
100-m Effelsberg


30-m IRAM


12-m APEX

# Physics of AGNs through cm to sub-mm F-GAMMA and Planck radio observations


E. Angelakis

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5 INAF - Osservatorio Astronomico di Brera, Italy
6 Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, Garching, Germany

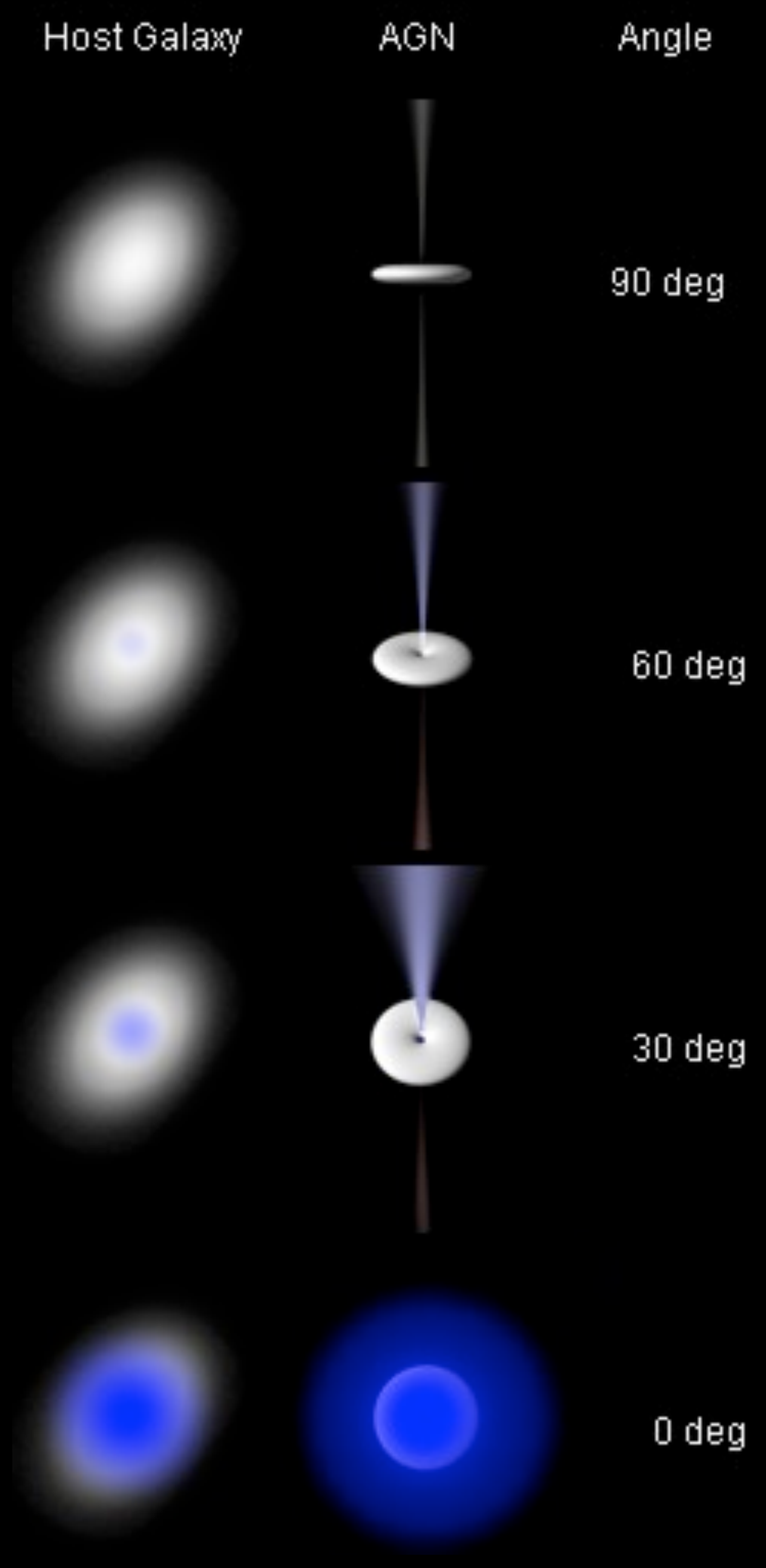
# Active Galactic Nuclei:

## The unified model and blazars

- emission originating in jets oriented very close ($\leq 20 - 30^\circ$ ) to the line of sight (e.g. *Urry & Padovani 1995*), causing:
  - high apparent luminosities and extreme flux density variability

$$L_{\mathrm{app}} = \delta^4 L \qquad \delta = \frac{1}{\gamma\,(1 - \beta cos\phi)}$$

  - moderate degree of linear and circular polarization
  - high superluminal motions
  - high brightness temperatures
  - flat radio spectra




credit: wikipedia

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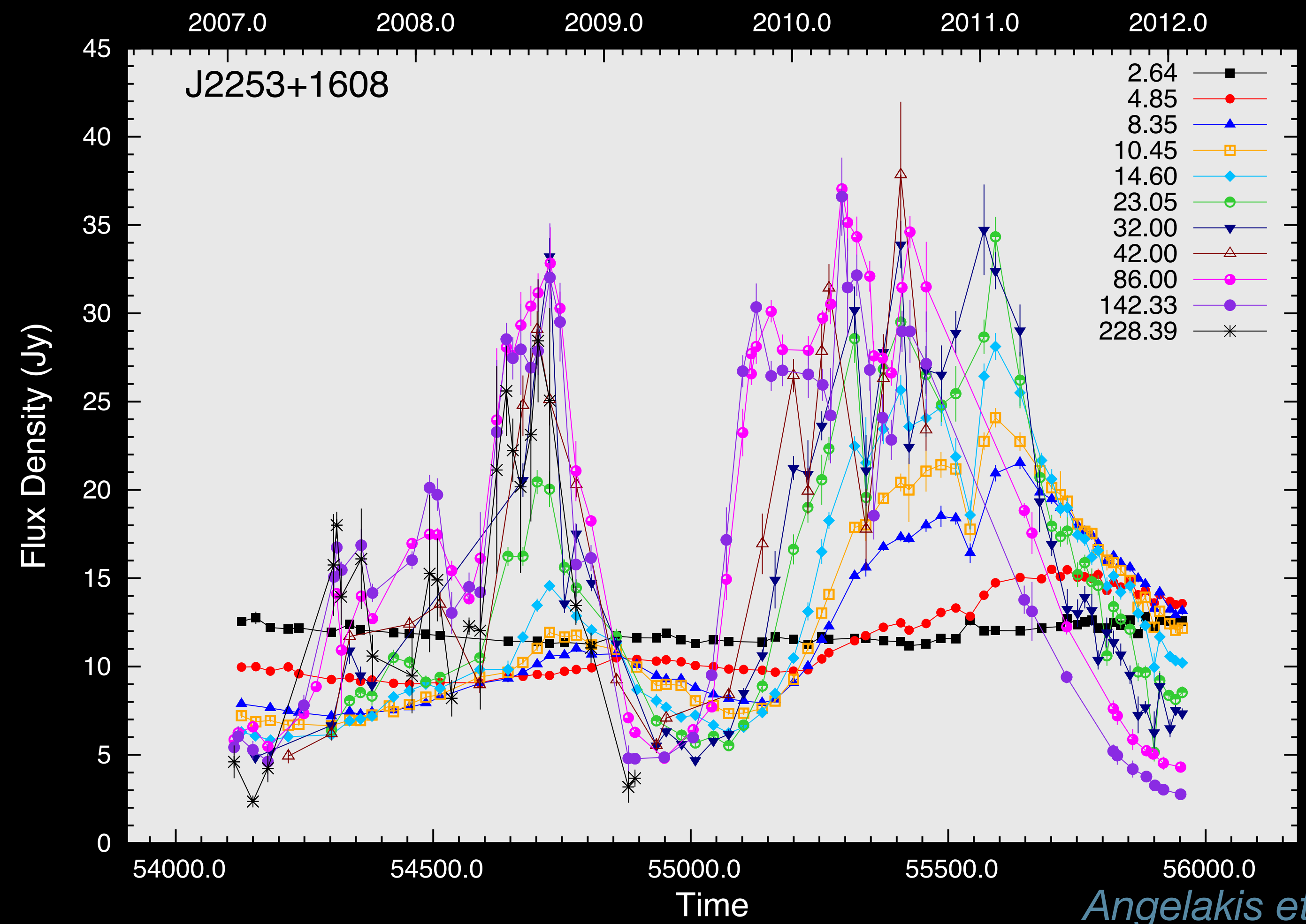
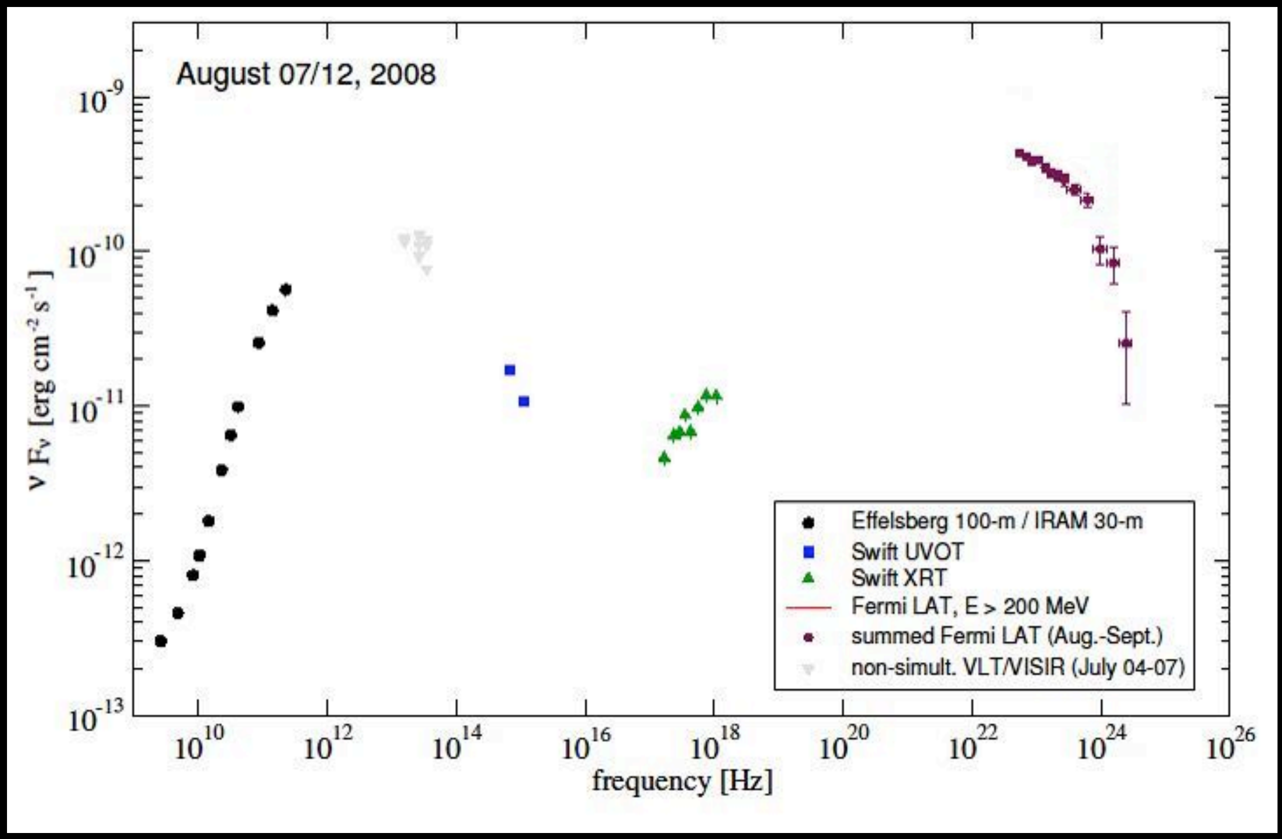
# Active Galactic Nuclei:

## The unified model and blazars




*Angelakis et al.*




*Abdo et al. (2009b)*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# F-GAMMA:

## multi-frequency monitoring

F-GAMMA PROJECT

FERMI-GST
AGN
MULTI-FREQUENCY
MONITORING
ALLIANCE

**Effelsberg 100-m telescope**

**IRAM 30-m telescope**

**APEX telescope**

- **monthly** monitoring program for ~60 *Fermi*/LAT blazars since January 2007
- at 2.6 - 345 GHz at **12 frequencies**, optical and gamma-rays
- cross-telescope **coherency 5-6 days**
- Linear and Circular **Polarization** of the Effelsberg data
- **optical polarimetry** (expected 2012)

***Fermi*-GST**

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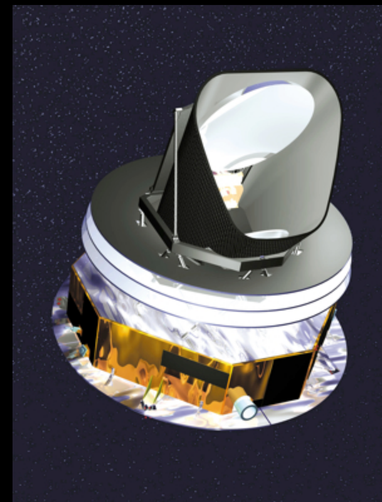
# F-GAMMA:

## multi-frequency monitoring

F-GAMMA PROJECT
Fermi-GST AGN Multi-frequency Monitoring Alliance



### The Planck satellite

- Occasional monitoring of ~20 sources
- 30-857 GHz

J. P. Rachen - Planck WG 6

### KVN 21-m rt

- Monthly monitoring of ~90 sources
- 13 , 7 mm

Bong Won Sohn, Pulun Park, Sang-Sung Lee, Do-Young Byun, Jee Won Lee, Jung Hwan Oh

### 40-m OVRO telescope (Caltech)

- ~1200 blazars at least 2–3 times per week (Richards et al. in prep.)
- 15 GHz

A. C. S. Readhead, V. Pavlidou, J. Richards, W. Max-Moerbeck, T. Pearson

### 70-cm meniscus and 125-cm Ritchey-Chretien telescopes. Abastumani Observatory

- Monthly monitoring of ~90 sources

Omar Kurtanidze, Maria Nikolashvili, Givi Kimeridze, Lorand Sigua, Revaz Chigladze

### 1.3 m Skinakas telescope, Greece

- polarimetry (Expected Spring 2012)

I. Papadakis, Papamastorakis, Caltech, MPIFR

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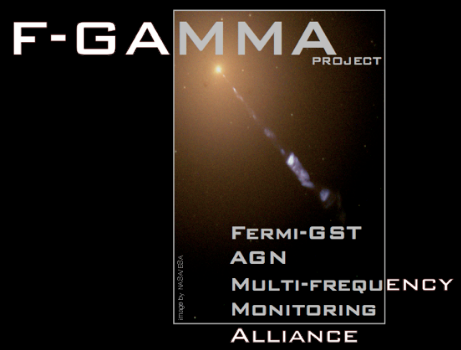
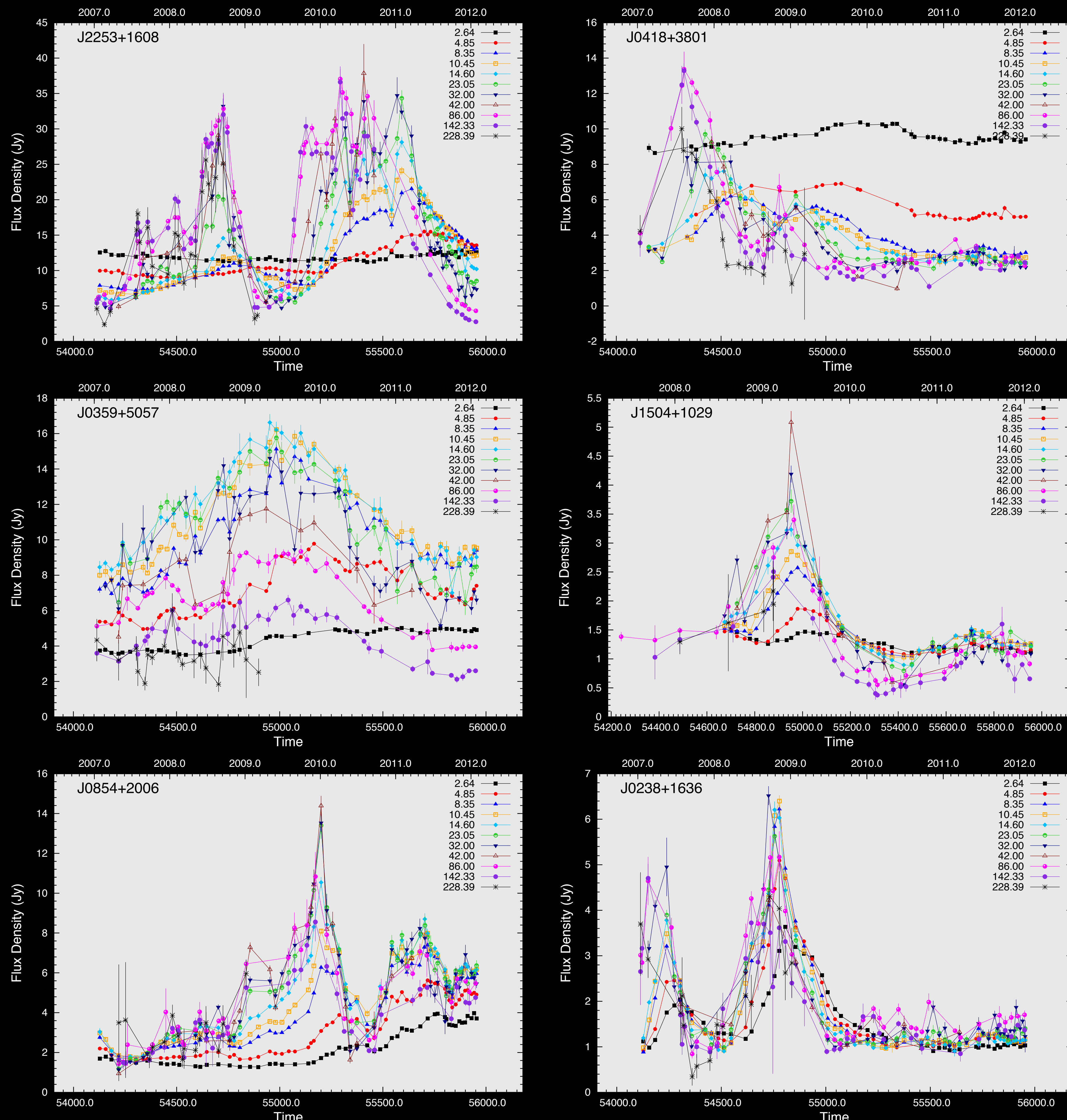
# F-GAMMA:

## multi-frequency monitoring





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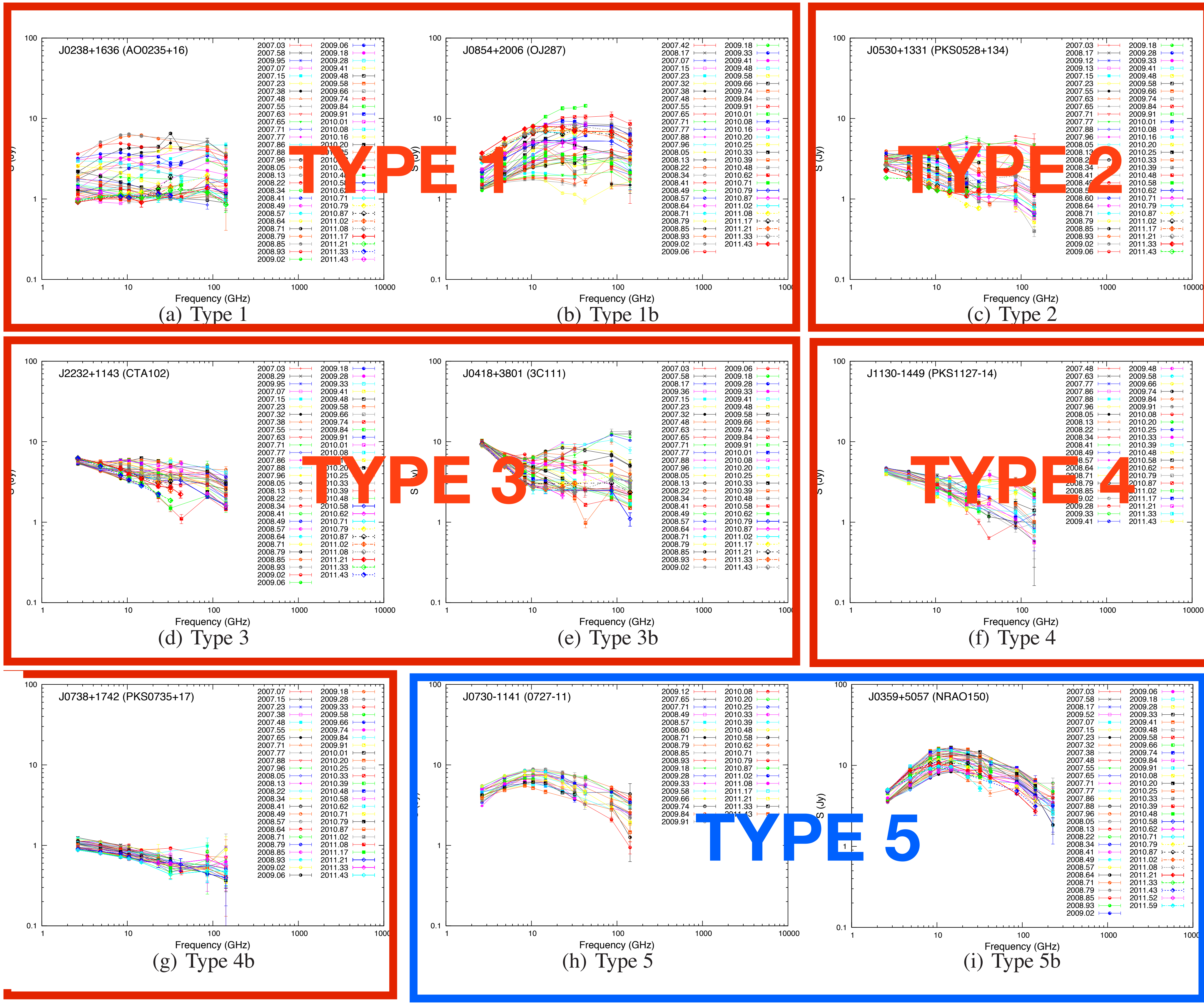
# F-GAMMA spectra:

## Unification of the variability patterns



(a) Type 1
(b) Type 1b
(c) Type 2
(d) Type 3
(e) Type 3b
(f) Type 4
(g) Type 4b
(h) Type 5
(i) Type 5b

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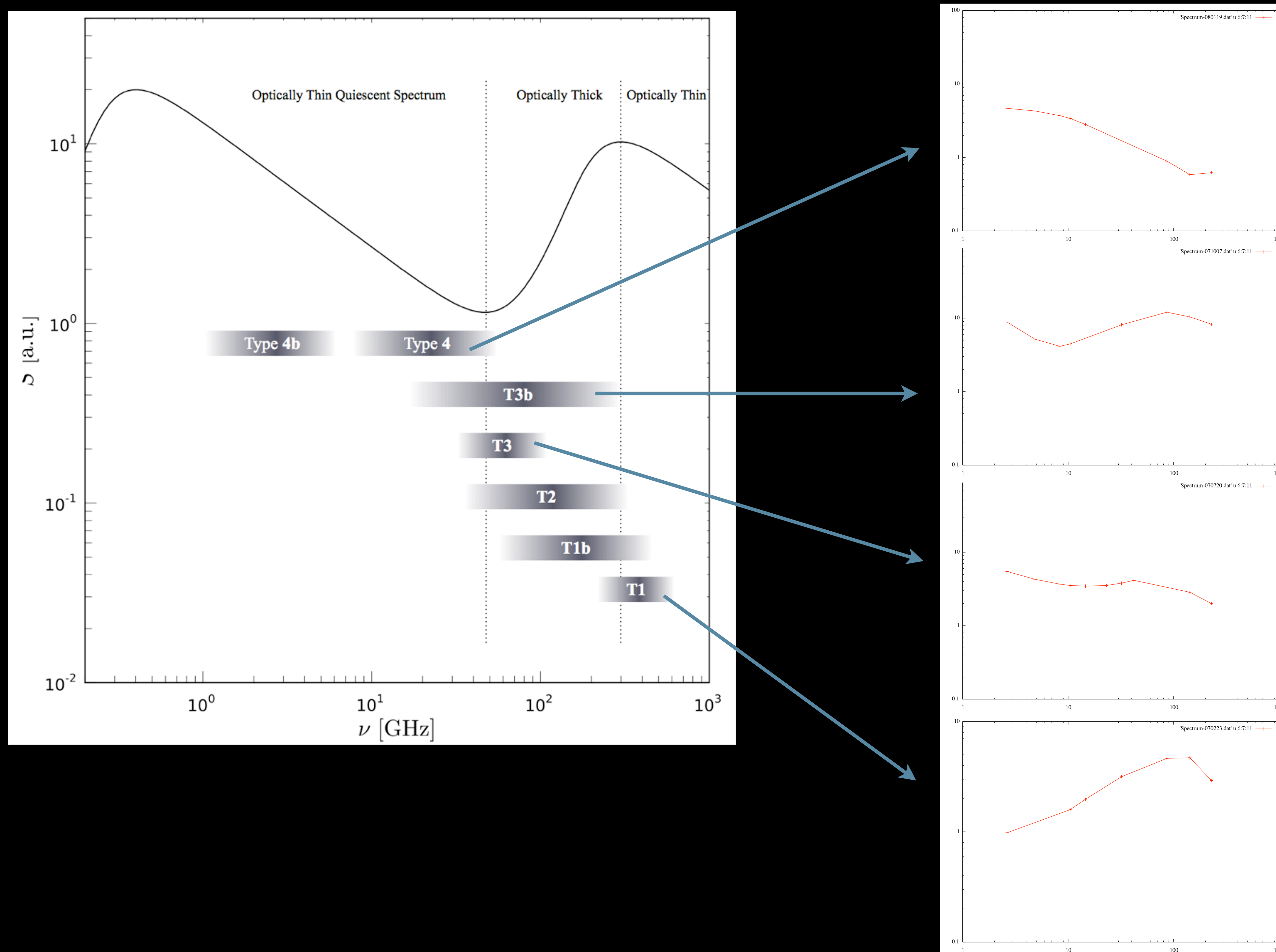
# F-GAMMA spectra:

## physical interpretation of the observed variability patterns




*Angelakis et al. in prep.*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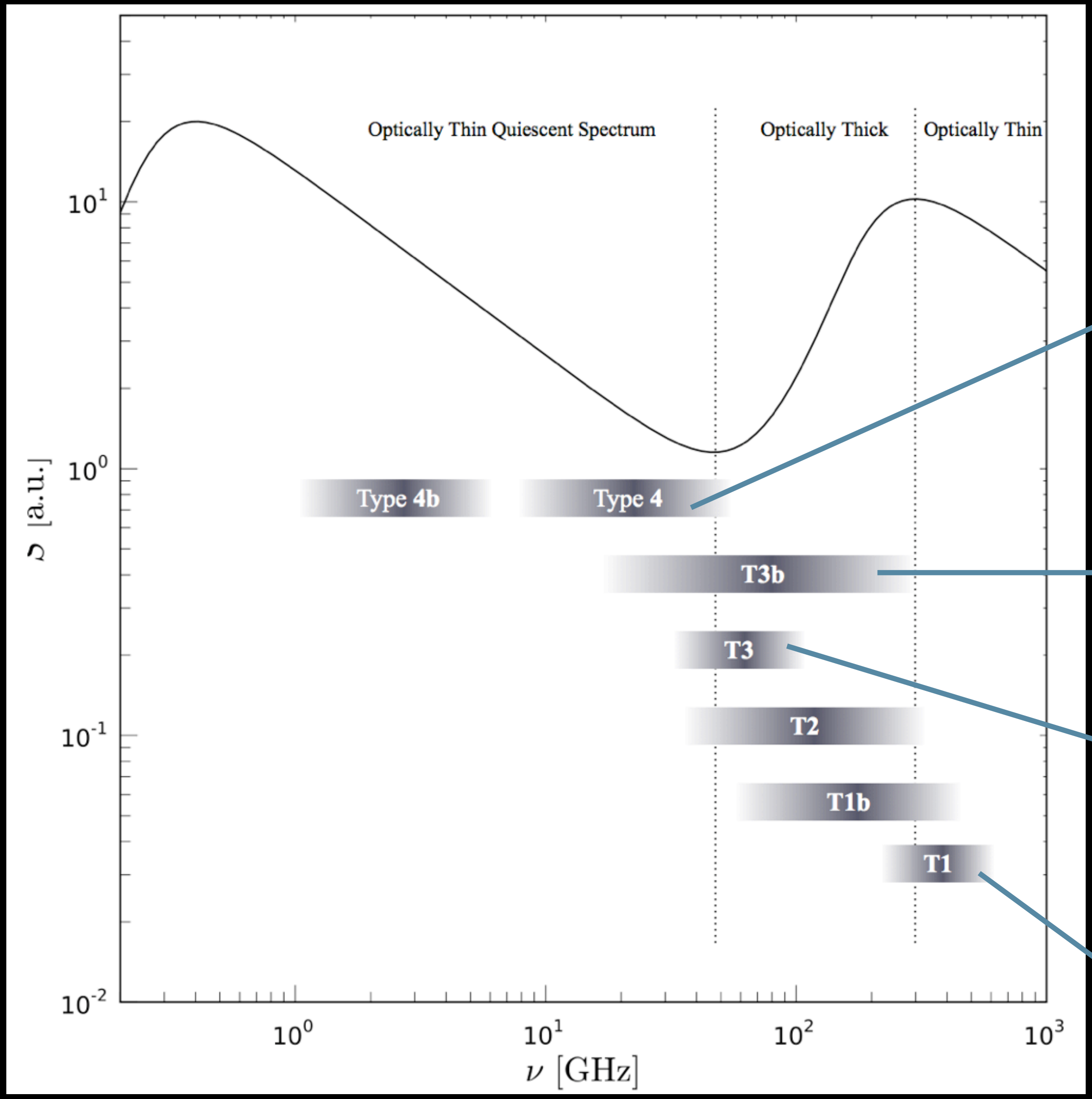


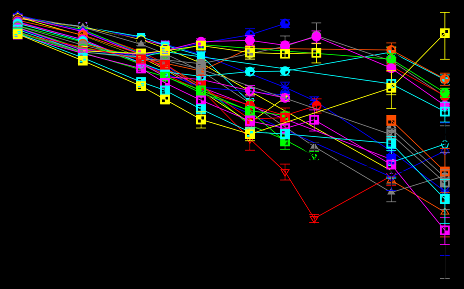

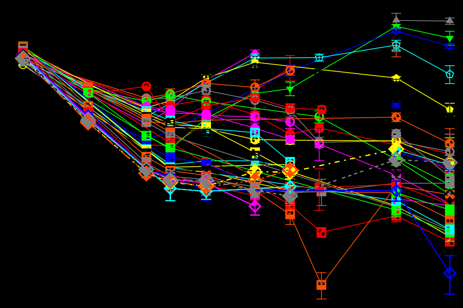

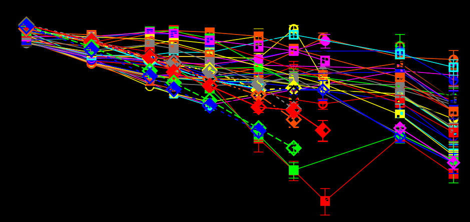

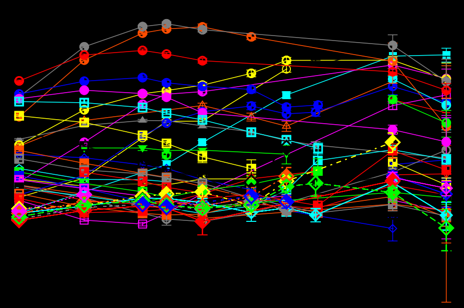

*Angelakis et al. in prep.*


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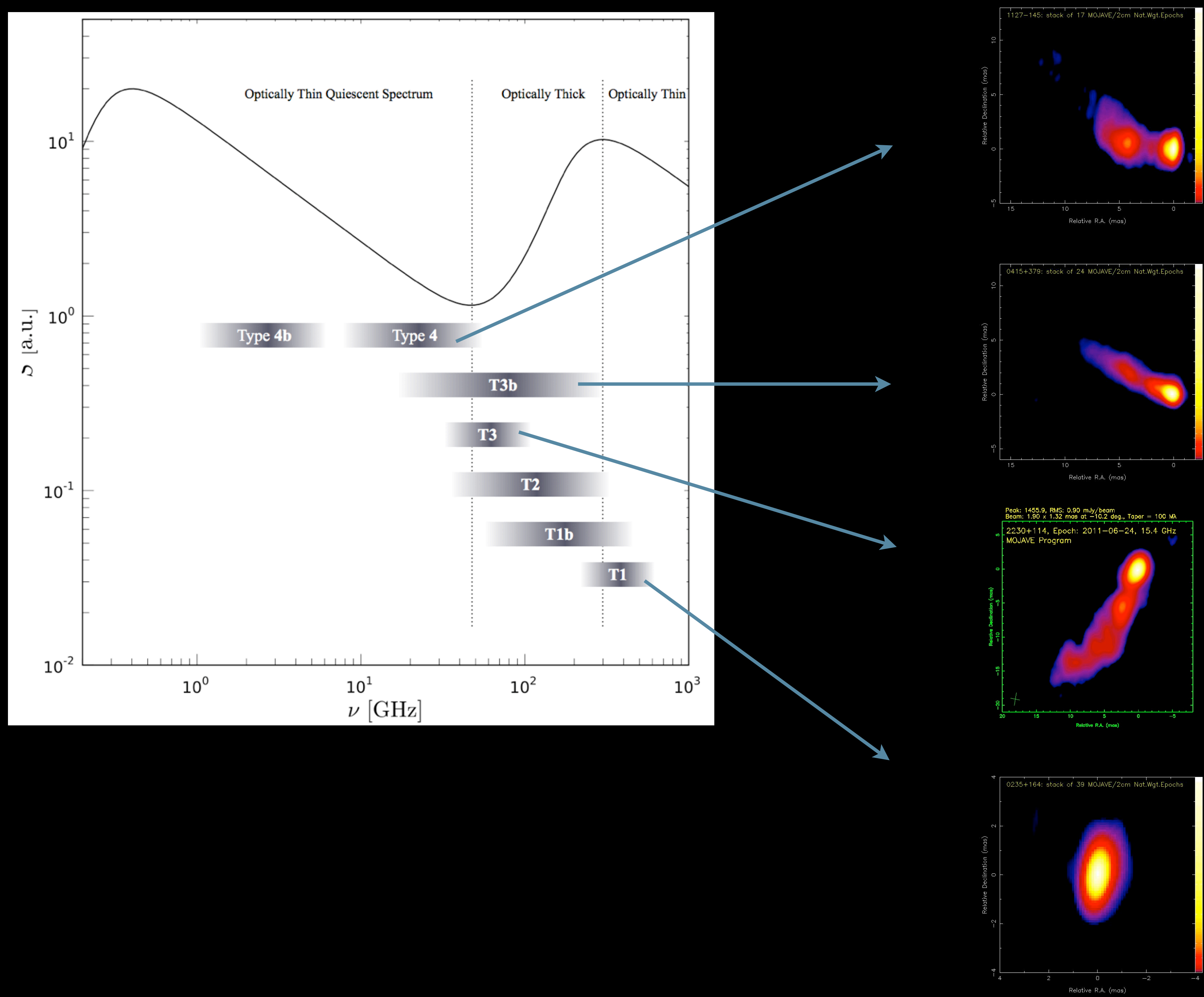
# F-GAMMA spectra:

physical interpretation of the observed variability patterns




*from the MOJAVE 2cm database*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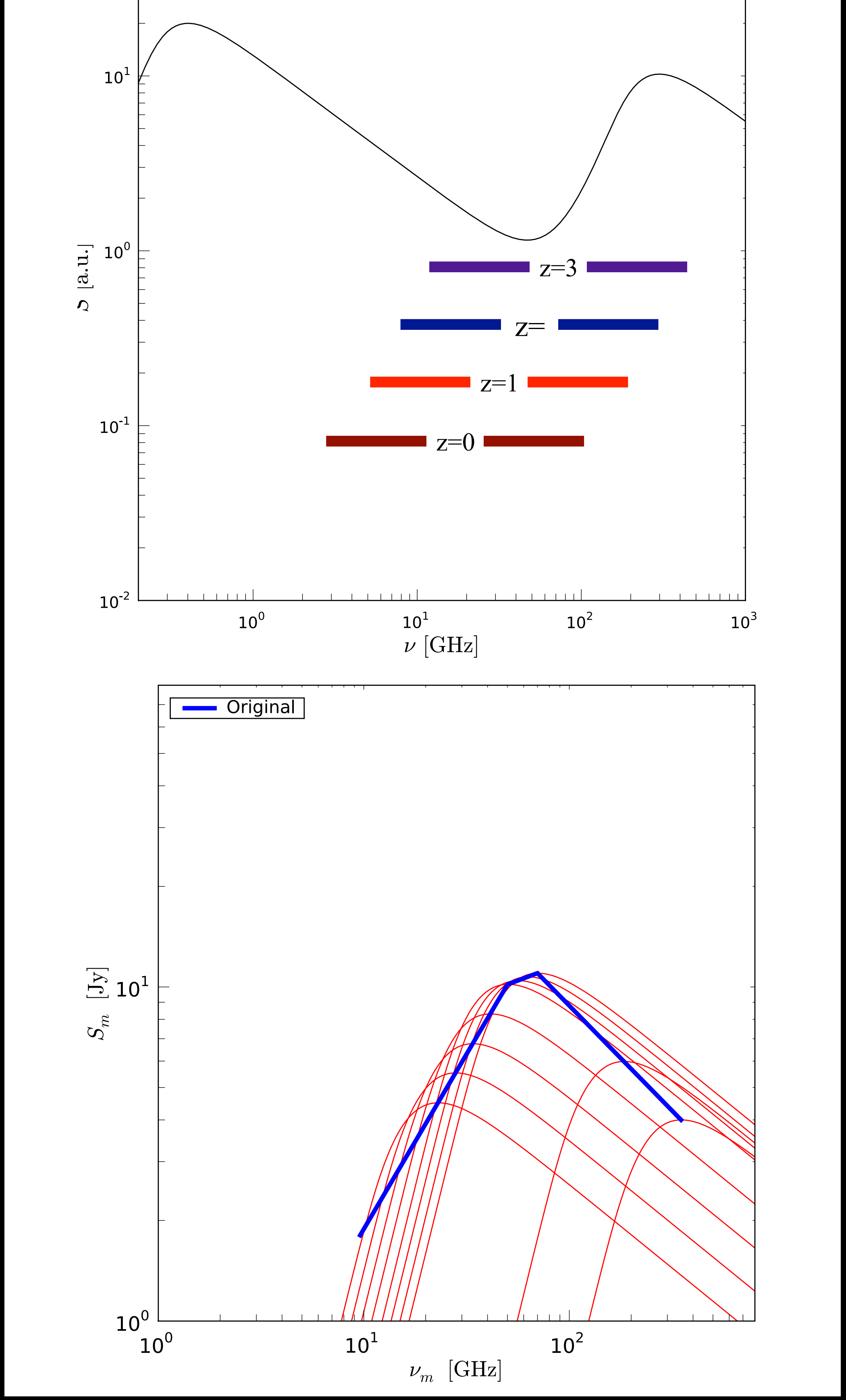
# F-GAMMA spectra:

## reproducing the observed variability pattern

- source redshift
- source intrinsic properties
  - peak frequency of the SSA spectrum
  - outburst excess relative to the quiescence spectrum
  - broadness of the SSA spectrum of the outburst and
  - broadness of the valley
- spectral evolution

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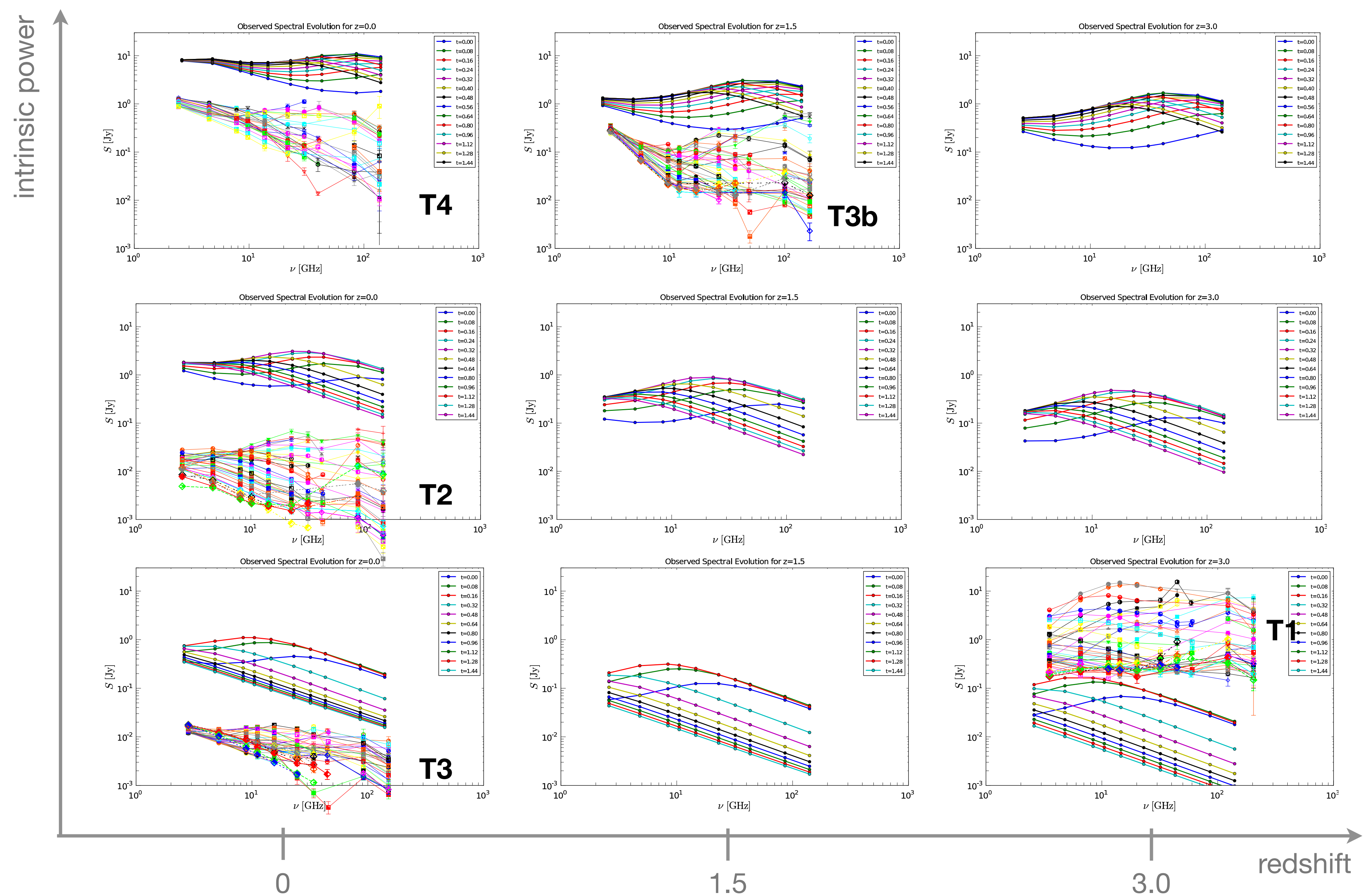
# F-GAMMA spectra:

## reproducing the observed variability pattern




*Angelakis et al. in prep.*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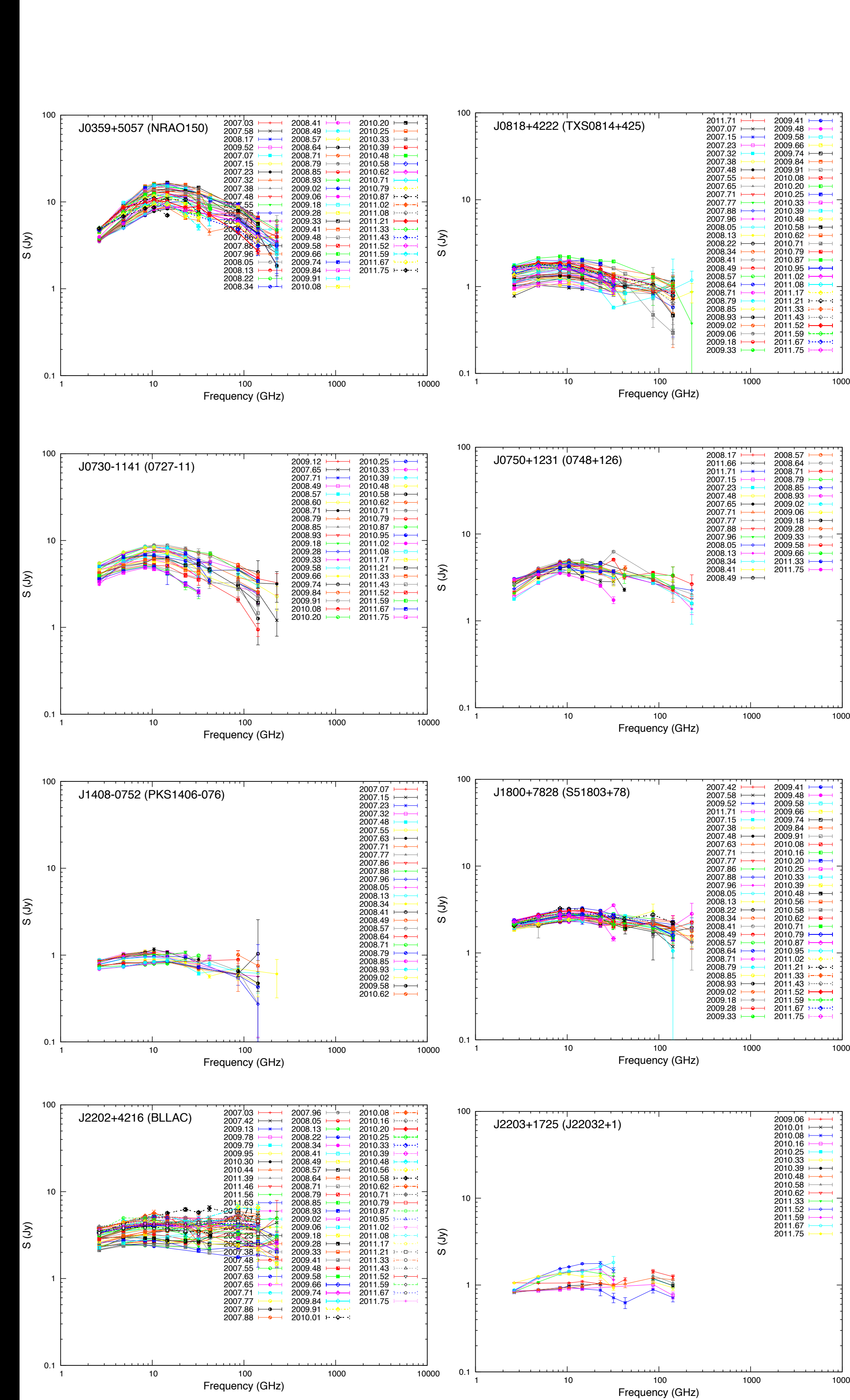
# F-GAMMA spectra:

## Achromatic variability

- spectrum changing self-similarly with possibly a mild shift of the peak towards low frequencies as the flux increases
  - geometry?
  - changes in the B topology?
  - changes in D?
  - opacity effects?




*Angelakis et al. in prep.*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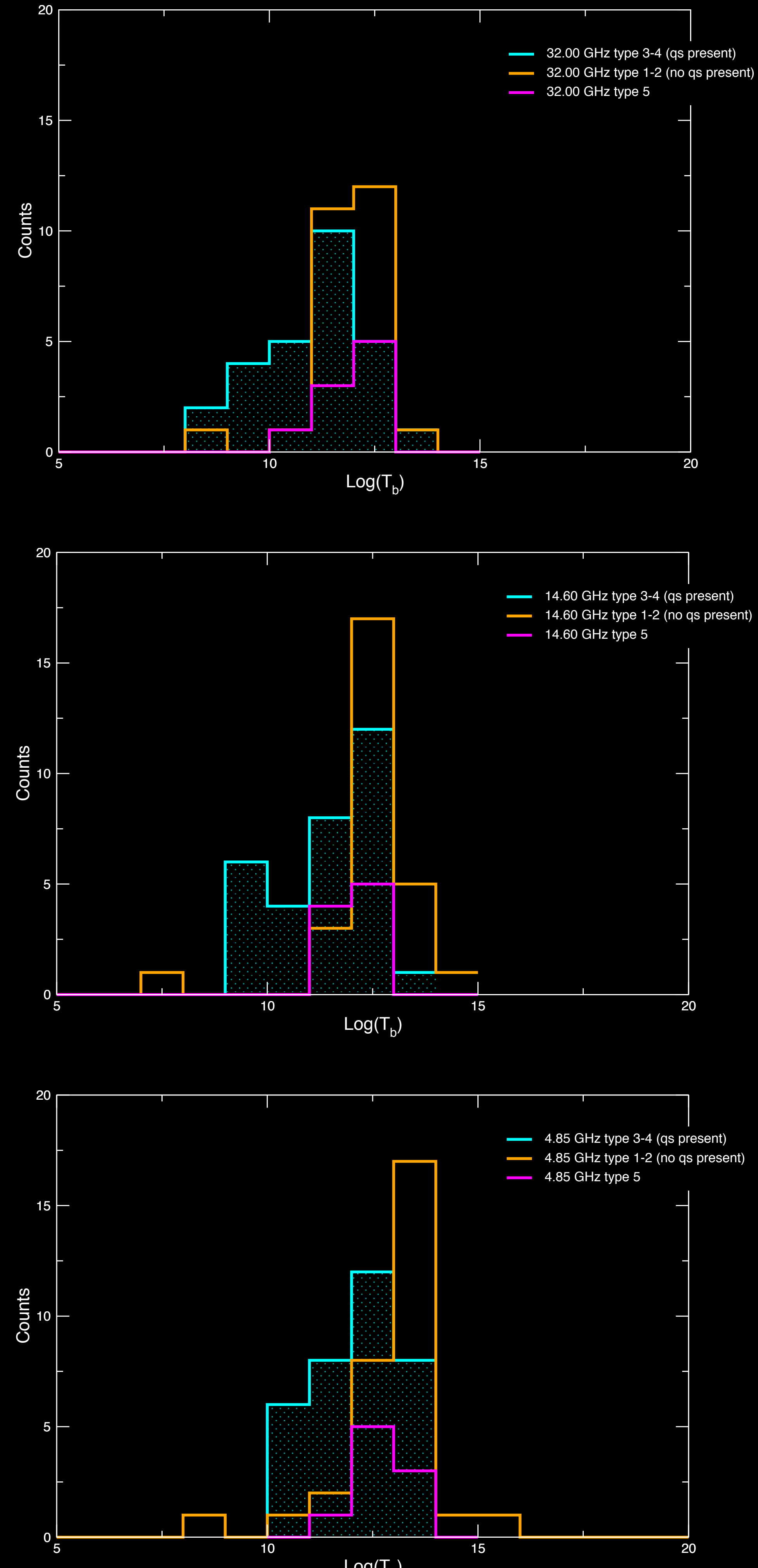
# F-GAMMA spectra:

## variability brightness temperature




$$T_{\mathrm{b}} = 4.5 \times 10^{10} \cdot \delta S \cdot \left( \frac{\lambda \cdot D_{\mathrm{l}}}{\delta t \cdot (1+z)^2} \right)^2$$

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# F-GAMMA spectra: Conclusions

- **only two** mechanisms produce variability:
  - achromatic variability
  - spectral evolution dominated: Marscher & Gear model can reproduce the observations for a large area parameter space
- no type switch observed, suggesting:
  - mechanism is a source fingerprint
  - mechanism is determined by source intrinsic properties that stay invariant or change with pace slower than we can sample
- unclear mechanism producing achromatic variability
- our toy model provides a tool to calculate the evolution of physical parameters
- spectral monitoring is probing smallest spatial scales (uniform clouds of emitting particles)

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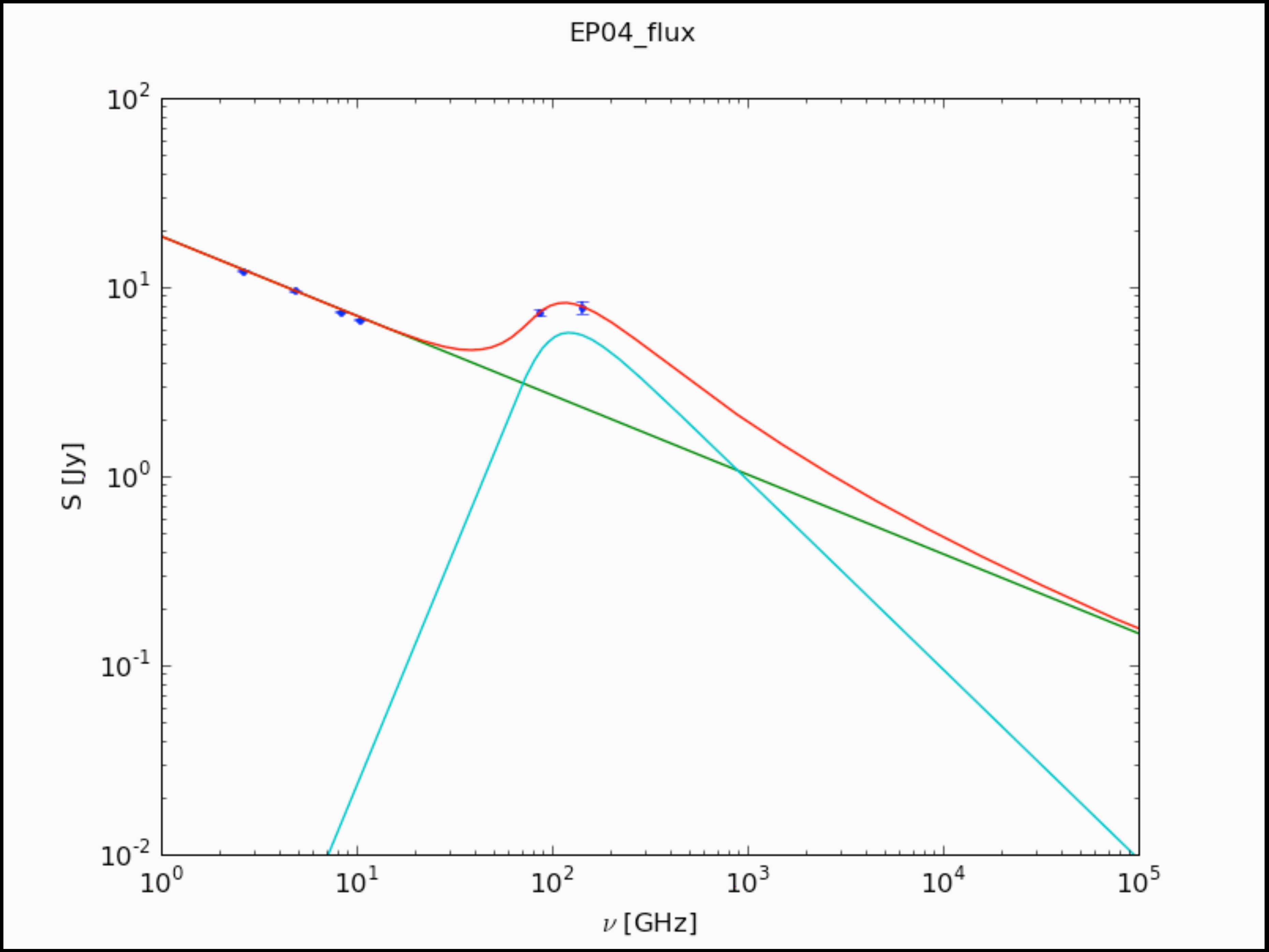
# F-GAMMA spectra:

## Spectral Decomposition




3C454.3

*Schmidt et al. in prep.*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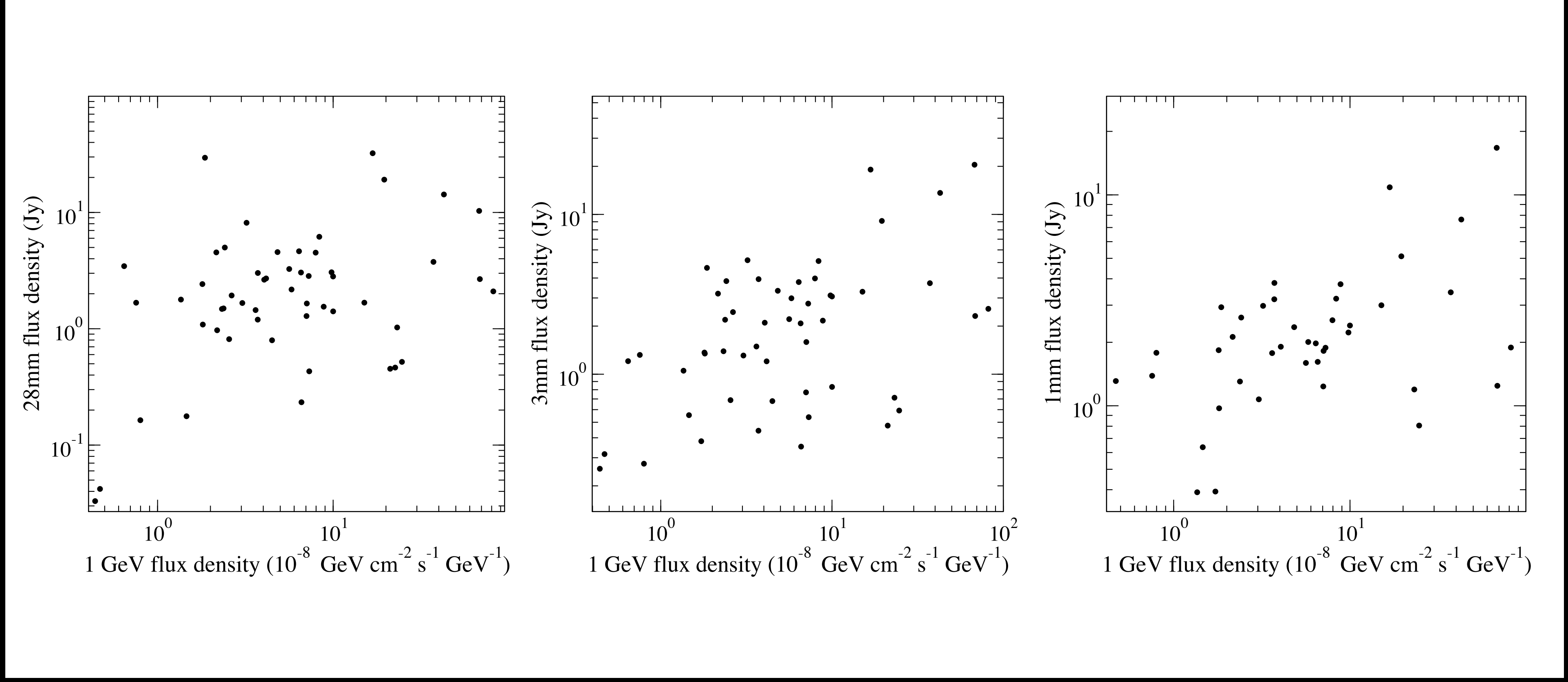
# F-GAMMA spectra:

## Search for bias-fee $S_{radio}$ - $S_{gamma}$ correlations




*Fuhrmann, Angelakis et al. in prep.*
*Pavlidou et al. submitted.*

- data concurrent with measurements of γ-ray fluxes
- concurrently measure a radio spectral index
- flux densities at wavelengths ≤ 7 mm correlate with 1 GeV fluxes at a significance always better than 2 sigma => γ-ray emission very close to the mm-band emission region
- longer wavelengths do not show significant correlations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# NLSy1s:
## Generalities


- in spiral galaxies
- appear to accrete with high Eddington ratios having low black-hole masses (e.g. *Grupe & Mathur, 2004*)
- typically RQ (*Komossa, S., et al. 2006, AJ, 132, 531*)

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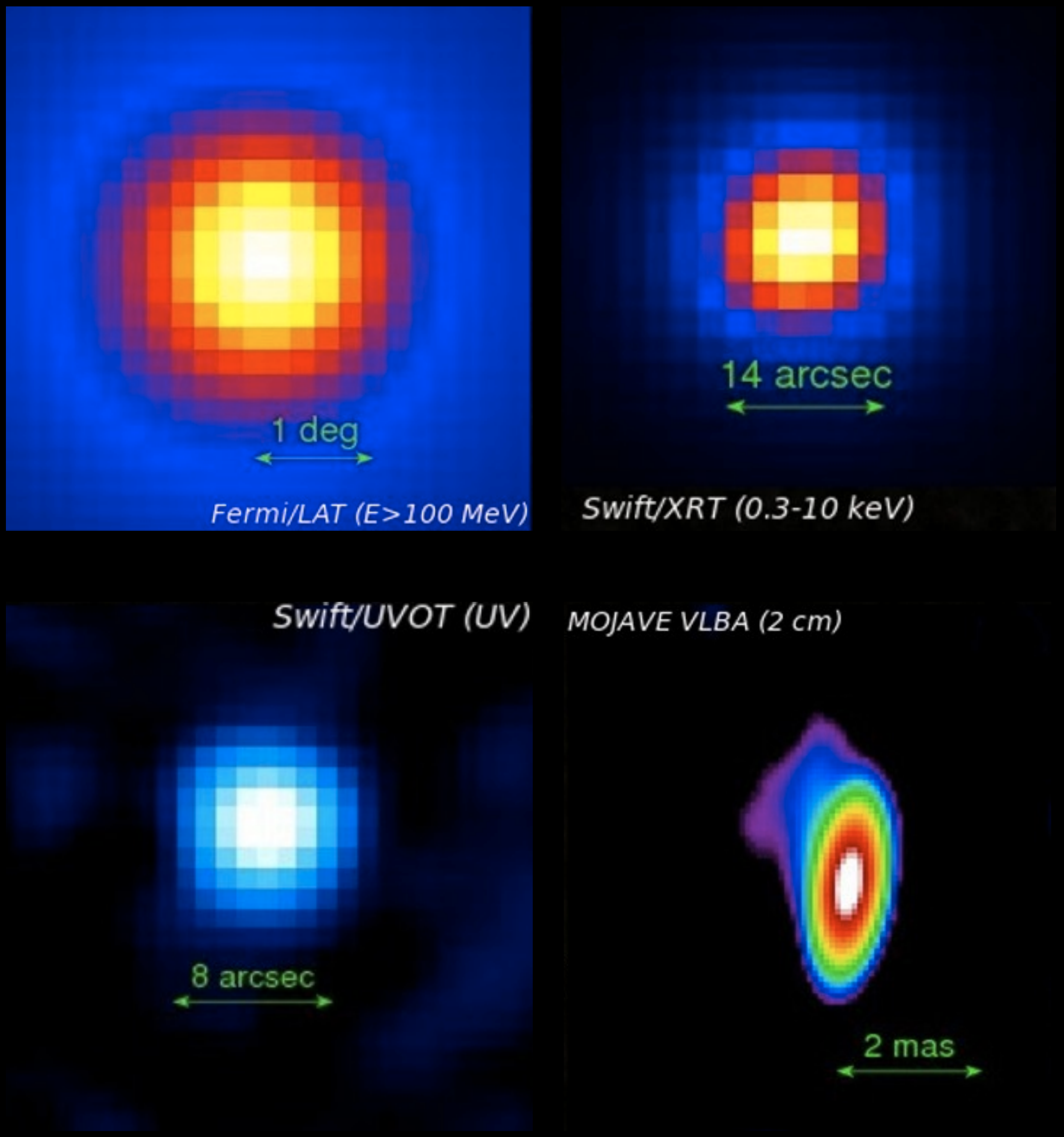
# NLSy1s:
## *Fermi* LAT detection

- *Fermi*/LAT detects 4 radio loud NLSy1 galaxies in the first year (7 in 30 months):
  - 1H0323+342 (z = 0.061)
  - PMNJ0948+0022 (z = 0.585)
  - PKS1502+036 (z = 0.409)
  - PKS2004-447 (z = 0.24)

  (*Abdo et al. 2009*)




*PMNJ0948+0022 for the July 2010 outburst*
*Foschini et al. 2010 (image compilation by L. Foschini)*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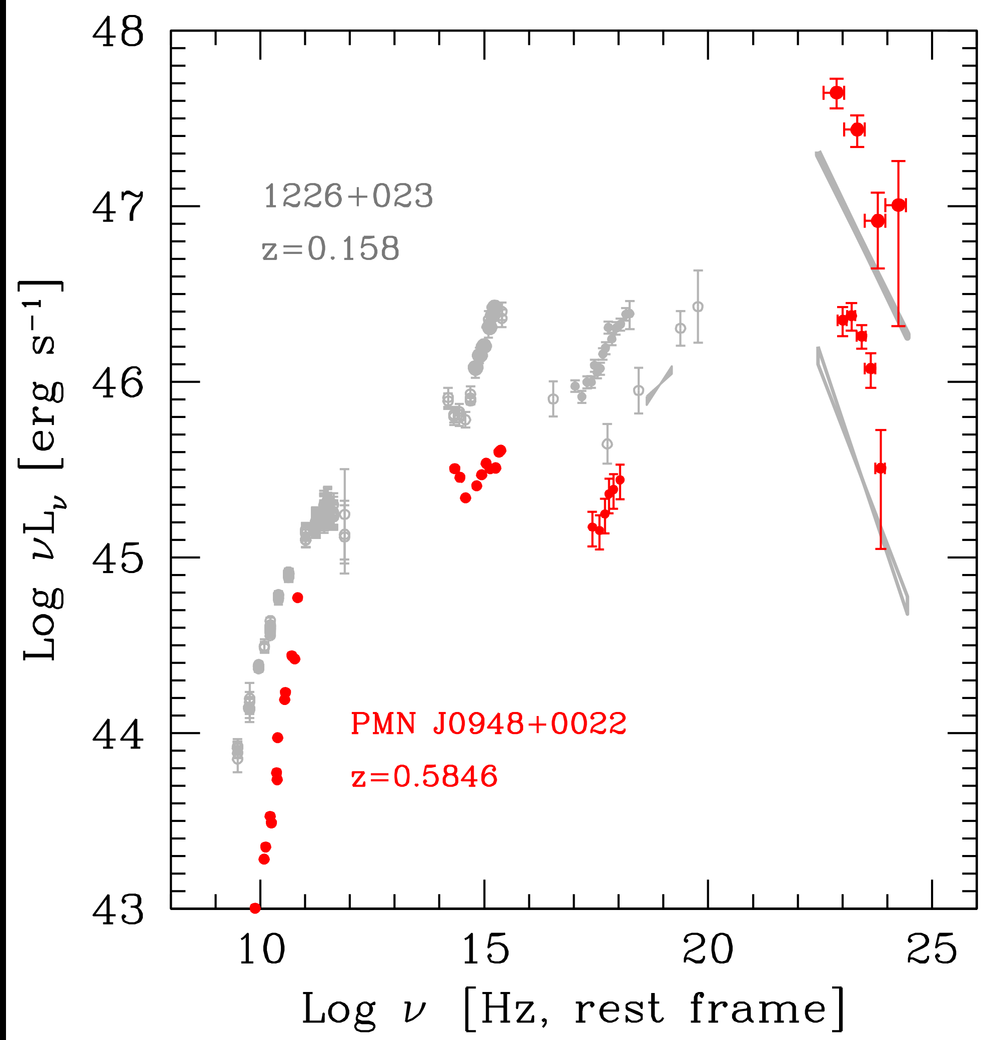
# NLSy1s: *J0948+0022*

- L$\gamma$ ~ $10^{48}$ erg $s^{-1}$ at 0.1–100 GeV (first time that such a power is measured from a NLS1)

- confirms, that NLS1s can host relativistic jets as powerful as those in blazars and radio galaxies, despite the relatively low mass ($1.5 \times 10^{8}$ M⊙)




*Foschini et al. 2010*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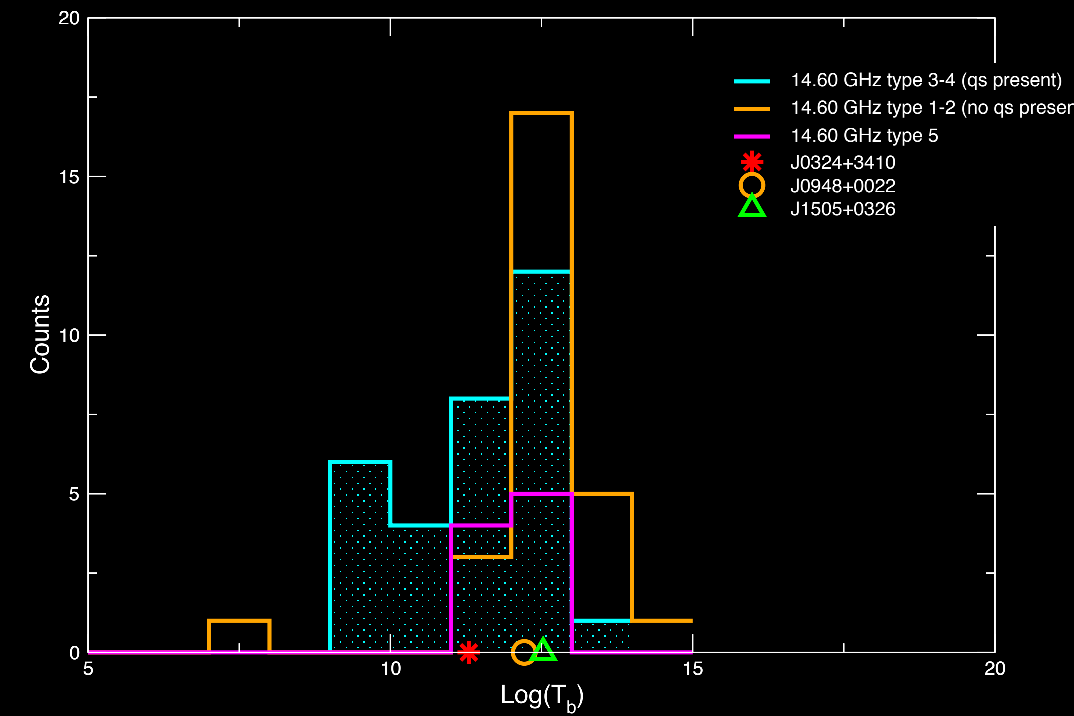
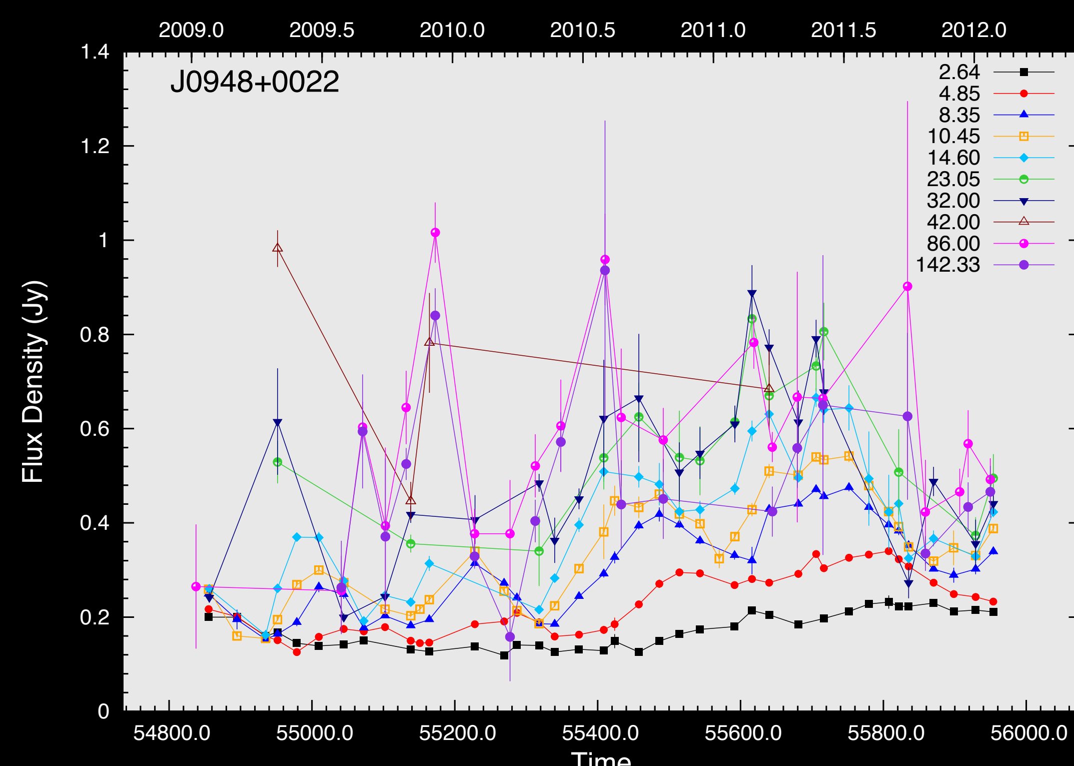
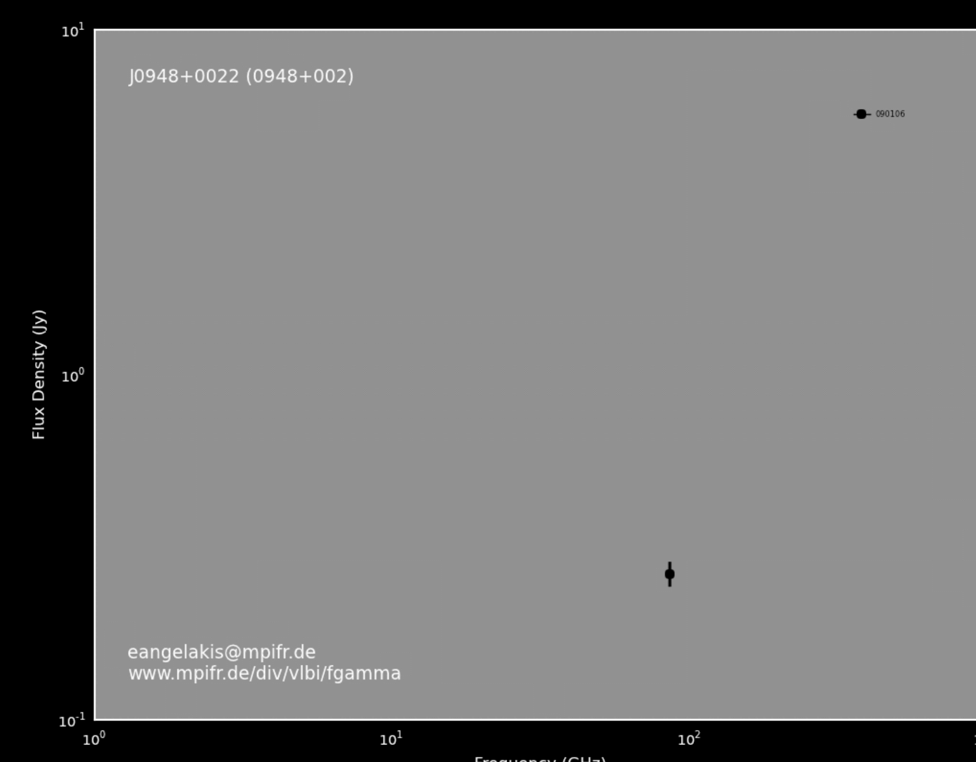
# NLSy1s:
*J0948+0022*

- blazar-like, relativistic-jet-like behavior, rapid spectral variability (weeks to month)!
- intense spectral evolution present
- SF analysis:

**15 GHz:** $\mathrm{Log}(T_B) \sim 1.6 \cdot 10^{12} \Longrightarrow \delta \sim 4$

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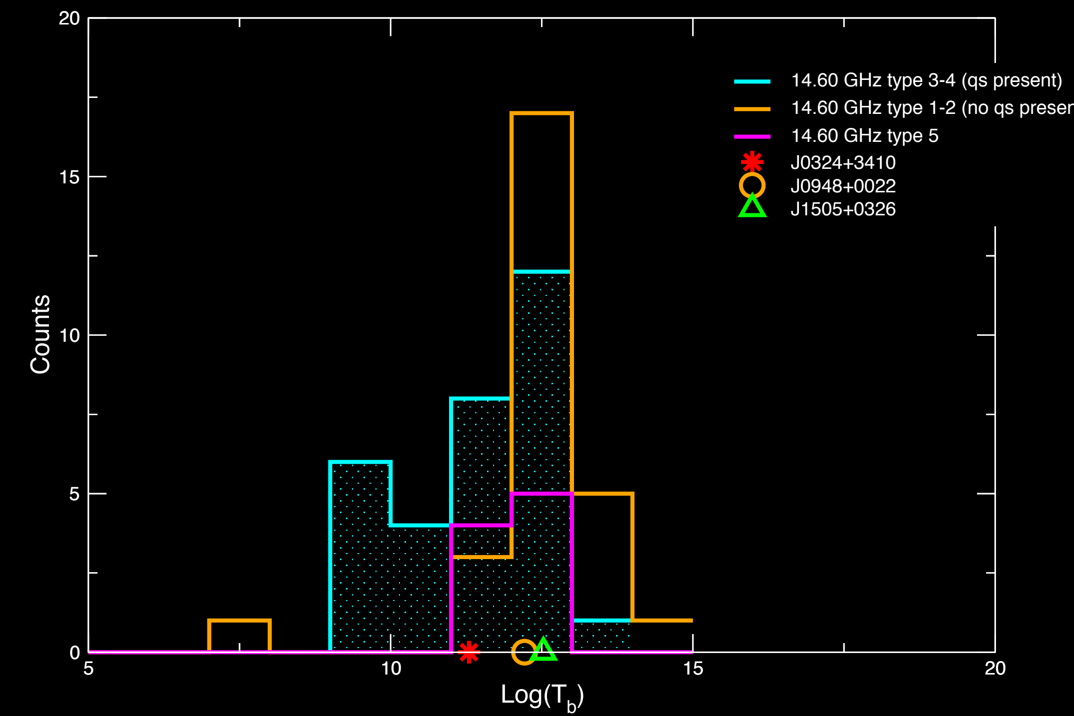
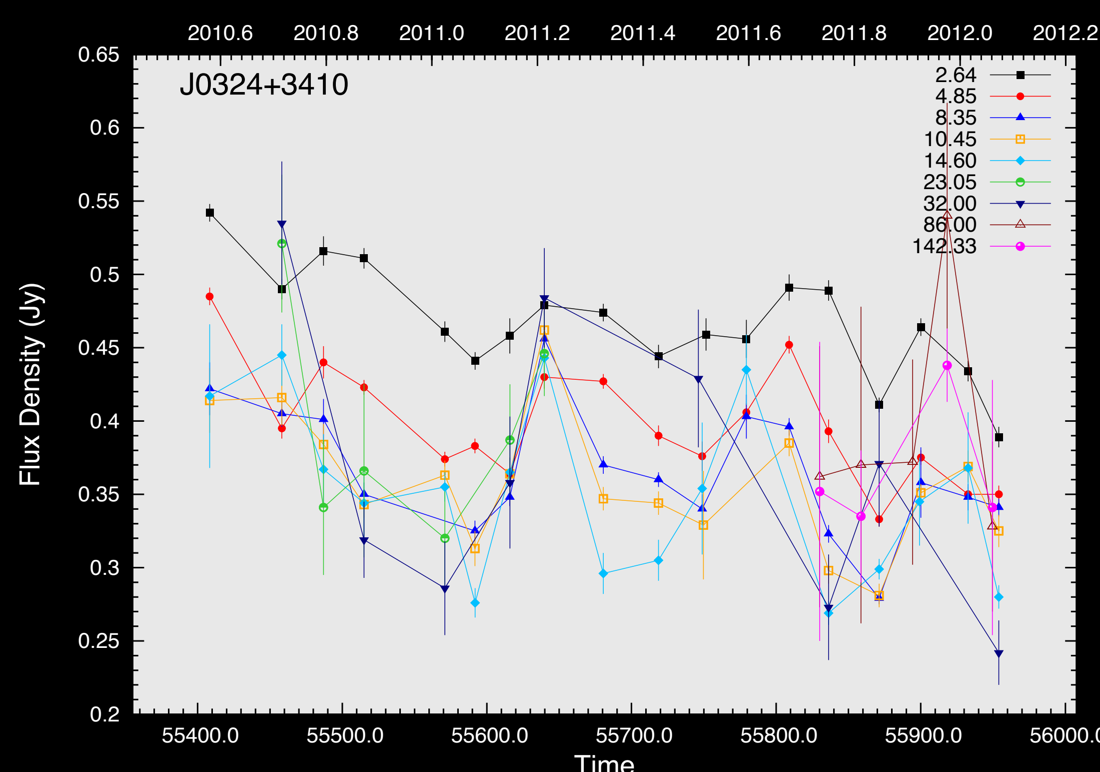
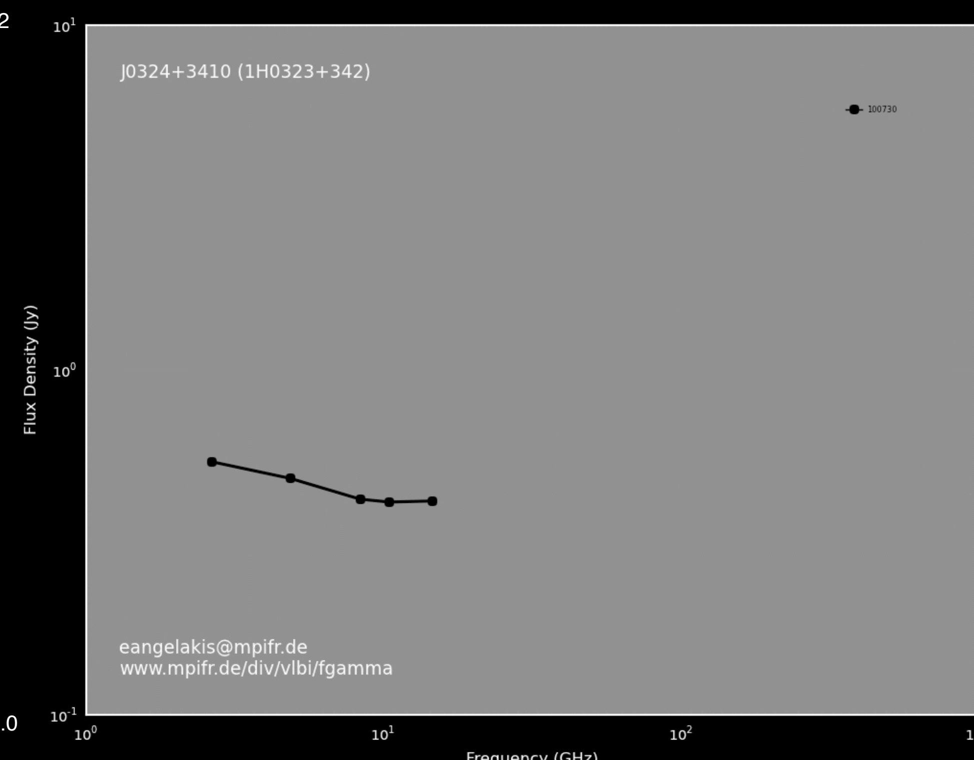
# NLSy1s:
## *J0324+3410*

- blazar-like, relativistic-jet-like
- intense spectral evolution present
- rapid spectral variability
- SF analysis:




**15 GHz:** $\mathrm{Log}(T_B) \sim 2 \cdot 10^{11} \Longrightarrow \delta \sim 2$





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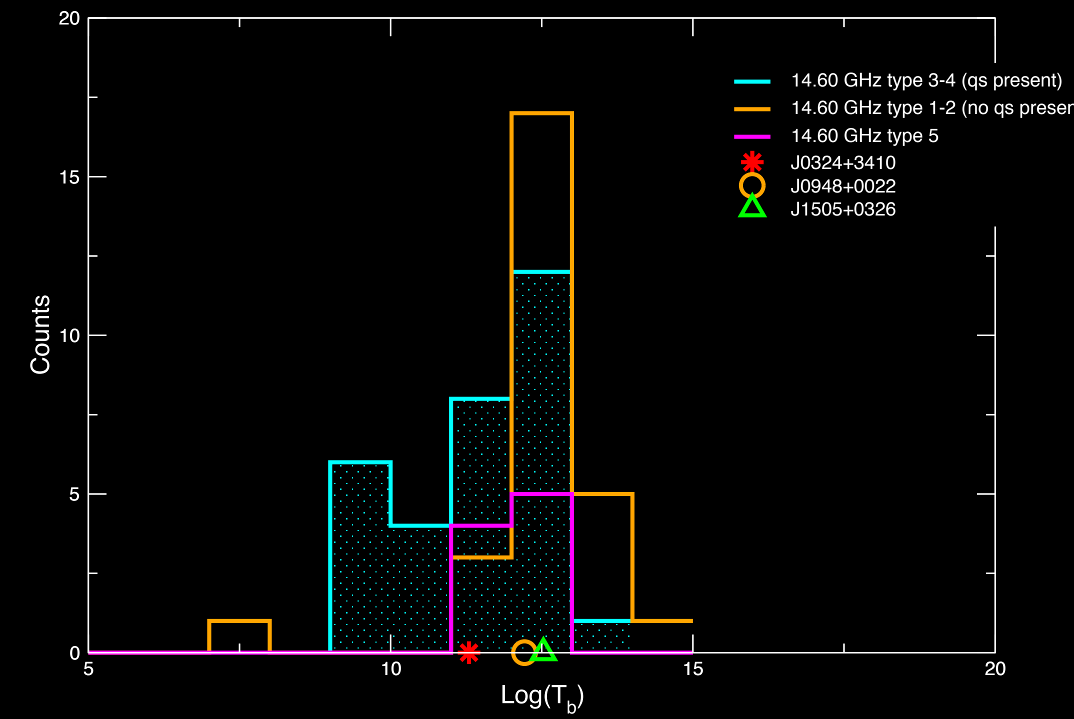
# NLSy1s:

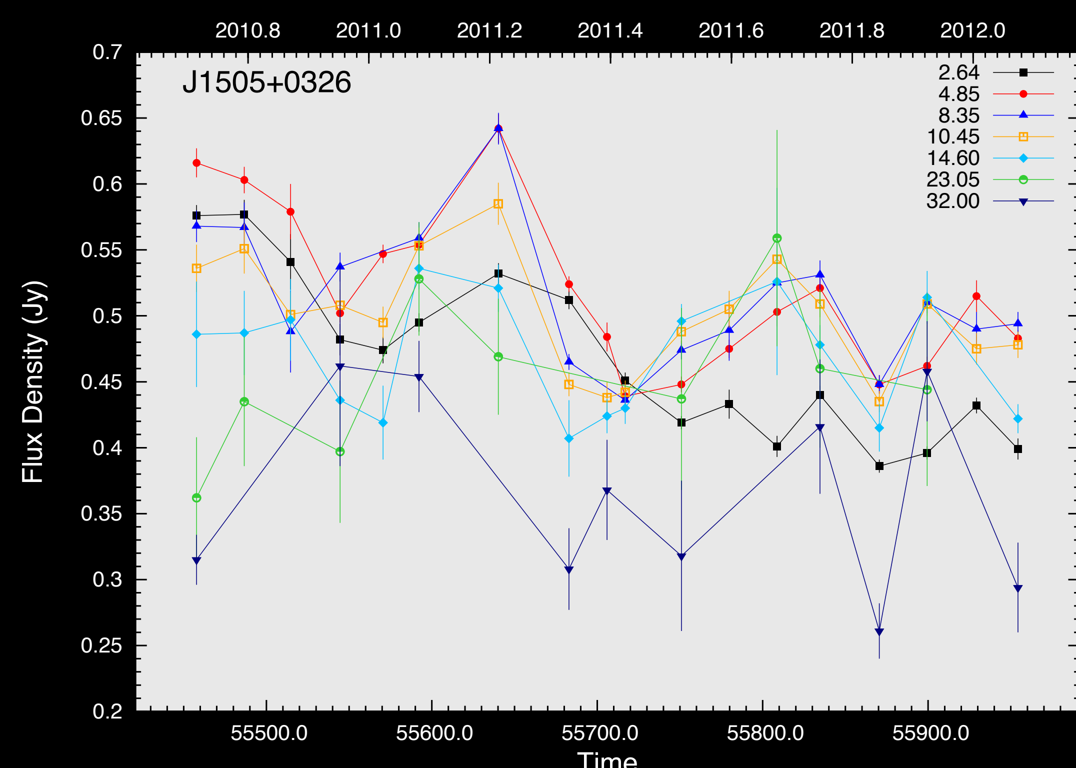
*J1505+0326*

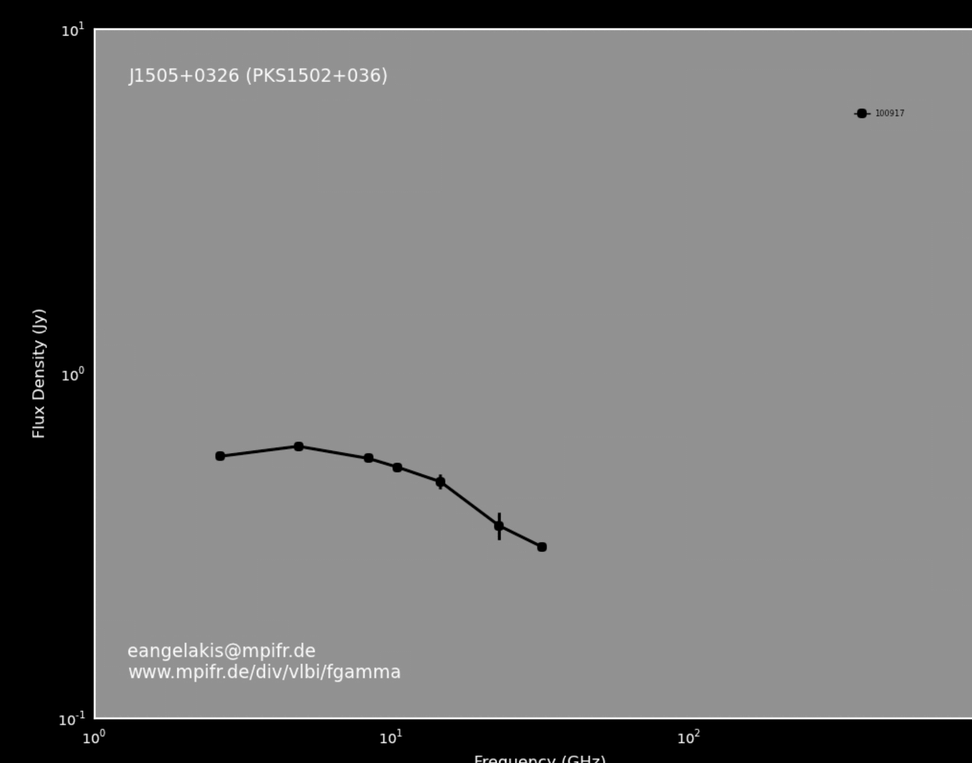
- similarly, blazar-like, relativistic-jet-like, intense spectral evolution present, rapid spectral variability

- SF analysis:

**15 GHz:** $\mathrm{Log}(T_B) \sim 3 \cdot 10^{12} \Longrightarrow \delta \sim 4$

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# F-GAMMA spectra:
## Conclusions

- blazar-like behavior indicative of the presence of  a jet
- particularly fast variability at radio bands (couple of weeks)
- intense spectral evolution: with peculiar characteristics (e.g. very inverted or very steep spectra)
- J0324 shows a rather small D while J0948 and J1505 larger ones

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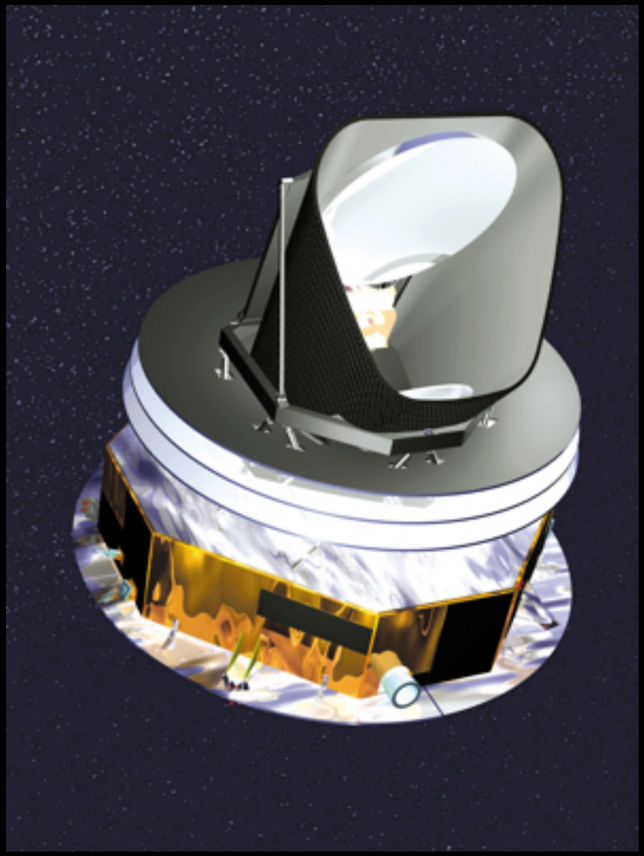
# F-GAMMA spectra:

## F-GAMMA - Planck synergy

**P.I. : J. Rachen** + F-GAMMA team

- *Observation of north ecliptic pole blazars:*
  - **Goal:** study different blazar variability models and **distinguish between flare** and **galactic contribution**
  - **Observations:** Effelsberg since October 2010, at 2.6 - 32 GHz and Planck 30-857 GHz. Sampling: 1-3 months, 2-6 weeks (since April 2011). Planck: sampling daily in at least one frequency.
  - **Objects:** 1642+690, 1749+701, 1807+649 (3C371), 1849+670, 1928+738



The Planck satellite

- Occasional monitoring of ~20 sources
- 30-857 GHz

J. P. Rachen et al.

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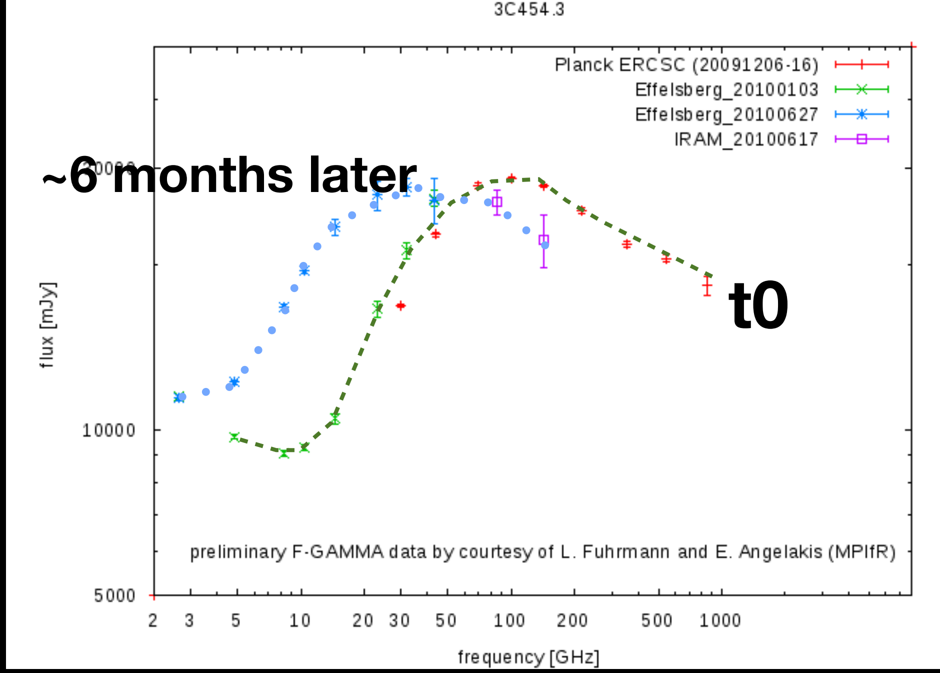
# F-GAMMA spectra:

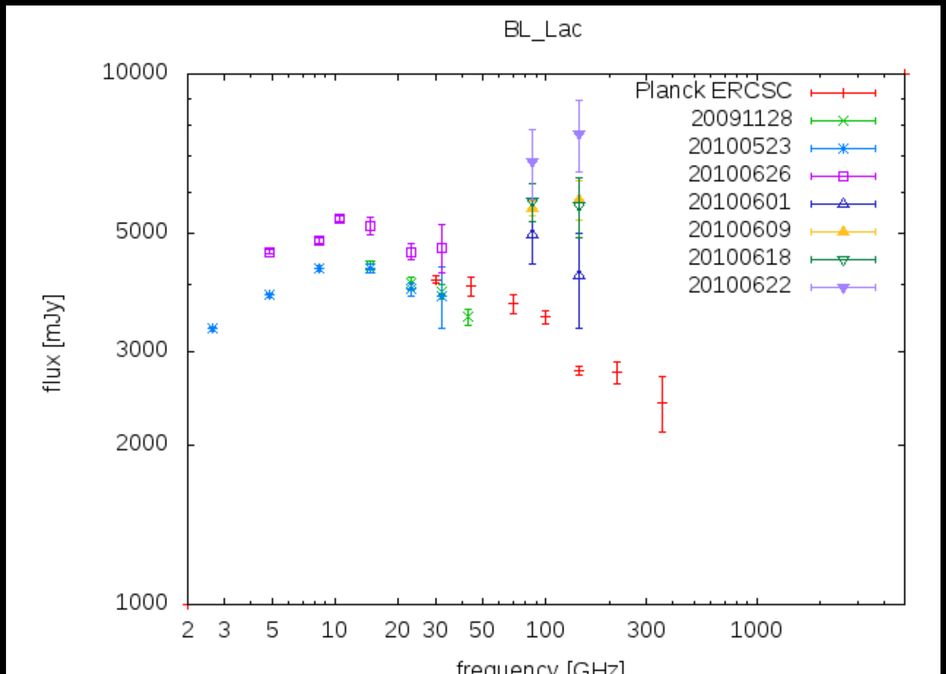
## F-GAMMA - Planck synergy

**P.I. : J. Rachen** + F-GAMMA team

- *Observations of a complete sample of high-frequency flat spectrum blazars:*
  - **Goal:** study different blazar variability models - precisely determine the peak turnover => B
  - **Observations:** Effelsberg, sampling 2 weeks (April 2011 - Feb. 2012). Sources within +-2months of Planck scan.
  - **Objects:** 32 blazars, complete sample, selected from the ERCSC data









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# Thank you!

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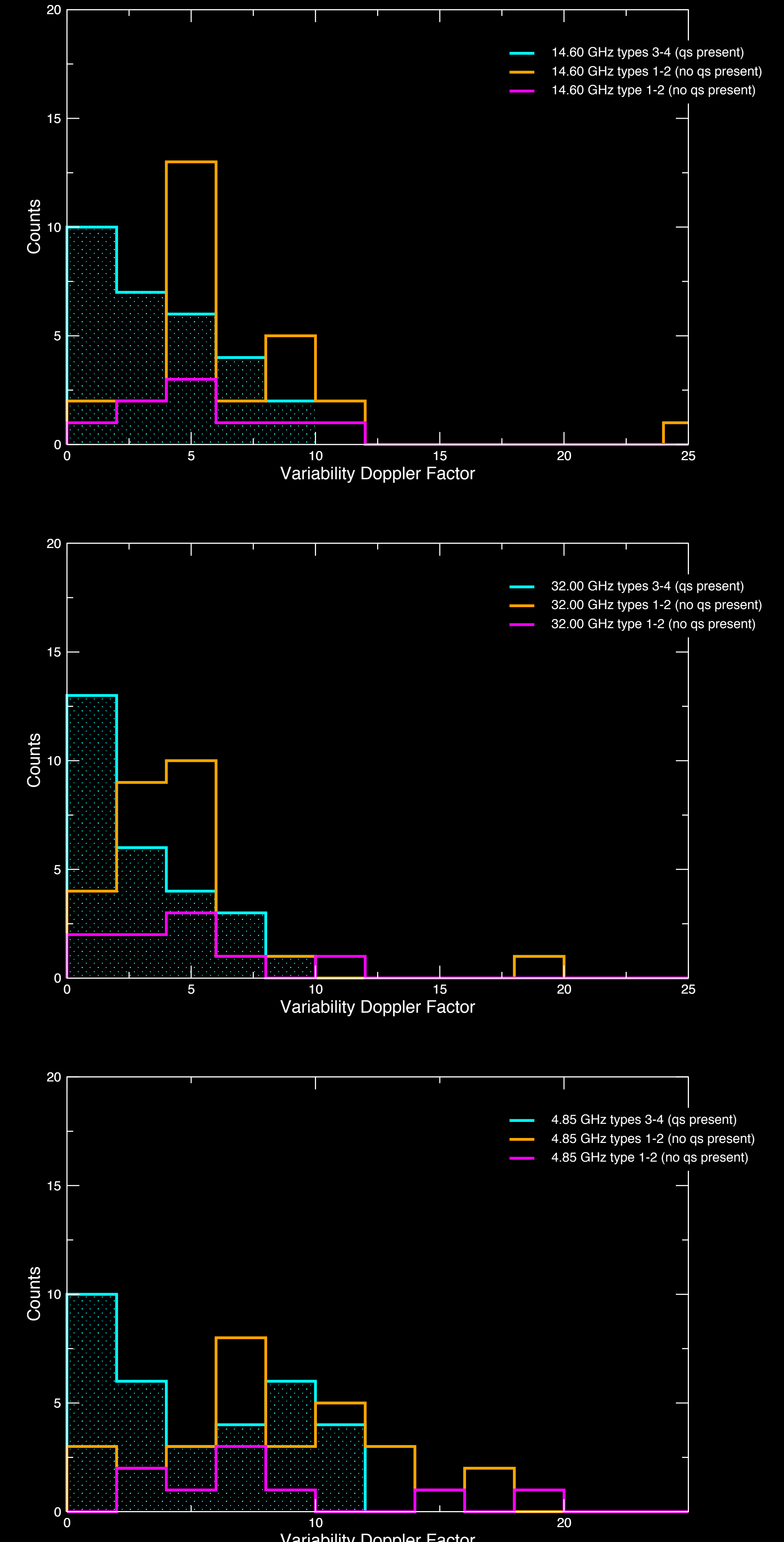
# F-GAMMA spectra:

## variability Doppler factors

$$D = (1+z) \cdot \left( \frac{T_{\mathrm{b}}}{5 \cdot 10^{10}} \right)^{\frac{1}{3+\alpha}}$$

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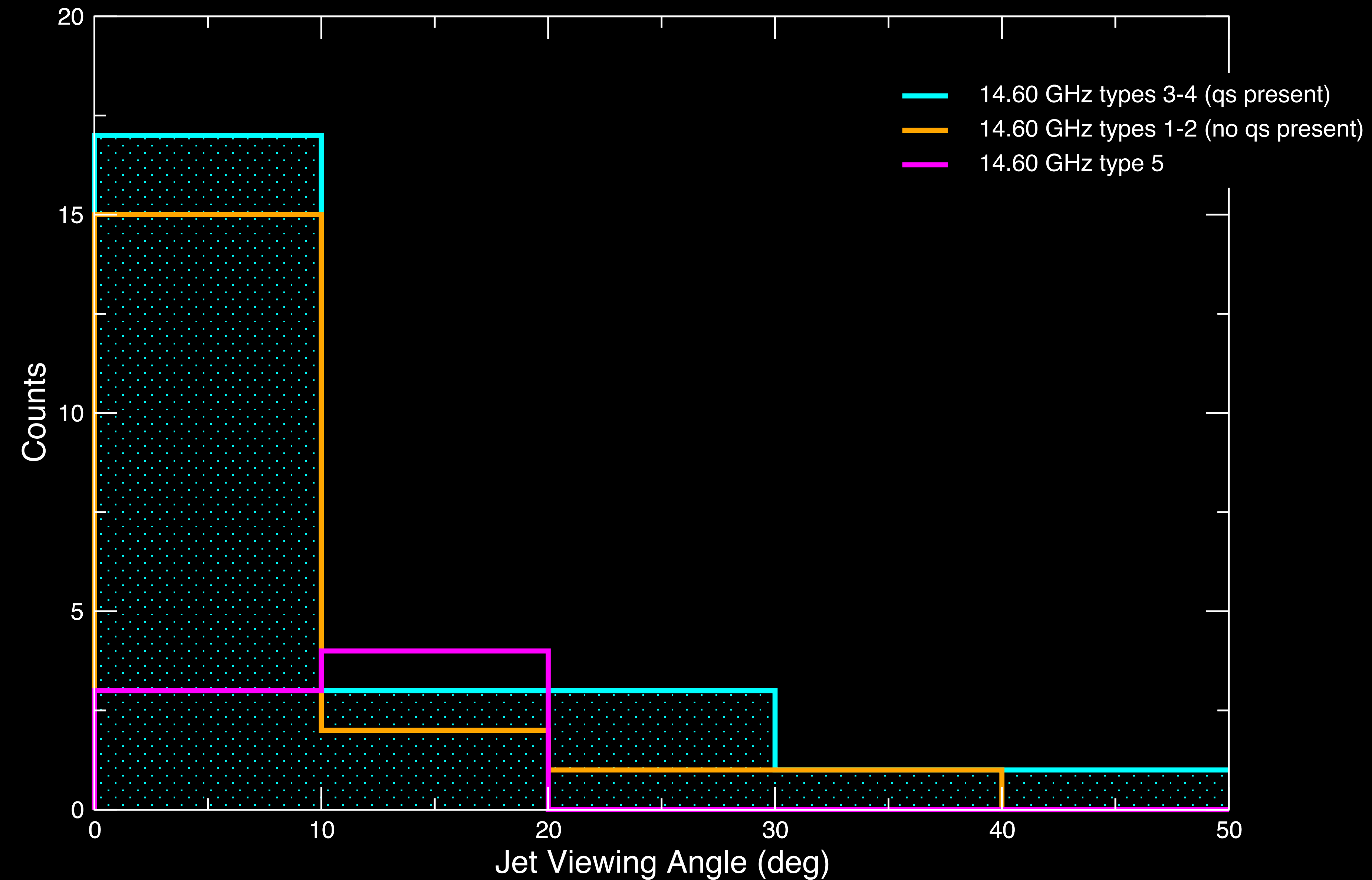
# F-GAMMA spectra:
## Viewing angles

$$\theta_{\mathrm{var}} = \arctan \frac{2\beta_{\mathrm{app}}}{\beta_{\mathrm{app}}^2 + D_{\mathrm{var}}^2 - 1}$$

$$\Gamma_{\mathrm{var}} = \frac{\beta_{\mathrm{app}}^2 + D_{\mathrm{var}}^2 + 1}{2D_{\mathrm{var}}}$$

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Active Galactic Nuclei:

Variability Mechanisms

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- shock-in-jet model: *Marscher & Gear, 1985*
  - changes in injection rate of relativistic electrons and/or magnetic field or in Γ:
    - → formation of shock waves
    - → variability of observed spectrum
  - relativistic shock propagates outwards along the jet:
    - → jet plasma expands adiabatically
    - → electrons are accelerated
    - → magnetic field is amplified via adiabatic compression
- internal shock model *Spada et al., 2001*
- geometrical models *Camenzind et al., 1992*

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## Achromatic variability

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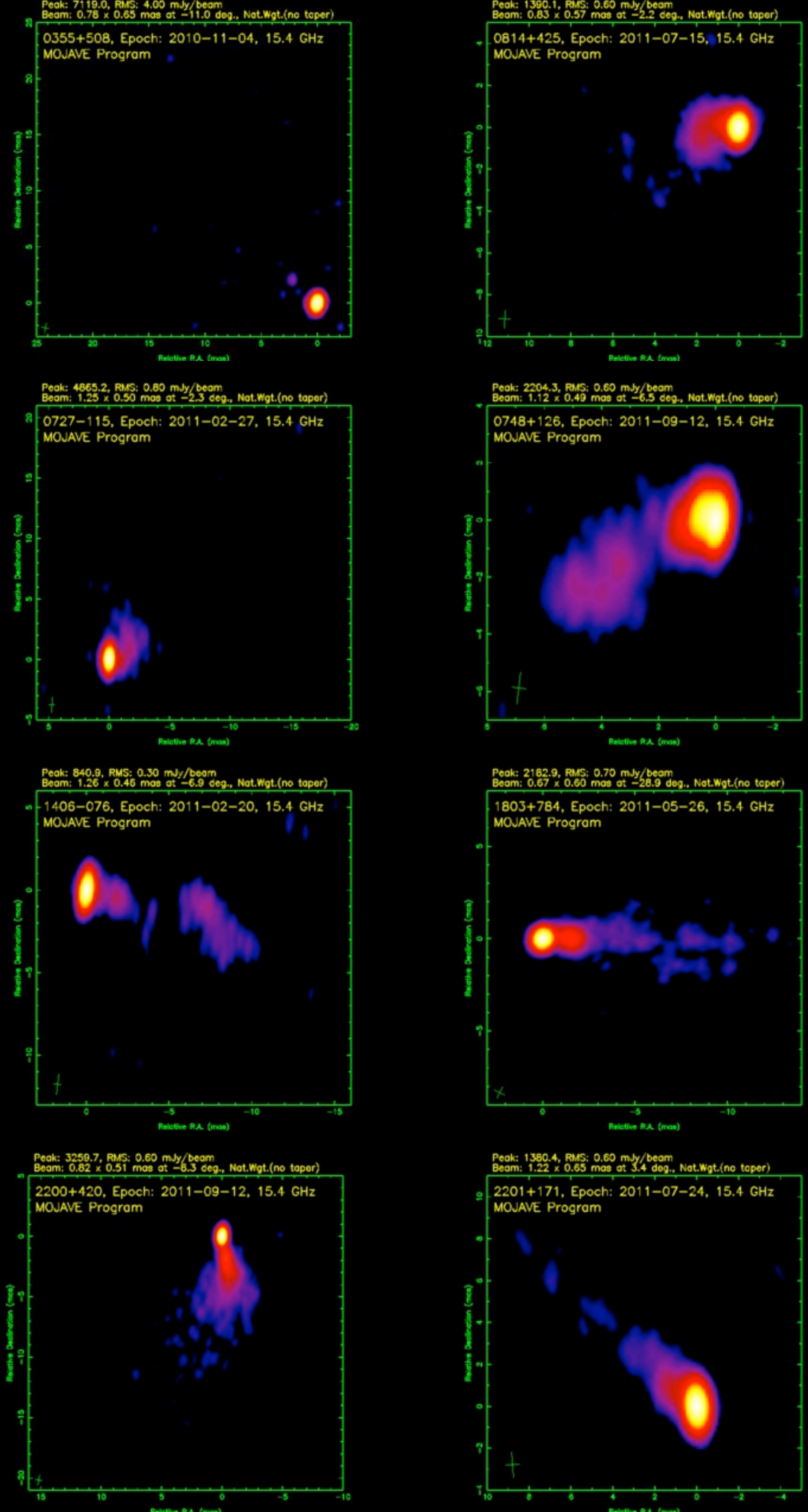
    - geometry?
    - changes in the B topology?
    - changes in D?
    - opacity effects?




*from the MOJAVE database*

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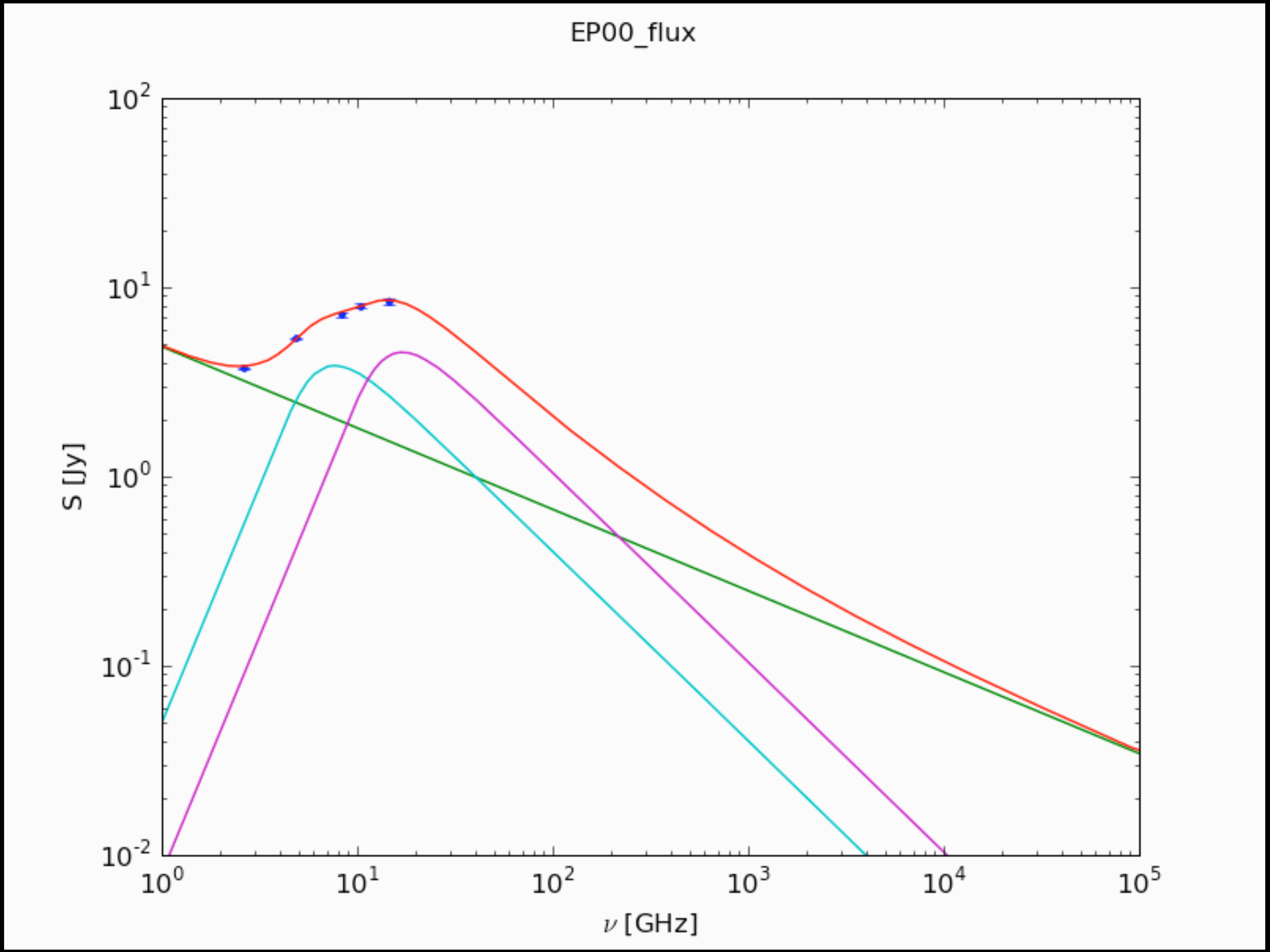
# F-GAMMA spectra:

## Spectral Decomposition




NRAO150

*Schmidt et al. in prep.*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