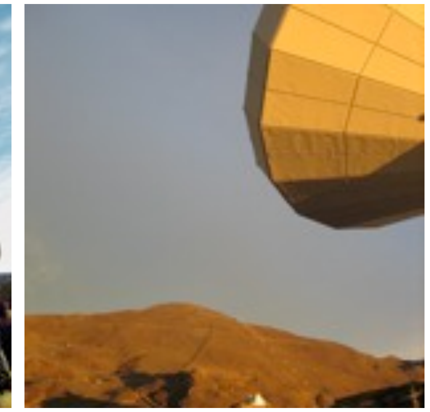
100-m Effelsberg



30-m IRAM

12-m APEX

F-GAMMA program:

Unification and physical interpretation of the radio spectra variability patterns in Fermi-*GST* blazars and detection of radio jet emission from NLSy1 galaxies

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E. Angelakis

and **L. Fuhrmann[1], I. Nestoras[1], R. Schmidt[1], J. A. Zensus[1], N. Marchili[1], T. P. Krichbaum[1]**, and H. Ungerechts[2], A. Sievers[2], D. Riquelme[2], C. M. Fromm[1], M. Perucho-Pla[4], L. Foschini[5], G. Ghisellini[5], G. Ghirlanda[5], G. Tagliaferri[5], F. Tavecchio[5], L. Maraschi[5], M. Giroletti[6], G. Calderone[7], M. Colpi[7], R. Decarli[8]

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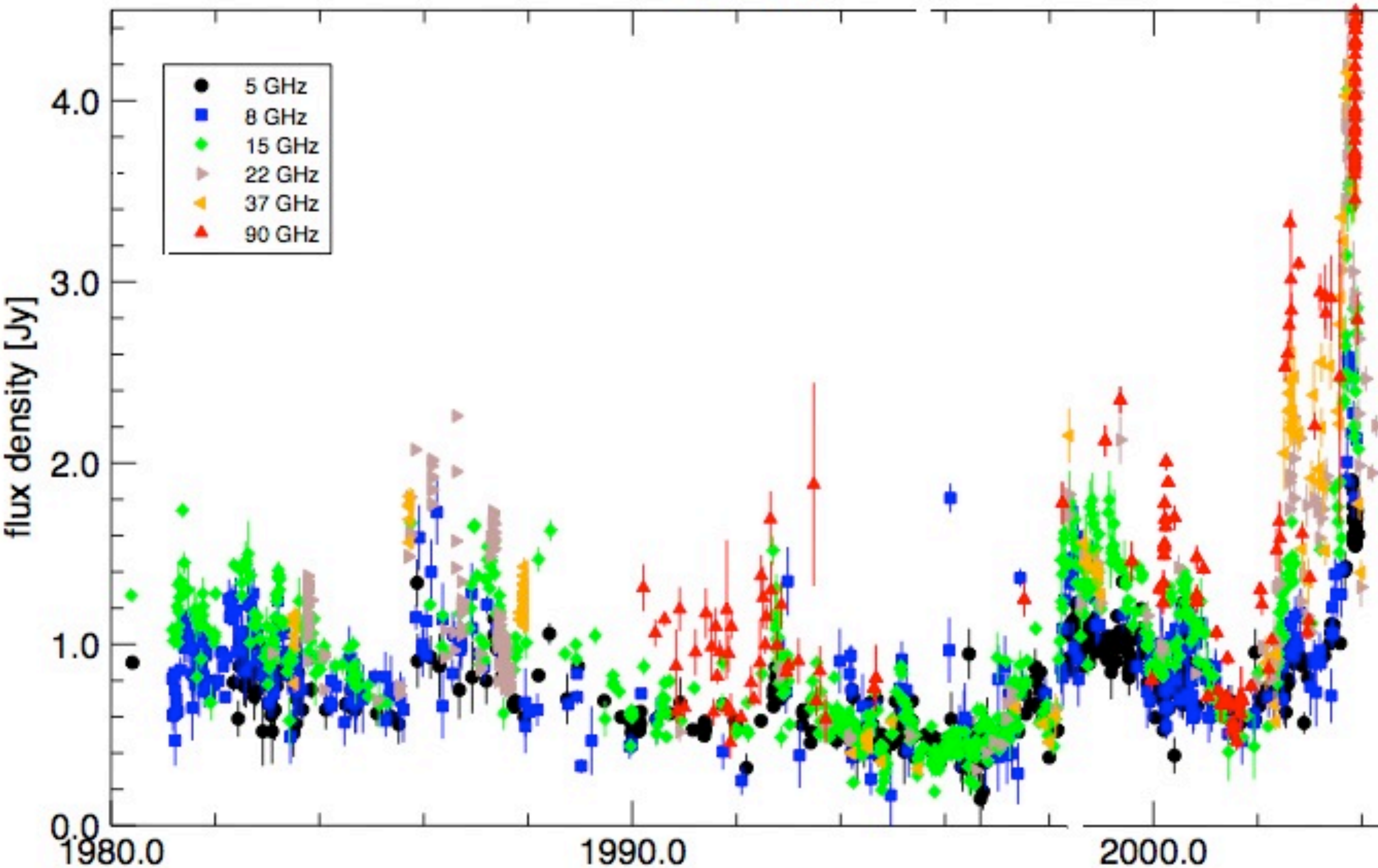
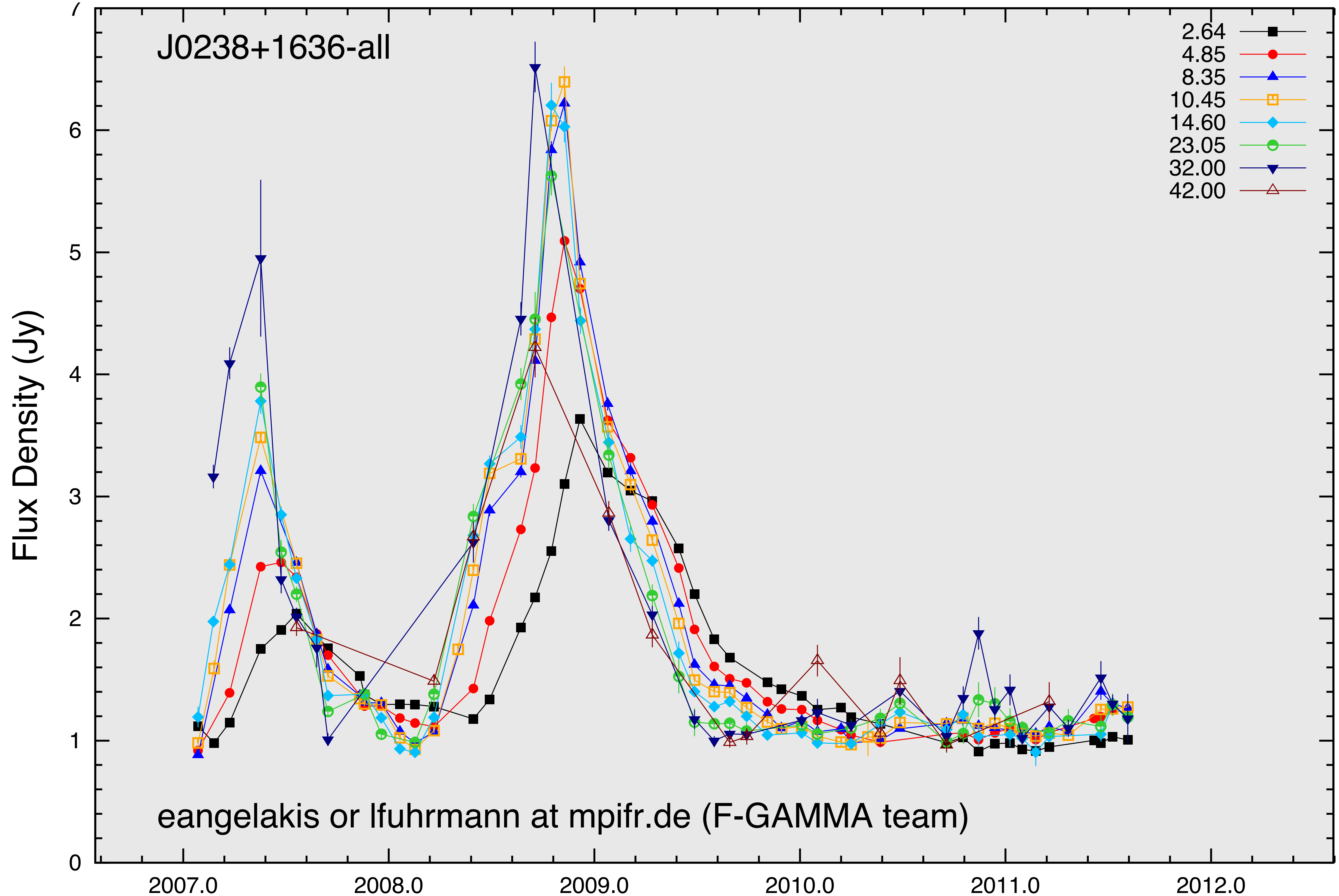


Fuhrmann et al. 2008

blazar phenomenology

extreme variability - time domain



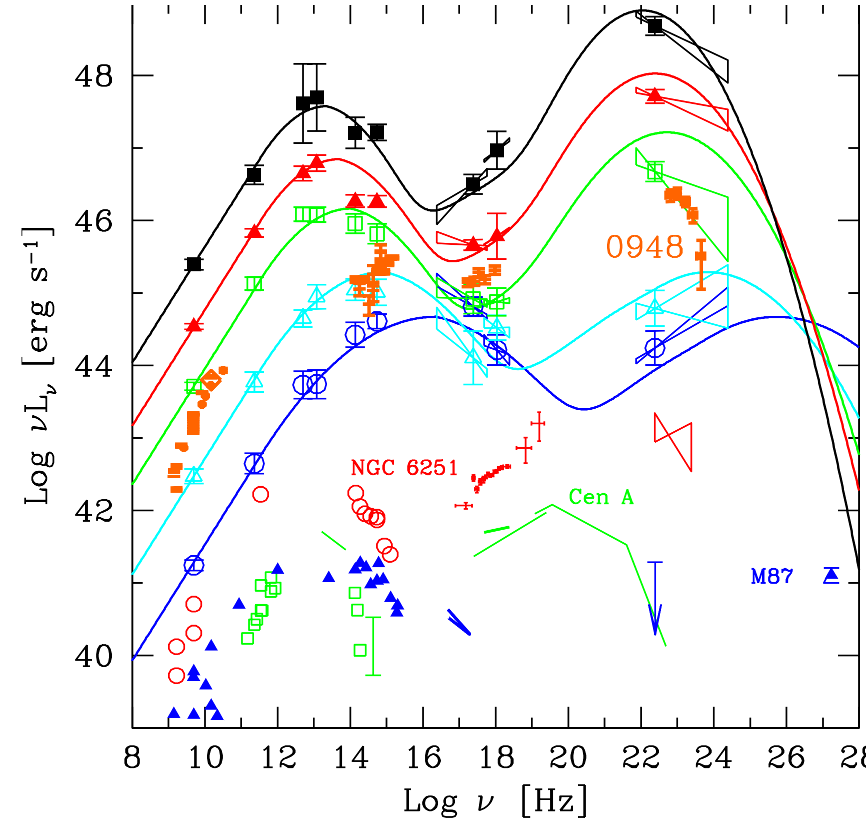
Angelakis et al. in prep.

blazar phenomenology

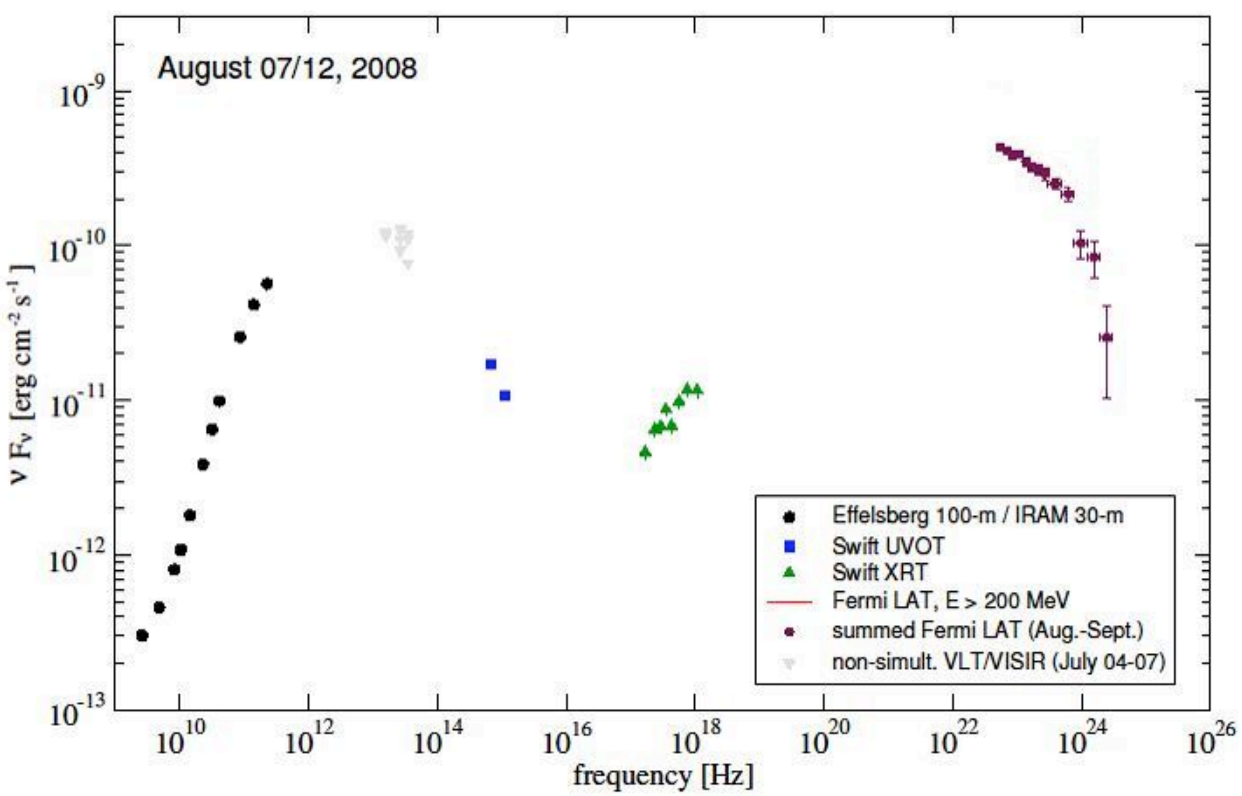
extreme variability - time domain

incoherent
synchrotron

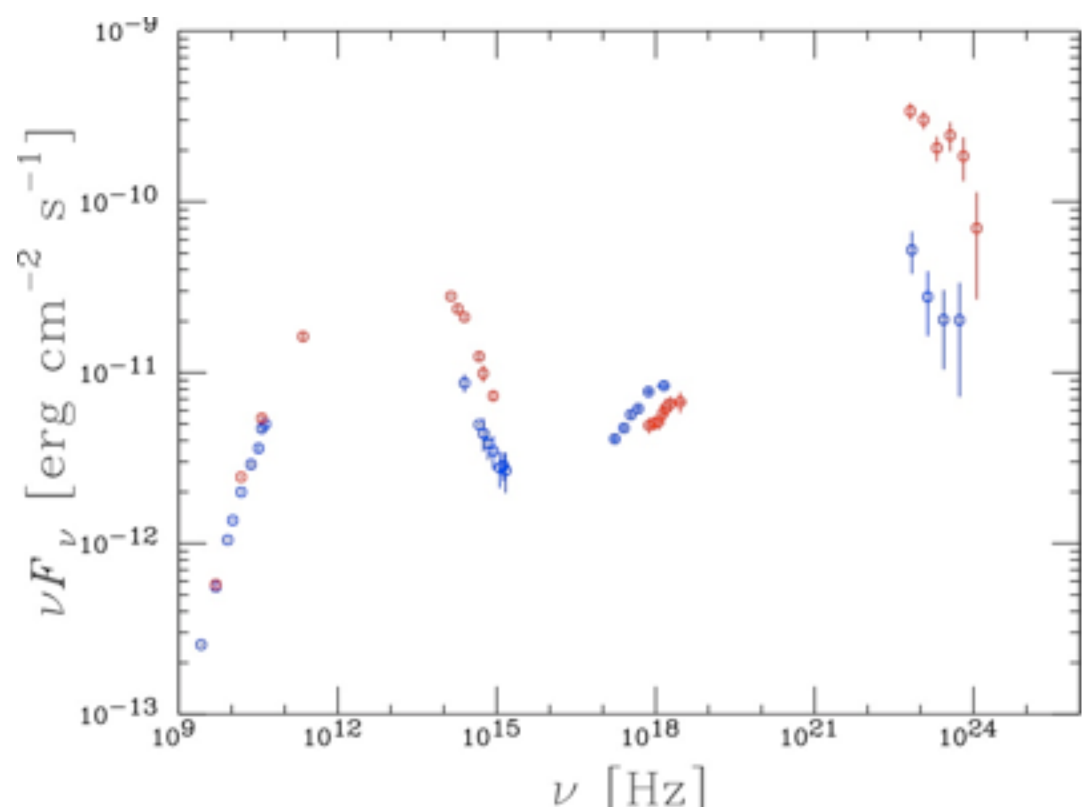
inverse
Compton



Abdo et al. (2009e)

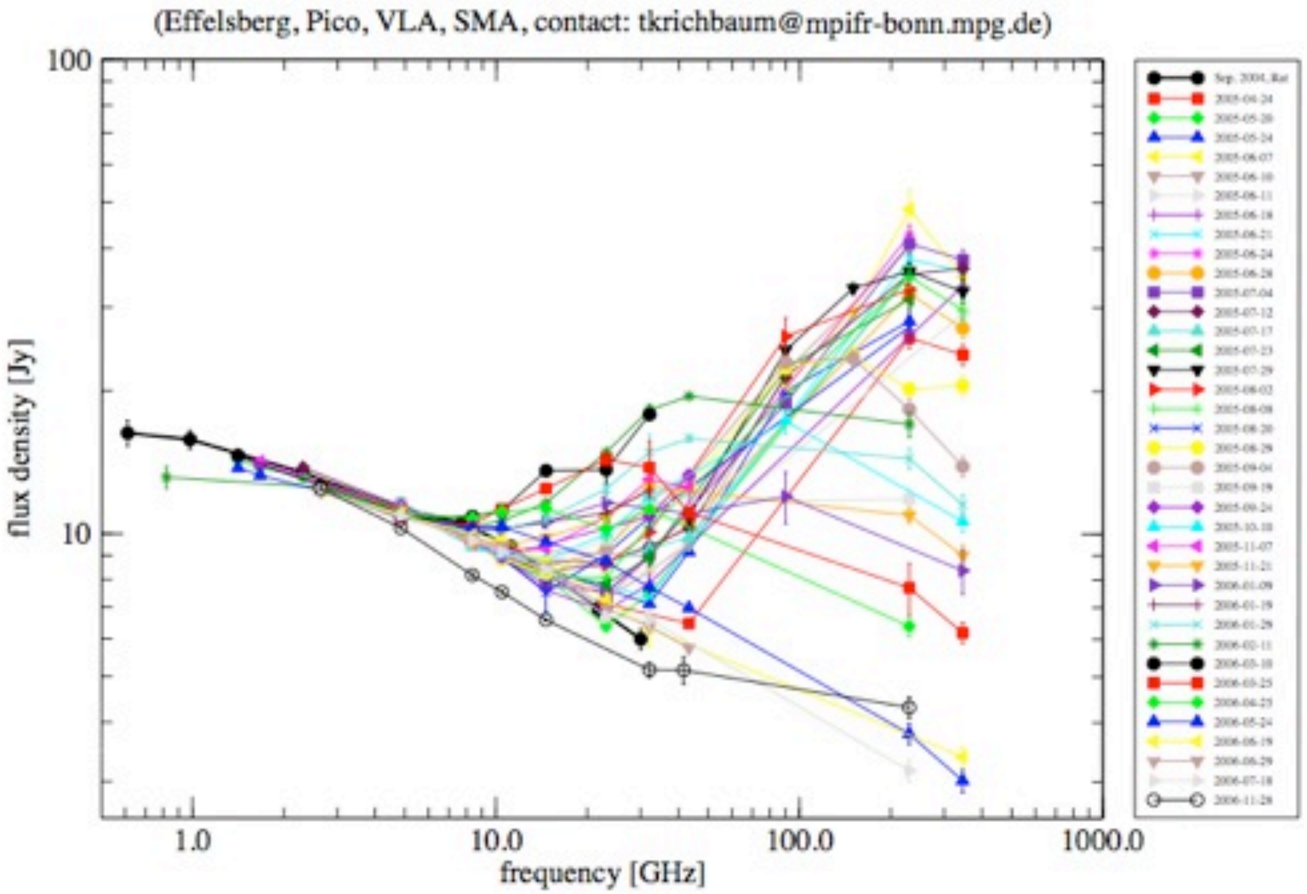


Abdo et al. (2009b)

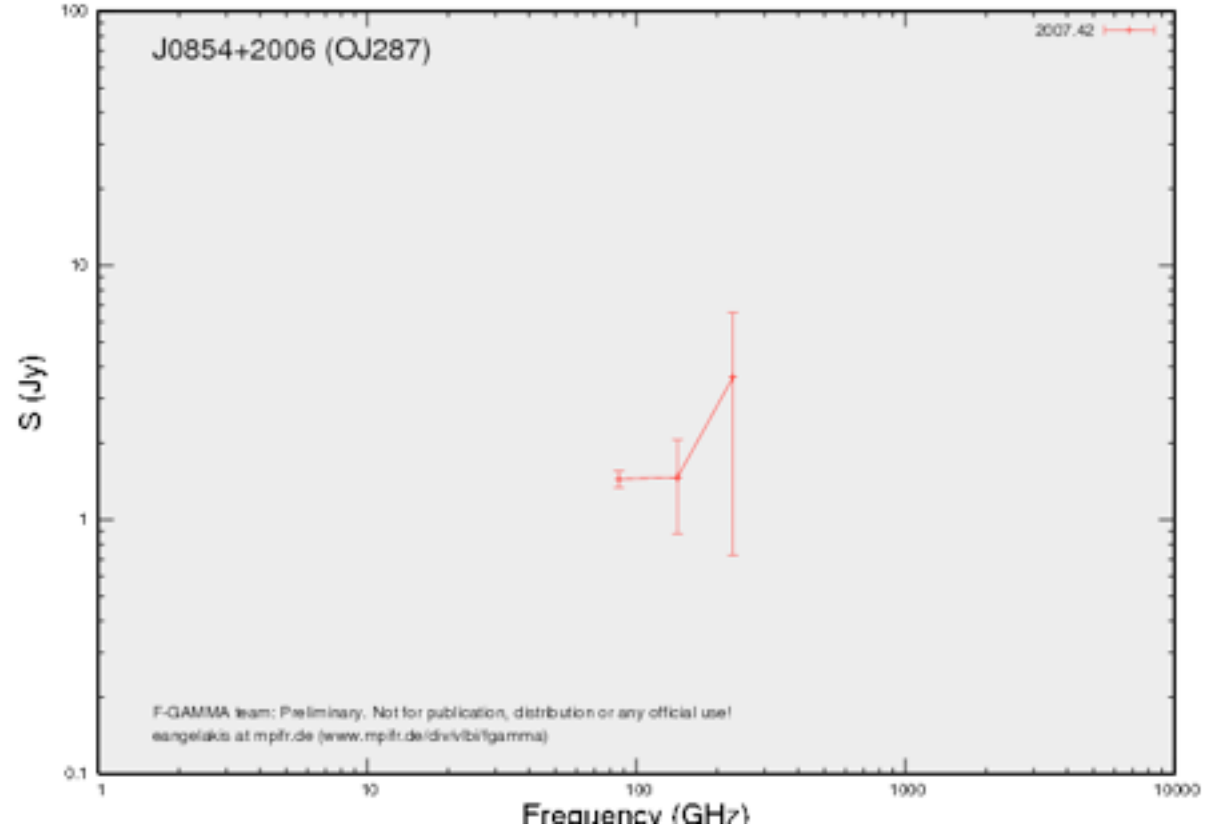


Abdo et al. (2010b)

broad-band emission



Krichbaum et al. in prep.



Angelakis et al. in prep.

blazar phenomenology

extreme variability - frequency domain

blazars

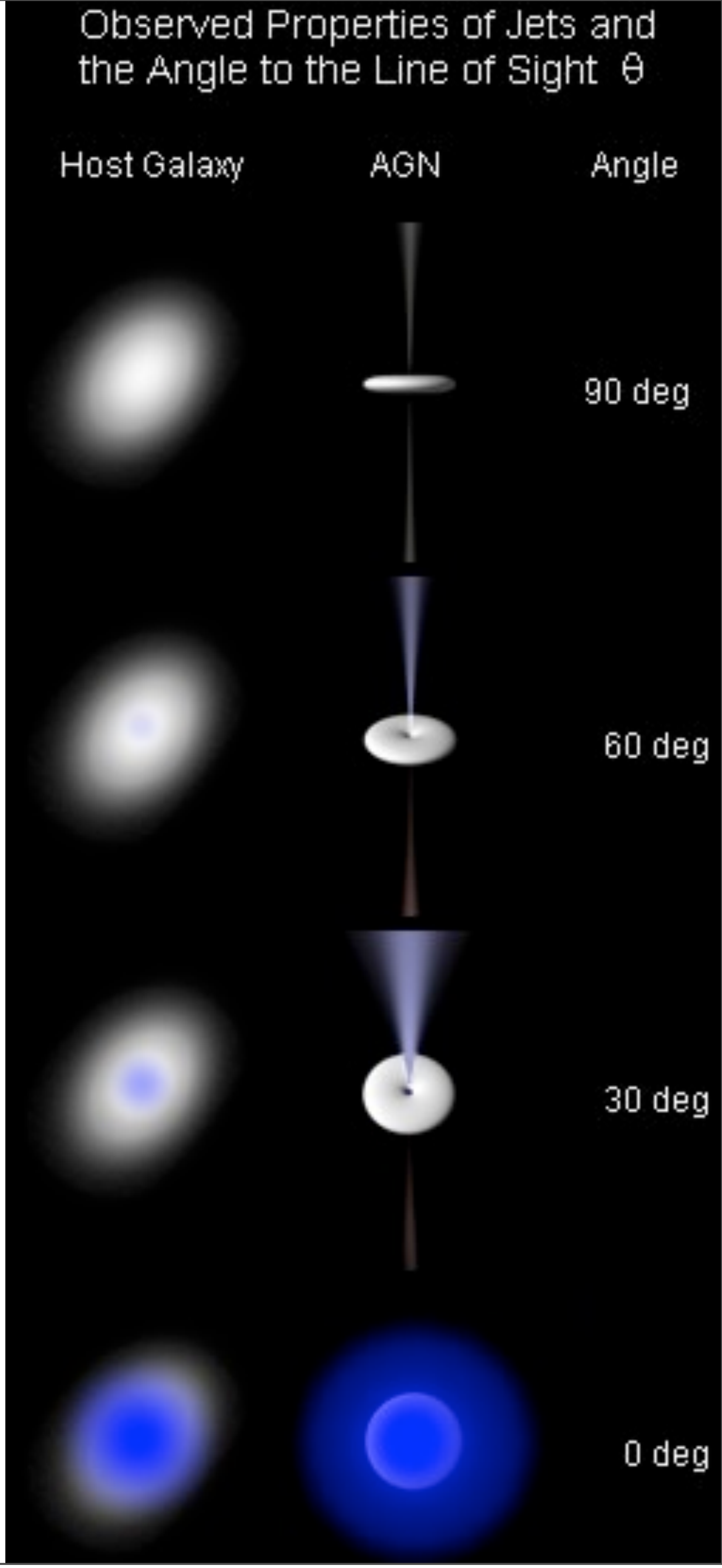
- emission originating in jets oriented very close (≤ 20 – 30○) to the line of sight (e.g. Urry & Padovani 1995) ,

  causing:

  - extreme flux density variability, moderate degree of linear polarization, high superluminal motions and brightness temperatures

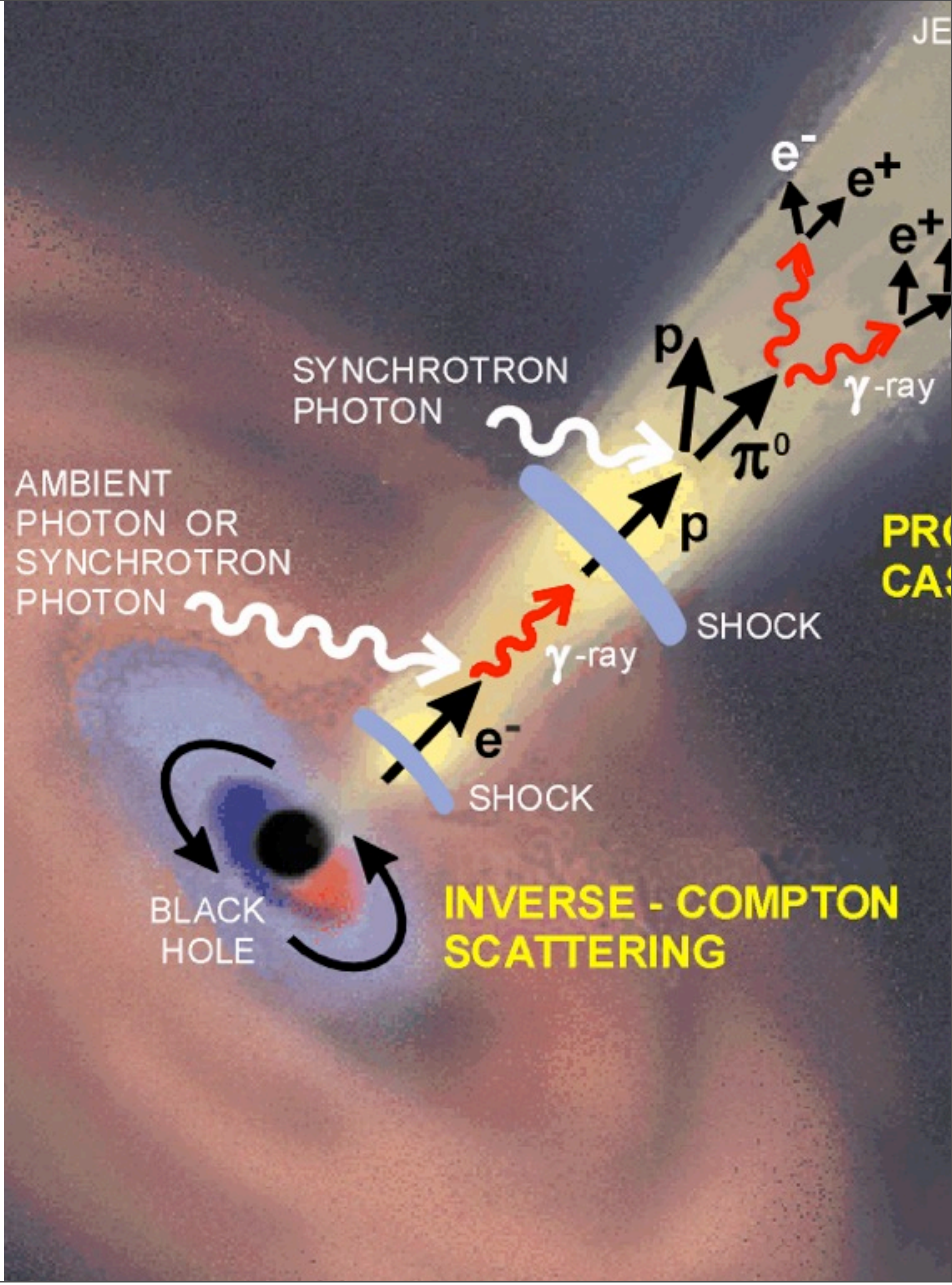
  etc ...

taken by wikipedia



the basic question

- where does it happen: close to the engine in the BLR or far out in the jet re-acceleration regions
- what is the photon field? is it the same photons a those we see as synchrotron or do they come from the torus
- after all, what is the emission mechanism, are the radio and gamma-rays, correlated?



F-GAMMA program
Fermi-GST AGN Multi-wavelength Monitoring Alliance:

www.mpifr.de/div/vlbi/fgamma

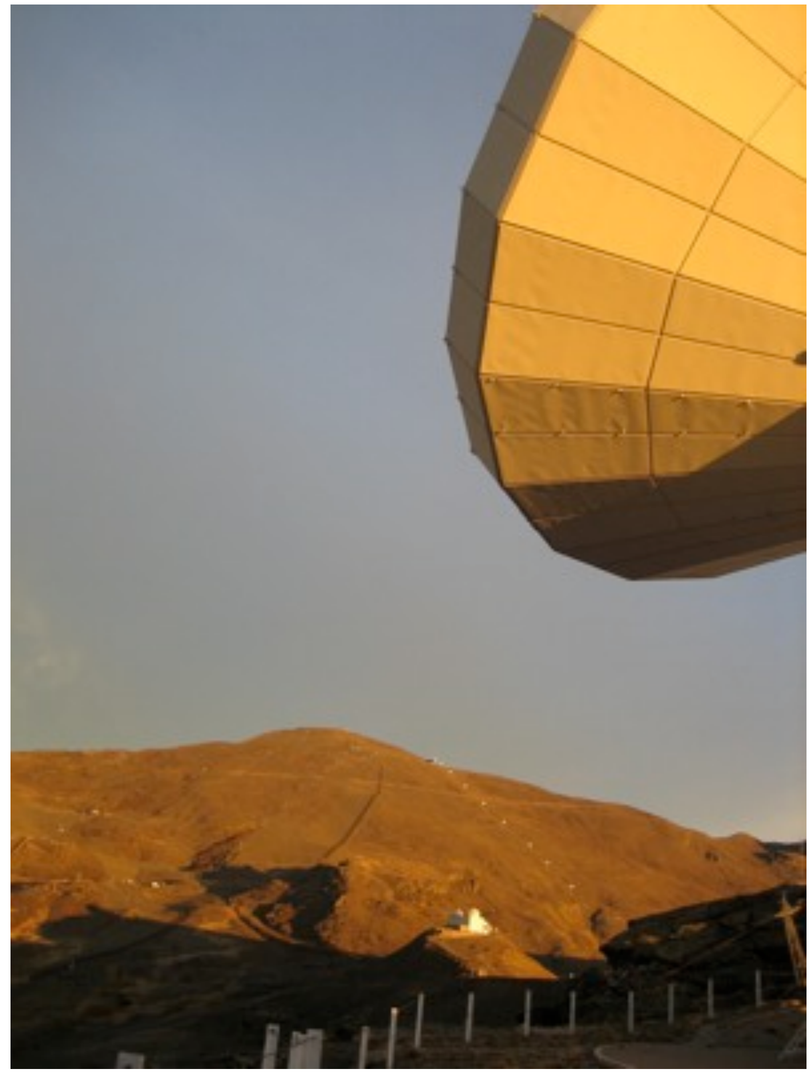
monthly monitoring program for ~60 *Fermi*-GST blazars
at 2.6 - 345 GHz + optical, optical polarimetry and gamma-rays

L. Fuhrmann, E. Angelakis, J. A. Zensus, T. P. Krichbaum
I. Nestoras, R. Schmidt

100-m Effelsberg

- Monthly monitoring of ~60 sources
- 2.64 - 43 GHz at 8 frequency steps
- Simultaneous spectra within 40 minutes

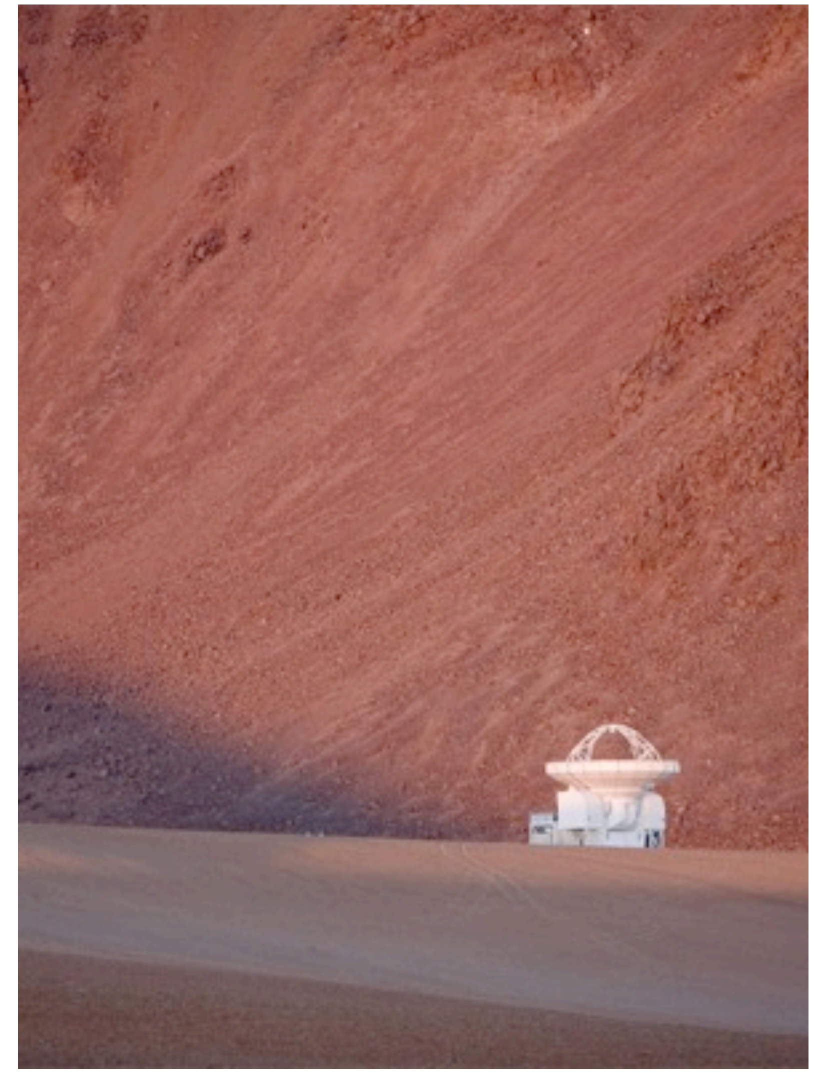
L. Furhmann, E. Angelakis, I. Nestoras, J. A. Zensus, N. Marchili, T. P. Krichbaum



30-m IRAM

- Monthly monitoring of ~60 sources
- 86, 142 and 228 GHz
- Simultaneous spectra within 2 minutes

H. Ungerechts, A. Sievers, D. Riquelme



12-m APEX

- Irregular “filler” monitoring
- 345 GHz
- accuracy <15%

S. Larson, A. Weiss

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, Crete, Greece

- polarimetry (Expected Spring 2012)

I. Papadakis

40-m OVRO telescope

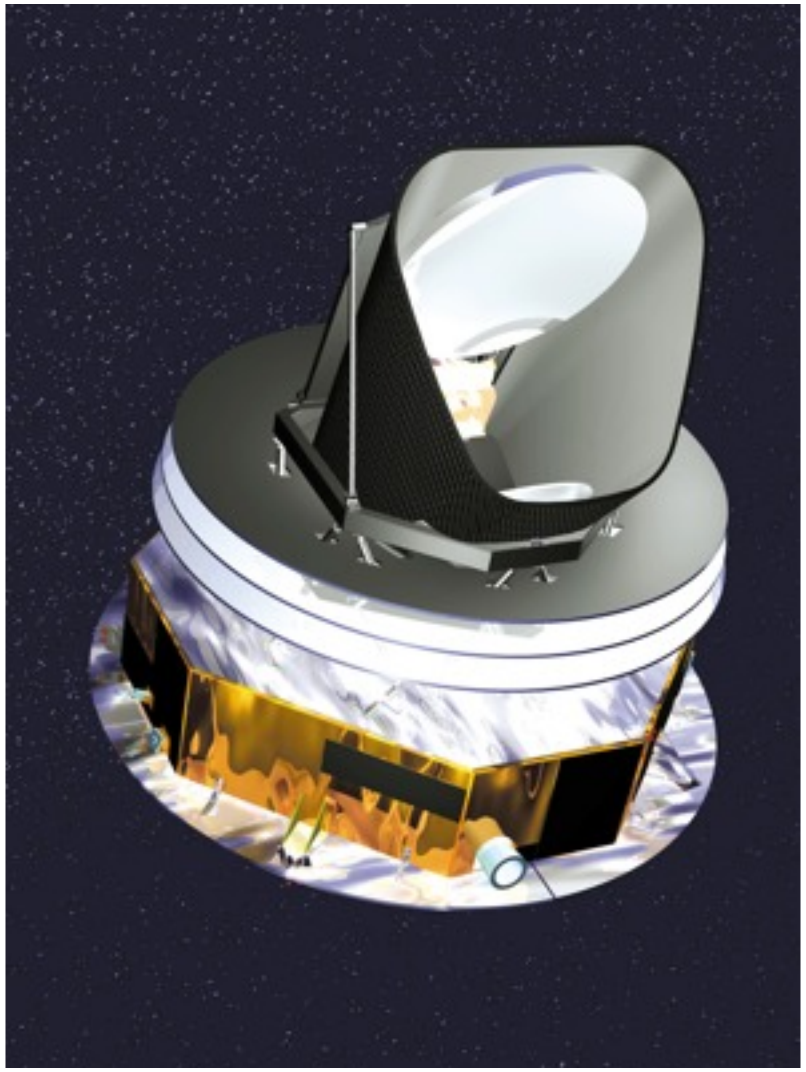
- ~1200 blazars at least 2–3 times per week (Richards et al. in prep.)
- 15 GHz

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

Korean VLBI Network 21-m radio telescope Korea Astronomy and Space Science Institute

- 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



The Planck satellite

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

J. P. Rachen et al.

Fermi-GST

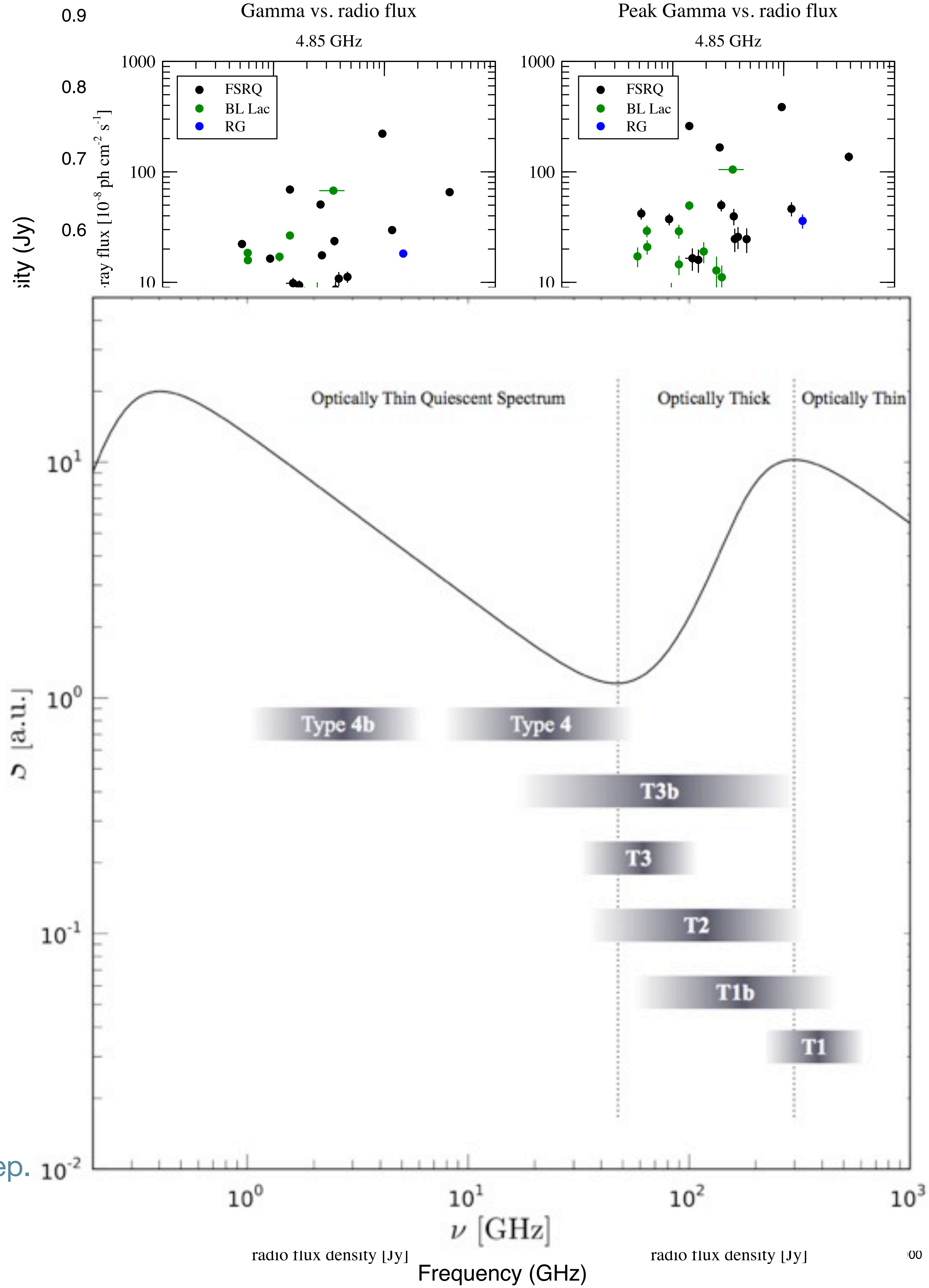
- 4π / 3 hours
- 20 MeV to 300 GeV

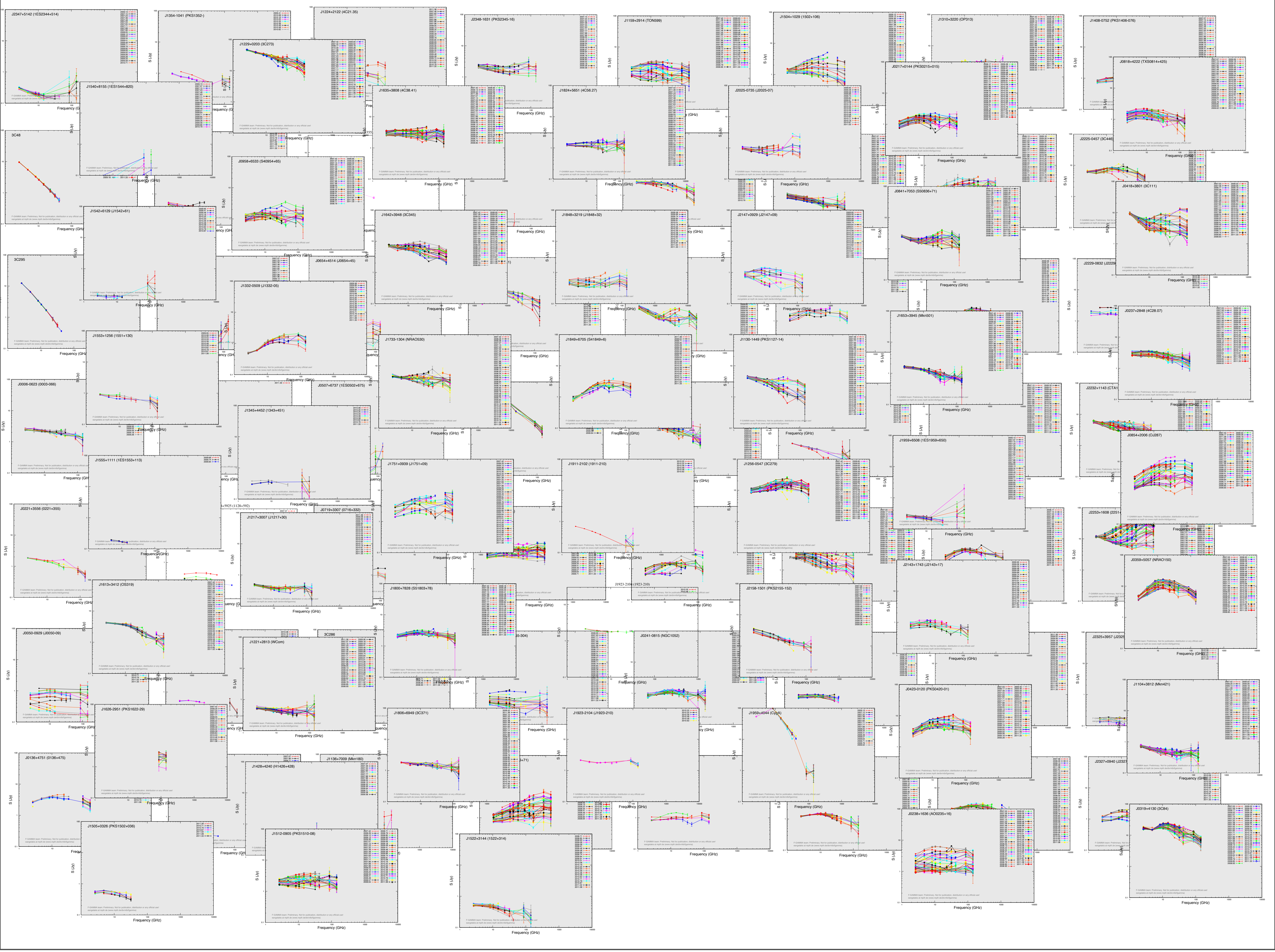
L. Fuhrmann, J. A. Zensus, I. Nestoras

F-GAMMA program

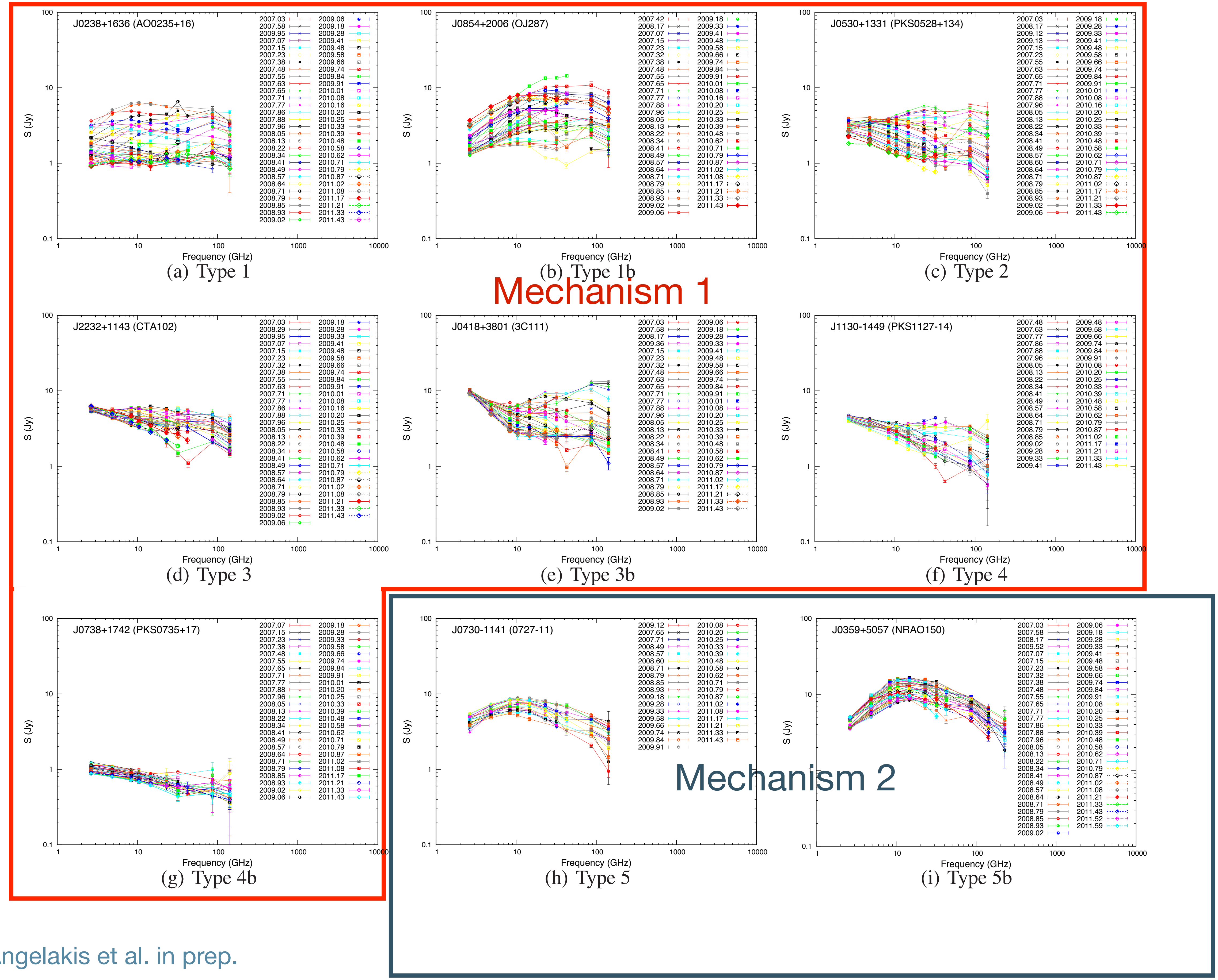
- detection of radio jet emission in a NLSY1, challenging our current understanding that jets are associated exclusively with “old” ellipticals (Foschini et al. 2010)
- unification and physical interpretation of the radio spectra variability patterns in Fermi-GST blazars
- a correlation between S_{radio} and S_{gamma} free of redshift biases

Angelakis et al. in prep.
Fuhrmann, Angelakis et al., in 2011nlsg.confF
Pavlidou et al. subm



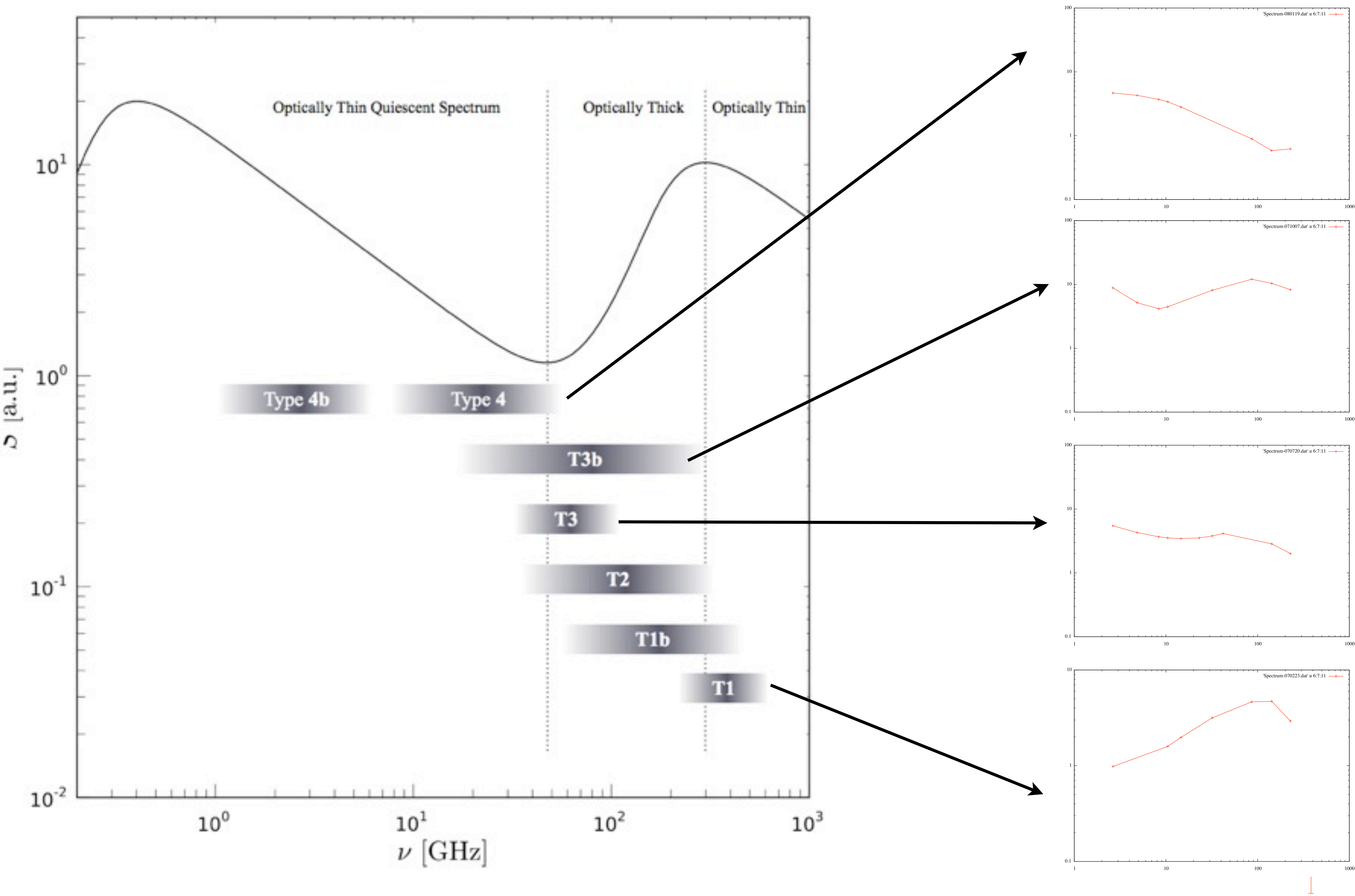


Tuesday, September 6, 2011

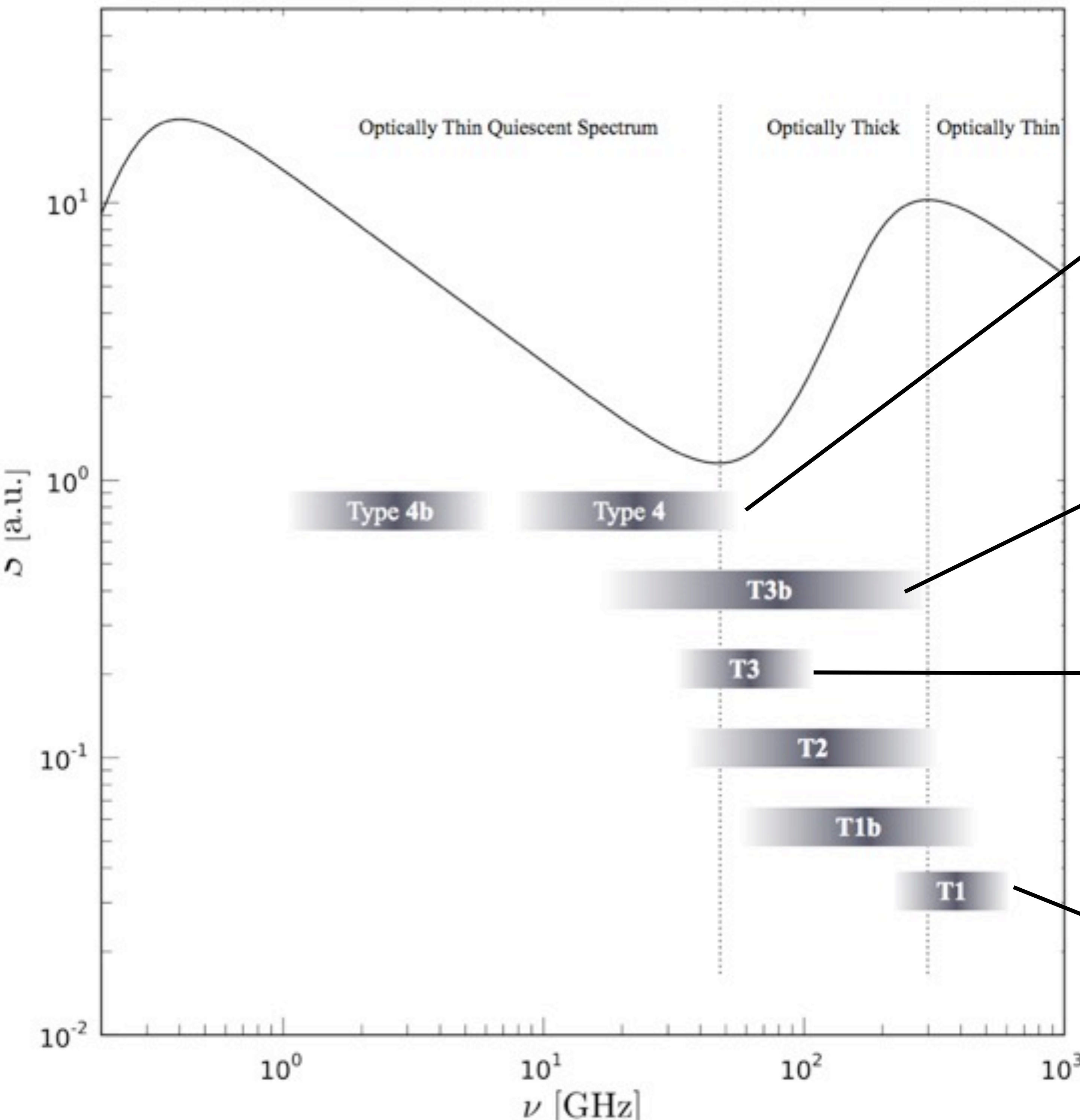


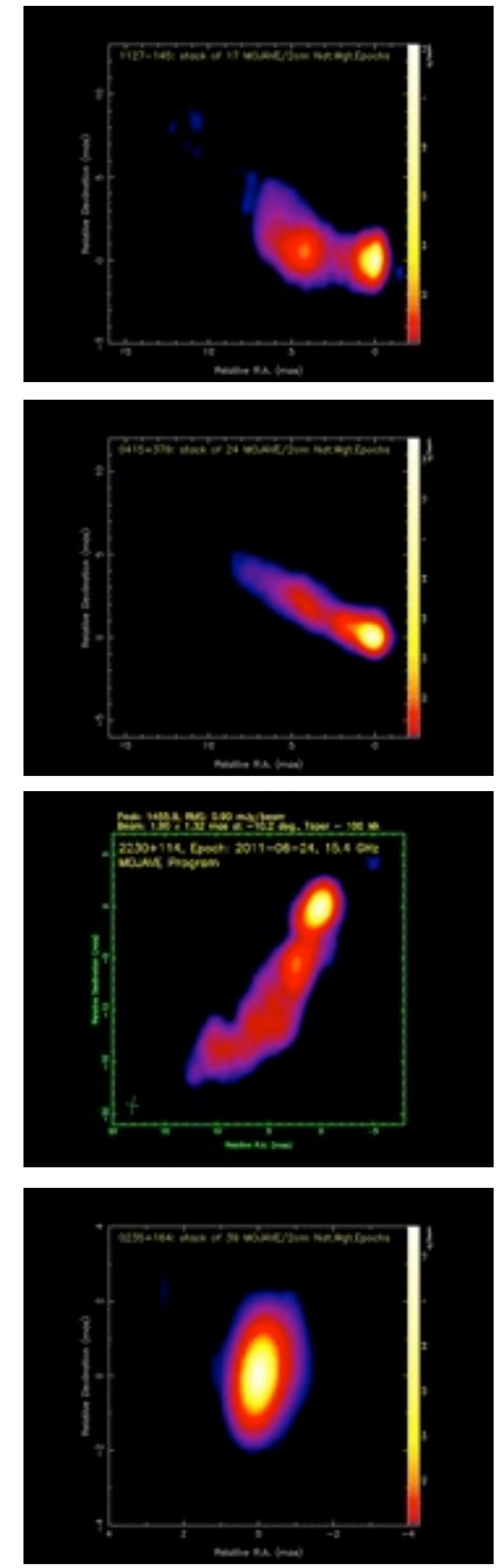
Angelakis et al. in prep.

Unification of the variability pattern



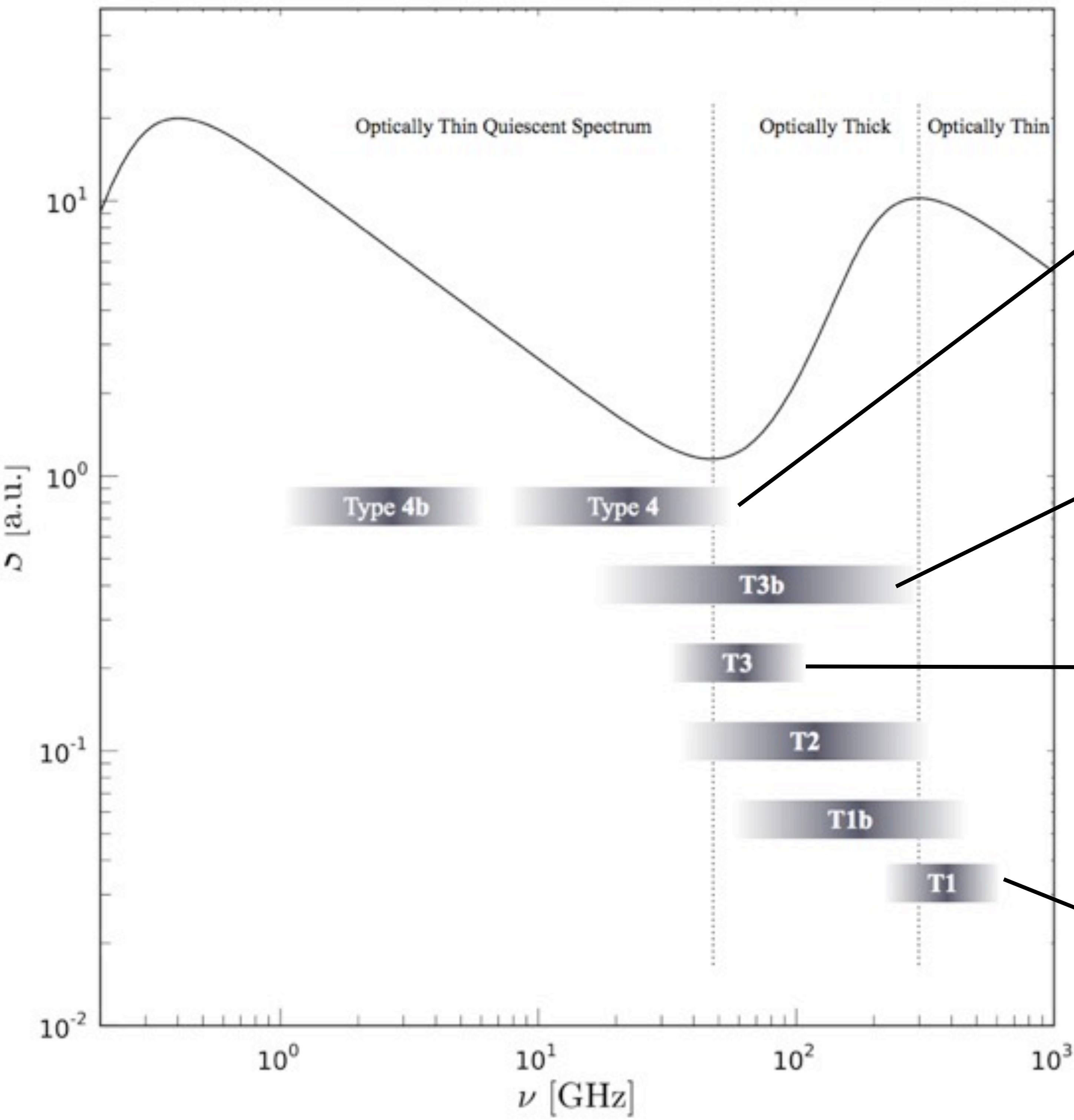
Unification of the variability pattern

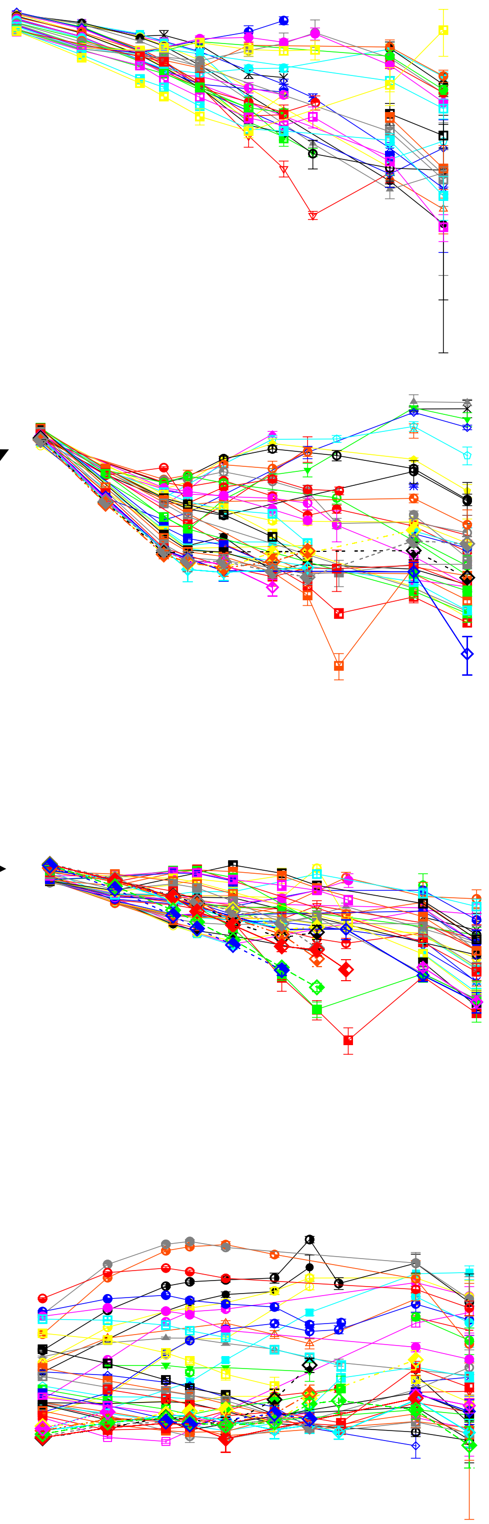




from the MOJAVE 2-cm database

Unification of the variability pattern





Unification of the variability pattern

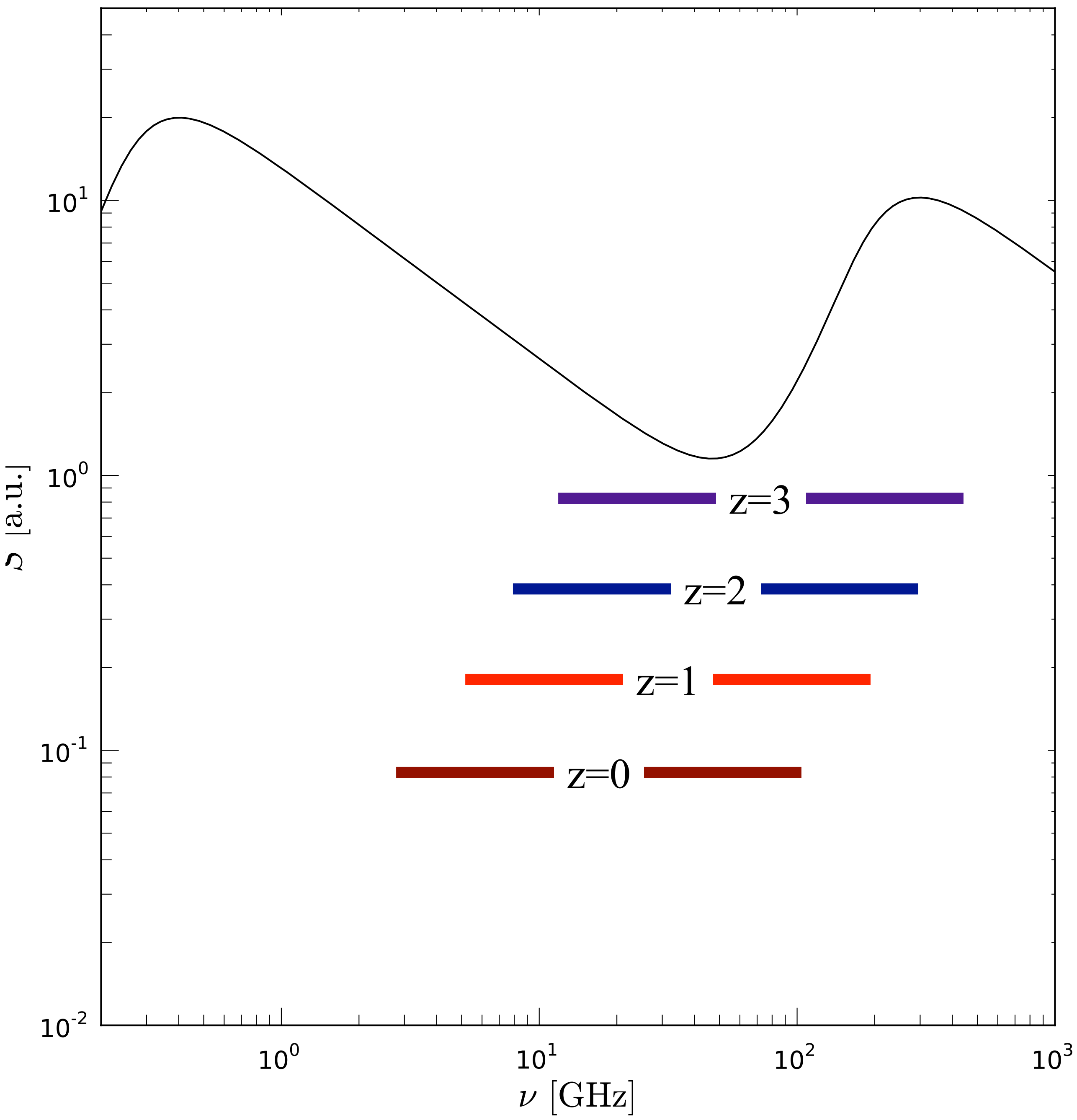
The unification of the variability pattern henceforth could naturally be explained with the **“appropriate” modulation** of **two properties**:

- the **relative position** of our **band-pass** with respect to the source spectrum
- the **relative width** of our **band-pass** with respect to the width of the bridge (the total minimum) between the optically thick part of the outburst and the steep part of the quiescence spectrum

Three factors control this:

Unification of the variability pattern

1. Redshift factor



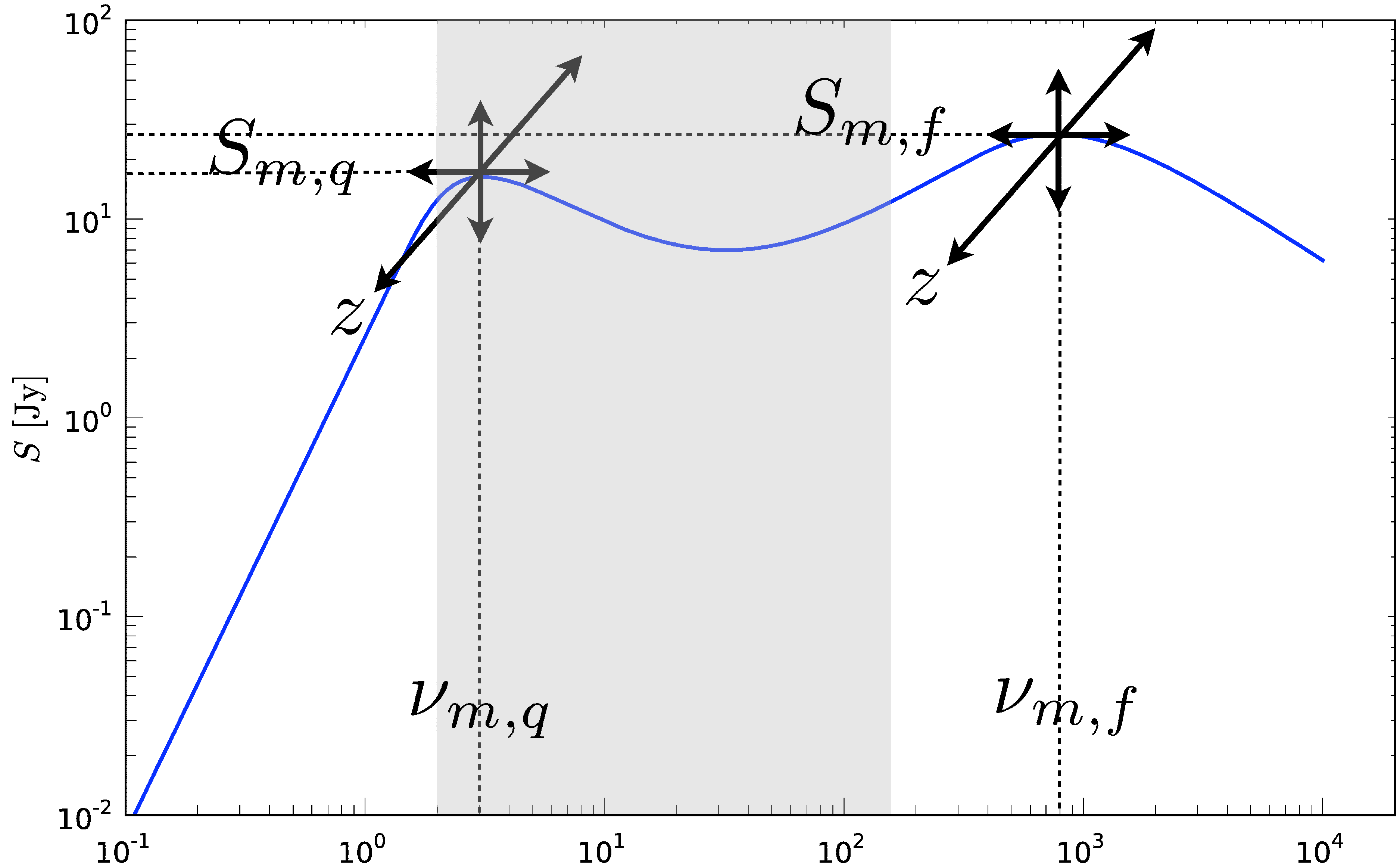
2. Intrinsic properties factor

- different peak frequency of the SSA spectrum
- different peak flux density excess of the outburst relative to the quiescence spectrum
- different broadness of the SSA spectrum of the outburst
- different broadness of the valley

Unification of the variability pattern

1. Redshift factor

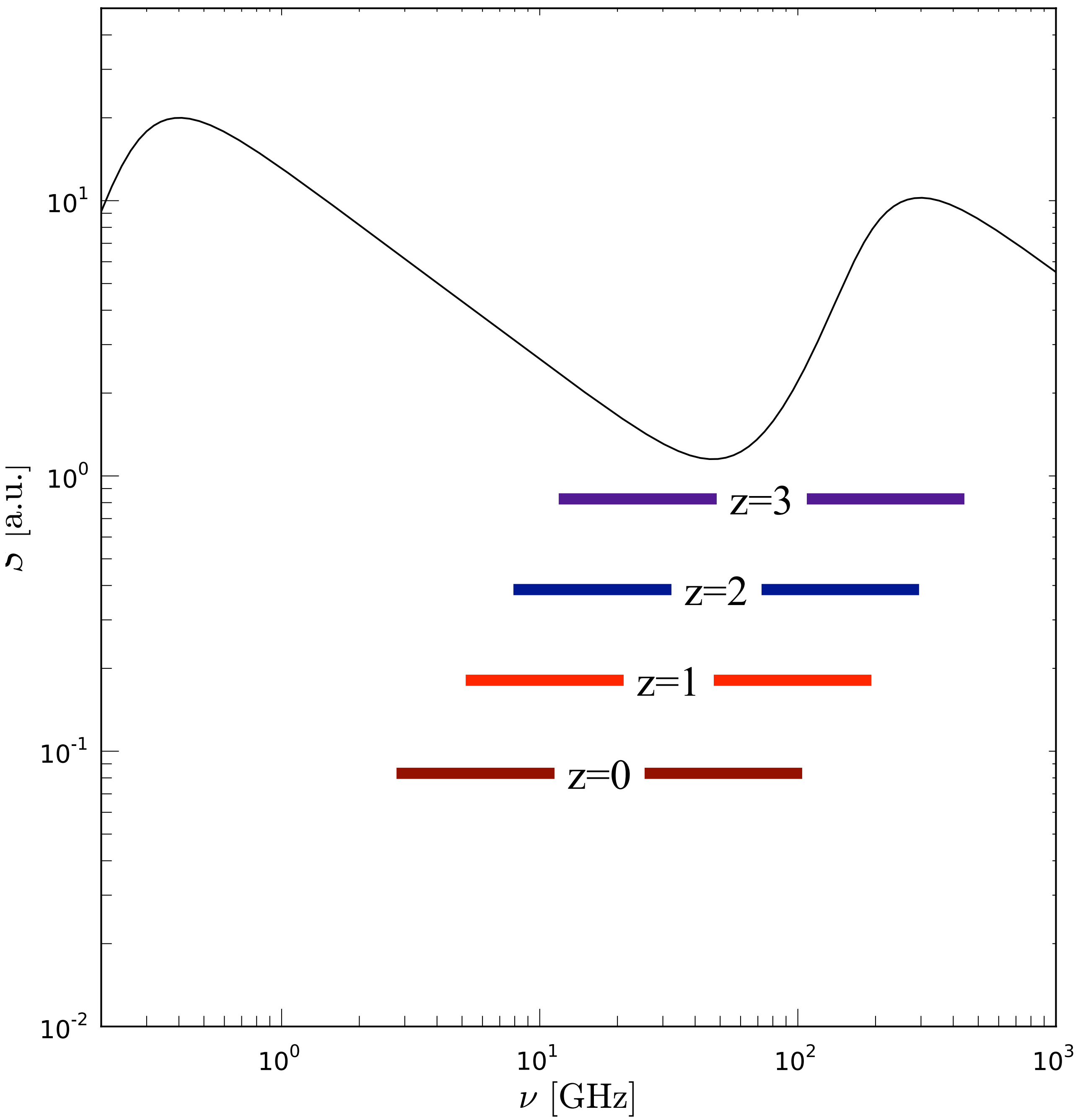
2. Intrinsic properties factor



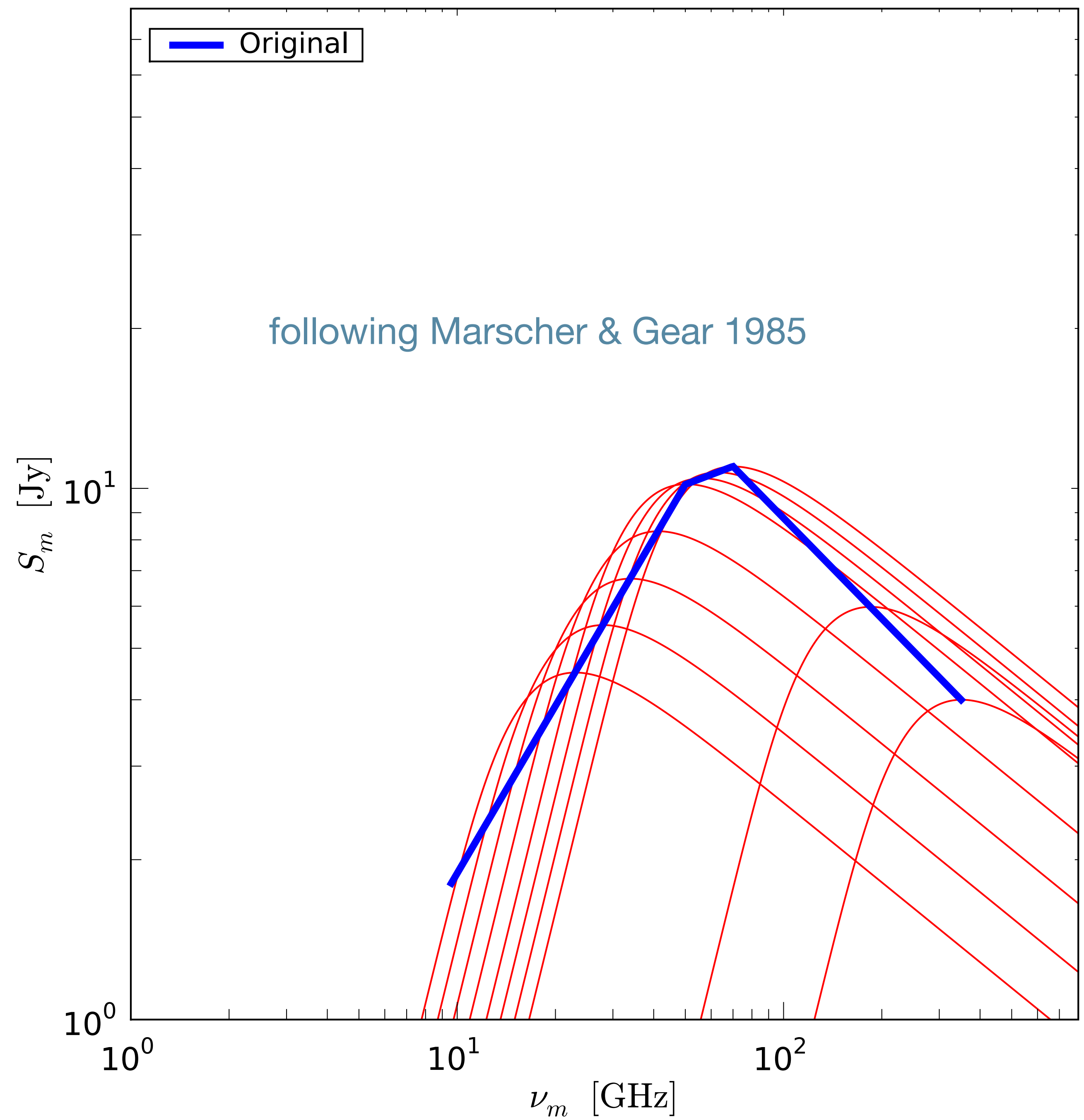
courtesy of C. M. Fromm

Unification of the variability pattern

1. Redshift factor



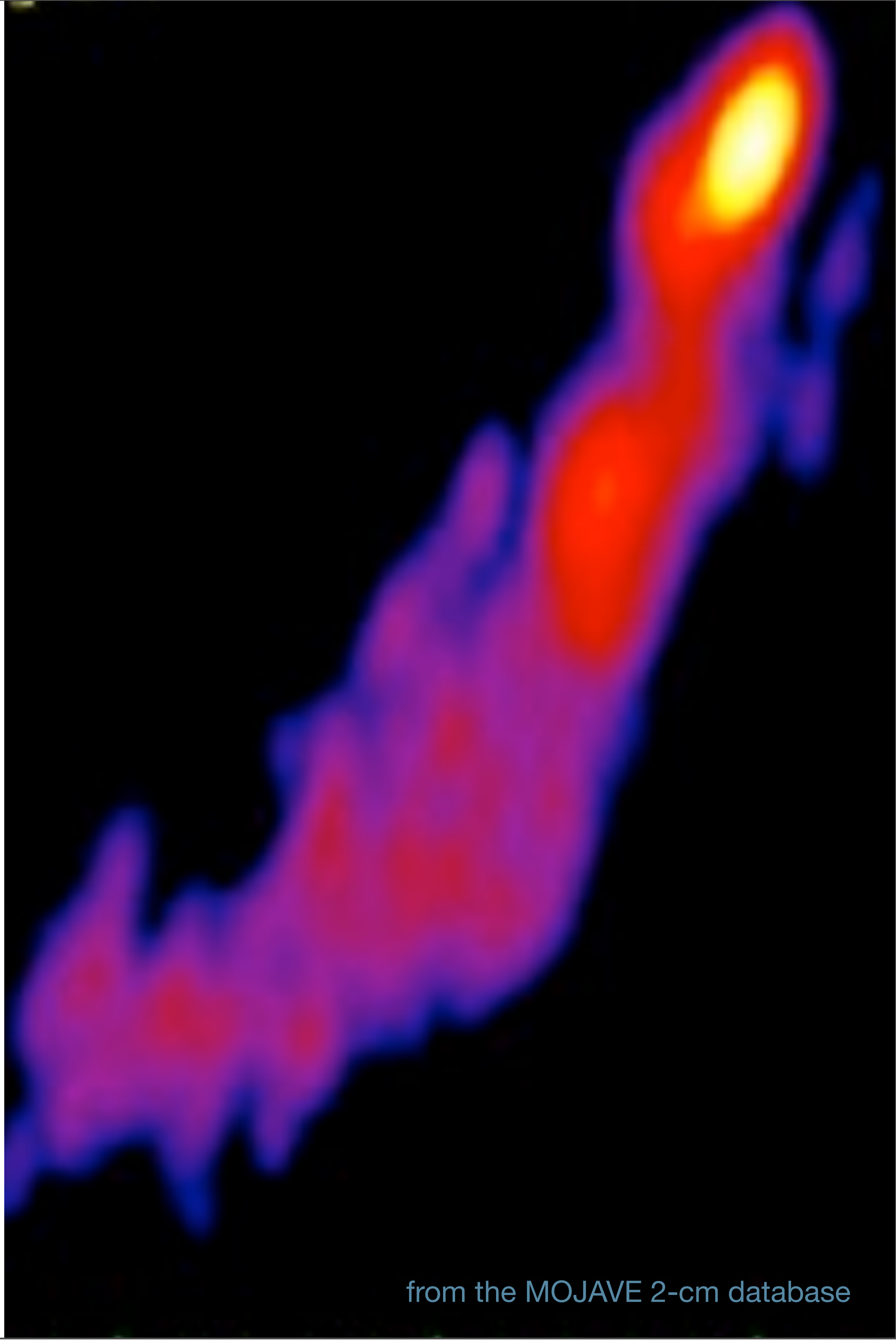
3. Spectral evolution



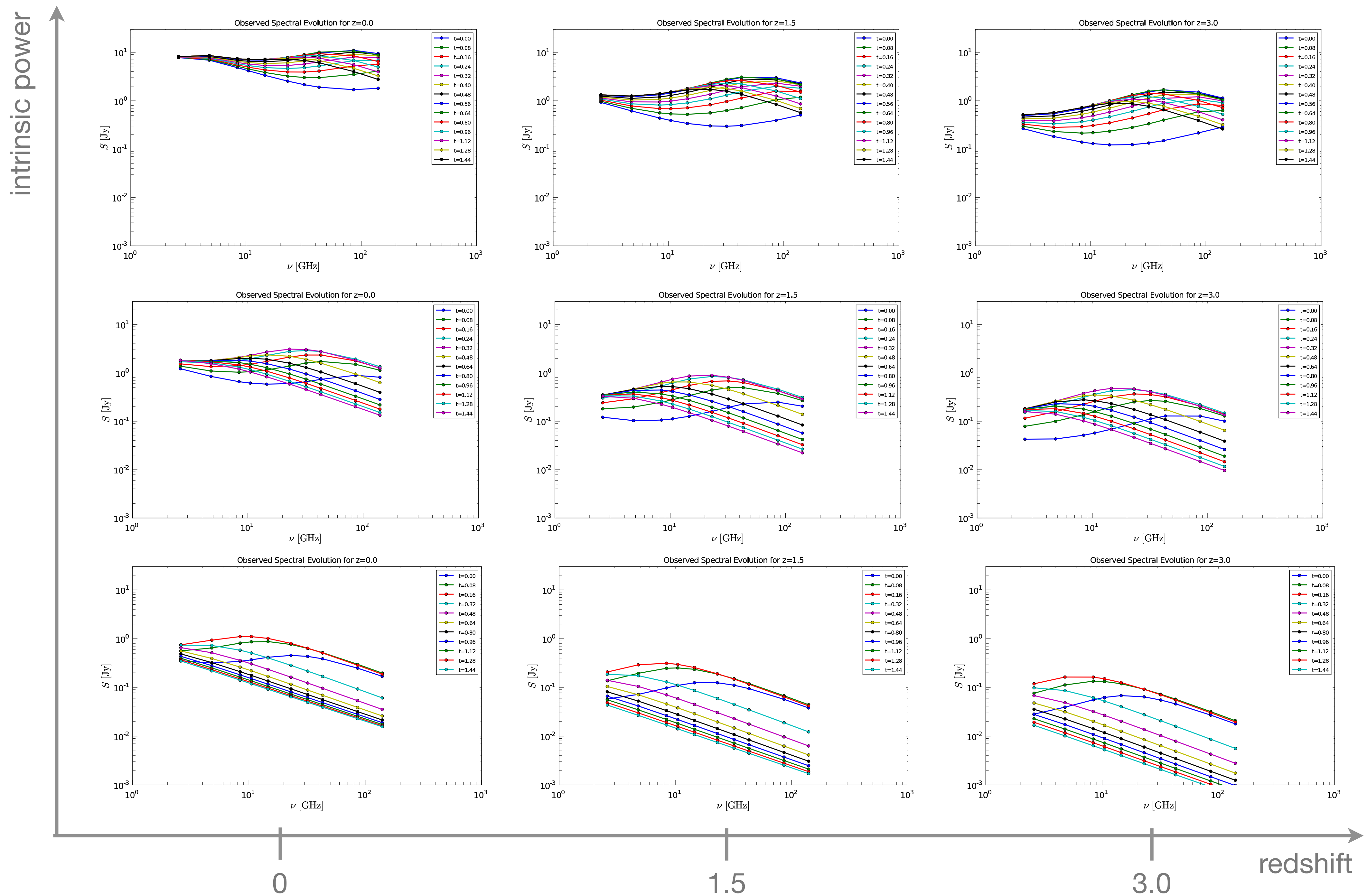
courtesy of C. M. Fromm

Modeling the spectral evolution

- parameter **"b"**: evolution of the **magnetic field**
- parameter **"d"**: evolution of the **Doppler factor**
- parameter **"r"**: **jet opening angle**
- parameter **"s"**: **spectral index** (estimated from quiescent spec.)
- parameter **"k"**: **normalization parameter**



simulations done by C. M. Fromm and M. Perucho-Pla
Angelakis et al. in prep.

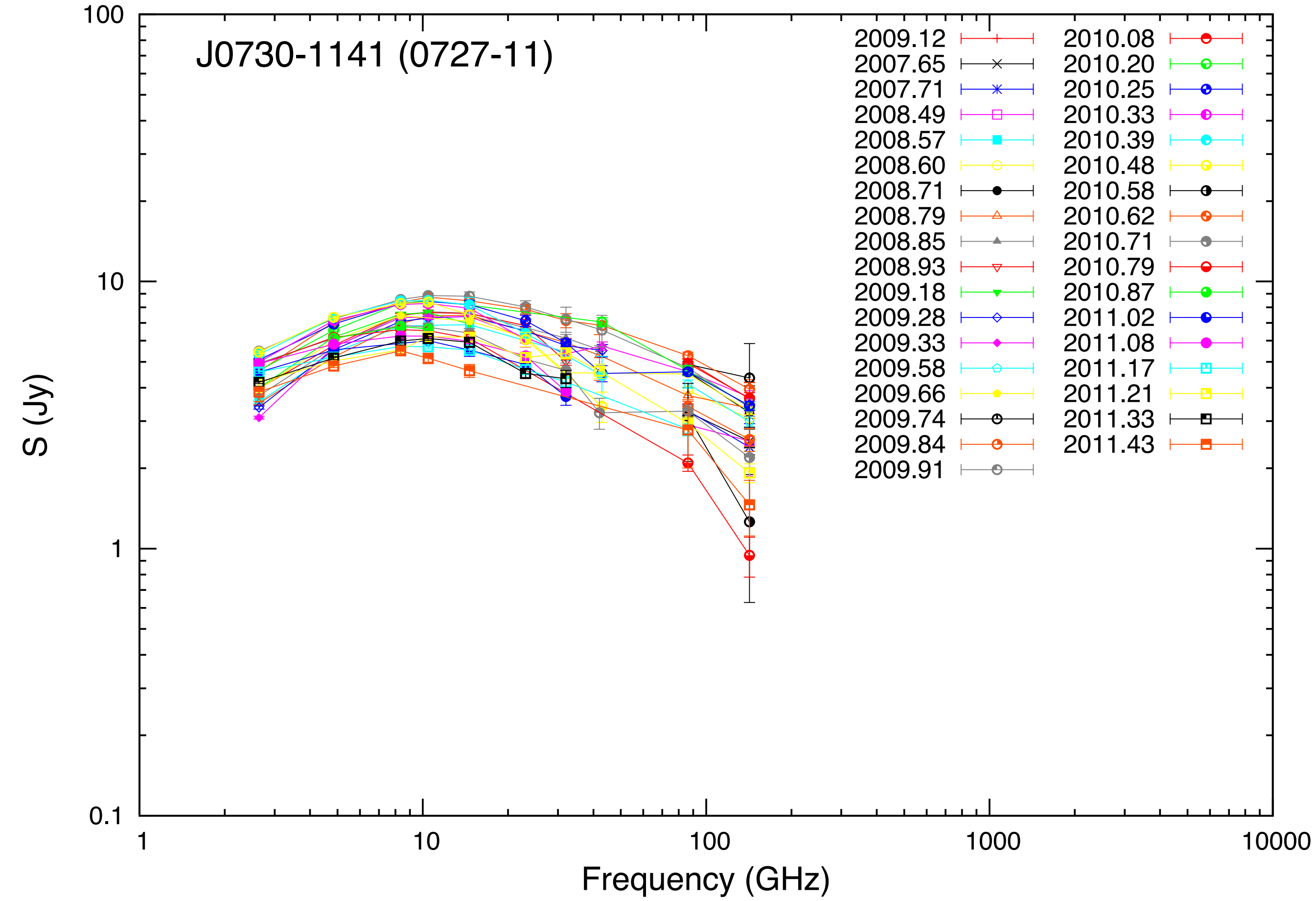


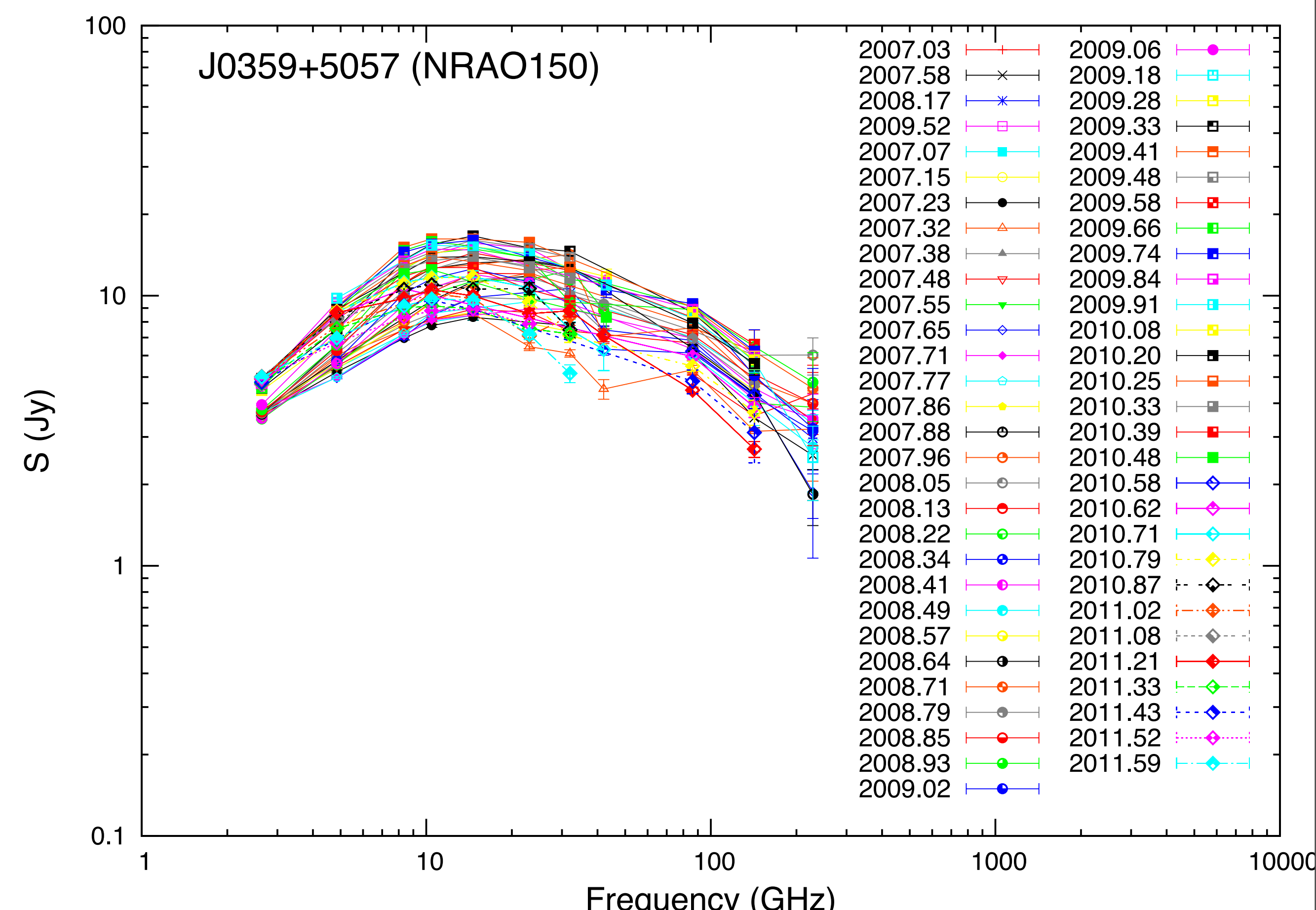
reproducing the observed phenomenology

by modeling the evolution of events at different z and of different power

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?





conclusions

- the **spectral evolution monitoring** method is probing smallest spatial scales (uniform clouds of emitting particles), otherwise unaccessible to current observing apparatus

- there are only **5 phenomenological types of variability pattern** that a source may follow

- so far **no source** has shown **a switch** in type. This strongly suggests that:

  - either the mechanism is a **source fingerprint** and hence we must investigate what determines them

  - it is determined by source intrinsic properties that stay invariant in time or change with pace much slower than we can sample

conclusions

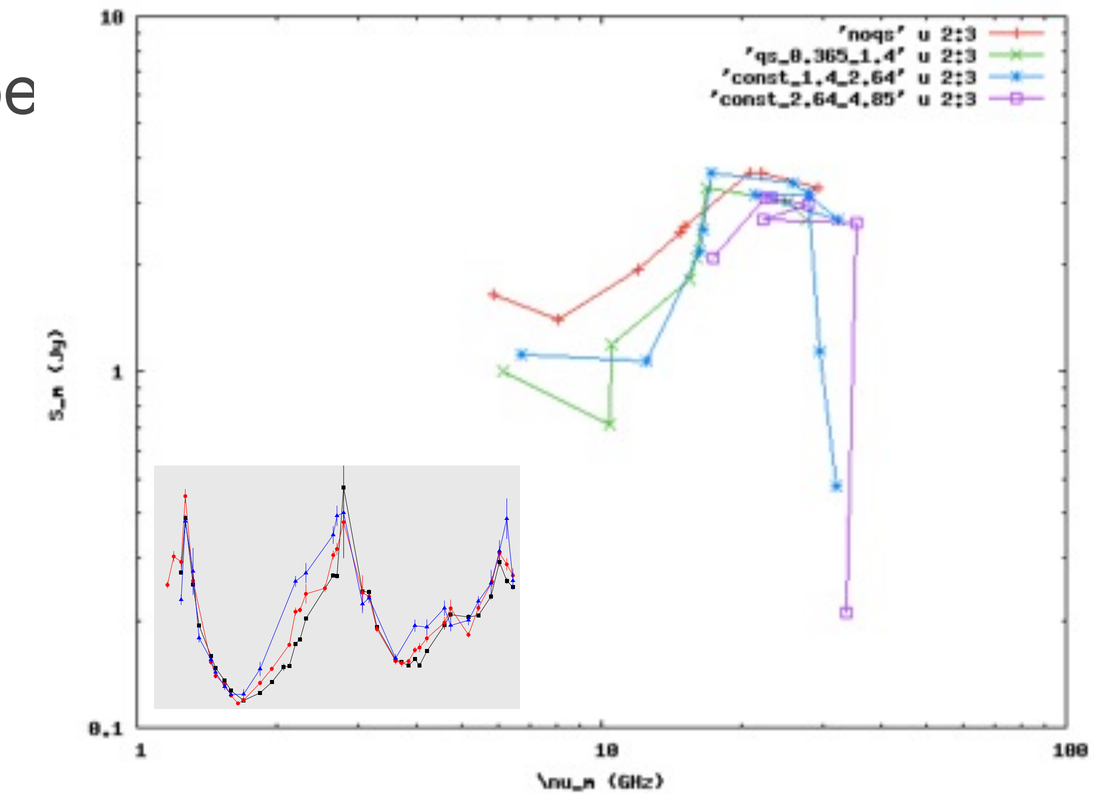
- it seems that only **two distinct mechanisms produce variability**:
  - achromatic variability
  - spectral evolution dominated
- the **shock-in-jet** model seems to provide a satisfactory description of the latter mechanism over a range of intrinsic properties

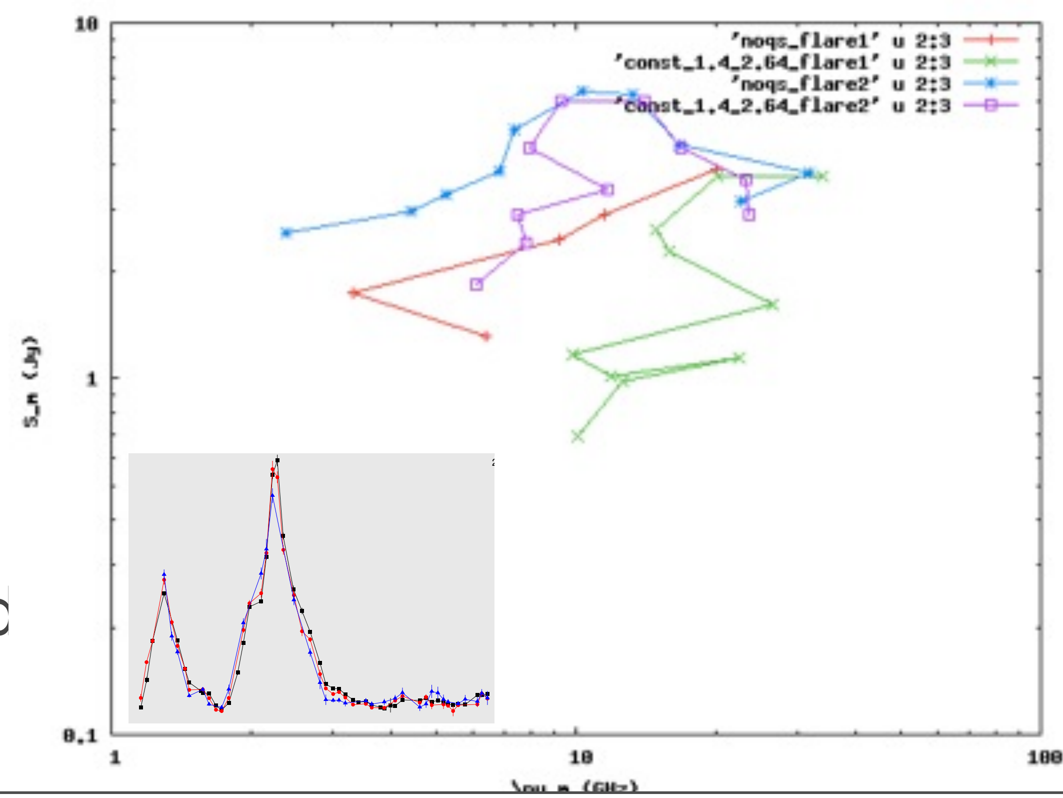
conclusions

- it is very **unclear** what mechanism produces achromatic variability: changes in the topology of **B** that would imply changes in the doppler factor **D**, **do not** seem to be the case. further investigation needed.

next steps

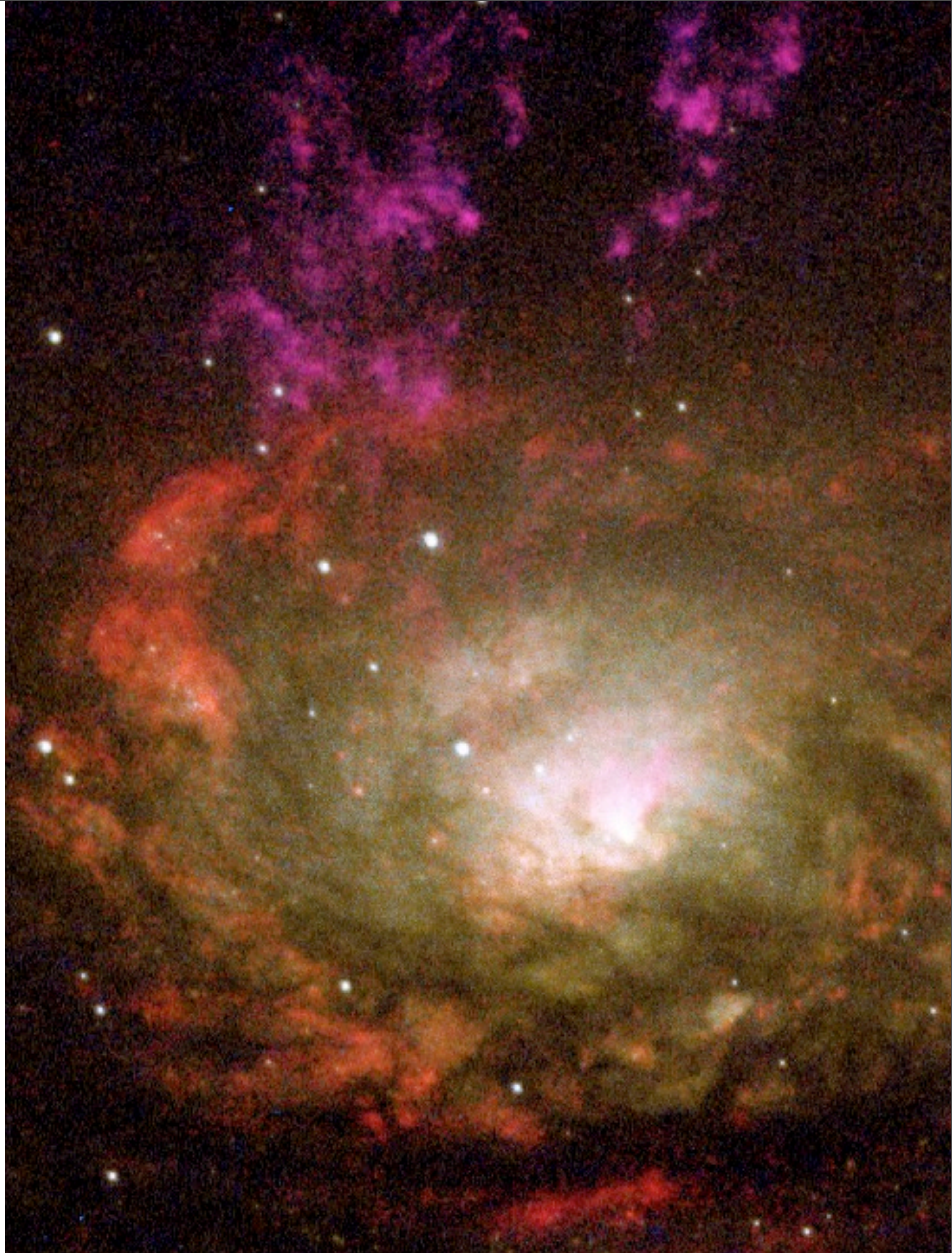
- the physical properties that determine the type
- the pace at which every evolutionary stage happens as compared with the theory
- construct the synthetic light curves
- calculate the physical parameters during the evolution of the events:
  - magnetic field strength **B** and particle density **ρ**
  - calculate the co-moving energies deposited in each event





Narrow Line Seyfert 1

- permitted lines from the BLR, BUT much narrower than typically those seen in Seyfert 1 or blazars (FWHM(Hβ) < 2000 km s^{-1})
- 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)



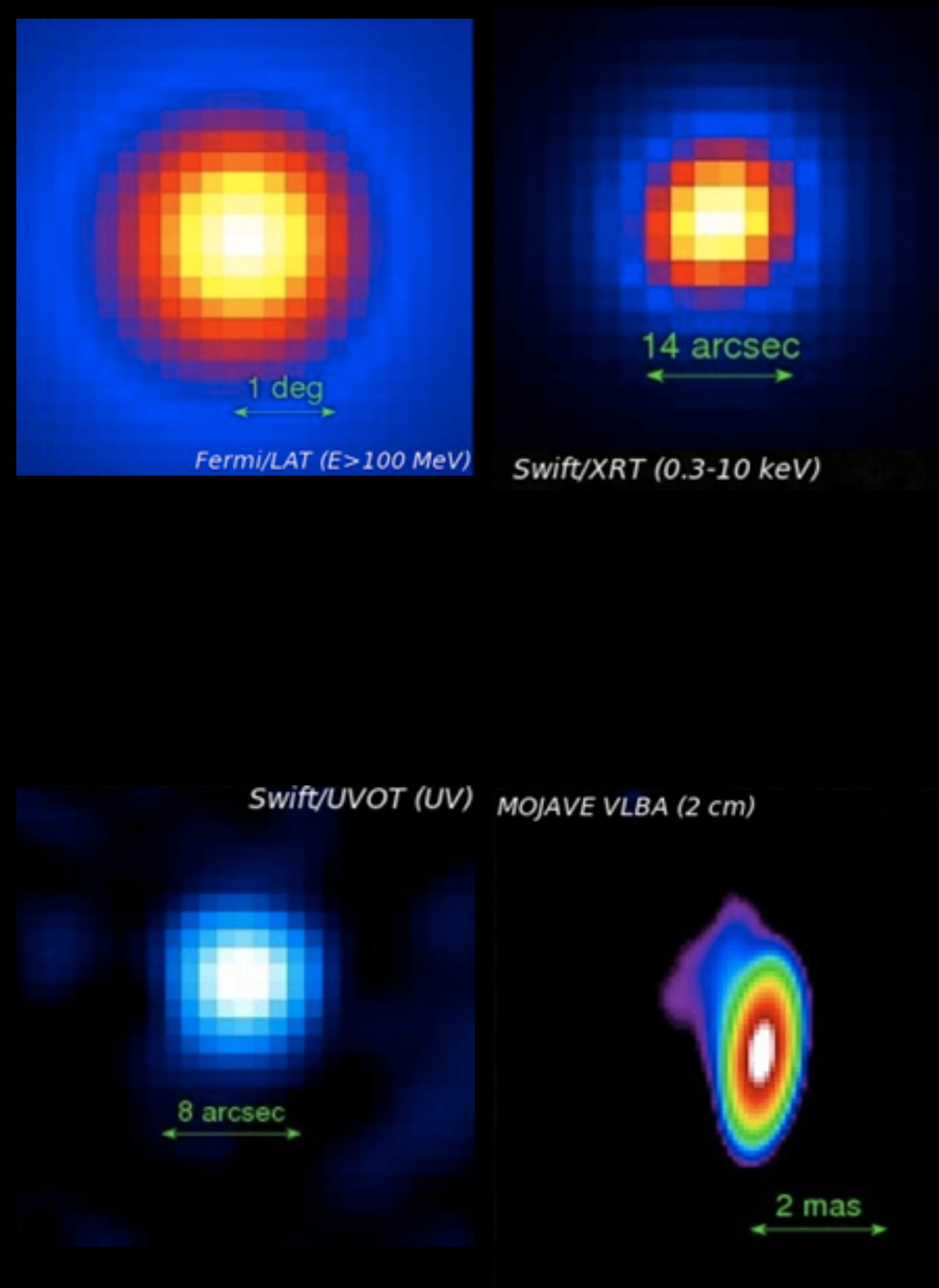
The Circinus Galaxy, a Seyfert 2 galaxy. Credit: A. S. Wilson, P. L. Shopbell, C. Simpson, T. Storchi-Bergmann, F. K. B. Barbosa, M. J. Ward, WFPC2, HST, NASA.

Fermi-GST detection of NLSy1s

- Fermi-GST detects 4 radio loud NLSy1 galaxies:

- PKS1502+036 (z = 0.409)
- 1H0323+342 (z = 0.061)
- PKS2004-447 (z = 0.24)
- PMNJ0948+0022 (z = 0.585)

(Abdo et al. 2009)

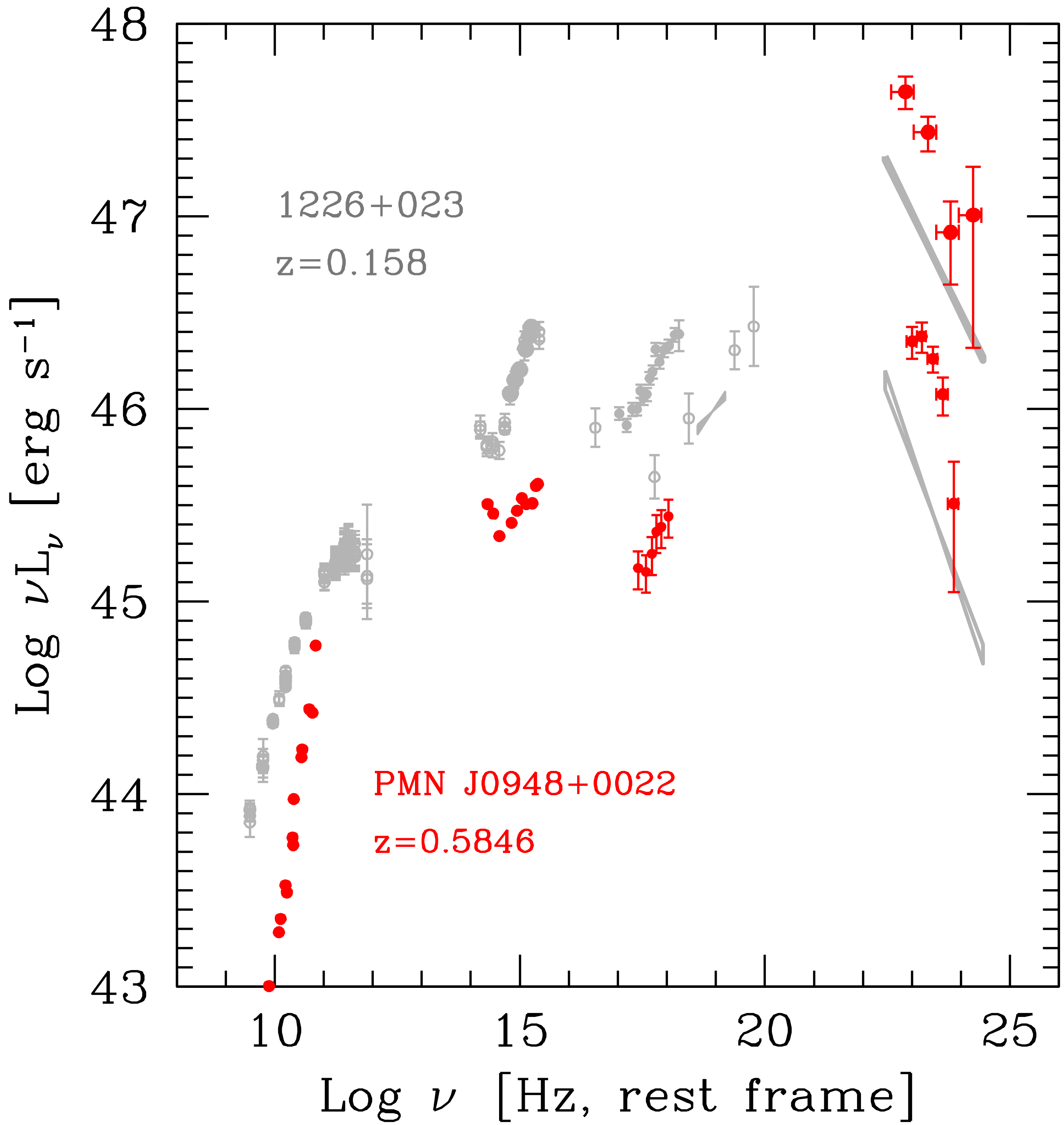


PMNJ0948+0022 for the July 2010 outburst
Foschini et al. 2010

image compilation by L. Foschini

PMN J0948+0022

- $L_\gamma \sim 10^{48}$ 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 ($1.5 \times 10^8\ M_\odot$)

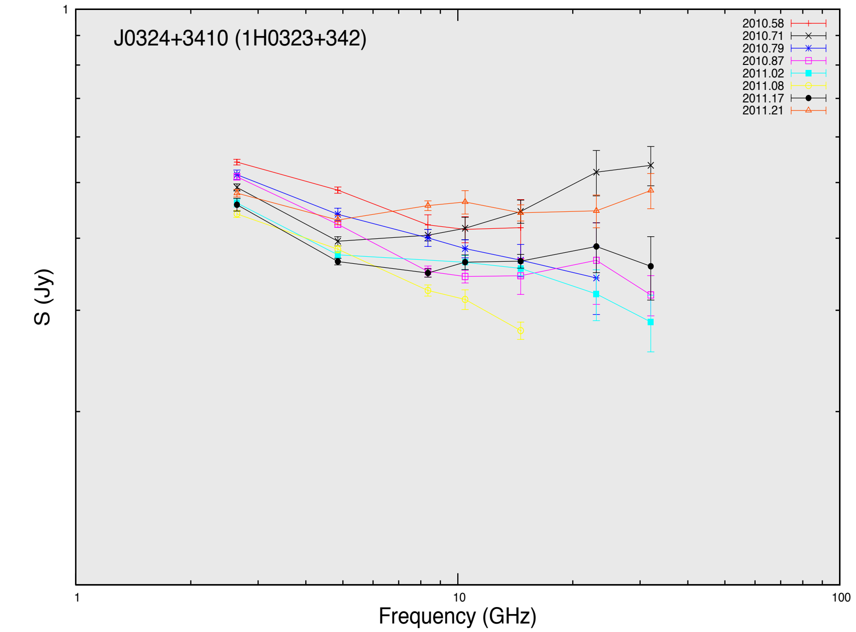


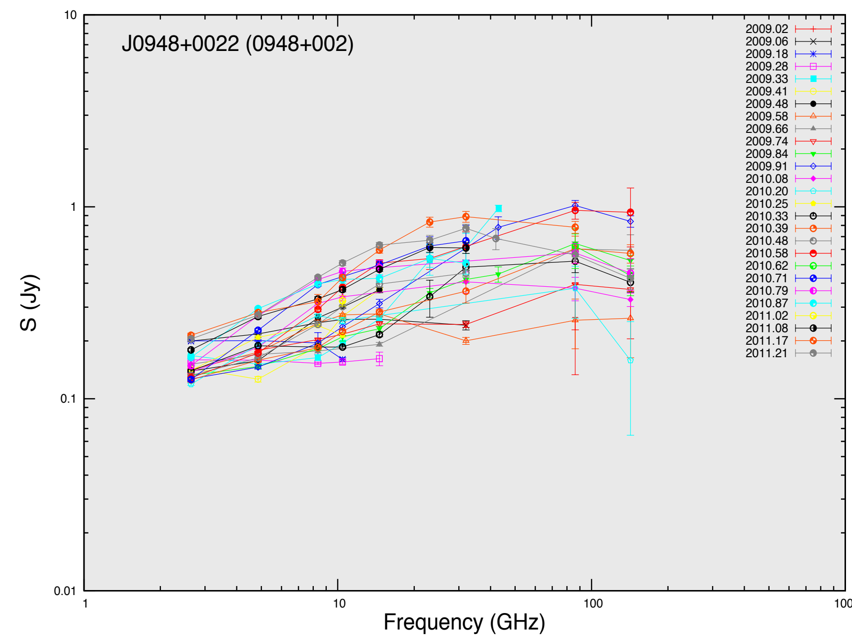
Foschini et al. 2010

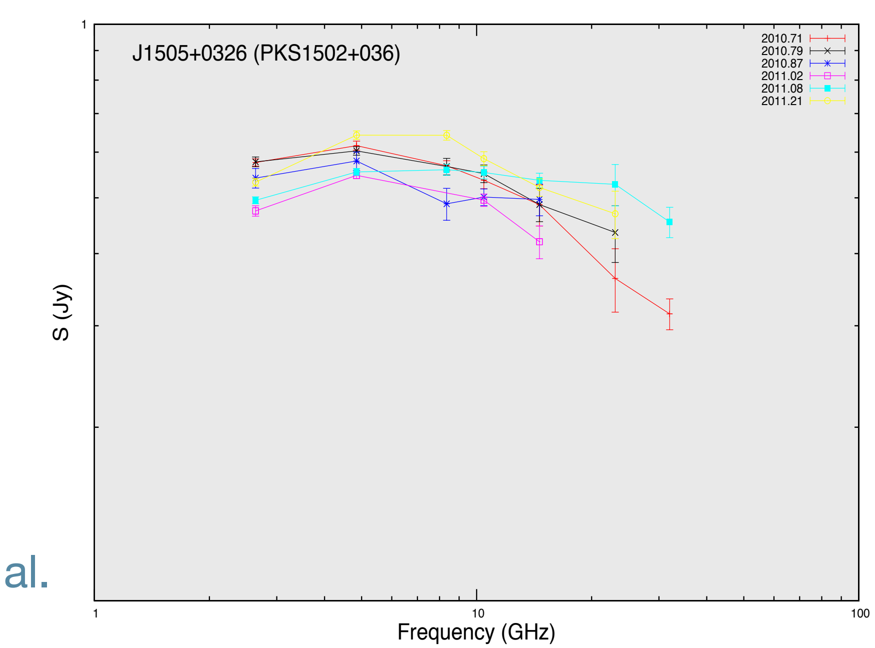
gamma-ray loud NLSy1s in radio

- J0948+0022:
  - blazar-like relativistic-jet-like behavior!
  - variability: month(s), factor 2

- J0324+3410:
  - blazar-like relativistic-jet-like
  - t_{var} > ~185 days, ΔS > ~ 20%> ~ 50 days, ΔS > ~ 70%







Fuhrmann , Angelakis et al.

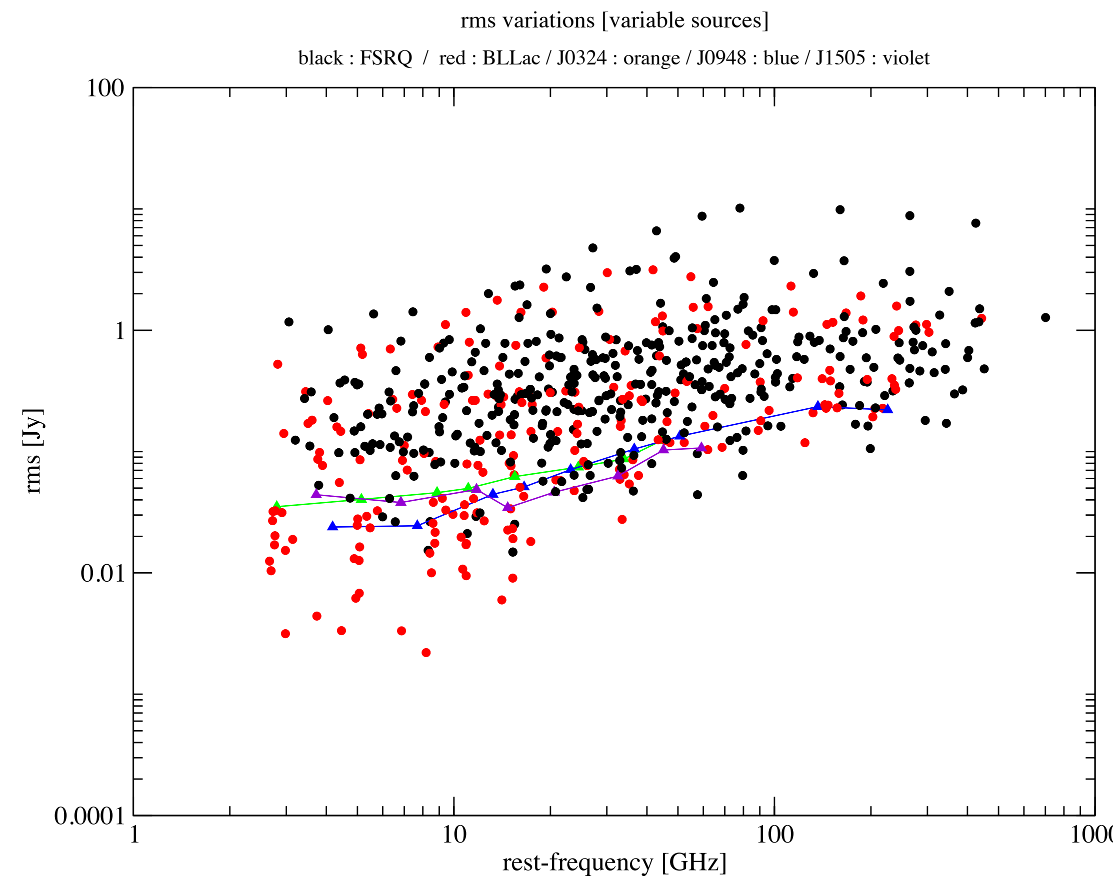
comparison with F-GAMMA blazars

- NLSy1s: lower end of rms-values
- variability characteristics:

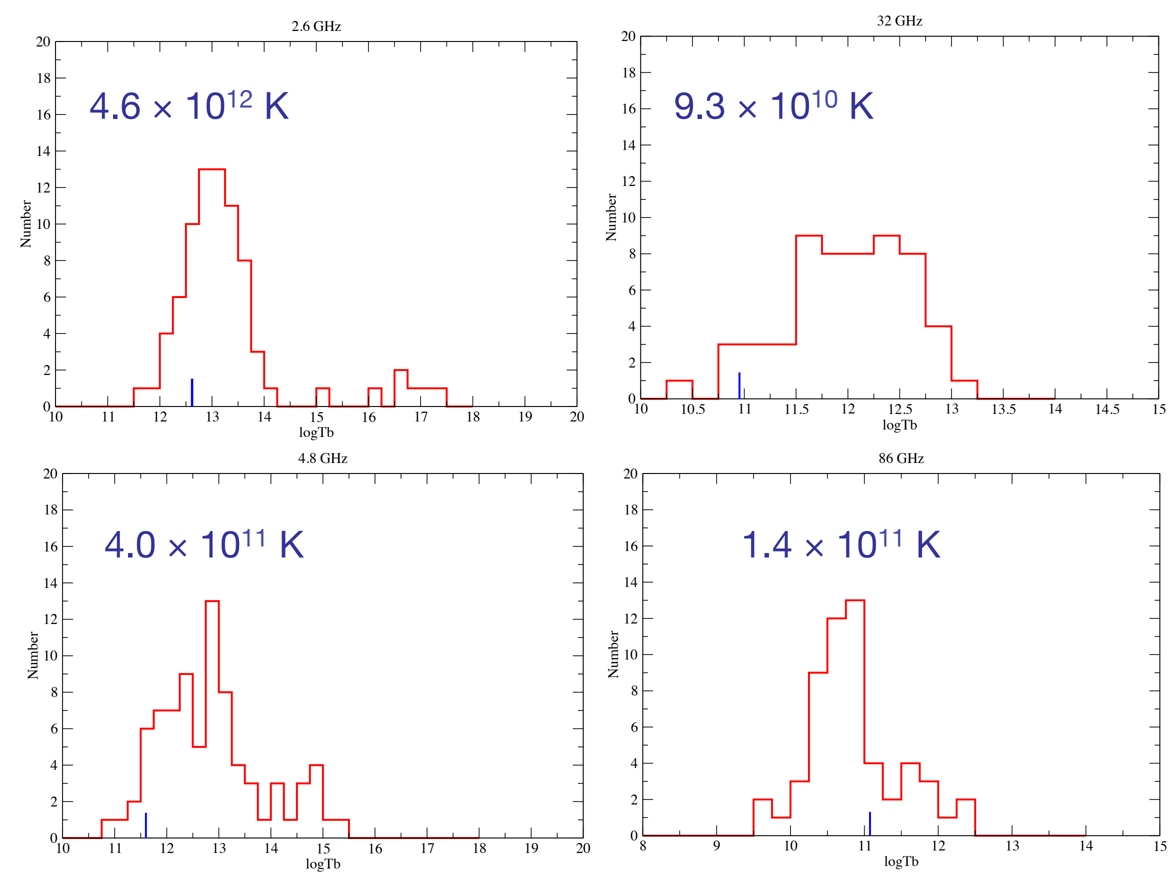
$$T_{\mathrm{B}} = 8.47 \times 10^{4} \cdot S_{\lambda} \left(\frac{\lambda\, d_L}{t_{\mathrm{var},\lambda}\,(1+z)^2} \right)^2$$

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

- blazars: typically $T_B \sim 10^{12}$–10^{14}K, corresponding Doppler factors: $T_B^{app} \sim \delta^3 \times T_B^{lim,IC}$ -> $\delta \sim 1 - 5$
- NLSy1s: typically lower T_B



NOTE in blue are the T_B for J0948+0022



Fuhrmann , Angelakis et al.

conclusions

- typical blazar jet-like behavior
- differences in the variability characteristics e.g. lower T_B, less Doppler-boosted than typical blazars
- intense spectral evolution behavior in J0948+0022 rather fast
- future VLBI monitoring important to study NLSy1 jet parameters
- "The comparison with the SED of a typical blazar with a strong accretion disk (3C 273) shows that the Compton dominance is more extreme in the NLSy1s. The disagreement of the two SEDs can be accounted by the differences in mass of the central black hole and Doppler factor of the two jets."

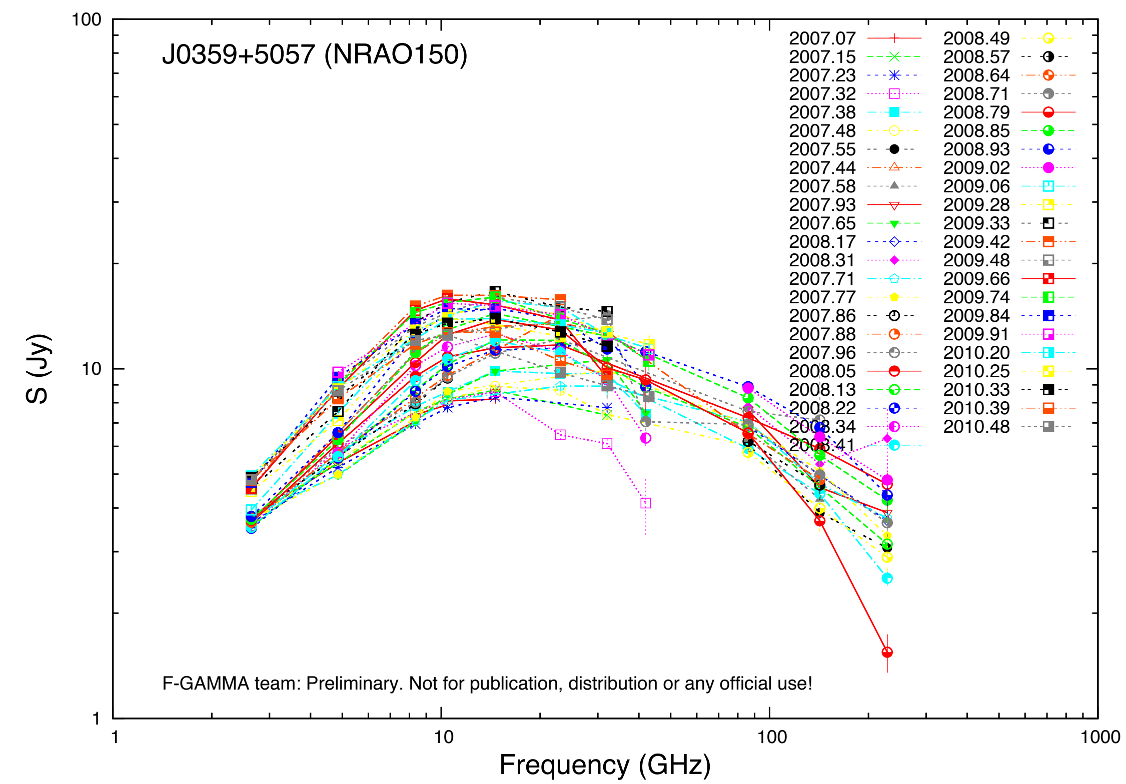
Foschini et al. 2010.

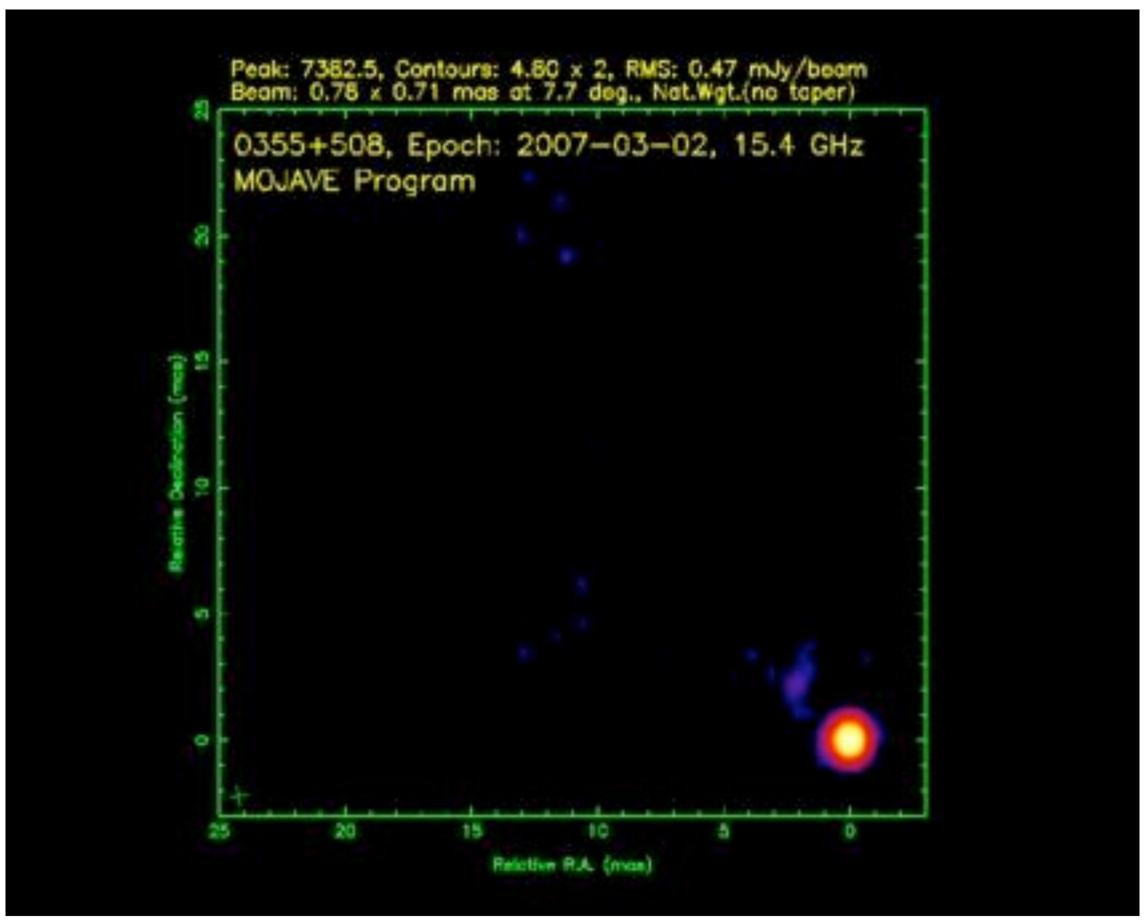
F-GAMMA PROJECT

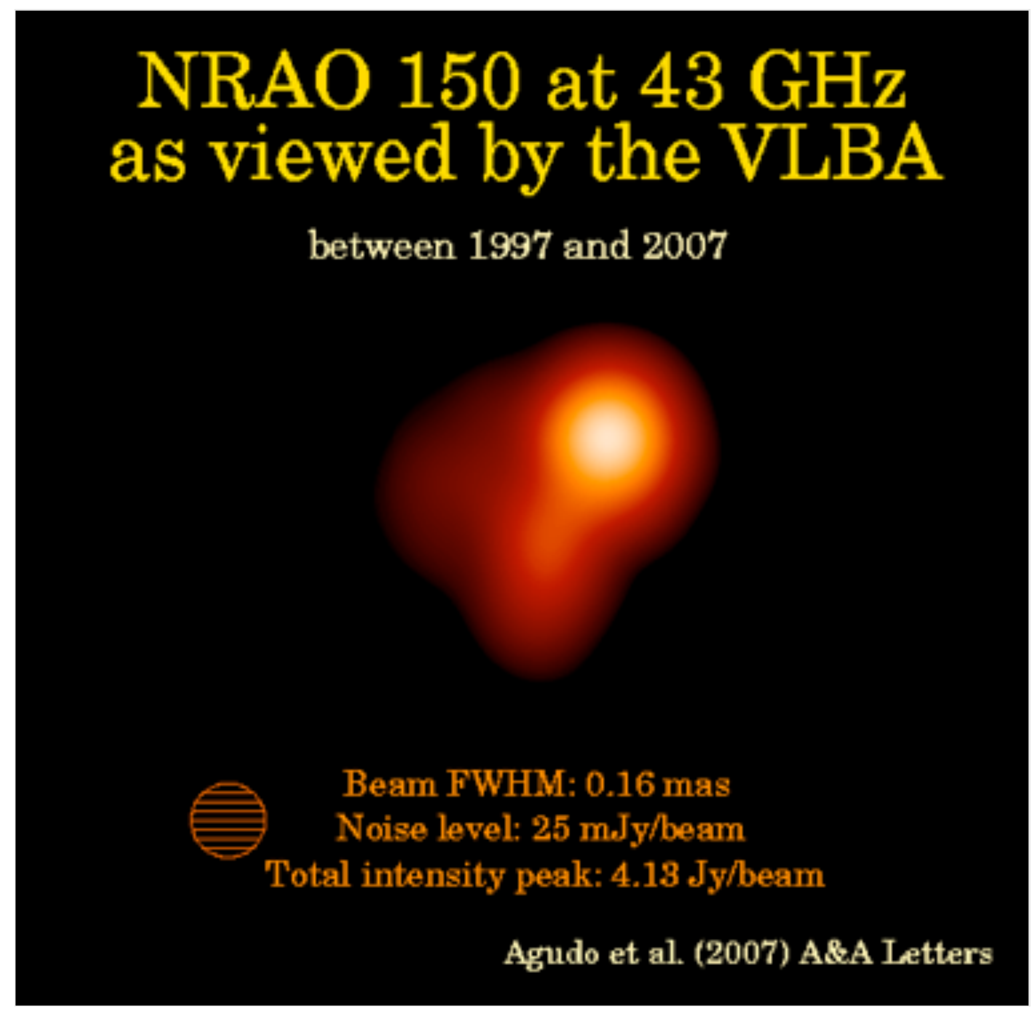
FERMI-GST AGN MULTI-FREQUENCY MONITORING ALLIANCE

thank you!

www.mpifr.de/div/vlbi/fgamma







The case of NRAO 150

Agudo et al. 2007