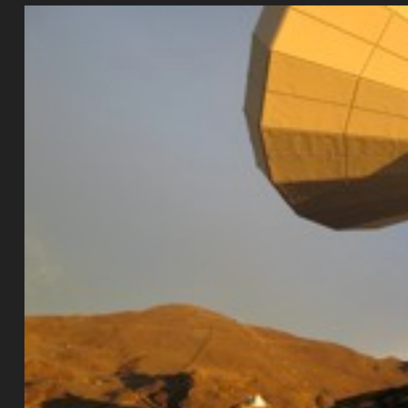
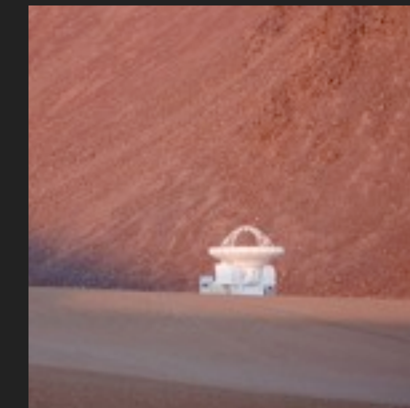
100-m Effelsberg
covers the band 2.64 - 43 GHz with a precision of a few percent for monthly sampling of 60 sources



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 program: multi-wavelength AGN studies in the Fermi-GST era

E. Angelakis

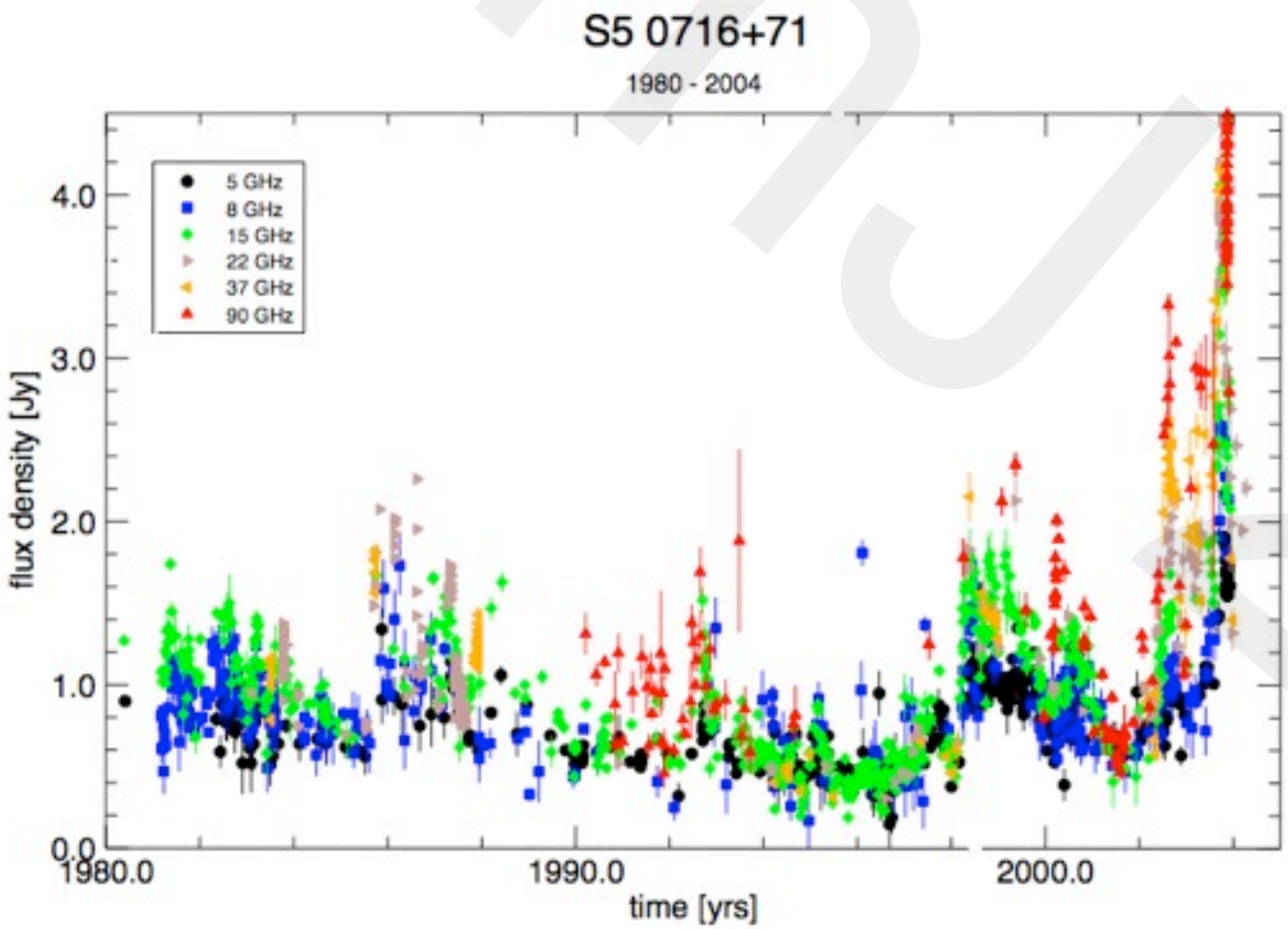
and L. Fuhrmann[1], I. Nestoras[1], J. A. Zensus[1], N. Marchili[1] and T. P. Krichbaum[1]
A. C. S. Readhead[2], V. Pavlidou[2], J. Richards[2], W. Max-Moerbeck[2], T. Pearson[2]

[1] Max-Planck-Institut für Radioastronomie, Auf dem Hgel 69, Bonn 53121, Germany
[2] California Institute of Technology, 1200 East California Blvd., Pasadena CA 91125, USA

blazar phenomenology

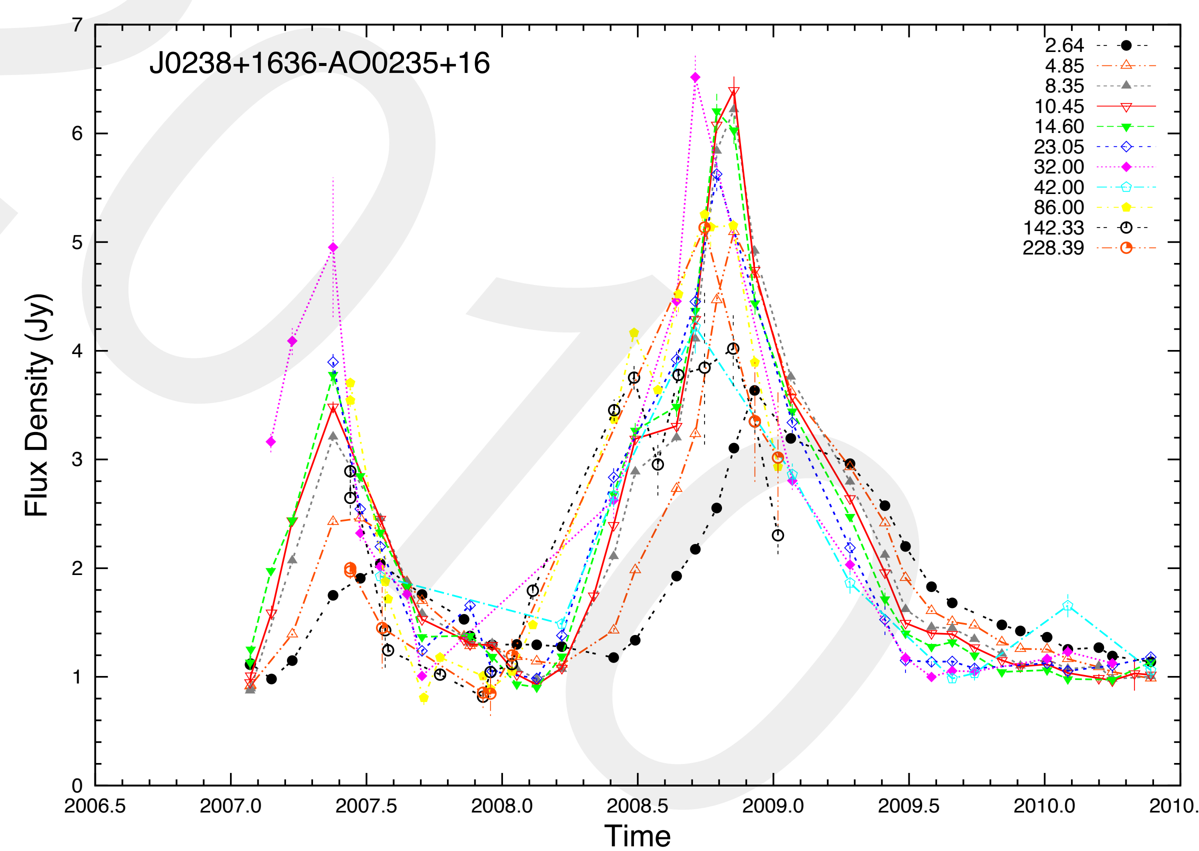
F-GAMMA

extreme variability - time domain



Fuhrmann et al. 2008

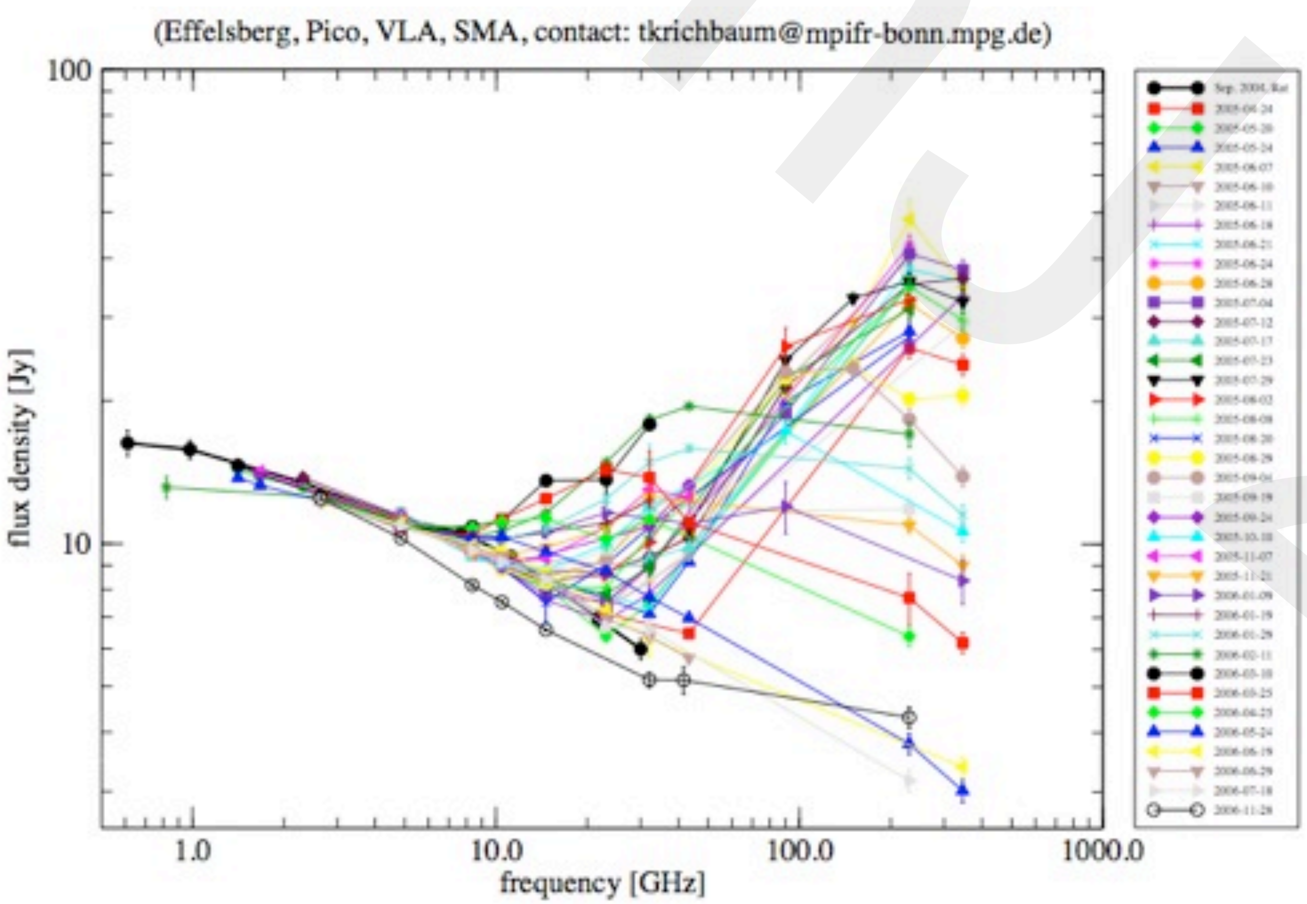
Angelakis et al. in prep.



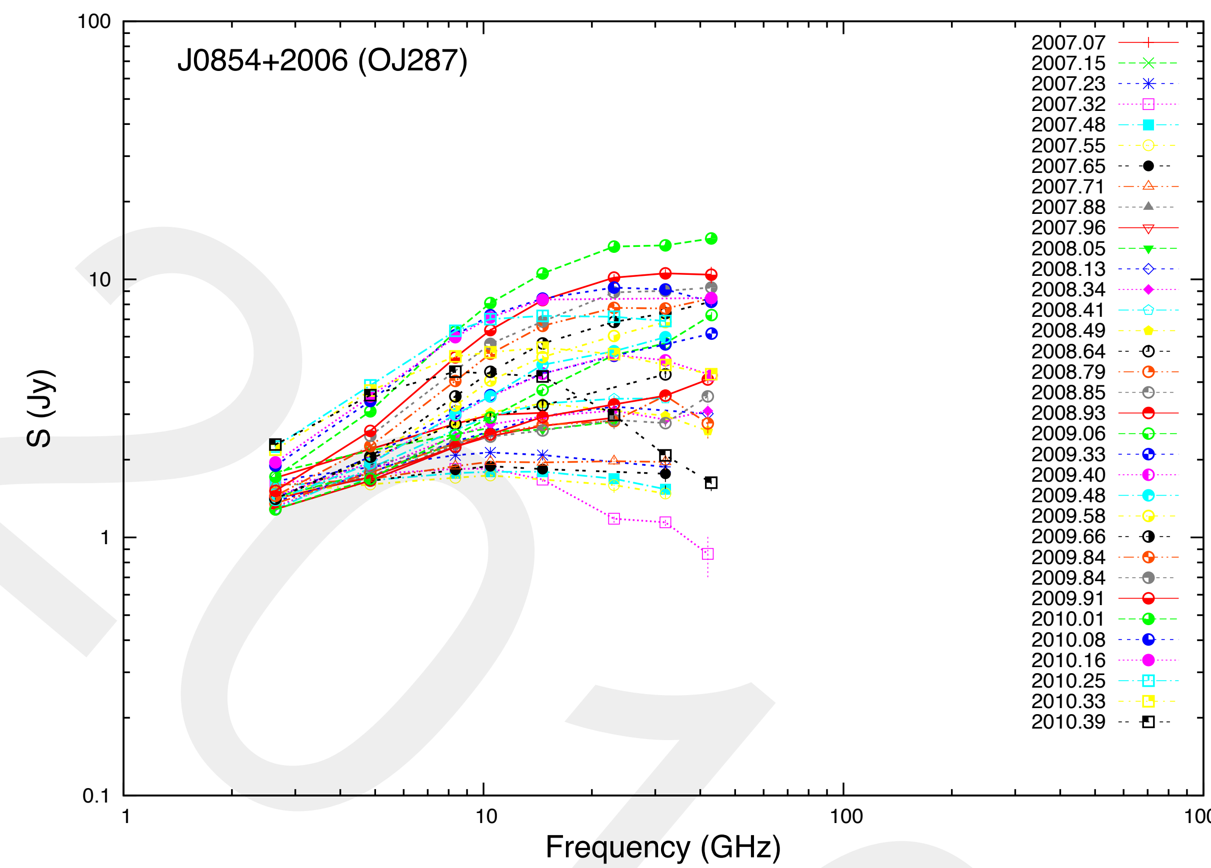
blazar phenomenology

F-GAMMA

extreme variability - frequency domain



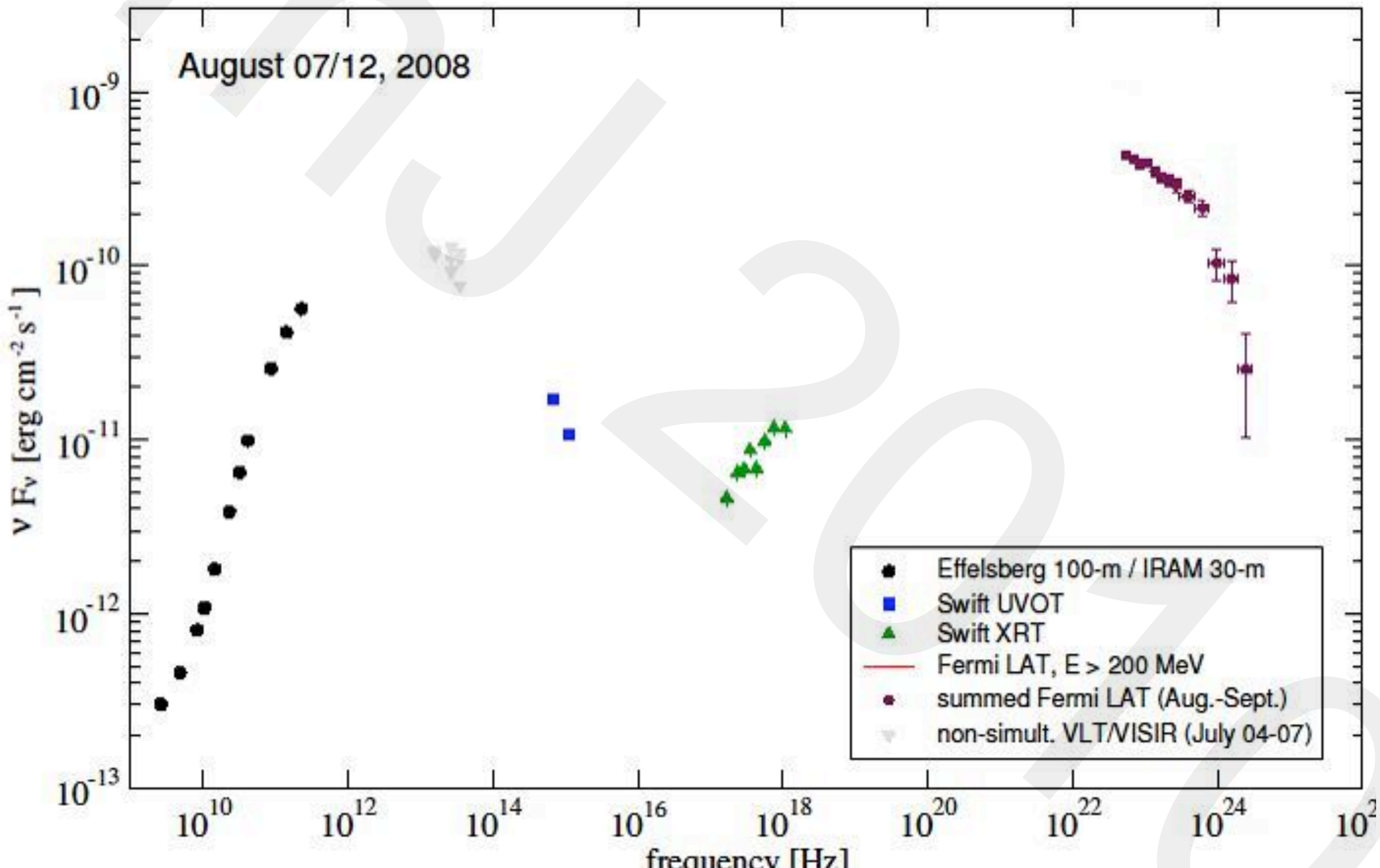
Krichbaum et al. in prep.



Angelakis et al. in prep.

blazar phenomenology

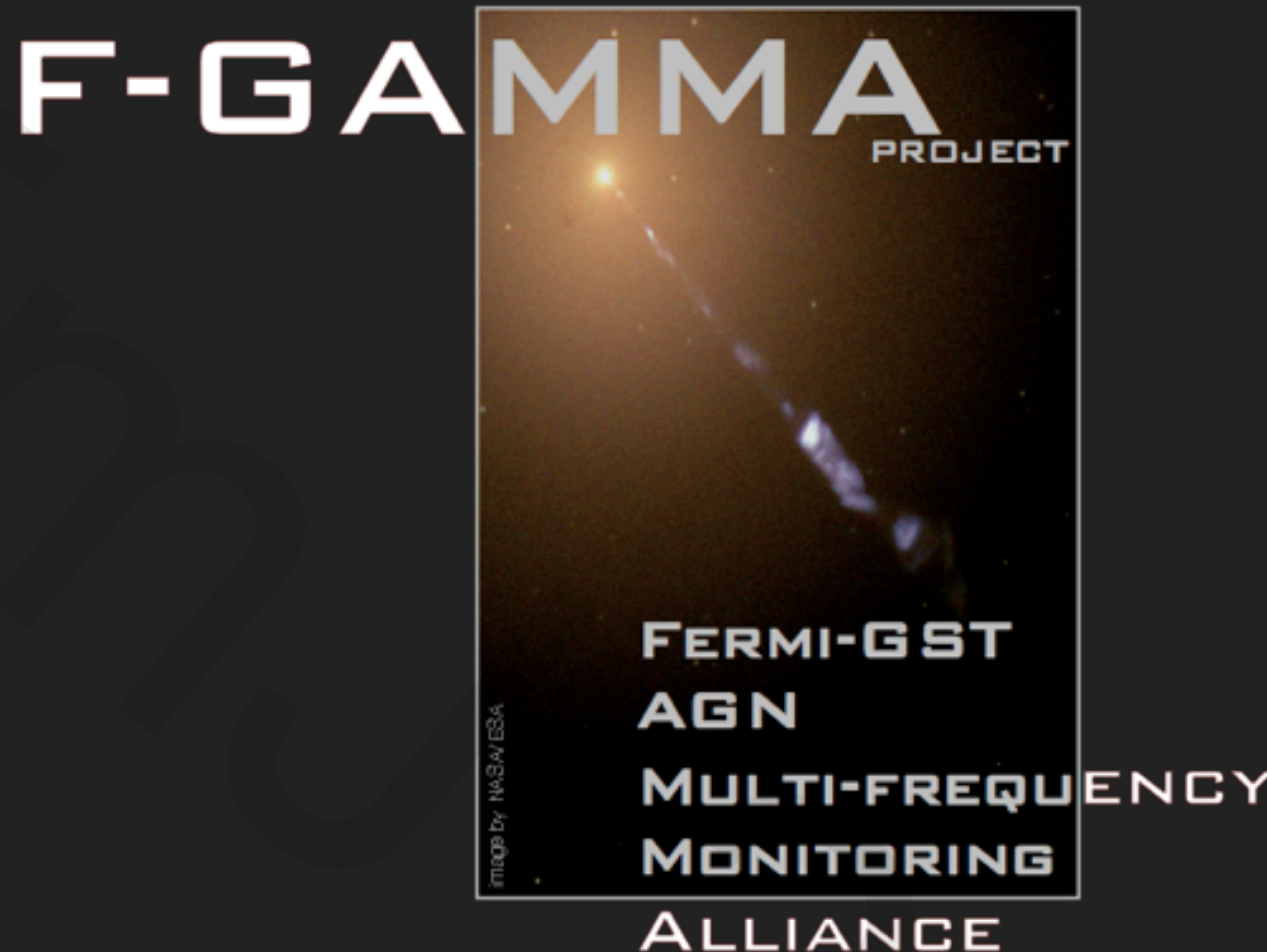
broad-band emission characteristics



Abdo et al. 2009

blazar phenomenology

high degree of linear polarization
extreme brightness temperatures
highly super-luminal motions



for spectra and LCs visit:

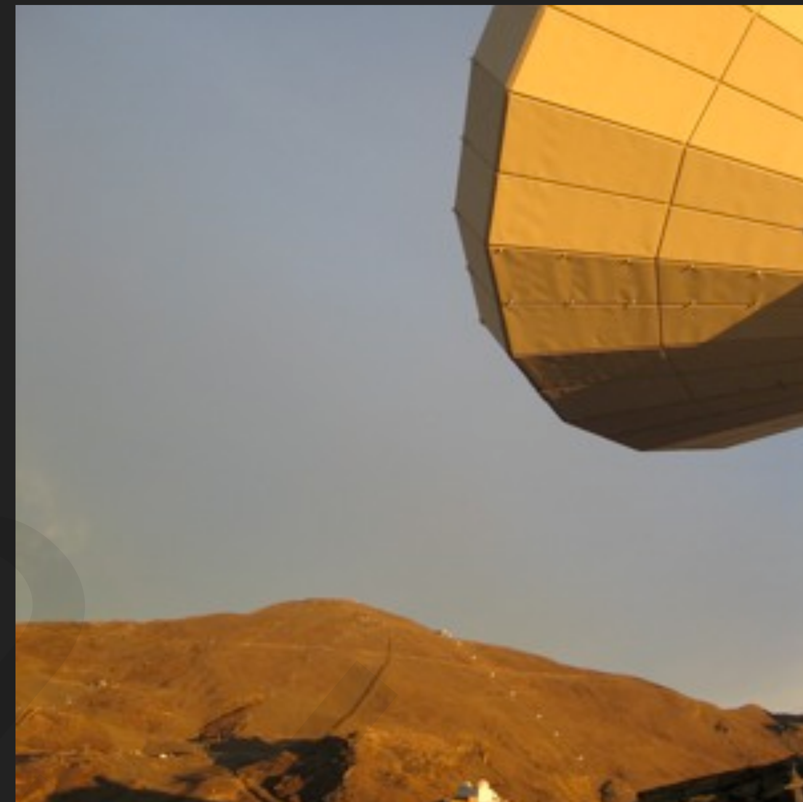
www.mpifr.de/div/vlbi/fgamma

F-GAMMA program

Fermi-GST AGN Multi-wavelength Monitoring Alliance:
monthly monitoring program of ~60 *Fermi*-GST blazars at 2.6 - 345 GHz

100-m Effelsberg

- Monthly monitoring of ~60 sources
- 2.64 - 43 GHz at 8 frequency steps
- LCP/RCP 2.64, 4.85, 8.35, 10.45, 14.60 GHz and LCP: 32 GHz
- Simultaneous spectra within 40 minutes
- accuracy ~1% at low and <5% at high frequencies



30-m IRAM

- Monthly monitoring of ~60 sources
- 86, 142 and 228 GHz
- Linear Polarization
- Simultaneous spectra within 5-10 minutes
- accuracy <15%

12-m APEX

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

F-GAMMA program

Fermi-GST AGN Multi-wavelength Monitoring Alliance:
monthly monitoring program of ~60 *Fermi*-GST blazars at 2.6 - 345 GHz

100-m Effelsberg

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

30-m IRAM

H. Ungerechts, D. Riquelme, A. Sievers, C. Thum, I. Agudo

12-m APEX

S. Larson, A. Weiss et al.

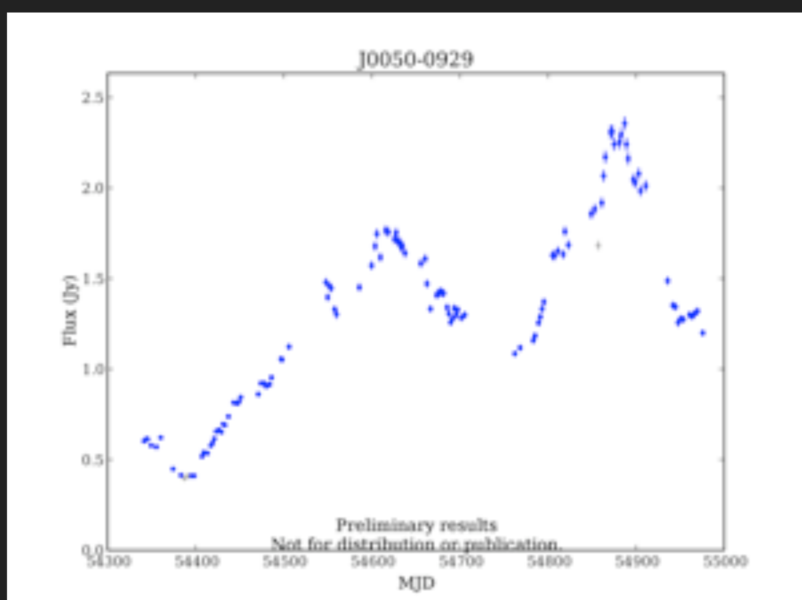
F-GAMMA program

Fermi-GST AGN Multi-wavelength Monitoring Alliance:
monthly monitoring program of ~60 *Fermi*-GST blazars at 2.6 - 345 GHz

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



Richards et al. et al. in prep.

F-GAMMA program

Fermi-GST AGN Multi-wavelength Monitoring Alliance:

monthly monitoring program of ~60 *Fermi*-GST blazars at 2.6 - 345 GHz

1.3 m Skinakas telescope, Crete, Greece

I. Papadakis

AIT, Perugia, Italy

G. Tosti

***Fermi*-GST**

J. A. Zensus (Affiliated Scientist), L. Fuhrmann (Affiliated PostDoc), I. Nestoras (Affiliated Student)

F-GAMMA program

Fermi-GST AGN Multi-wavelength Monitoring Alliance:

monthly monitoring program of ~60 *Fermi*-GST blazars at 2.6 - 345 GHz

“first” source sample

prominent gamma-ray candidate blazars:

0003-066	3C120	3C273	1ES1959+650
0059+581	1ES0502+675	M87	PKS2155-152
PKS0215+015	PKS0528+134	3C279	2155-304
3C66A	S50716+71	OP313	BLLac
4C28.07	PKS0735+17	PKS1406-076	S51803+78
AO0235+16	0748+126	H1426+428	3C371
NGC1052	TXS0814+425	1502+106	4C56.27
4C47.0	OJ248	PKS1510-08	Mkn180
1E0317.0+1835	S50836+71	1ES1544+820	TON599
3C84	OJ287	OS319	WCom
OE355	S40954+65	1622-297	4C21.35
PKS0336-01	PKS1038+064	4C38.41	4C31.63
NRAO150	Mkn421	3C345	3C446
3C111	1128+592	Mkn501	OY150
PKS0420-01	PKS1127-14	PKS1730-13	
3C454.3	1ES2344+514	PKS2345-16	

Fuhrmann et al. in prep.

“first” source sample

detectability in the 3-month list Abdo et al. (2009a):

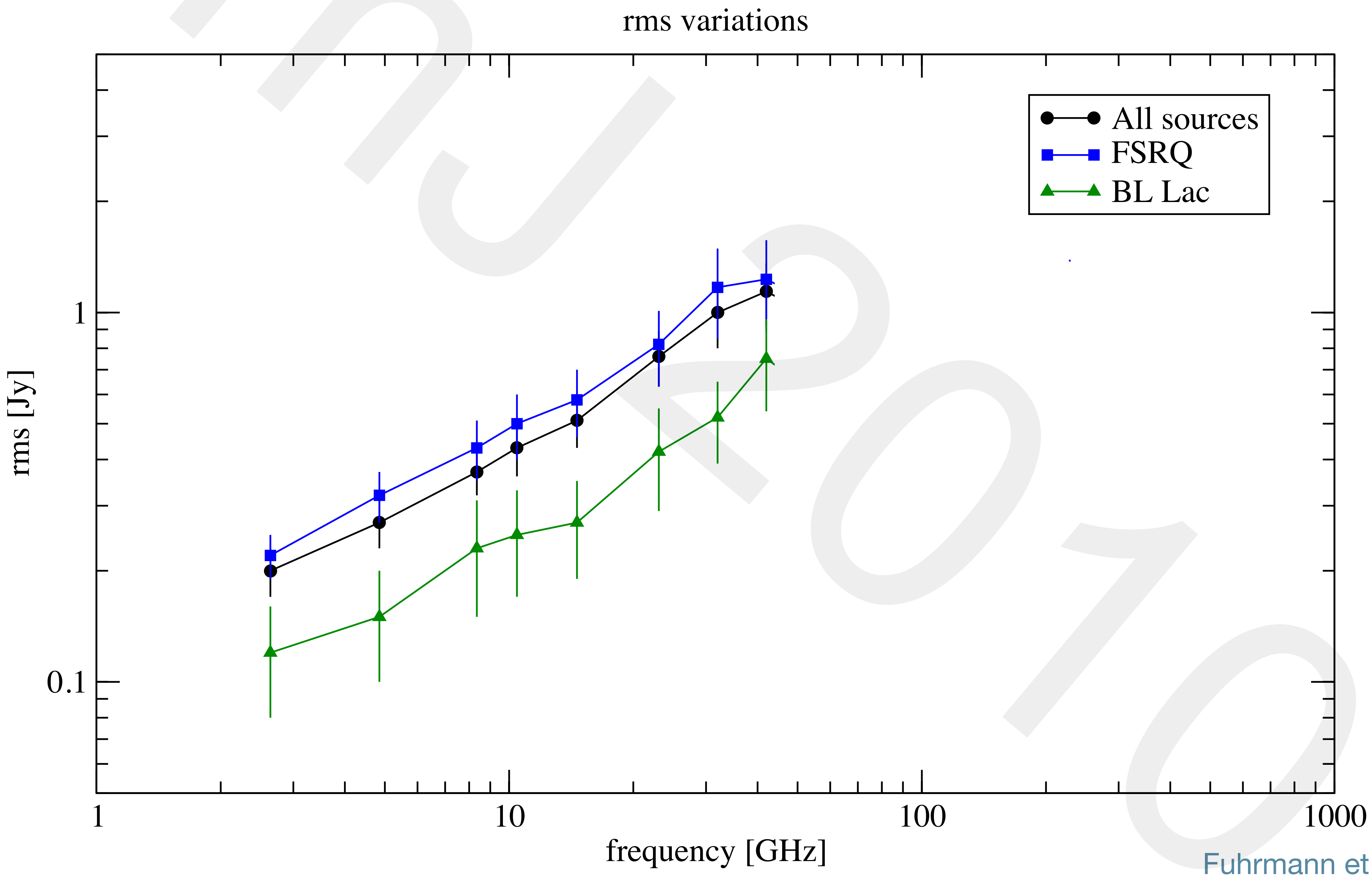
			LAT detected[*]
FSRQs[**]	32	52%	15
BL Lacs[**]	23	38%	12
Radiogalaxies[**]	3	5%	1 (3C84)
Blazars[**]	3	5%	0
Total	61		28 (46%)

[*]Abdo et al., 2009a
[**]Massaro et al. 2005, 2008, 2009,

Fuhrmann et al. in prep.

2.5-year data

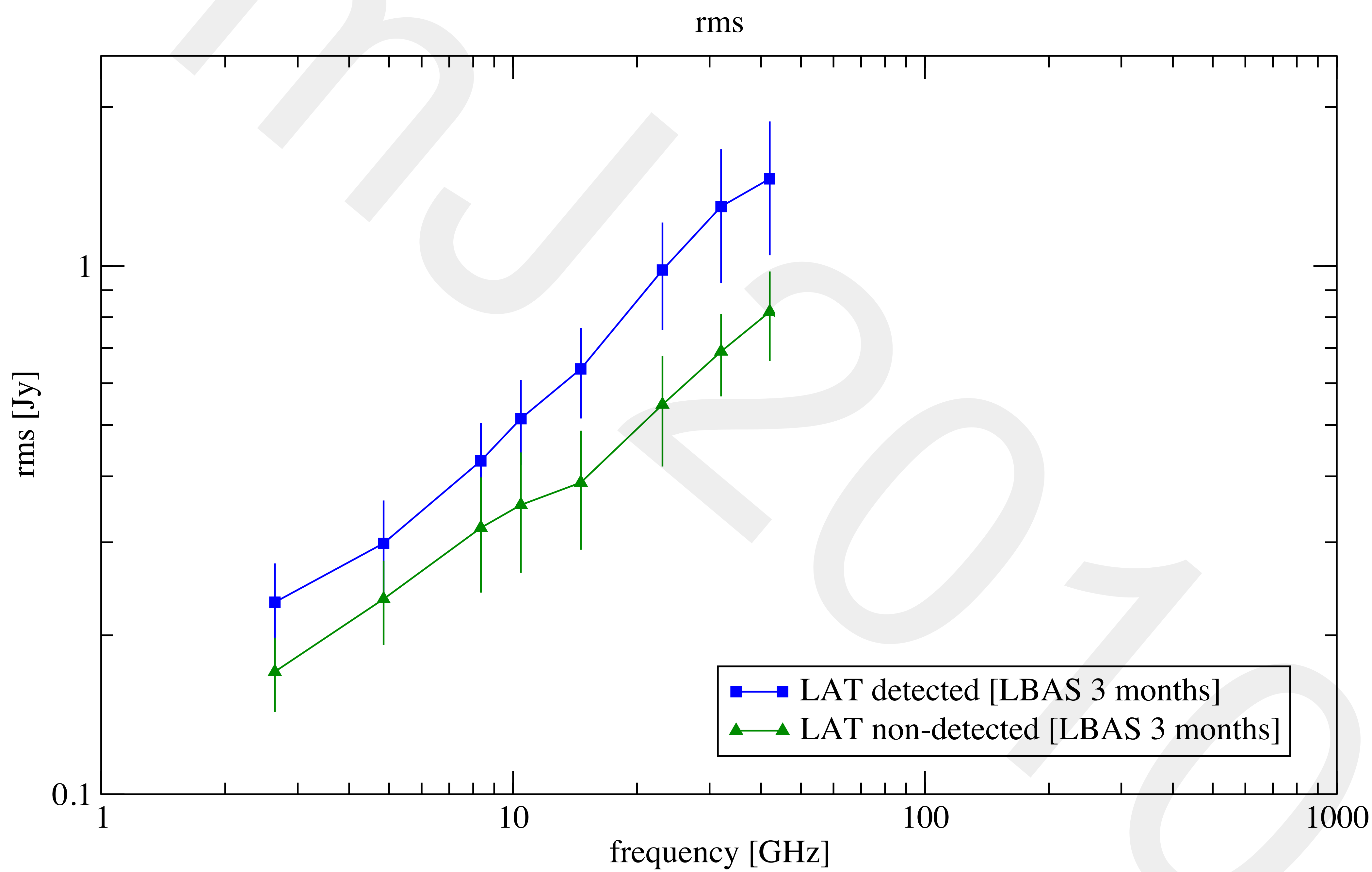
dependence of the variability amplitude on class and frequency:



Fuhrmann et al. in prep.

2.5-year data

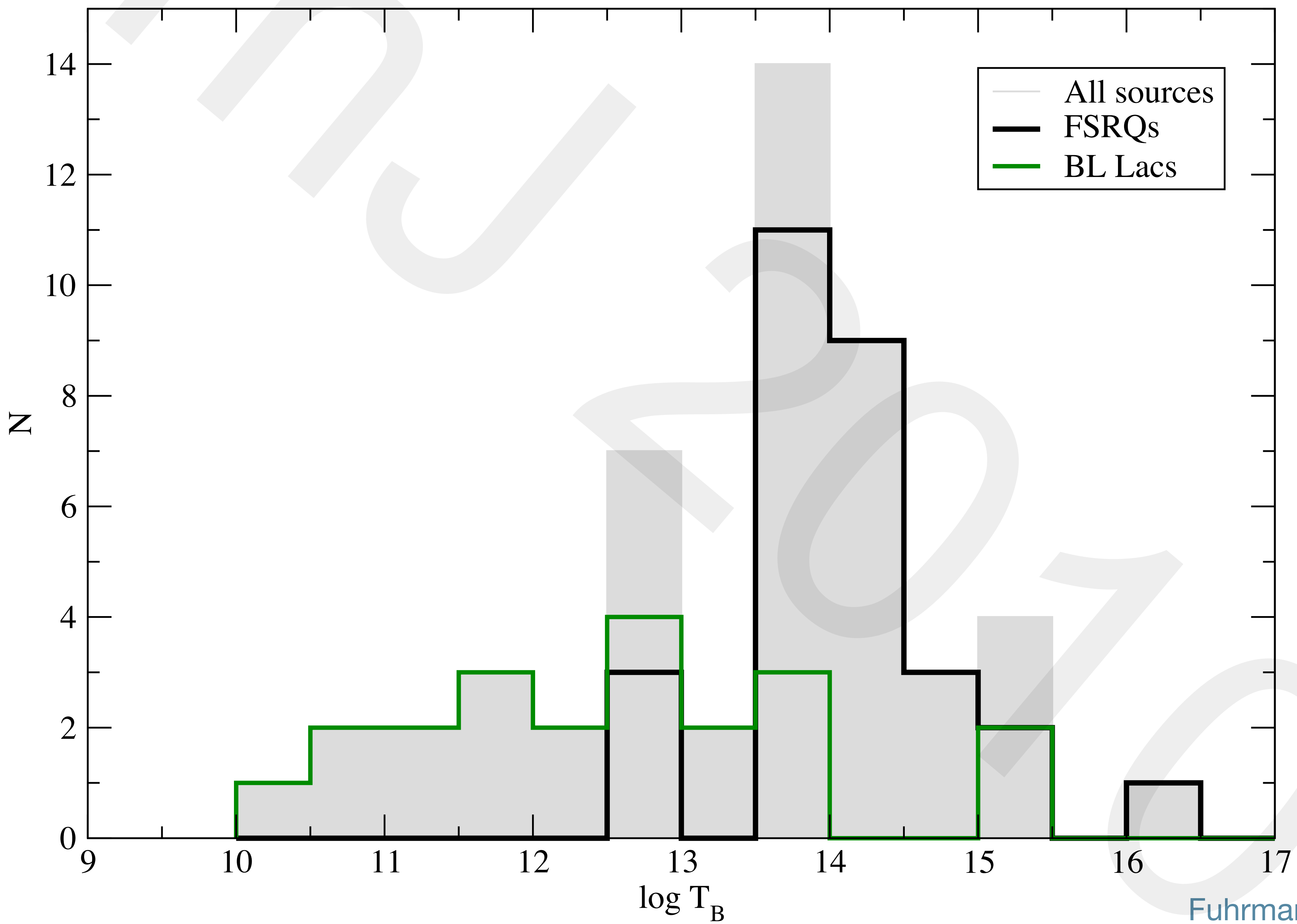
variability amplitude vs. LAT detectability:



Fuhrmann et al. in prep.

2.5-year data

the maximum brightness temperature distribution:

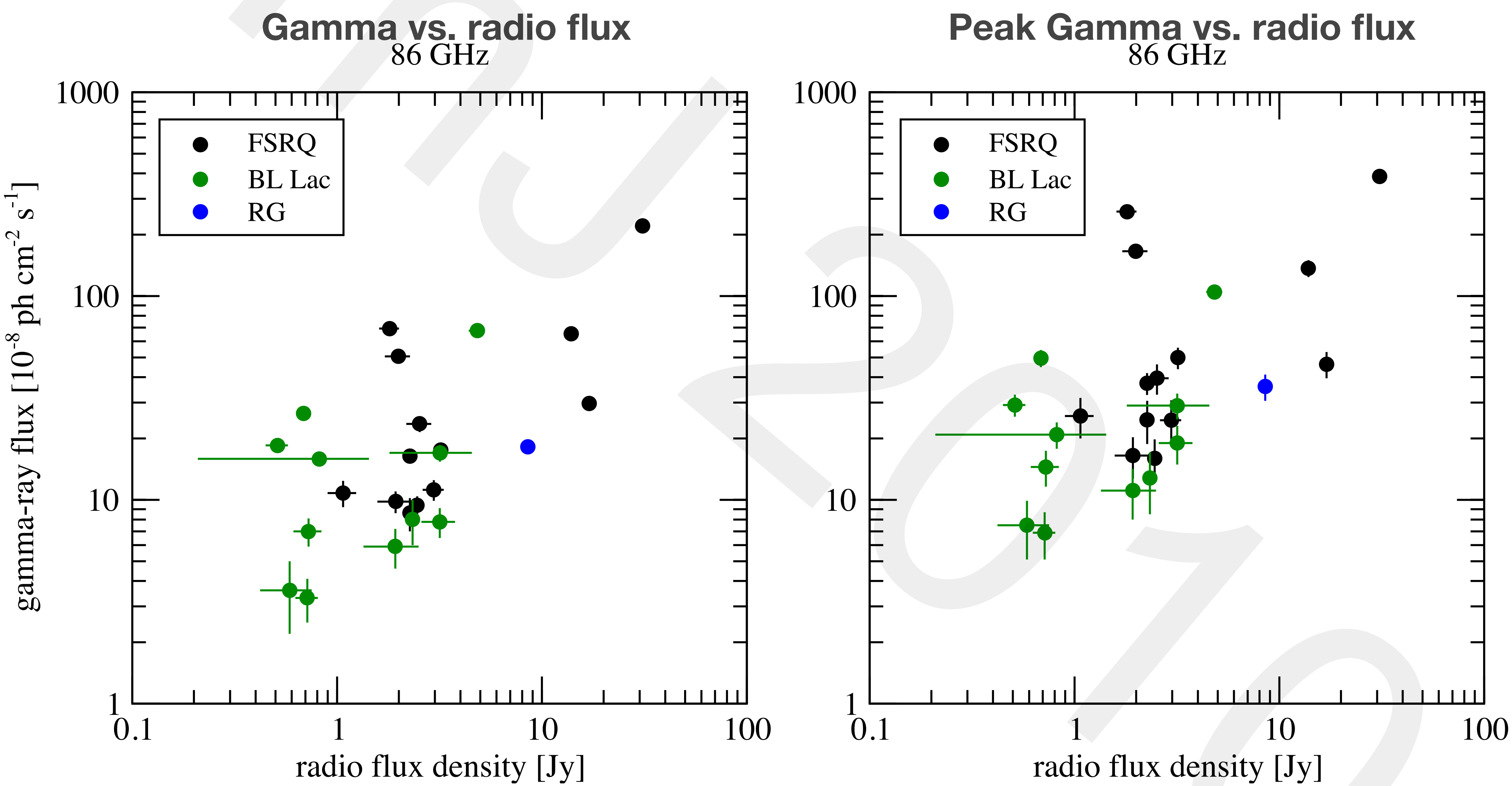


Fuhrmann et al. in prep.

2.5-year data

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

S-S correlation: P = 2.2 x10^{-4} for r=0.68 to come from uncorrected S's:



Pavlidou et al. in prep.

	FSRQs	BL Lacs	Blazars	Sy	RG	Total
old sources	19	13	3	1	2	38
3-month list	19	14	3	0	1	37
11-month list	34	17	6	0	1	58
Total	36	17	9	1	2	65

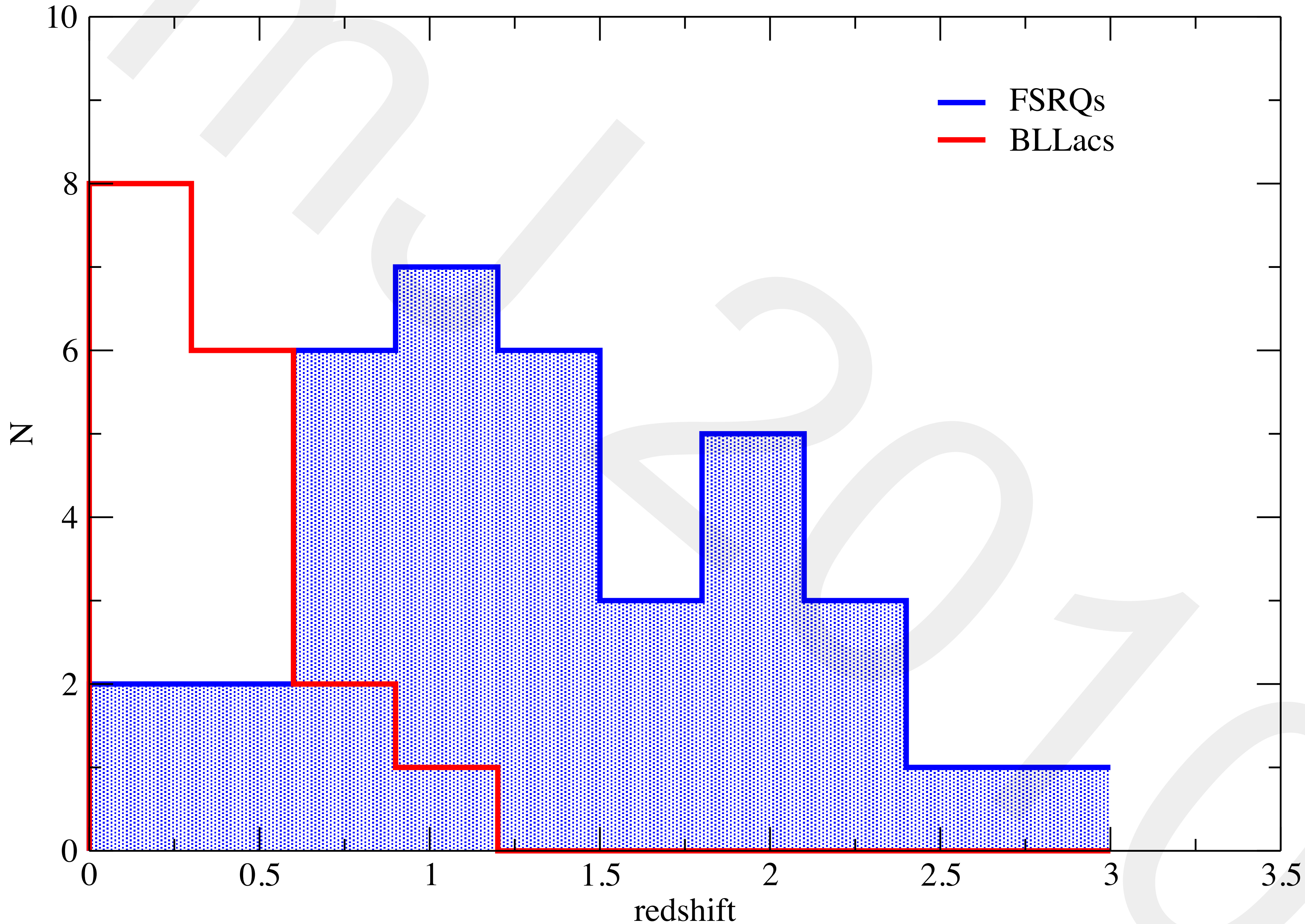
F-GAMMA program

the new sample

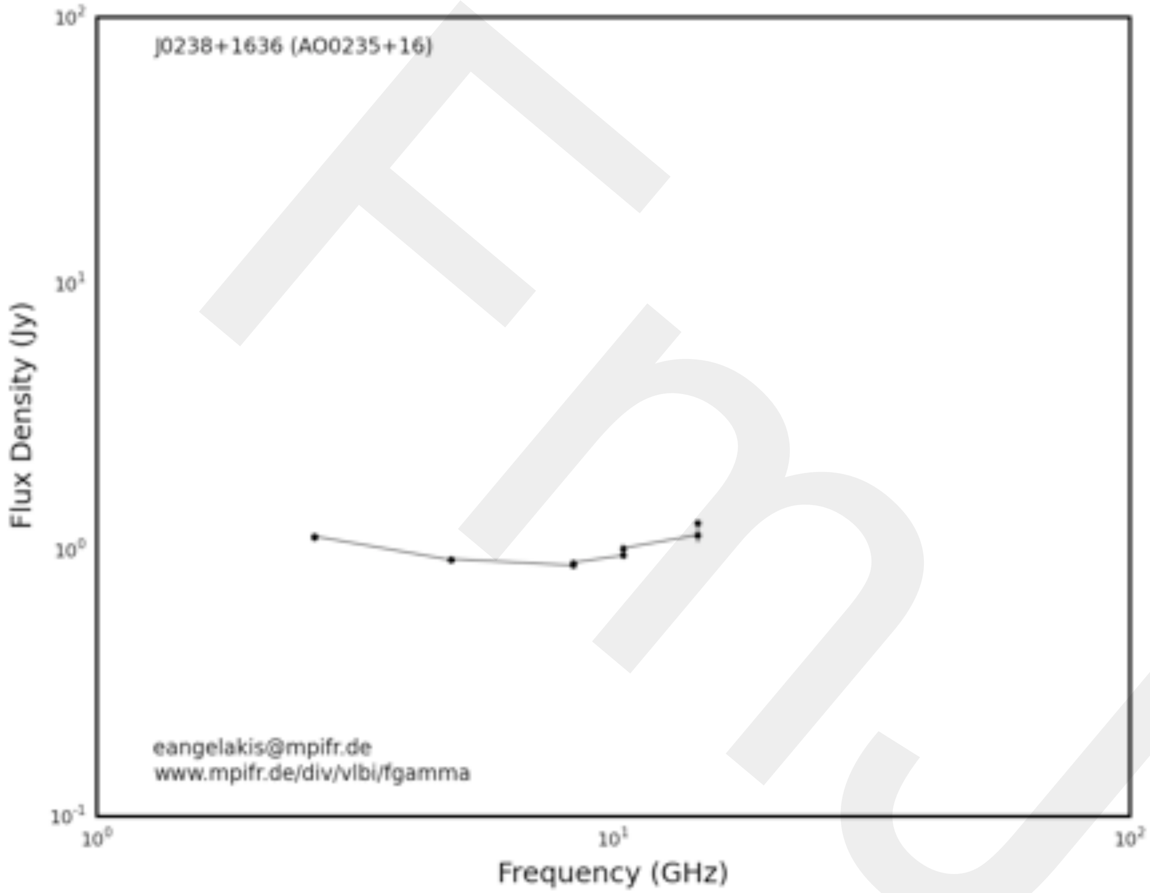
3.5-year data

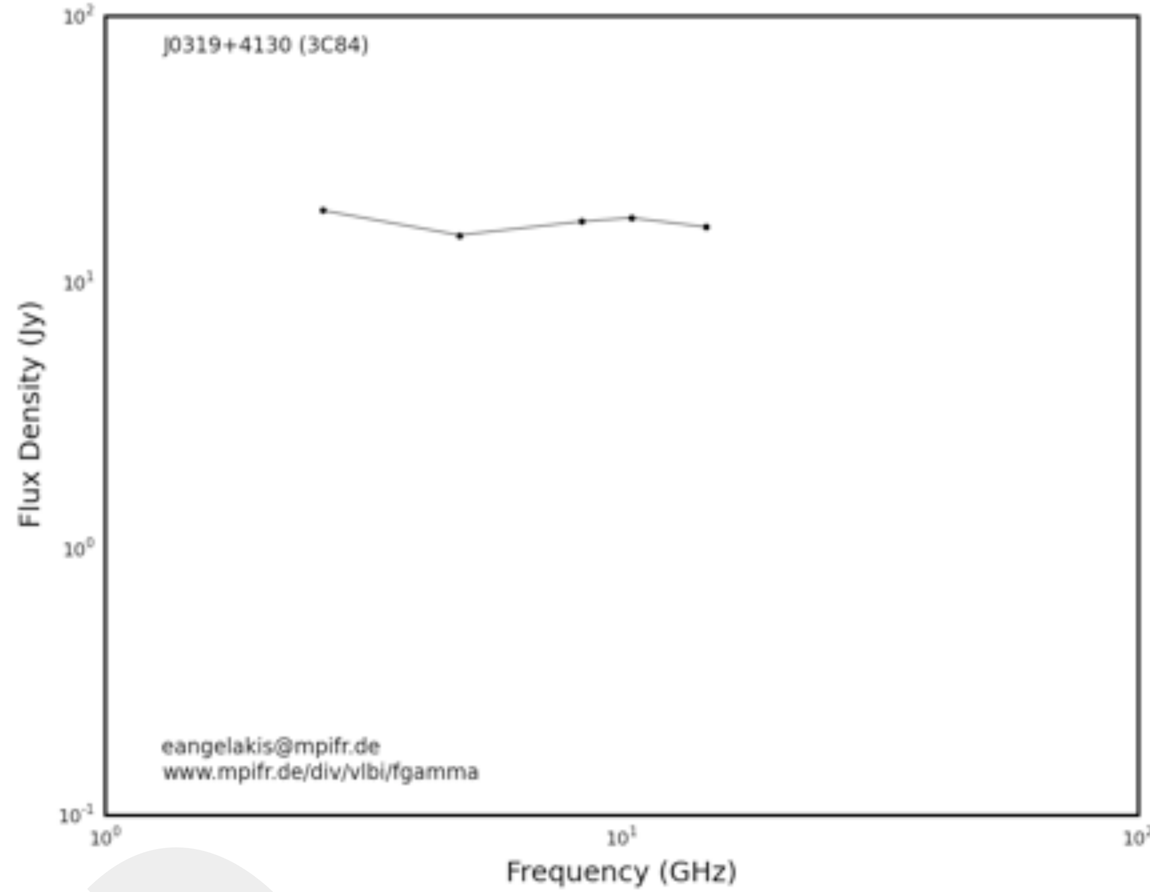
F-GAMMA PROJECT
Fermi-GST AGN Multi-frequency Monitoring Alliance

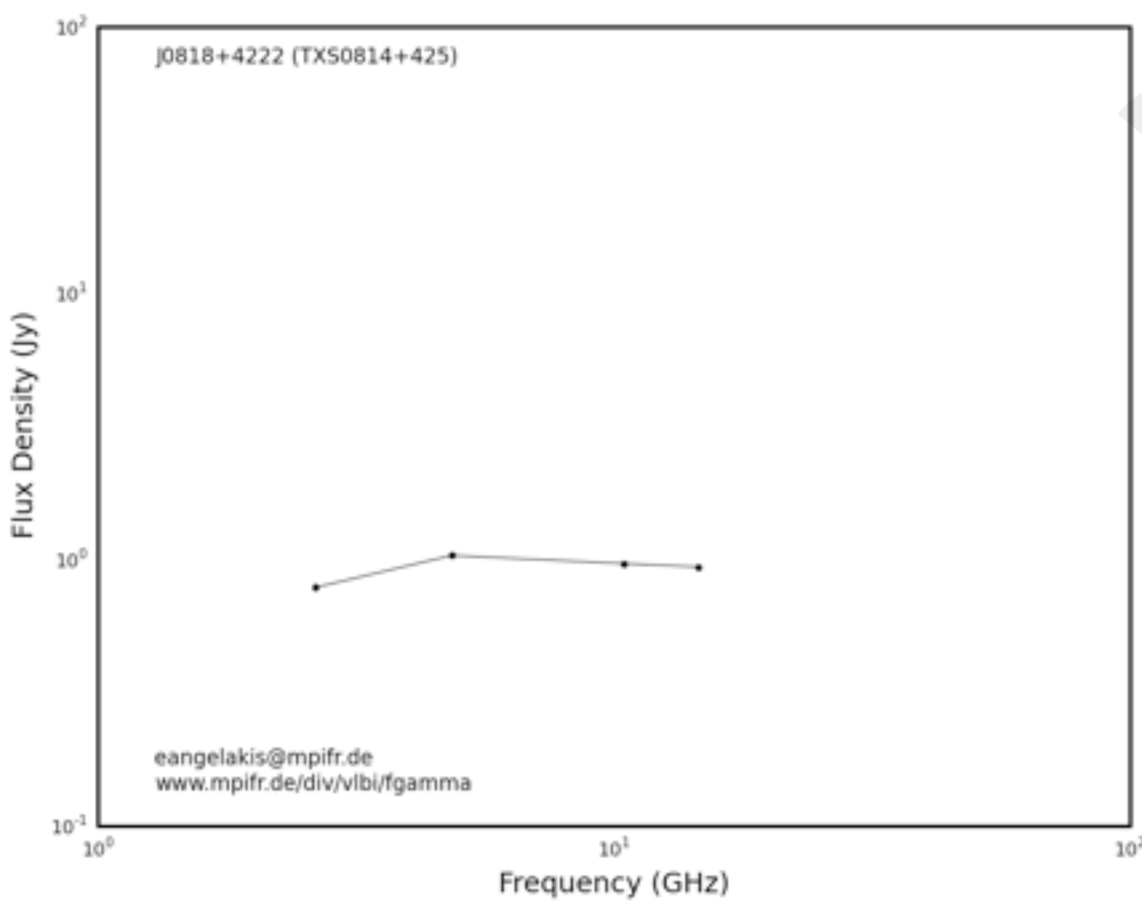
redshift distribution

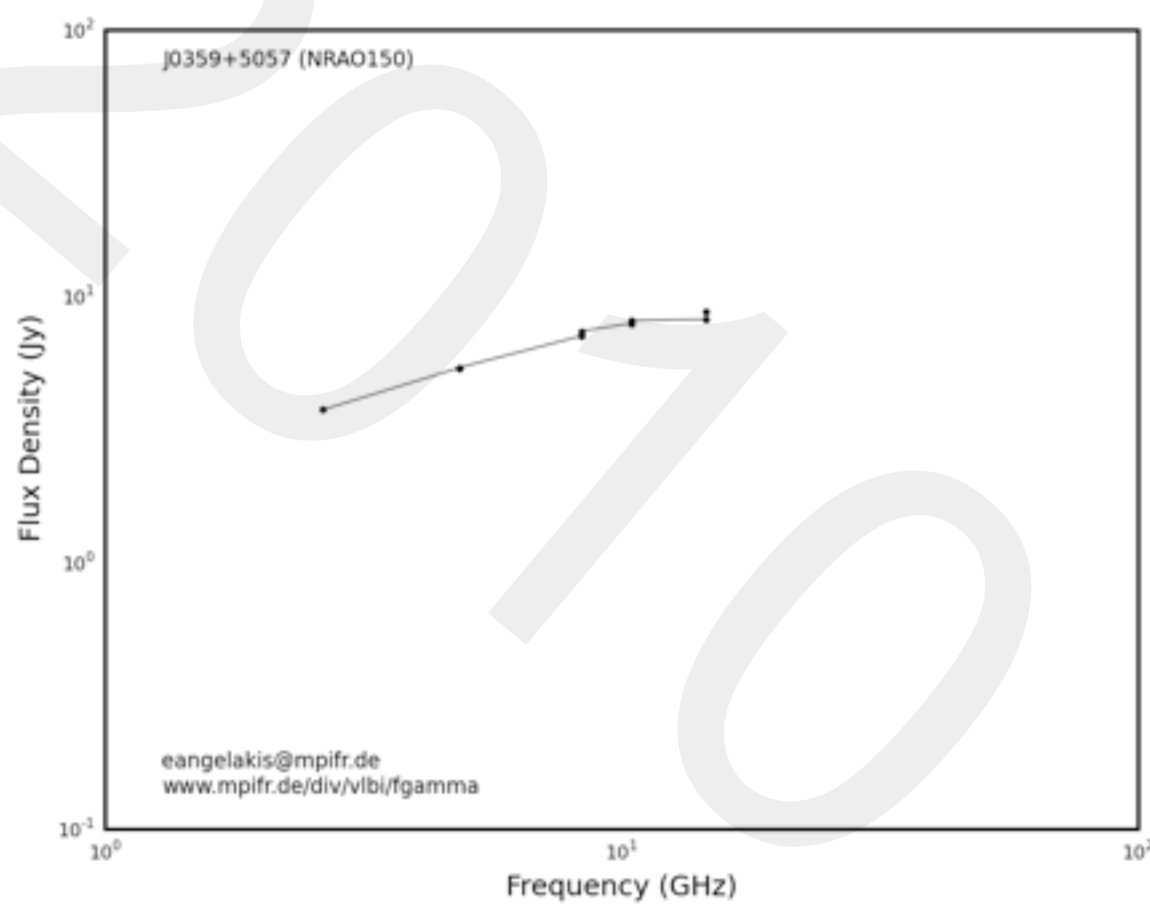


Angelakis et al. in prep.


J0238+1636 (AO0235+16)
Flux Density (Jy)
Frequency (GHz)
eangelakis@mpifr.de
www.mpifr.de/div/vlbi/fgamma

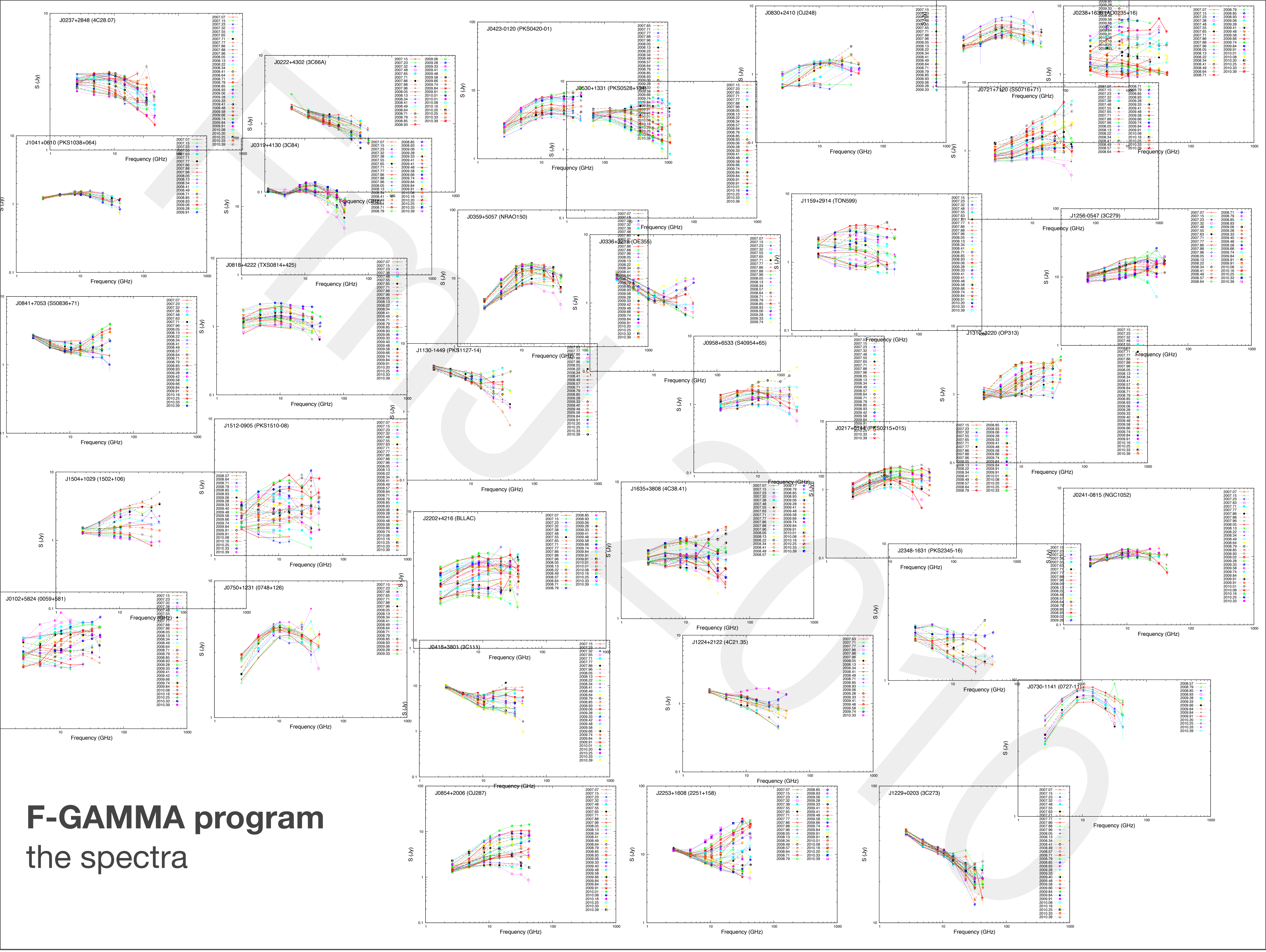

J0319+4130 (3C84)
Flux Density (Jy)
Frequency (GHz)
eangelakis@mpifr.de
www.mpifr.de/div/vlbi/fgamma


J0818+4222 (TXS0814+425)
Flux Density (Jy)
Frequency (GHz)
eangelakis@mpifr.de
www.mpifr.de/div/vlbi/fgamma


J0359+5057 (NRAO150)
Flux Density (Jy)
Frequency (GHz)
eangelakis@mpifr.de
www.mpifr.de/div/vlbi/fgamma

F-GAMMA program

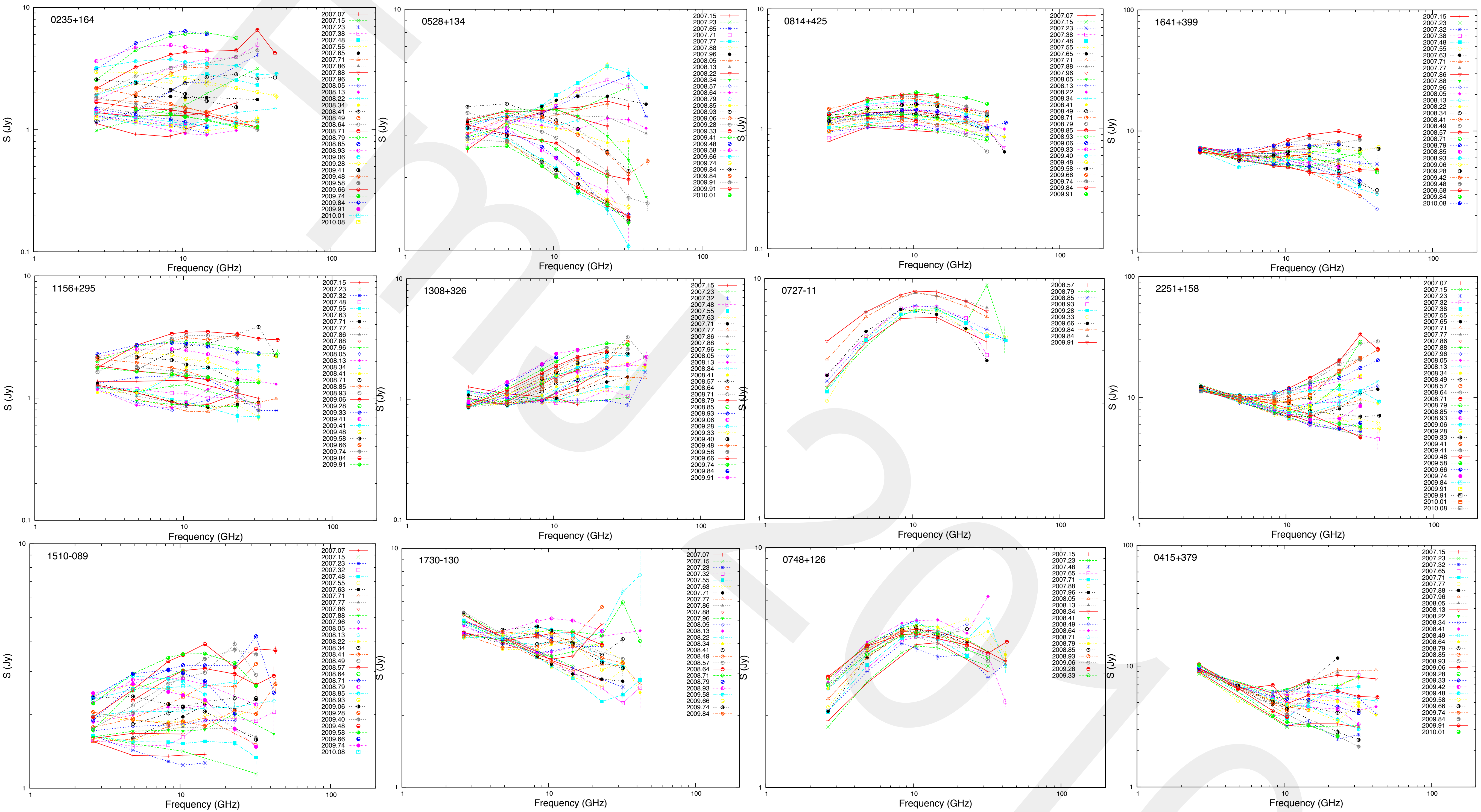
the spectra



F-GAMMA program

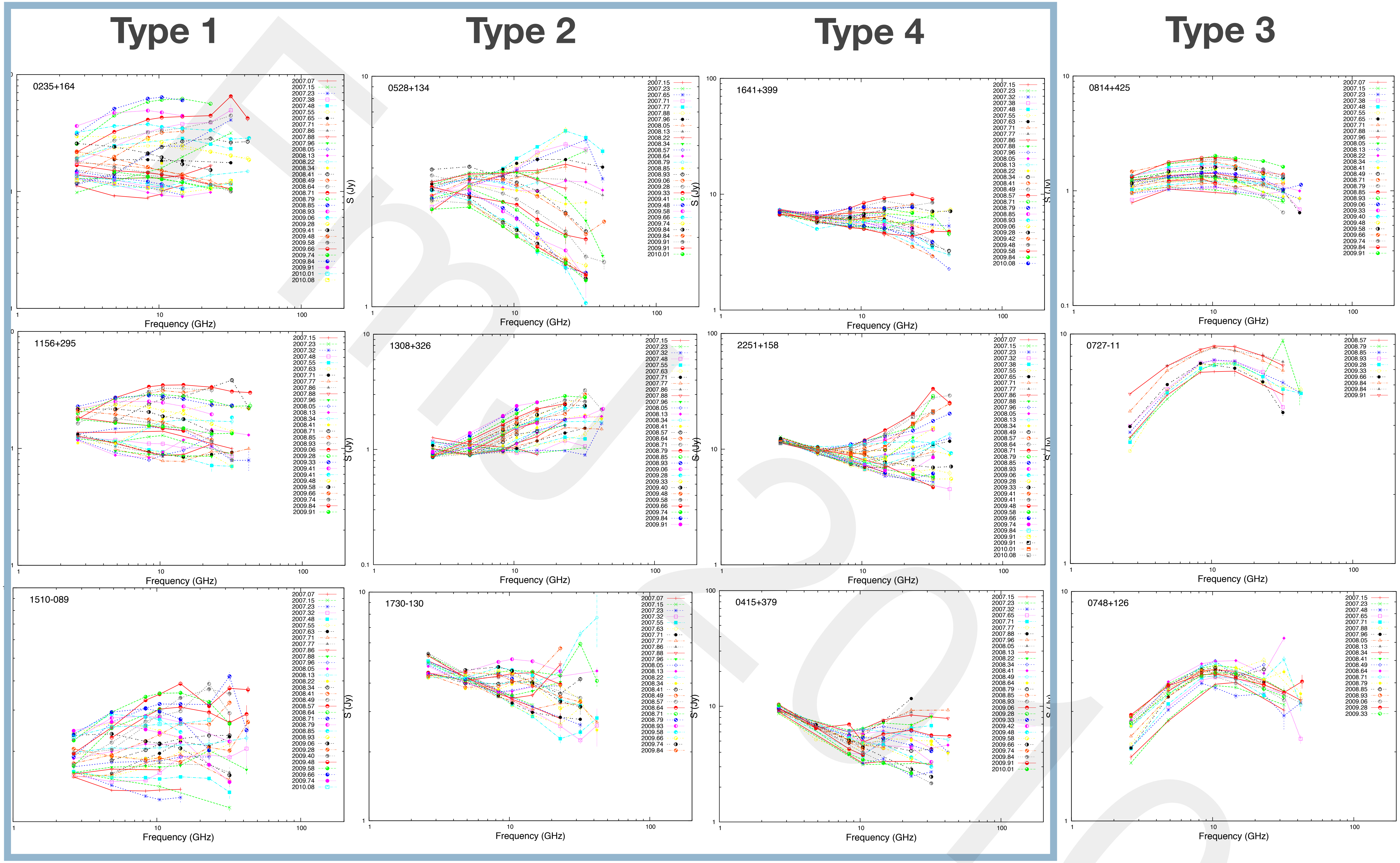
the spectra

Type 1 Type 2 Type 3 Type 4



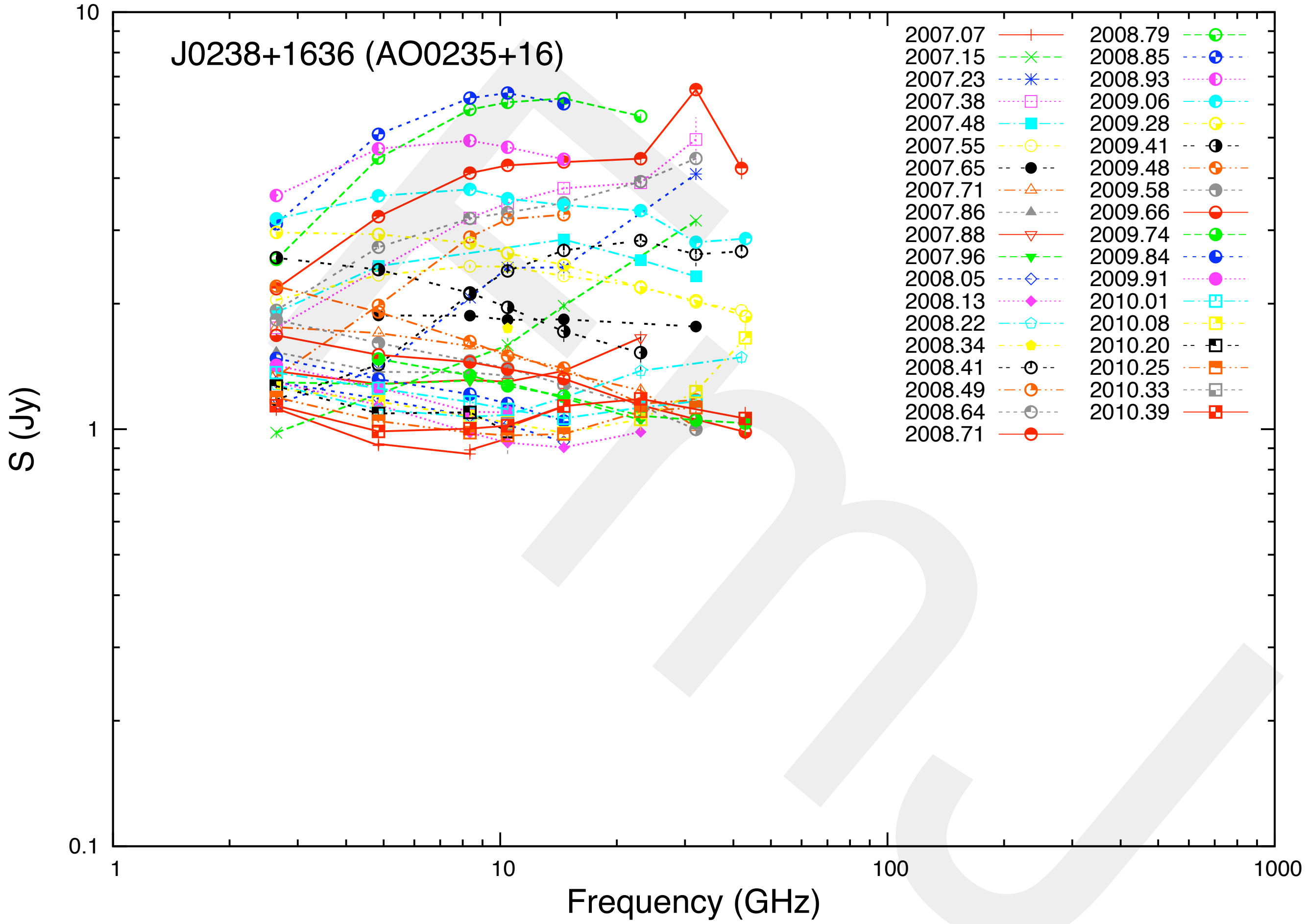
F-GAMMA program

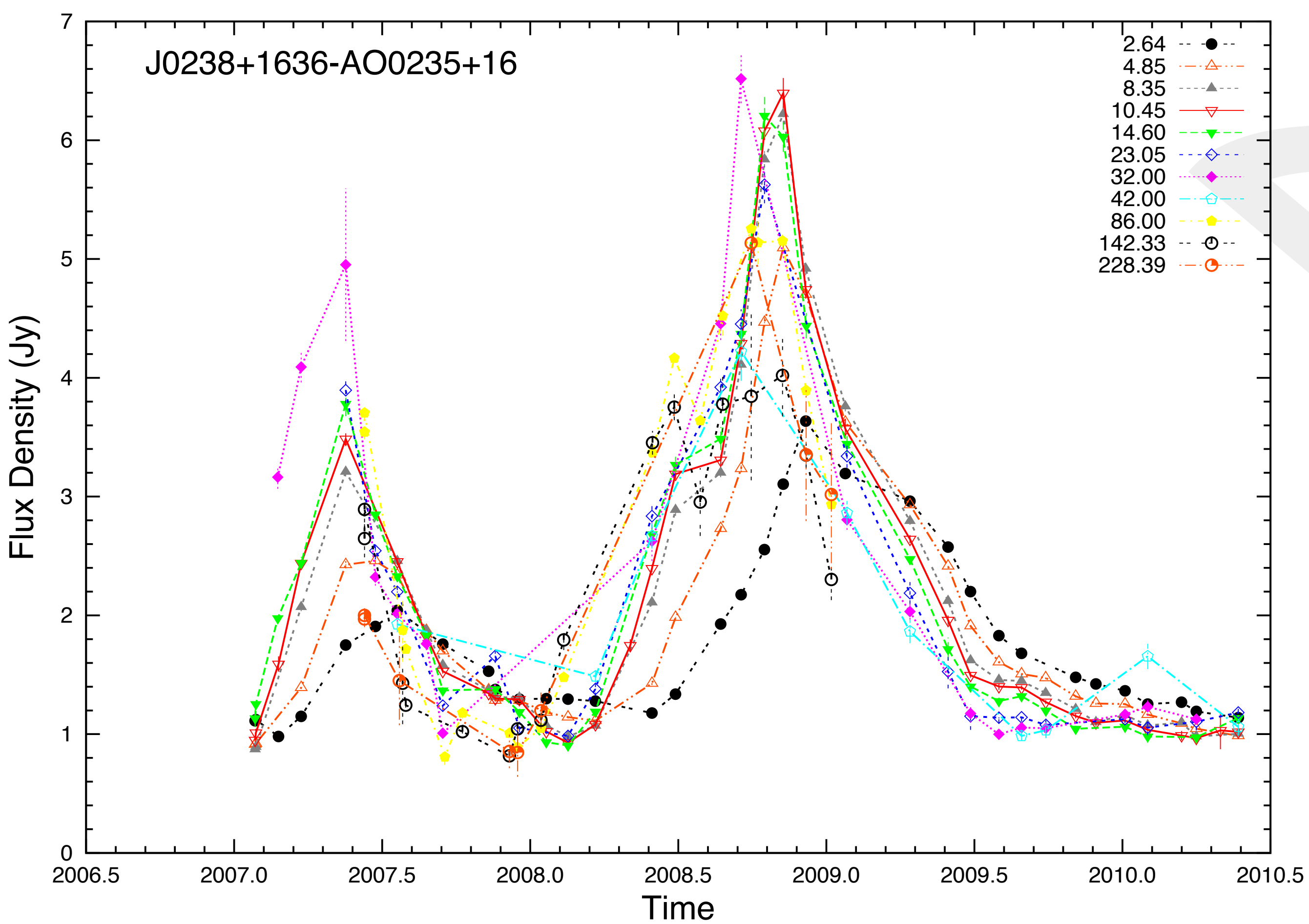
the spectra classification

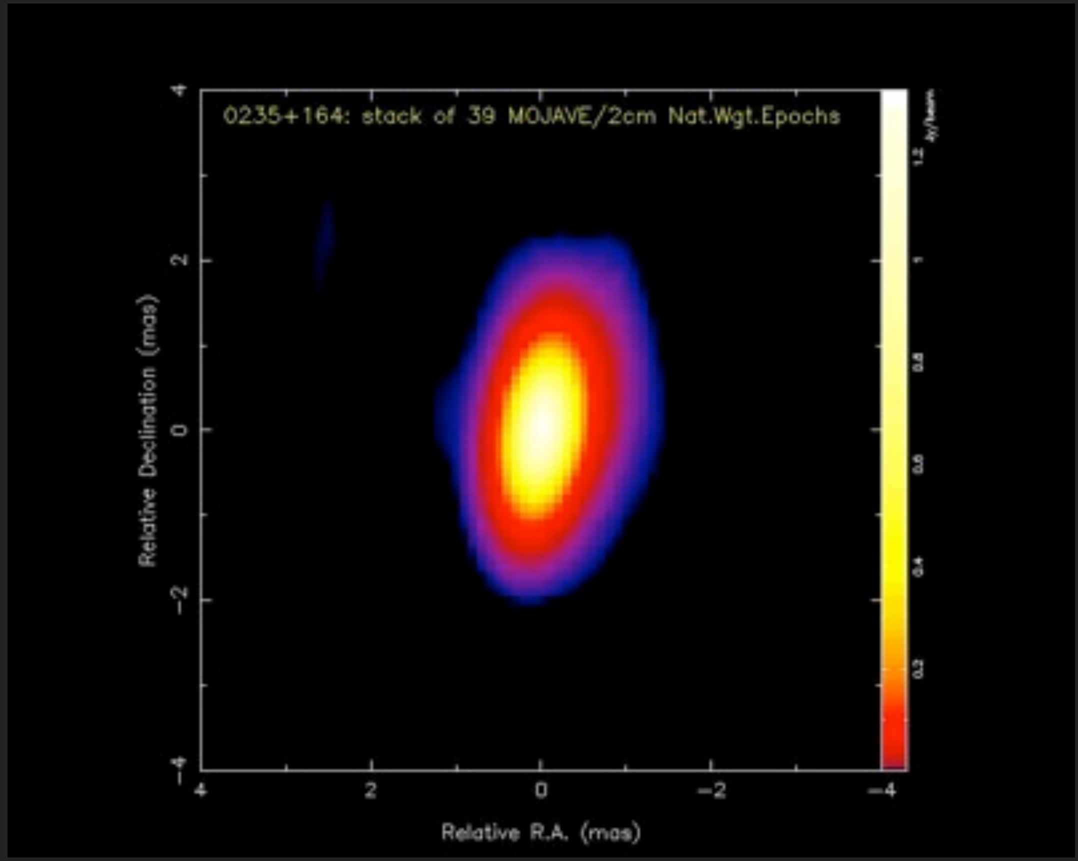


F-GAMMA program

the spectra classification

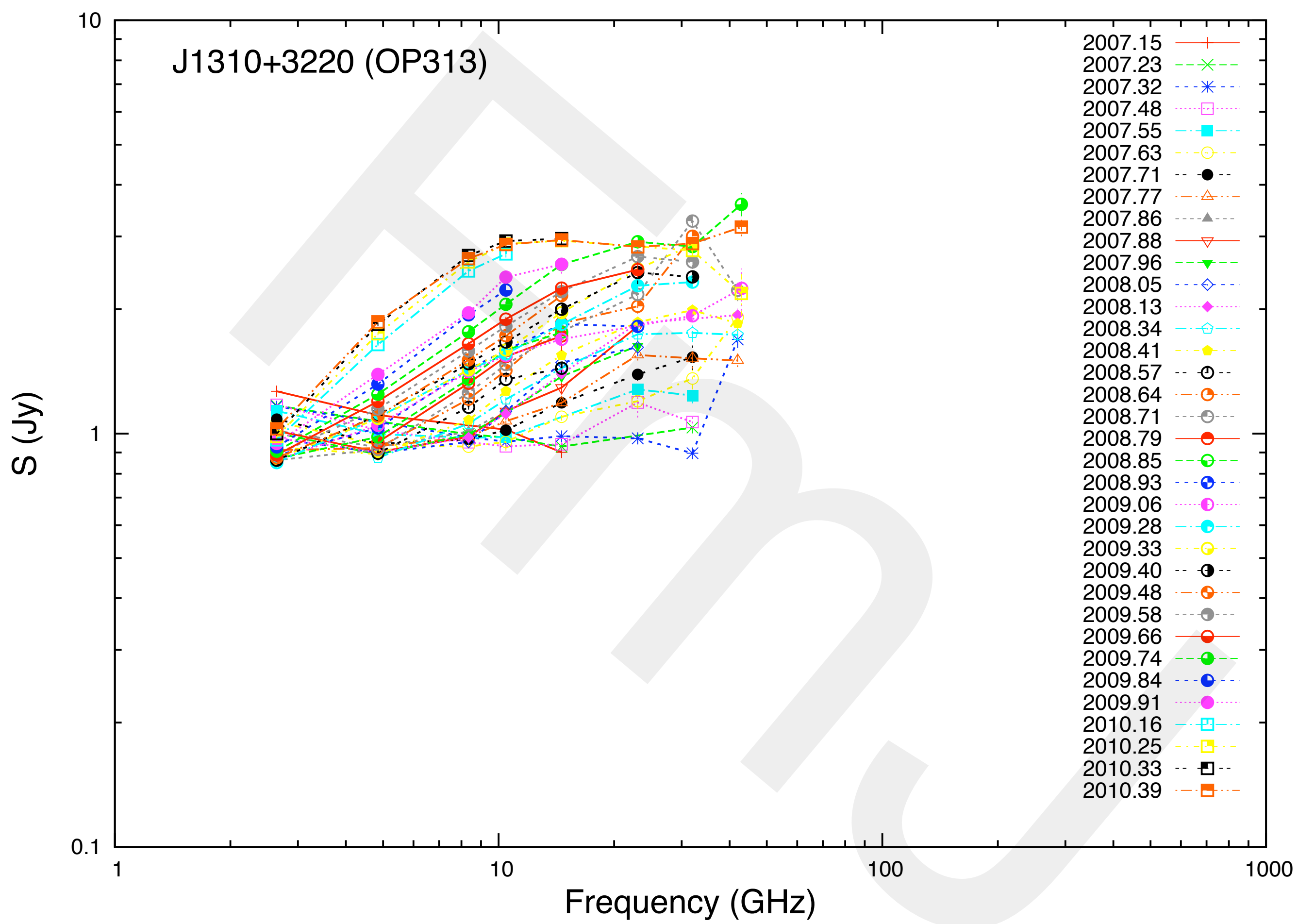


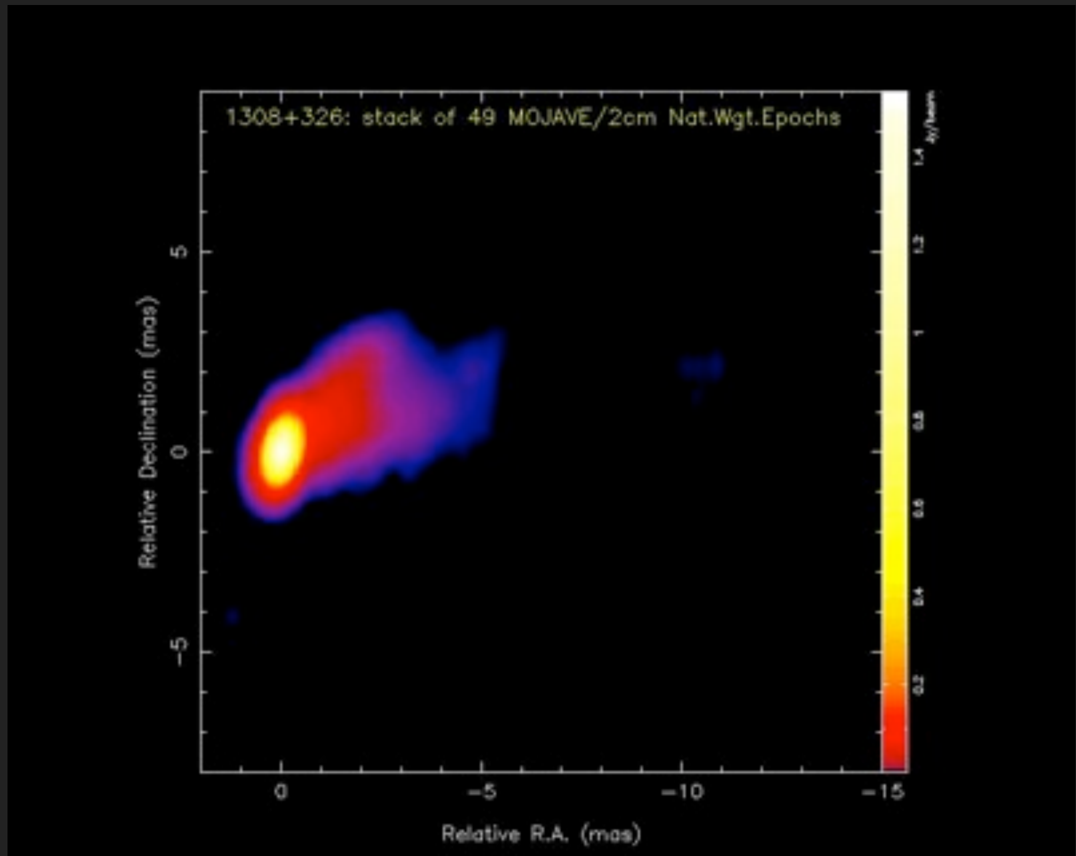




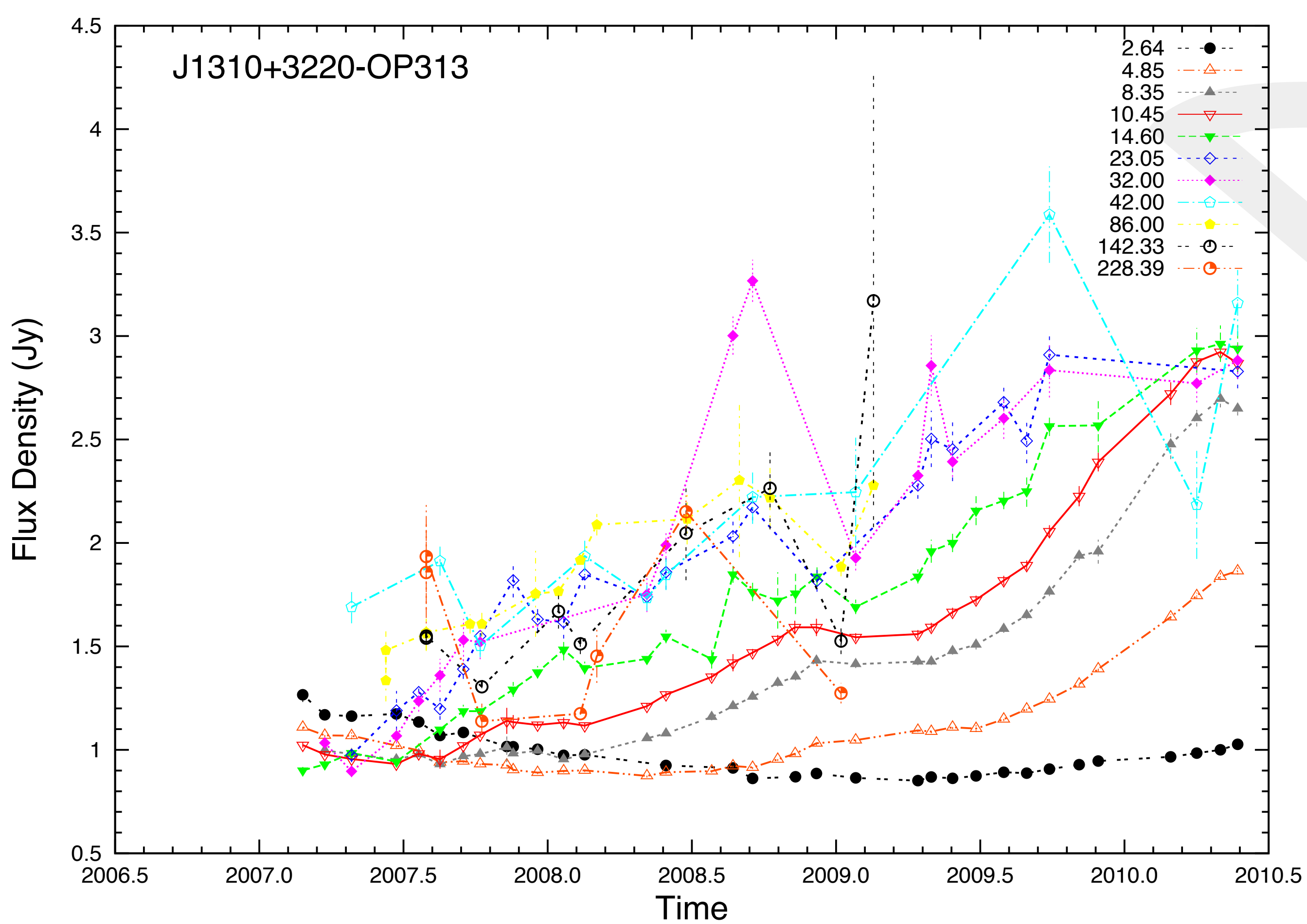
MOJAVE database

Type 1





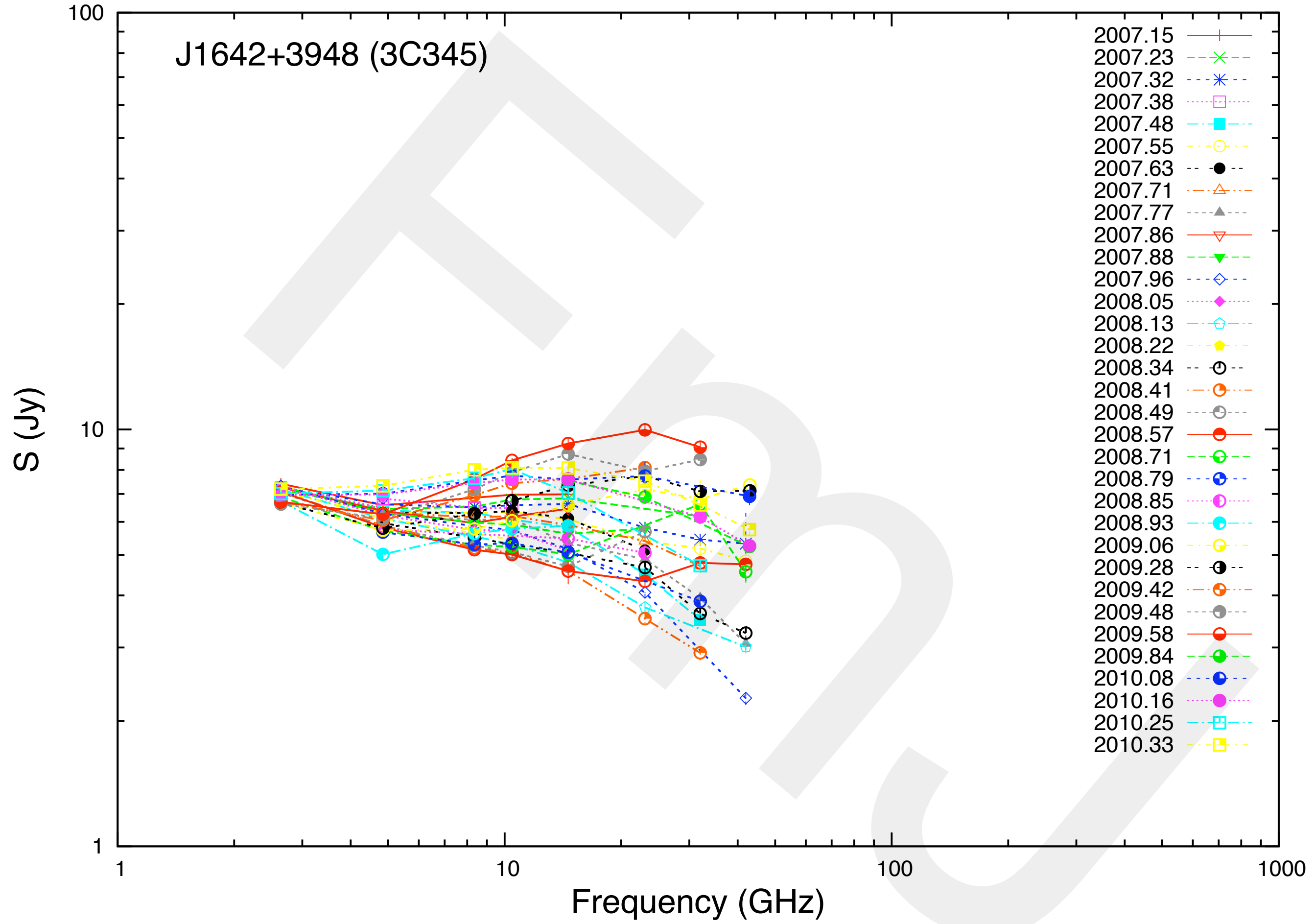
MOJAVE database

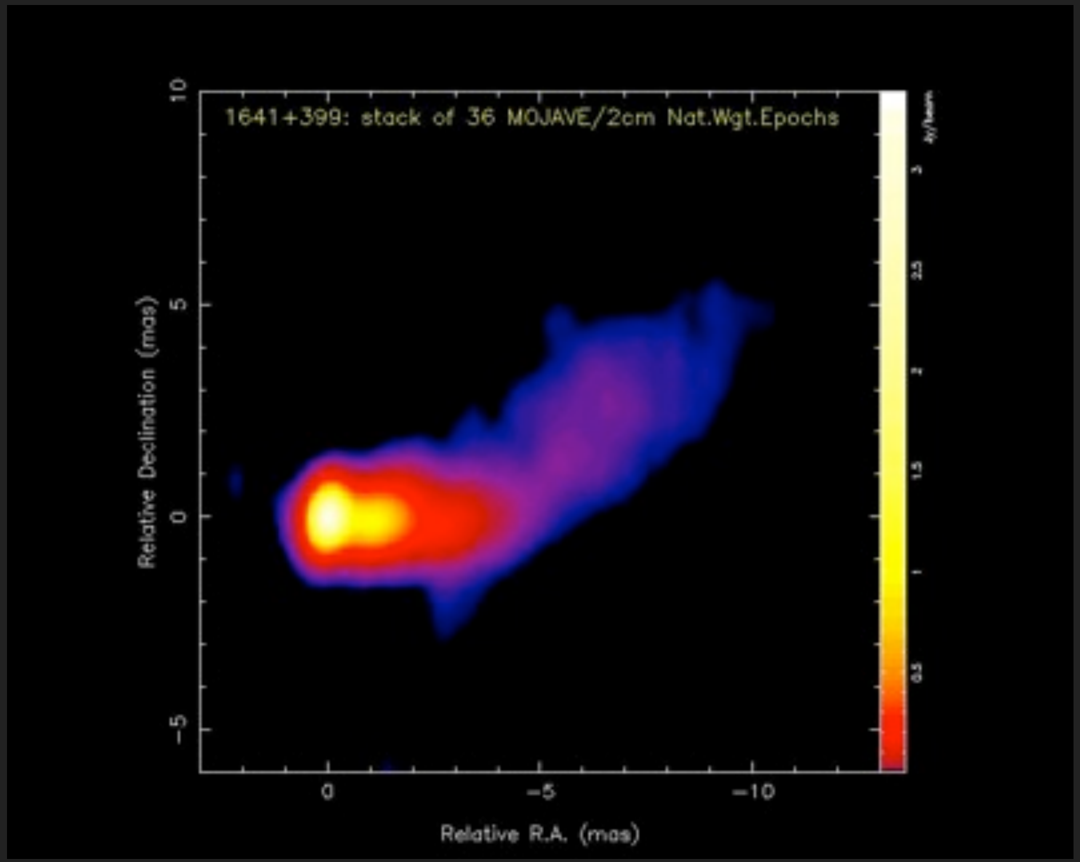


Type 2

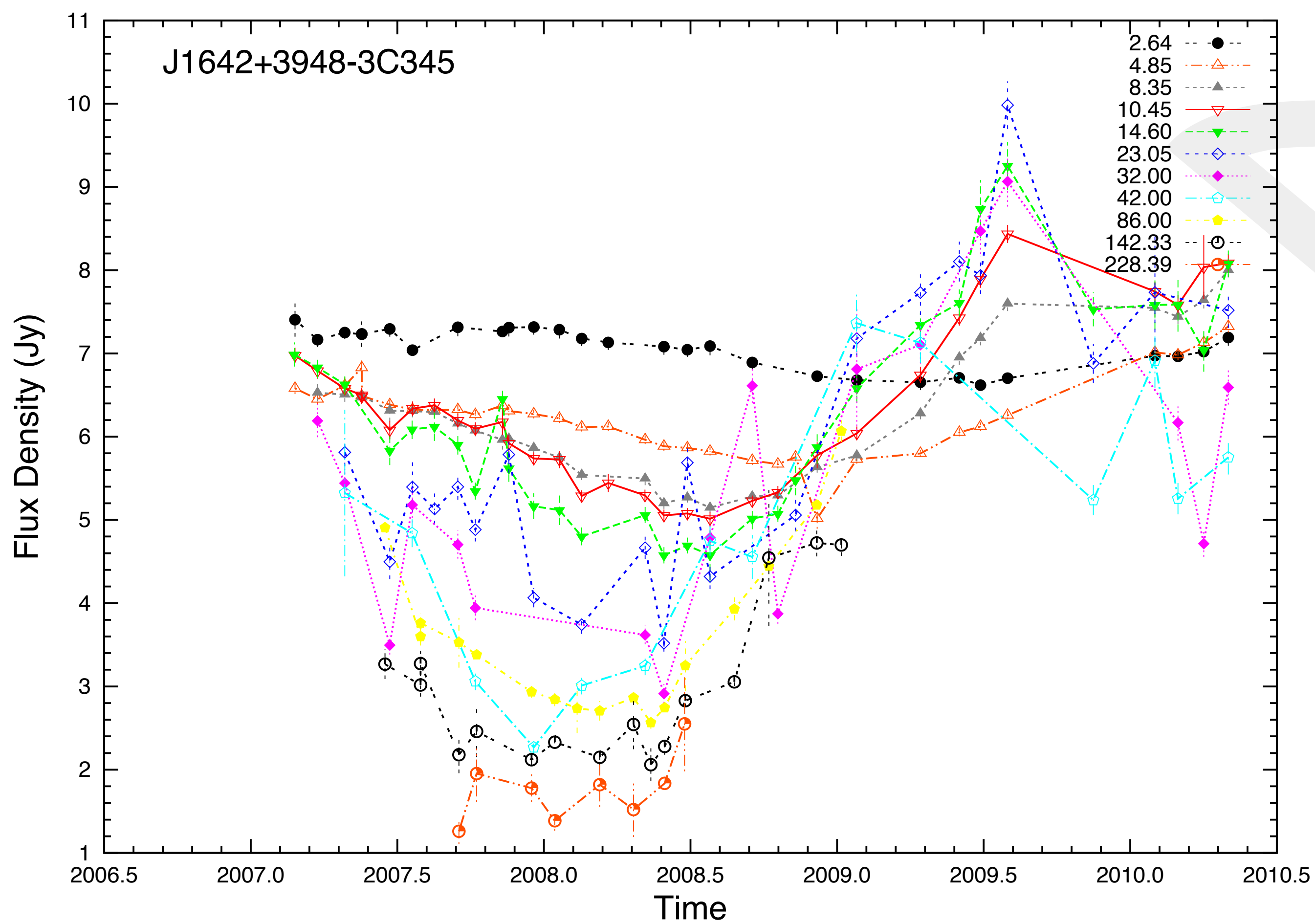
F-GAMMA PROJECT

Fermi-GST AGN Multi-frequency Monitoring Alliance

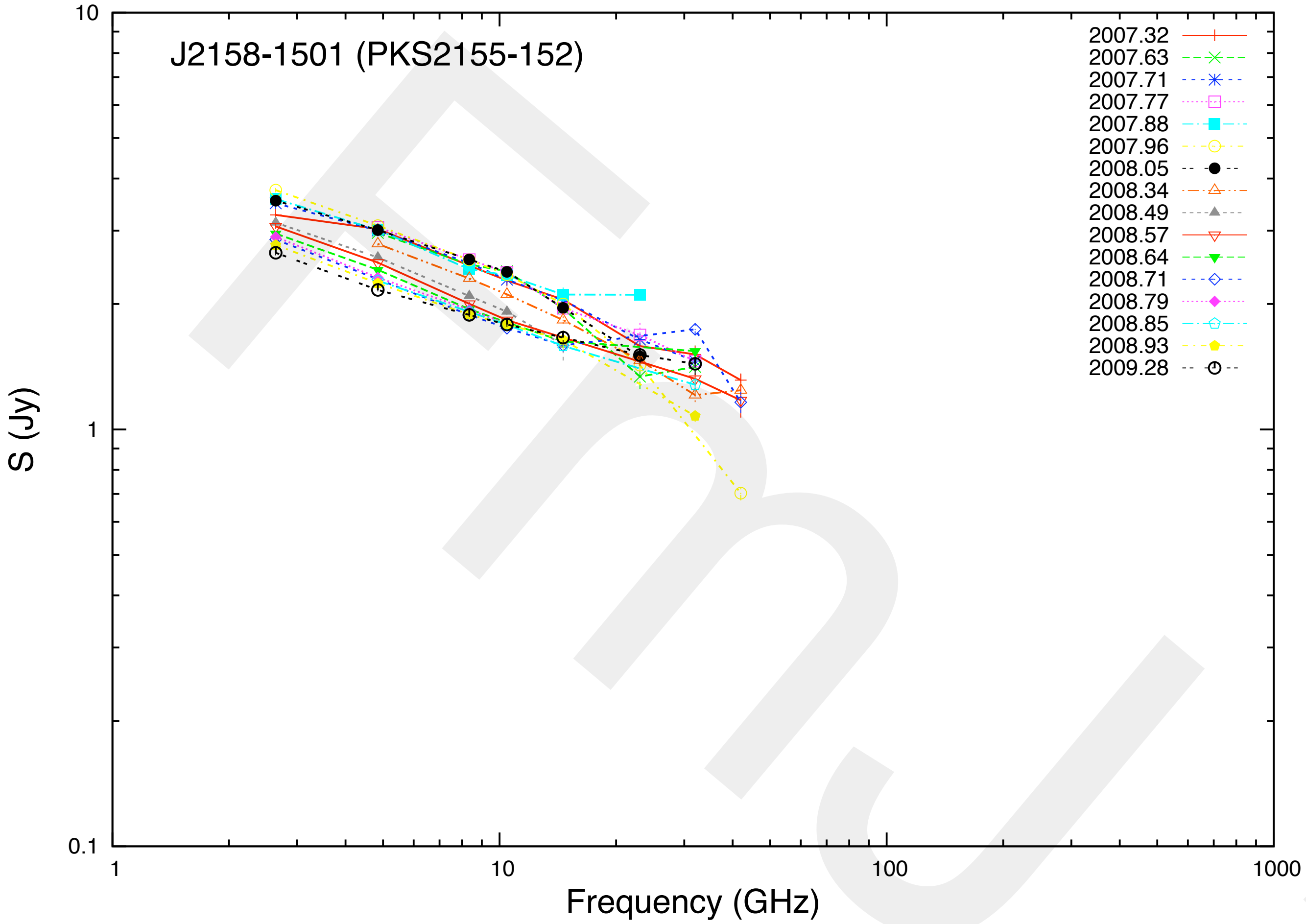


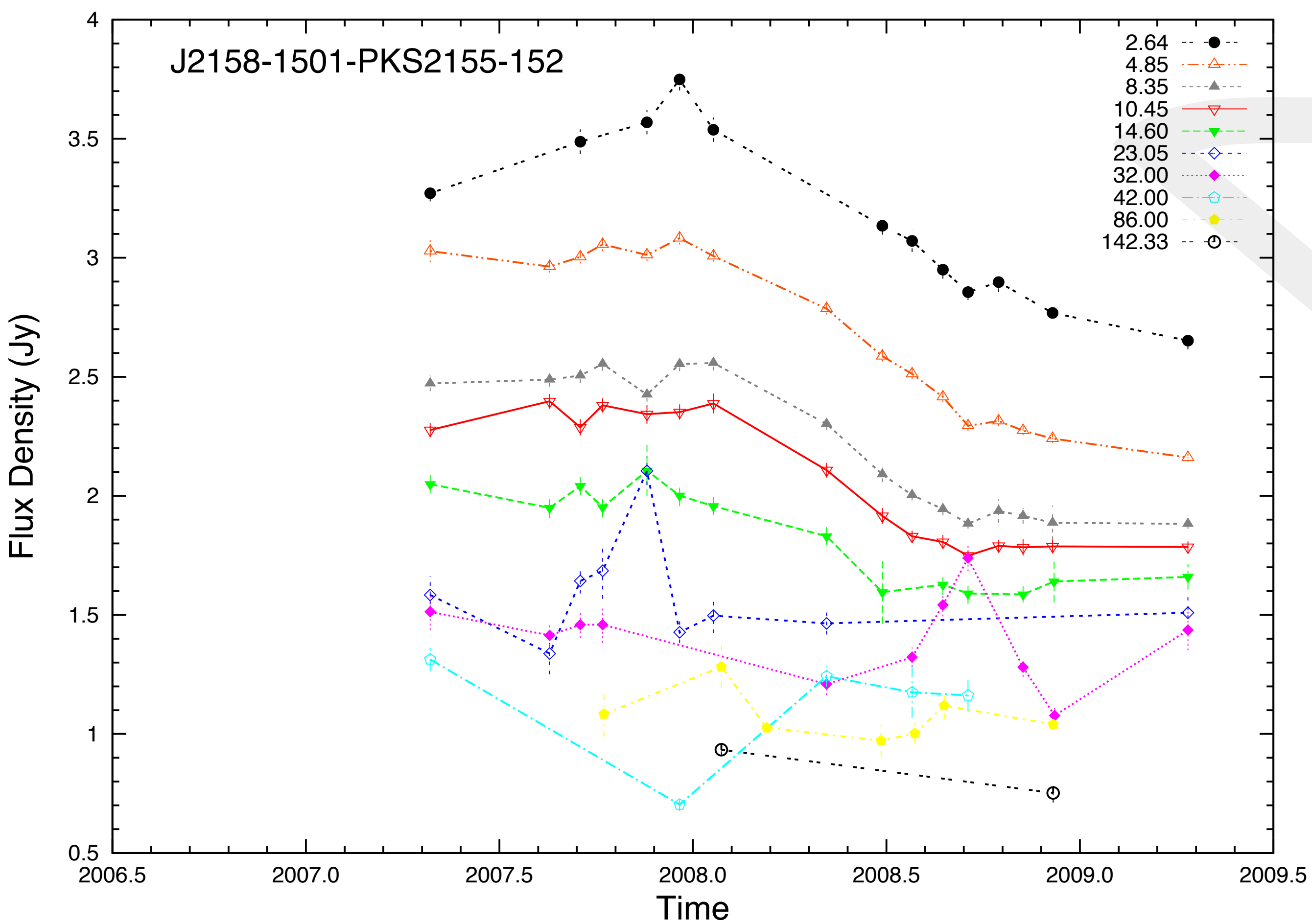


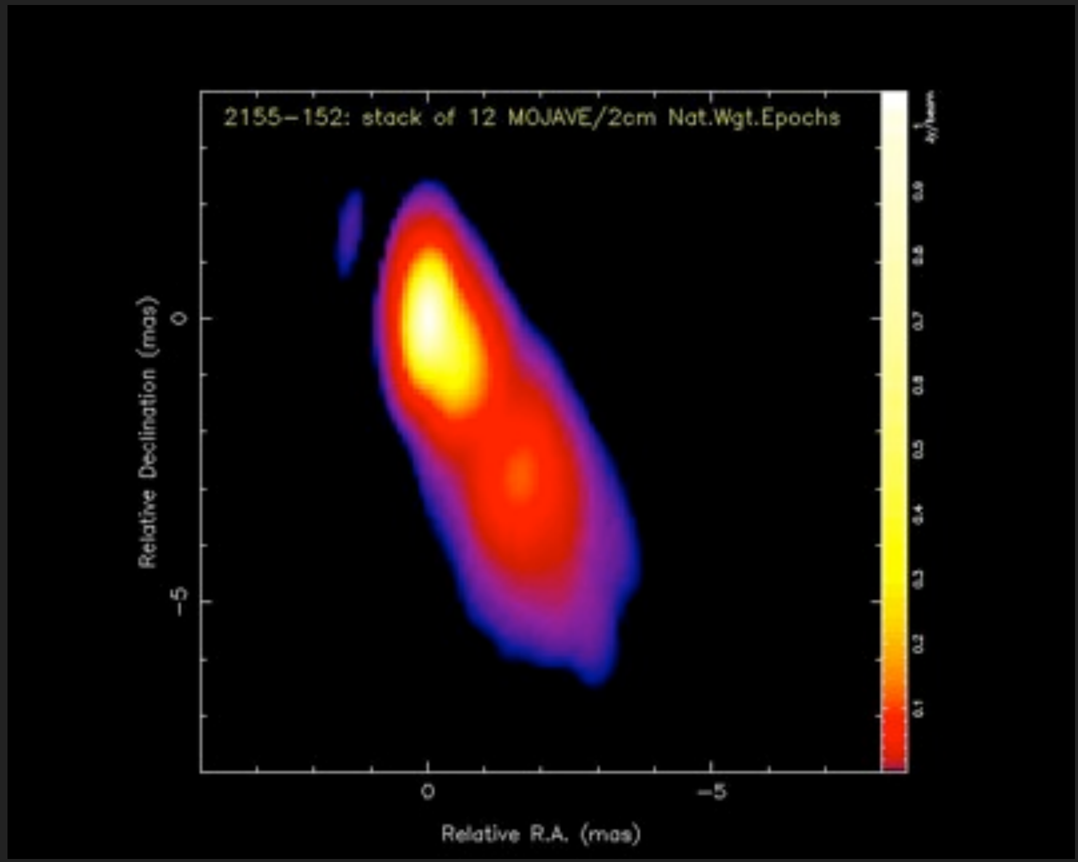
MOJAVE database



Type 4

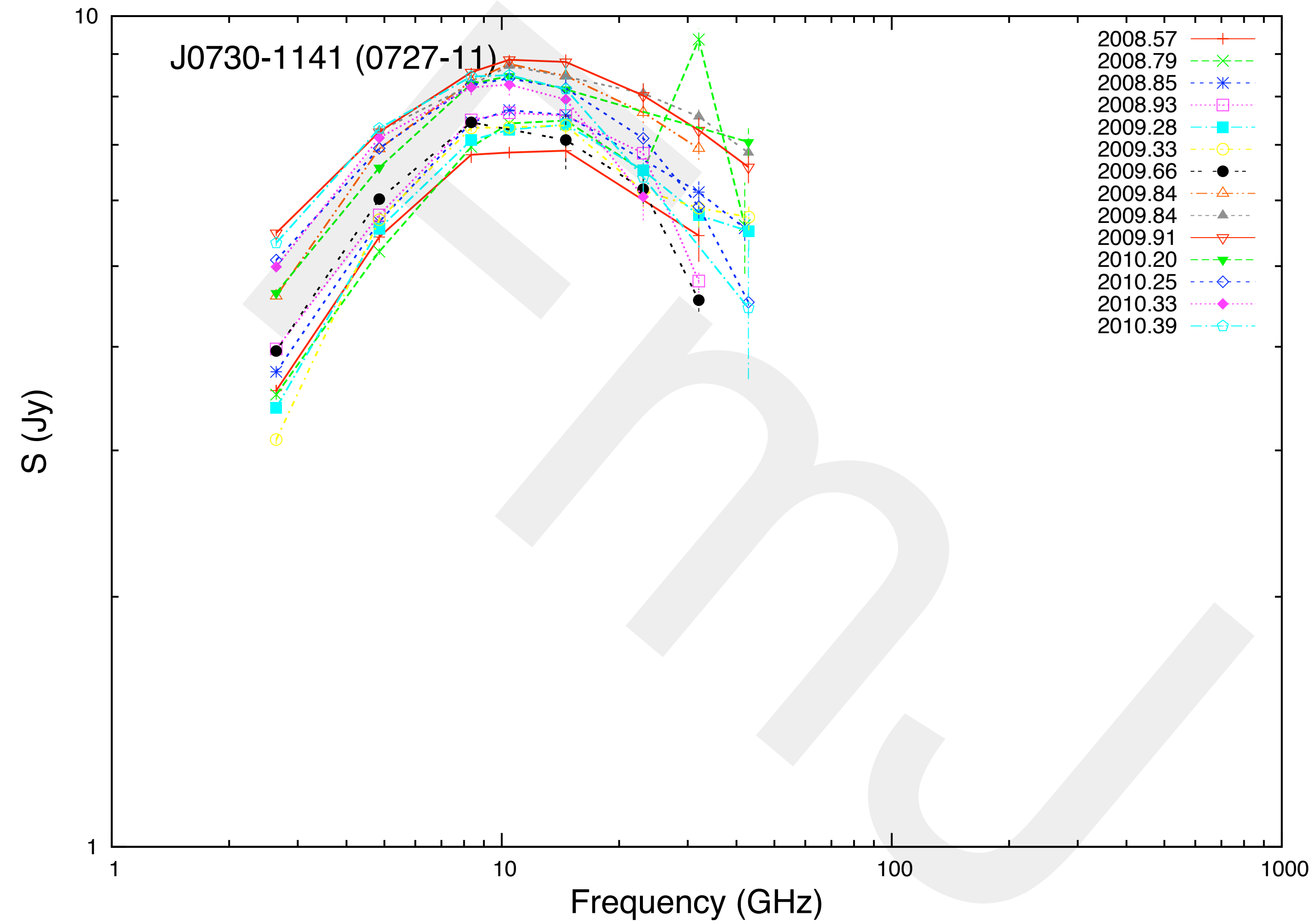


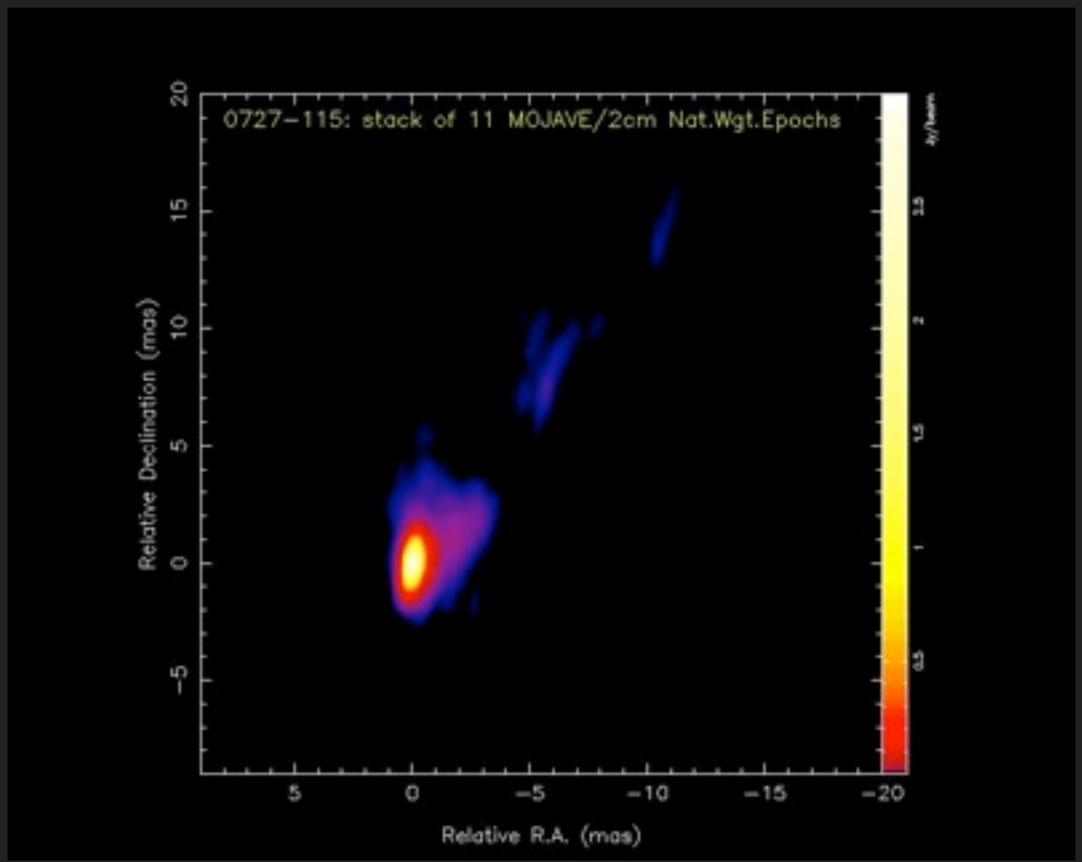




MOJAVE database

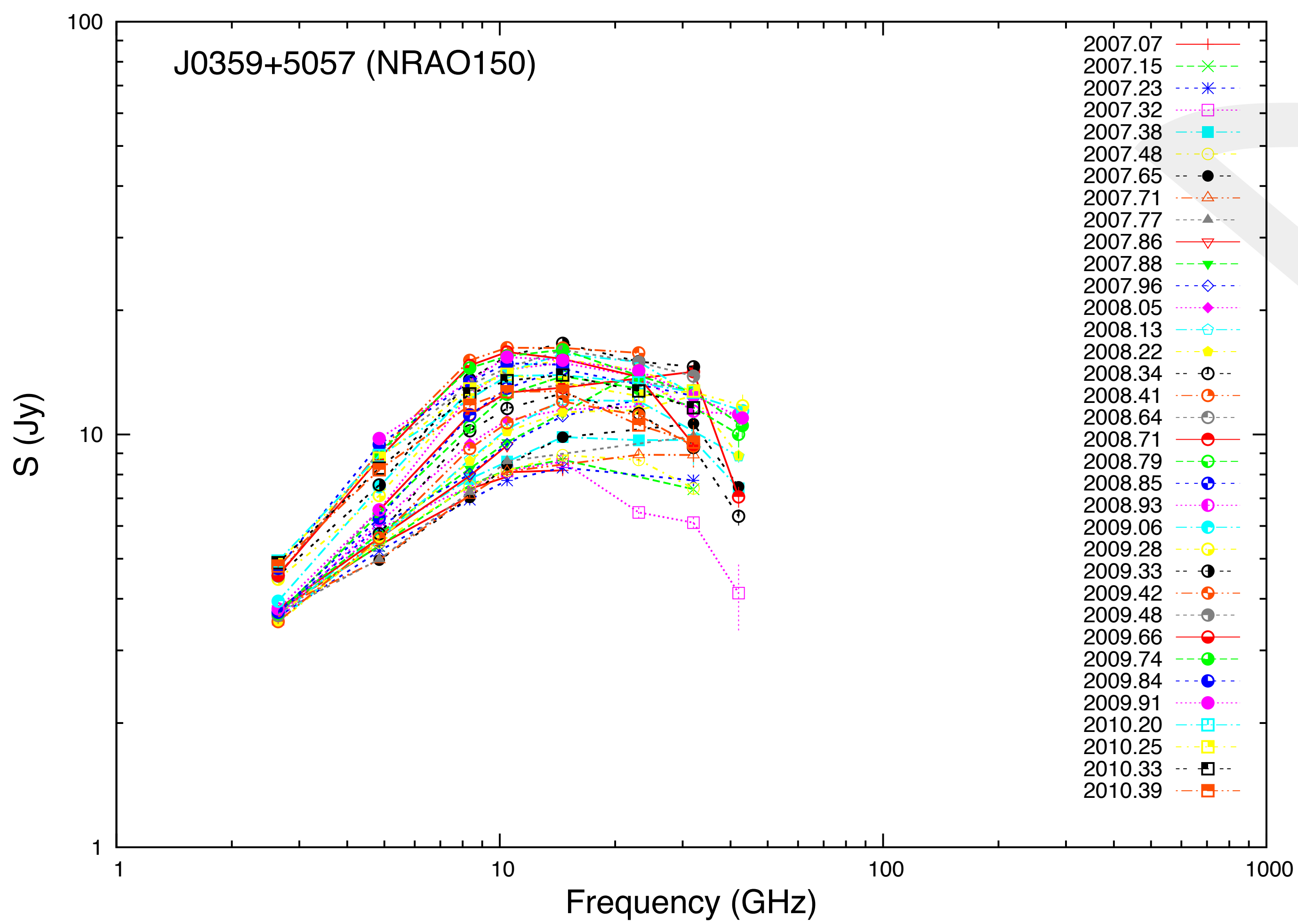
Type 5

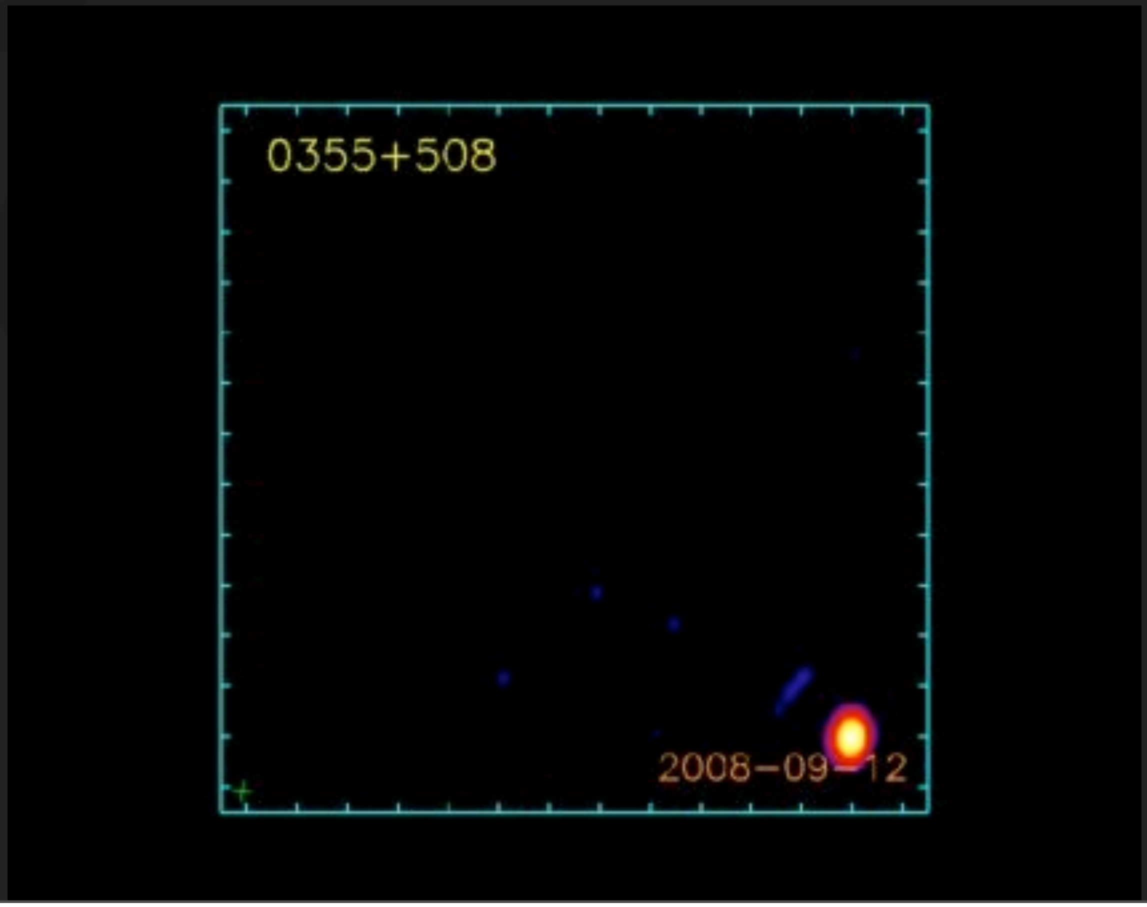




MOJAVE database

Type 3





	Total	T1+T2+T4	T3	T5
FSRQ	38	76% (29)	16% (6)	8% (3)
BL Lacs	20	40% (8)	35% (7)	25% (5)

two types of behavior + steep spectrum

	Total	T1+T2+T4	T3	T5
FSRQ	38	76% (29)	16% (6)	8% (3)
BL Lacs	20	40% (8)	35% (7)	25% (5)

↑ Spectral Evolution

two types of behavior + steep spectrum

	Total	T1+T2+T4	T3	T5
FSRQ	38	76% (29)	16% (6)	8% (3)
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Spectral Evolution

Achromatic Variability

two types of behavior + steep spectrum

	Total	T1+T2+T4	T3	T5
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Core activity dominates

two types of behavior + steep spectrum

	Total	T1+T2+T4	T3	T5
FSRQ	38	76% (29)	16% (6)	8% (3)
BL Lacs	20	40% (8)	35% (7)	25% (5)

Core activity dominates

Jet activity dominates

two types of behavior + steep spectrum

	Total	T1+T2+T4	T3	T5
FSRQ	38	76% (29)	16% (6)	8% (3)
BL Lacs	20	40% (8)	35% (7)	25% (5)

Core activity dominates (T1+T2+T4)

Jet activity dominates (T3)

Jet (T5)

two types of behavior + steep spectrum

	Total	T1+T2+T4	T3	T5
FSRQ	38	76% (29)	16% (6)	8% (3)
BL Lacs	20	40% (8)	35% (7)	25% (5)

Core activity dominates

Jet activity dominates

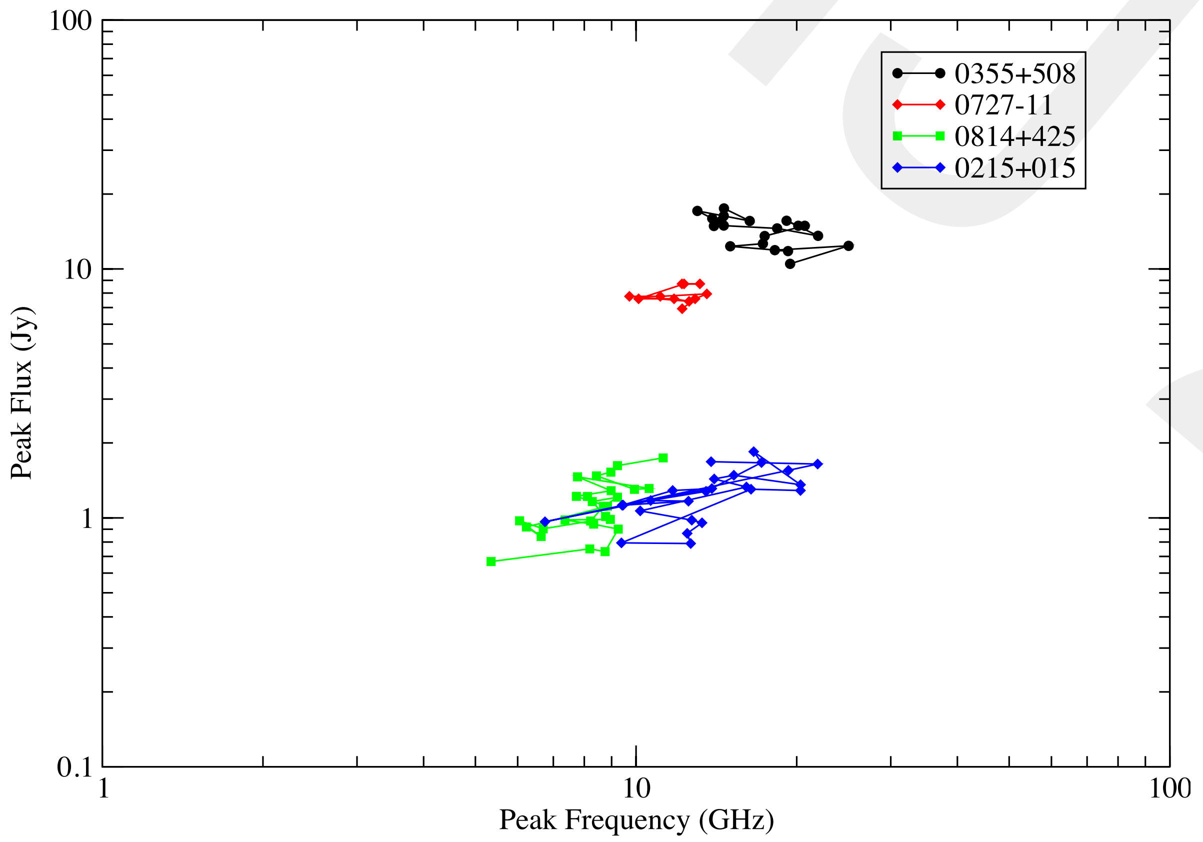
Jet

redshift “brings” the action into our band-pass

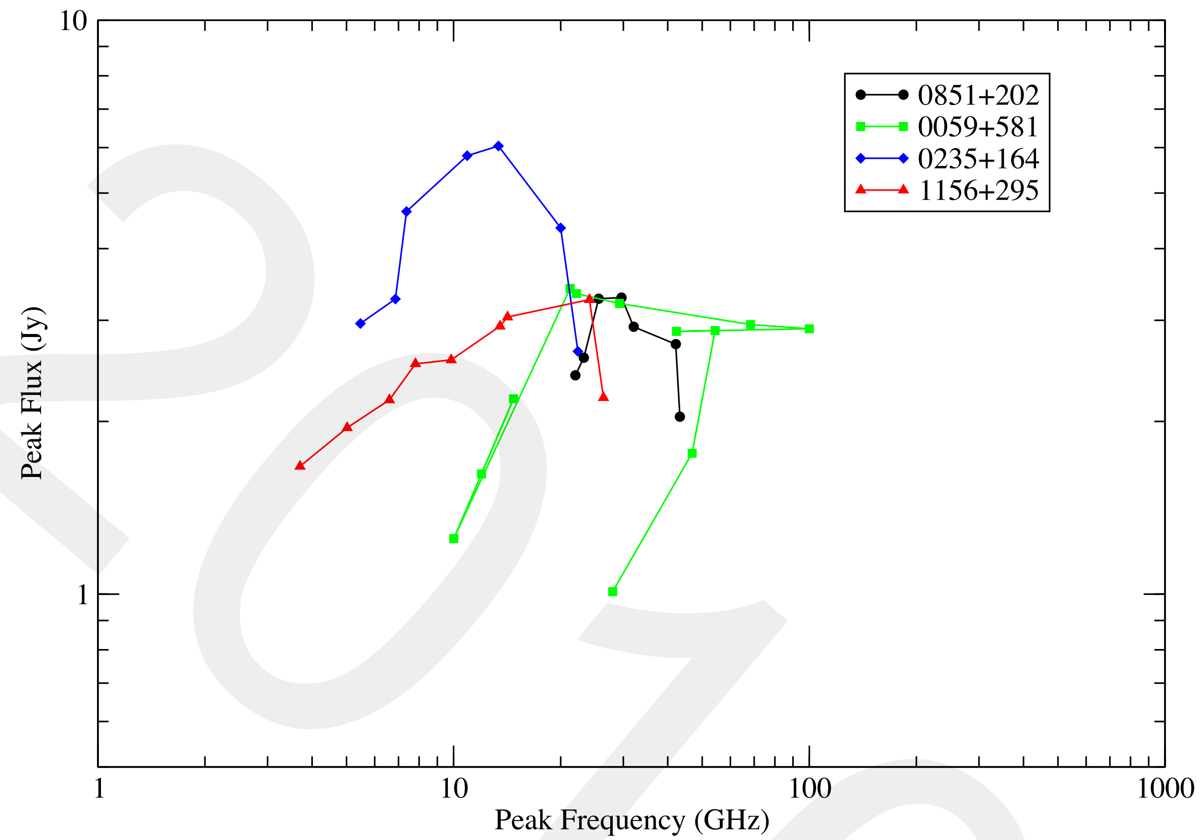
two types of behavior + steep spectrum

two types of behavior + steep spec.

spectral evolution qualitatively similar to “shock-in-jet” model by Marscher & Gear



Type 3



Type 1, 2 and 4

Angelakis, Fuhrmann, Nestoras et al. in prep.

Comments

- Incomplete sample
- Observational Biases
- Selection effects
- It seems though that **two major mechanisms** are producing variability

Questions

- What mechanism makes type 3 sources have such a persistently convex spectrum?
- Are there **“typical timescales”** corresponding to each?
- What physical processes could account for them?
- Could **magnetic field / orientation** changes cause the **type 3** variability?

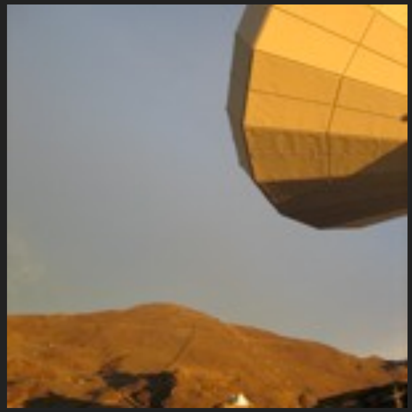
two types of behavior + steep spectrum

Next steps

- How are the Doppler factors distributed over variability types?
- Apparent speeds?
- Study other properties of each variability type
- gamma-ray correspondence of variability (type 3) => indicate the gamma-ray emission region
- cm, mm - gamma-rays cross-correlation analysis (on going)
- analyze out polarization data

two types of behavior + steep spectrum

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



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Located in Granada, Spain it covers the band 86 - 250 GHz monthly also for roughly 60 sources

12-m APEX
It covers the 345 GHz band and it is located in Atacama desert in Chile at an altitude of 5100 m

for spectra and LCs visit:

www.mpifr.de/div/vlbi/fgamma

Thank you!