An EVN survey of hard spectrum gamma-ray sources

Marcello Giroletti
INAF Istituto di Radioastronomia, Bologna

and

Rocco Lico, Monica Orienti, Filippo D’Ammando, Gabriele Giovannini, Hayley Bignall, Cormac Reynolds, et al.
Abstract

“The EVN is helping us to discover, identify, and understand astrophysical sources in which particles are accelerated to extremely high energies.”
The Large Area Telescope (LAT) onboard Fermi

- 20 MeV - 300 GeV photon energies
- 2.4sr fov, survey mode operated, views entire sky every 3 hrs
- provides uniform sensitivity over whole sky in ~day time scale, providing great opportunities for
  - MWL studies of single (flaring) sources
  - all sky survey and population studies
- latest catalog: 2FGL (2yr, 1873 src, Nolan et al. 2012)
  - AGN fraction ~58% (mix of FSRQs and BL Lacs, plus few radio galaxies)
  - unidentified fraction ~31%
- 3FGL in prep. based on 4yr
  - longer exposure, improved analysis
Fermi AGN radio-gamma connection

- All 599 sources in 1st “clean” LAT-AGN sample
  - black: with redshift
  - magenta: without redshift
  - correlation coefficient: $r=0.47$
  - chance probability: $p<10^{-7}$

NB only two unassociated sources have gamma-ray flux larger than $8 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$ (green dashed line)

Very High Energy (VHE) gamma rays and lack of radio-VHE connection

- observations above $\sim$100 GeV based on detection of Cherenkov atmospheric radiation (IACT)
- limited field of view, limited observing time, limited (integrated) sensitivity
- census: 47 AGNs over 151 detection (with 25 UNID and many galactic sources); mostly HSP-blazars
- bias: plenty of! no systematic survey, observations in flaring state, ...

- physical elements: anti-correlation between SED peak and source power (blazar sequence), EBL attenuation, complex framework!
The 1FHL

- 1FHL: first Fermi catalog of high energy sources (E>10 GeV, Ackermann et al. 2013)
- Three years of survey data, as uniform and unbiased as possible
- 514 sources, 76% of which are AGN, 13% unassociated
  - AGN fraction larger than in 2FGL, census leaning towards extreme spectral type blazars (HSP)
  - Still significant fraction of unidentified sources
    - Remarkable, given generally smaller positional ellipses
IFHL & VLBI

- Our goal: collect mas scale data for all northern IFHL sources
- through new observations for 77 unobserved ones, with EVN @1.6 GHz and VLBA @5 GHz
- to study parsec scale morphology, spectrum, luminosity of extreme blazars (Lico+11, Piner&Edwards05,...)
- to confirm classification for blazar candidates (Massaro+13)

(Rocco Lico’s PhD thesis)
EVN observations

- two 18-hr 1.6 GHz e-VLBI runs
  - April 2013 with Sh (sources with Dec>30°)
  - June 2013 with Ar (Dec<30°)
- phase reference, no known position
- found offsets as large as 6” from NVSS centroid
- detection rate
  - 83% overall
    - 100% for blazar candidates
    - 70% for unassociated sources
Radio flux densities

- Sources are generally weak (VLBI brightness distribution peaks ~10 mJy)
- A fair amount of resolved flux is present ($S_{\text{VLBI}}/S_{\text{NVSS}} \sim 0.1$)
- 1FHL AGNs and UNID behave ~similarly
IFHL vs radio flux scatter plots

- Weak trend
- somewhat better for AGNs and for VLBI data
  - simultaneity, physical scale
Correlation coefficients

<table>
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<th>nvss</th>
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<tr>
<td>Ifhl</td>
<td>0.21</td>
<td>0.050 (0.088 for AGNs)</td>
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<tr>
<td>2fgl</td>
<td>0.34</td>
<td>0.26</td>
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Correlation between radio and high energy data seems to vanish as we consider gamma-rays of higher energy.
Discussion

- EVN observations show that these sources have a radio jet
- *Fermi* data show that these sources have a gamma-ray relativistic jet
- radio and high energy emission do not correlate strongly
  - Doppler factor “crisis” continues
  - constraints on jet structure (stratification/deceleration), blazar sequence, ...
Take home notes

• EVN successful in revealing compact radio components in E>10GeV Fermi sources

• Lack of correlation between radio and gamma ray emission in blazars is not an artefact of IACT biases

• ...stay tuned for Rocco’s thesis
References