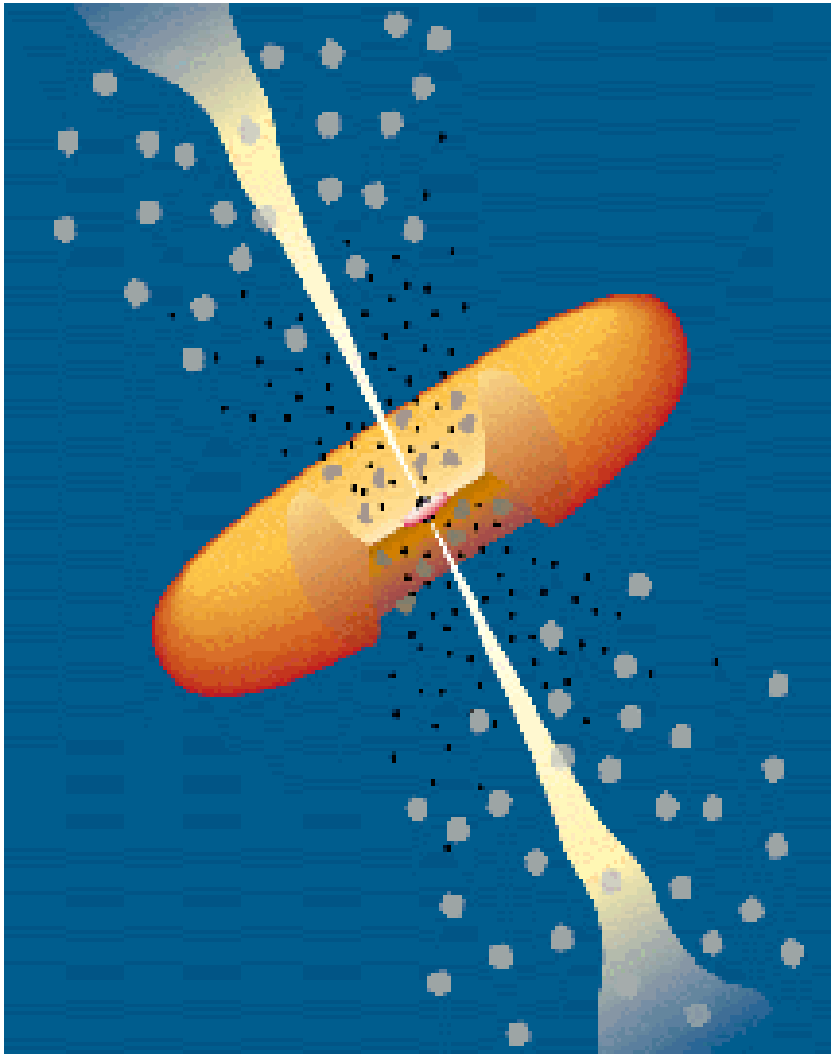
Multi mission-multi frequency Observations of Blazars

Paolo Giommi
ASI

Blazars



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

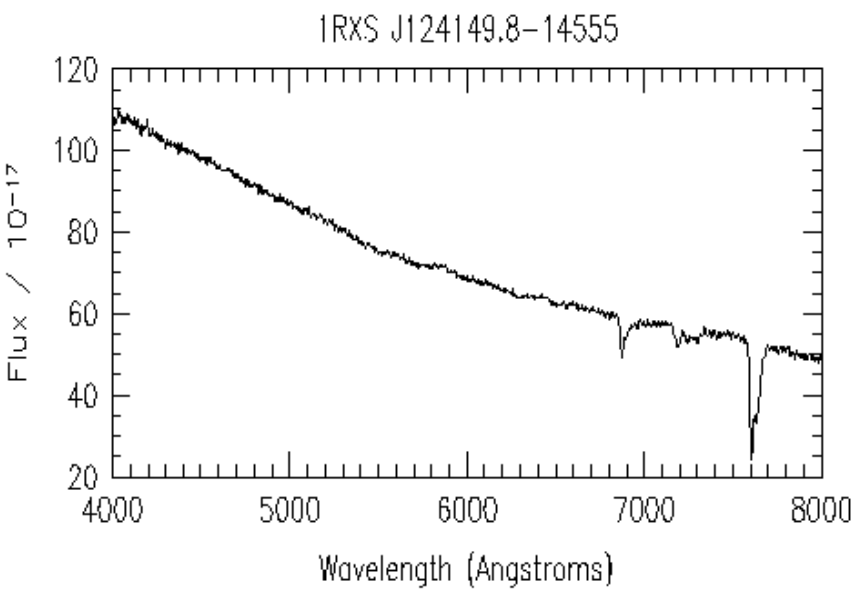
Observed at a small angle to the jet and therefore rare AGN : 5-8% of all AGN (but only at optical or X-ray frequencies!)

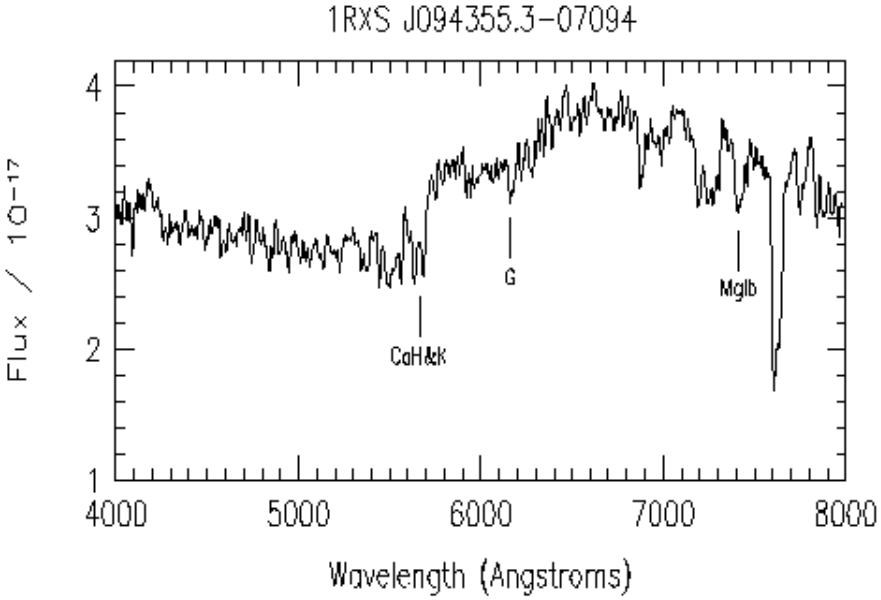
Blazars are the dominant population of extragalactic point sources at

- Gamma-ray
- TeV
- Microwave frequencies

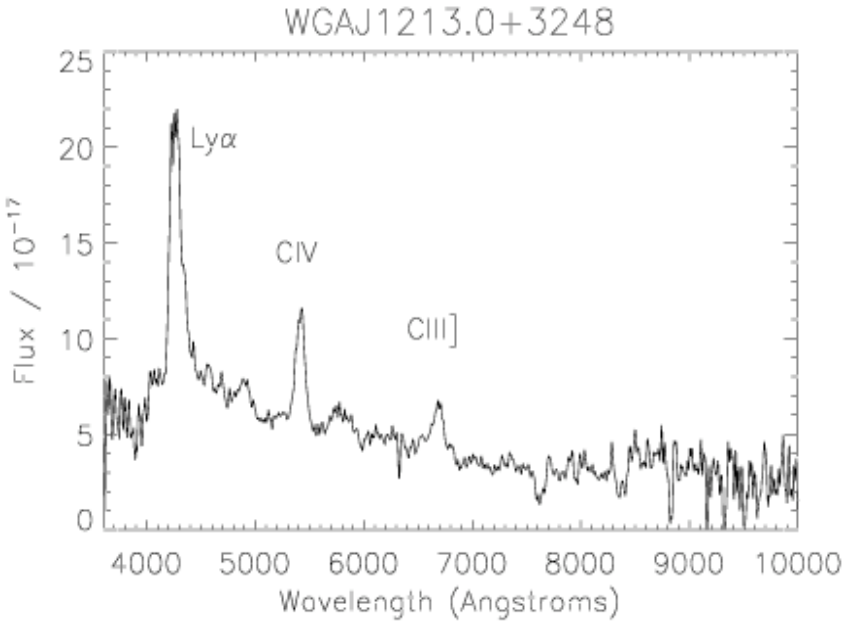
Two types of Blazars:

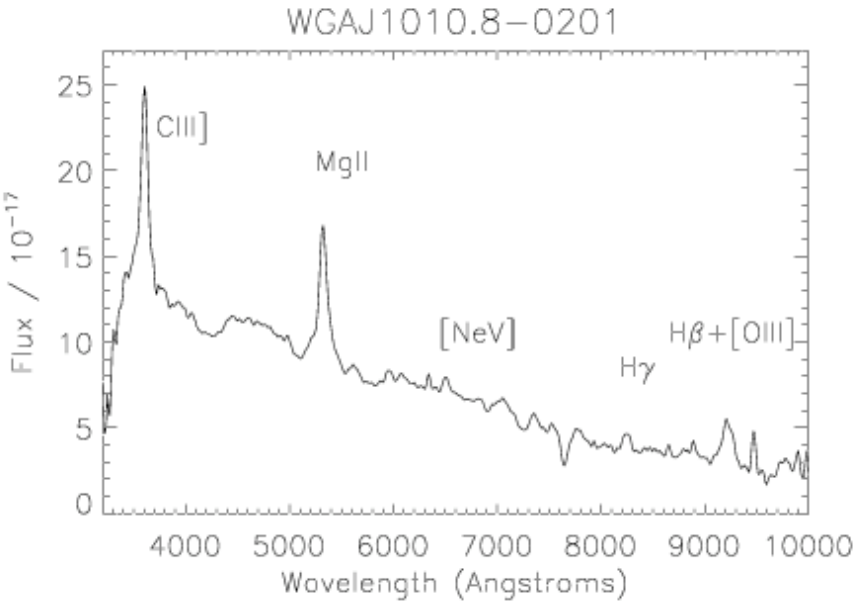
BL Lacs : no strong lines; no strong cosmological evolution



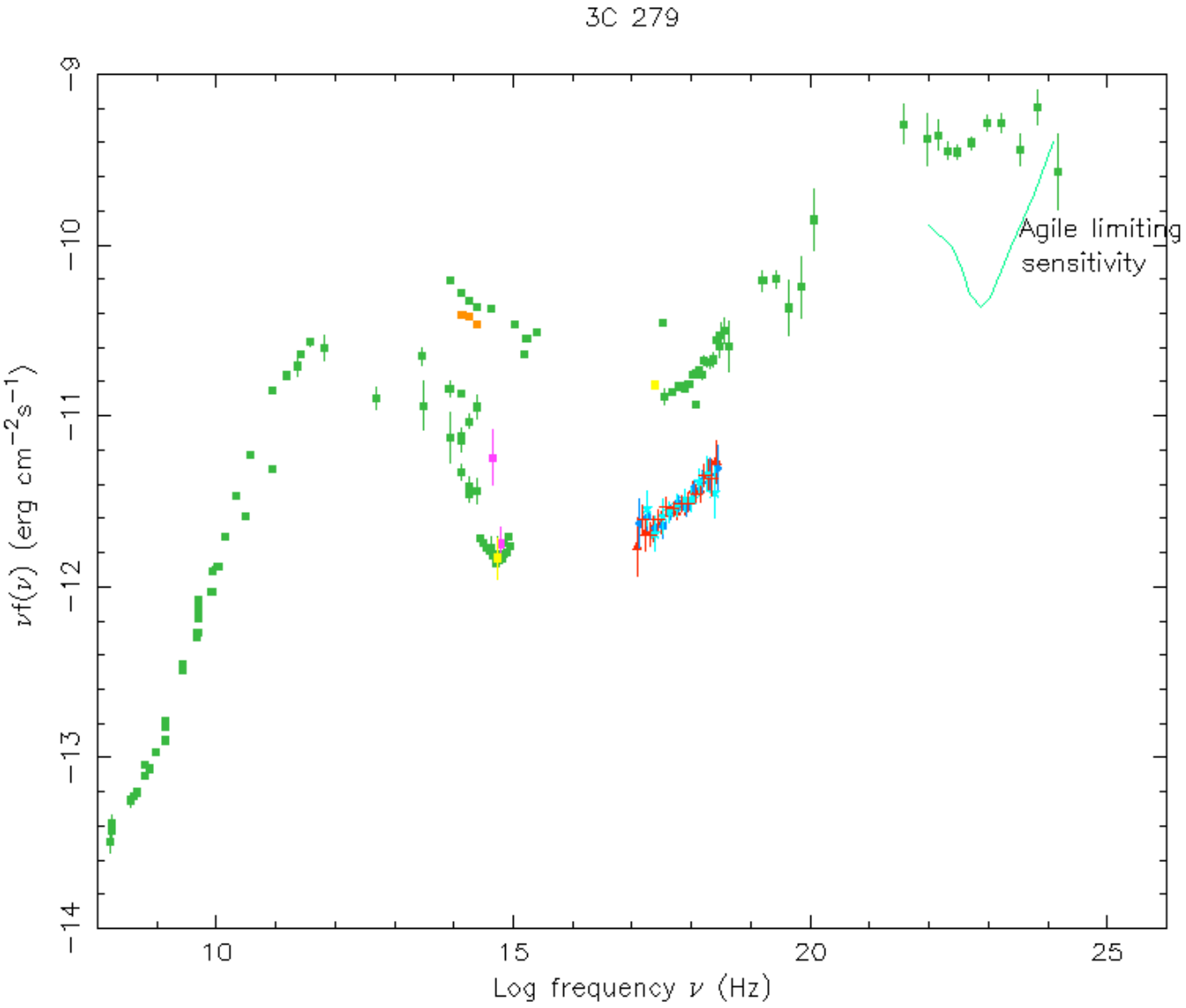


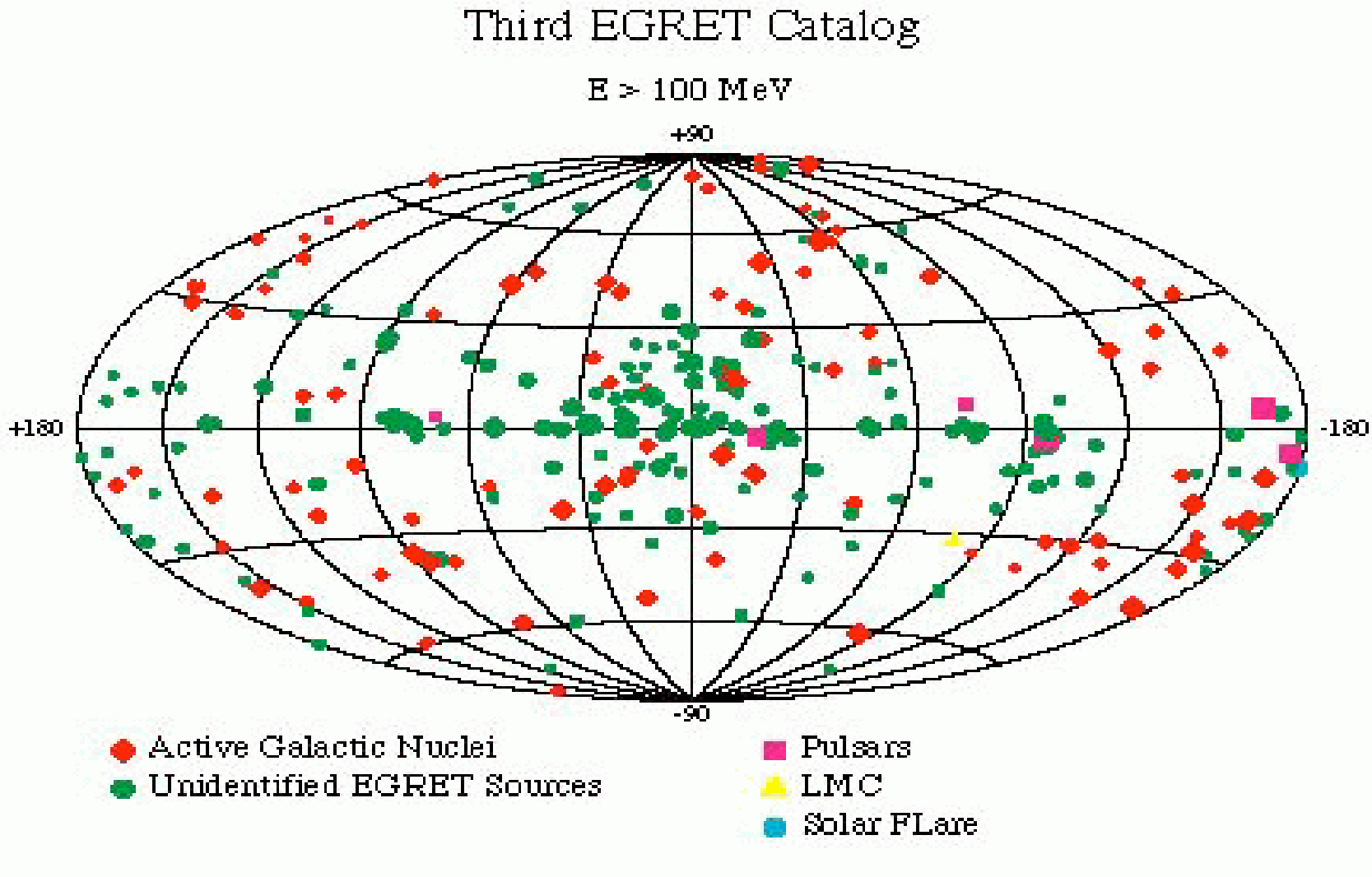
FSRQs : strong and broad emission lines; strong cosmological evolution





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

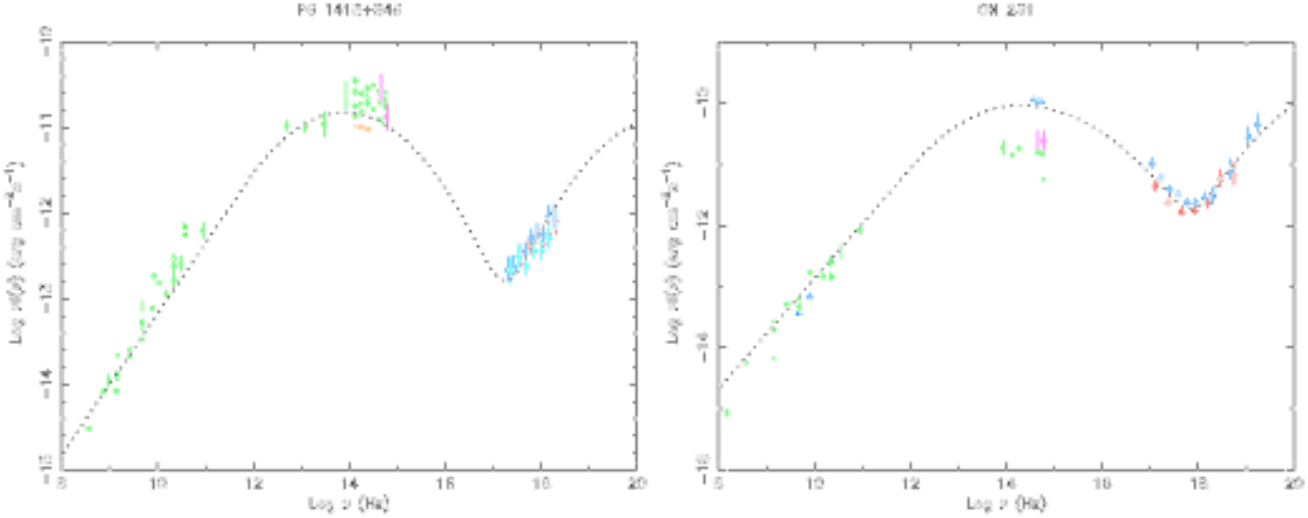


Fig. 4. Spectral energy distributions of a typical LBL object (PG 1418+546, $\nu_{peak} \approx 0.4$ eV $\approx 8 \times 10^{13}$Hz) for which the X-ray emission is dominated by the flat inverse Compton radiation and of an Intermediate BL Lac (ON 231, $\nu_{peak} \approx 1$ eV $\approx 2 \times 10^{14}$Hz) 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.

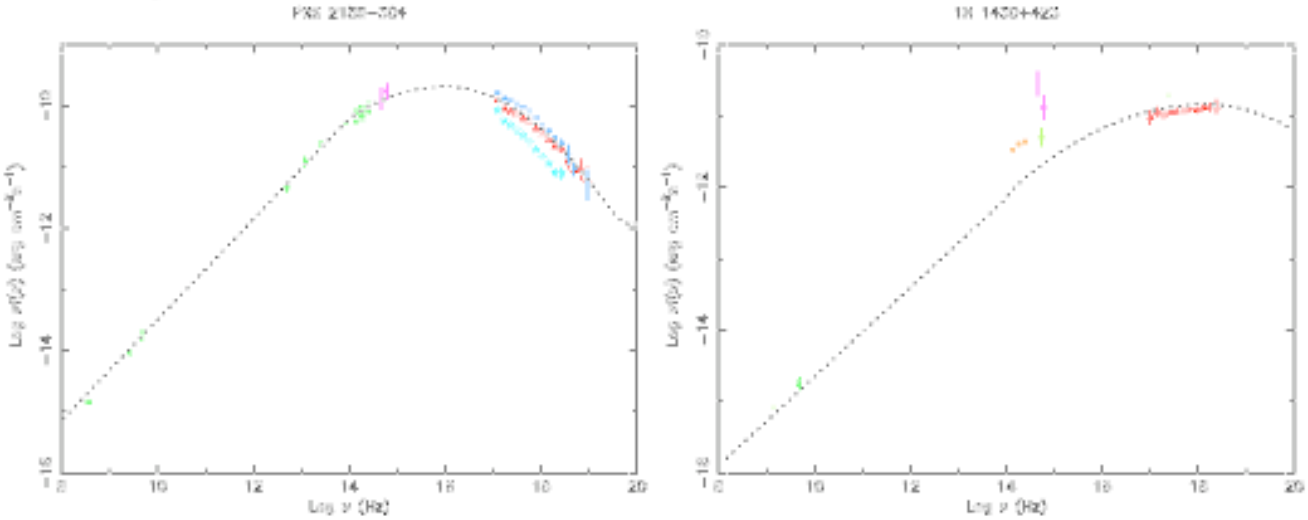
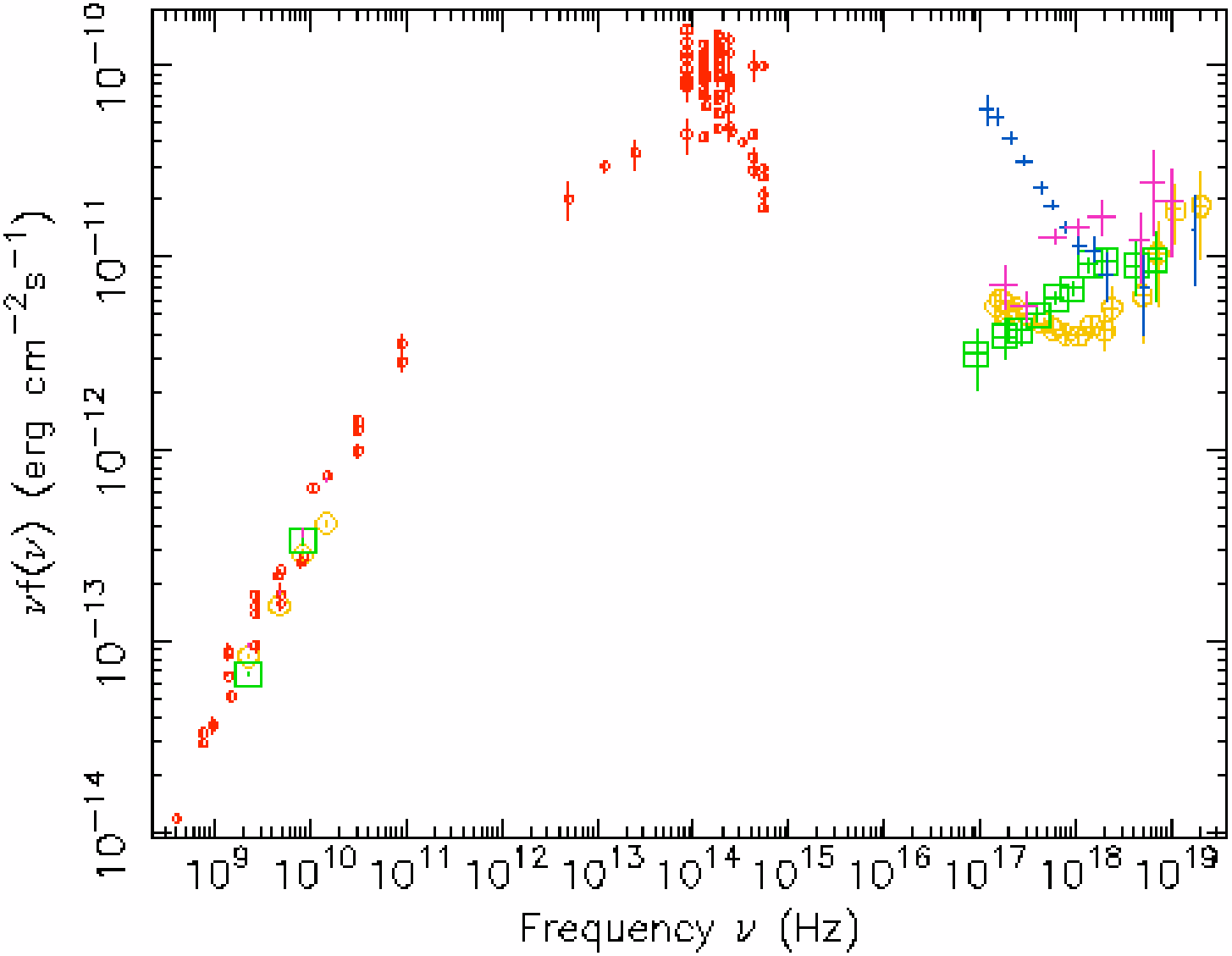
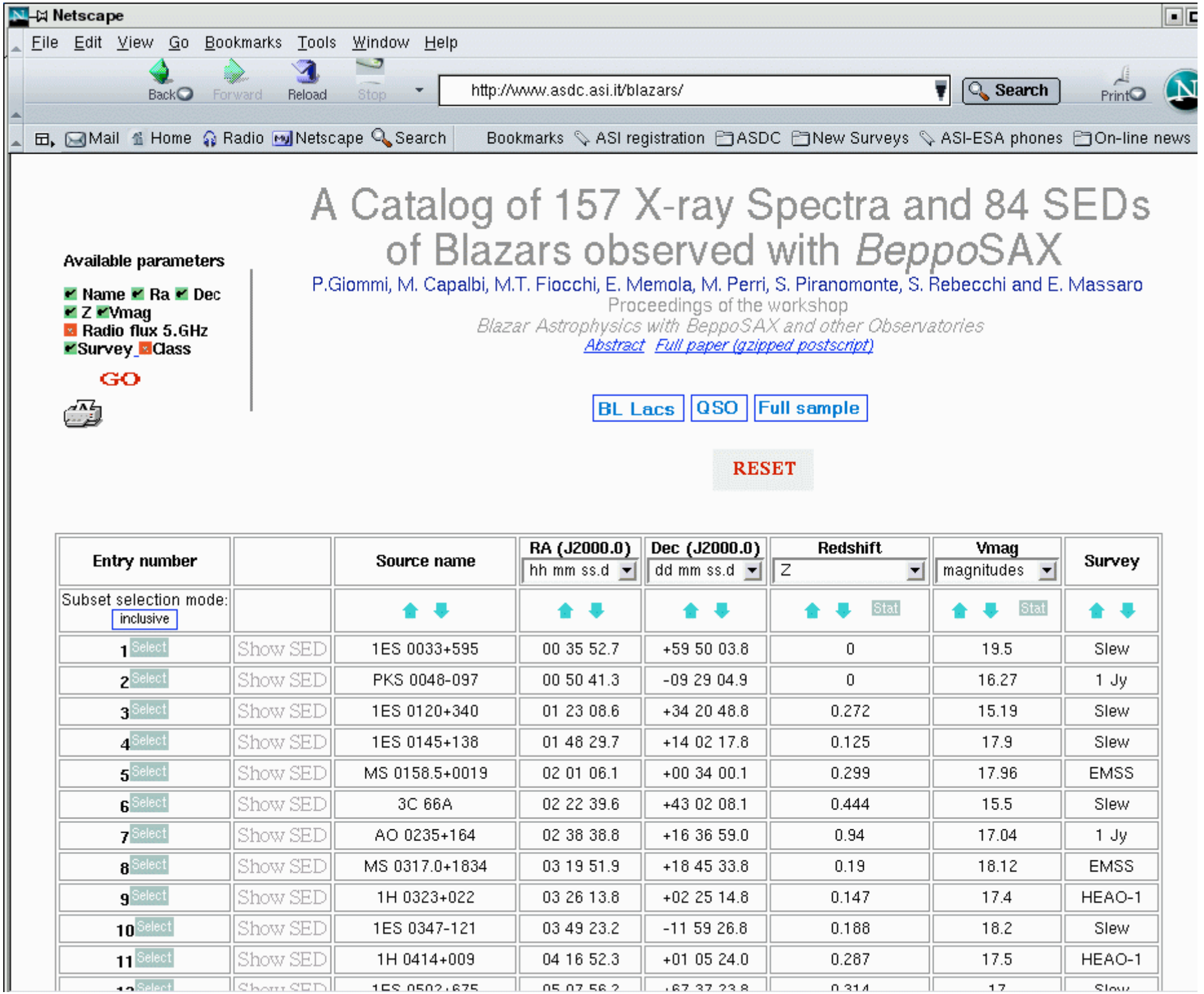


Fig. 5. Spectral energy distributions of HBLs where the X-ray emission is completely dominated by synchrotron radiation. In the case of PKS 2155−304 ν_{peak} is at ≈ 50 eV $\approx \times 10^{16}$ Hz while for the extreme HBL 1H 1430+423 ν_{peak} is above 10 keV.

BeppoSAX NFI data: BL Lacertae





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

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

File Edit View Go Bookmarks Tools Window Help

Back Forward Reload Stop http://www.asdc.asi.it/cgi-bin/pub_sax_sed_model_start Search Print

Mail Home Radio Netscape Search Bookmarks ASI registration ASDC New Surveys ASI-ESA phones On-line news

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

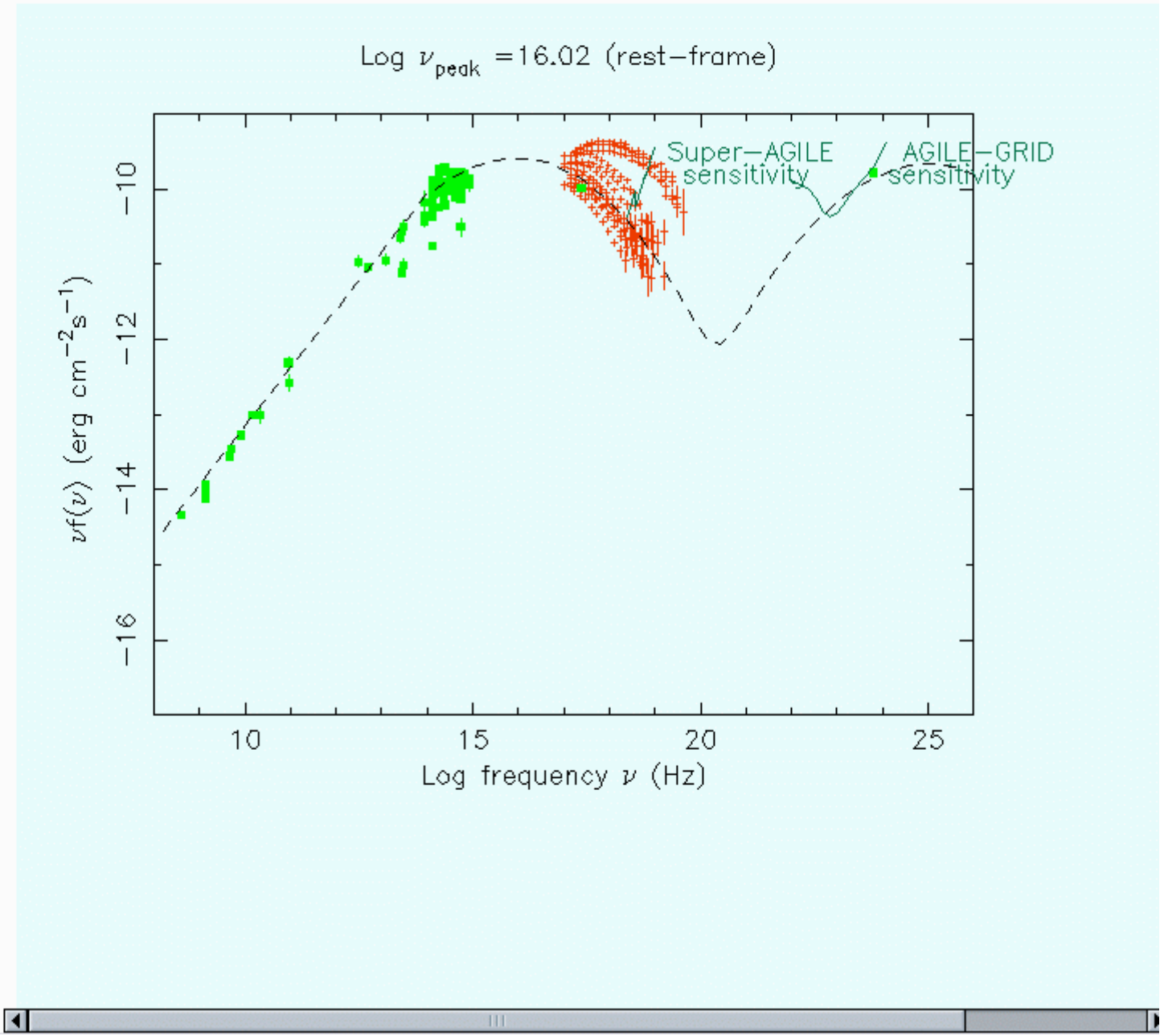
submit reset

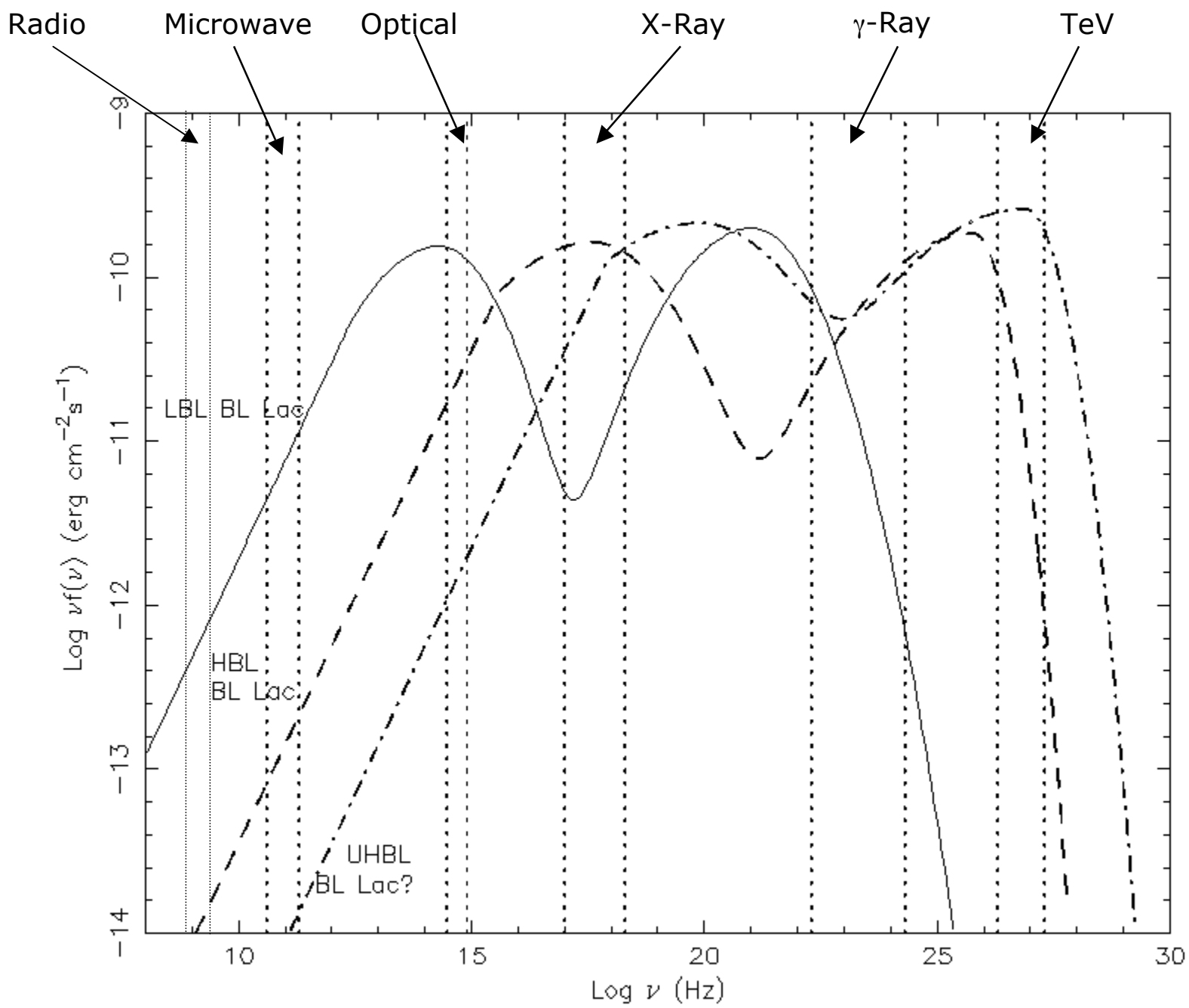
Show instruments limiting sensitivity?

none Integral-IBIS

AGILE

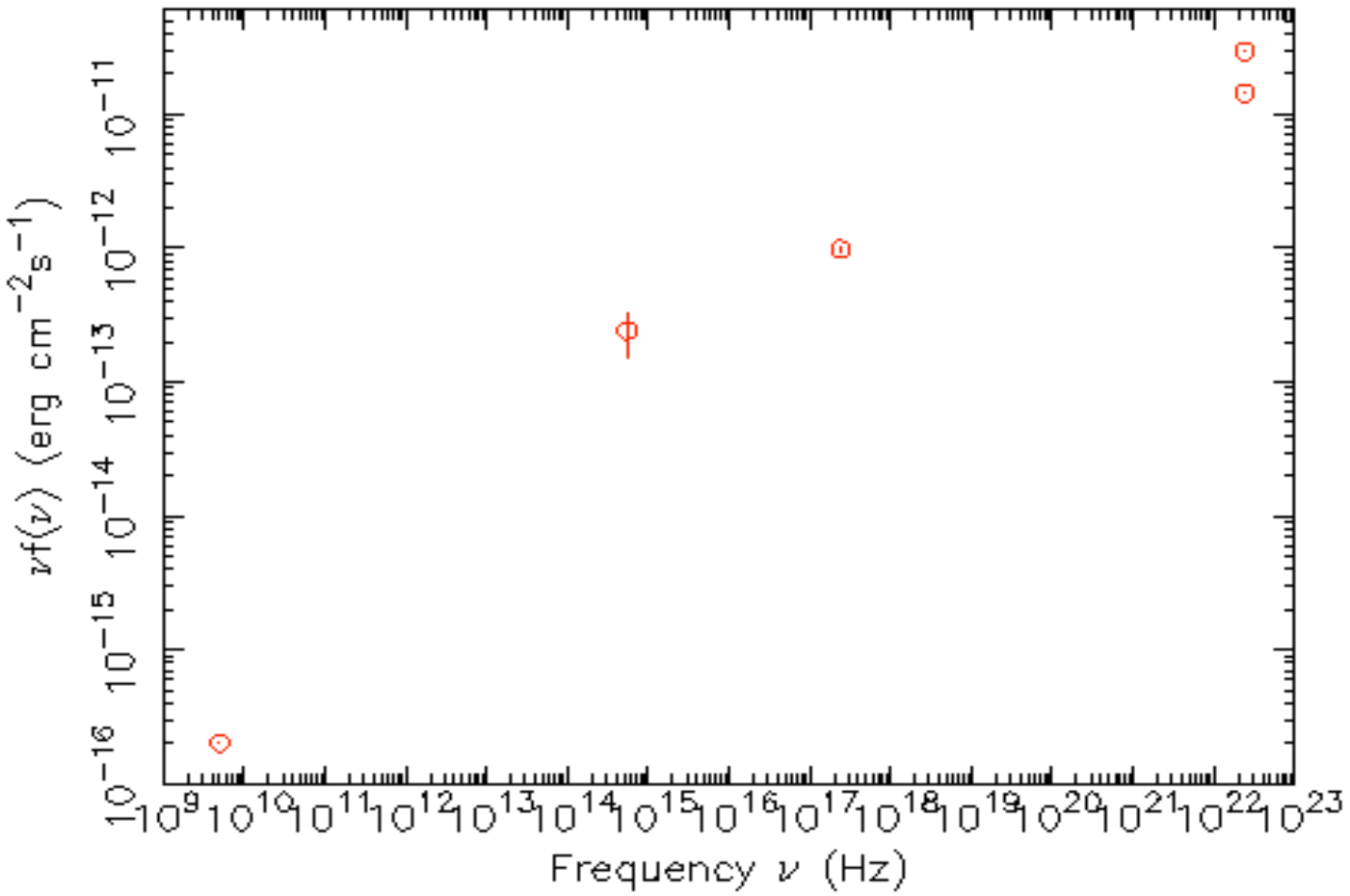
Get data file? no yes




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

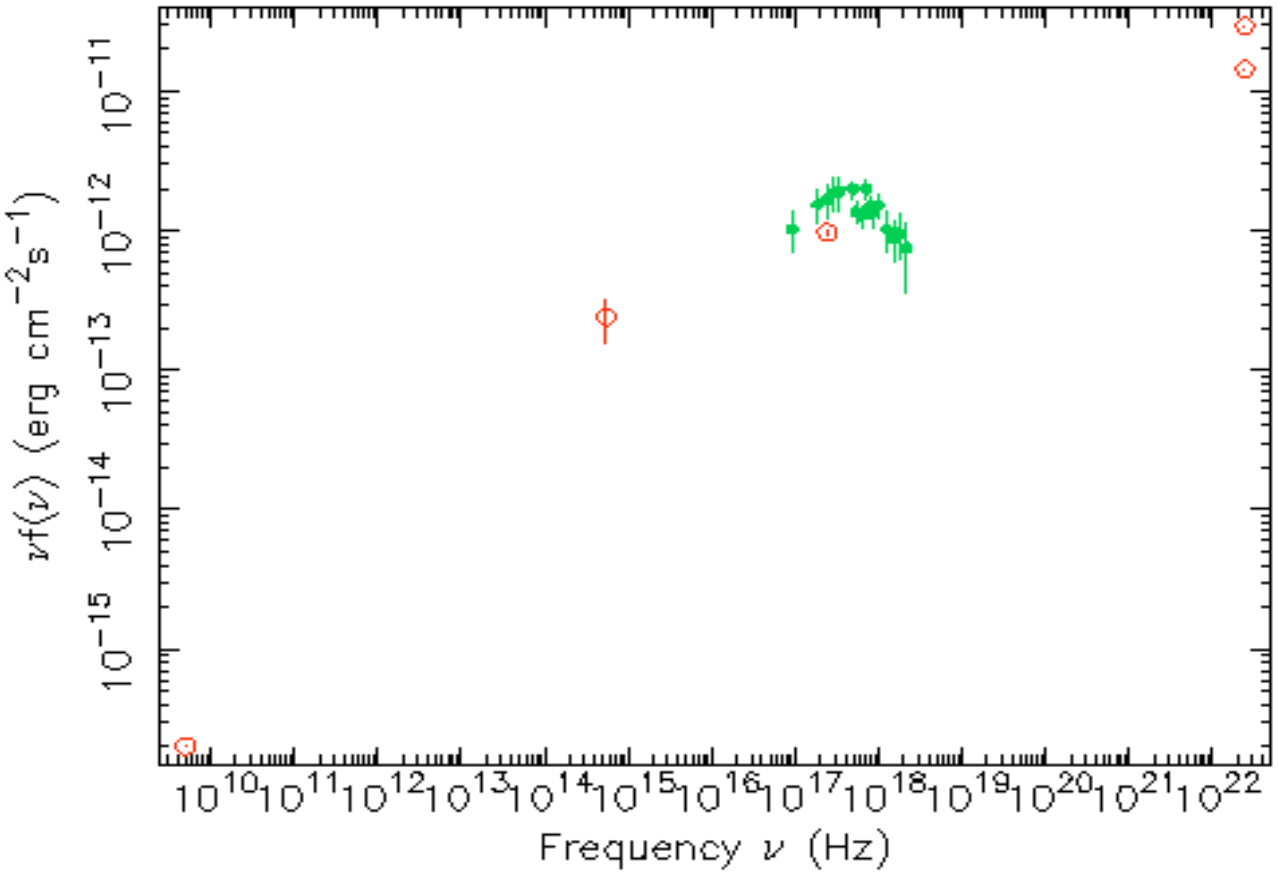
UHBLs as counterparts of EGRET high lblll unidentified sources?

1RXS J 123511.1-14033



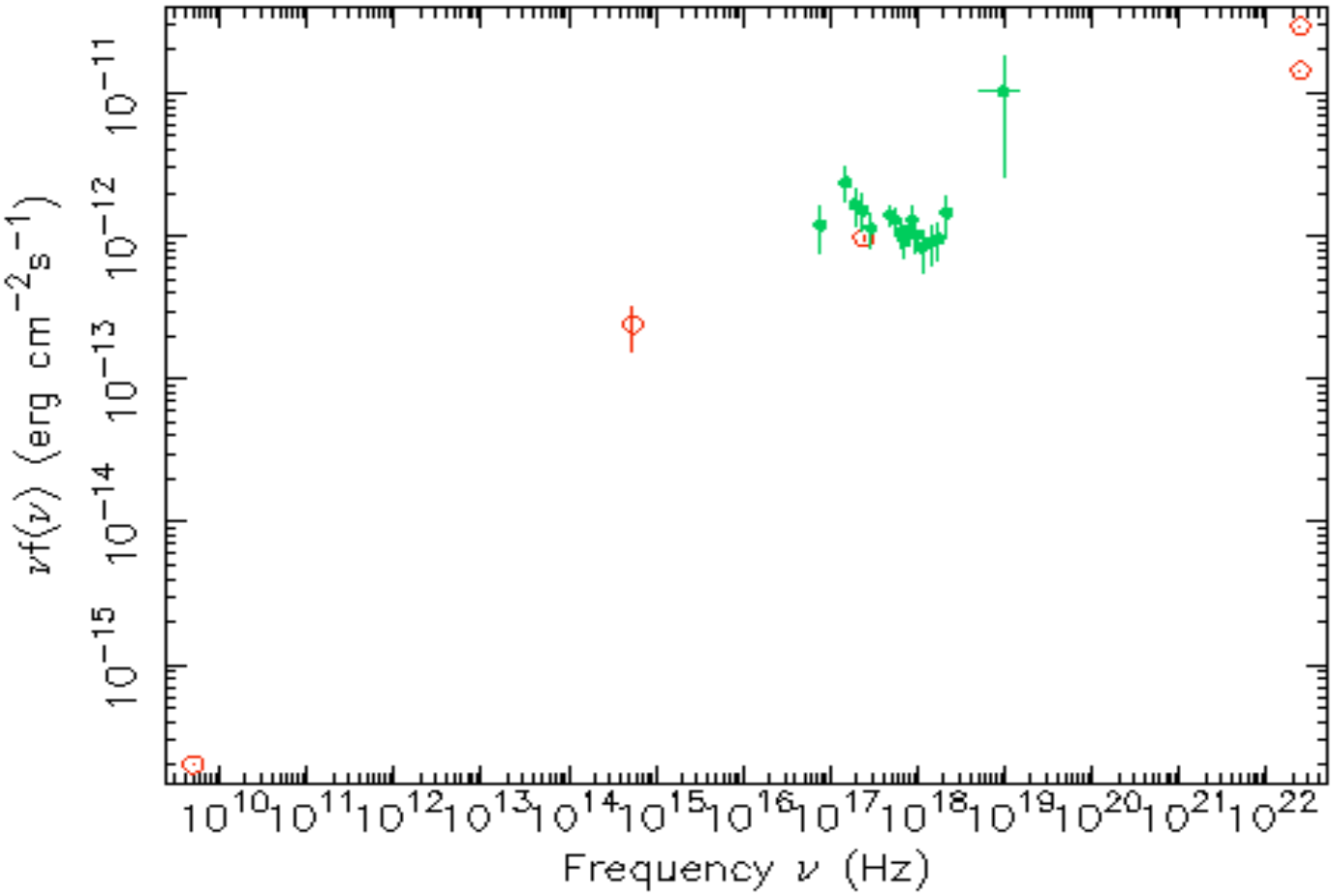
UHBLs as counterparts of EGRET high lblll unidentified sources?

Well, may be not...

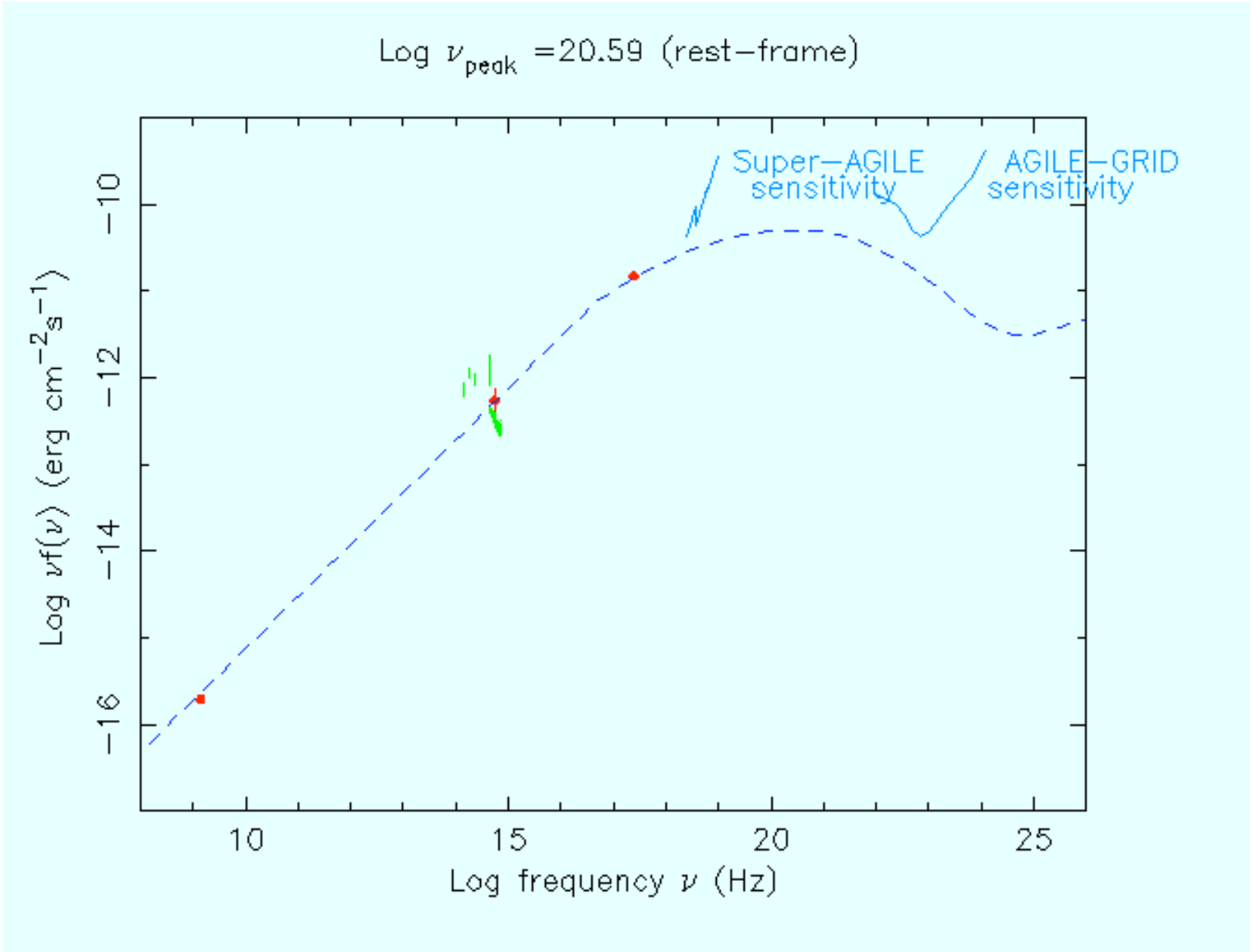


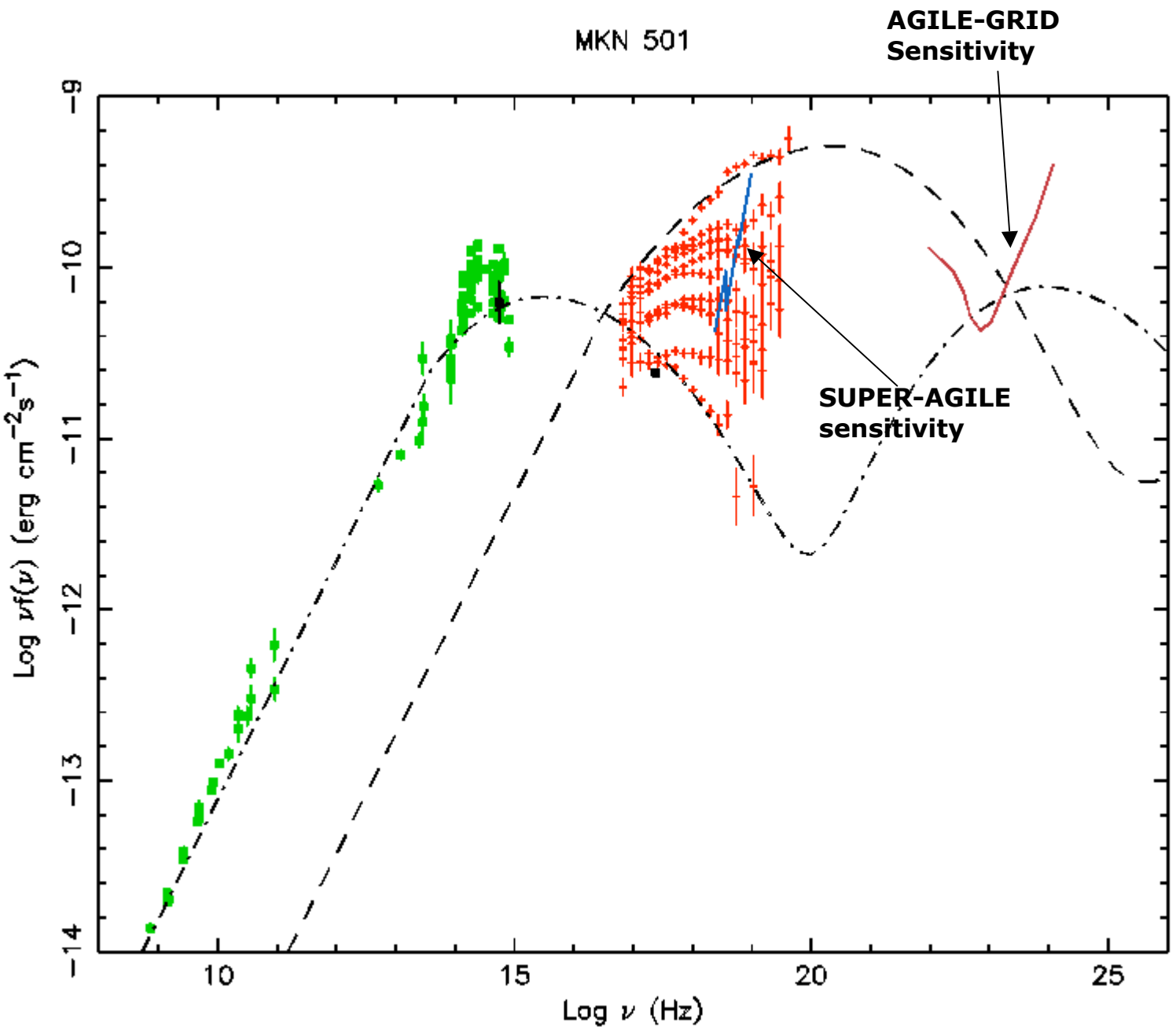
UHBLs as counterparts of EGRET high lblll unidentified sources?

But a few days later...

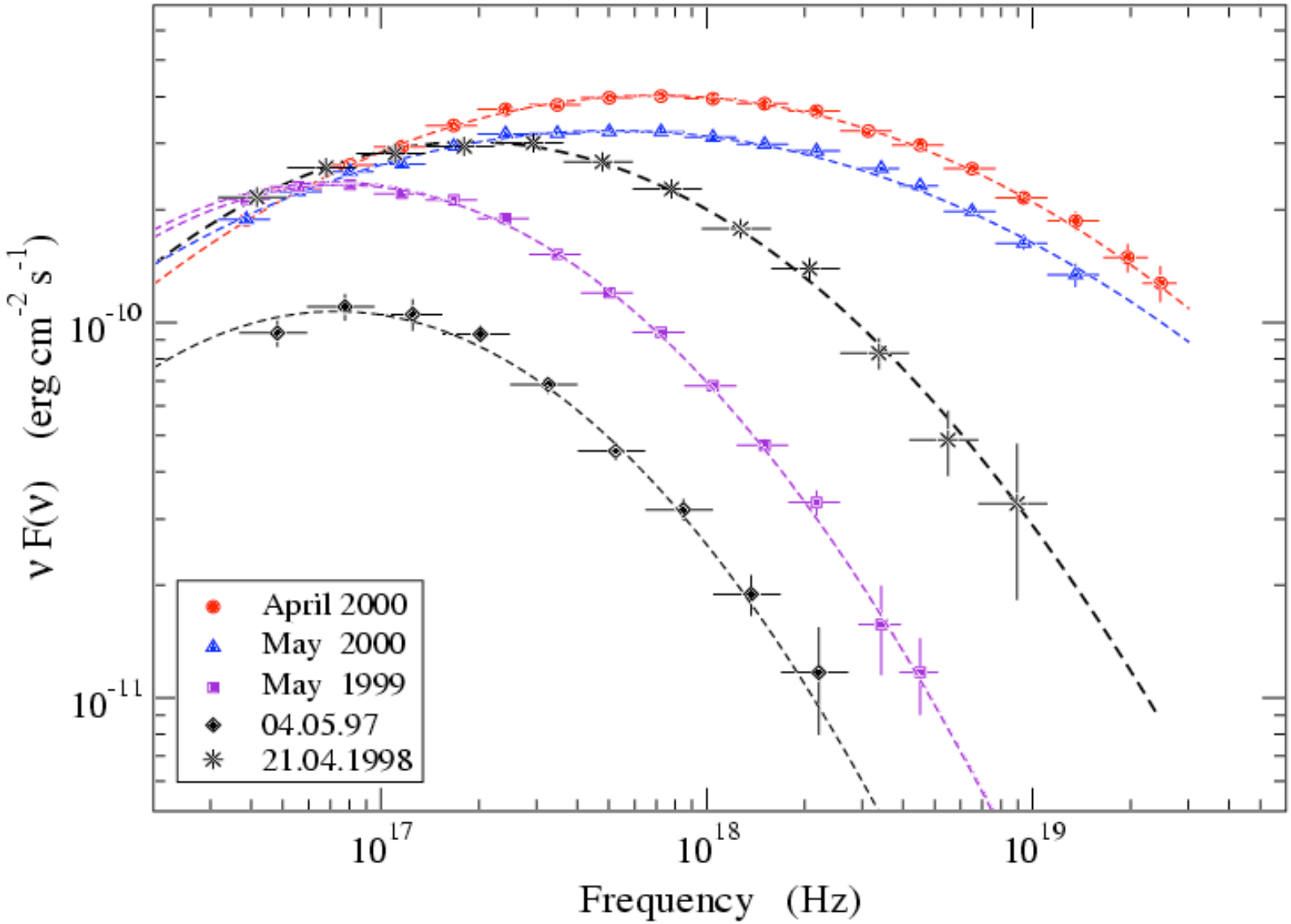


SHBL J044127.4+150456

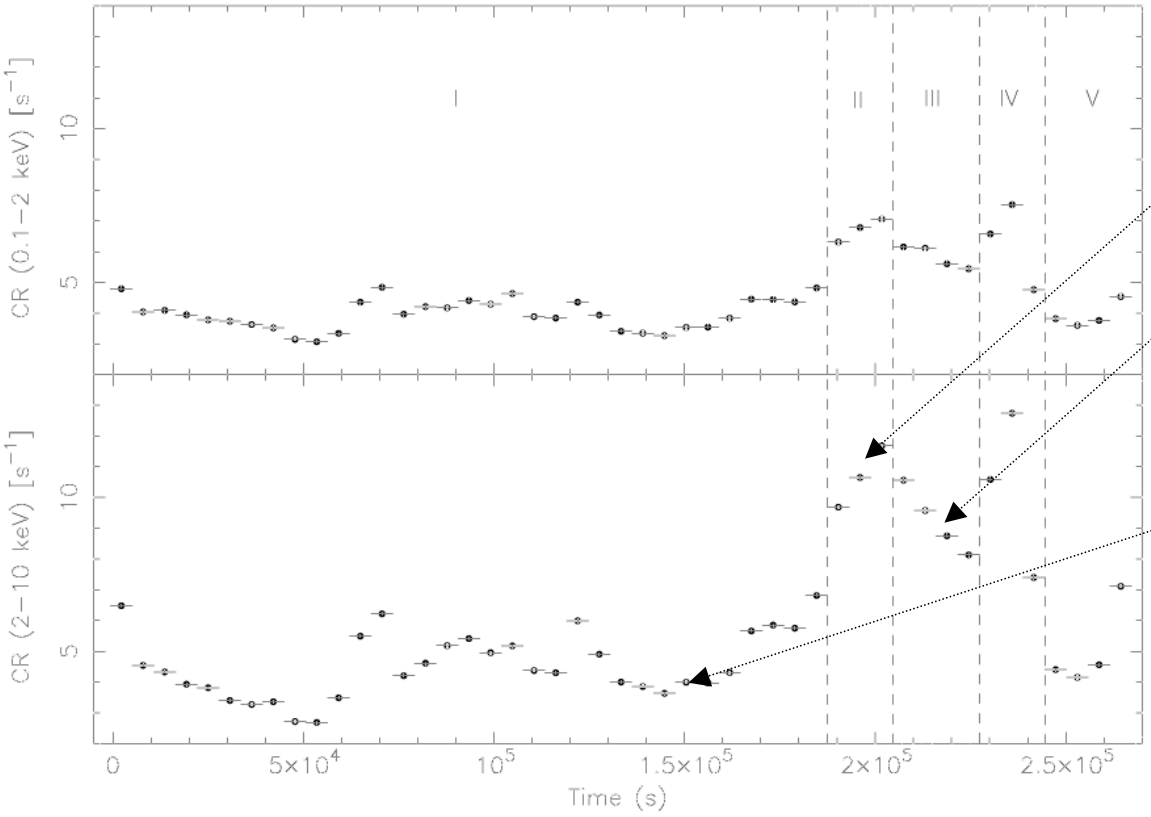


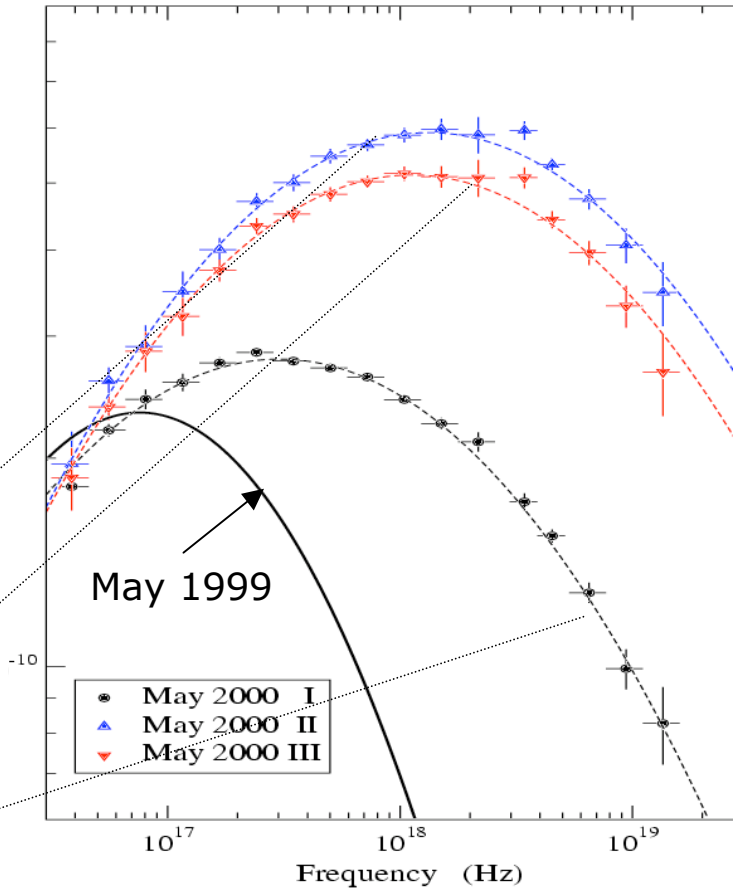

MKN 501
AGILE-GRID
Sensitivity
SUPER-AGILE
sensitivity
Log νf(ν) (erg cm⁻²s⁻¹)
Log ν (Hz)
−9
−10
−11
−12
−13
−14
10
15
20
25

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:

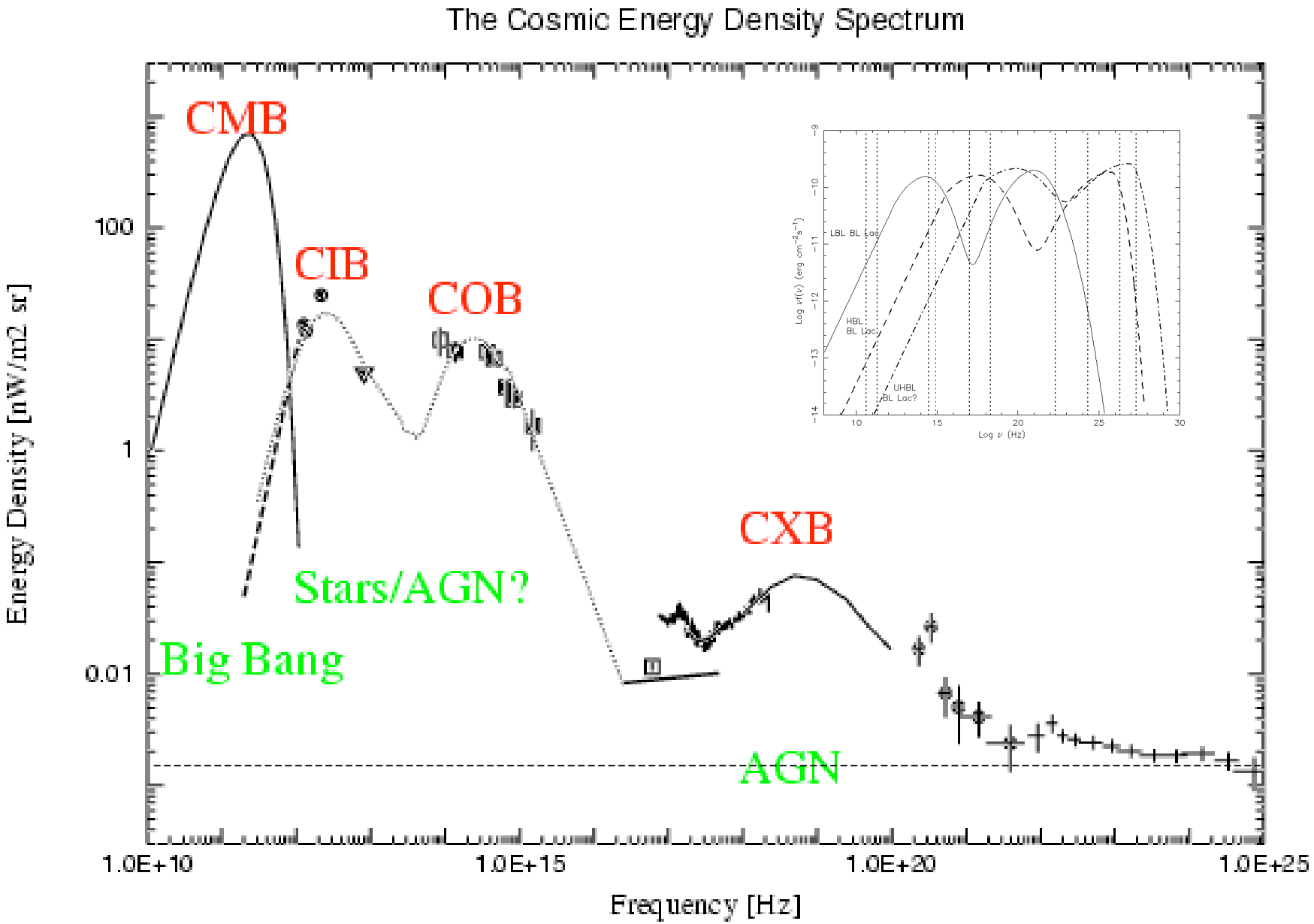
$$N_i = N_0\ (\frac{g}{\gamma_0^q})^i\ (\epsilon^q)^{i(i-1)/2} \quad . \tag{13}$$

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

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

with

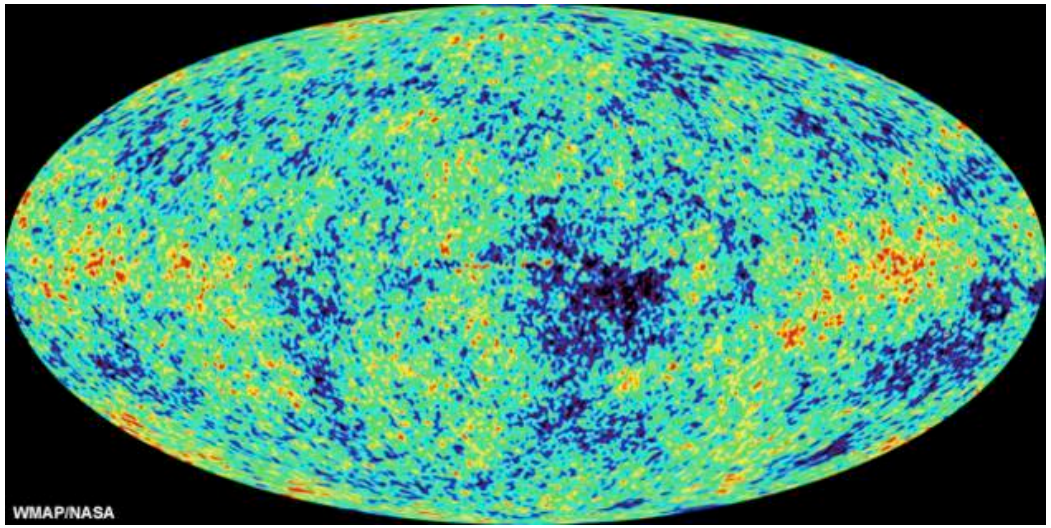
$$s = -\frac{Log(g/\gamma_0)}{Log\ \epsilon} - \frac{q}{2} \tag{15}$$


The Cosmic Energy Density Spectrum
CMB
CIB
COB
CXB
Stars/AGN?
Big Bang
AGN
100
1
0.01
Energy Density [nW/m2 sr]
1.0E+10
1.0E+15
1.0E+20
1.0E+25
Frequency [Hz]
LBL BL Lac
HBL
BL Lac
UHBL
BL Lac?
Log νf(ν) (erg cm⁻²s⁻¹)
Log ν (Hz)

WMAP bright foreground source catalog

208 bright sources, of which

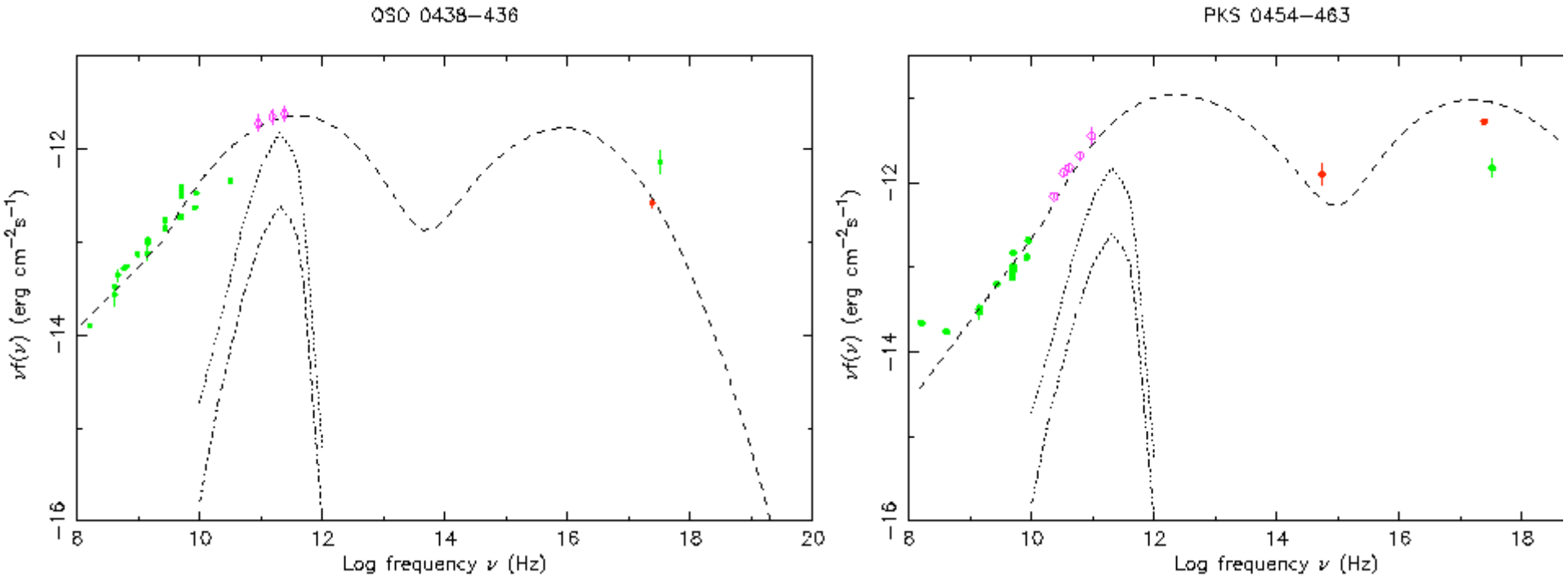
WMAP CMB fluctuation map



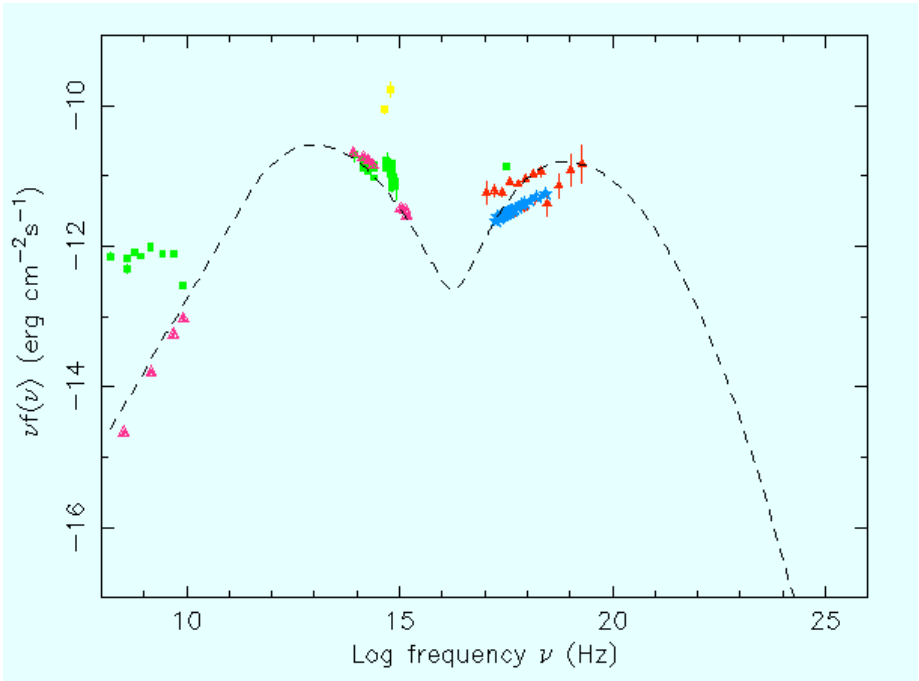
- **140 FSRQs**
- **23 BL Lacs**
- **13 Radio galaxies**
- **5 Steep Spectrum QSOs**
- **2 starburst galaxies**
- **2 planetary nebule**

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

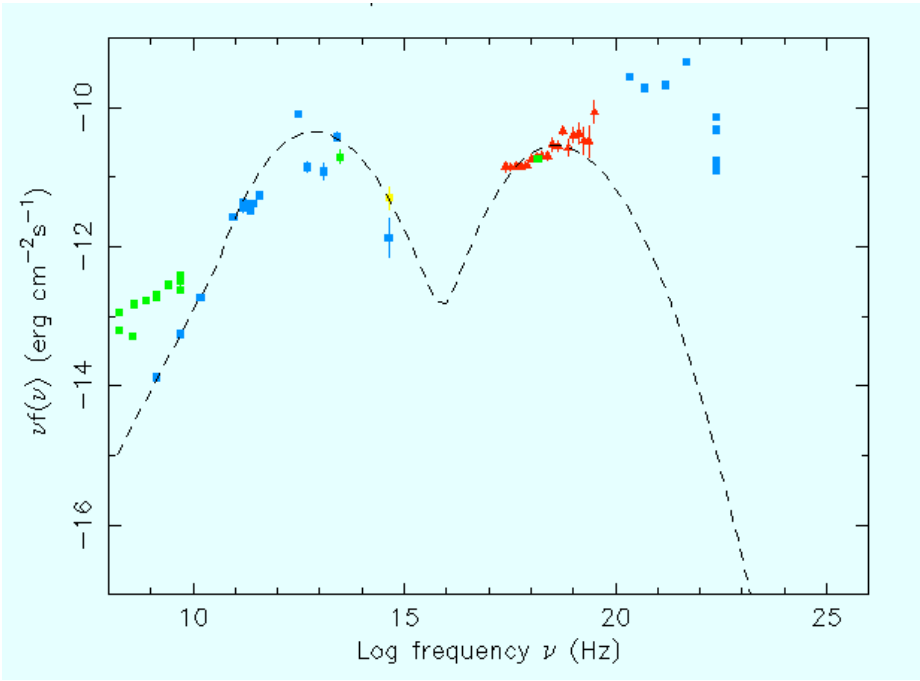
The vast majority of bright WMAP foreground sources are Blazars


OSO 0438−436
PKS 0454−463
νf(ν) (erg cm⁻²s⁻¹)
Log frequency ν (Hz)
−16
−14
−12
8
10
12
14
16
18
20

Radio Galaxy PKS 0518-45



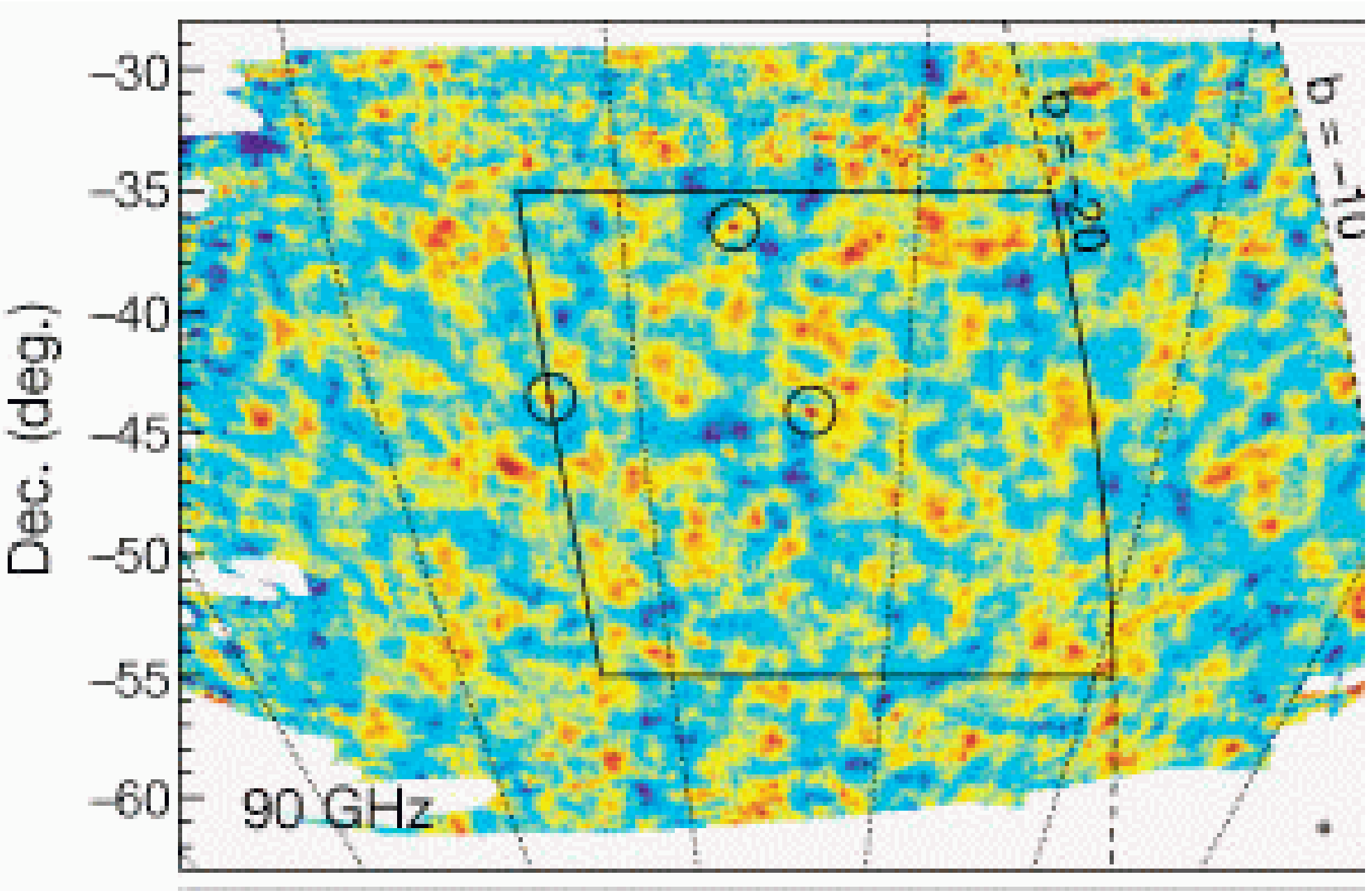
Radio Galaxy 3C 111

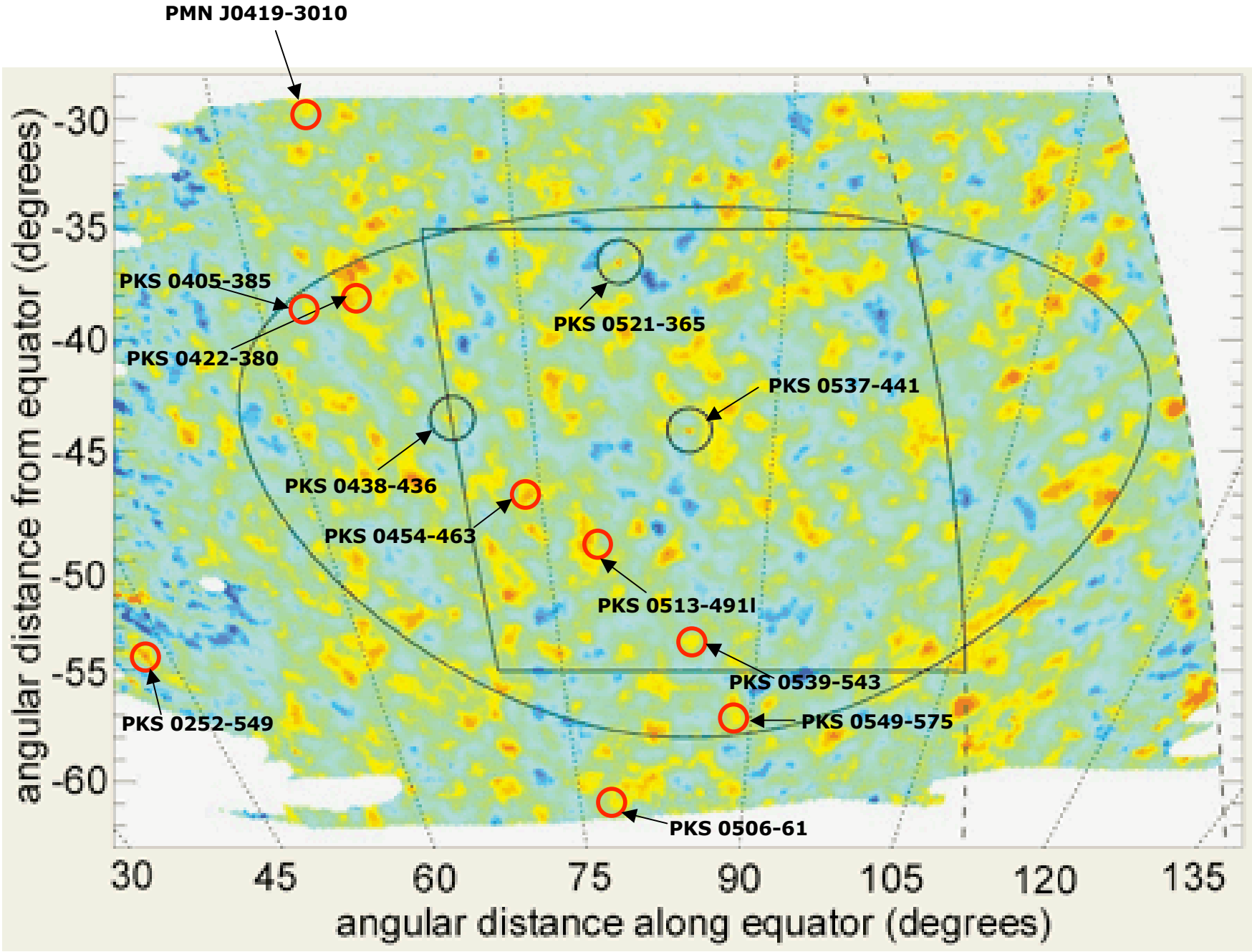


Fiocchi, Grandi et al. in preparation

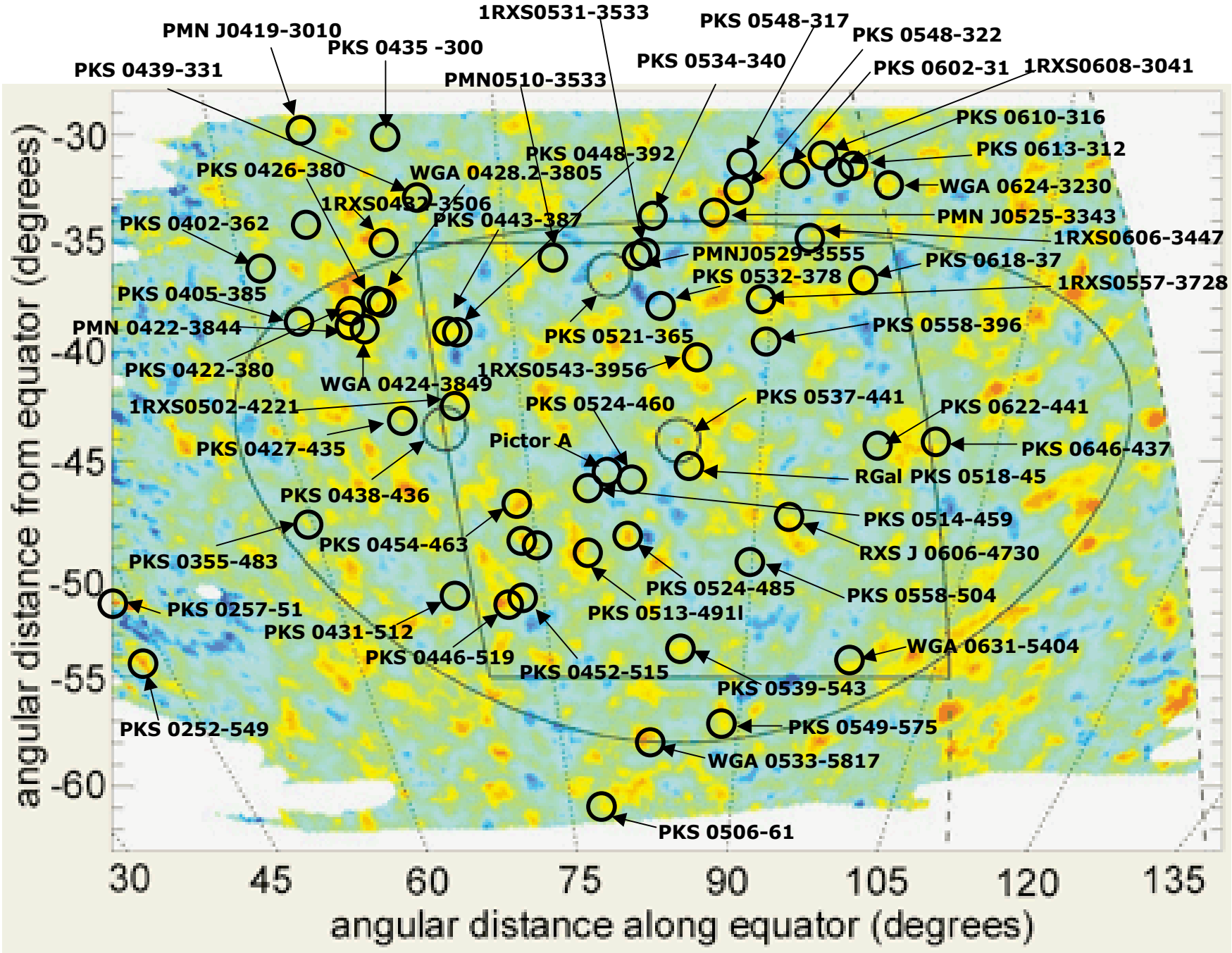
Boomerang 90 GHz CMB MAP

De Bernardis et al. 2000



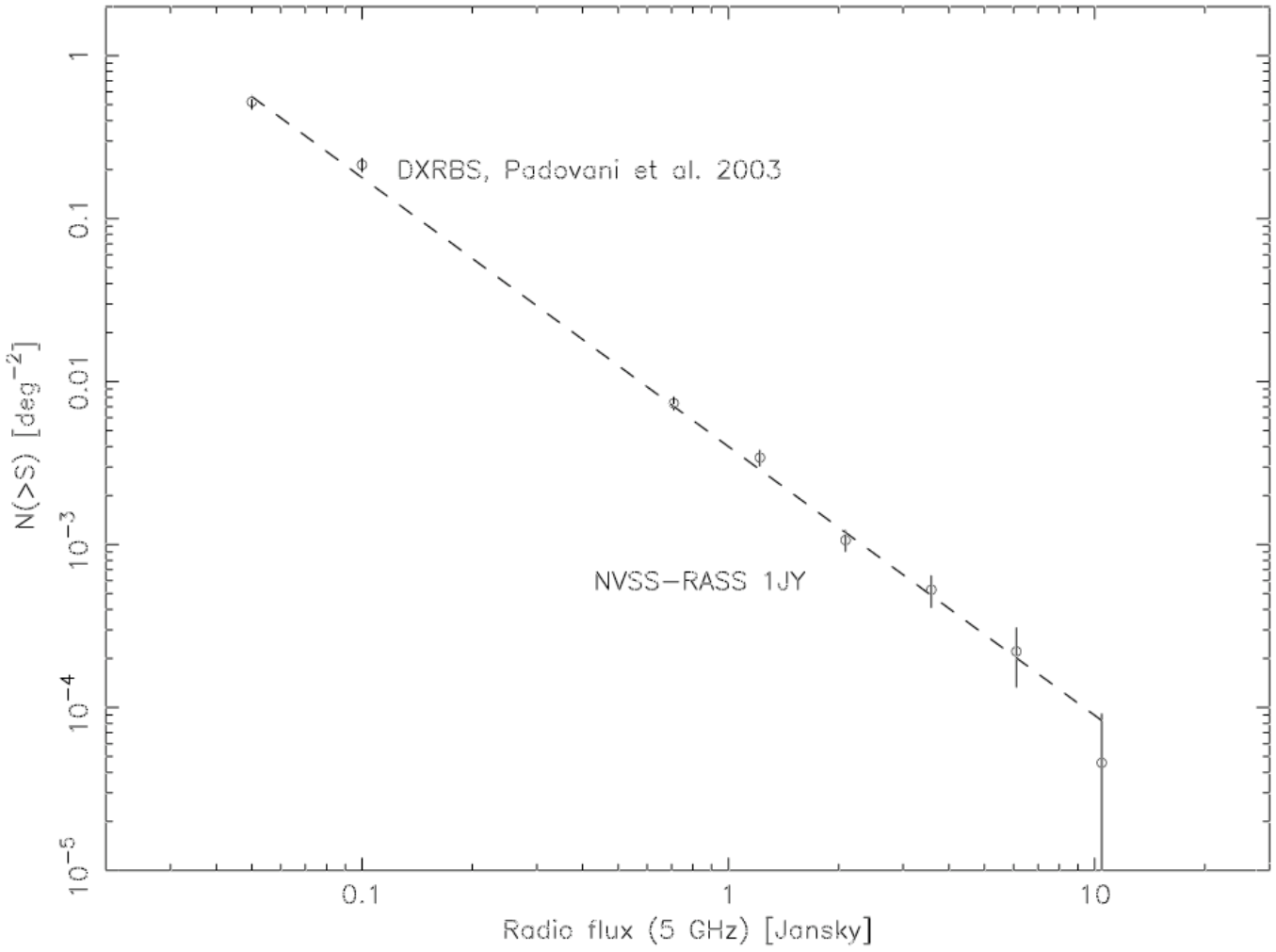


[Giommi & Colafrancesco 2003]



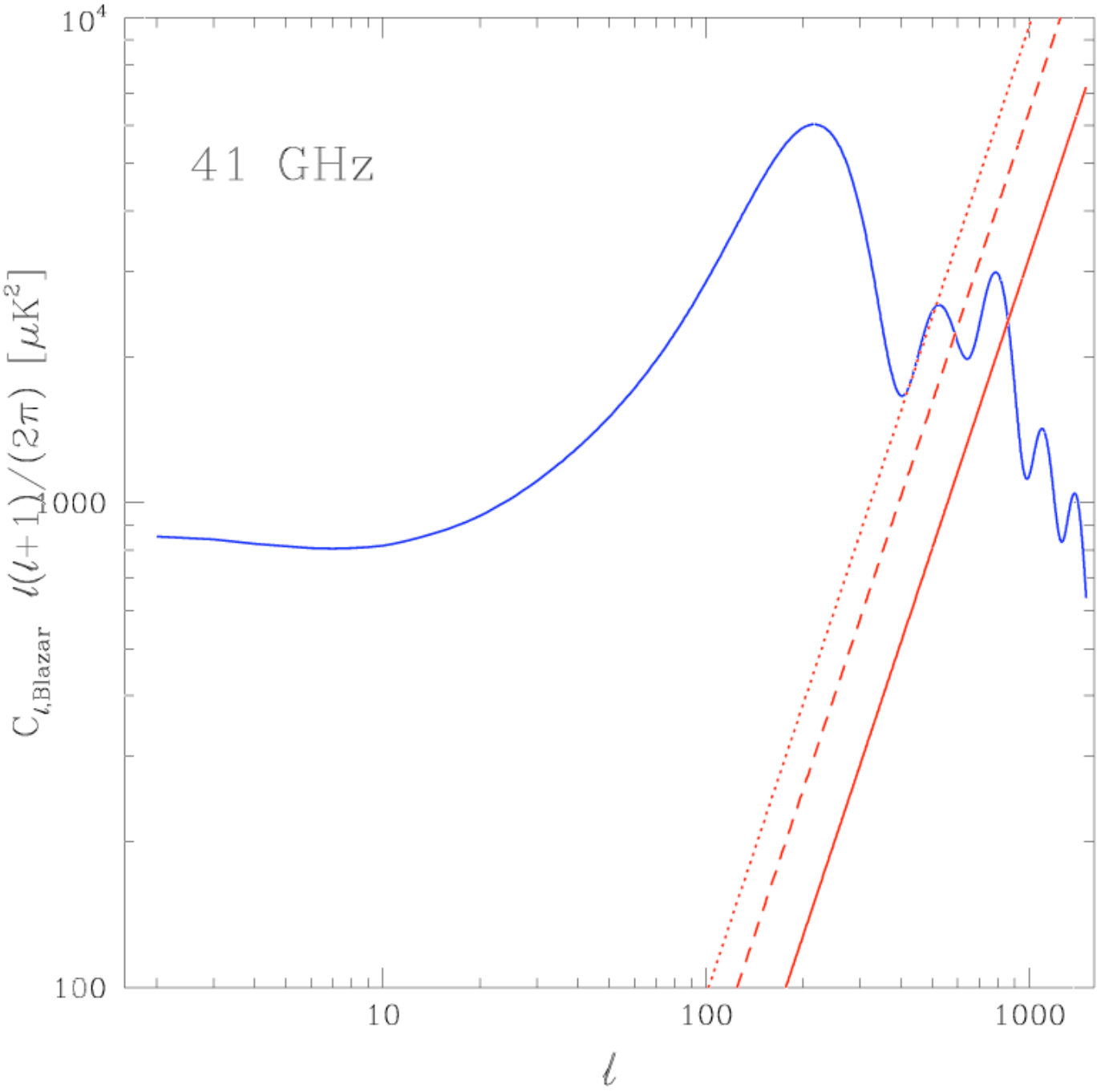
[Giommi & Colafrancesco 2003]

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

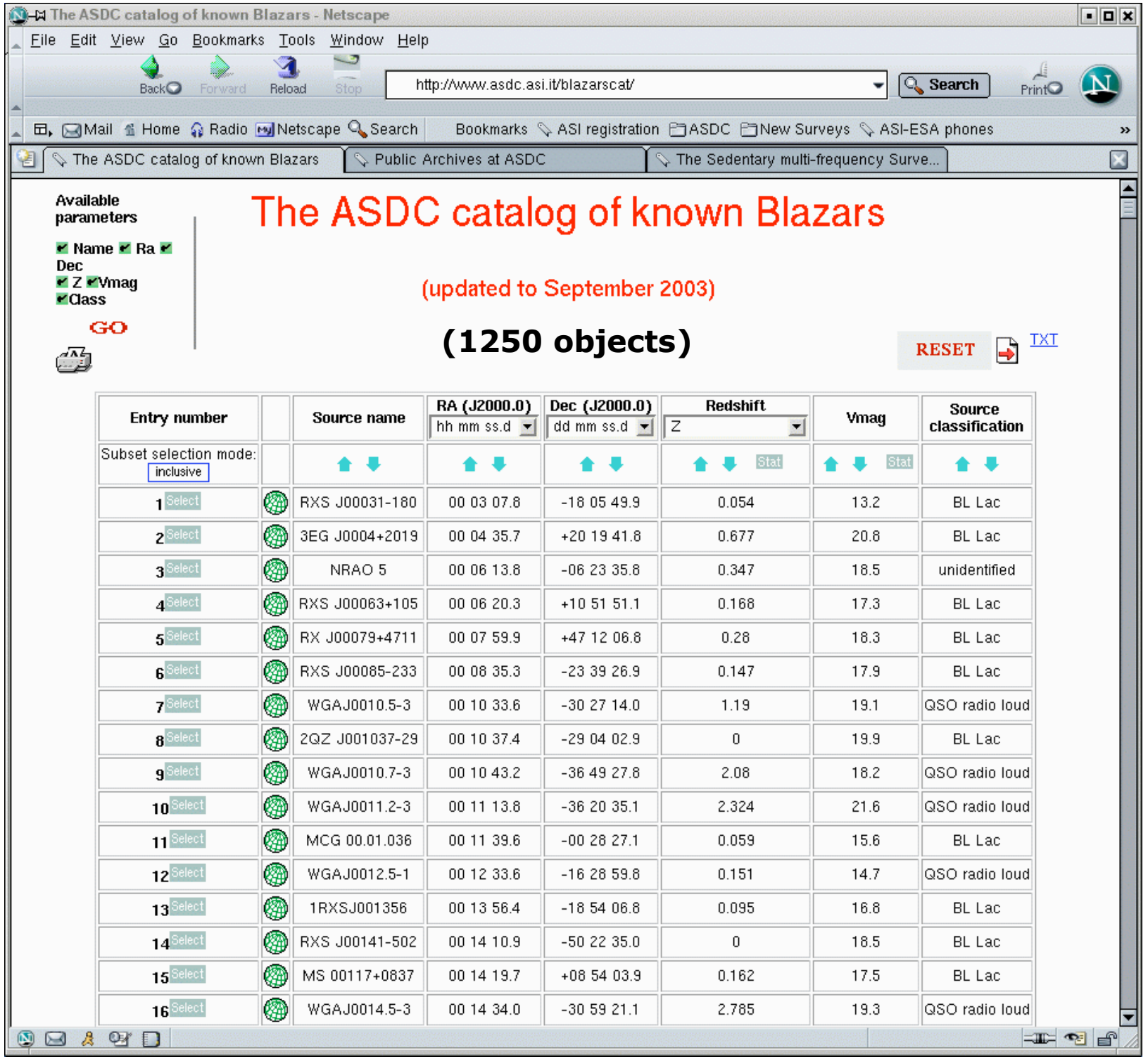
  Radio (FIRST), $f_{1.4GHz} > 35$ mJy, GB6 $f_{5GHz} > 20$ mJy, optical $B < 19$

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

- RASS-ASDC 1Jy sample

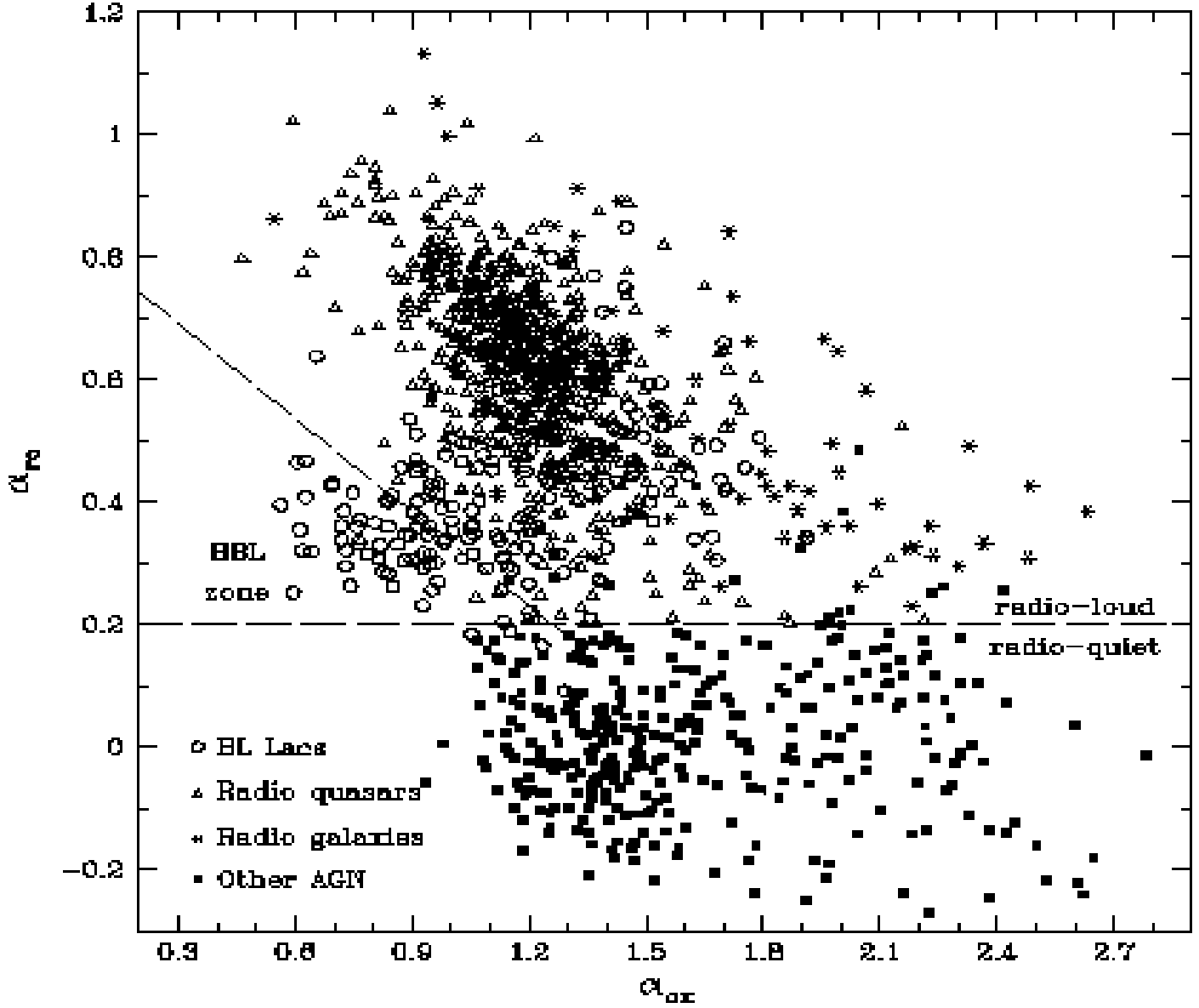
  Radio (NVSS) $f_{1.4GHz} > 1000$ mJy, X-ray RASS ($f_{(0.1\text{-}2.4\ keV)} > 8*10^{-14}$ cgs),

  25 objects , 93% identified



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

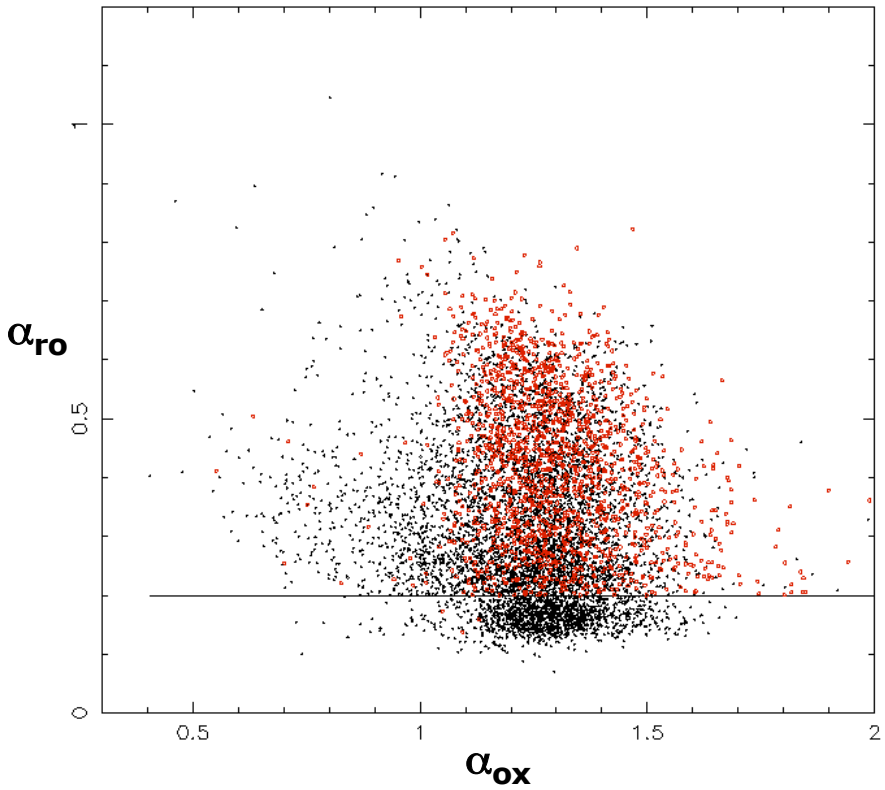
The broad-band color-color plane

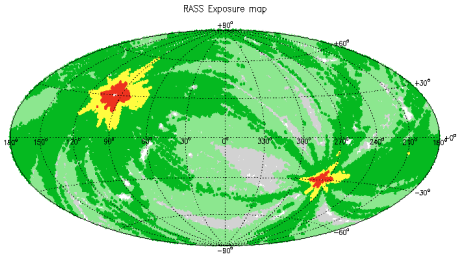
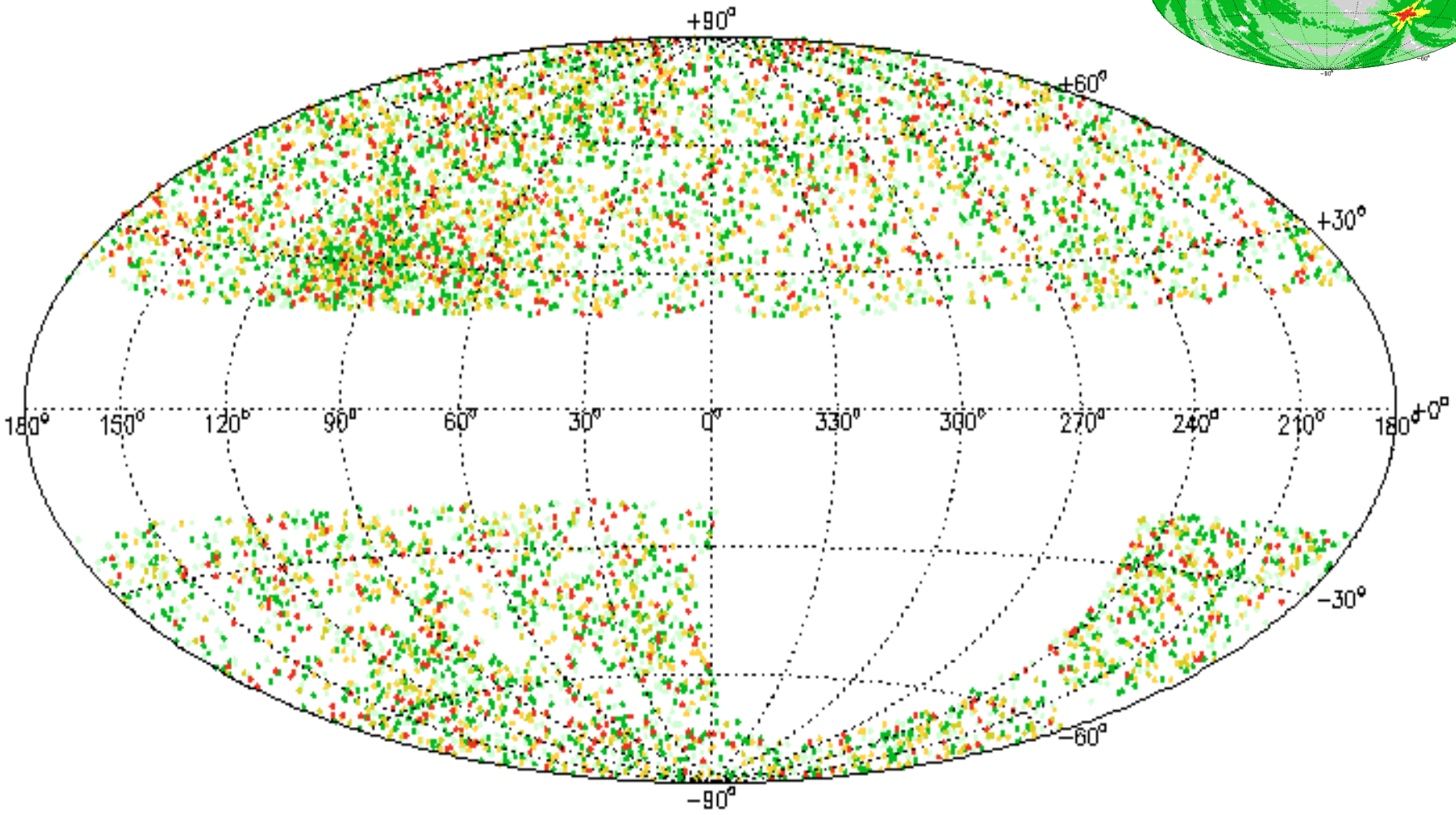


The ASDC Blazar candidate sample

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)

$\Delta_{r\text{-}x} < 2.5\ \sigma_{r\text{-}x}$ 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