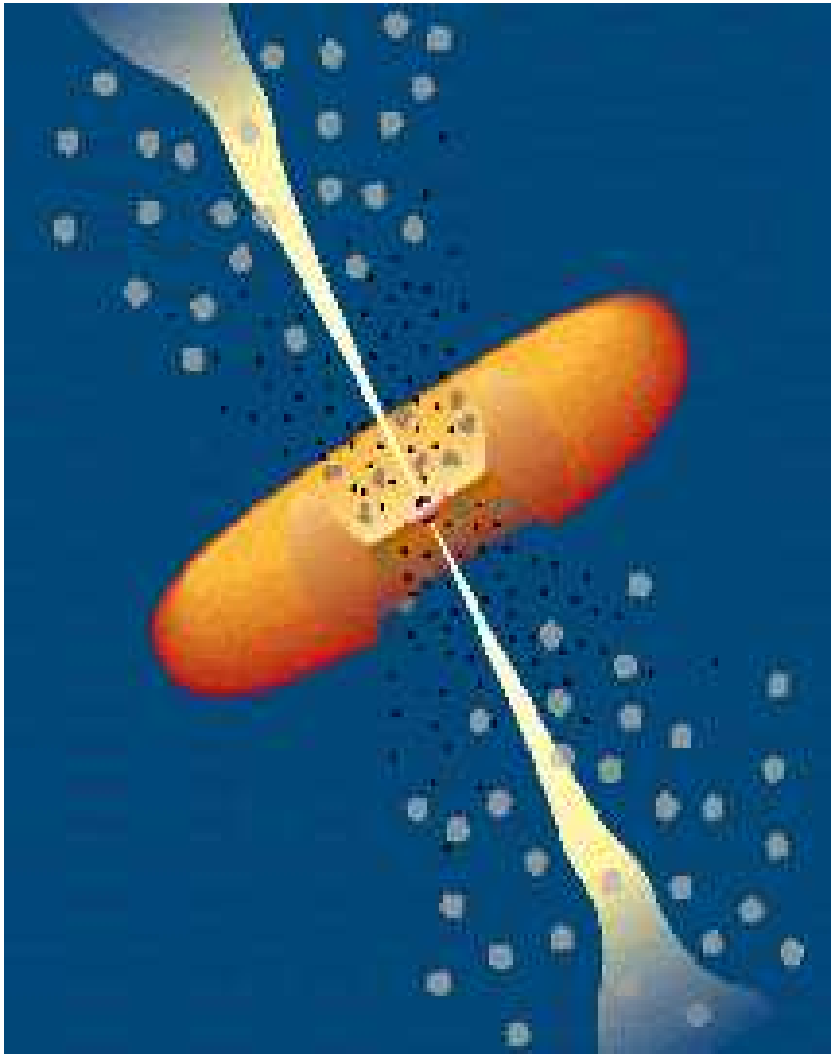
Multi mission-multi frequency Observations of Blazars

Paolo Giommi
ASI

Blazars



- AGN
- Highly variable at all frequencies
- Highly polarized
- Radio core dominance
- Superluminal speeds

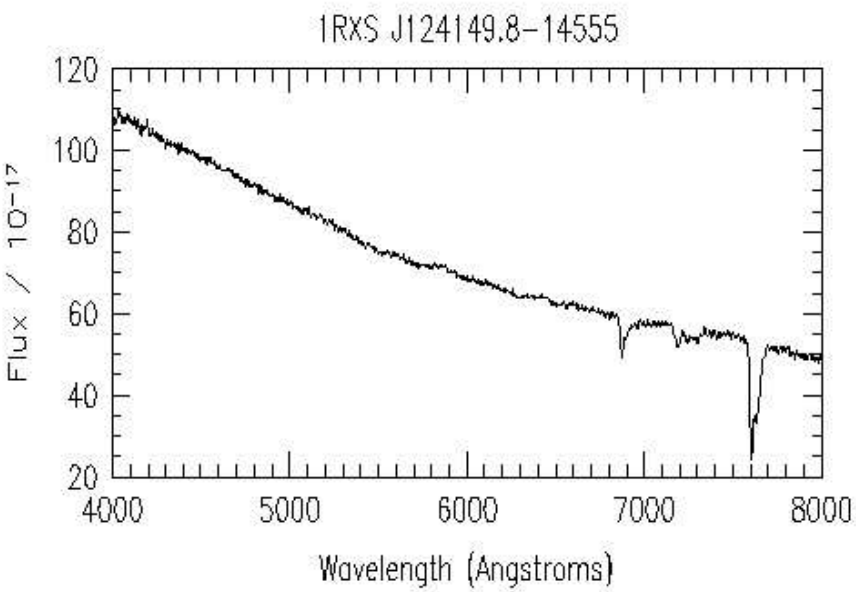
Observed at a small angle to the jet and therefore rare AGN : 5-8% of all AGN (but only at optical or X-ray frequencies!)

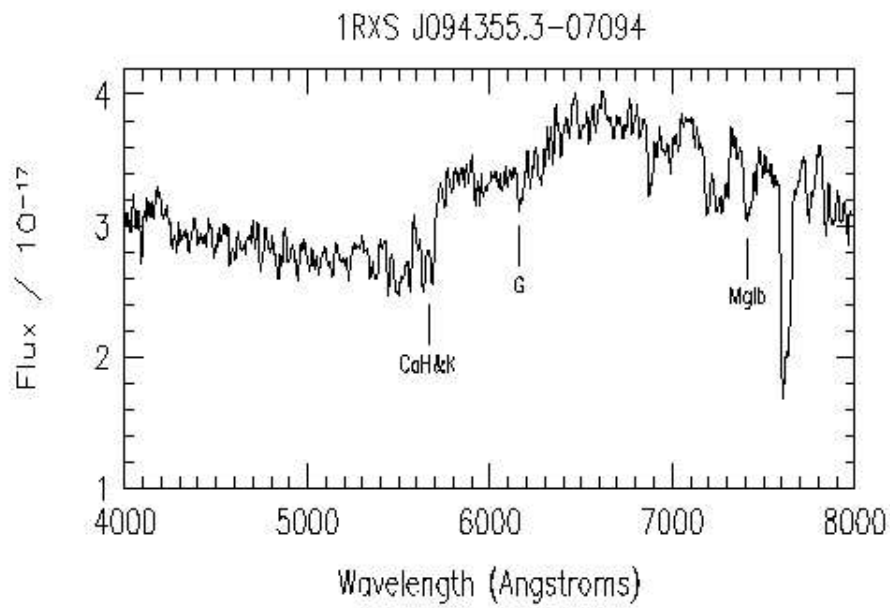
Blazars are the dominant population of extragalactic point sources at

- Gamma-ray
- TeV
- Microwave frequencies

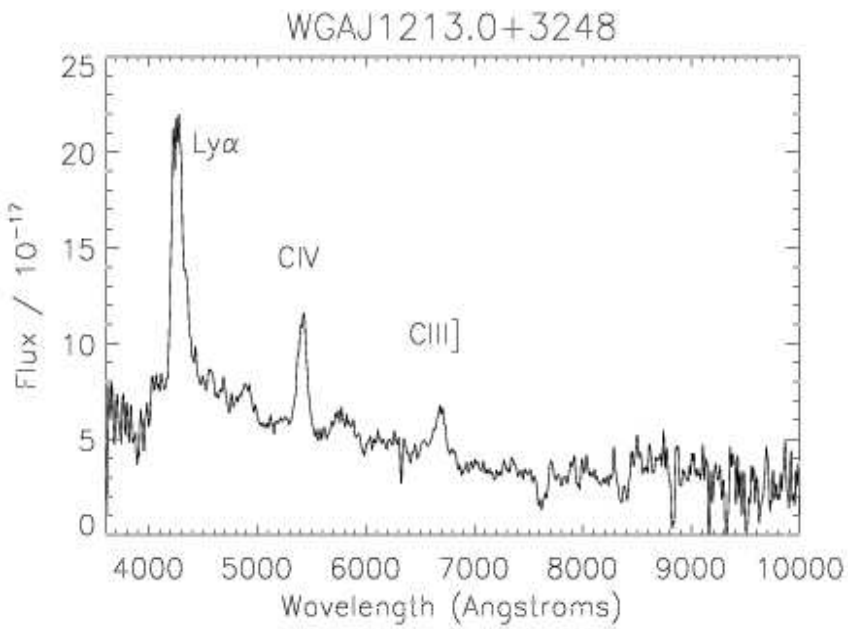
Two types of Blazars:

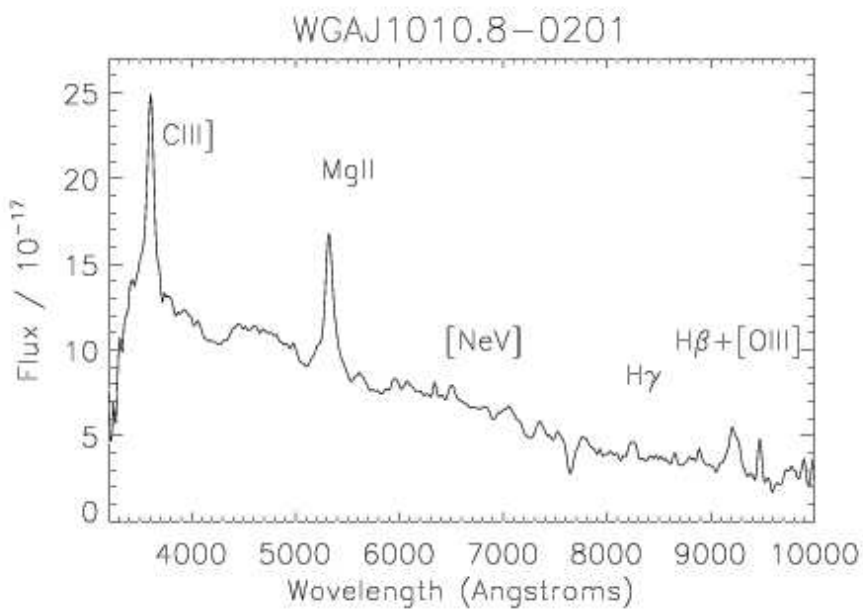
BL Lacs : no strong lines; no strong cosmological evolution



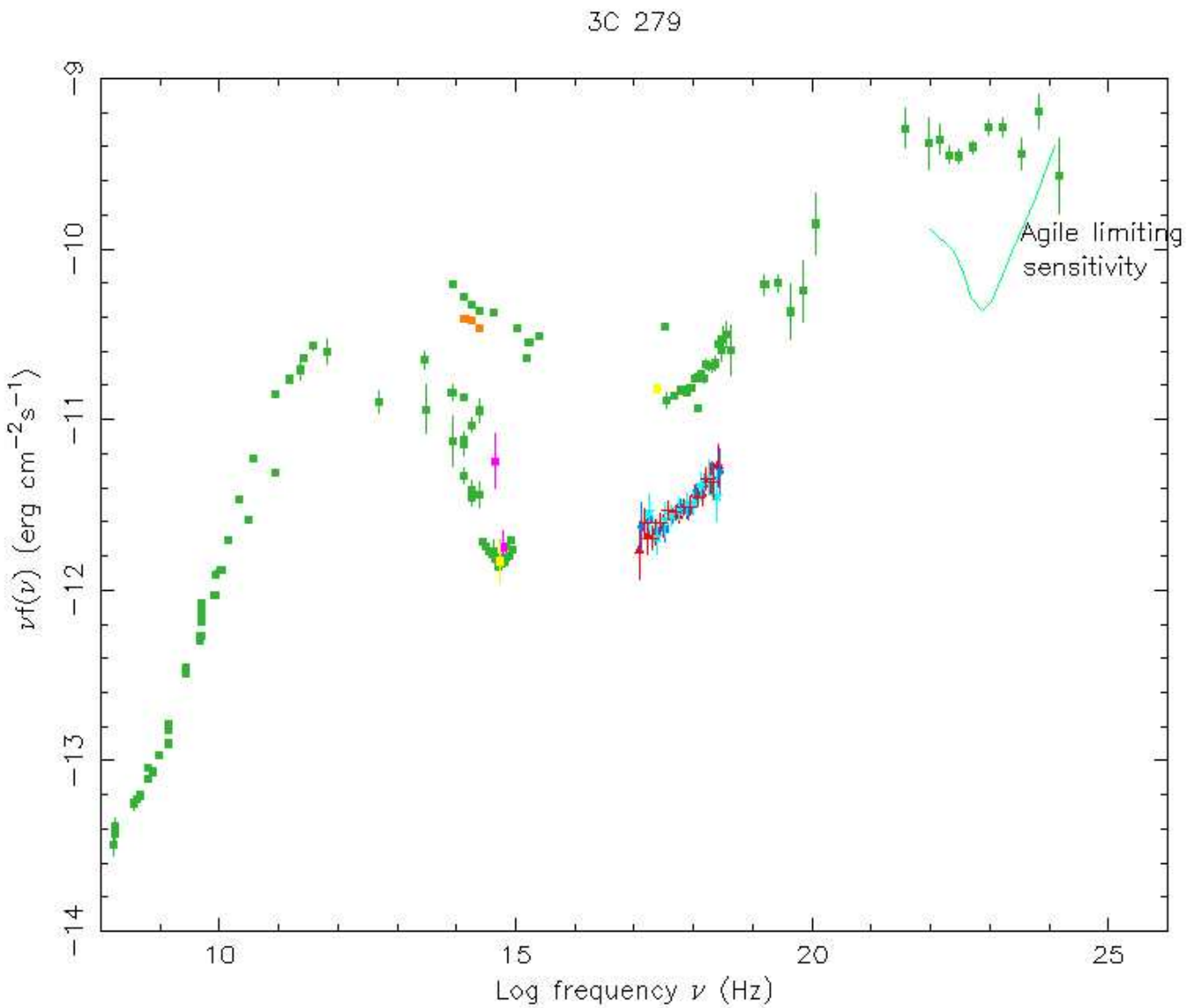


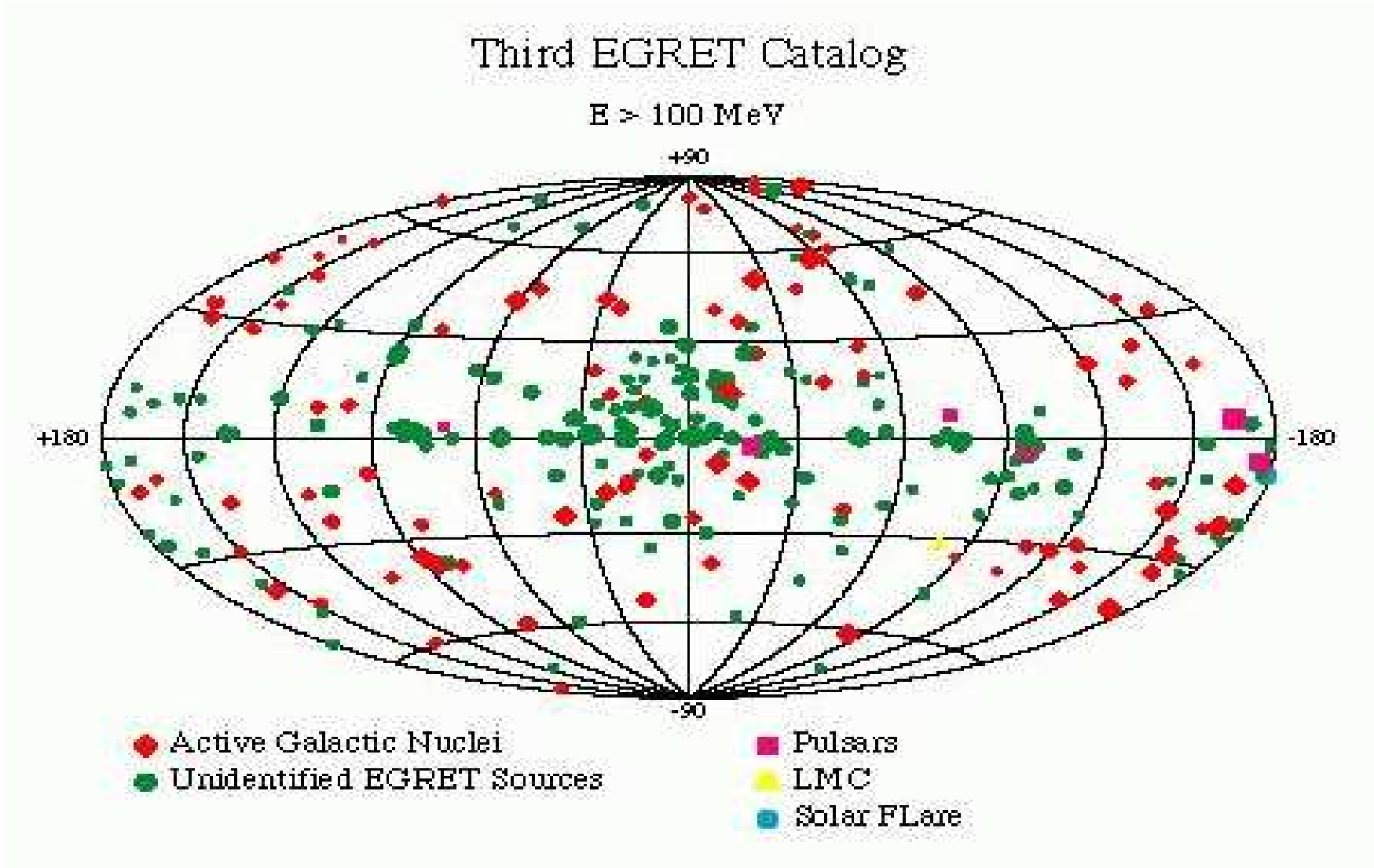
FSRQs : strong and broad emission lines; strong cosmological evolution





The overall Spectral Energy Distribution (SED) of a typical Blazar : 3C 279




Third EGRET Catalog
E > 100 MeV
+90
+180
-180
-90
Active Galactic Nuclei
Unidentified EGRET Sources
Pulsars
LMC
Solar FLare

*Beppo*SAX Blazars Observations Statistics

116 pointings of 60 BL Lacs for a total exposure of ~3.5Ms
83 pointings of 49 Radio Loud QSOs, exposure of~3.3Ms

About 15% of the full *Beppo*SAX scientific program.

BeppoSAX spectral fits

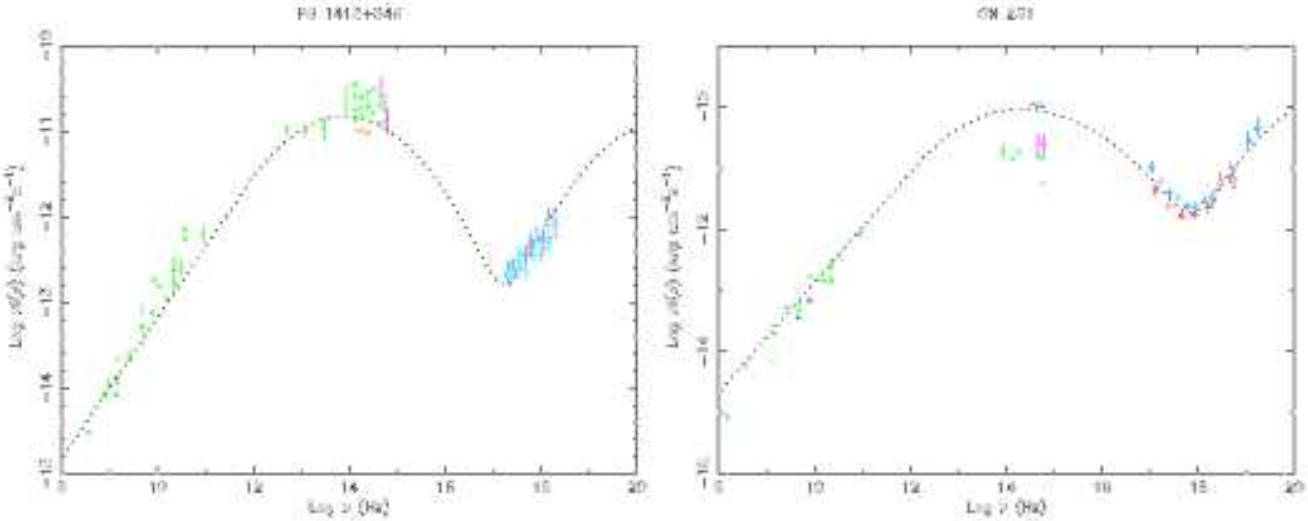


Fig. 4. Spectral energy distributions of a typical LBL object (PG 1418+546, $\nu_{peak} \approx 0.4$ eV $\approx 8 \times 10^{13}$Hz) for which the X-ray emission is dominated by the flat inverse Compton radiation and of an Intermediate BL Lac (ON 231, $\nu_{peak} \approx 1$ eV $\approx 2 \times 10^{14}$Hz) where the simultaneous optical and *Beppo*SAX observations (Tagliaferri et al. 2000) clearly show that the transition between the synchrotron and inverse Compton emission occurs in the soft X-ray band.

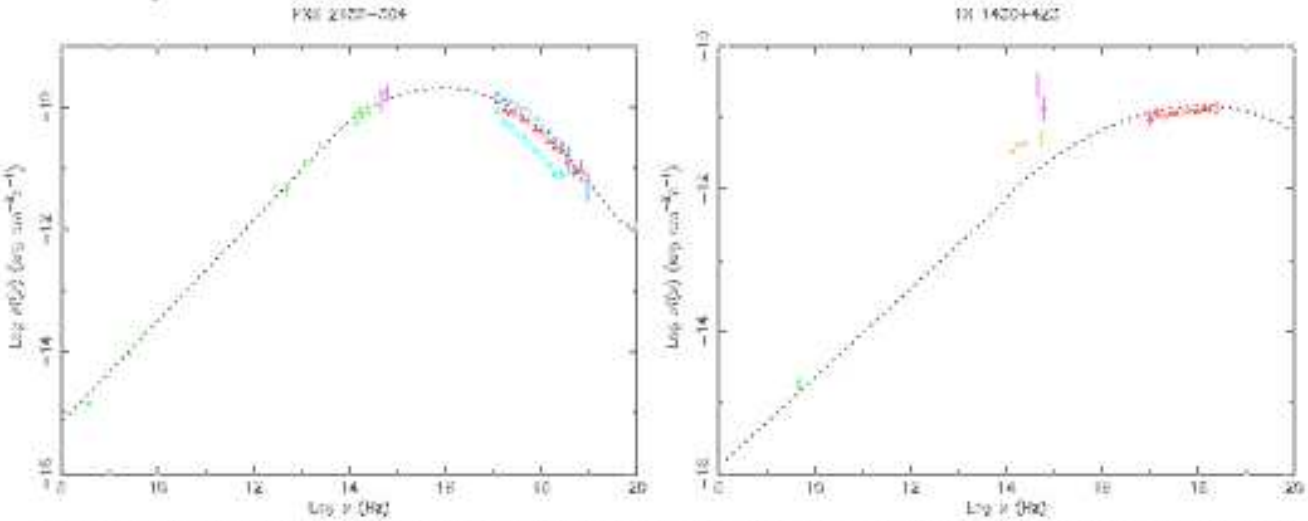
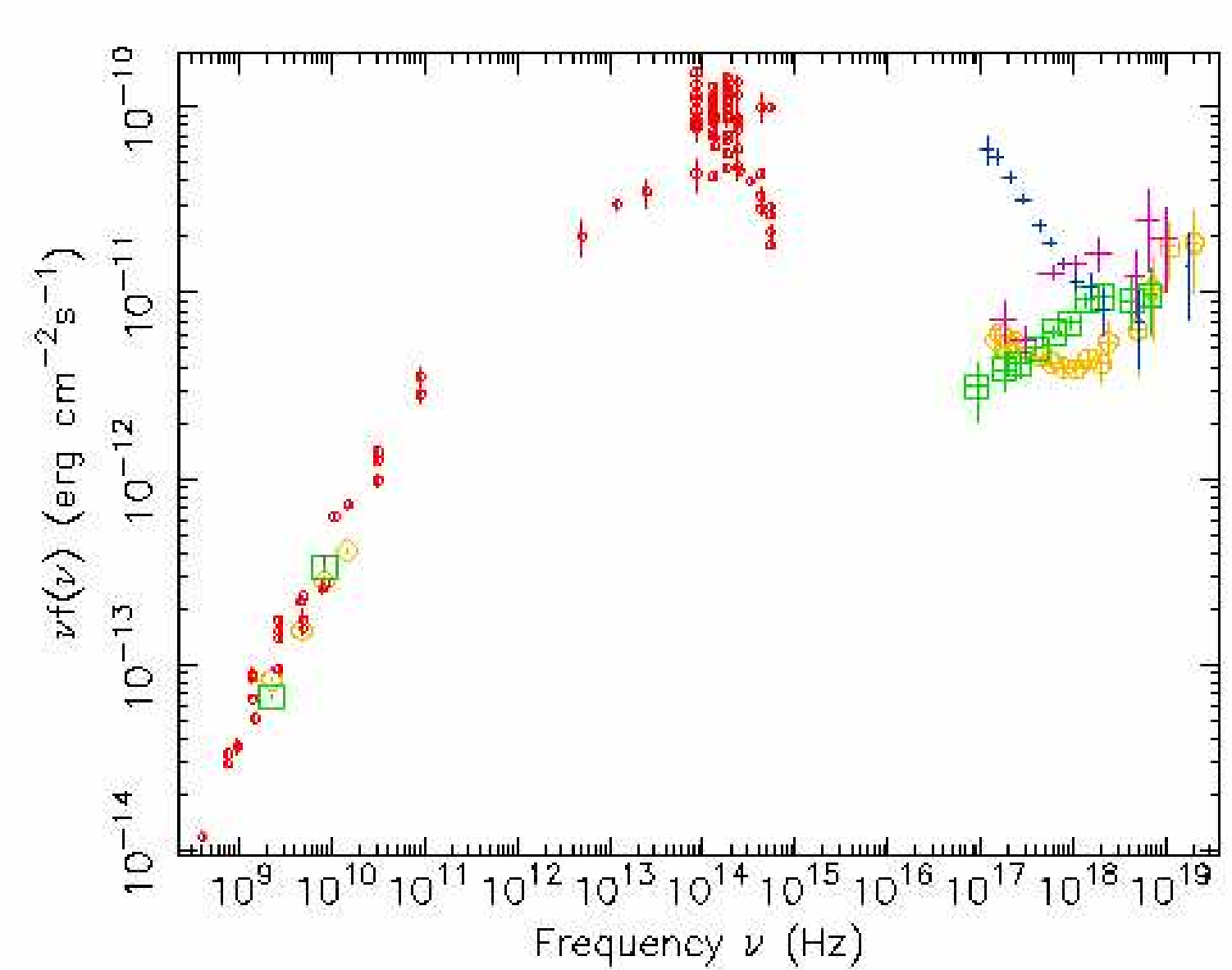


Fig. 5. Spectral energy distributions of HBLs where the X-ray emission is completely dominated by synchrotron radiation. In the case of PKS 2155−304 ν_{peak} is at ≈ 50 eV $\approx \times 10^{16}$ Hz while for the extreme HBL 1H 1430+423 ν_{peak} is above 10 keV.

BeppoSAX NFI data: BL Lacertae



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A Catalog of 157 X-ray Spectra and 84 SEDs of Blazars observed with *Beppo*SAX

P.Giommi, M. Capalbi, M.T. Fiocchi, E. Memola, M. Perri, S. Piranomonte, S. Rebecchi and E. Massaro

Proceedings of the workshop
Blazar Astrophysics with BeppoSAX and other Observatories

Abstract Full paper (gzipped postscript)

Available parameters

- Name Ra Dec
- Z Vmag
- Radio flux 5.GHz
- Survey Class

GO

BL Lacs | QSO | Full sample

RESET

Entry number		Source name	RA (J2000.0) hh mm ss.d	Dec (J2000.0) dd mm ss.d	Redshift Z	Vmag magnitudes	Survey
Subset selection mode: inclusive					Stat	Stat	
1 Select	Show SED	1ES 0033+595	00 35 52.7	+59 50 03.8	0	19.5	Slew
2 Select	Show SED	PKS 0048-097	00 50 41.3	-09 29 04.9	0	16.27	1 Jy
3 Select	Show SED	1ES 0120+340	01 23 08.6	+34 20 48.8	0.272	15.19	Slew
4 Select	Show SED	1ES 0145+138	01 48 29.7	+14 02 17.8	0.125	17.9	Slew
5 Select	Show SED	MS 0158.5+0019	02 01 06.1	+00 34 00.1	0.299	17.96	EMSS
6 Select	Show SED	3C 66A	02 22 39.6	+43 02 08.1	0.444	15.5	Slew
7 Select	Show SED	AO 0235+164	02 38 38.8	+16 36 59.0	0.94	17.04	1 Jy
8 Select	Show SED	MS 0317.0+1834	03 19 51.9	+18 45 33.8	0.19	18.12	EMSS
9 Select	Show SED	1H 0323+022	03 26 13.8	+02 25 14.8	0.147	17.4	HEAO-1
10 Select	Show SED	1ES 0347-121	03 49 23.2	-11 59 26.8	0.188	18.2	Slew
11 Select	Show SED	1H 0414+009	04 16 52.3	+01 05 24.0	0.287	17.5	HEAO-1
12 Select	Show SED	1ES 0502+675	05 07 56.2	+67 37 23.8	0.314	17	Slew

SED+Model for source: sed_J1104p3812 - Netscape

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SSC model parameters

1.40
Norm. el. sp. log (cm^{-3})

1.450
el. sp. Index 1 n < 3

4.70
el. sp. Index 2 n > 3

4.45
el. sp break en. log(e/mc^2)

0.260
mag field B (Gauss)

14.00
Doppler factor δ

0.0030
Jet radius (pc)

0.031 redshift

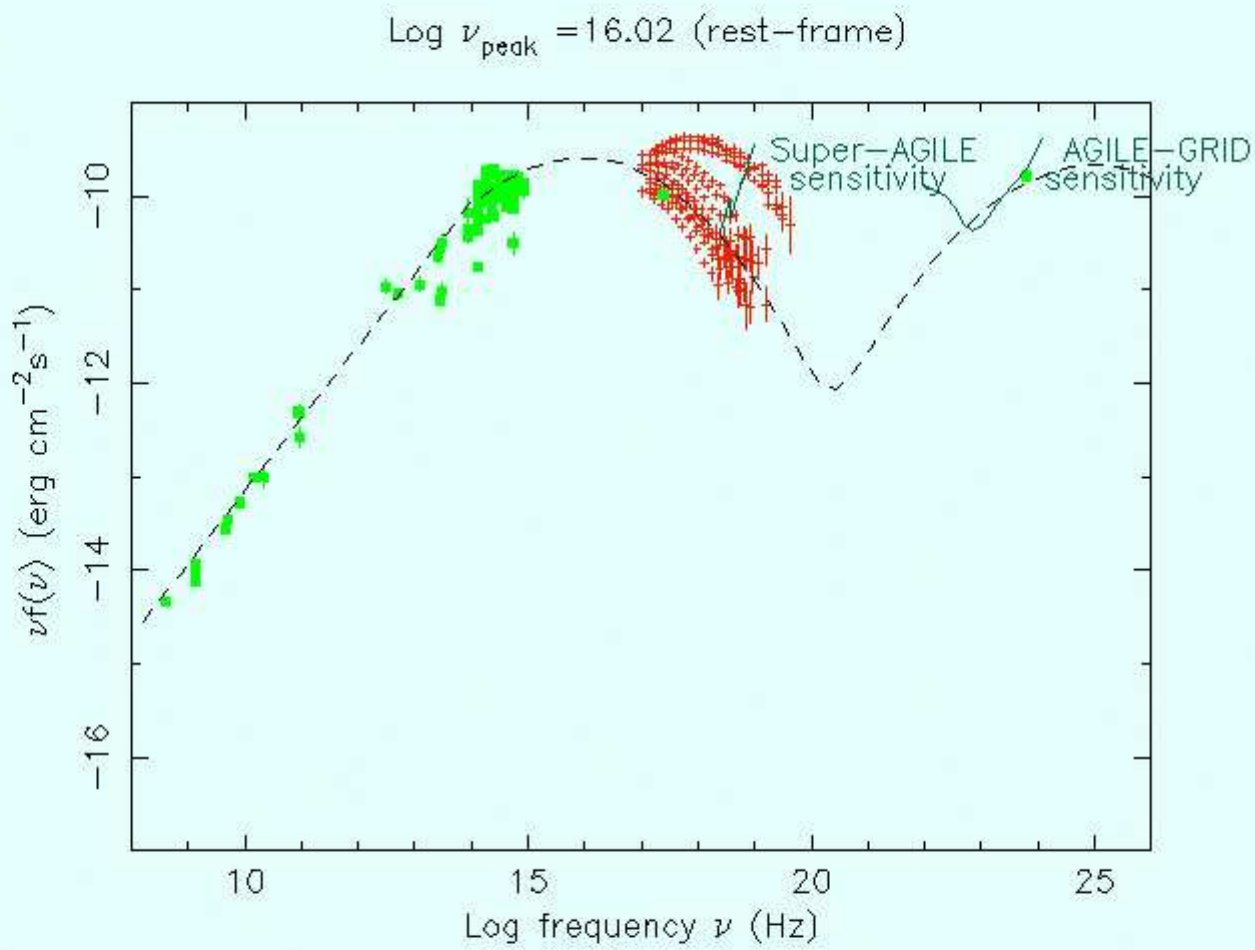
submit reset

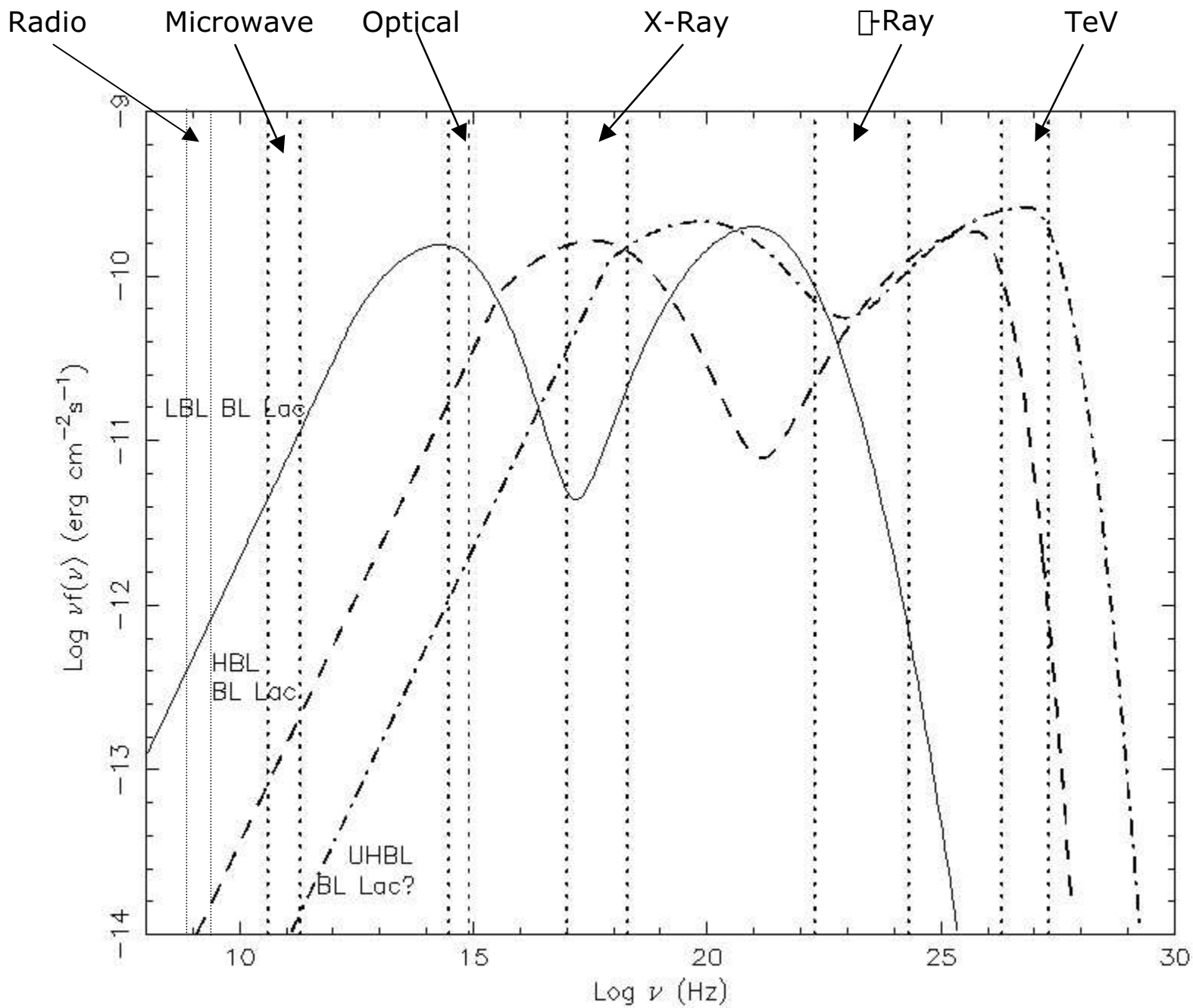
Show instruments limiting sensitivity?

none Integral-IBIS

AGILE

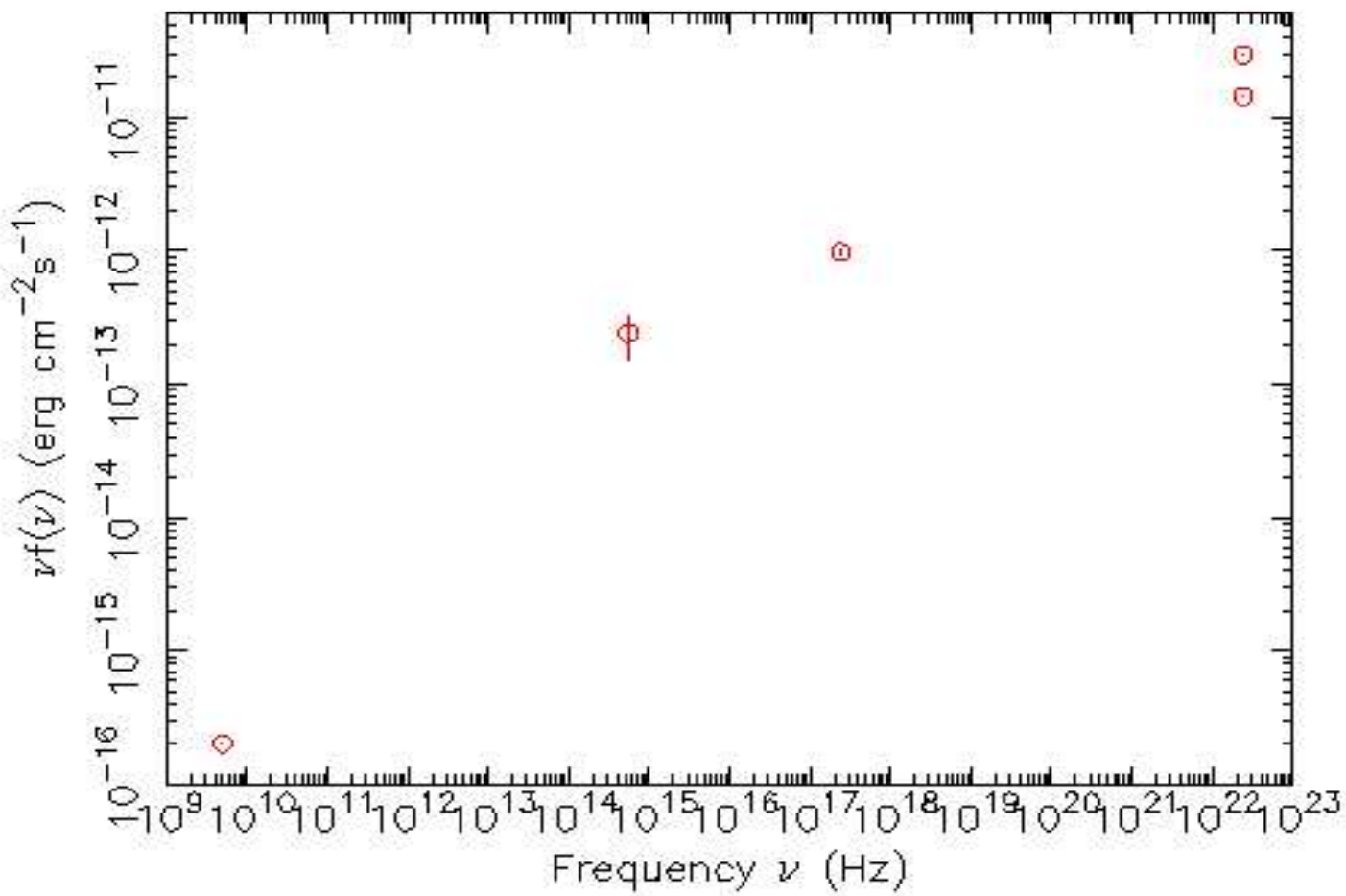
Get data file? no yes




Radio
Microwave
Optical
X-Ray
-Ray
TeV
LBL BL Lac
HBL
BL Lac
UHBL
BL Lac?
Log νf(ν) (erg cm^{-2}s^{-1})
Log ν (Hz)
−9
−10
−11
−12
−13
−14
10
15
20
25
30

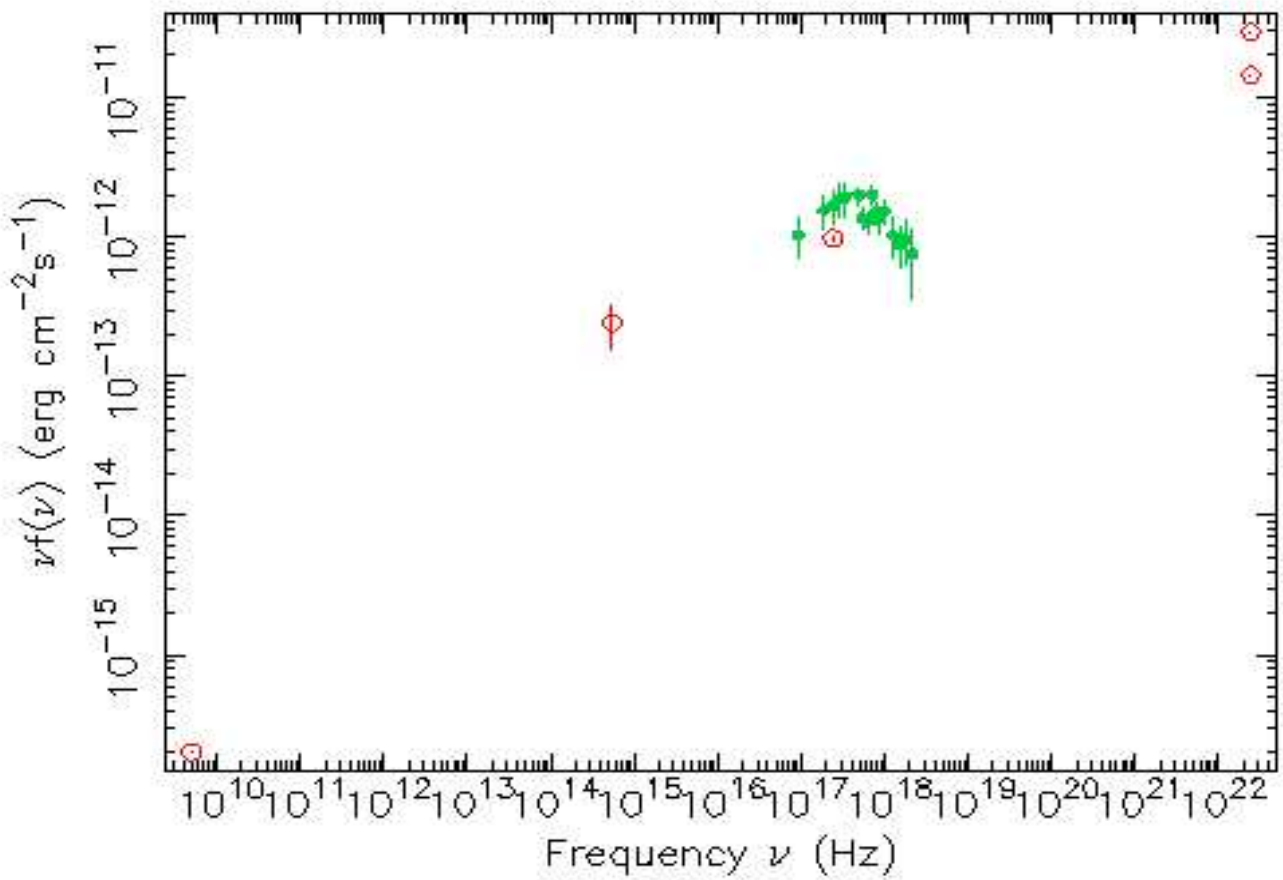
UHBLs as counterparts of EGRET high lblll unidentified sources?

1RXS J 123511.1-14033



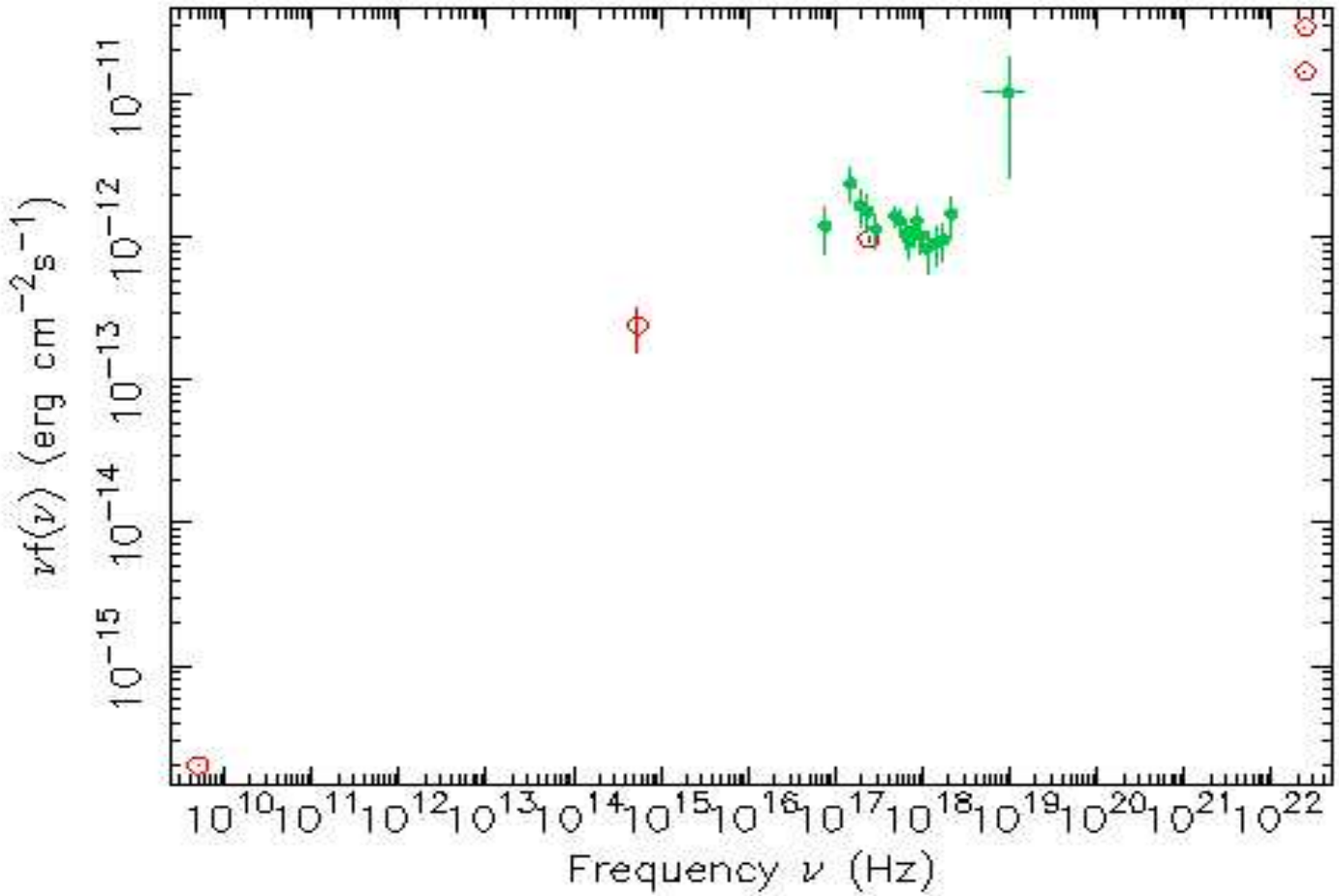
UHBLs as counterparts of EGRET high lblll unidentified sources?

Well, may be not...

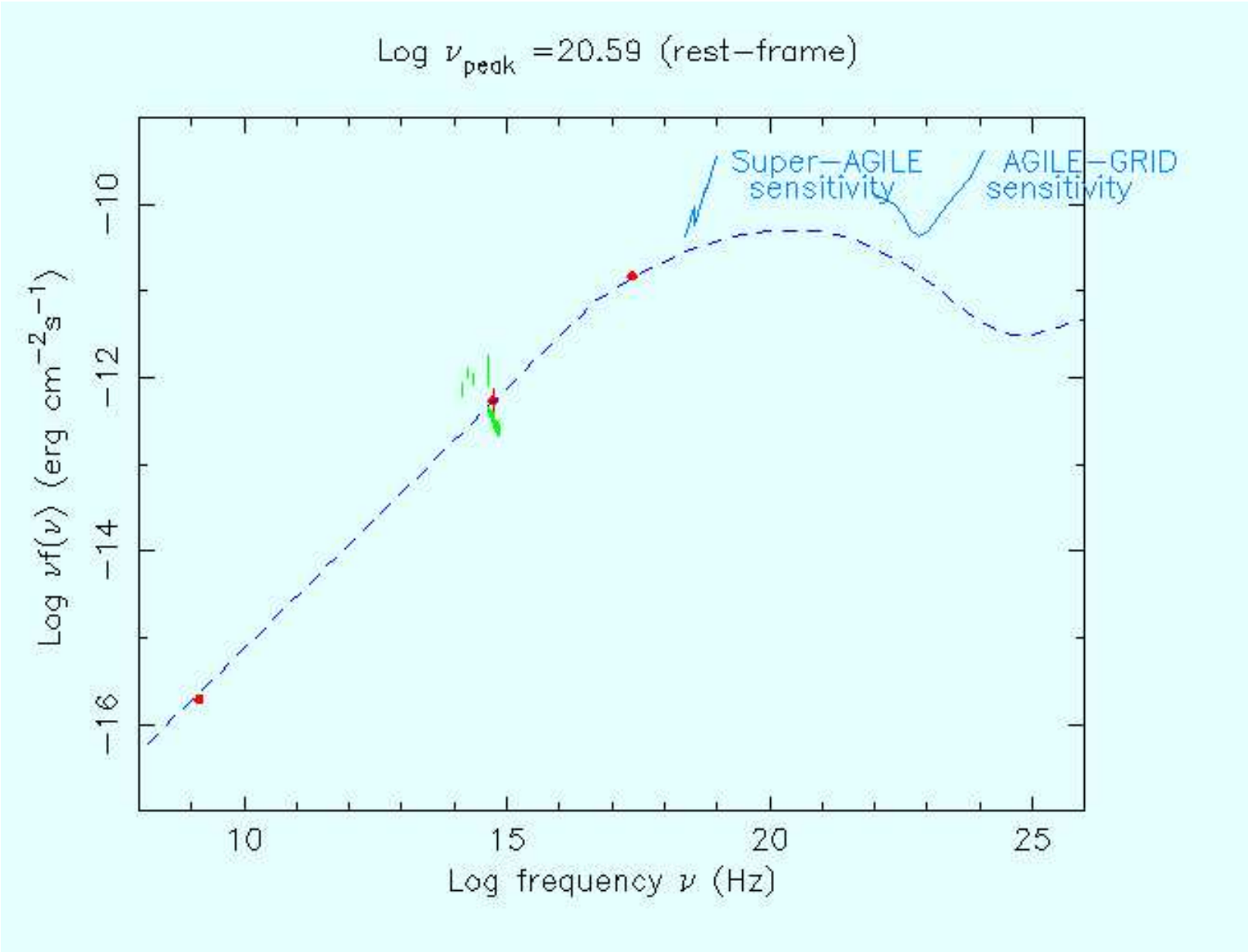


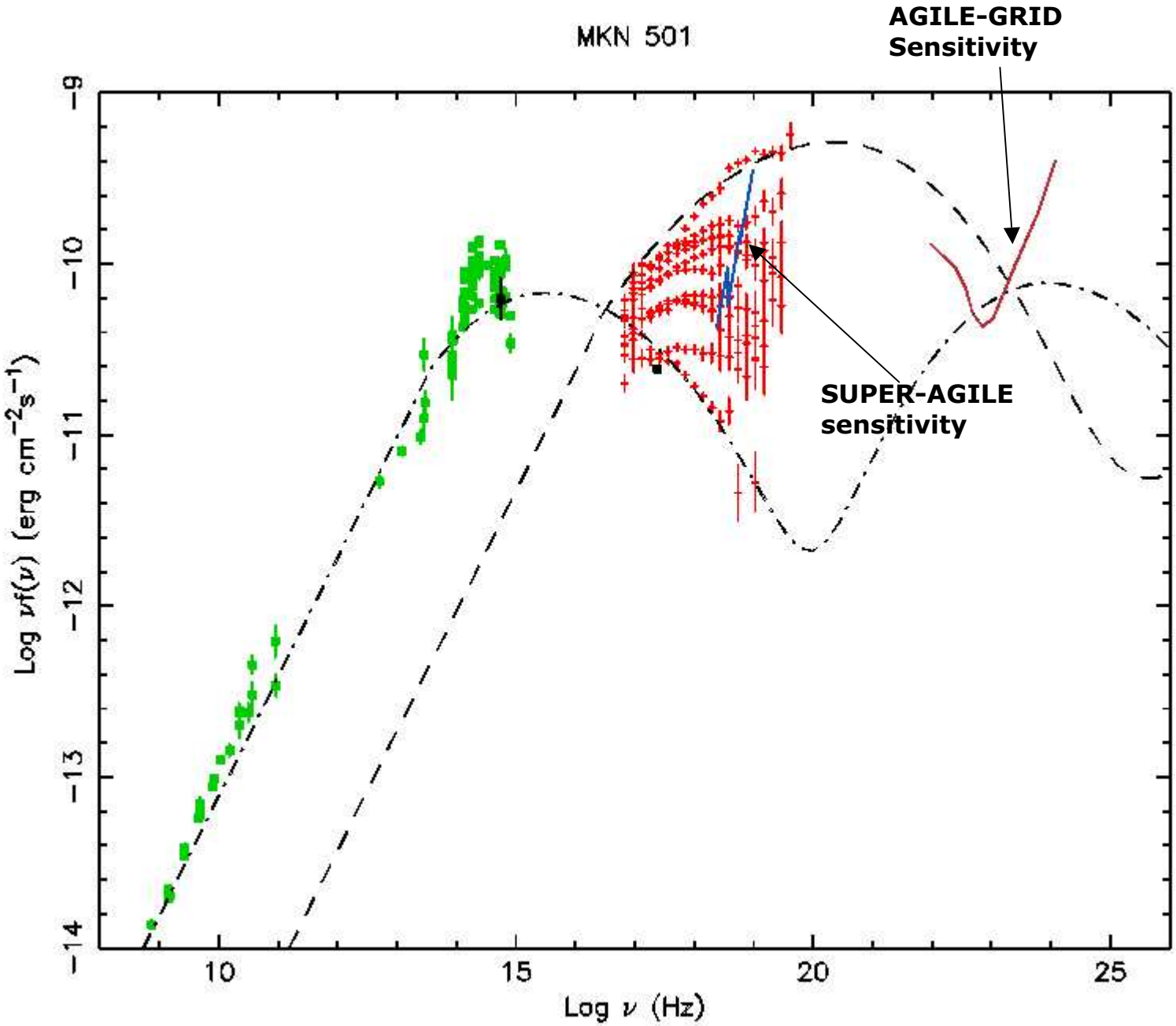
UHBLs as counterparts of EGRET high lblll unidentified sources?

But a few days later...

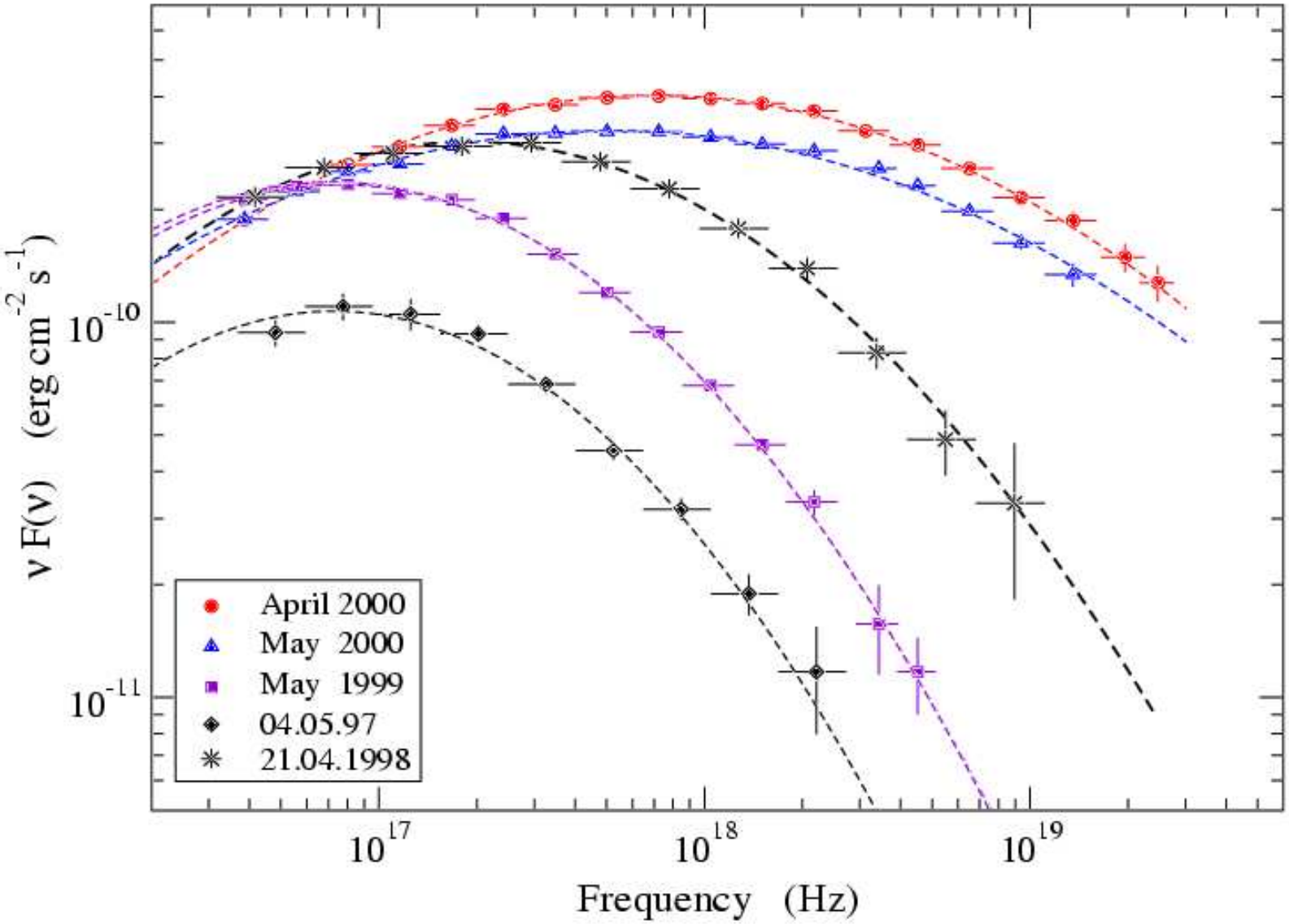


SHBL J044127.4+150456

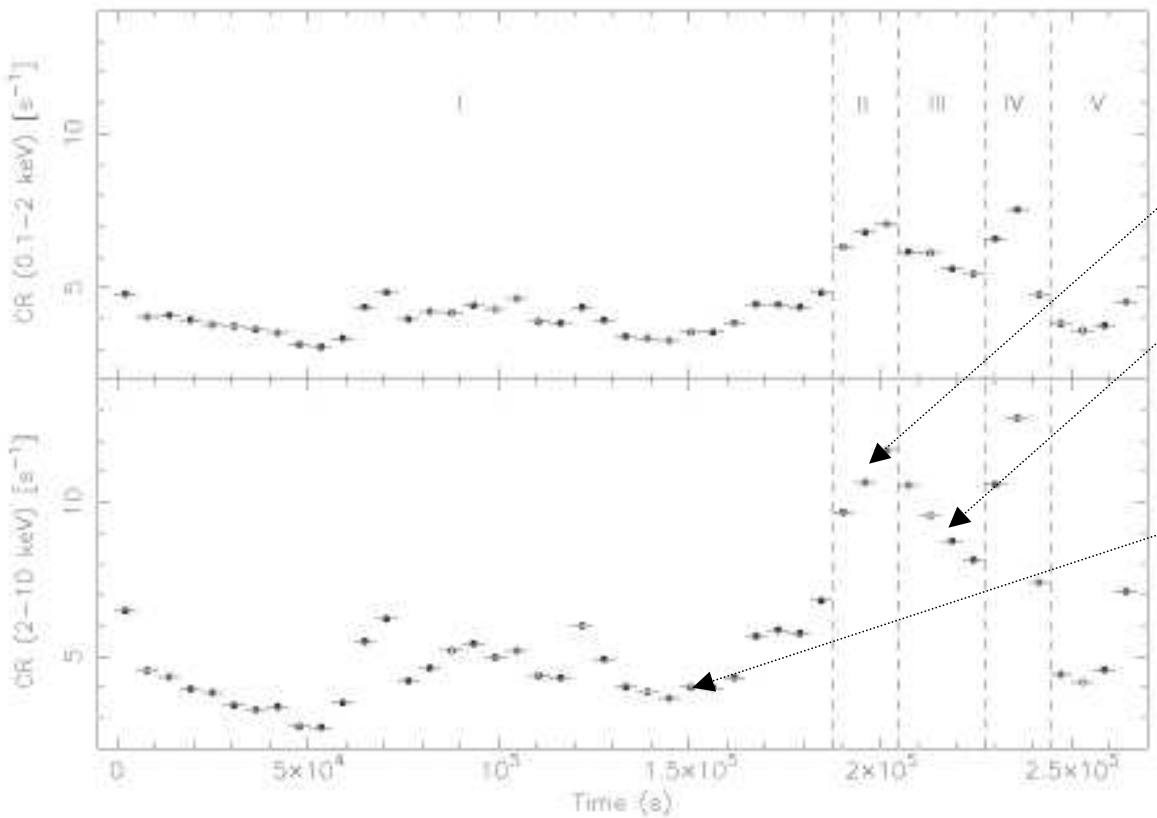


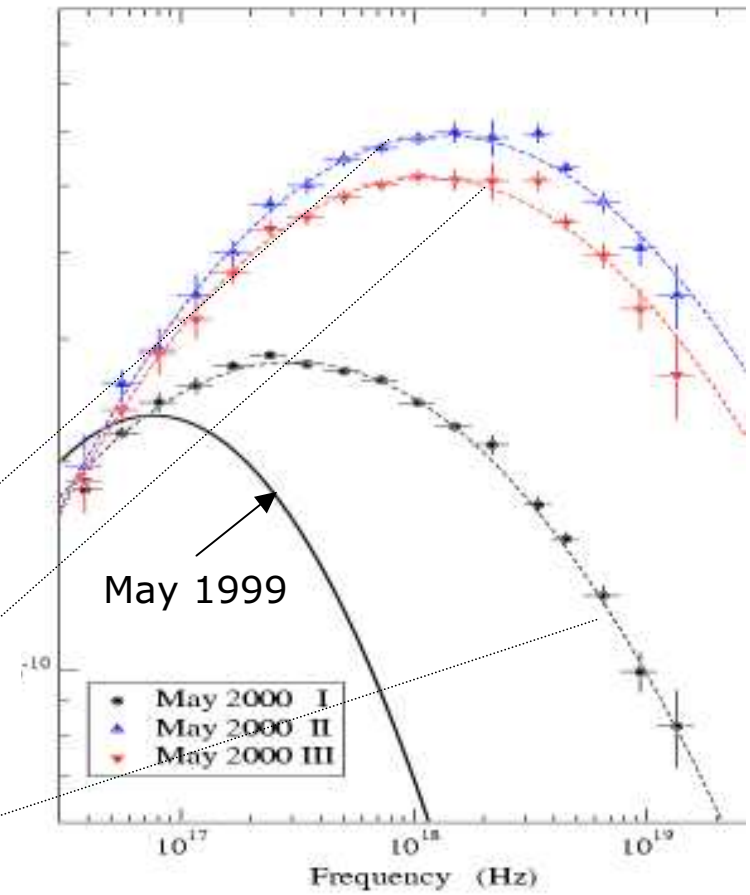

MKN 501
AGILE-GRID
Sensitivity
SUPER-AGILE
sensitivity
Log νf(ν) (erg cm^{-2}s^{-1})
Log ν (Hz)
−9
−10
−11
−12
−13
−14
10
15
20
25

A detailed analysis of all BeppoSAX observationd of MKN 421
Massaro, Perri, Giommi, Nesci, 2003 A&A in press



MKN421 in a bright state:
the BeppoSAX observation of May 2000





BeppoSAX spectral fits : main results

In HBL Objects, where the synchrotron component dominates the –ray spectrum, **the logarithmic parabola model describes the data significanly better than other models**

This is interpreted as evidence of intrinsic curvature in the particle sepctrum rather then cooling.

Such a curvature can be obtained in simple statistical acceleration processes where the probability for a particle to increase its energy is a decreasing function of energy itself.

5. Statistical particle acceleration and log-parabolic spectra

5.1. Energy distribution of accelerated particles

The energy spectrum of accelerated particles by some statistical process, like a shock wave, is usually written as a power law

$$N(>\gamma) = No(\gamma/\gamma_0)^{-s} \quad , \tag{6}$$

where $N(>\gamma)$ is the number of particles having a Lorentz factor greater than γ and s is the spectral index given by:

$$s = -\frac{Log\ p}{Log\ \epsilon} \quad , \tag{7}$$

here p is the probability that a particle is subject to the acceleration step i in which it has an energy gain equal to ϵ assumed both independent of energy :

$$\gamma_i = \epsilon\gamma_{i-1} \tag{8}$$

and

$$N_i = pN_{i-1} = N_0\ p^i \quad . \tag{9}$$

A log-parabolic energy spectrum follows when the condition that p is independent of energy is released and one assumes that it can be described by a power relation as:

$$p_i = g/\gamma_i^q \quad , \tag{10}$$

where g and q are constant; in particular, for $q > 0$ the probability for a particle to be accelerated is lower and lower when its energy decreases. Such a situation can be realized, for instance, if particles are confined by a magnetic field with confinement efficiency decreasing for an increasing gyration radius. After simple calculations opne finds instead of Eq.(9):

$$N_i = N_0\ \frac{g^i}{\prod_{j=0}^{i-1}\gamma_j^q} \quad . \tag{11}$$

Using Eq.(8) one can write this product as:

$$\prod_{j=0}^{i-1}\gamma_j^q \ = \ \gamma_0^{iq}\prod_{j=1}^{i-1}\epsilon^{jq} \ = \ \gamma_0^{iq}\ (\epsilon^q)^{i(i-1)/2} \quad , \tag{12}$$

where γ_0 is the initial Lorentz factor of the particles; inserting this result into Eq.(11) we obtain:

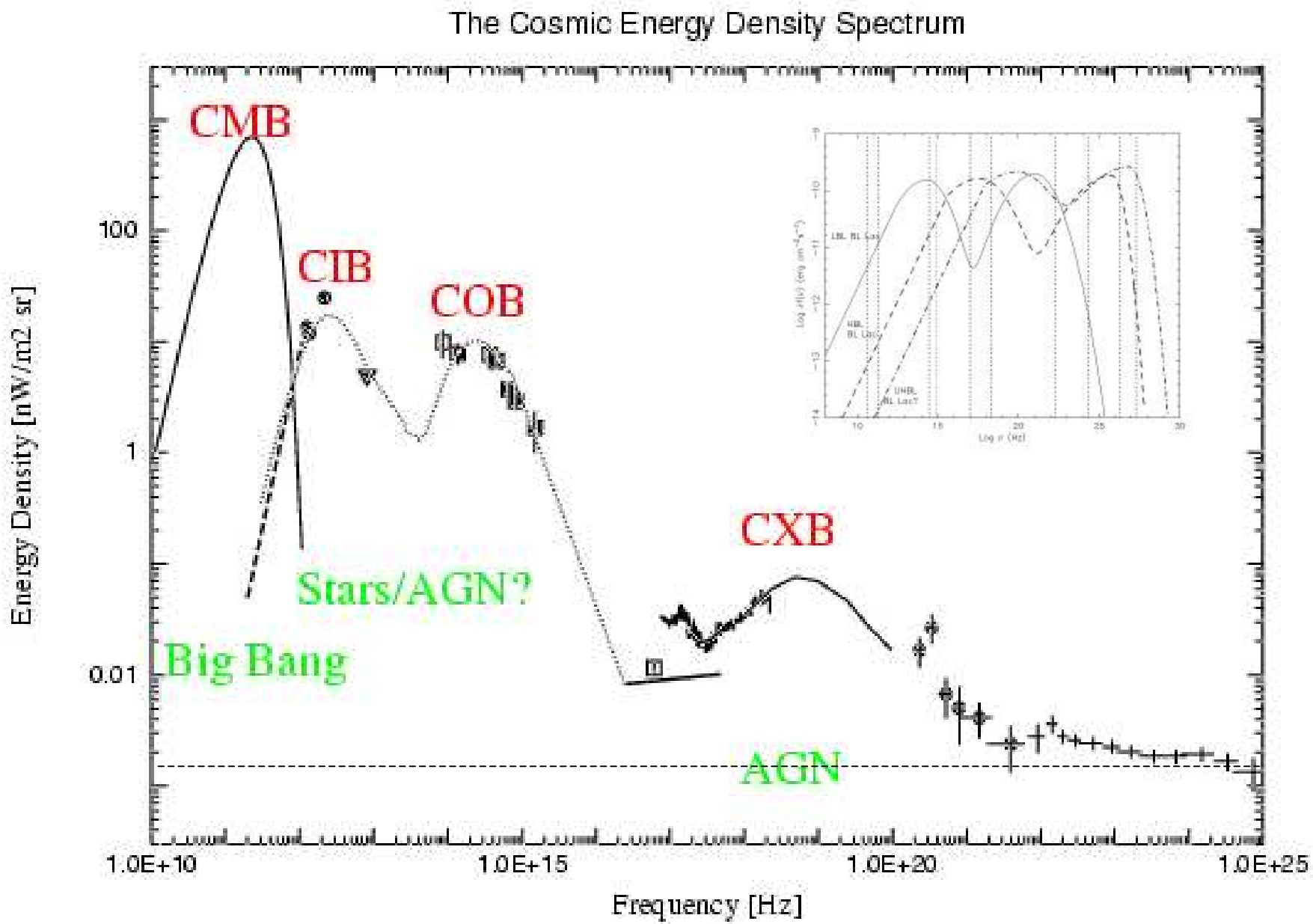
$$N_i = N_0\ (\frac{g}{\gamma_0^q})^i\ (\epsilon^q)^{i(i-1)/2} \quad . \tag{13}$$

Finally, combining this equation with Eq.(8) one can obtain the integral energy distribution of the accelerated particles:

$$N(>\gamma) = N_0(\gamma/\gamma_0)^{-s+rLog(\gamma/\gamma_0)} \quad , \tag{14}$$

with

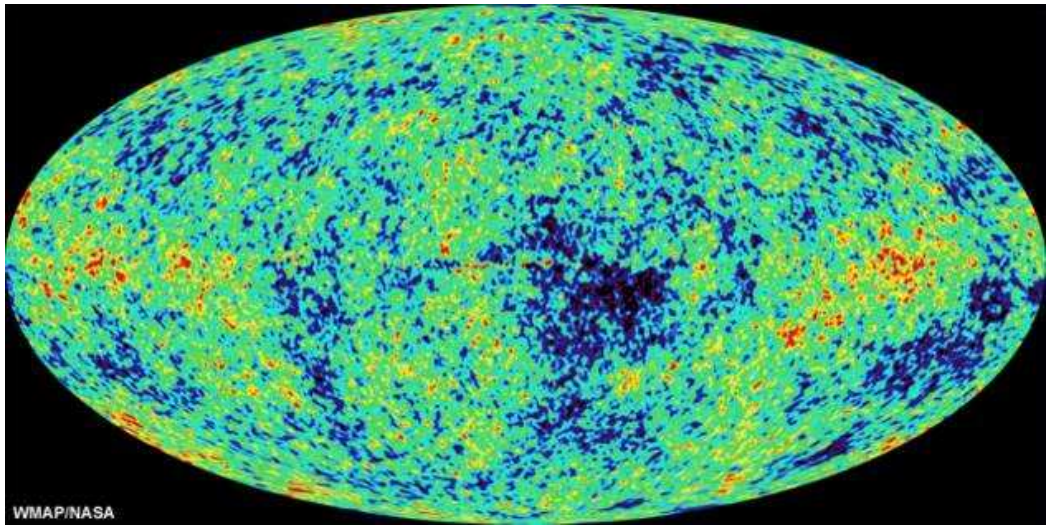
$$s = -\frac{Log(g/\gamma_0)}{Log\ \epsilon} - \frac{q}{2} \tag{15}$$


The Cosmic Energy Density Spectrum
CMB
CIB
COB
CXB
Stars/AGN?
Big Bang
AGN
Energy Density [nW/m2 sr]
100
1
0.01
1.0E+10
1.0E+15
1.0E+20
1.0E+25
Frequency [Hz]

WMAP bright foreground source catalog

208 bright sources, of which

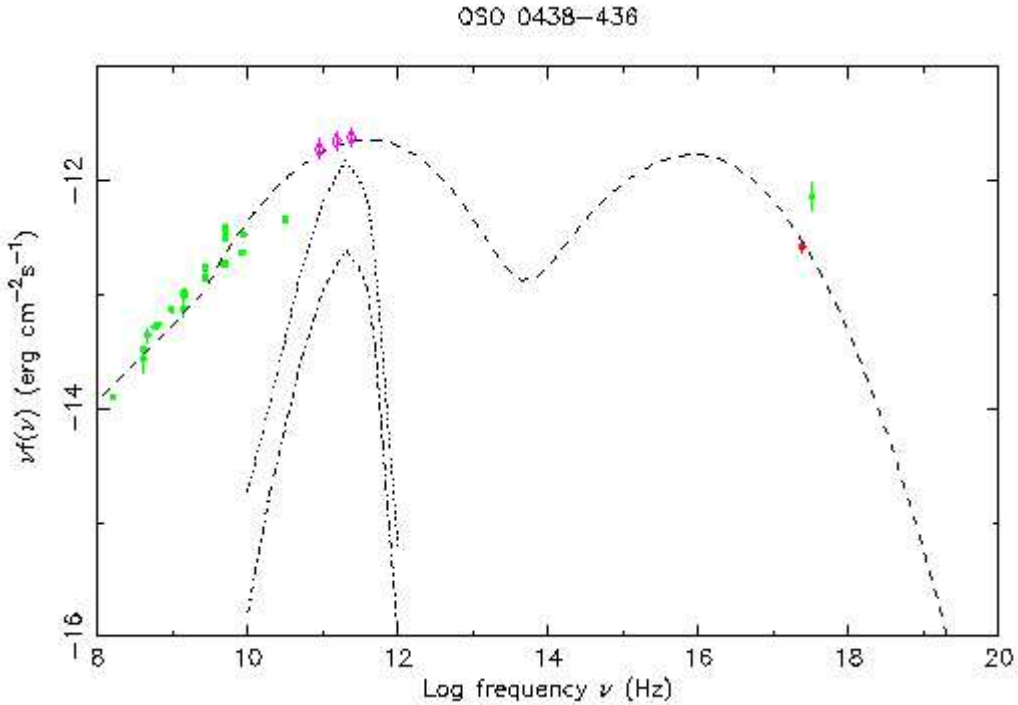
WMAP CMB fluctuation map

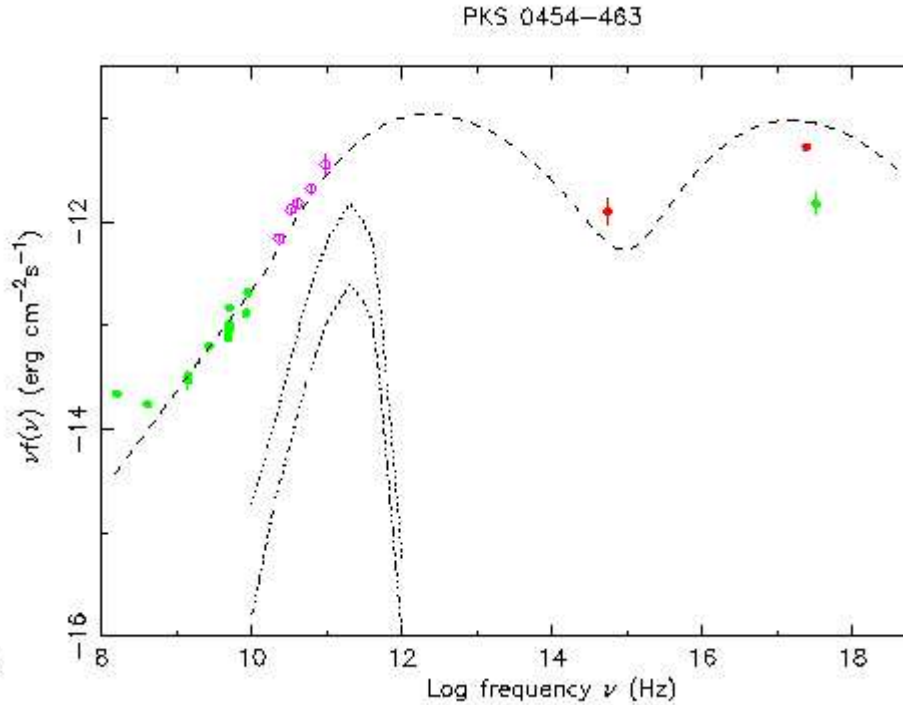


- **140 FSRQs**
- **23 BL Lacs**
- **13 Radio galaxies**
- **5 Steep Spectrum QSOs**
- **2 starburst galaxies**
- **2 planetary nebule**

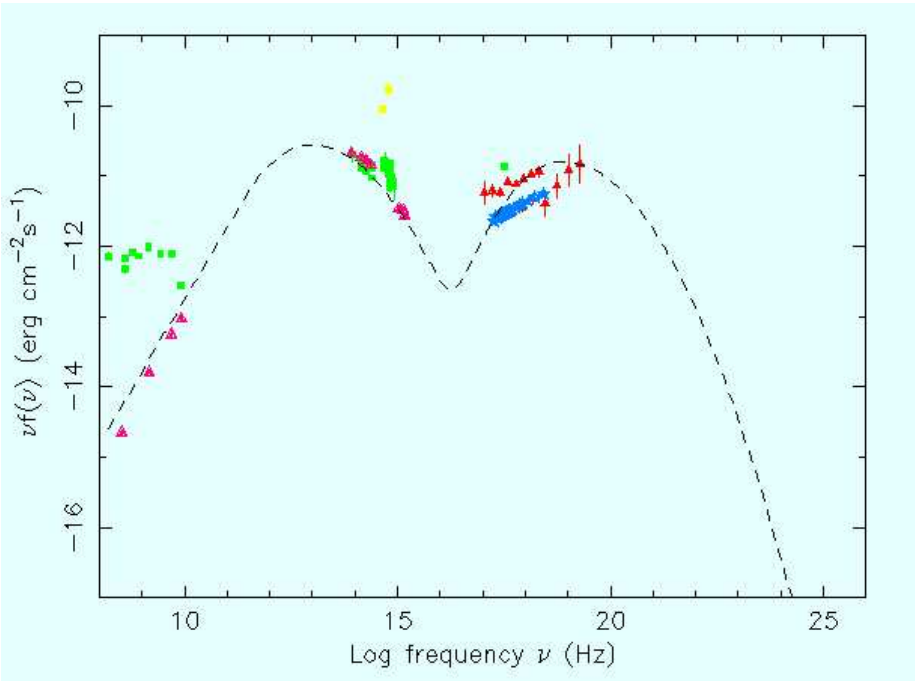
- **17 unidentified**
- **6 without radio counterpart (probably spurious)**

The vast majority of bright WMAP foreground sources are Blazars

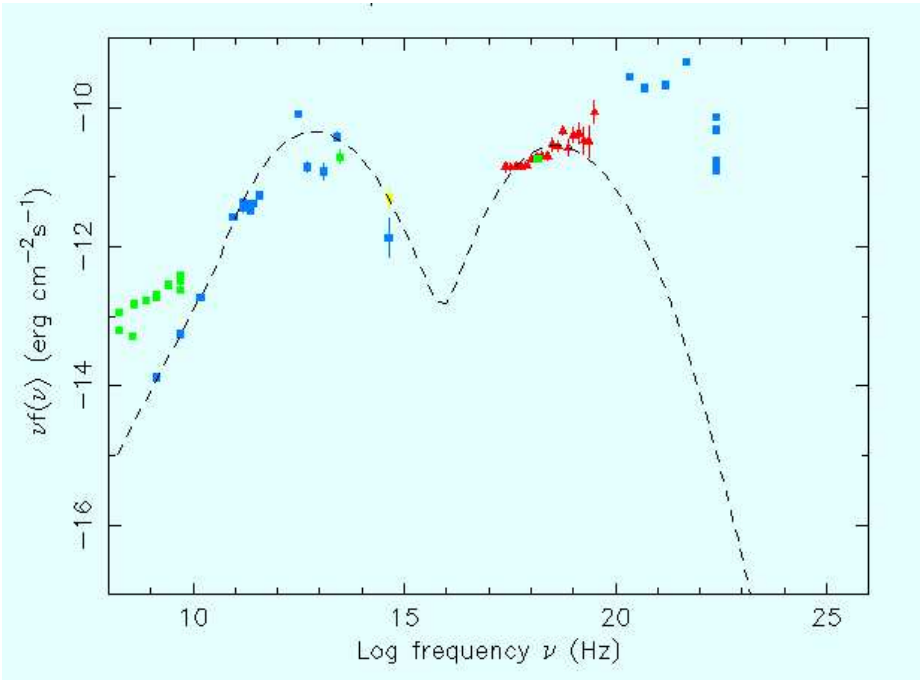

OSO 0438−436
$\nu f(\nu)$ (erg cm^{-2}s^{-1})
−12
−14
−16
8
10
12
14
16
18
20
Log frequency ν (Hz)


PKS 0454−463
$\nu f(\nu)$ (erg cm^{-2}s^{-1})
−12
−14
−16
8
10
12
14
16
18
Log frequency ν (Hz)

Radio Galaxy PKS 0518-45

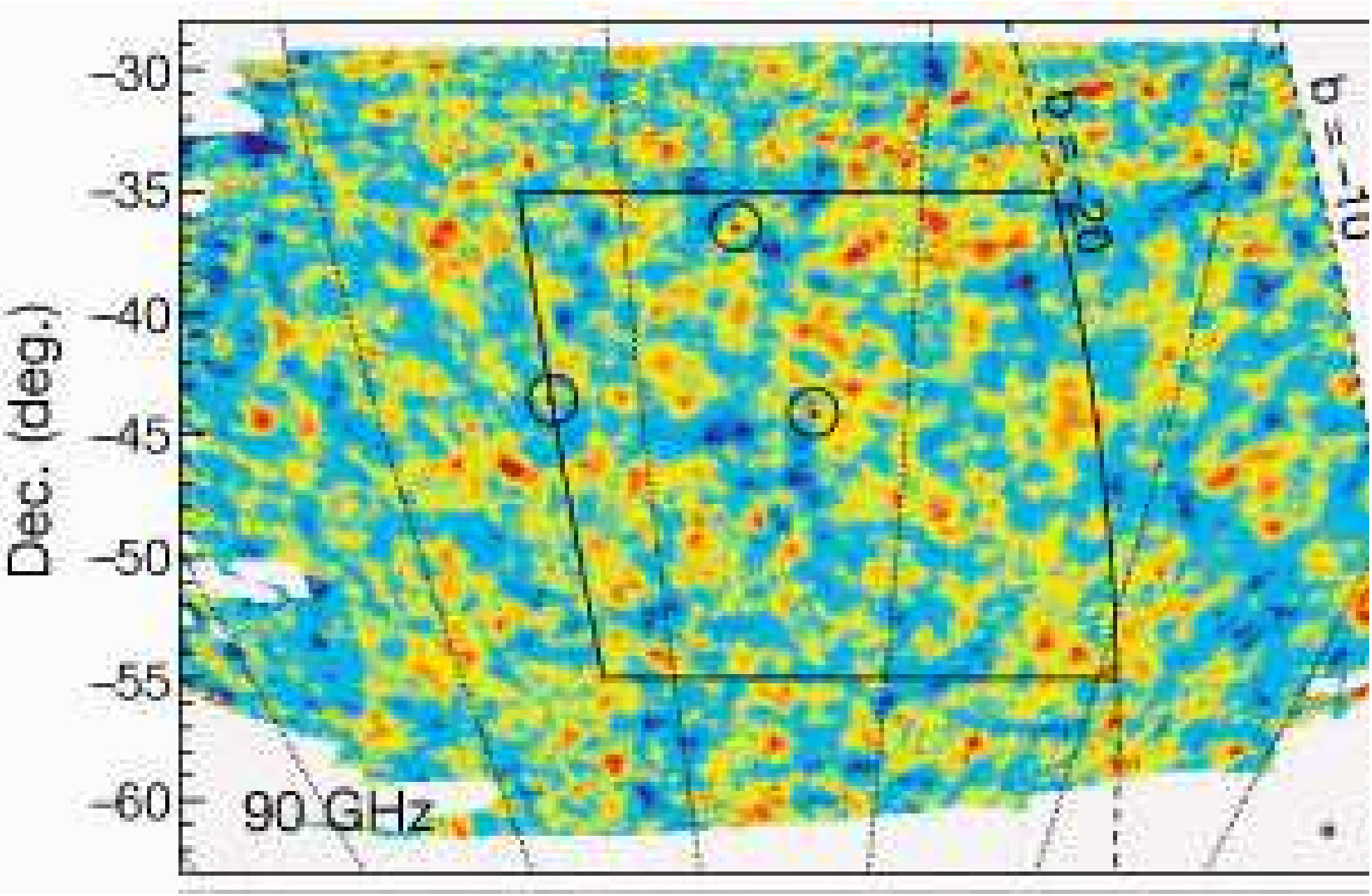


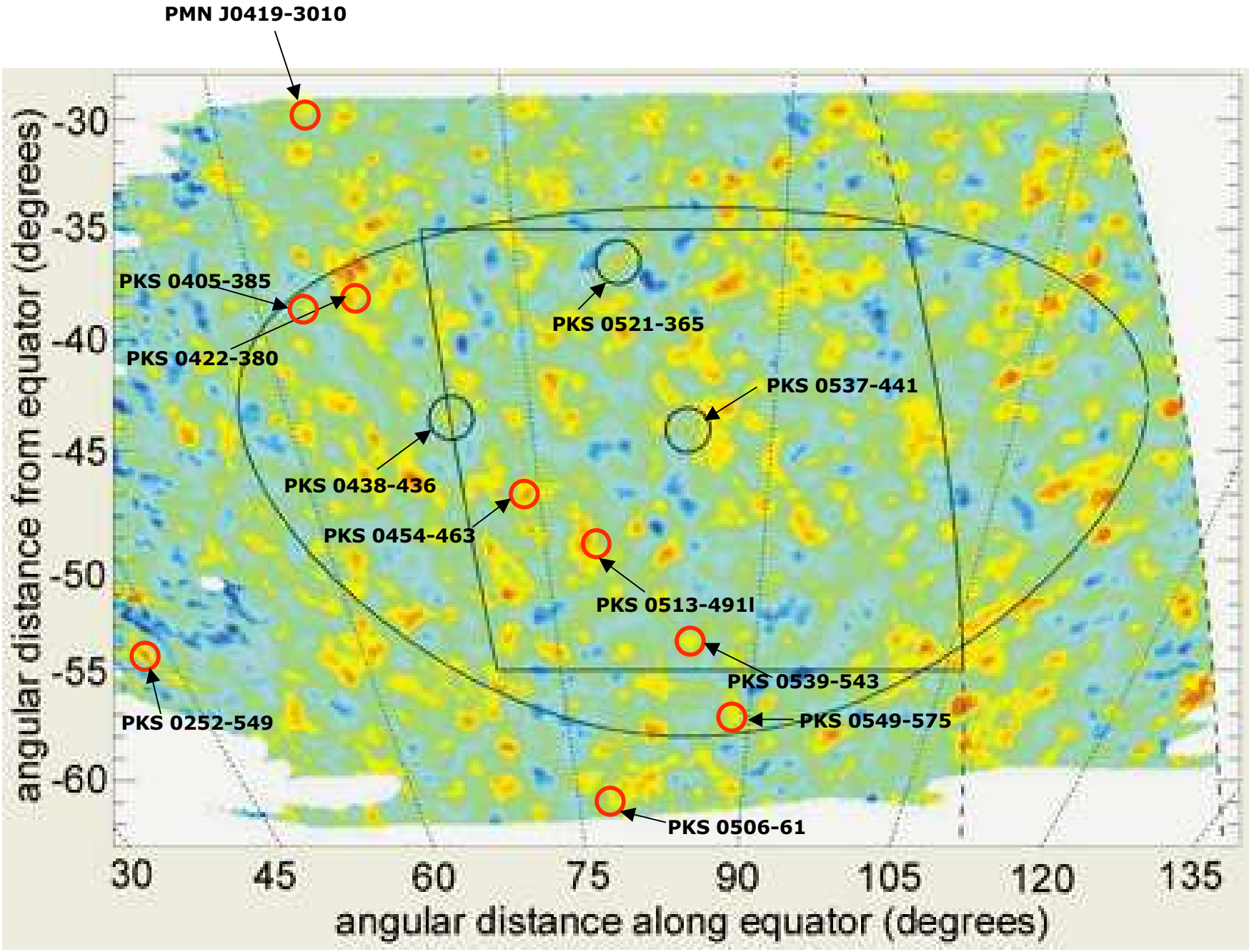
Radio Galaxy 3C 111



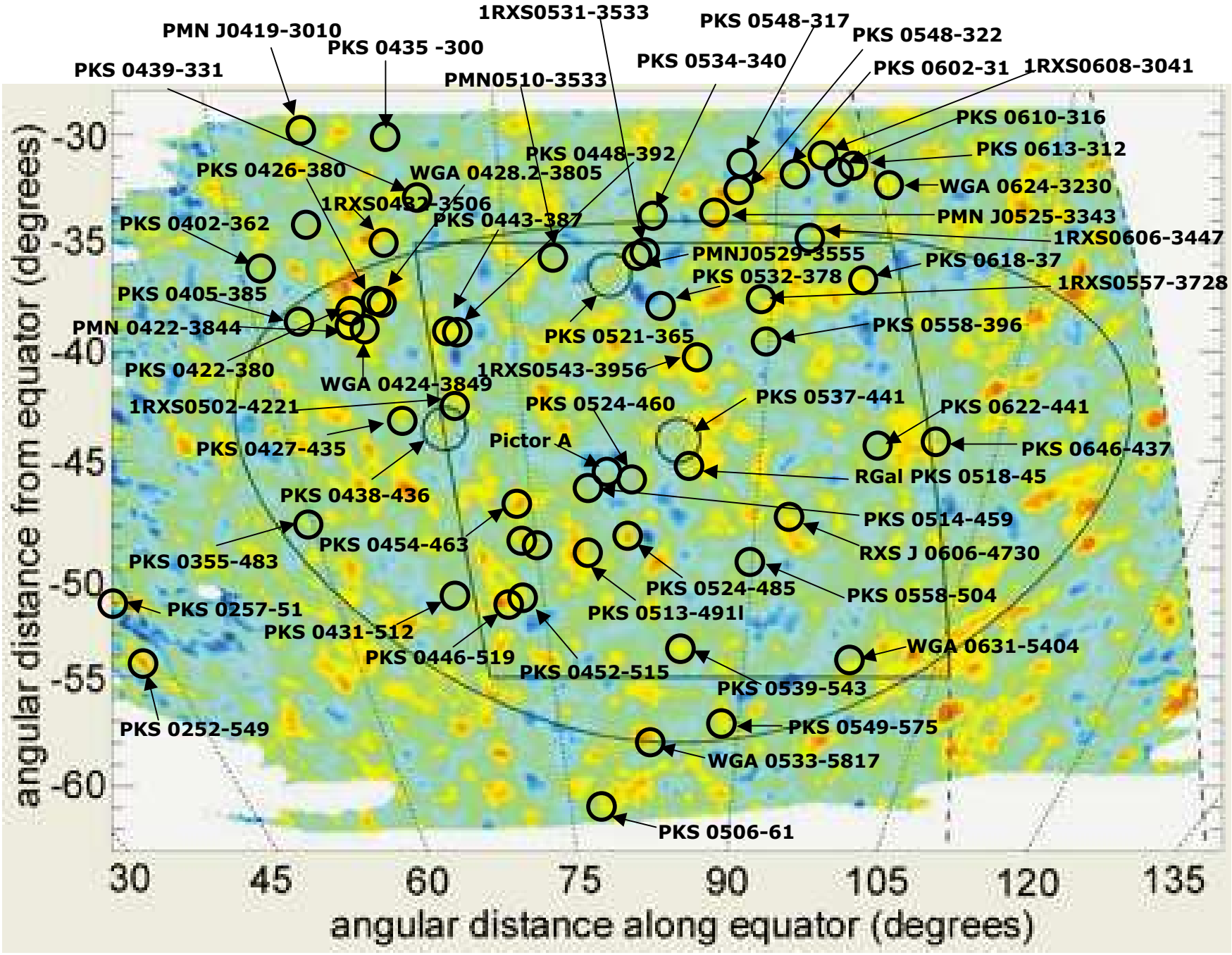
Fiocchi, Grandi et al. in preparation

Boomerang 90 GHz CMB MAP
De Bernardis et al. 2000



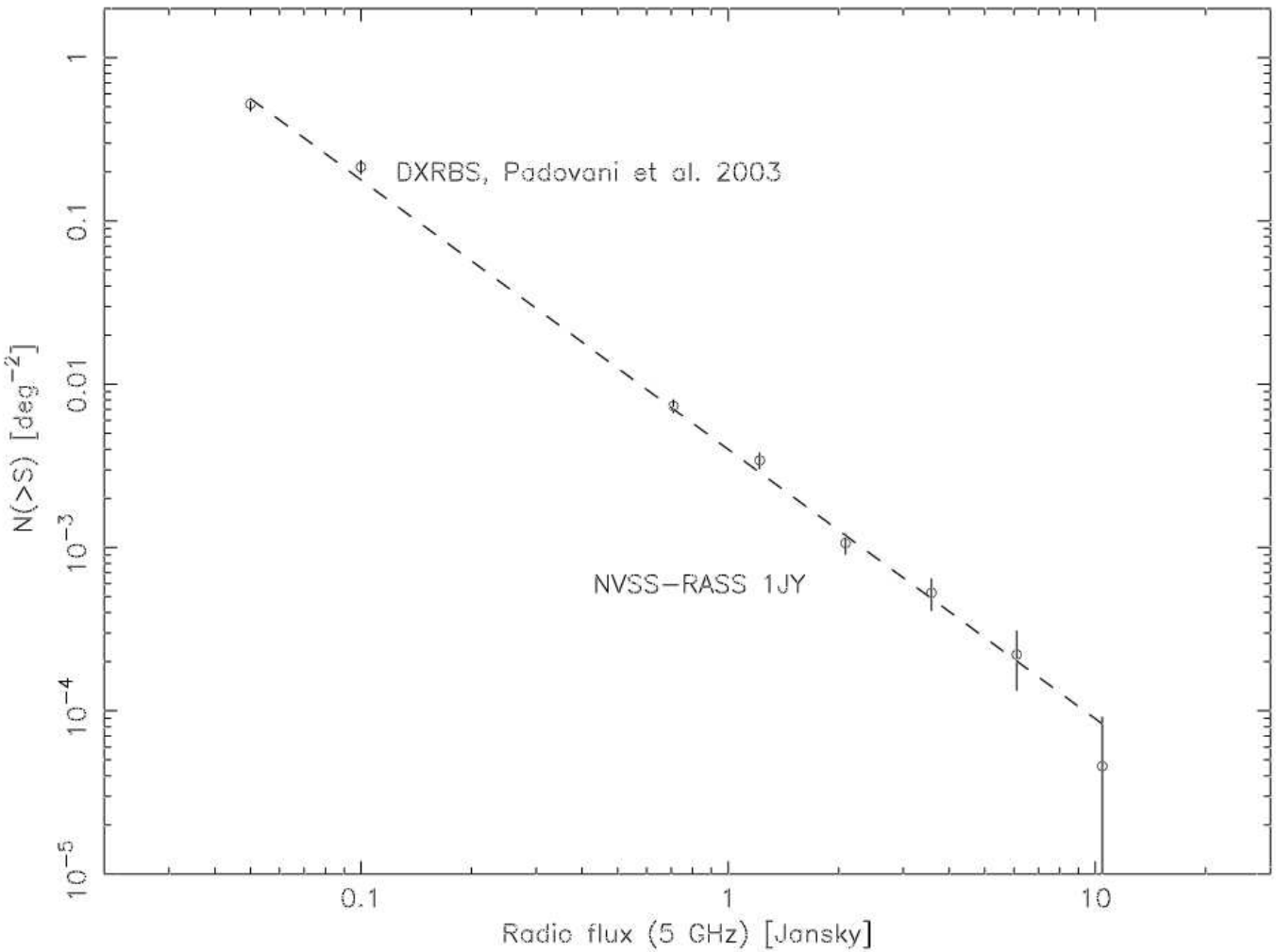


[Giommi & Colafrancesco 2003]



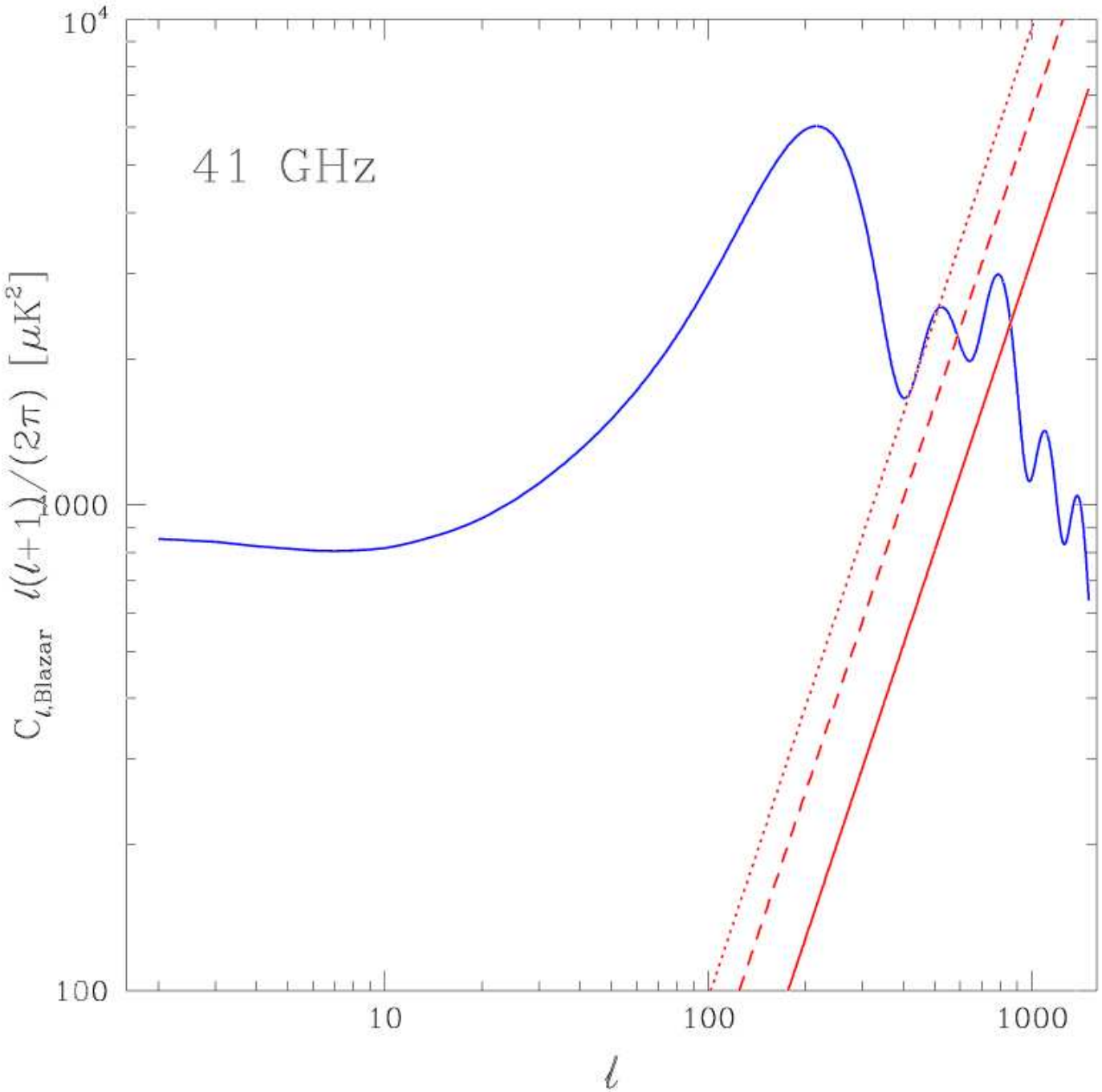
[Giommi & Colafrancesco 2003]

The Blazar LogN-LogS



$$C_{\ell,Blazar} = \int_{S_{min}}^{S_{max}} dS \, \frac{dN}{dS} \, S^2$$

Giommi & Colafrancesco 2003



Blazar Surveys

"Classical Approach"

BL Lacs

- 1 Jy, radio flux limited, 5GHz (34 objects)
- EMSS, X-ray flux limited (41 objects)
- IPC Slew Survey, X-ray (51)

Flat spectrum Radio Quasars

- 2 Jy, radio flux limited, 2.7 GHz (52 objects)

Blazar Surveys

Recent multi-frequency BL Lac samples

- DXRBS Deep X-ray Radio Blazar Survey

  Radio (BG6, PMN) $f_{5GHz} > 50$ mJy, X-ray (ROSAT WGACAT) $f_{(0.1\text{-}2.4\ keV)} > \sim 2*10^{-14}$ cgs

  44 objects ~ 95% identified
- RGB RASS-Green Bank

  Radio (GB6), $f_{5GHz} > 20$ mJy, X-ray ROSAT All Sky Survey $f_{(0.1\text{-}2.4\ keV)} > \sim 3*10^{-13}$ cgs

  Optical $m_B < 18$ ~94% identified

  33 objects in complete sample, 127 total
- REX Radio Emitting X-ray survey

  X-ray (ROSAT PSPC serendipitous sources) $f_{(0.1\text{-}2.4\ keV)} > \sim 3*10^{-14}$ cgs,

  Radio (NVSS) $f_{1.4GHz} > 5$ mJy

  72 objects , 30% identified,

  sub-sample of 55 objects ($f_{(0.1\text{-}2.4\ keV)} > 4*10^{-13}$ cgs) ~90% identified
- Sedentary multi-frequency survey (extreme HBL s only)

  X-ray RASS ($f_{(0.1\text{-}2.4\ keV)} > \sim 10^{-12}$ cgs), radio NVSS ($f_{1.4GHz} > 3.5$ mJy),

  optical APM/COSMOS/GSC2

  153 objects, 100% identified

Blazar Surveys

Recent multi-frequency BL Lac samples Continued..

- CLASS Cosmic Lens All Sky Survey

  Radio (GB6,NVSS) $f_{5GHz} > 30$ mJy, Optical $R < 1.7.5$, $\alpha_{radio} < 0.5$

  47 objects ~ 70% identified

- FIRST Flat Spectrum sample

  Radio (FIRST), $f_{1.4GHz} > 35$ mJy, GB6 $f_{5GHz} > 20$ mJy, optical $B < 19$

  $\alpha_{radio} < 0.5$ 87 sources ~84% identified

- RASS-ASDC 1Jy sample

  Radio (NVSS) $f_{1.4GHz} > 1000$ mJy, X-ray RASS ($f_{(0.1\text{-}2.4\ keV)} > 8*10^{-14}$ cgs),

  25 objects , 93% identified

The ASDC catalog of known Blazars - Netscape

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Available parameters

Name Ra Dec
Z Vmag
Class

GO

The ASDC catalog of known Blazars

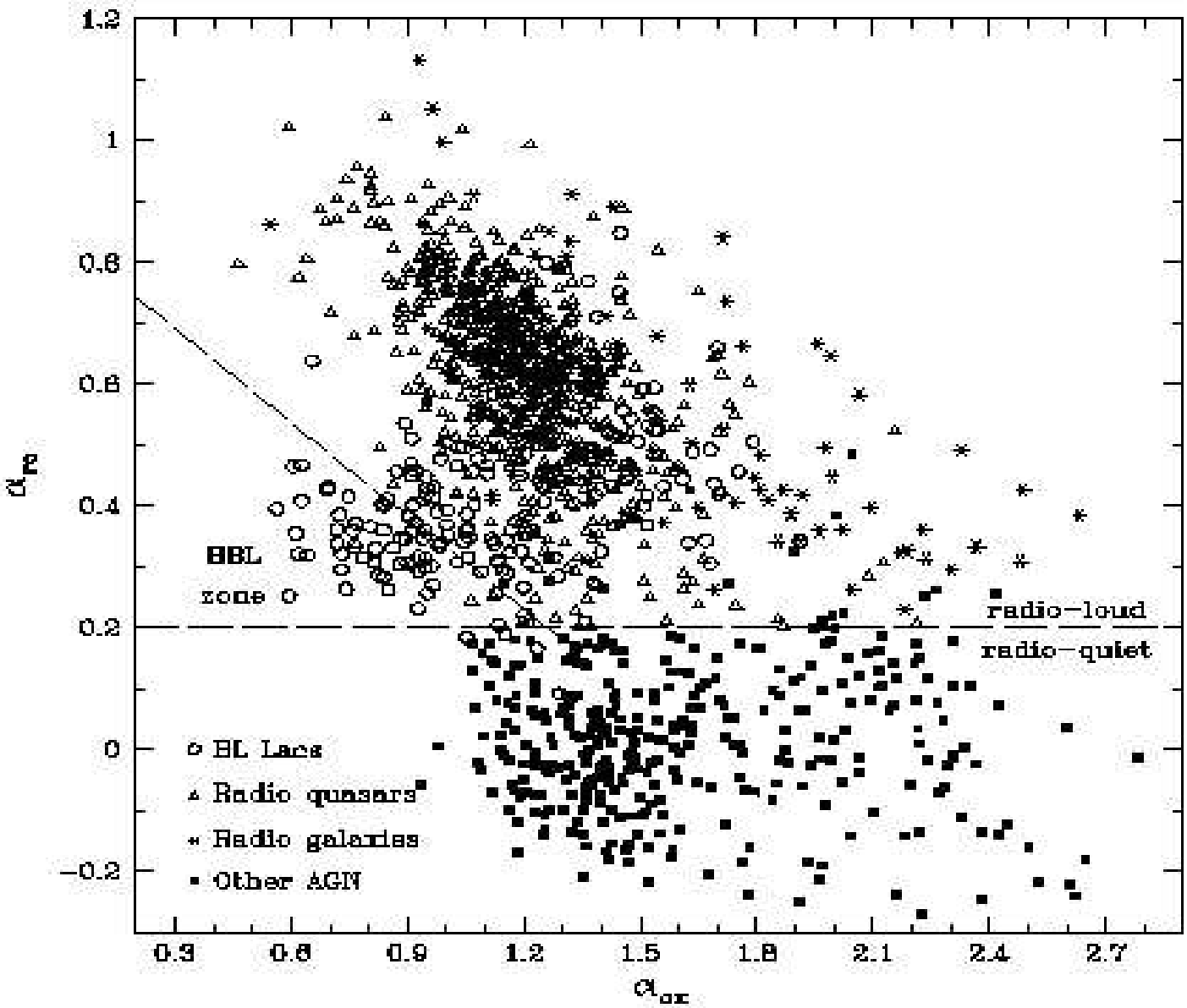
(updated to September 2003)

(1250 objects)

RESET TXT

Entry number		Source name	RA (J2000.0) hh mm ss.d	Dec (J2000.0) dd mm ss.d	Redshift Z	Vmag	Source classification
Subset selection mode: inclusive					Stat	Stat	
1 Select		RXS J00031-180	00 03 07.8	-18 05 49.9	0.054	13.2	BL Lac
2 Select		3EG J0004+2019	00 04 35.7	+20 19 41.8	0.677	20.8	BL Lac
3 Select		NRAO 5	00 06 13.8	-06 23 35.8	0.347	18.5	unidentified
4 Select		RXS J00063+105	00 06 20.3	+10 51 51.1	0.168	17.3	BL Lac
5 Select		RX J00079+4711	00 07 59.9	+47 12 06.8	0.28	18.3	BL Lac
6 Select		RXS J00085-233	00 08 35.3	-23 39 26.9	0.147	17.9	BL Lac
7 Select		WGAJ0010.5-3	00 10 33.6	-30 27 14.0	1.19	19.1	QSO radio loud
8 Select		2QZ J001037-29	00 10 37.4	-29 04 02.9	0	19.9	BL Lac
9 Select		WGAJ0010.7-3	00 10 43.2	-36 49 27.8	2.08	18.2	QSO radio loud
10 Select		WGAJ0011.2-3	00 11 13.8	-36 20 35.1	2.324	21.6	QSO radio loud
11 Select		MCG 00.01.036	00 11 39.6	-00 28 27.1	0.059	15.6	BL Lac
12 Select		WGAJ0012.5-1	00 12 33.6	-16 28 59.8	0.151	14.7	QSO radio loud
13 Select		1RXSJ001356	00 13 56.4	-18 54 06.8	0.095	16.8	BL Lac
14 Select		RXS J00141-502	00 14 10.9	-50 22 35.0	0	18.5	BL Lac
15 Select		MS 00117+0837	00 14 19.7	+08 54 03.9	0.162	17.5	BL Lac
16 Select		WGAJ0014.5-3	00 14 34.0	-30 59 21.1	2.785	19.3	QSO radio loud

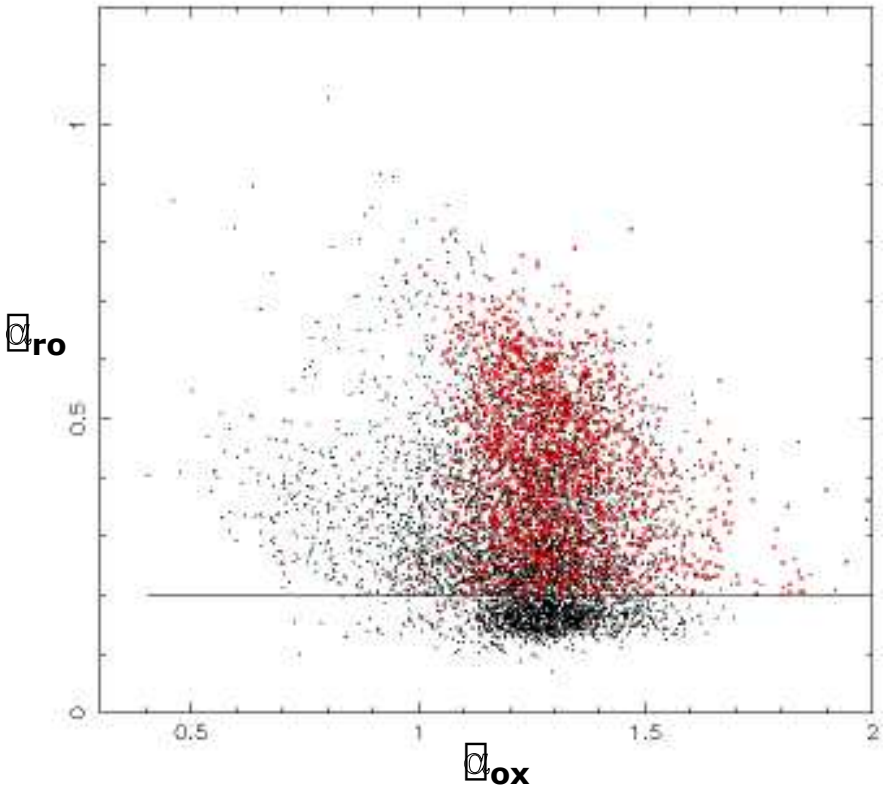
The broad-band color-color plane

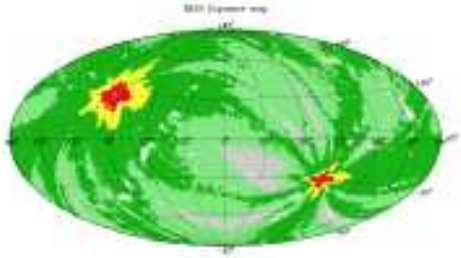
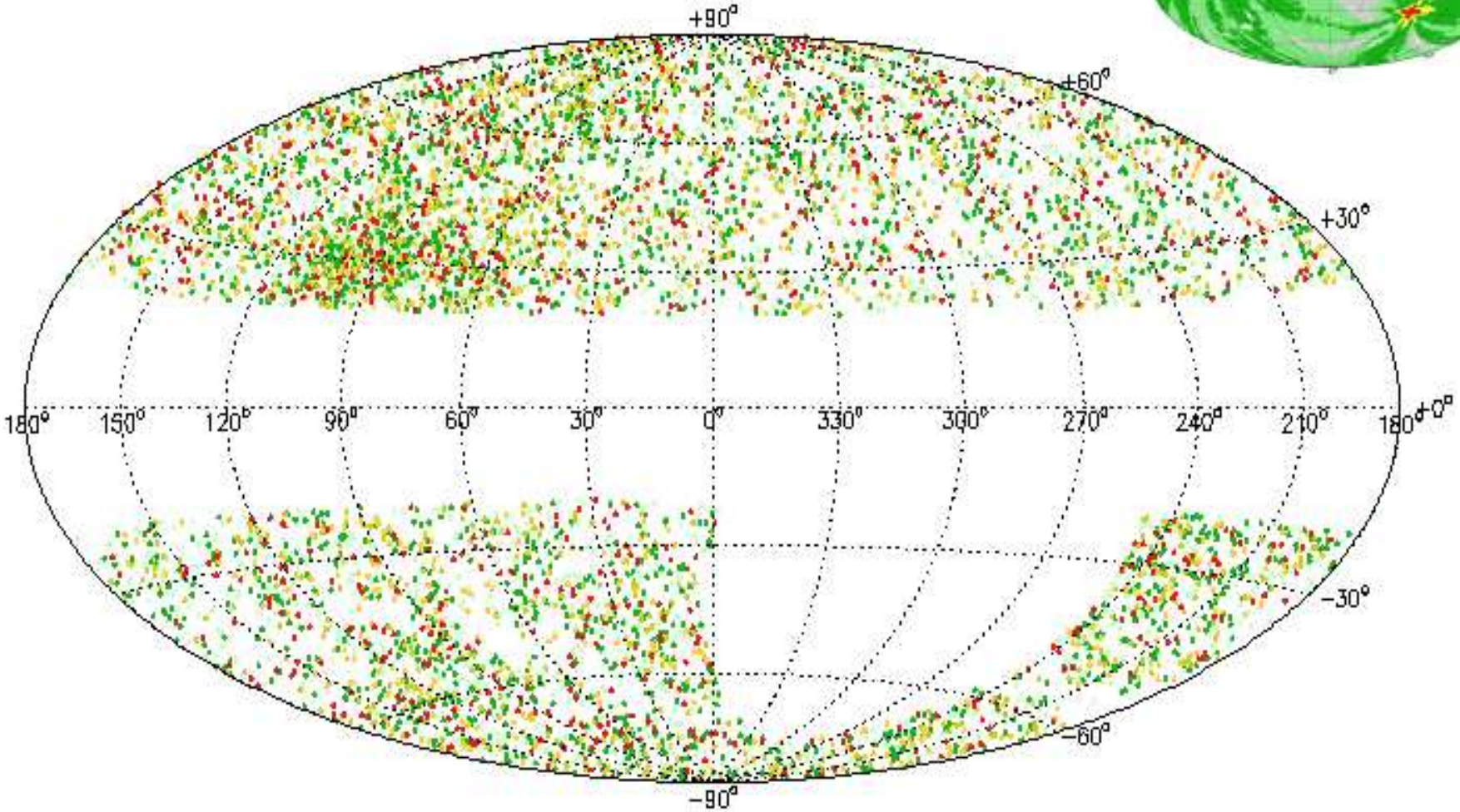


The ASDC Blazar candidate sample

Cross-correlation between NVSS and RASS radio and X-ray surveys.
Optical magnitudes from GSC2
(assuming Jmag < 19.5 when no counterpart is found in GSC2)

$\Delta\theta_{r-x} < 2.5\ \sigma_{r-x}$ and < 0.8 arcmin
α_{ox} and α_{ro} within Blazar area



Over 7400 objects (500 of which are included in the catalog of known Blazars).
A subsample of about 450 objects for which Sloan survey data are available is being used to estimate the quality of the sample

Blazars candidate sample