares are Mostly Symmetric: Rise and Decay Timescale Comparable



Long-Term Optical Flares are Mostly Symmetric: Rise and Decay Timescale Comparable

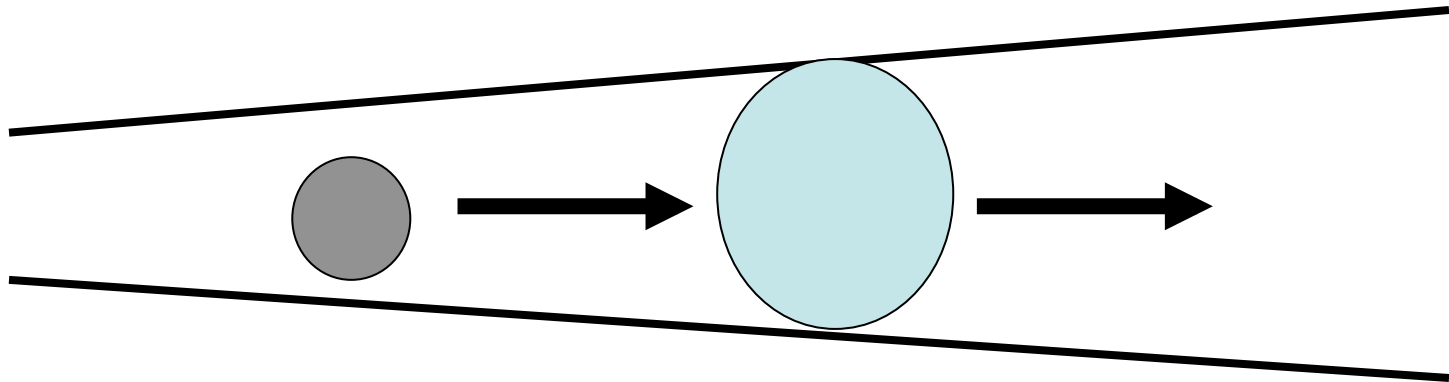


Probing Cooling Timescales

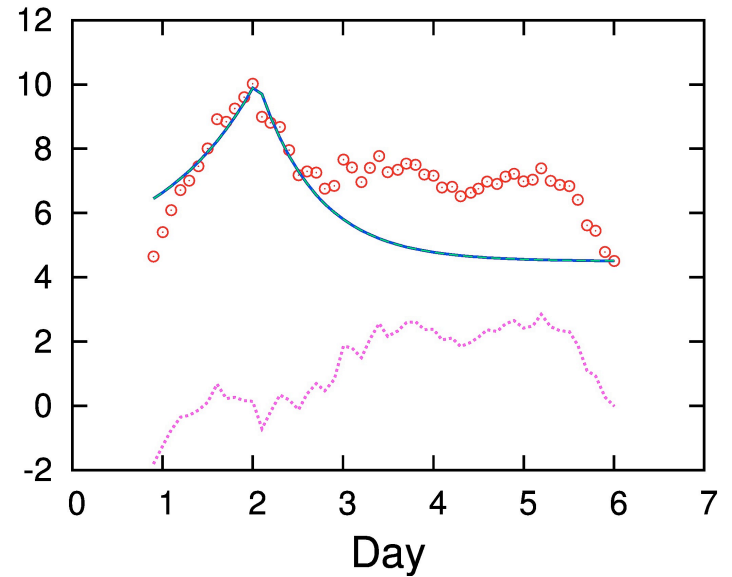
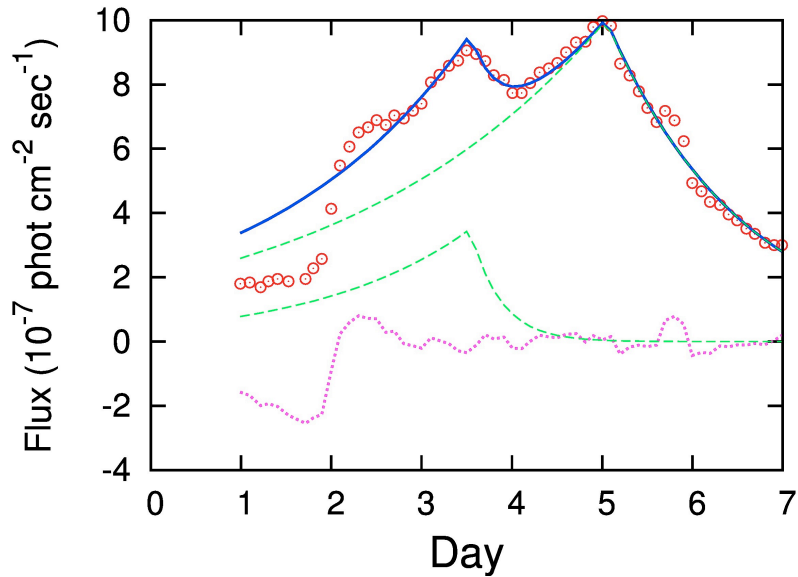
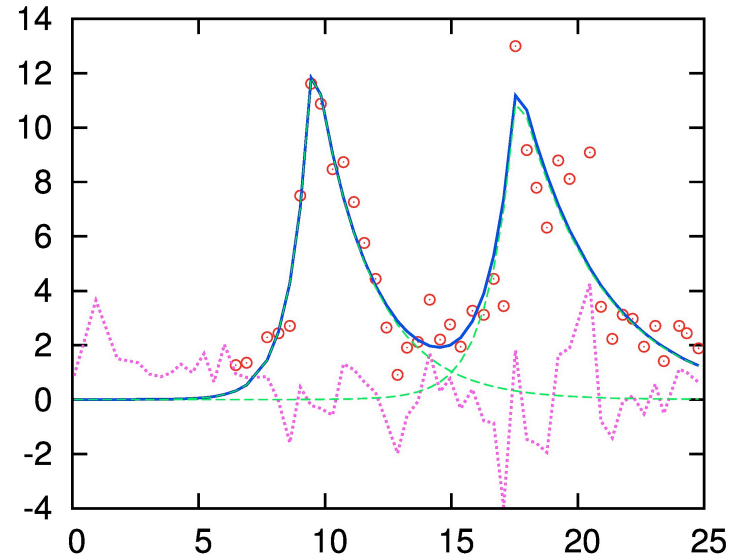
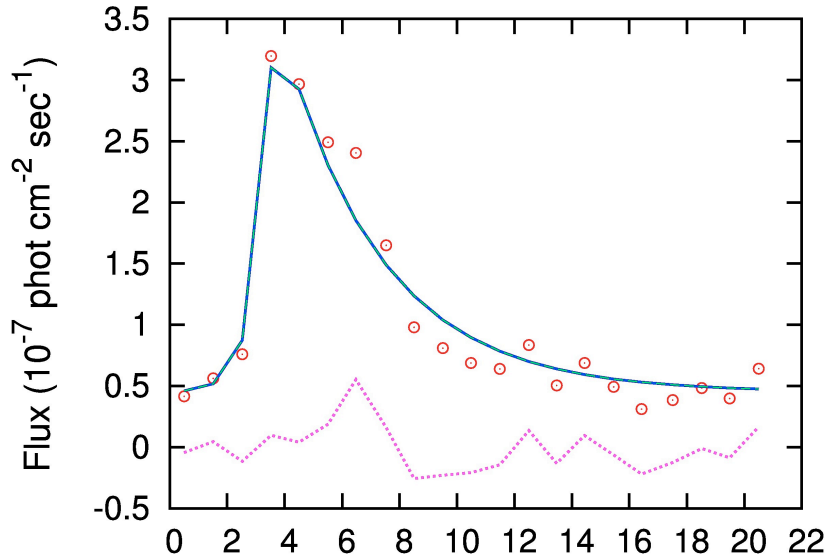
- Radiation cooling timescale $\gg$ acceleration timescale
 - $\Rightarrow$ fast rise-slow decay
 - $\Rightarrow$ asymmetric flare

Probing ~~Cooling~~ Crossing Timescales

- Symmetric flare
- $\tau_{\text{var}} = \delta^{-1} \max[\tau_{\text{cool}}, \tau_{\text{inj}}, \tau_{\text{acc}}, R/c]$

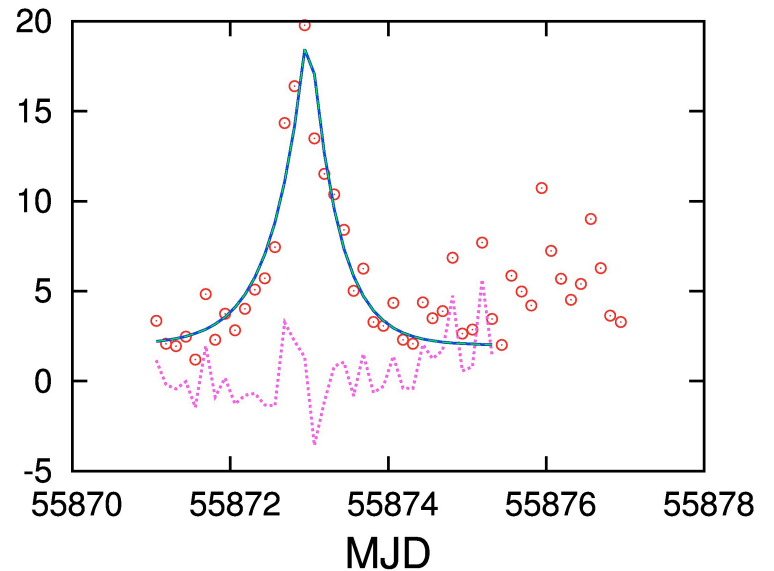
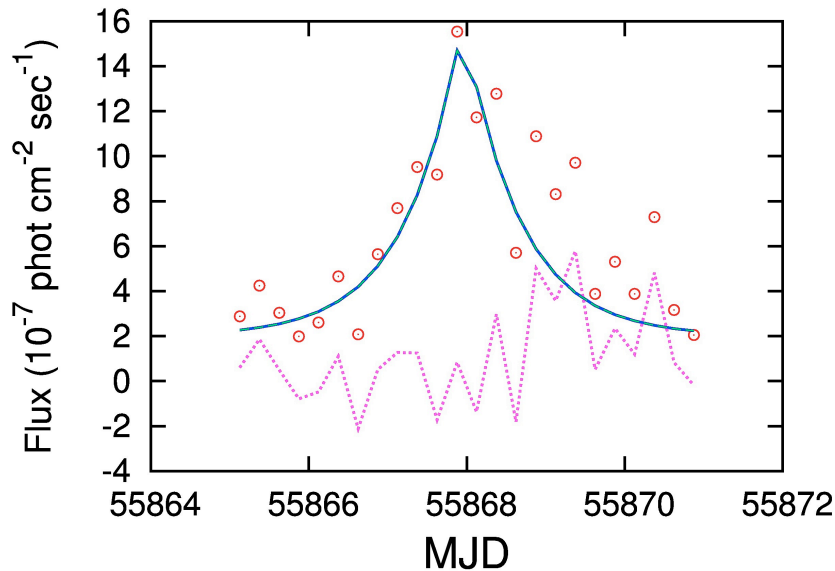
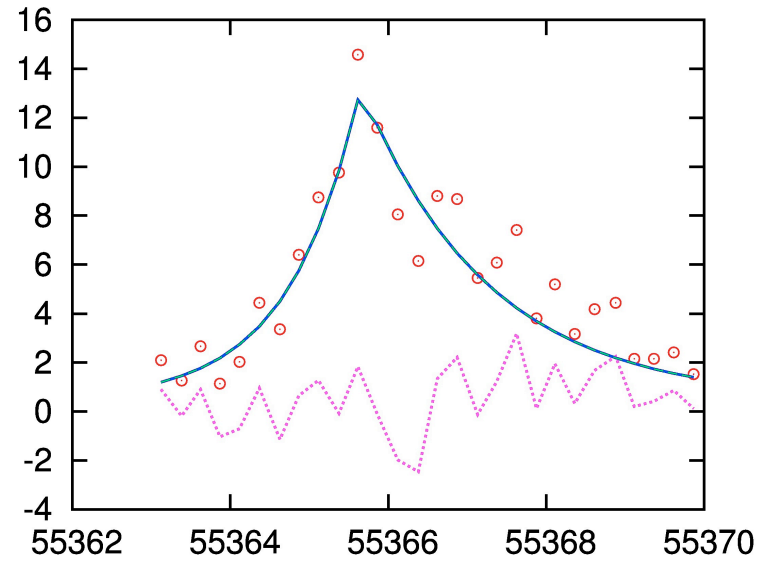
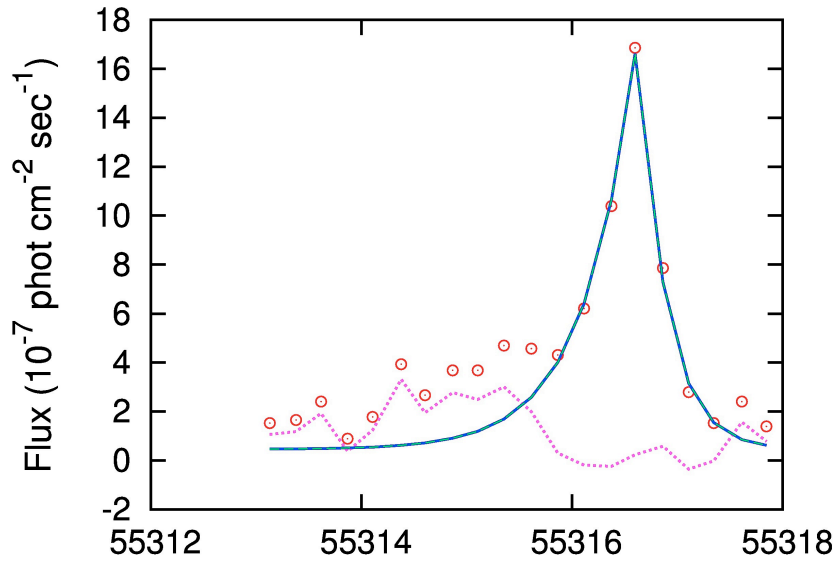


Short-Term GeV Flares



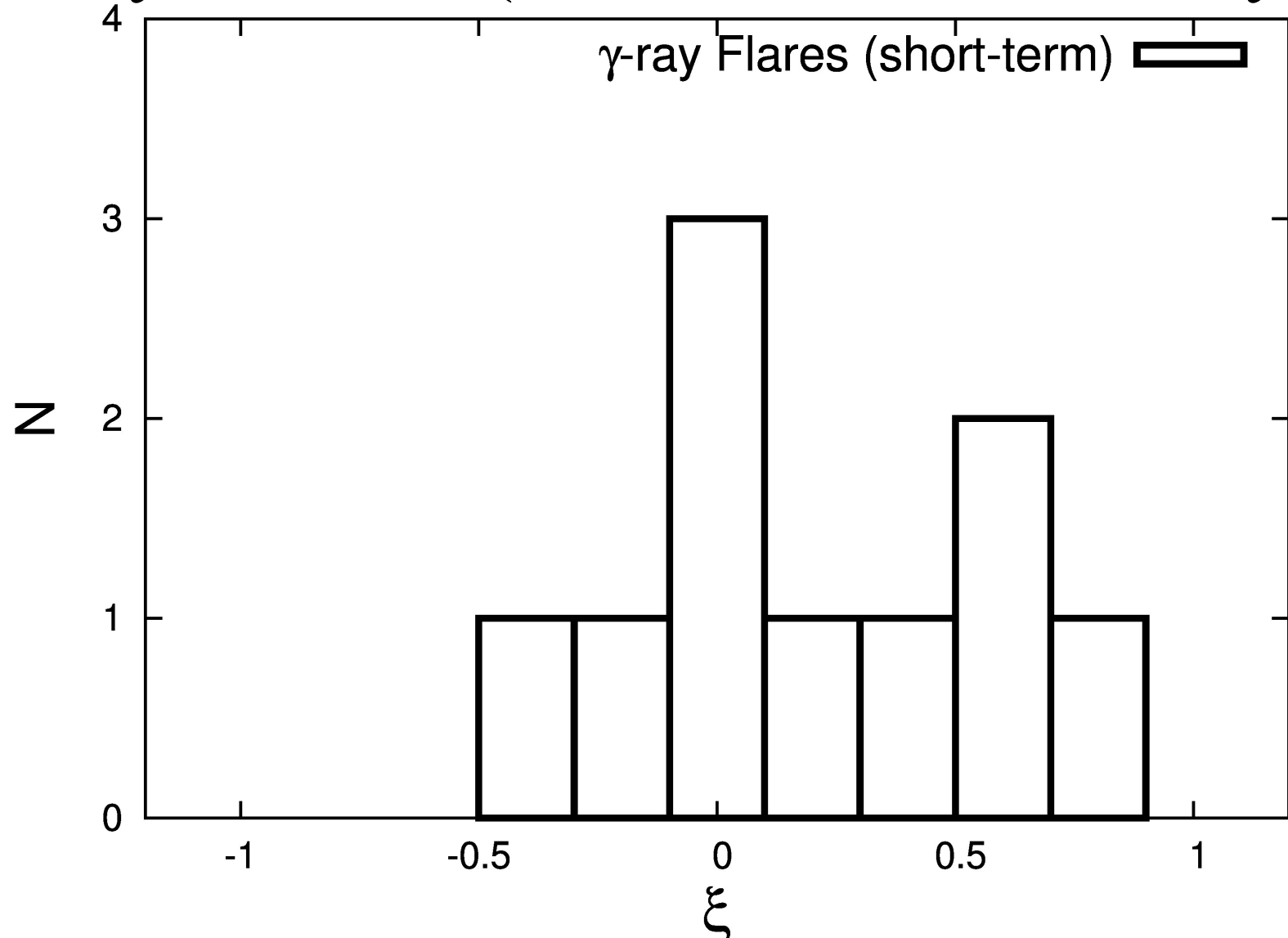
PKS 1502+106: Abdo+ (2010), 3C 273: Abdo+ (2010), 3C 454.3: Nalewajko (2013)

Short-Term GeV Flares



PKS 1222+216: Kushwaha+ (2014), PKS 1510-089: Saito+ (2013)

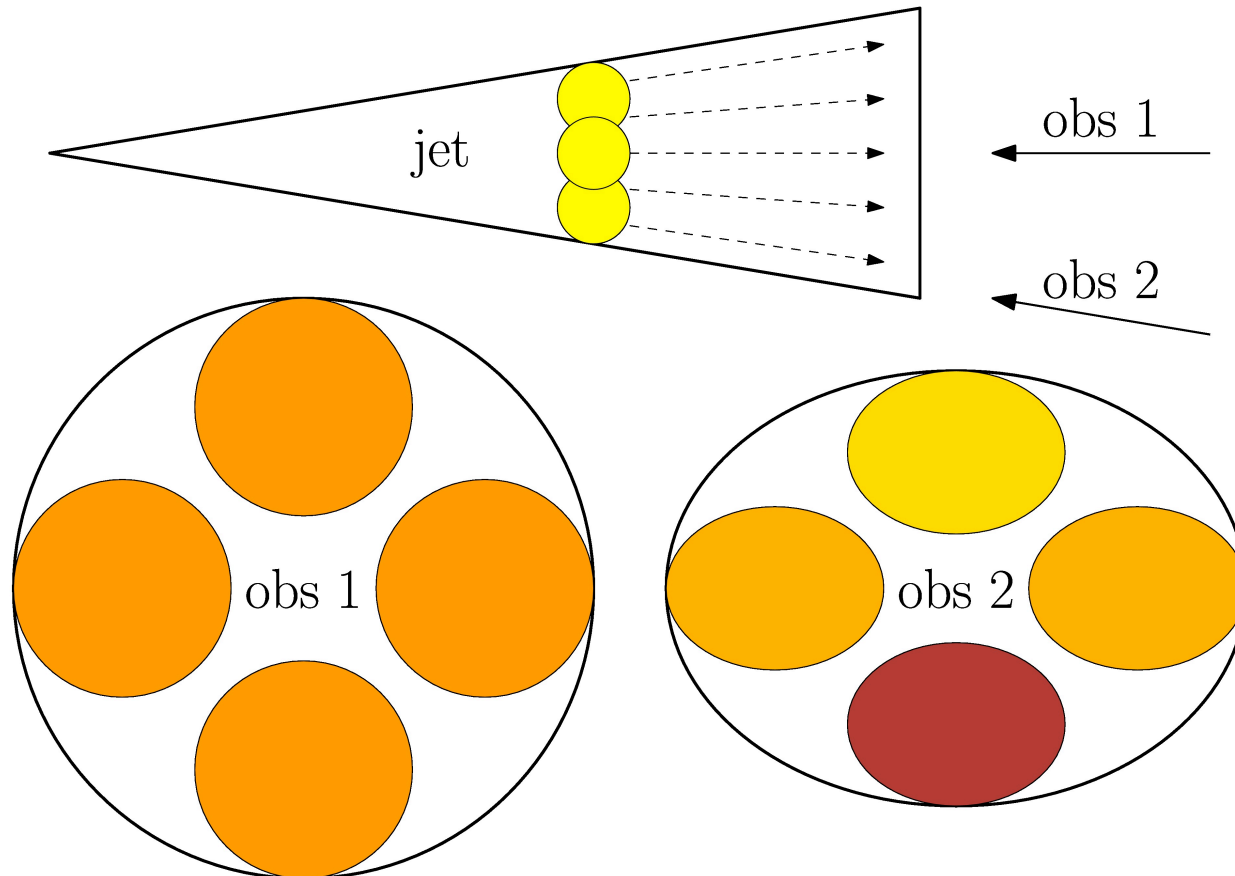
Short-Term GeV Flares are Often Asymmetric (Fast Rise-Slow Decay)



Cooling Timescale is Even Shorter?

- $\tau_{\text{cool}} \sim 10 \text{ min.}$
- $\tau_{\text{cool}} = f(u_{\text{BLR}})$
- $u_{\text{BLR}} = f(\xi, \Gamma, L_{\text{disk}}, r_{\text{BLR}})$

Varying Doppler Boosting Across the Jet: Asymmetric Flares



Summary

- Long-term (> 5 days) outbursts are mostly symmetric: Crossing timescale
- Short-term (sub-day) flares are often asymmetric
 - Cooling timescale?
 - Varying Doppler boosting?