F-GAMMA/QUIVER Full-Stokes, multi-frequency radio monitoring of Fermi blazars

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Extragalactic jets on all scales - launching, propagation, termination 17.06.2021

Max-Planck-Institut für Radioastronomie



The scope

- F-GAMMA | 2007 2015
 - complement the operation of *Fermi* gamma ray telescope
 - monitoring the variable multi-frequency radio emission of AGN jets
- QUIVER | 2015 now
 - focuses on a sub-sample of highly polarized sources, monitored with higher cadence
- The sample
 - ~300 sources observed at least once
 - ~100 sources monitored regularly
 - uniform northern sky coverage (min. declination ~ $-23^{\circ}24$ ')
- More information & 1st data release (2.6 43 GHz, 2007-2015)
 - Fuhrmann, Angelakis, Zensus et al. 2016, A&A, 596A, 45F
 - Angelakis, Fuhrmann, Myserlis et al. 2019, A&A, 626A, 60A

ASO042 0059 + 583FGLJ1522.2 PKS0215+015 PKS0048-097 3FGLJ0221.1+3556



Vizier catalog number: J/A+A/626/A60







Number of sources

- F-GAMMA | 2007 2015
 - ~60-70 sources monitored at all times
 - 30 sources replaced around 2009.5
- QUIVER | 2015 now
 - ~20 sources (always the same)
 - most polarized and variable





Cadence

- F-GAMMA | 2007 2015
 - monthly for all sources
 - 2011 2015: biweekly for a subset of "fast" sources \bullet
- QUIVER | 2015 now
 - biweekly \bullet
 - resolving n-pi ambiguity in polarization plane rotations ullet



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Frequency coverage

- Effelsberg 100-m
 - 2.5 45 GHz (8 bands) | 2007 2018
 - 2.5 45 GHz (9 bands 22 sub-bands) | 2018 2
 - better RFI mitigation
 - intraband studies, e.g. RM (synthesis)
 - SPECPOL backend
- IRAM 30-m
 - 86 230 GHz (3 bands) | 2007 2014.5
- APEX 12-m
 - 345 GHz (1 band) | 2007 2011.5







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4.8				••• •• ••	•		•••••		 • • • • • • • • •	• •• ••••••	
5.2	500 GHZ										• •••••
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10.4	4500 GHz			•••• •• •••			•••••		 		
14.2	2500 GHz								 		
14.	6000 GHz			• • • • •	••••	•••••	•••••		 	•	
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19.	0000 GHz										
19.2	2500 GHz								 		
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21.	1500 GHz									•	
22.	0000 GHz					-					
22.2	2350 GHz					A			 		
22.8	8500 GHz		•	• • •							
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228	3.9300 GHz										
345	5.0000 GHz	· F - (MR	ΛΛ						/ 6
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High precision, linear and circular polarimetry

- complete pipeline
 - from telescope observables to *I*, *Q*, *U*, *V*
 - designed for CP feeds but easily applicable also to LP feeds \bullet
- several correction steps (general & polarization-specific)
 - pointing, opacity, elevation-dependent gain
 - airy disk instead of gaussian beam pattern
- minimization of instrumental effects:
 - instrumental linear polarization correction across the telescope beam \bullet
 - absolute EVPA calibration with Lunar observations \bullet
 - instrumental circular polarization correction with **two** independent methods
- polarimetric precision:
 - linear & circular polarization degree: 0.1–0.2 %
 - polarization angle (EVPA): 1°

IM et al. 2018, A&A, 609A, 68M IM et al. 2016, Galaxies, vol. 4, issue 4, p. 58

→ Sect. 3.1 → Sect. 3.2 → Sect. 3.3 → Sect. 3.4 → Sect. 3.5.1 → Sect. 3.5.2 → Sect. 3.5.3 → Sect. 3.1

→ Sect. 3.1

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Multi-frequency total flux and polarization monitoring

- F-GAMMA + QUIVER monitoring programs
 - since Jan 2007
 - total of ~100 sources (mostly *Fermi* blazars) \bullet
 - mean cadence ~ 20 days
 - 2.64–345 GHz at multiple frequency steps
- high-cadence, full-Stokes light curves
 - LP at 2.64, 4.85, 8.35, 10.45 and 14.6 GHz
 - CP at 2.64, 4.85, 8.35, 10.45, 14.6, 23.05 GHz •
 - recovered data since 2010.5

Locating the y-ray emission site using multi-frequency variability in total flux (Stokes I)

- source: PKS 1502+106
- delay origin: opacity of the synchrotron self-absorbed jet
- relative timing of flare maxima (DCCF) & knot kinematics (mm-VLBI)
 - precise core-shifts
 - γ -ray emission site

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Karamanavis et al. 2016, A&A 590, 48 Fuhrmann et al. 2014, MNRAS 441, 1899

Summary

- F-GAMMA (2007 2015) & QUIVER (2015 now) dataset
 - ~100 monitored sources
 - min. cadence: 15 days •
 - max. frequency coverage: 2.6 345 GHz (lately with several sub-bands) \bullet
- High-precision, linear and circular polarimetry
 - linear & circular polarization degree accuracy: 0.1–0.2 %, EVPA accuracy: 1° \bullet
- Examples:
 - variability in Stokes I: localizing the gamma-ray emission site in PKS 1502+106

• variability in Stokes I, Q, U, V: constraining physical conditions and variability mechanisms in 3C 454.3

For more information & data requests, contact us: imyserlis@iram.es , <a href="mailto:easier:easie