F-GAMMA monitoring
Gamma-ray NLSy1s and 'classical' blazars: Are they different at radio cm/mm bands?

Lars Fuhrmann

L. Foschini, G. Calderone, M. Colpi, R. Decarli, G. Ghisellini, G. Giancarlo, M. Giroletti, G. Tagliaferri, F. Tavecchio, L. Maraschi
Introduction:

• **NLSy1s at radio bands: poorly studied in detail!**
  • past: large radio surveys (NVSS, FIRST etc.) e.g. for NLSy1 radio-loudness, spectral indices, variability etc. (e.g. Komossa et al. 2006, Yuan et al. 2008)
  • few VLA and VLBI studies (e.g. Ulvestad et al. 1995, Doi et al. 2006, Giroletti et al. 2011) & maser studies (e.g. Tarchi et al.)
  • NLSy1s typically very compact and no large-scale jet emission
  • VLBI scales: compact sources, some jet features
  • detailed “monitoring” to study their jets rare!
  • blazars: different situation!

![Flux Density vs Time](image1.png)

![S (Jy) vs Frequency](image2.png)

![0528+134 stack of MOJAVE/20m Nat.Hgt. Epoch](image3.png)

MOJAVE database
F-GAMMA program

Fermi-GST γ-ray blazars: complementary broad band monitoring of variability and spectral evolution at cm/mm/sub-mm wavelengths

Fuhrmann et al. 2007, Angelakis et al. 2008
Core program: some facts

- **Core-Team:** L. Fuhrmann, E. Angelakis, J. A. Zensus, T. P. Krichbaum, N. Marchili
  PhD students: I. Nestoras, R. Schmidt

- **coordinated, monthly monitoring** of about 60 Fermi gamma-ray blazars
  (total intensity and polarisation)

- **Effelsberg 100-m:** since January 2007: high-precision, (quasi-)
  simultaneous broad band spectra at 8 frequencies between 2.6 and 42 GHz

- **IRAM 30-m:** since June 2007 monthly observations at 86, 140 (230, 270)
  GHz highly coordinated with Effelsberg (in close collab. with IRAM: H.
  Ungerechts, A. Sievers, D. Riquelme et al.)

- **APEX:** since 2008 quasi-regular observations at 345 GHz (in close collab.
  with S. Larsson, A. Weiss et al.)
Core program: some facts

- **optical monitoring** at R band with Abastumani (O. Kurtanidze et al.)
- **plus complementary collaborations**: Fermi team, OVRO 40-m program, optical monitoring, VLBI programs (GMVA, MOJAVE etc.), Planck, TeV
- **Fermi/LAT MW campaigns**: complementing the multi-wavelength coverage
- Study of the “radio-gamma connection”, broad-band variability & emission processes

- **Source sample:**
  - since 2007, Fermi-GST “pre-selected sample” of ~ 60, prominent, famous, typically highly variable AGN/blazars, previously EGRET detected
  - since 2009: sample revision according to Fermi-detections
  - not statistically complete in any sense!!!
F-GAMMA program: monitoring the radio jet emission from gamma-ray emitting NLSy1 galaxies

- Fermi-GST detections of NLSy1s in 2008/2009 relativistic jets in these sources?

- since January 2009: Fermi-detected NLSy1 PMN J0948+0022 included (EB+PV)

- since mid-2010: further extension - Fermi-NLSy1s 1H0323+342 & PKS 1502+036 (so far EB only)

- study the presence of relativistic jets in NLSy1‘s from radio bands:
  - flux density & spectral variability/flare:
    - brightness temperatures, Doppler factors & magnetic fields
  - polarisation

are the physical parameters of NLSy1‘s and “classical“ Fermi-blazars different???
F-GAMMA program: monitoring the radio jet emission from gamma-ray emitting NLSy1 galaxies

J0948+0022

F-GAMMA team: Preliminary. Not for publication, distribution or any official use!

eangelakis at mpifr.de (F-GAMMA team)

blazar, relativistic jet like behavior!

variability: months

> factor 2
F-GAMMA program: monitoring the radio jet emission from gamma-ray emitting NLSy1 galaxies

also blazar like behavior!

variability:

\[ t_{\text{var}} > \sim 185 \text{ days}, \quad \Delta S > \sim 20\% \]

\[ > \sim 50 \text{ days}, \quad \Delta S > \sim 70\% \]
F-GAMMA program: monitoring the radio jet emission from gamma-ray emitting NLSy1 galaxies

J1505+0326

variability: yes, but too few data!
First results: variability

- **Time series analysis:** [blazars: 4 years of data]
  - $\chi^2$-test for variability
  - variability amplitude/modulation index $m \% = 100 \times \text{rms} / \langle S \rangle$
  - variability time scales via SF, wavelet analysis

1. **Statistics:**

   - **blazar sample:** > 90% variable at cm-bands, mm-bands decreasing to 70%
   - **NLSy1s:** variable at all bands (except two frequencies)

2. **Variability amplitude:**

   - **blazar sample:** increasing strengths towards higher frequencies
   - **NLSy1s:** lower end of rms-values
First results: variability

3. Variability brightness temperatures:

- blazar sample:
  - increasing $T_B$ towards lower frequencies, typically $\sim 10^{12} - 10^{14} \text{K}$
  - corresponding Doppler factors: $T_B^{\text{app}} \sim \delta^3 \times T_{\text{lim}}^{\text{B, IC}}, \delta \sim 1 - 5$

NLSy1s:

- J0948+0022: tends to be at the lower $T_B$ values!
- J0324+3410: $4 \times 10^{11} - 2 \times 10^{12} \text{K} (2.6 \text{ GHz})$
  $2-5 \times 10^{10} \text{K} (32 \text{ GHz})$
- Doppler factors $<\sim 1-2$

\[
T_B = 8.47 \times 10^4 \cdot S_{\lambda} \left( \frac{\lambda d_L}{t_{\text{var}, \lambda} (1 + z)^2} \right)^2
\]

\[
\delta_{\text{var,IC}} = (1 + z)^{3+\alpha} \sqrt{\frac{T_B^{\text{app}}}{10^{12}}}
\]
F-GAMMA program
the spectra
F-GAMMA program
the spectra classification

Angelakis et al. in prep., Fuhrmann et al. in prep.
two types of behavior + steep spec.

Type 5

spectral evolution qualitatively similar to “shock-in-jet” (Marscher & Gear, 1985)
First results: spectral evolution

1. Spectral type:
   - **blazar sample:** variety of spectral behaviors, reducible to basically two physical mechanisms
   - **NLSy1s:**
     - J0948+0022: “Type 1” - spectral evolution dominated!
     - other two NLSys: too few data still!

2. Spectral peaks:
   - **blazar sample:** two-fold behavior in $S_{\text{max}} - \nu_{\text{max}}$
   - **NLSy1s:** J0948+0022 evidence for adiabatic phase, shock-in-jet? more data needed!
First results: spectral evolution

2. Spectral indices:

- 4yr-mean spectral indices: high (32, 86, 142 GHz) and low (4.8, 10, 15 GHz) frequencies ($S \sim \nu^\alpha$)
- blazar sample: flat to inverted
- NLSy1s: similar
Summary and Outlook

• since 2009: monitoring program to study the jet emission in 3 NLSy1s

• NLSy1s:
  • typical blazar/jet-like behavior: seem to exhibit (relativistic) jets
  • there seem to be differences in flare/variability behavior: lower $T_B$, less Doppler-boosted than typical blazars
  • spectral behavior in J0948+0022 like “blazar type 1”, spectral evolution dominated, shock-in-jet?!?
  • longer data streams necessary
  • a more systematic future VLBI monitoring important to study NLSy1 jet parameters (speeds, Doppler/Lorentz factors, viewing angles etc.) on pc-scales in detail!