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/
Variability and linear polarization

Gamma-ray
X-ray
Optical/UV
Near infrared
Radio

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 originate 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

- 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 $\sim 1/f^\beta$:
    \[
    \begin{align*}
    \beta_{\text{radio}} &= 2.0, \\
    \beta_{\text{gamma}} &= 1.5
    \end{align*}
    \]

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

\[ \beta_{\text{radio}} = 0.0 \text{ and } \beta_\gamma = 0.0 \]
\[ \beta_{\text{radio}} = 2.0 \text{ and } \beta_\gamma = 1.5 \]
\[ \beta_{\text{radio}} = 2.0 \text{ and } \beta_\gamma = 2.0 \]
Measuring the power spectral density

Example radio light curves

Good fit

Bad fit

Power spectral density (PSD) fits

Well constrained for a large fraction of sources

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 $3\sigma$ 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