F-GAMMA program: Probing the AGN physics via broad-band radio variability studies

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on behalf of the F-GAMMA team
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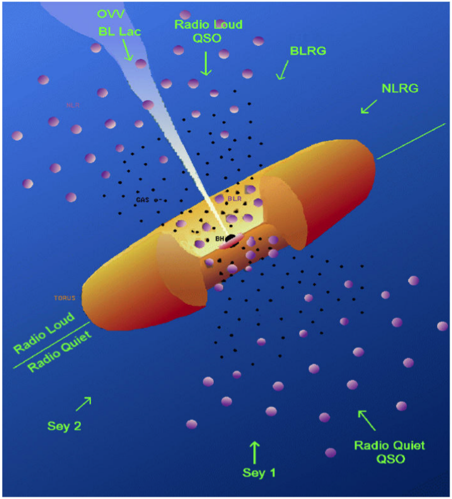
Introduction

- investigating the spectral evolution of blazars
- data from cm-mm monitoring program (F-GAMMA)
- presenting here:
  - phenomenological classification E. Angelakis et al., in prep
  - spectral evolution of flaring events (first results)

AGNs and Blazars



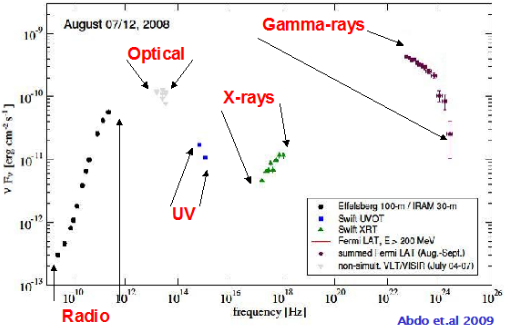
Antonucci (1993), Urry & Padovani (1995)

- nucleus outshines the galactic disk
- observed a large variety of AGNs
  $\rightarrow$ unification scheme
- blazars: looking almost directly into the radio jet

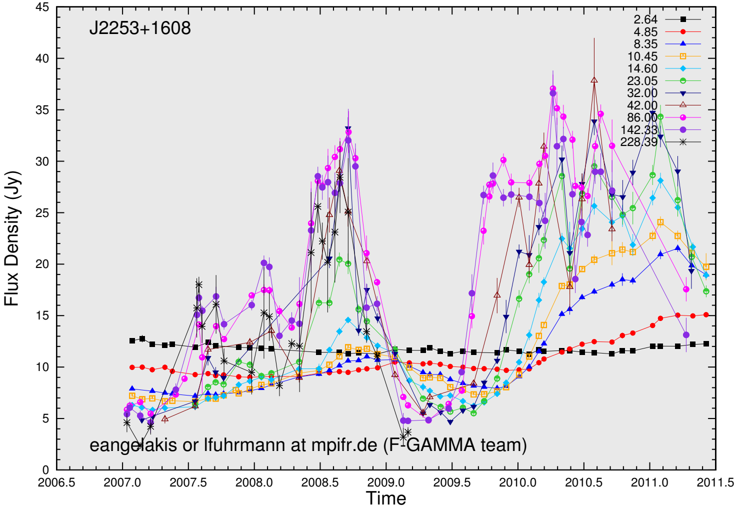
Blazar characteristics

- collimated ejection of relativistic plasma from SMBH
- high energy beamed γ-rays (Compton or photo-hadronic processes)
- extreme variability
- high degree of polarization
- highly superluminal motions
- double peaked SED (Spectral Energy Distribution)

Broadband, (quasi–) simultaneous SED of 3C 454.3



Blazar characteristics



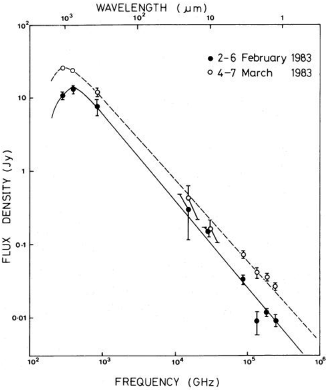
Variability Models

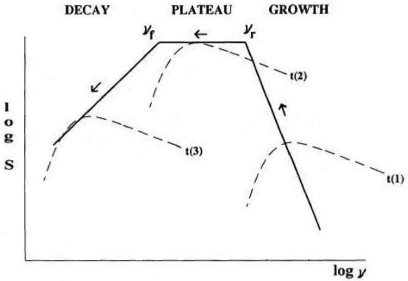
- different mechanisms predict different variability characteristics
- examples of variabiliy models:
    - shock-in-jet model Marscher & Gear, 1985
    - internal shock model Spada et al., 2001
    - geometrical models Camenzind et al., 1992
- focus on shock-in-jet model
    - extract physical parameters
    - explains classification

Variability Models

Marscher & Gear (1985)

purpose: investigation of the 1983 flare in 3C273



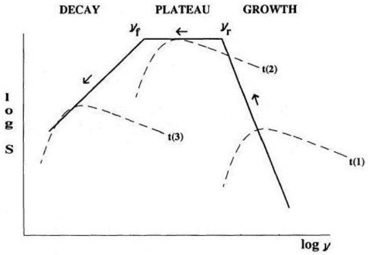


- later: S_m roughly constant, ν_m decreases
- late april: S_m dropped to quiescent level

Variability Models

Marscher & Gear (1985)

- variability caused by shock waves
- shock waves through changes in
  - injection rate of relativistic electrons
  - magnetic field
  - Lorentz factor
- acceleration of particles in a small layer behind shock front
  $\rightarrow$ width dependent on dominant cooling process
- three stages:
  - Compton stage
  - Synchrotron stage
  - adiabatic stage



F-GAMMA

Fuhrmann et al. (2007), Angelakis et al. (2008), Fuhrmann et al. (in prep), Angelakis et al. (in prep), Nestoras et al. (in prep)

F-GAMMA program

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

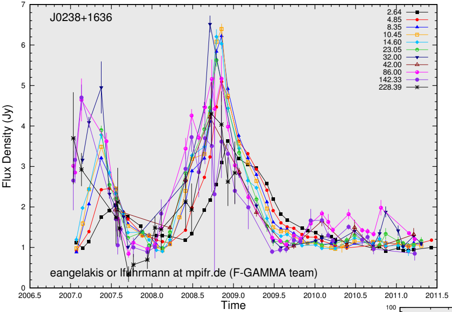
F-GAMMA

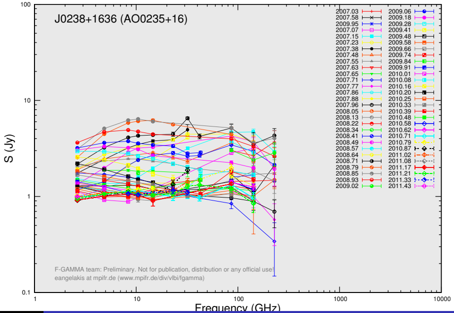
- F-GAMMA program:
  coordinated, monthly monitoring of blazars since 2007 (total intensity and polarization)
- core program:
  - Effelsberg 100m telescope: 8 frequencies (2.6-42 GHz)
  - IRAM 30m telescope: 3 frequencies (86, 142, 228 GHz)
  - APEX 12-m telescope: 345 GHz

  $\rightarrow$ quasi-simultaneous spectra (10 days)
  $\Rightarrow$ cross-band studies
- Source sample: Fermi-GST "pre-selected sample" of $\sim$ 65 blazars, famous, typically highly variable
- Fermi-GST scans entire sky every three hours
  $\rightarrow$ densely sampled gamma-ray light curves

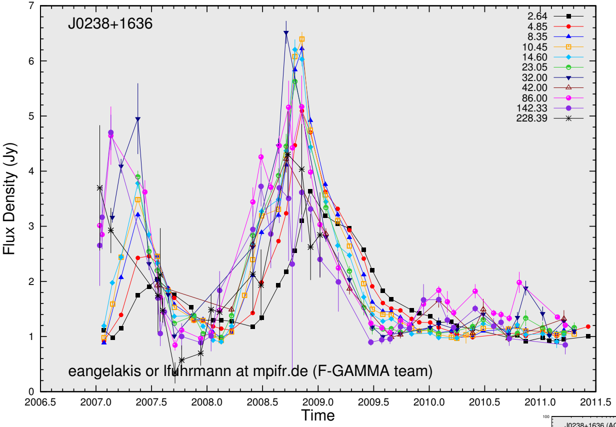
$\Rightarrow$ study of the "radio-gamma connection"

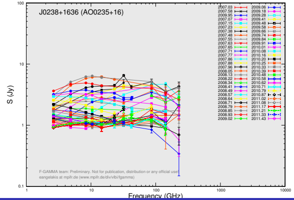
Spectra and Lightcurve





Spectra and Lightcurve





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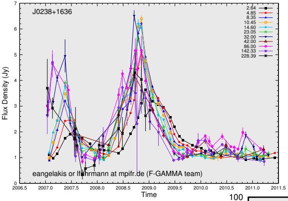
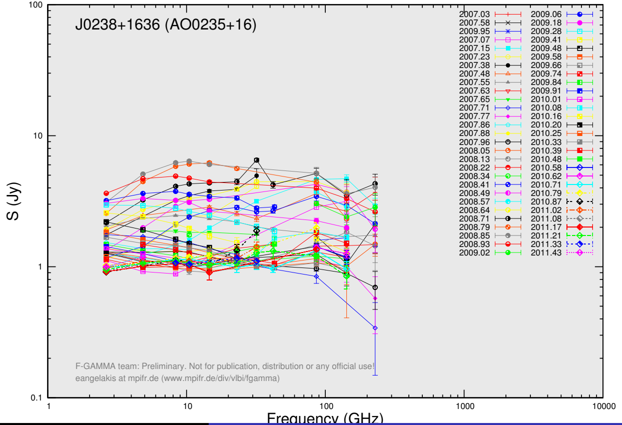
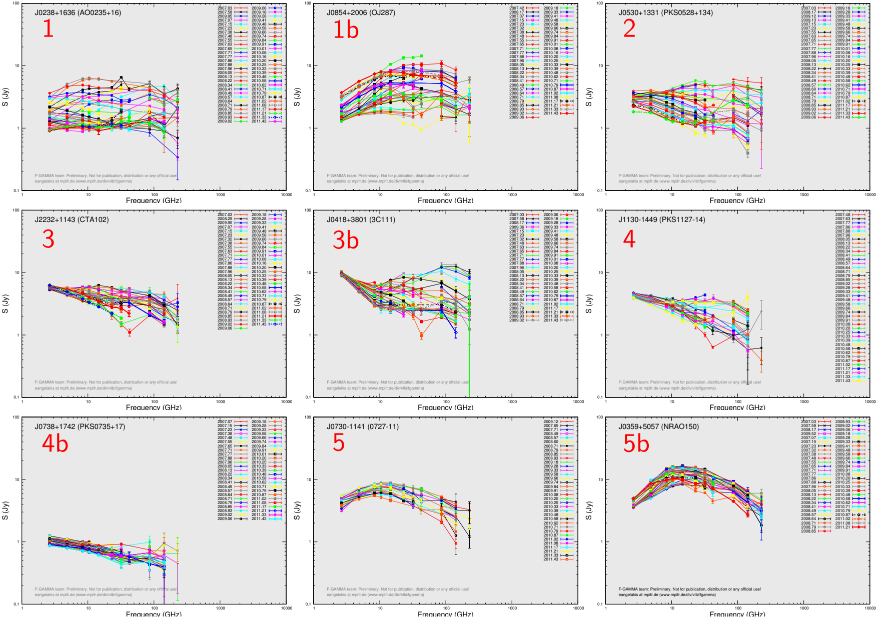


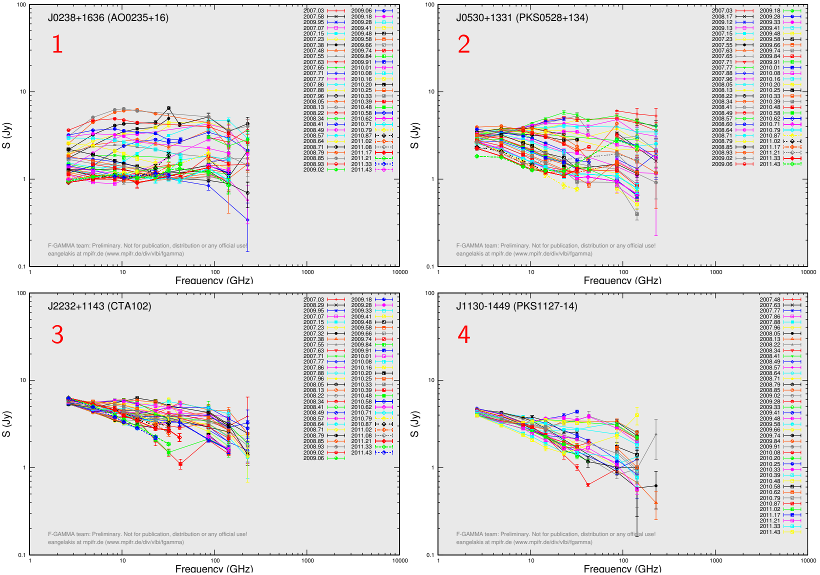


Phenomenological Classification



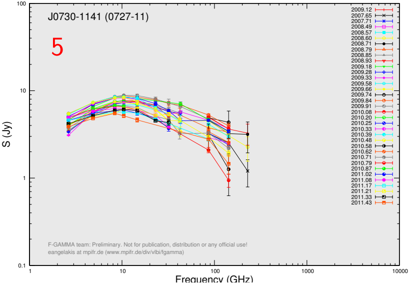
Phenomenological Classification

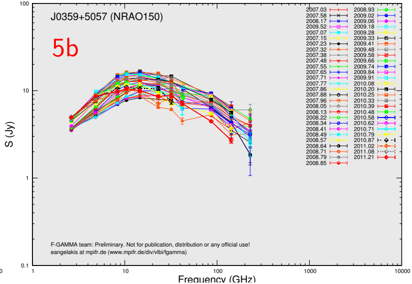
Spectral Evolution



Phenomenological Classification

Achromatic Evolution

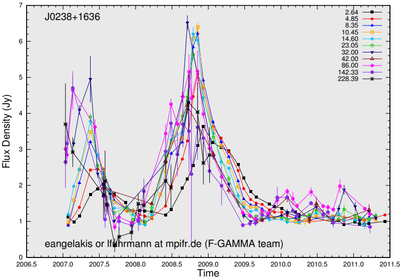


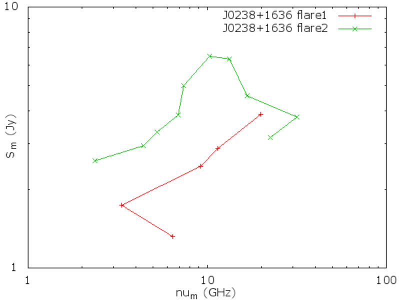


E. Angelakis et al., in prep

Spectral Evolution of Flaring Events

- choose flaring period
- calculate maximum flux and turnover frequency
- produce S_m-ν_m plots for flares





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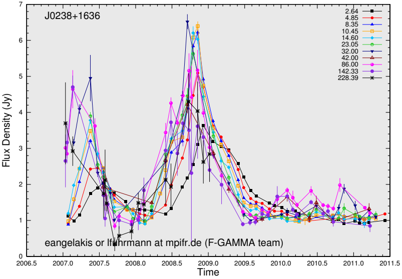
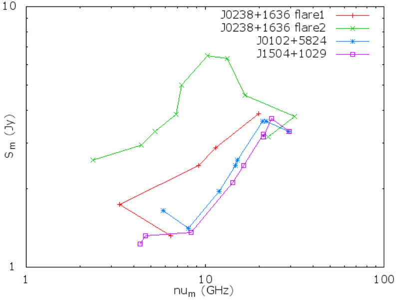
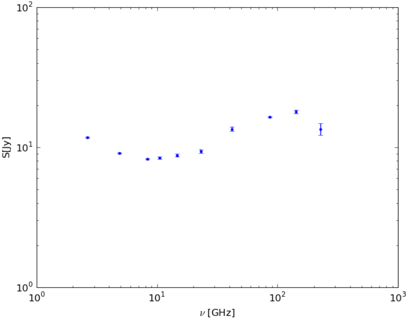




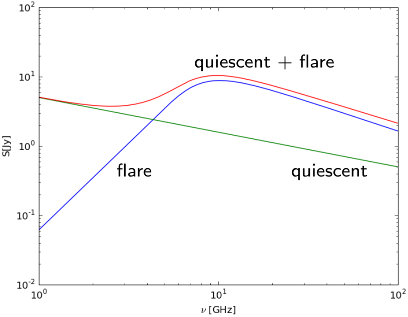
Spectral Evolution of Flaring Events

subtract quiescent spectrum

- assume quiescent + flare component
- substract quiescent component



example data



model

Conclusion

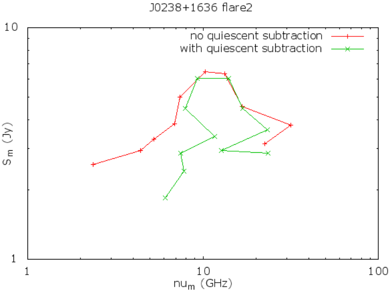
- F-GAMMA team observes roughly 65 blazars monthly
  $\rightarrow$ investigating variability & emission mechanisms, cross-band studies
- spectra can be sorted into 5 phenomenological classes
  - 4 classes show spectral evolution
  - 1 class varies achromaticly
- spectral evolution of flaring events
  - modelling spectral evolution of class 1-4: shock-in-jet behaviour
  - next step: substract quiescent spectrum

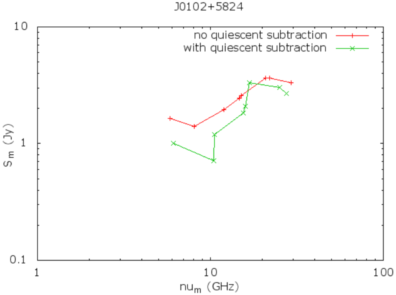
Fuhrmann et al. (2007), Angelakis et al. (2008), Fuhrmann et al. (in prep), Angelakis et al. (in prep), Nestoras et al. (in prep)

Thank you for your attention!

Spectral Evolution of Flaring Events

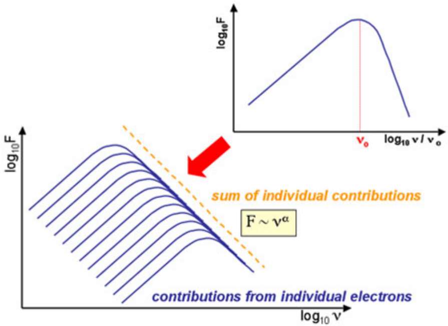
subtract quiescent spectrum





- quiescent spectrum with NVSS (1.4GHz) and Texas Survey (365MHz)
- steeper growth and decay stage
- further investigation needed

Synchrotron Radiation and Synchrotron Self-Absorption



sum of individual electron spectra

synchrotron self absorbed spectrum