What is the connection between radio and gamma-ray emission in blazars?

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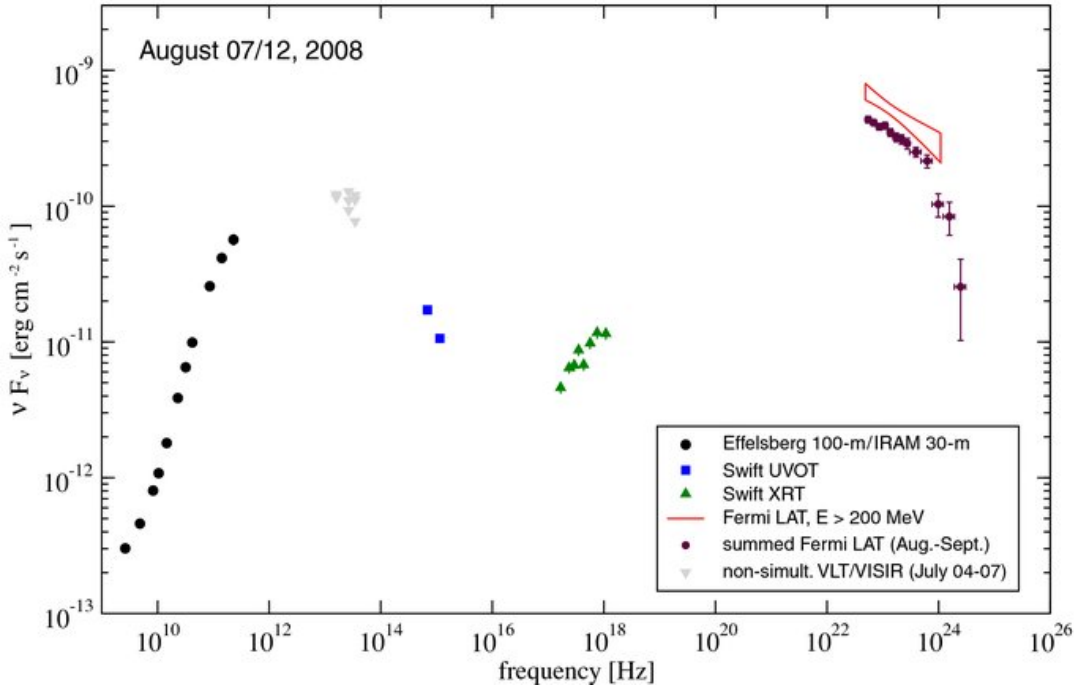
KISS – Digging Deeper Workshop – Caltech, Pasadena, CA
June 9, 2011

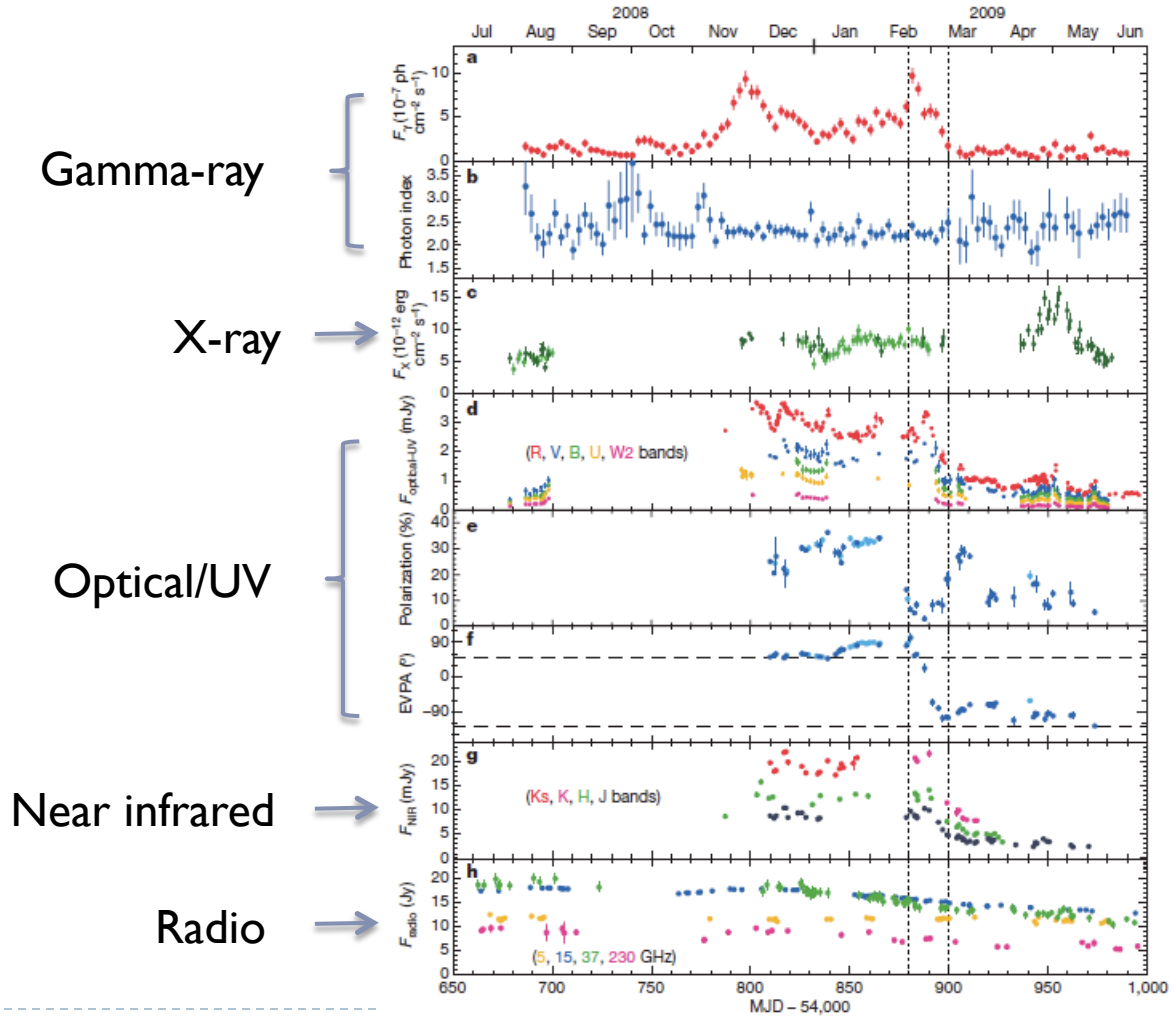
Double peaked SEDs

Artist impression
http://imagine.gsfc.nasa.gov/



3C 454.3 from Abdo et al. 2009, ApJ 699, 817

Variability and linear polarization



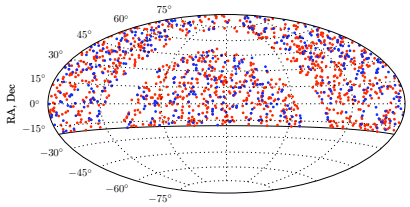
3C 279 multi-wavelength campaign, Abdo et al. 2010, Nature 463, 919

Correlated radio and gamma-ray variability

- Problem:
  - Where does the gamma-ray emission originates in blazars?
    - In the same radio region?
    - Close to central black hole/accretion disk?
    - Far from central engine, shocks in the jets?
- Our strategy:
  - Study radio and gamma-ray light curves for a large number of sources
    - If the location is the same we expect to see correlations

OVRO 40 m Telescope
Blazar monitoring program and Fermi-LAT

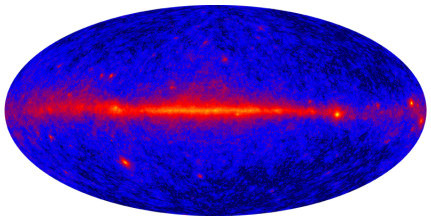
- Radio monitoring 1550 blazars
- Radio continuum 15 GHz, 3 GHz bandwidth



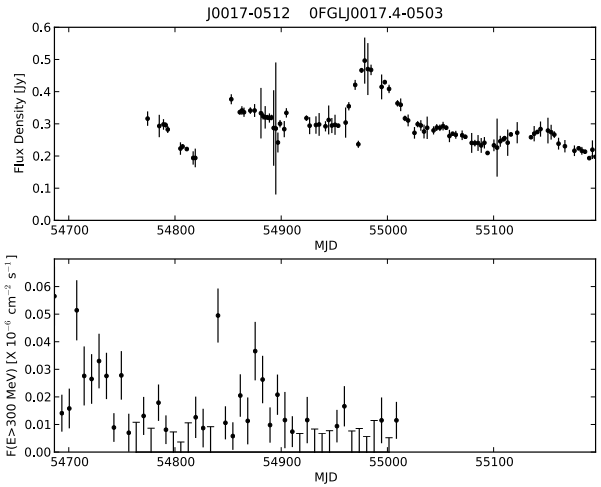
Distribution of CGRaBS sources in equatorial coordinates.
Red circles CGRaBS, Blue circles 1LAC

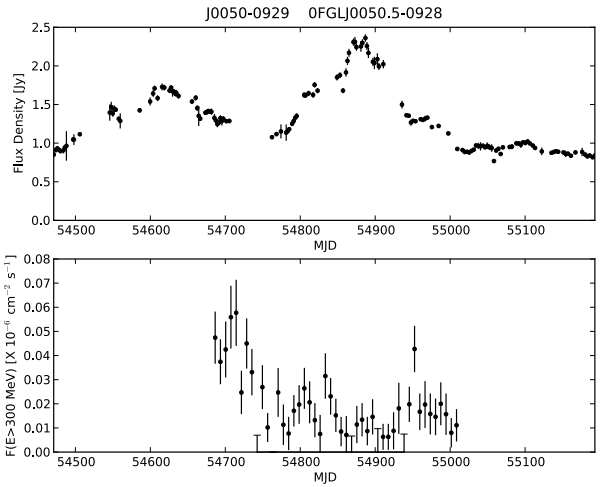
The OVRO 40 m Telescope at night
By Joey Richards

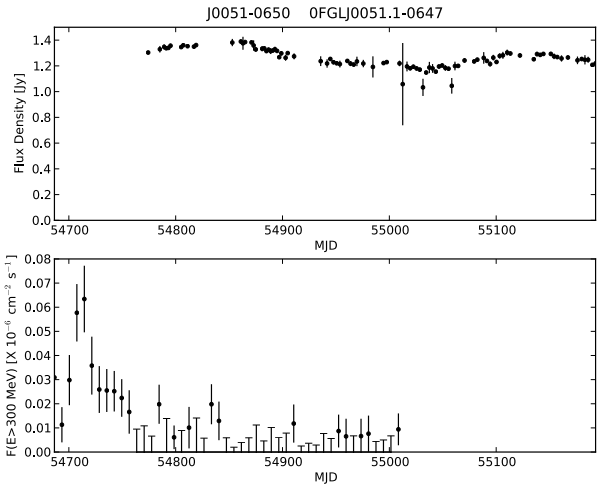
- Fermi monitors sky continuously
- A full map every 3 hours
- Light curves for any position can be obtained for few hundred sources

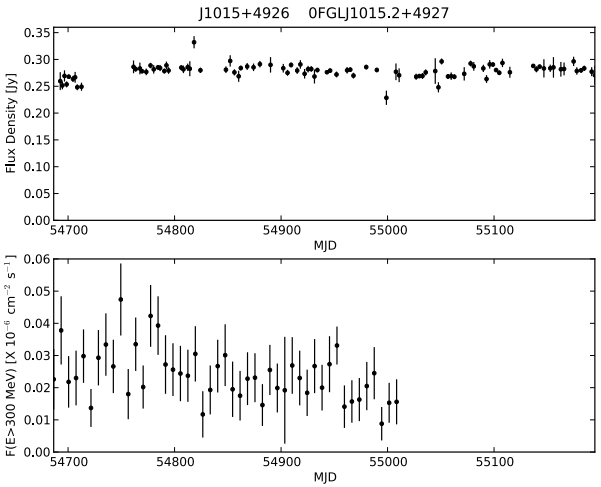


Examples from our data set combined with Fermi-LAT data



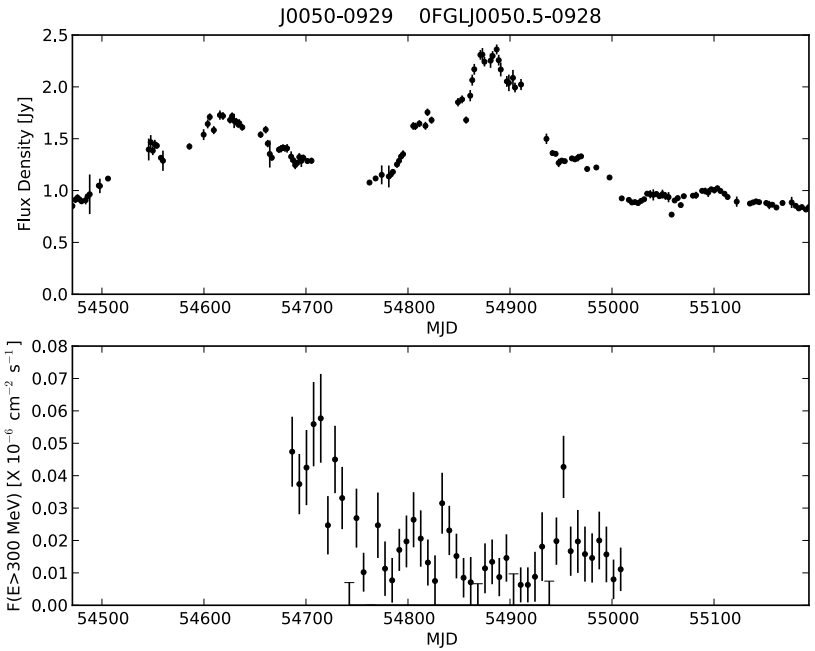


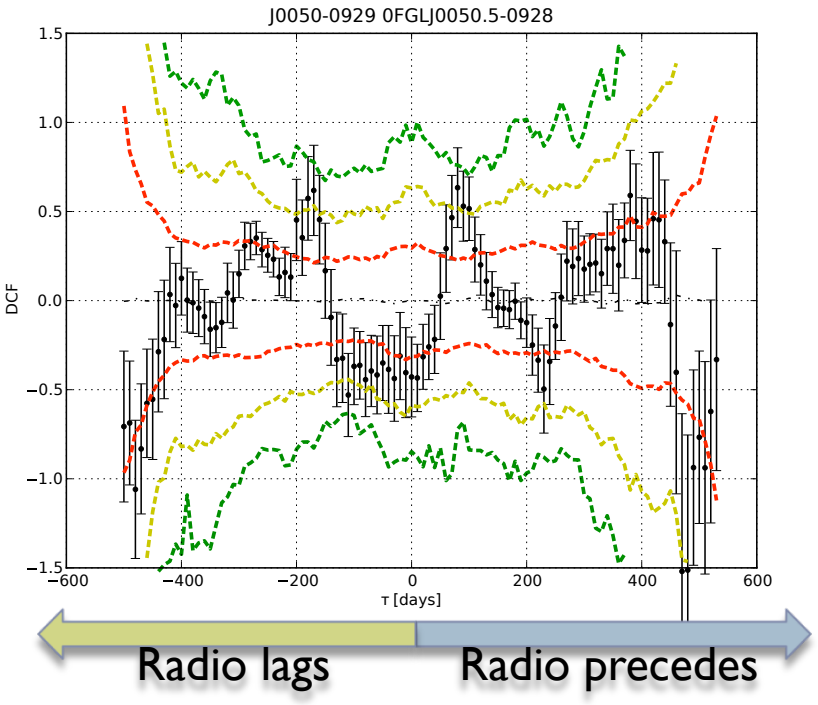




Radio/gamma-ray time lags and their significance

- Example cross-correlation. 3-month Fermi detections, using 11-months of Fermi data and 2 years of radio monitoring
  - Significance evaluated using simulated data with a power-law PSD ~ 1/f^ β { β _radio = 2.0, β _gamma = 1.5

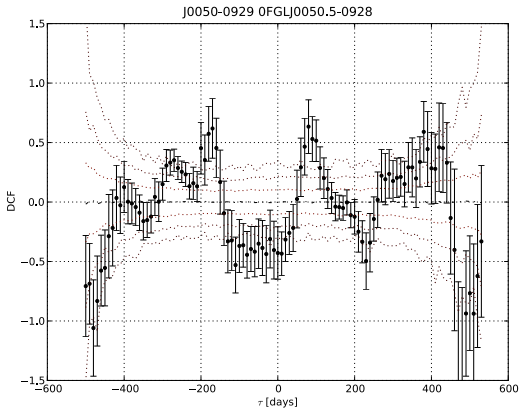




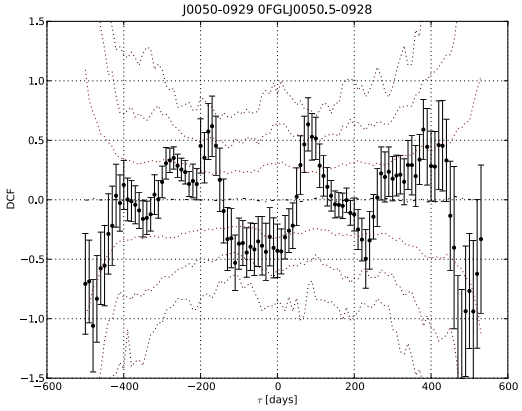
- Using these parameters only 4 out of 52 sources show significant correlations!

Statistical tests for the cross-correlations: Model dependence of the significance

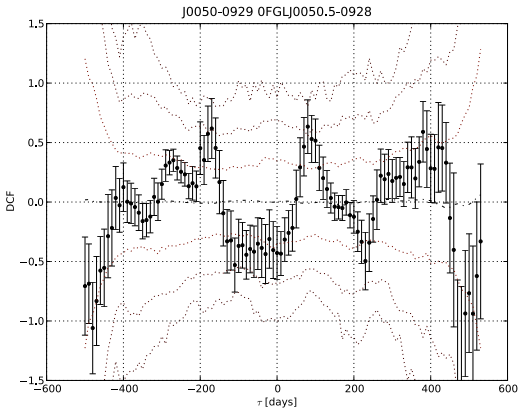
- The significance of the cross-correlation depends on the model used for the light curves
- PSD commonly assumed to be simple power law



$\beta_{radio} = 0.0$ and $\beta_{\gamma} = 0.0$



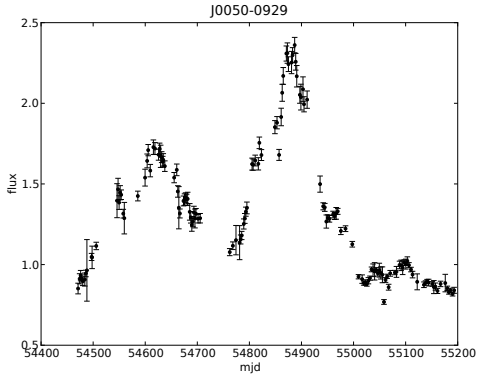
$\beta_{radio} = 2.0$ and $\beta_{\gamma} = 1.5$



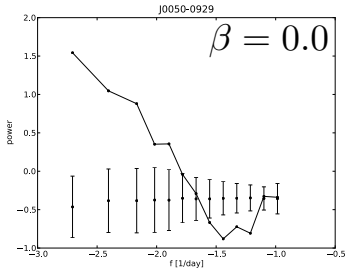
$\beta_{radio} = 2.0$ and $\beta_{\gamma} = 2.0$

Measuring the power spectral density

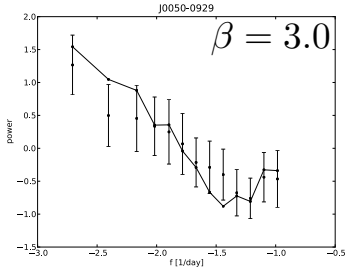
Example radio light curves



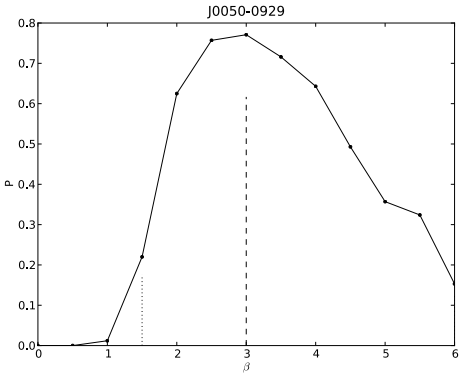
Bad fit



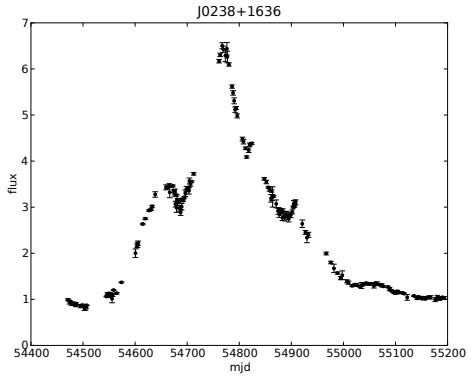
Good fit



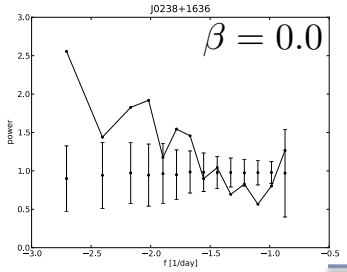
PSD fits



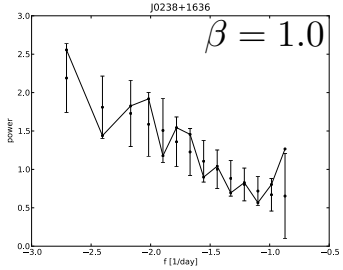
Well constrained for a large fraction of sources

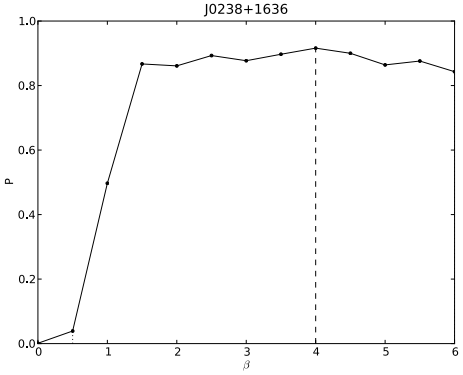


Bad fit



Good fit





Some are hard to constrain
=> we need longer time series

Summary

- Using high cadence radio and gamma-ray light curves we study the connection between radio and gamma-ray emission in Fermi detected blazars
- A method to estimate the significance is implemented
  - Using typical parameters we find that 4 out of 52 sources have 3σ correlations
- The significance depends on the model for the light curves => a method to characterize them is implemented
  - Gamma-ray detected sources have steeper PSDs
  - Final significance will be computed using these results after separating statistical versus per source variability