OVRO 40m blazar monitoring program: Understanding the relationship between 15 GHz radio variability properties and gamma-ray activity in blazars

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Locating the gamma-ray emission site and radio variability of blazars

• Problems:
  • Where does the gamma-ray emission originate in blazars?
  • What characterizes Fermi detected blazars as viewed in radio?

• Strategy:
  • Study radio and gamma-ray light curves for a large number of sources
    • Large sample of objects
    • Preselected as gamma-ray candidates
    • Observed independently of gamma-ray state
    • High cadence, observed twice per week
    • Robust statistical tests
OVRO 40 m Telescope
Blazar monitoring program

- Monitoring 1550 blazars
- 454 detected by Fermi on 1LAC “clean” sample
- Radio continuum 15 GHz, 3 GHz bandwidth
- 4 mJy thermal noise, ~3% typical uncertainty

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

The OVRO 40 m Telescope at night
By Joey Richards
Our radio light curves:
A better picture of Fermi and Jansky
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A better picture of Fermi and Jansky
First results of the monitoring program: 2 years of data

- First data release, 2 years of data for original CGRaBS sample
- Radio variability properties studied using “intrinsic modulation index” $m = \sigma/S$
  - Gamma-ray detected sources are more variable in radio than non-detected ones
  - BL Lacs are more variable in radio than FSRQs
  - Low redshift FSRQs are more variable than high redshift ones

Richards et al 2011
ApJS, 194, 29
An update on radio variability properties: 3.5 years of data

- Gamma-ray detected still more variable than non-detected
- BL Lacs vs FSRQs

![Graphs showing pdf of variables for BL Lac and FSRQ sources for 1LAC and CGRaBS samples.]

- Well defined samples are required to study population properties
- Redshift trend still there but less significant
Correlated radio and gamma-ray variability: Constraining the location of the gamma-ray emission

• Where in the jet are the gamma-rays produced?

  • Close to central engine < 1 pc
  • Further down the jet, a few parsecs

Marscher 2005, Mem. S.A.It 76, 13
Results for brightest Fermi detected sources

- **Radio data**
  - 2 year light curves of CGRaBS + a few calibrators
  - Published in Richards et al 2011, ApJS 194, 29

- **Gamma-ray data**
  - 106 sources
  - 11 month light curves, weekly sampling
  - 52 / 106 are in CGRaBS and have simultaneous radio 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 $\sim 1/f^\beta$
    - $\beta_{\text{radio}} = 2.0$, $\beta_{\text{gamma}} = 1.5$
  - Only 7 out of 52 sources show significant correlations!

\[ \text{Radio lags} \quad \text{Radio precedes} \]
Time lags and significance

All sources

<table>
<thead>
<tr>
<th>LAT Name</th>
<th>CGRABS name</th>
<th>Optical class</th>
<th>SED class</th>
<th>$\tau$ days</th>
<th>significance %</th>
<th>uncertainty %</th>
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<tbody>
<tr>
<td>0FGLJ0050.5-0928</td>
<td>J0050-0929</td>
<td>BLLac</td>
<td>ISP</td>
<td>-170.0 ± 13.0</td>
<td>&gt;99.98</td>
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<td>ISP</td>
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<td>FSRQ</td>
<td>LSP</td>
<td>20.0 ± 12.0</td>
<td>99.96</td>
<td>0.03</td>
</tr>
</tbody>
</table>

> 3$\sigma$ significance

preliminary
Radio power spectral density
Detected vs non-detected

• Gamma-ray detected sources have steeper power spectral densities

• No clear difference for the case of BL Lacs vs FSRQs

• What will happen with longer radio time series?

BL Lacs vs FSRQs

We use Uttley et al 2002, MNRAS 332, 231, with some modifications
What is ahead?

• Longer time series in radio and gamma-ray for more sources
  • Population studies
  • Individual source variability. More flares on each one
  • PSD characterization, populations, breaks, other models for light curves

• Polarization monitoring

• Optical monitoring
Polarization monitoring: KuPol

- Polarization probes the structure of magnetic fields in emission region
- KuPol a new receiver in the 12 to 18 GHz band
Optical monitoring: RoboPol

- Aim: high-cadence monitoring of linear polarization of a large (~100) sample of blazars
- Automated observing, dynamic observing schedule capable of responding to changes in a source
  - Goal: high-cadence light curves of polarization events
- Will use the Skinakas 1.3 m telescope at U. Crete
- Polarimeter is funded and under construction
- Observations to start in the Northern summer of 2012
- Participating institutions are: Caltech, MPIfR, Torun, U. Crete/FORTH and IUCAA
Summary

- Using high cadence radio and gamma-ray light curves we study the connection between radio and gamma-ray emission in Fermi detected blazars.

- We find that 7 out of 52 sources studied have $3\sigma$ significant correlations.

- The significance depends on the model for the light curves => robust methods to characterize them are required.

- Polarization monitoring will start observing next year.
  - Radio with KuPol
  - Optical with RoboPol