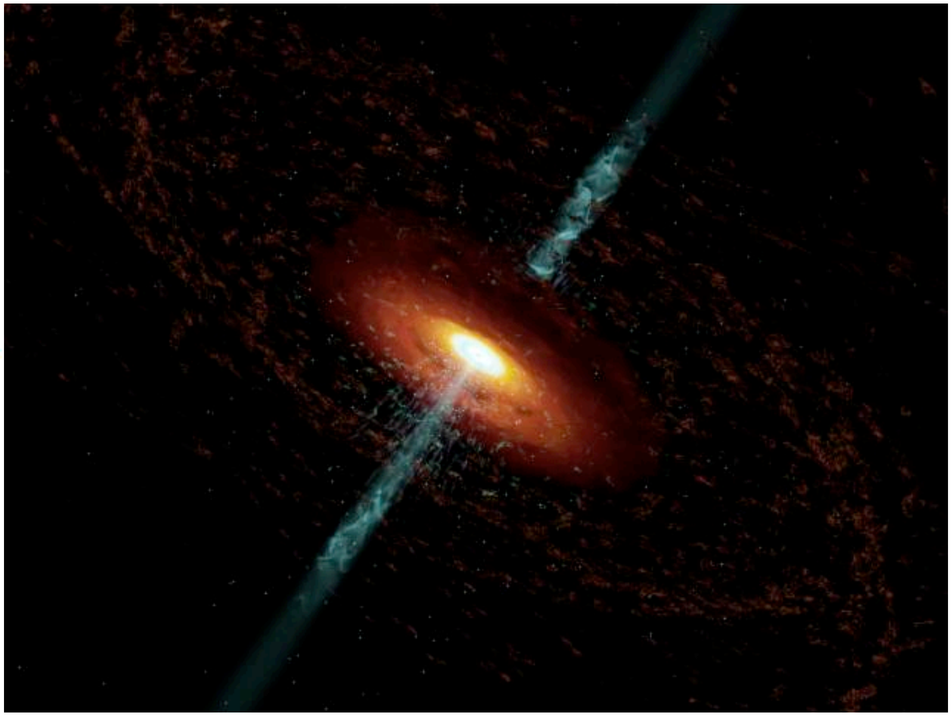


Multiwaveband Opportunities to Study AGN (Mostly Blazars) Detected by Fermi

Alan Marscher

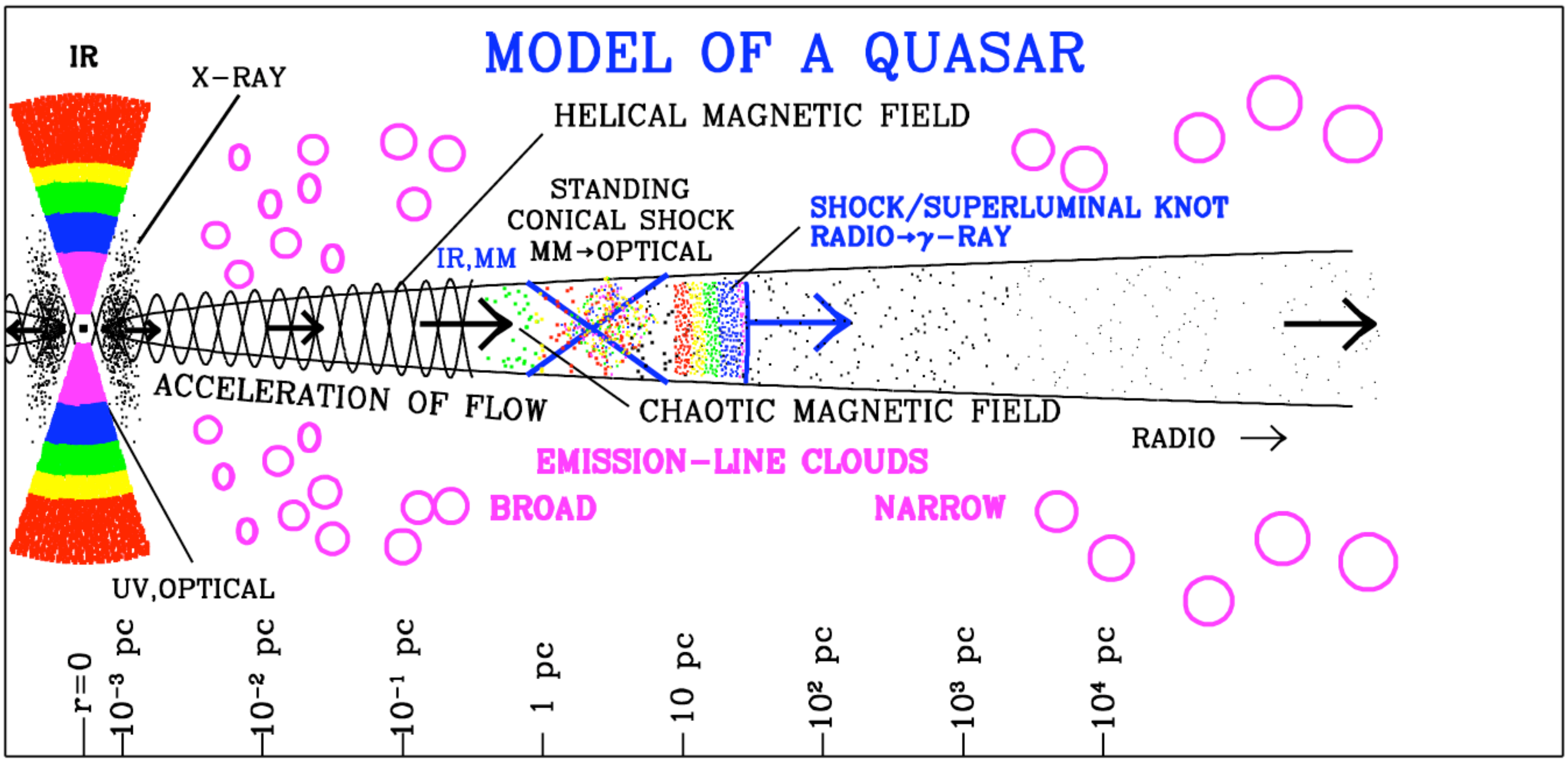
Boston University, Incoming Chair of Fermi Users Group

Research Web Page: www.bu.edu/blazars

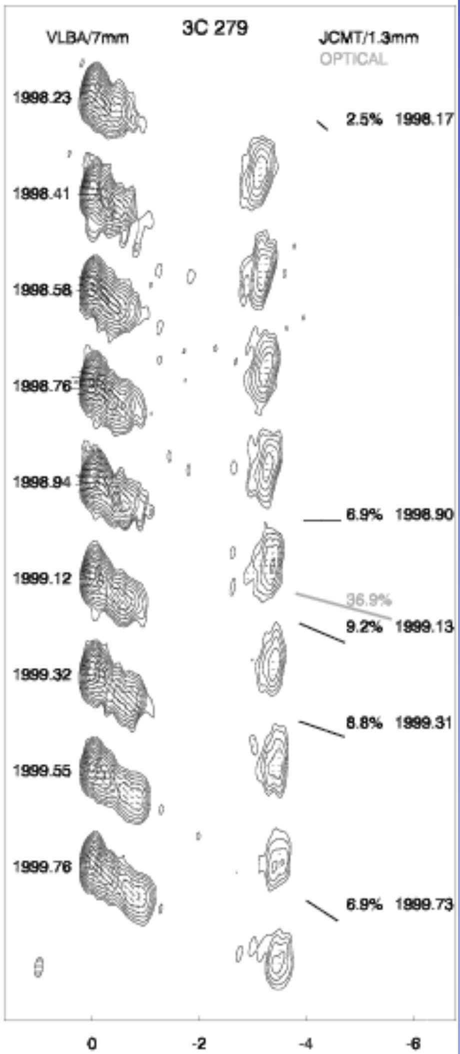
Sketch of Physical Structure of Jet, AGN Based on Current Observations & Theory

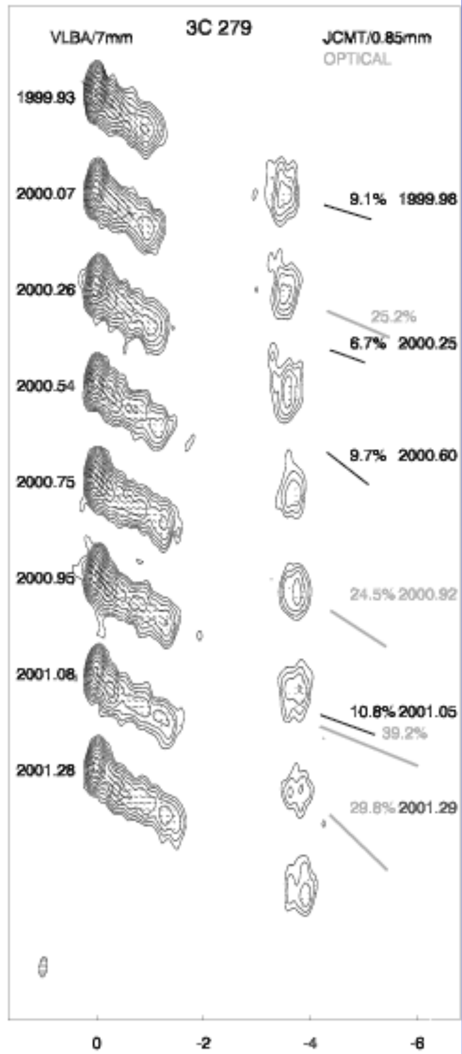
Basic Goals: 1. Determine where & how gamma-ray emission originates

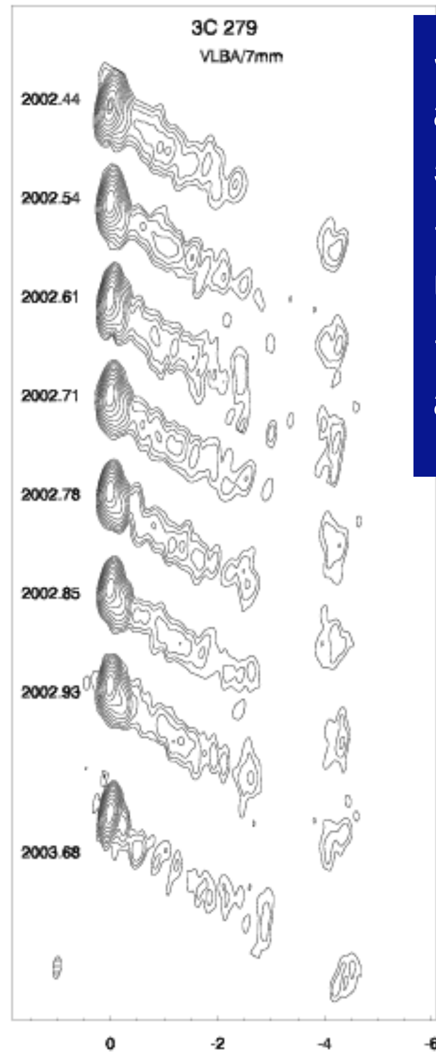
2. Probe physics of compact jets



Sequences of VLBA Images of Jets of γ-ray Blazars







Superluminal motion as high as almost 50*c*
→Bulk Lorentz factor up to 50
→ Doppler factor can approach 100

3C 279: apparent speeds range from ~ 5*c* to >20*c*

Publicly Available Datasets

Fermi LAT-monitored source list: Fluxes vs. time at 2 energy bands from automatically processed data, posted on Fermi website

SMARTS: www.astro.yale.edu/smarts/glast/targets.html

MOJAVE 15 GHz VLBA monitoring: 200 AGN, mostly blazars, total intensity images at www.physics.purdue.edu/MOJAVE/

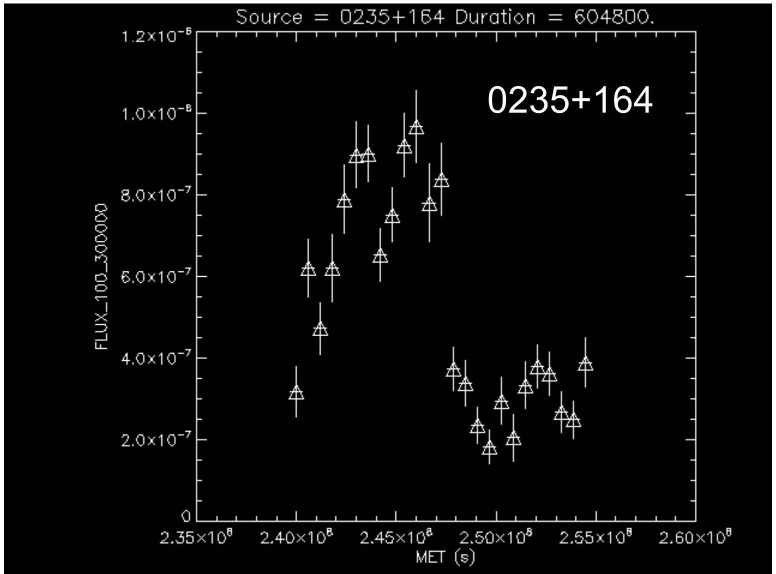
BU 43 GHz VLBA monitoring: Total and polarized intensity images: 29 blazars at www.bu.edu

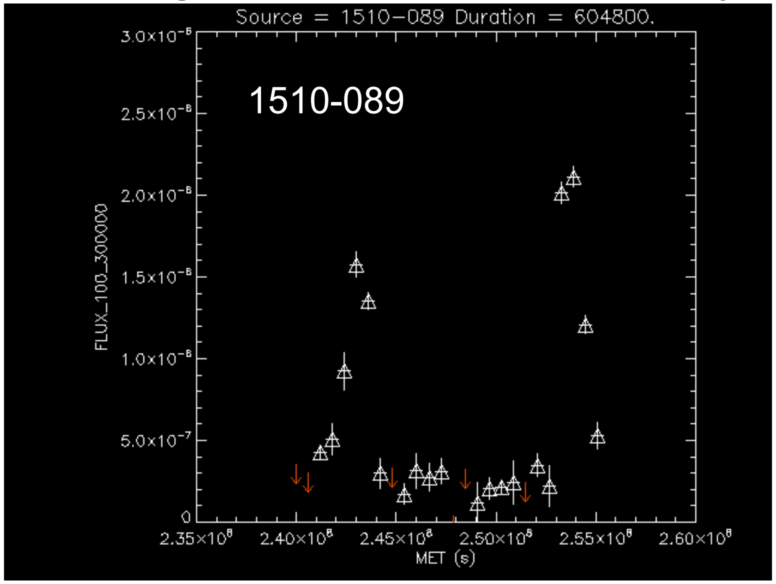
Swift partial X-ray light curves of gamma-ray sources
http://swift.gsfc.nasa.gov/docs/swift/results/transients/index.html

Nature of Blazar γ-ray Variability Seen by Fermi

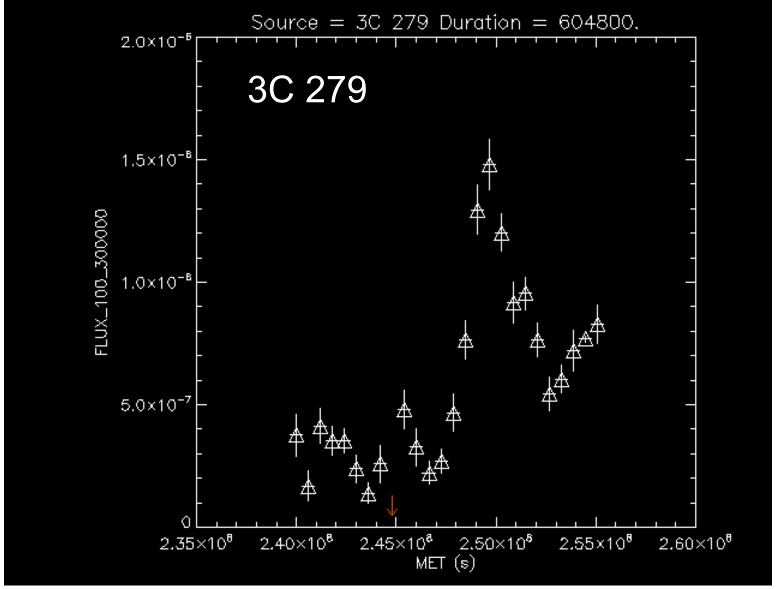
In high fraction of bright blazars, γ-rays occur in sharp flares that rise from the noise

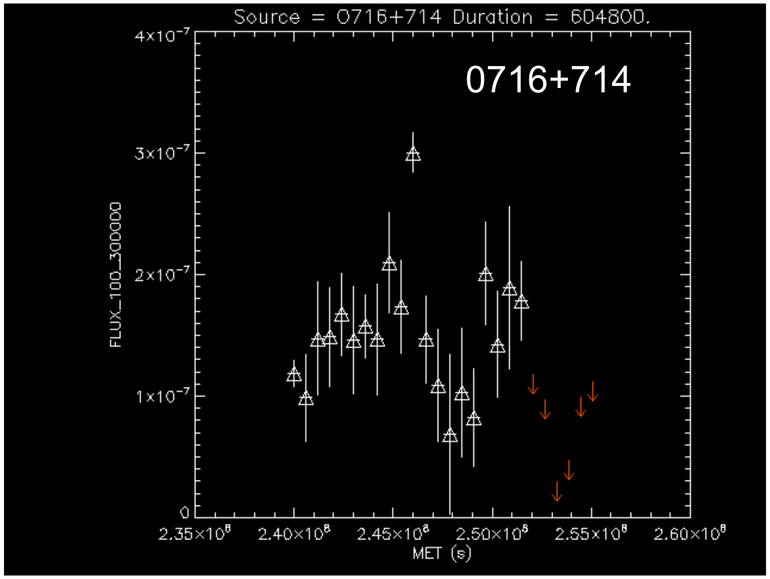
→ ToO's tend to miss early stage of events, steady monitoring needs to sample densely





Fermi light curves (weekly averages)





Possibilities for accessing ground-based telescopes via the Fermi peer review

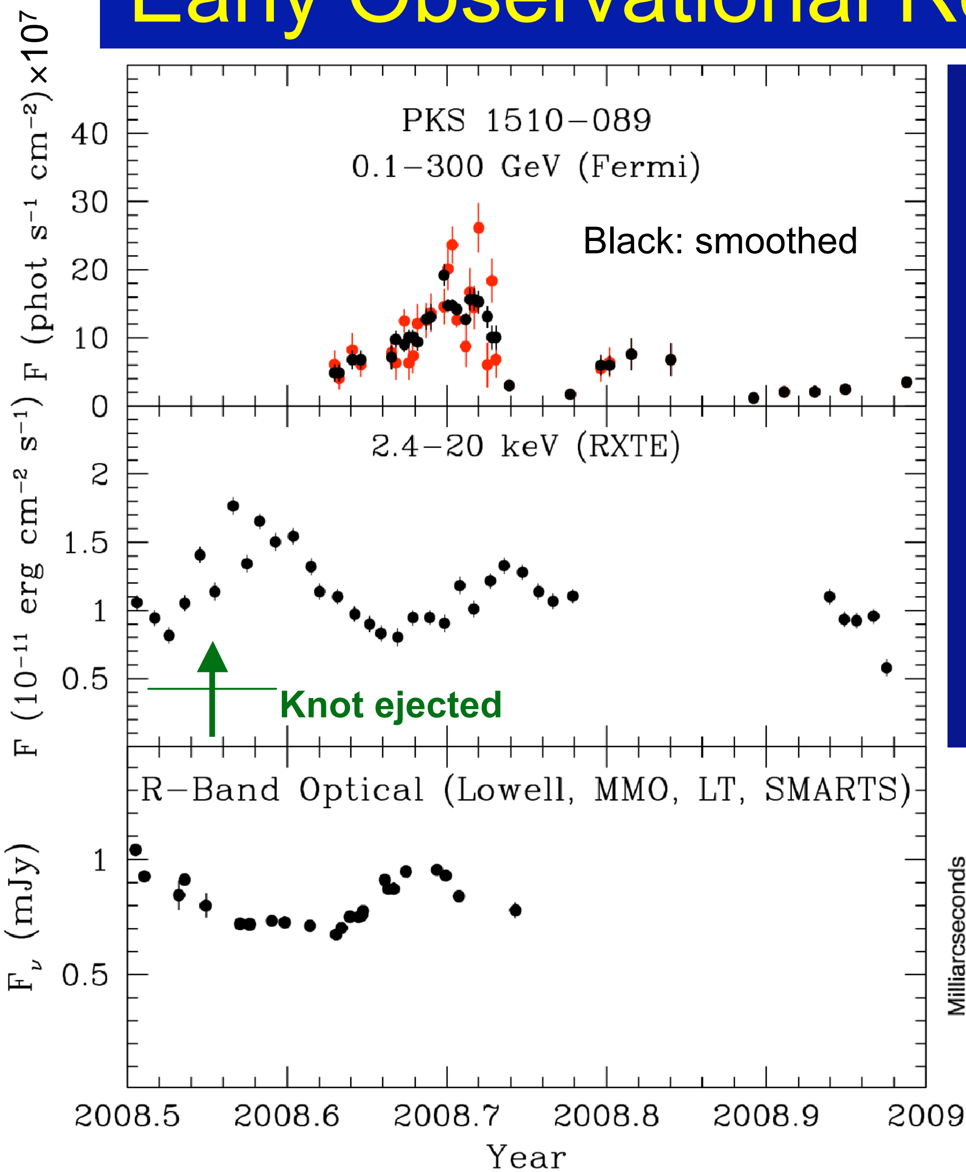
NRAO (radio): VLBA (imaging with resolution as high as 0.15 milliarcsec)

EVLA (imaging with resolution of arcseconds or sub-arcseconds)

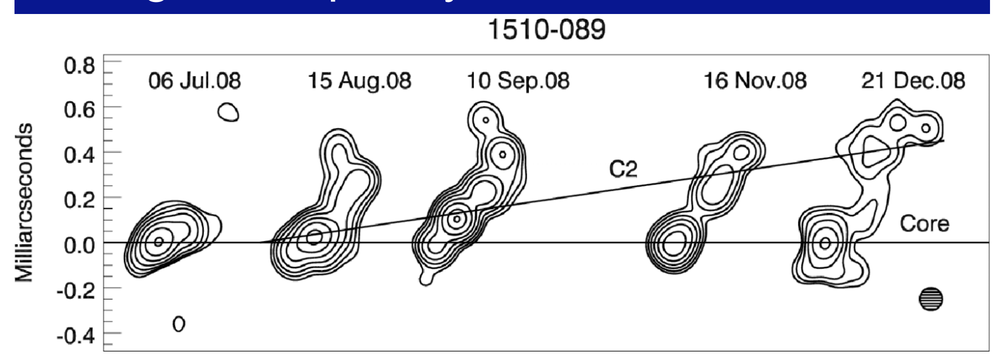
GBT (single antenna, high sensitivity, spectra, timing)

NOAO (optical, near-IR, mid-IR): all telescopes, including 8 m Gemini North & South, 4 m-class telescopes, & smaller telescopes in US & Chile

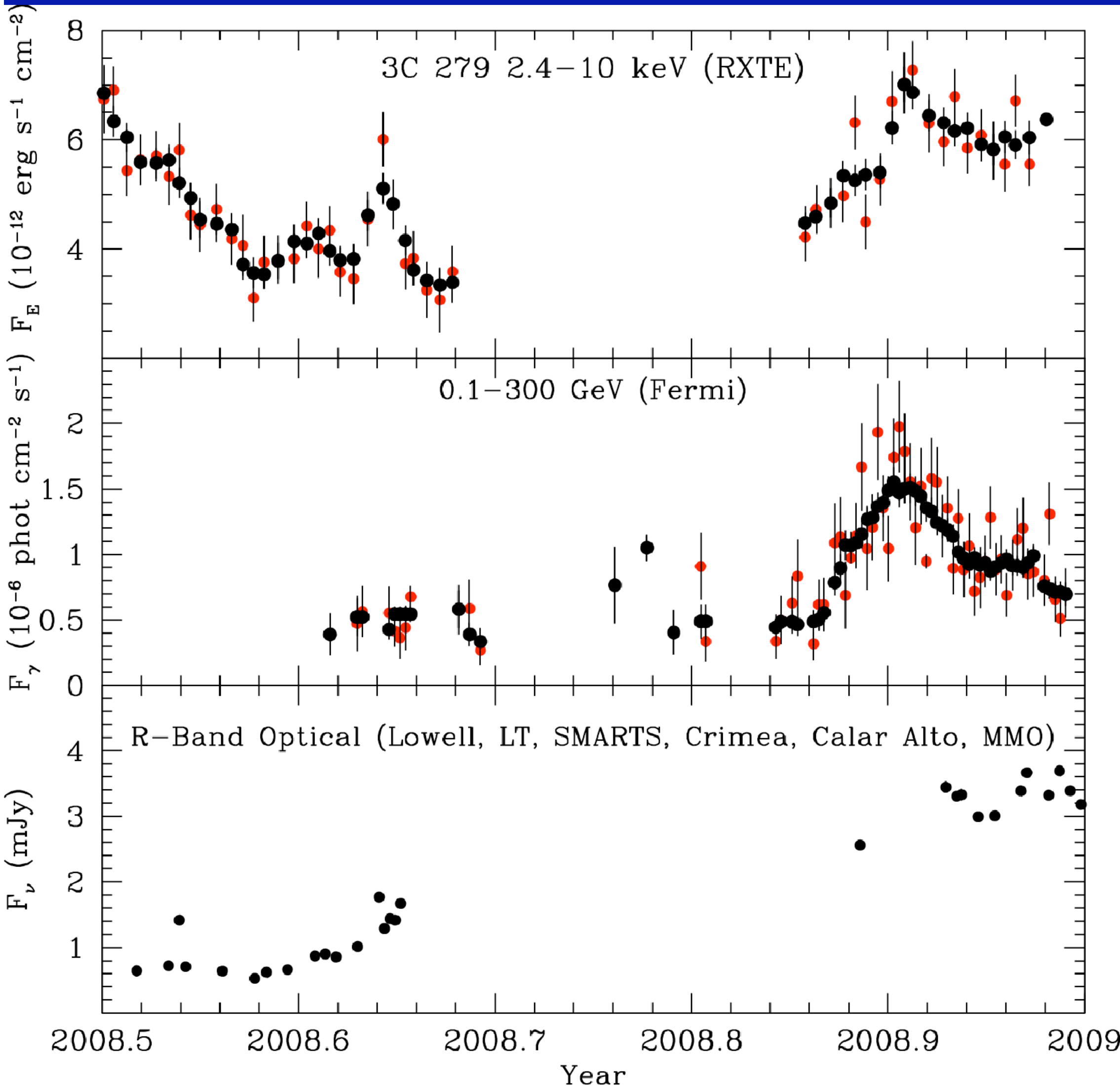
Early Observational Results: PKS 1510-089



- Multiwaveband monitoring: densely sampled light curves from radio to γ-ray for correlation analysis
- Multi-epoch VLBA observations: times of superluminal ejections & flux + polarization history of core & knots
- Cross-correlate light curves at different $\lambda \rightarrow$ connections & time lags
- ID features on VLBI images responsible for higher-frequency outbursts



The Quasar 3C 279: Results from Fermi & RXTE



Short X-ray flare at 2008.64 not apparent in gamma-ray data

Coincident X-ray & gamma-ray flare at 2008.9

- Gamma-ray flare peaks ~ same time as X-ray flare; latter decays more slowly

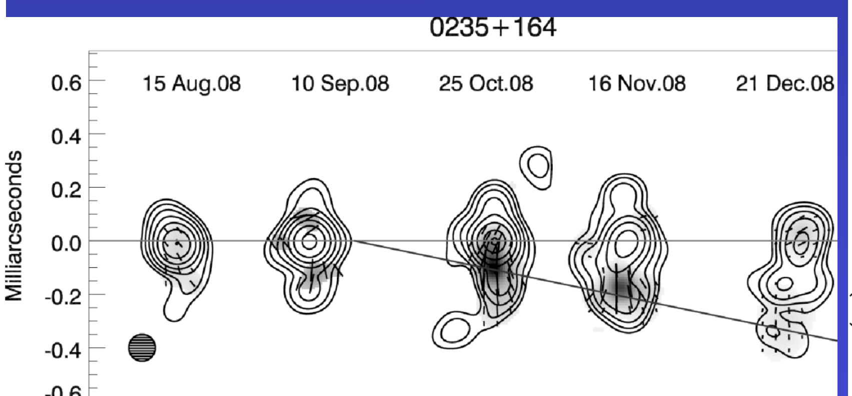
Consistent with higher average scattering electron energies for gamma rays than for X-rays

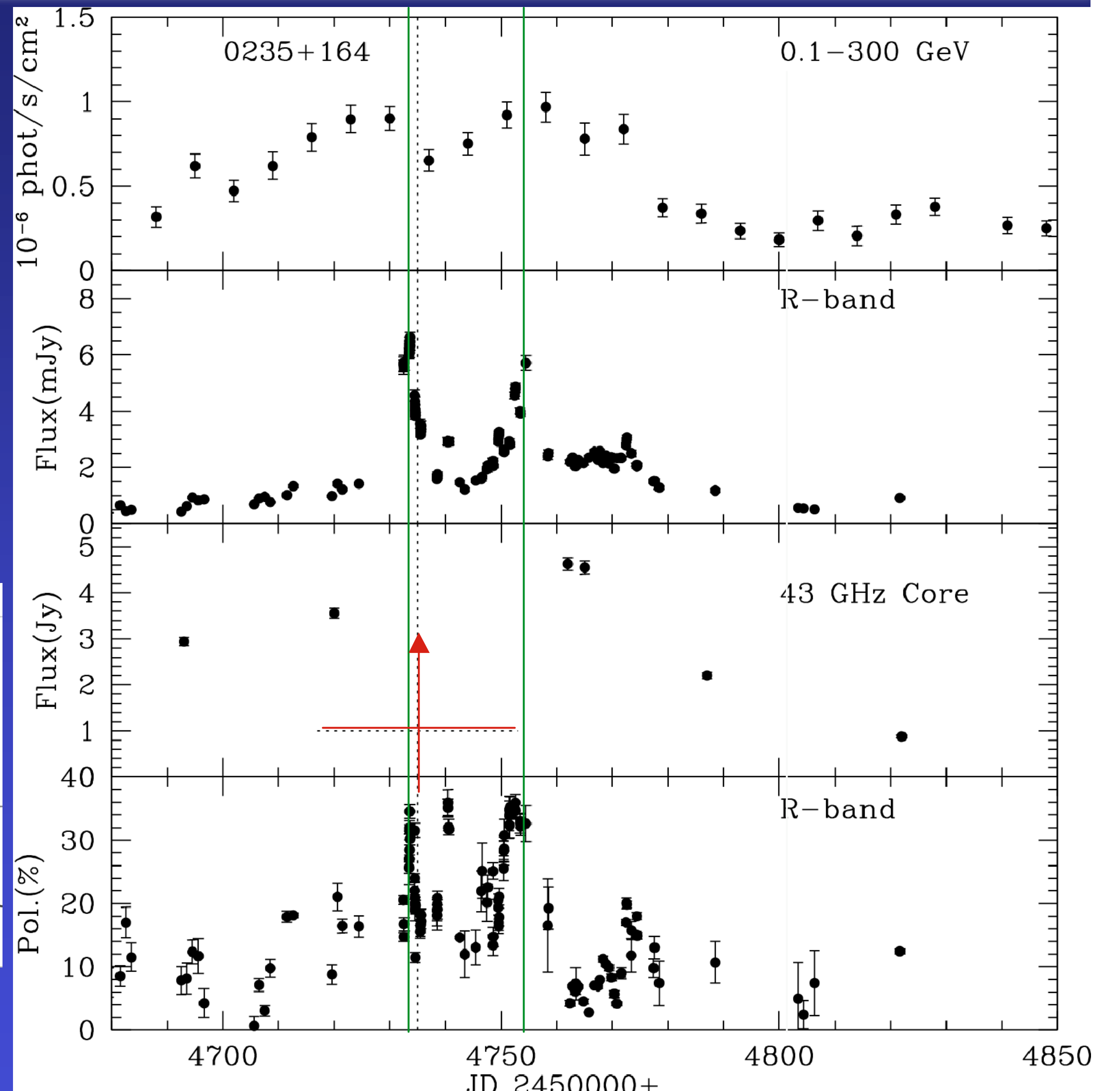
Gamma-ray & X-ray data points:
Red: actual measurements
Black: median smoothed (3 days)

(Too early to determine whether flare is associated with a new superluminal knot)

The BL Lac Object AO 0235+164

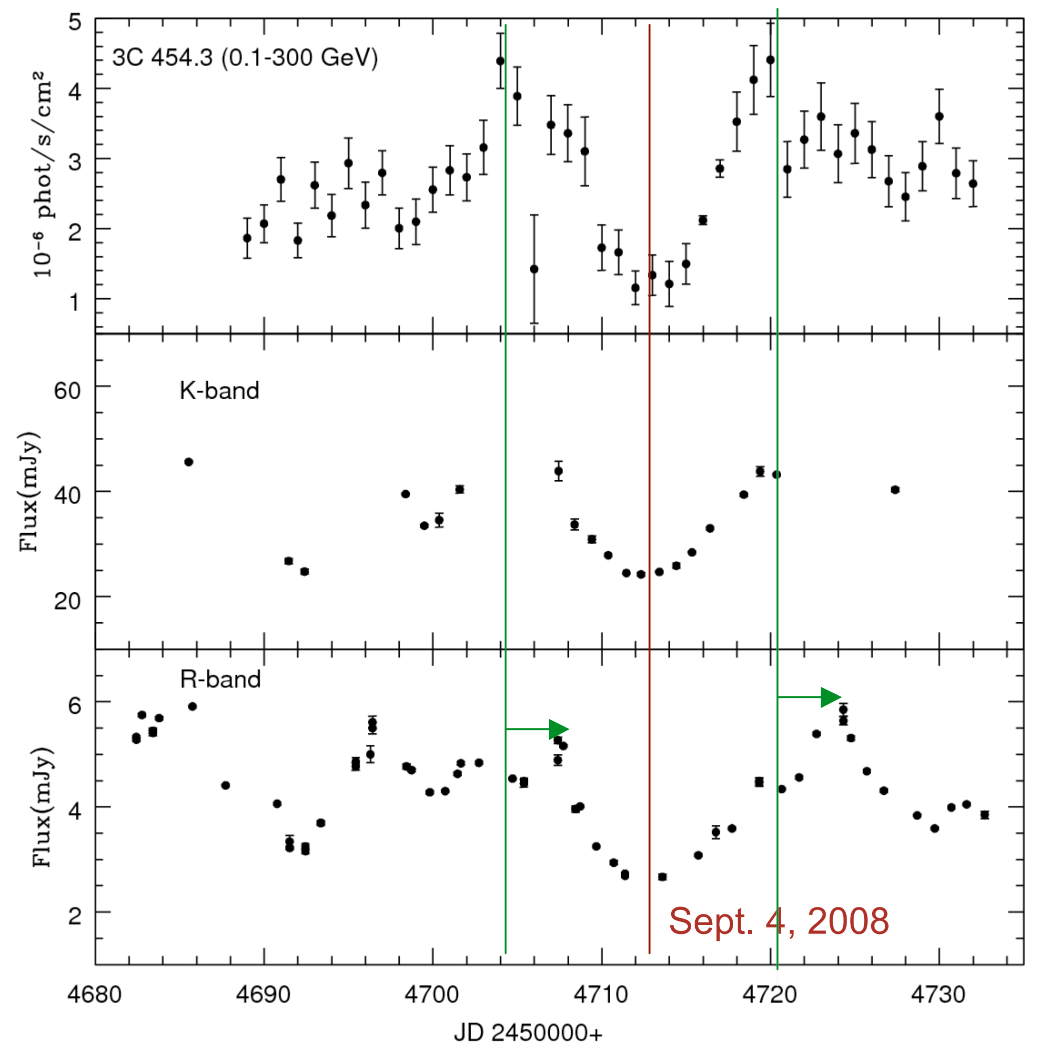
- **Pair of γ-ray & optical outbursts; optical higher amplitude**
- **Superluminal knot ejected at time of 1st outburst**
- **Possible 2nd knot ejected at time of 2nd outburst**





The Quasar 3C 454.3: Fermi & Optical Monitoring

- **Dip in flux essentially simultaneous at γ-ray, optical, & near-IR frequencies**
- **Maxima at R band lag gamma-ray by 4 days**
- **Higher amplitude in γ-ray**
- **VLBA images show core brightening & getting larger but only weak knots emerge (severe inverse Compton energy losses?)**
- **Bonning et al. (2009, arXiv preprint): X-ray flux ~ constant during dip**



Conclusions

- Gamma-ray flares & dips coincide with similar lower-frequency events; often some wavebands don't participate
- Some events are frequency-stratified, others are not
- Flares are related to superluminal knots in VLBA images
- High-E photon emission in the jet occurs in multiple zones
- Clear interpretations require comprehensive programs →multiple wavebands, minimal gaps in time coverage, VLBA imaging, polarization)