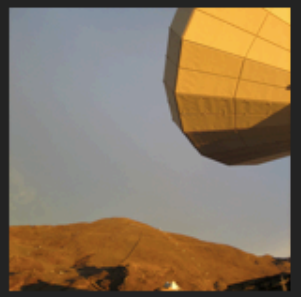
100-m Effelsberg
covers the band 2.64 - 43 GHz with a precision of a few percent for monthly sampling of 60 sources



30-m IRAM
covers the band 86 - 250 GHz monthly also for roughly 60 sources

12-m APEX
345 GHz, located in Atacama desert in Chile at an altitude of 5100 m

F-GAMMA monitoring

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

Lars Fuhrmann

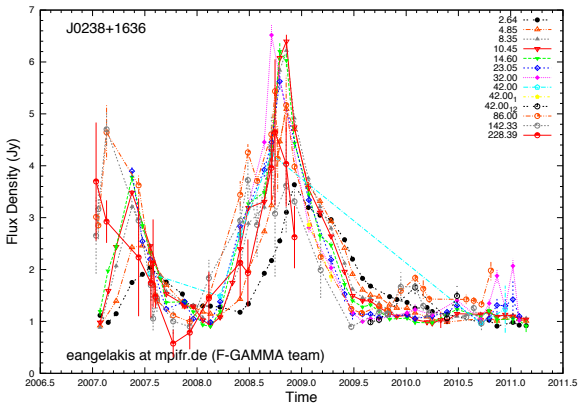
and E. Angelakis, I. Nestoras, N. Marchili, T. P. Krichbaum, R. Schmidt, J. A. Zensus, C. M. Fromm, H. Ungerechts, A. Sievers, D. Riquelme on behalf of the F-GAMMA team **&**

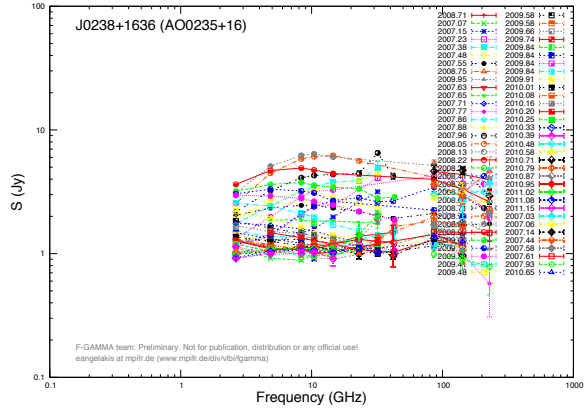
L. Foschini, G. Calderone, M. Colpi, R. Decarli, G. Ghisellini, G. Giancarlo, M. Giroletti, G. Tagliaferri, F. Tavecchio, L. Maraschi

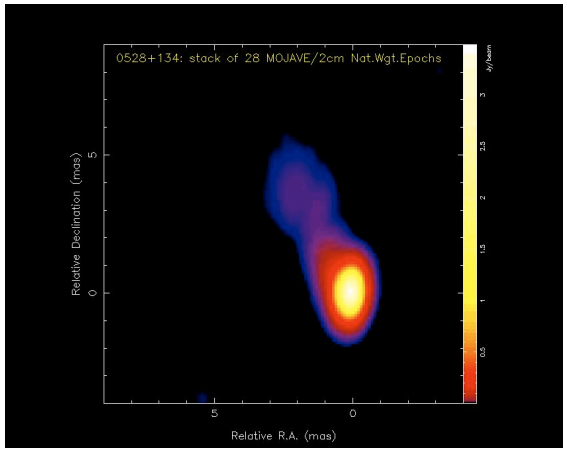
Max-Planck-Institut für Radioastronomie

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!







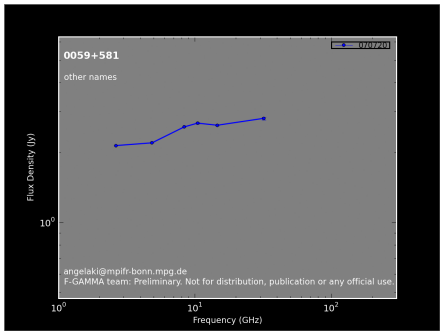
MOJAVE database

Fuhrmann et al. 2007, Angelakis et al. 2008

F-GAMMA program

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

Core program: some facts



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

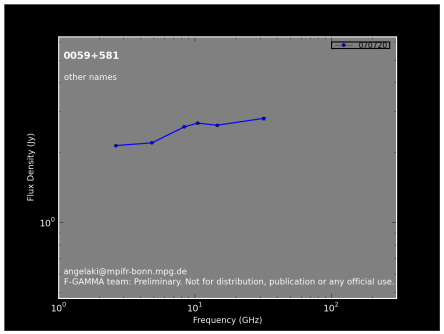
- **coordinated, monthly monitoring** of about 60 Fermi gamma-ray blazars (total intensity and polarisation)

- **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

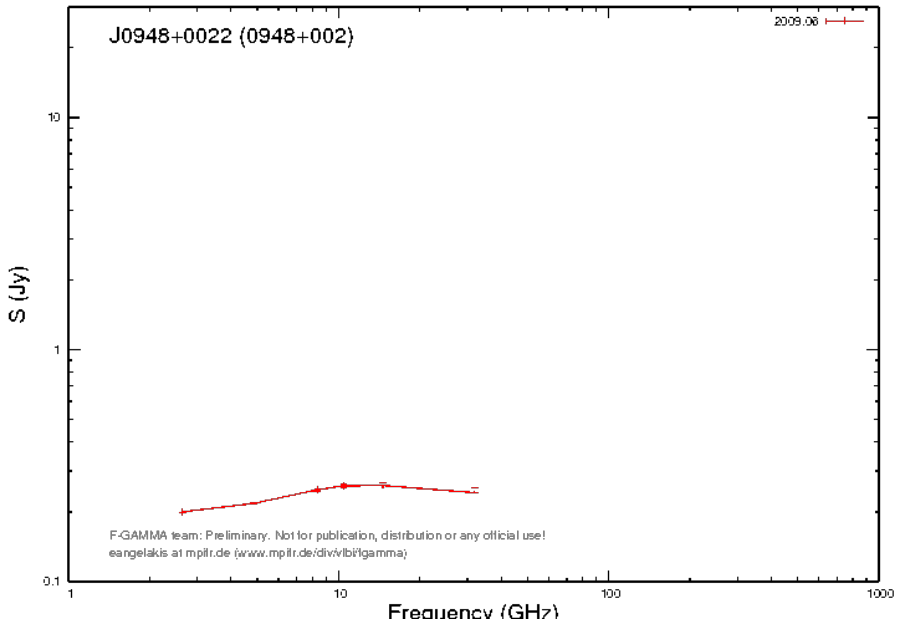
→ relativistic jets in these sources?

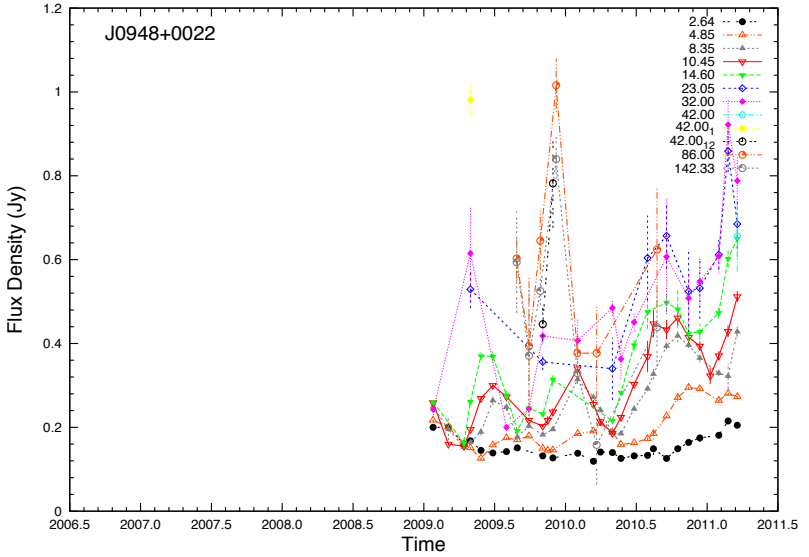
- since January 2009:
  Fermi-detected NLSy1
  PMN J0948+0022 included
  (EB+PV)
- since mid-2010: further extension - Fermi-NLSy1s 1H0323+342 & PKS 1502+036 (so far EB only)
- study the presence of relativistic jets in NLSy1‘s from radio bands:
  - flux density & spectral variability/flares:
    - brightness temperatures, Doppler factors & magnetic fields
  - polarisation

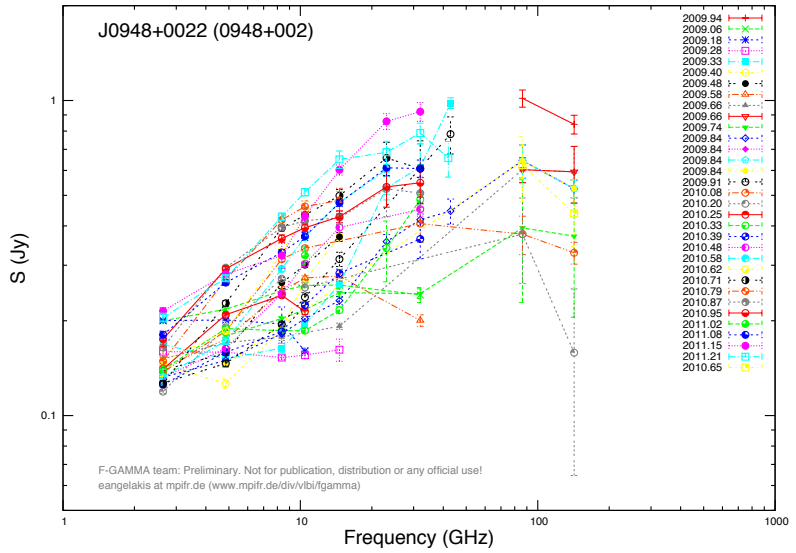
→ are the physical parameters of NLSy1‘s and “classical“ Fermi-blazars different???

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

J0948+0022







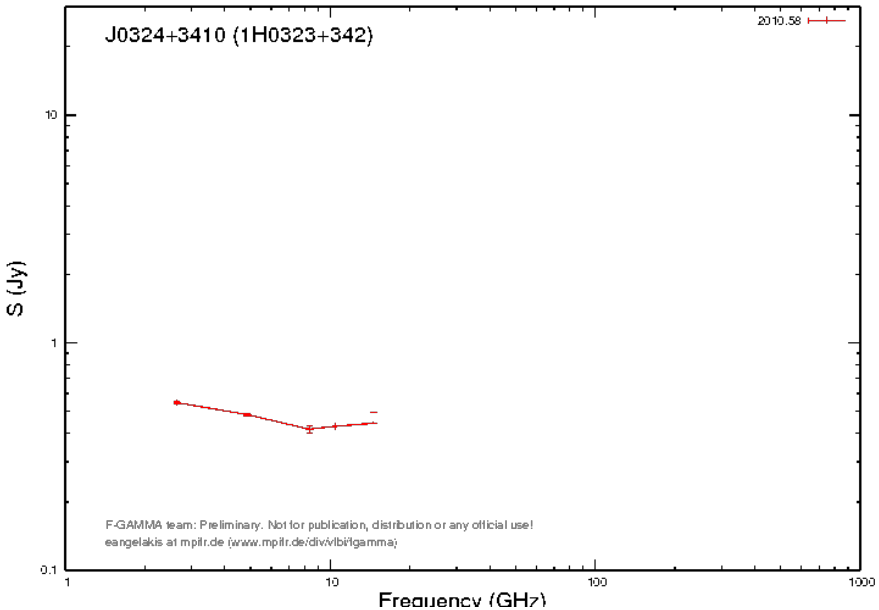
blazar, relativistic jet like behavior!

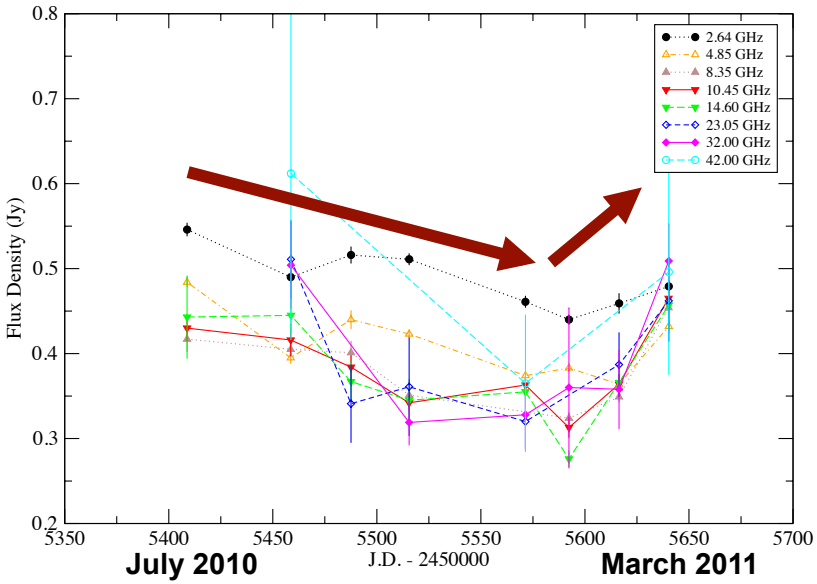
variability: months

> factor 2

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

J0324+3410



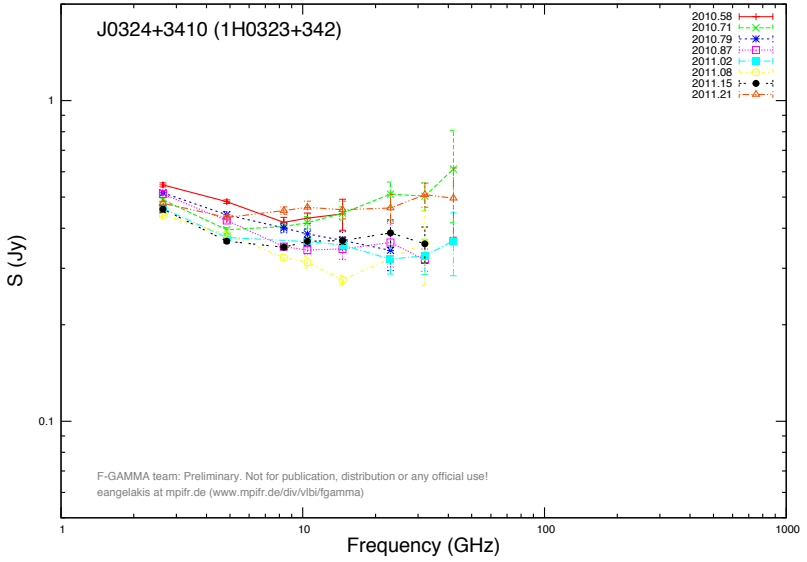


also blazar like behavior!

variability:

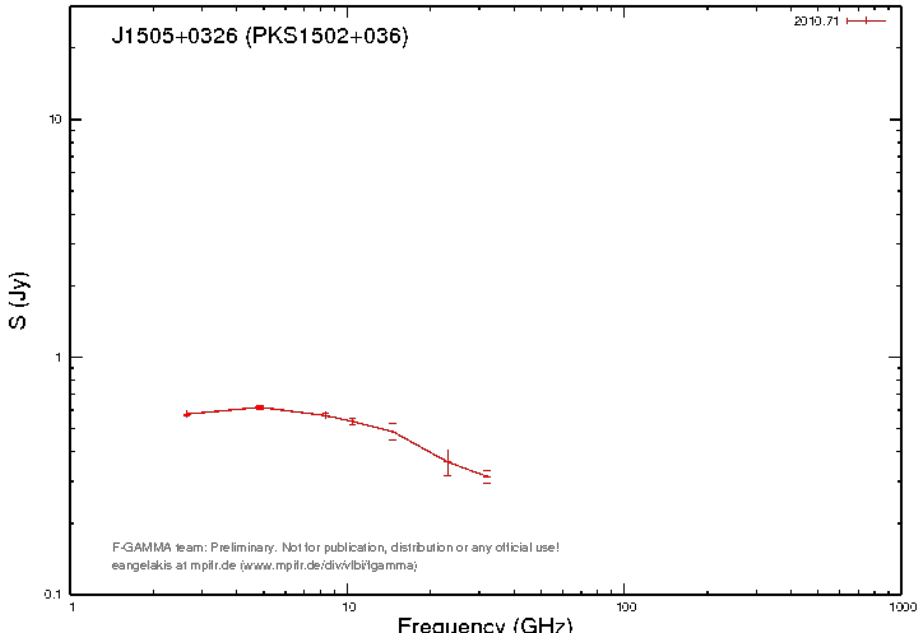
t_{var} > ~185 days, ΔS > ~ 20%

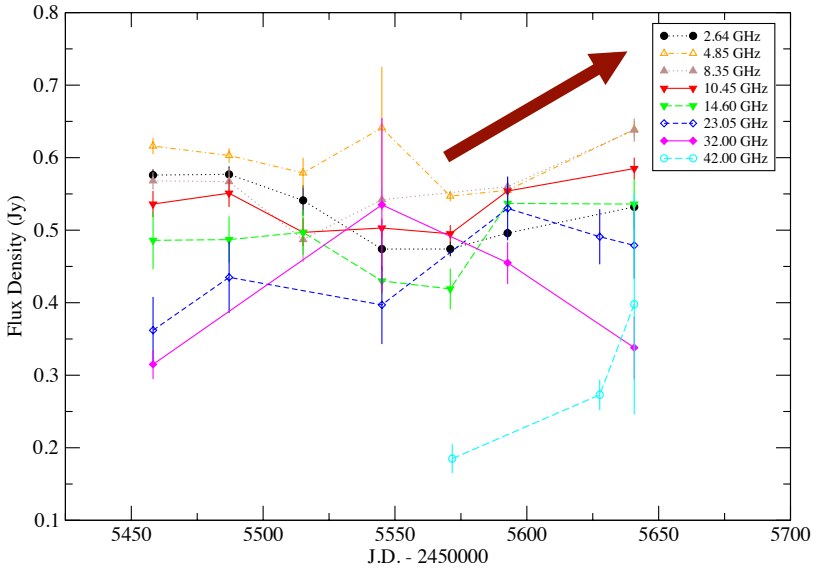
> ~ 50 days, ΔS > ~ 70%



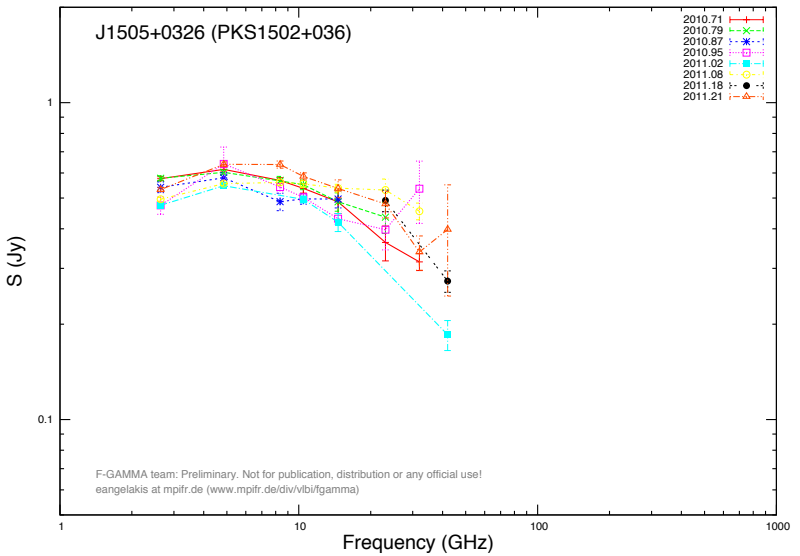
F-GAMMA program: monitoring the radio jet emission from gamma-ray emitting NLSy1 galaxies

J1505+0326





variability: yes, but too few data !



First results: variability

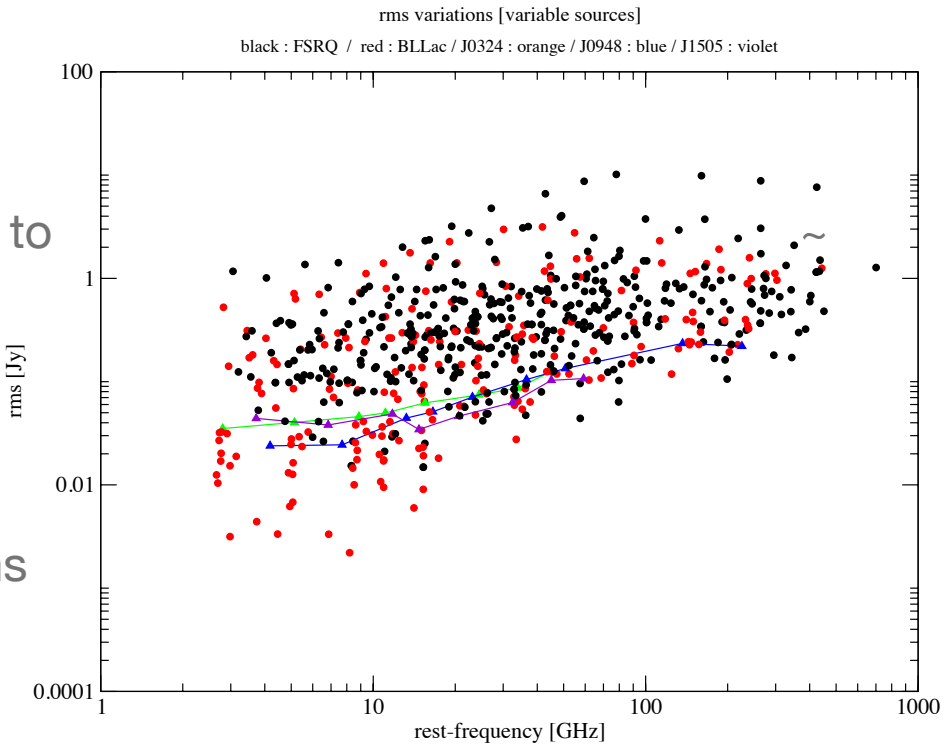
- **Time series analysis: [blazars: 4 years of data]**
  - χ^2-test for variability
  - variability amplitude/modulation index m [%] = 100 × rms / <S>
  - variability time scales via SF, wavelet analysis

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

$$T_{\mathrm{B}} = 8.47 \times 10^4 \cdot S_\lambda \left(\frac{\lambda \, d_L}{t_{\mathrm{var},\lambda} \, (1+z)^2} \right)^2$$

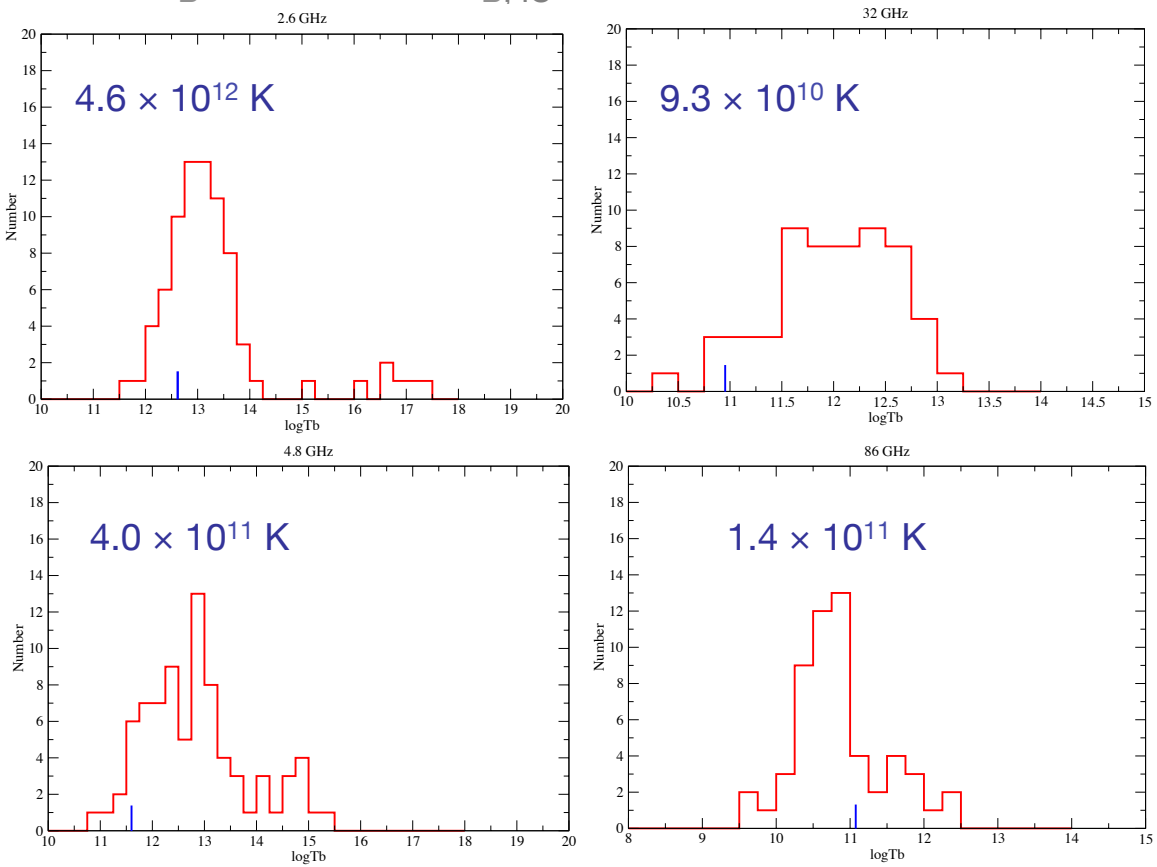
$$\delta_{\mathrm{var,IC}} = (1+z) \sqrt[3+\alpha]{T_{\mathrm{B}}^{\mathrm{app}} / 10^{12}}$$

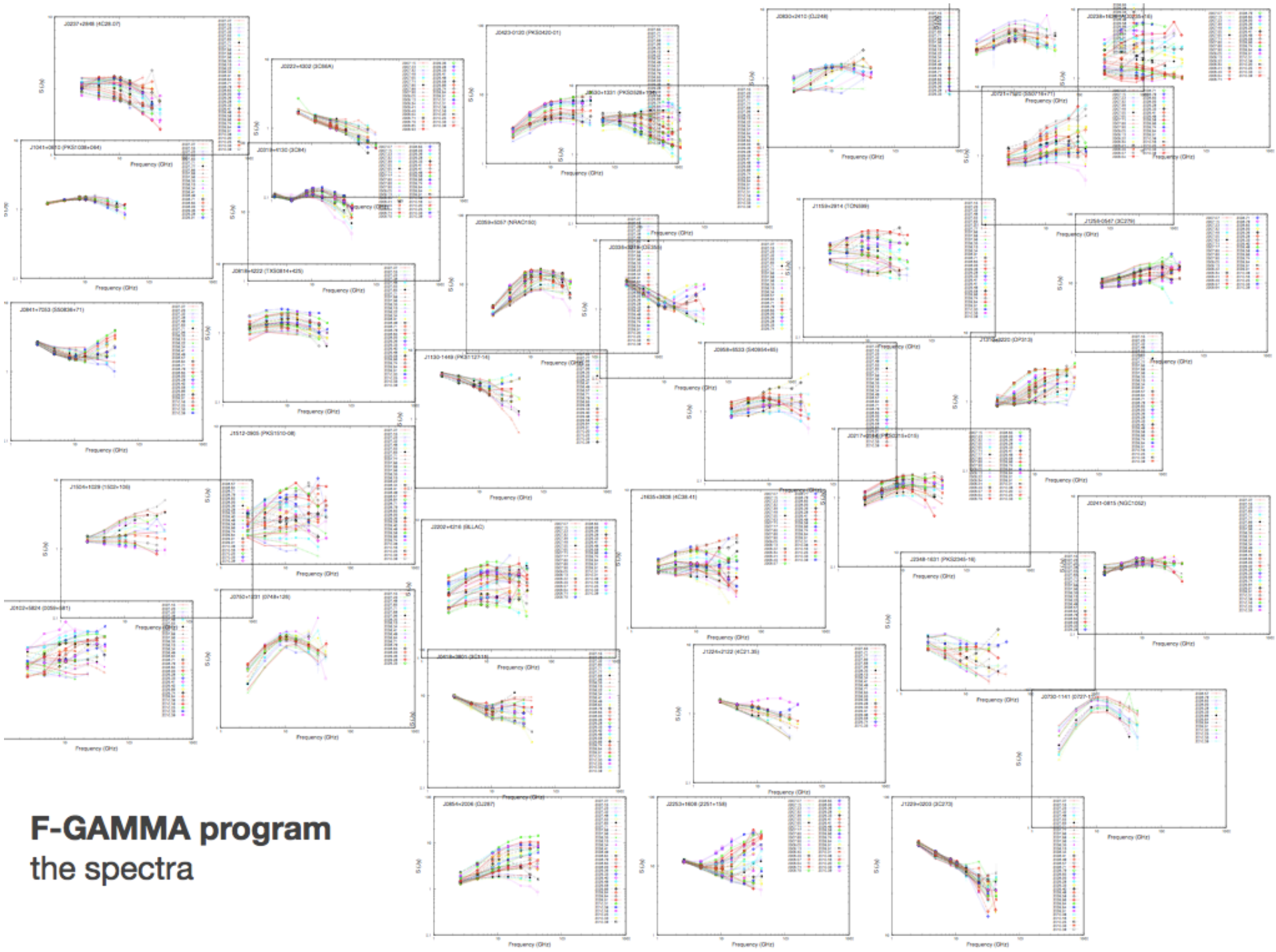
3. Variability brightness temperatures:

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

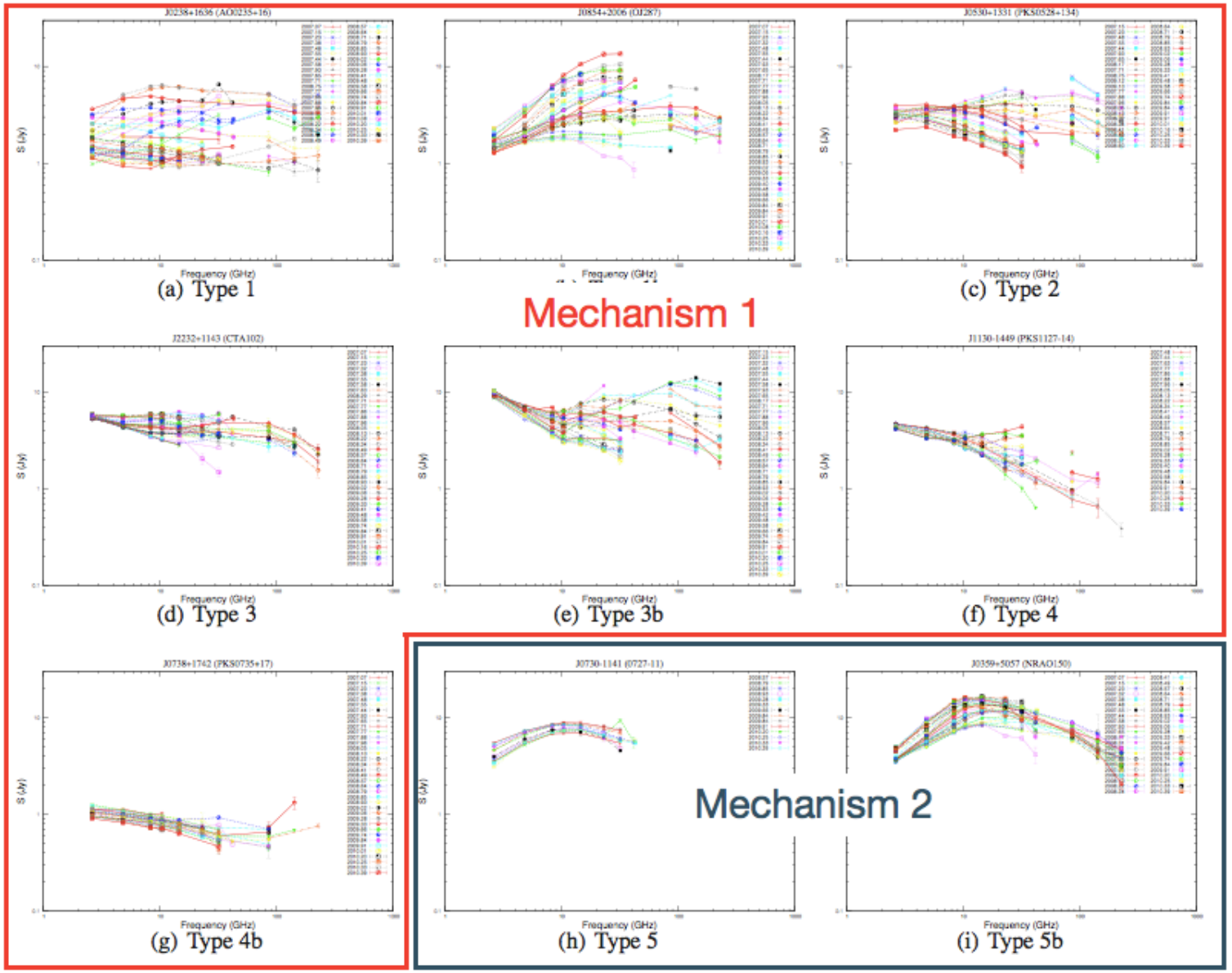
NLSy1s:

- J0948+0022: tends to be at the lower T_B values!
- J0324+3410:
  4×10^{11}- 2×10^{12} K (2.6 GHz)
  2-5x10^{10}K (32 GHz)
- Doppler factors <~ 1-2





F-GAMMA program
the spectra

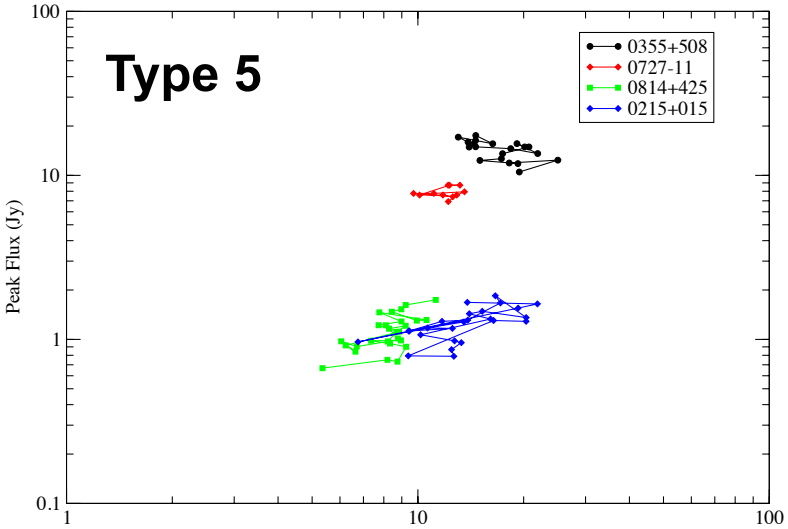


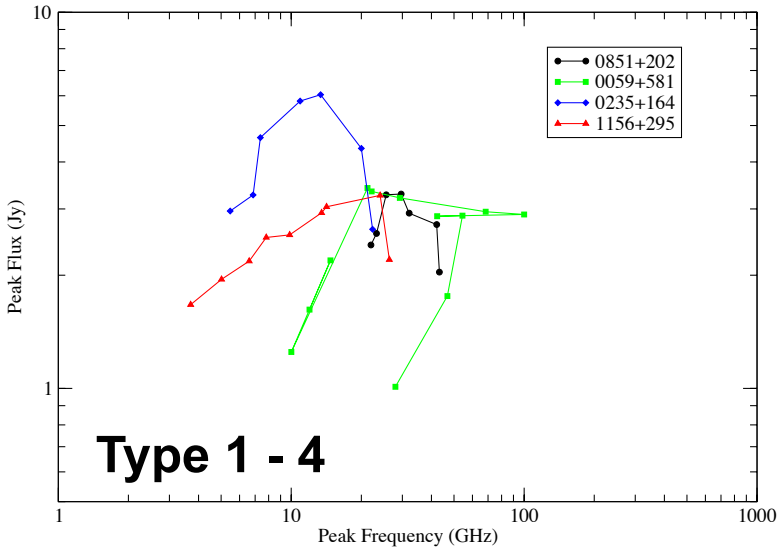
F-GAMMA program

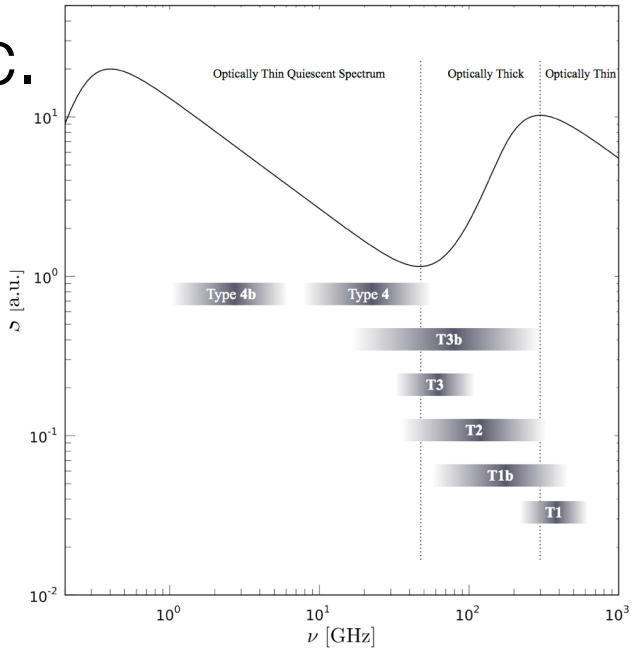
the spectra classification

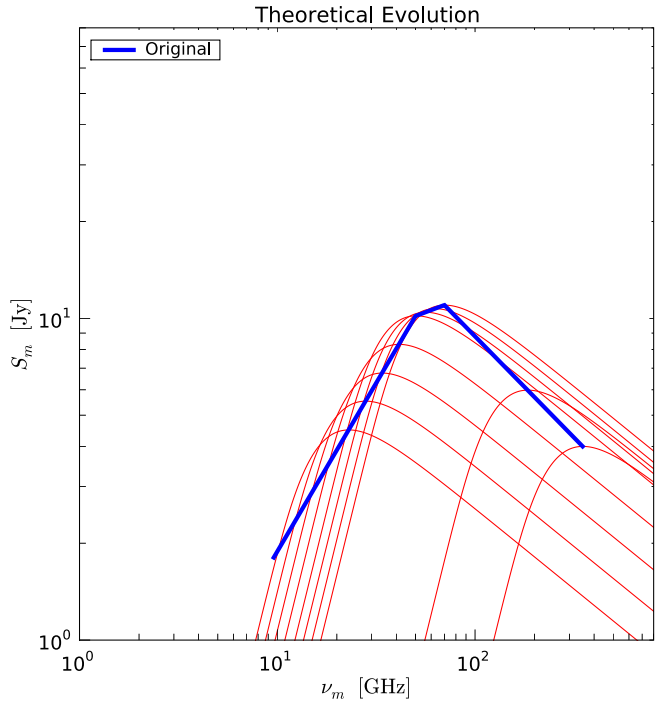
Angelakis et al. in prep., Fuhrmann et al. in prep.

two types of behavior + steep spec.









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

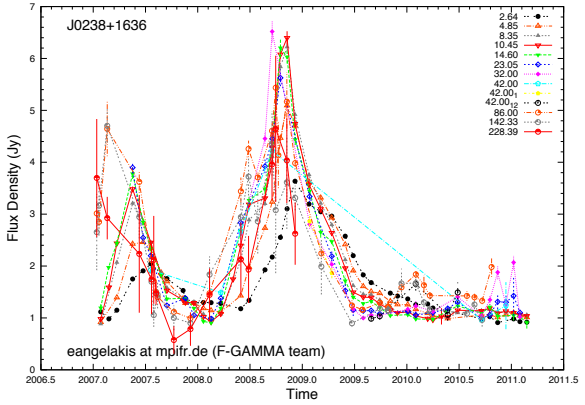
First results: spectral evolution

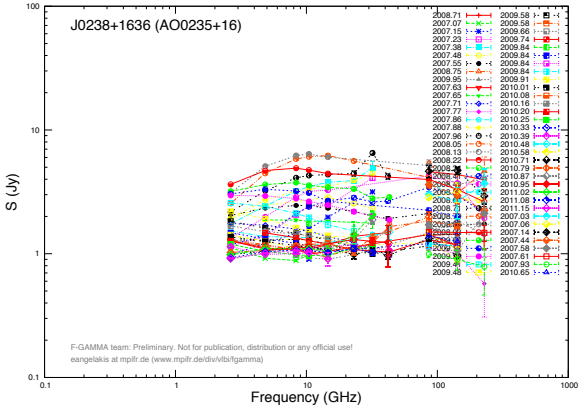
1. Spectral type:

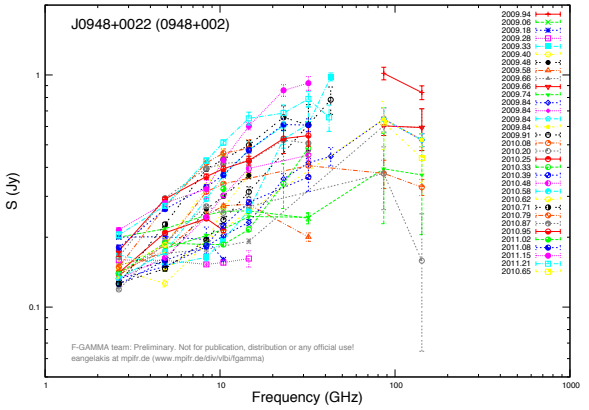
- blazar sample: variety of spectral behaviors, reducible to basically two physical mechanism
- NLSy1s:
  - J0948+0022: “Type 1” - spectral evolution dominated!
  - other two NLSys: too few data still!

2. Spectral peaks:

- blazar sample: two-fold behavior in S_{max}- ν_{max}
- NLSy1s: J0948+0022 evidence for adiabatic phase, shock-in-jet? more data needed!



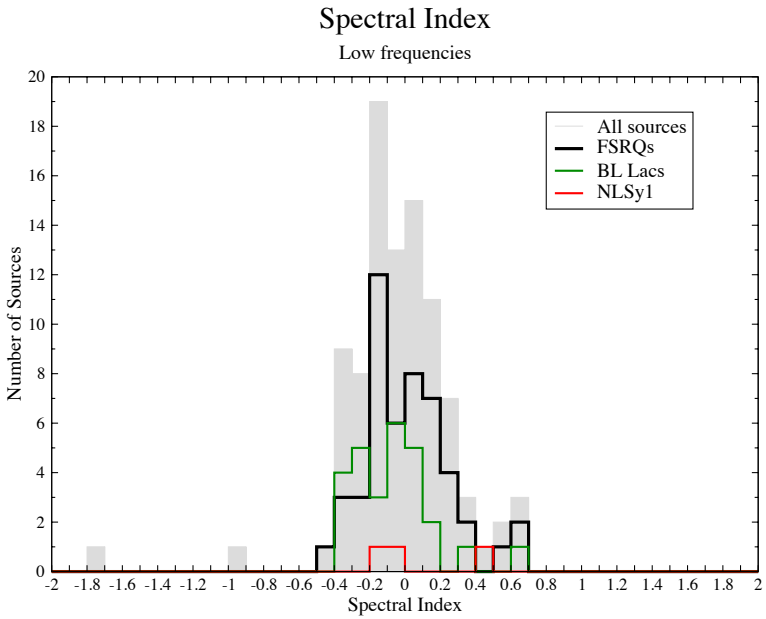


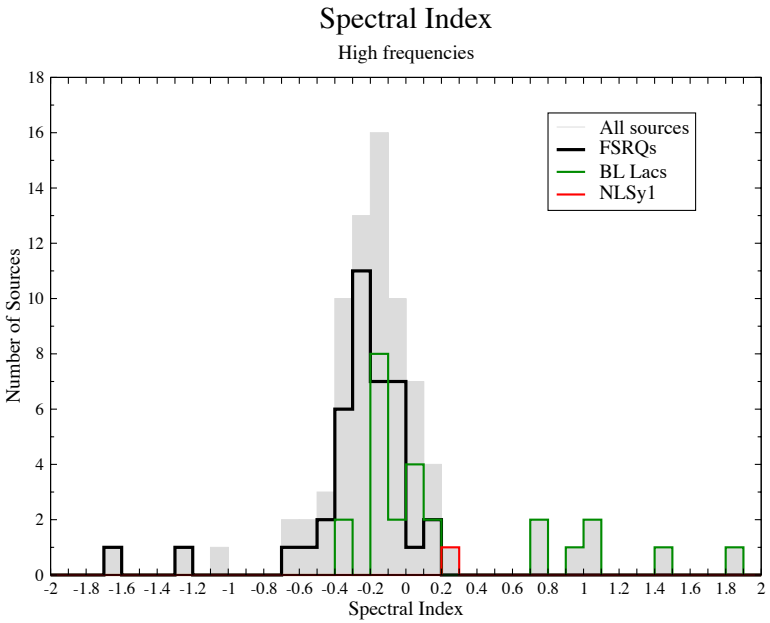


First results: spectral evolution

2. Spectral indices:

- 4yr-mean spectral indices: high (32, 86, 142 GHz) and low (4.8, 10, 15 GHz) frequencies (S ~ ν^{α})
- 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!