Non-Thermal Cosmic Backgrounds from Blazars

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This talk is mostly based on

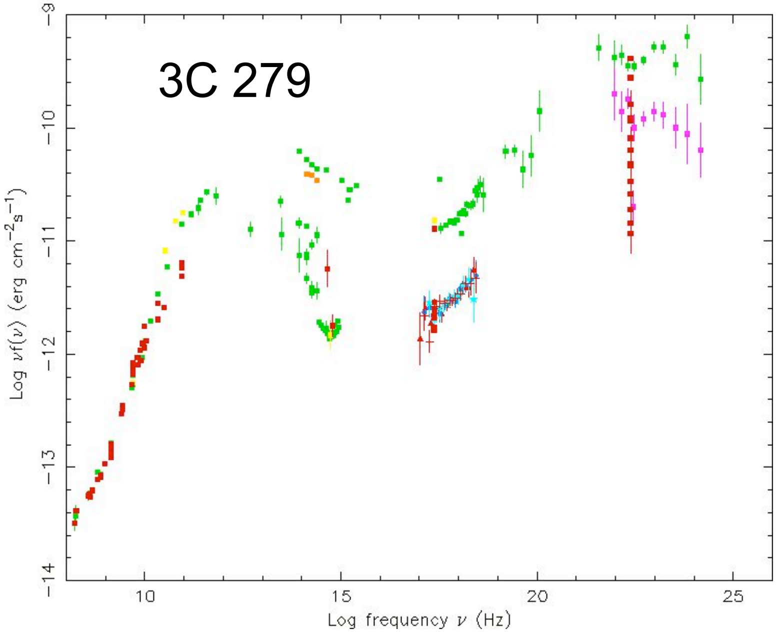
Non-thermal cosmic backgrounds from blazars: the contribution to the CMB, X-ray and γ-ray backgrounds

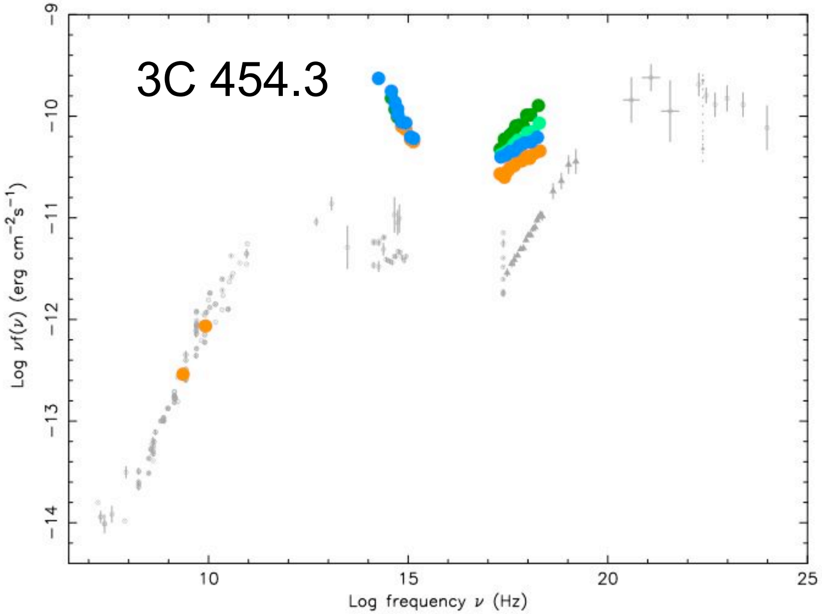
P. Giommi[1,2], S. Colafrancesco[3], E. Cavazzuti[1,2], M. Perri[1], and C. Pittori[1,4]

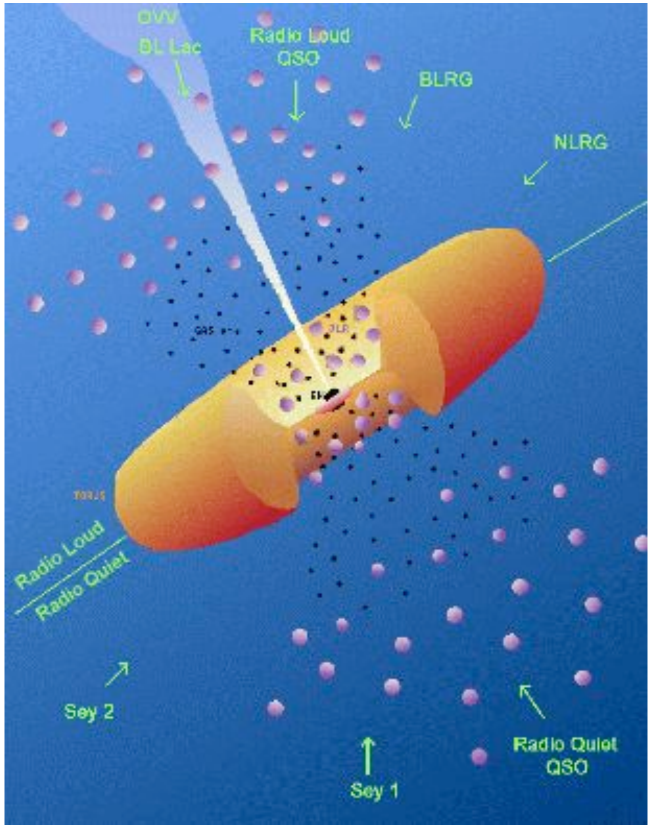
Astronomy and Astrophysics, in press astro-ph/0508034

..and on more recent developments

What’s a Blazar?







AGN : Two main categories

1. *Powered by accretion - disk emission -* AP-AGN
2. *Powered by Non-Thermal radiation - jet emission -* NT-AGN

Blazars:

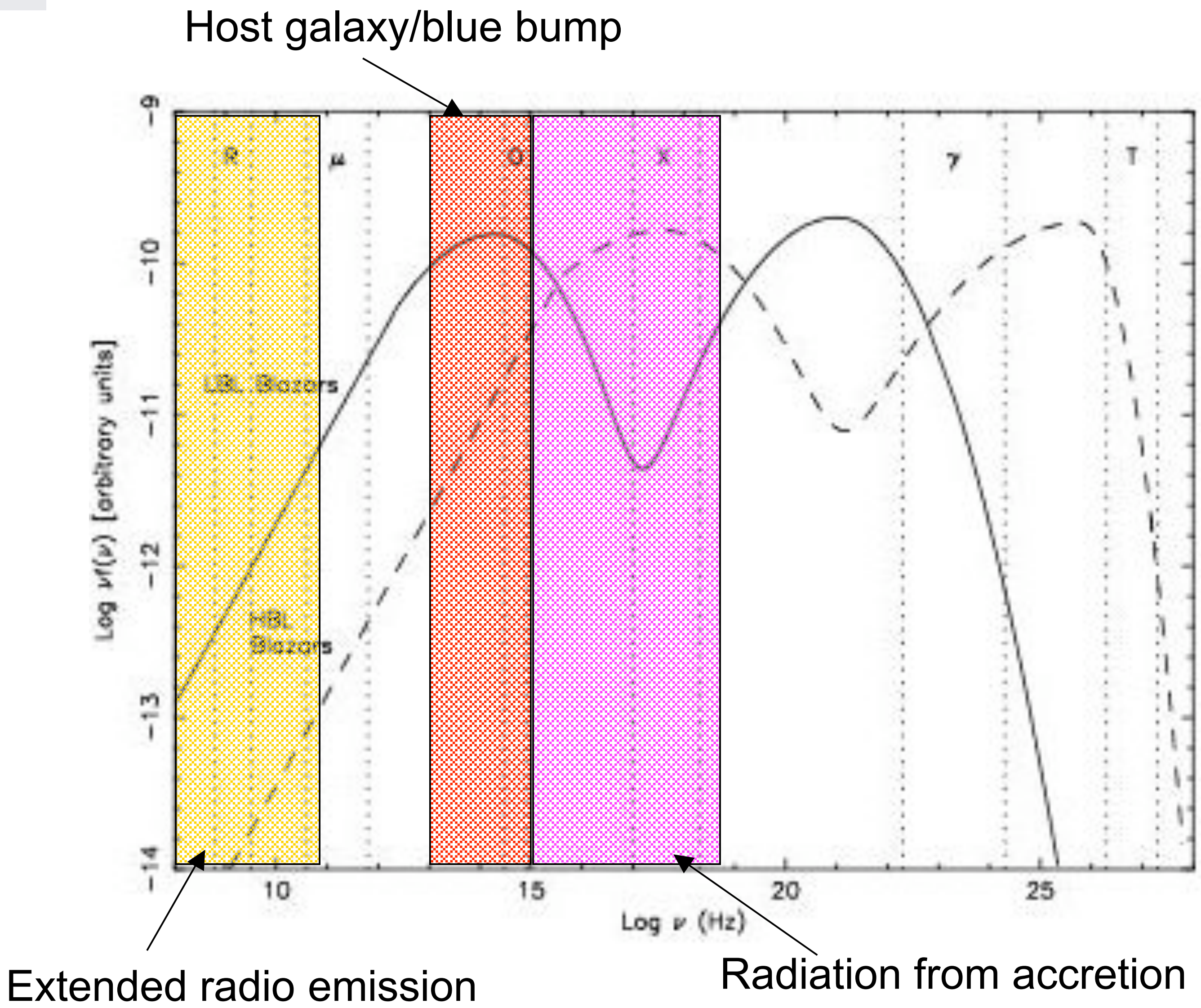
NT-AGN viewed at a small angle w.r.t. jet axis

Radio Galaxies:

NT-AGN viewed at a large angle w.r.t. jet axis

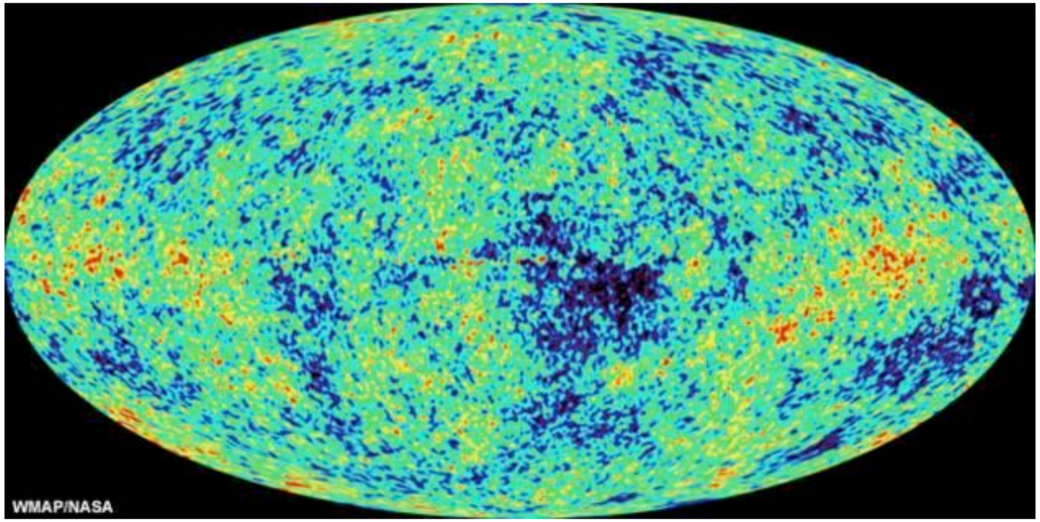
Broad-line radio galaxies (e.g. 3c120) :

A combination of AP-AGN and "misdirected" NT-AGN


Host galaxy/blue bump
R
μ
O
X
γ
T
LBL Blazars
HBL Blazars
Log νf(ν) [arbitrary units]
Log ν (Hz)
−9
−10
−11
−12
−13
−14
10
15
20
25
Extended radio emission
Radiation from accretion

Blazars & WMAP

WMAP CMB fluctuation map



WMAP bright foreground source catalog

208 bright sources

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

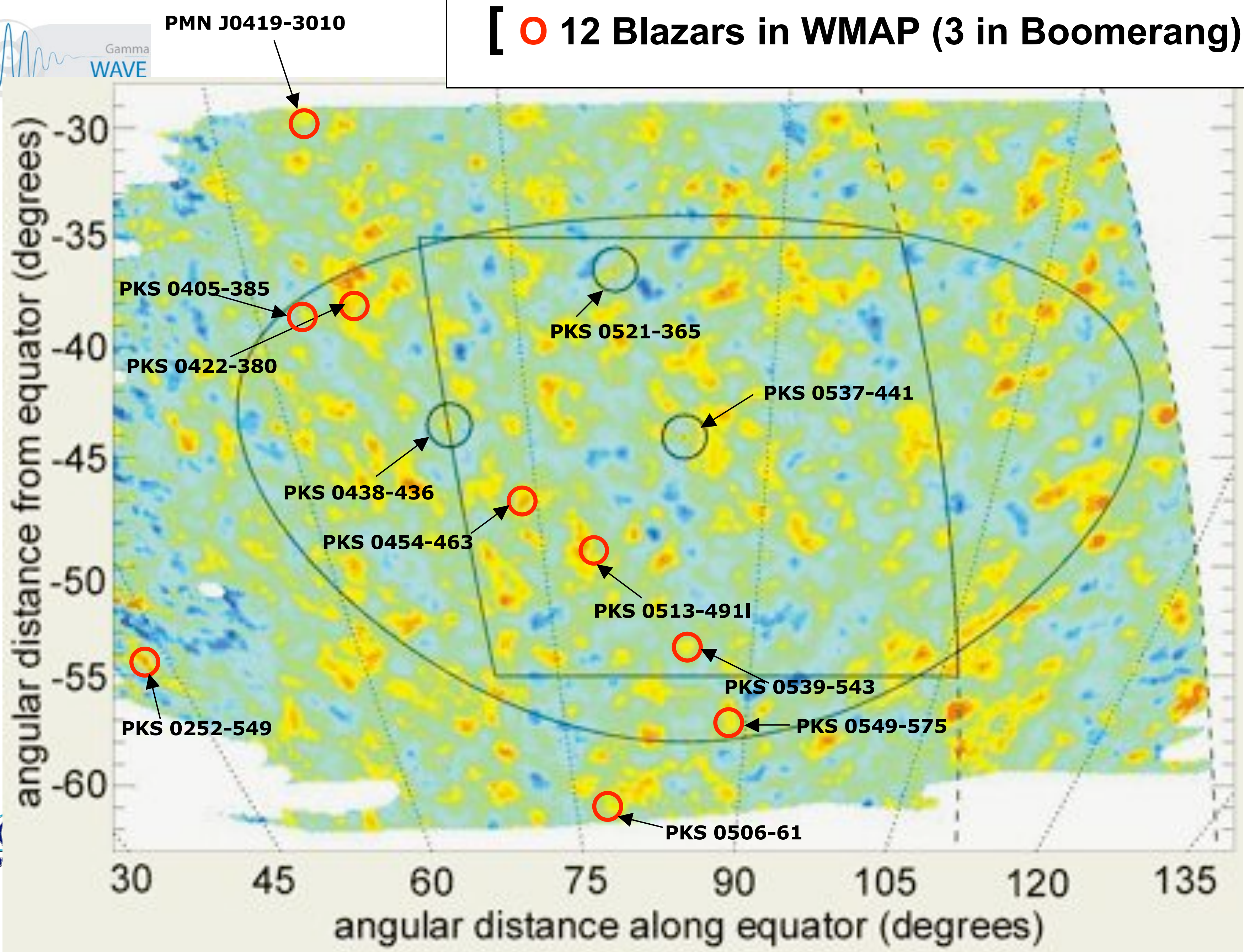
- **17 unidentified**
- **5 without radio counterpart (probably spurious)**

http://www.asdc.asi.it/wmap/

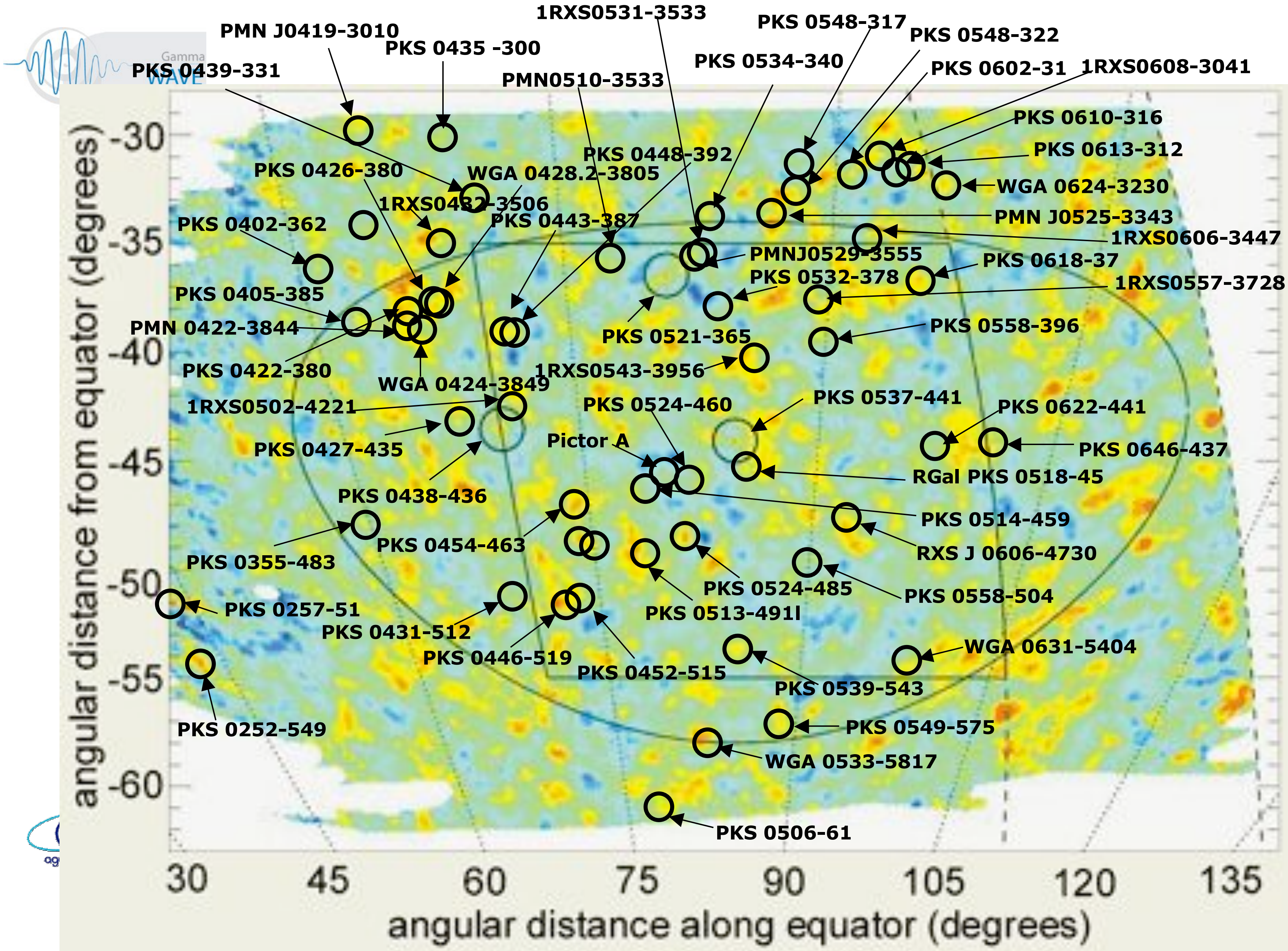
12 September 2005

The vast majority (85%-90%) of bright WMAP foreground sources are Blazars

[O 12 Blazars in WMAP (3 in Boomerang)]



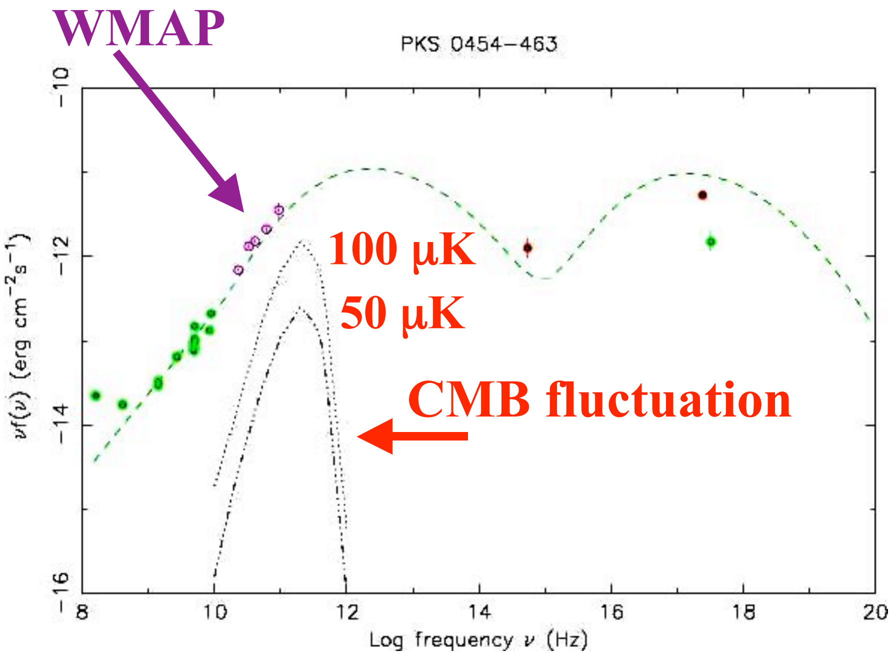
[Giommi & Colafrancesco 2004]

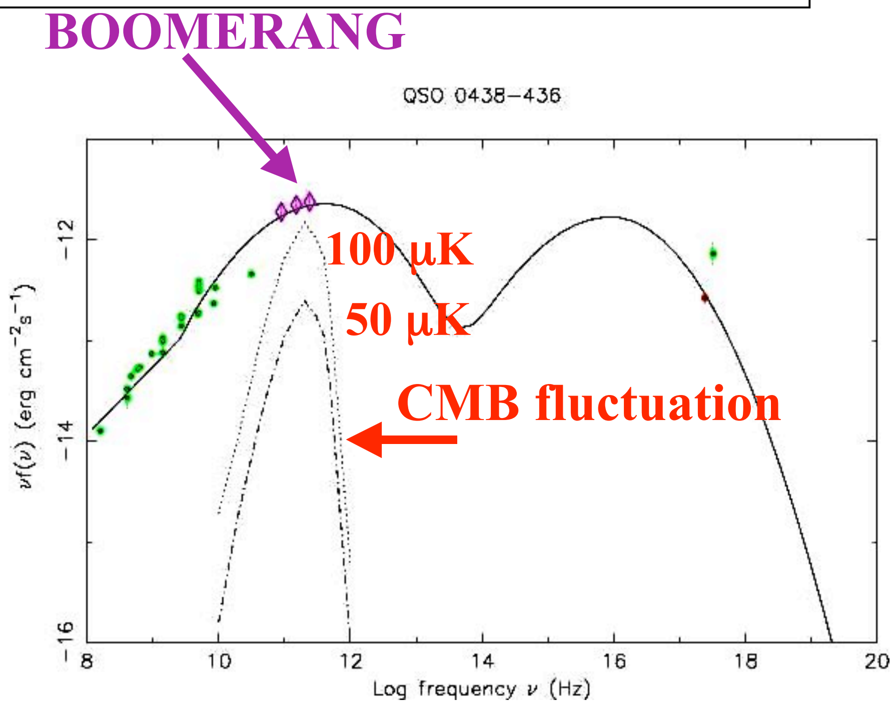


[Giommi & Colafrancesco 2004]

[O 54 Blazars with ΔT > 50 μK]

Blazar SEDs

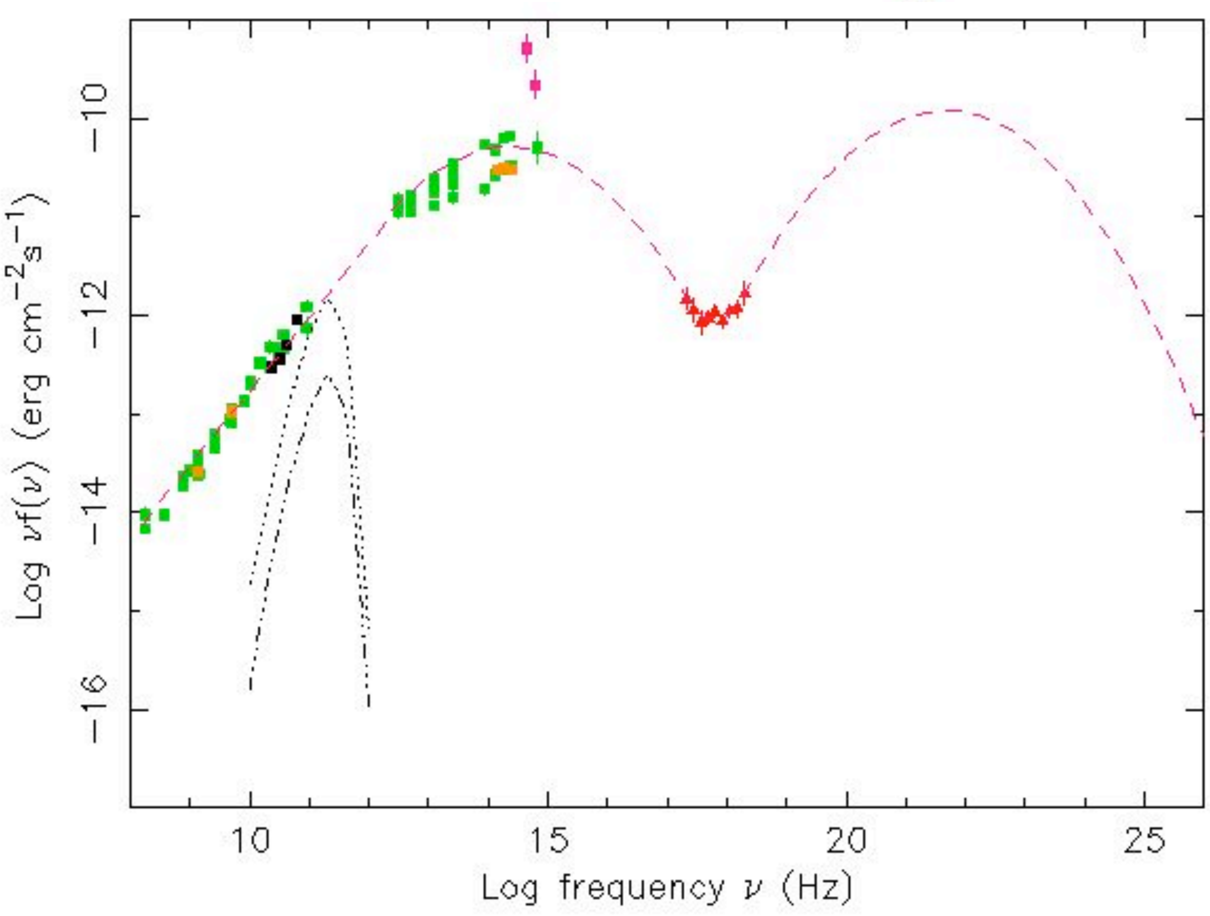




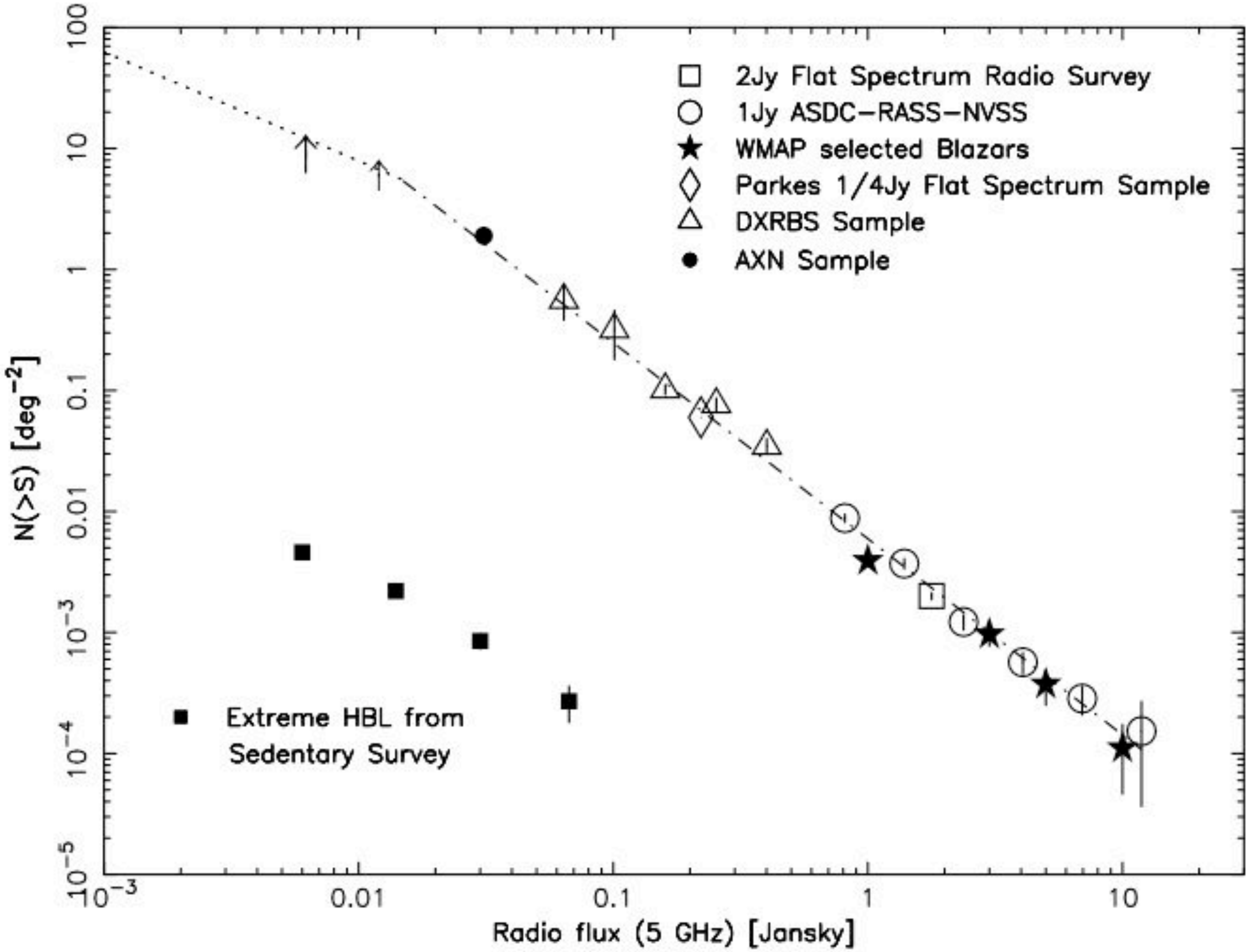
WMAP source

BOOMERANG source

WMAP Blazar SEDs



The Blazar radio LogN-LogS



The Blazar power spectrum

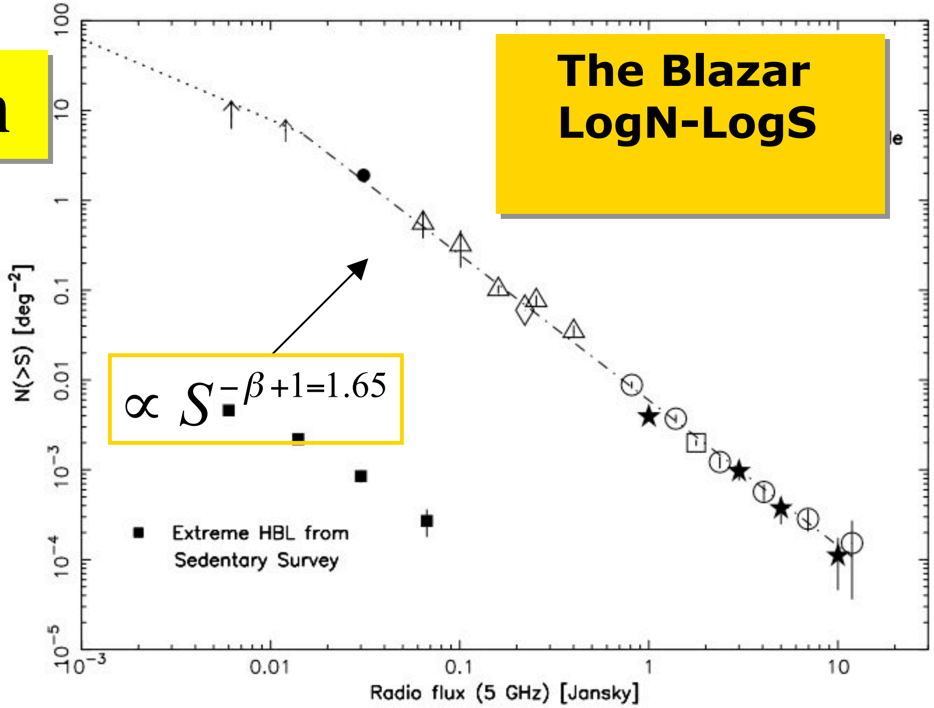
$$\left\langle \Delta T^2_{CMB} \right\rangle = \frac{1}{2\pi} \cdot l(l+1) C_{l,Blazar}$$

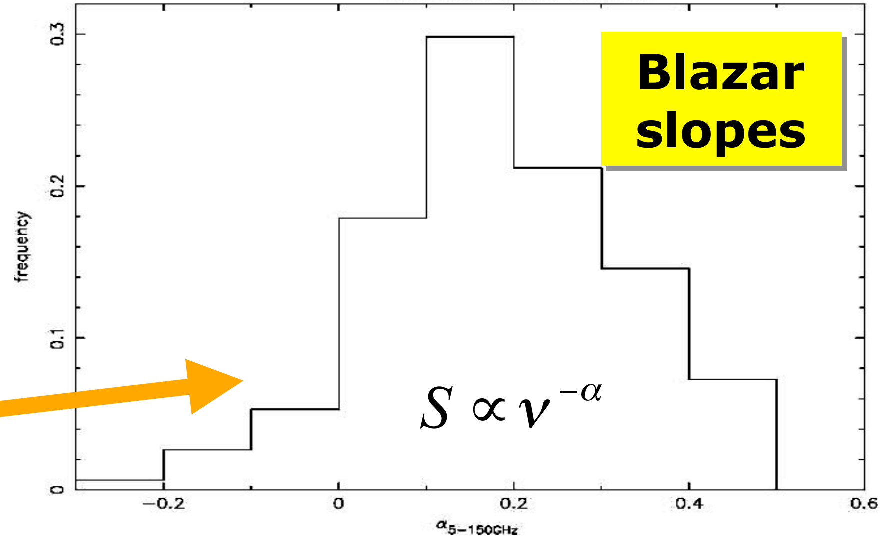
$$C_{l,Blazar} = \underbrace{\int dS \cdot \frac{dN}{dS} \cdot S^2}_{\text{Poisson}} + \underbrace{\omega_{l,Blazar} (I)^2}_{\text{Clustering}}$$

Poisson **Clustering**

$$\propto \frac{1}{2-\beta} \cdot \left[S_{max}^{2-\beta} - S_{min}^{2-\beta} \right]$$

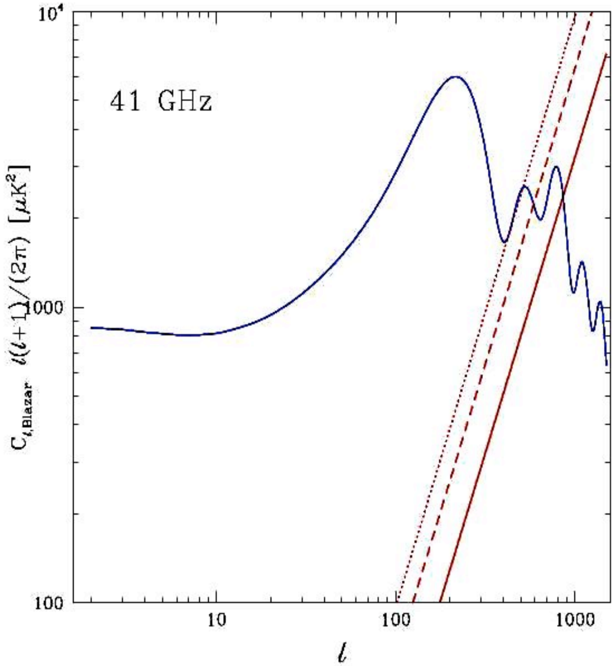
Go to high-ν using



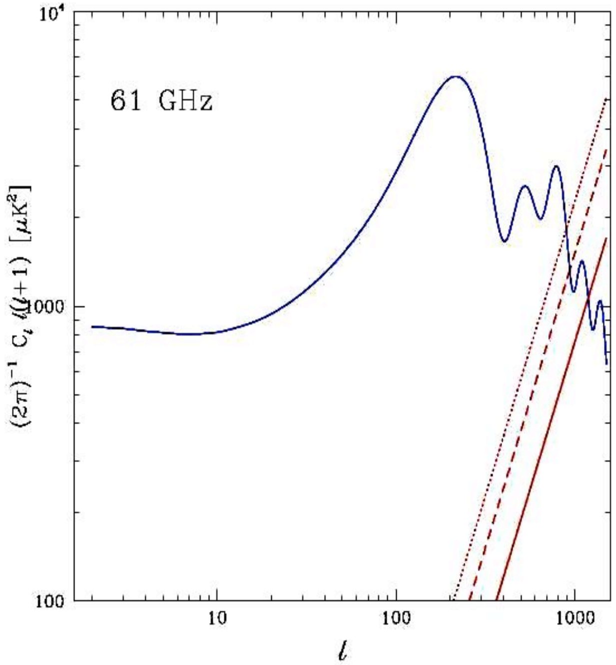


Blazar contamination vs. ν

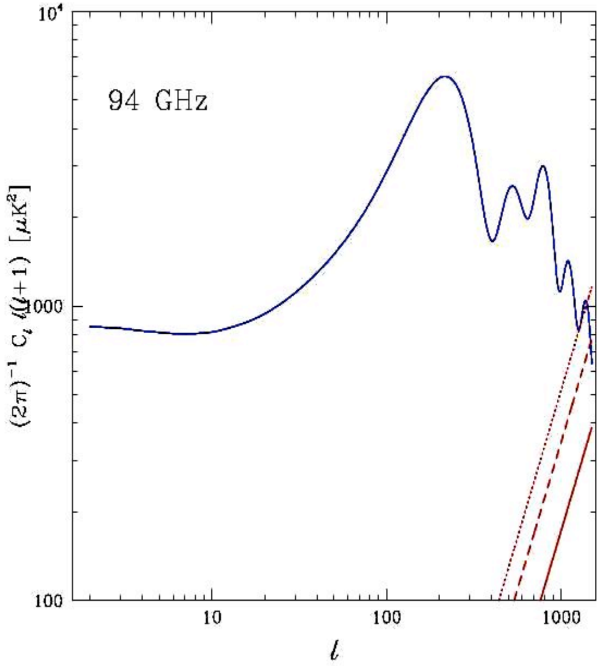
WMAP Q-band



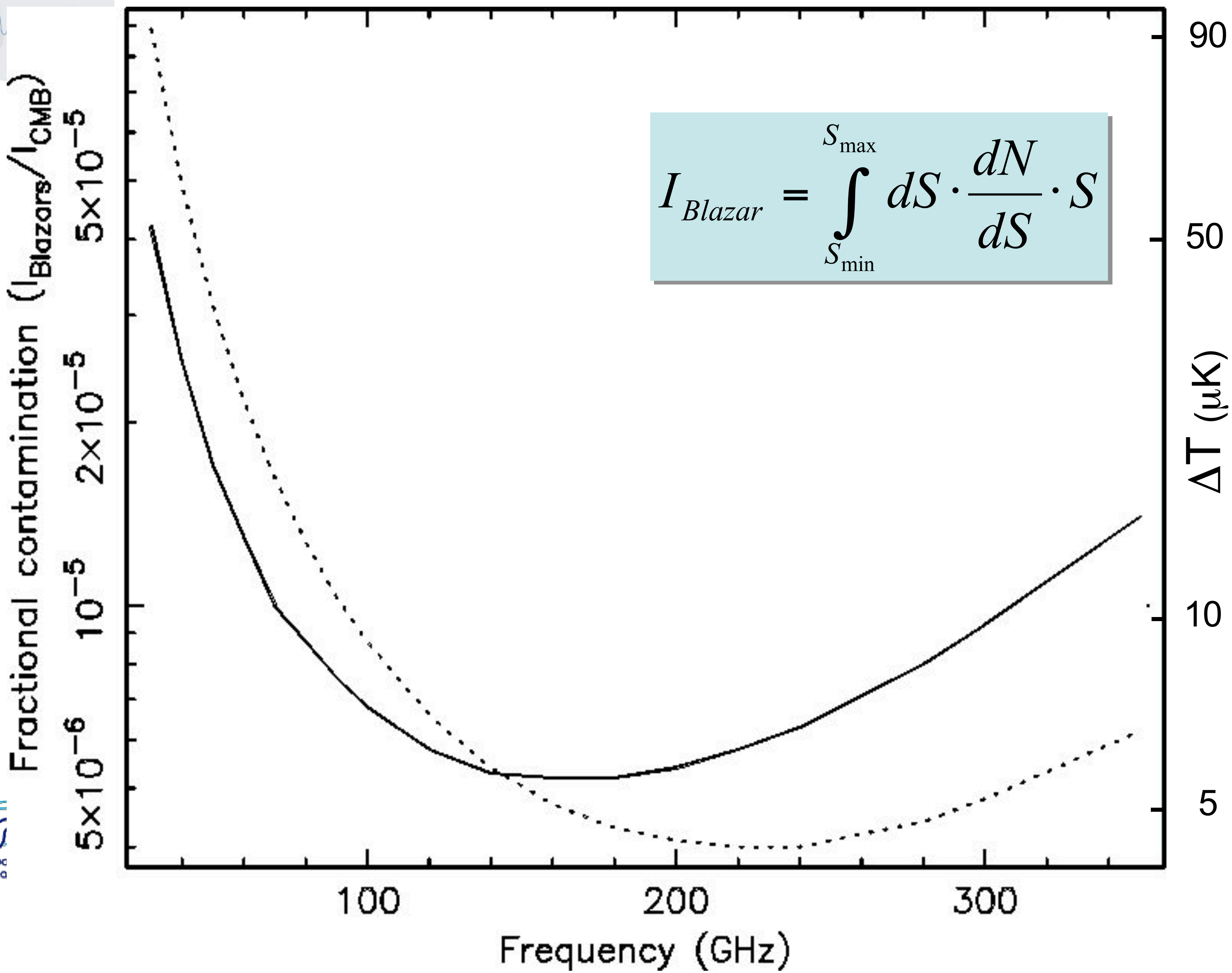
WMAP V-band



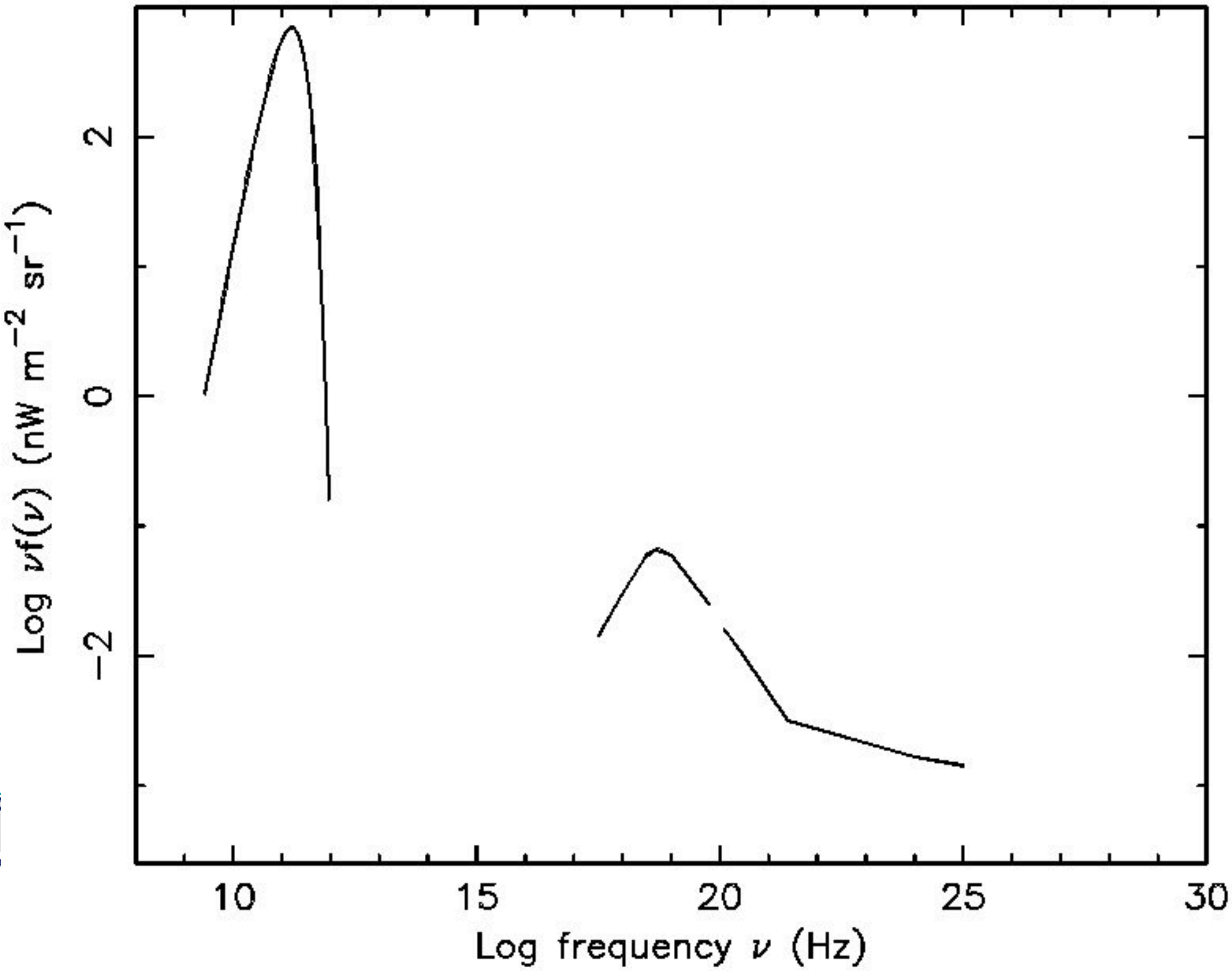
WMAP W-band



agenzia spaziale italiana



$$I_{Blazar} = \int_{S_{\min}}^{S_{\max}} dS \cdot \frac{dN}{dS} \cdot S$$



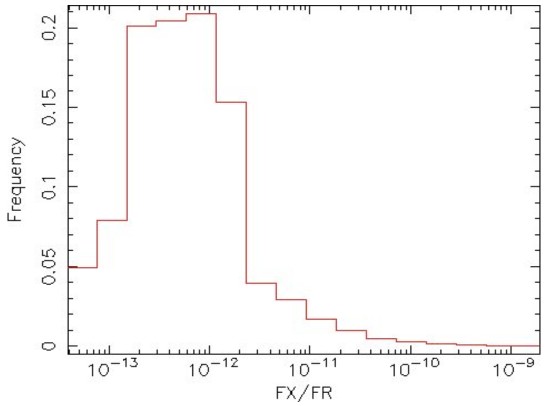
Log νf(ν) (nW m^−2 sr^−1)
2
0
−2
10
15
20
25
30
Log frequency ν (Hz)

f_x/f_r

Radio LogN-LogS

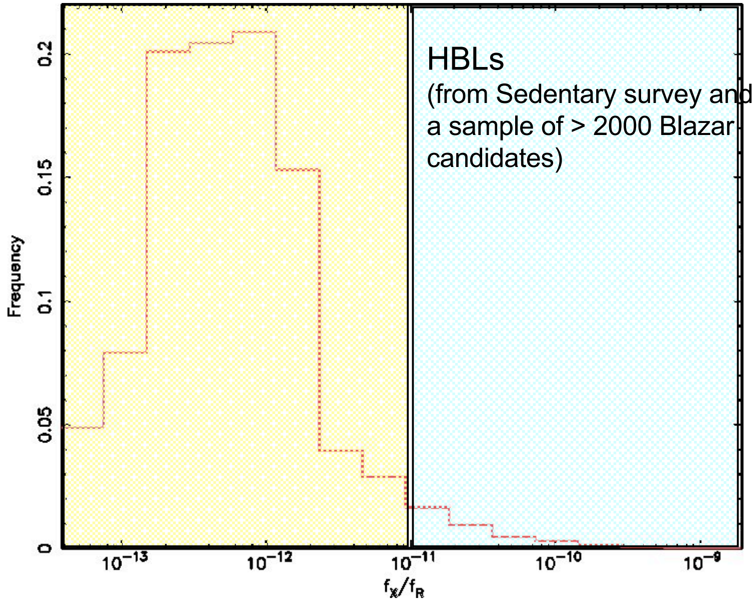
$$I = \int_{S\,\min}^{S\,\max} S \cdot \frac{dN}{dS} \cdot dS$$

\+



=> I_{CXB}

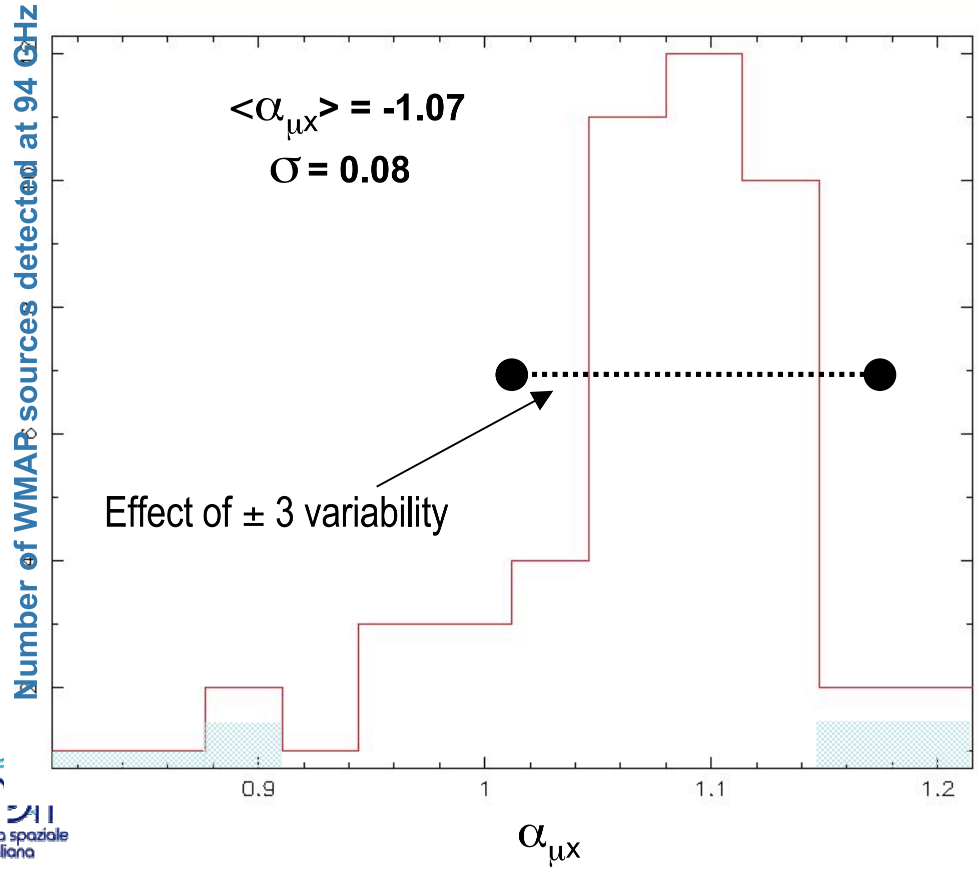
LBLs (from ANR 1Jy sample)



Blazar contribution to soft CXB = 12% (1/3 from LBLs, 2/3 from HBLs!)

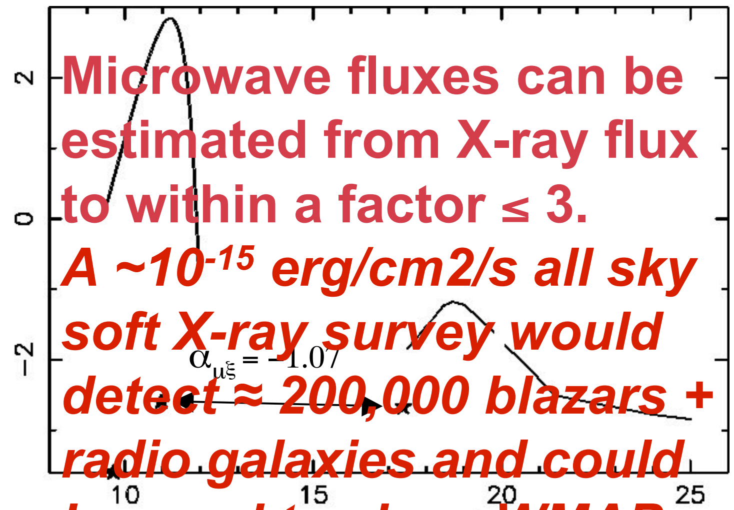
From μ–wave flux to X-rays and vice-versa

$$\alpha_{\mu x} = \frac{\log(f_{94GHz}/f_{1keV})}{\log(\nu_{94GHz}/\nu_{1keV})} = -\frac{\log(f_{94GHz}/f_{1keV})}{\log(2.42\times10^{17}/9.410^{10})} = -\frac{\log(f_{94GHz}/f_{1keV})}{6.41}$$



$$f_{94GHz} = f_{1keV} \cdot 10^{6.41<\alpha_{\mu x}>}$$

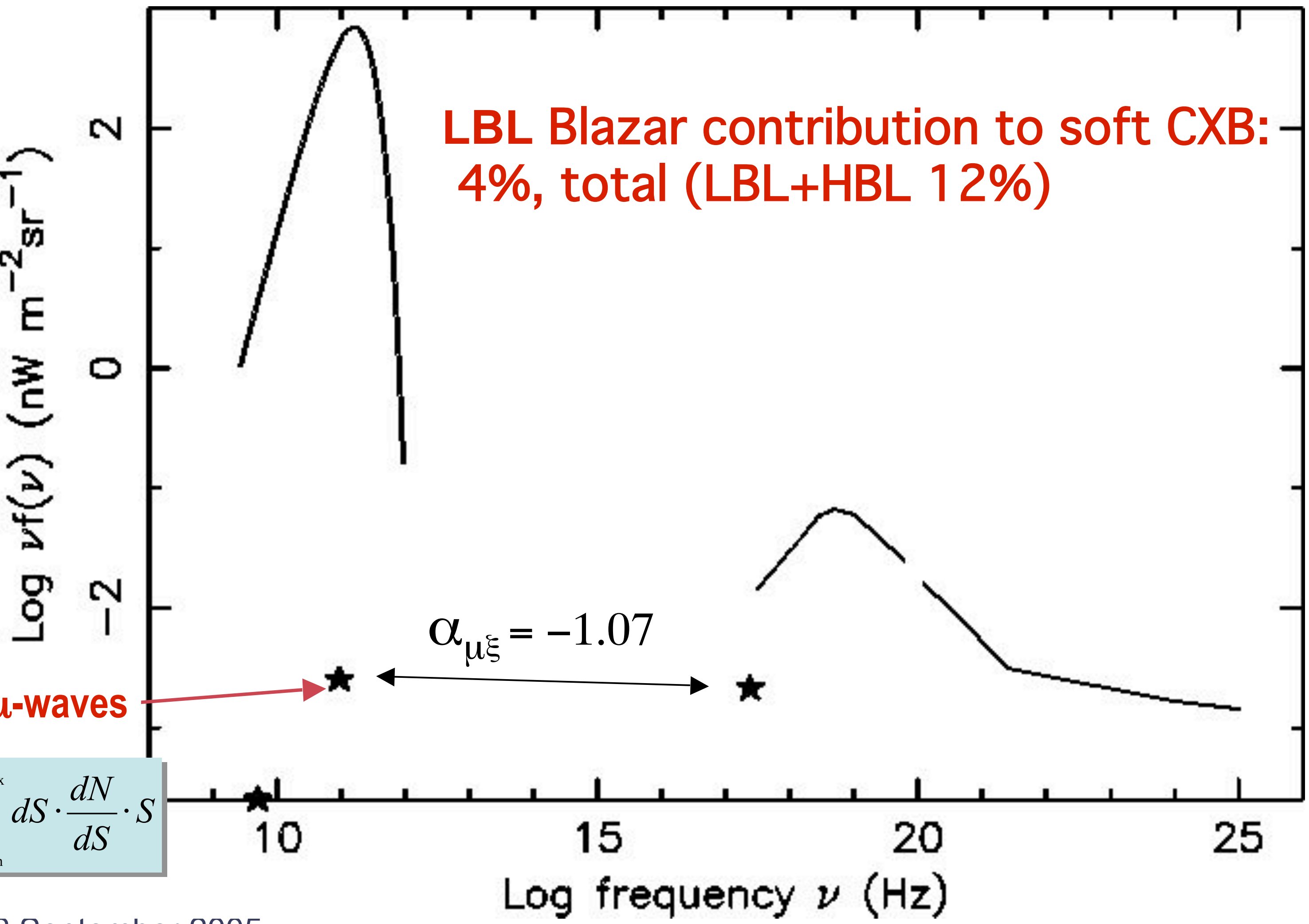
$$f_{94GHz} = 7.1 \cdot 10^{6}\, f_{1keV}$$



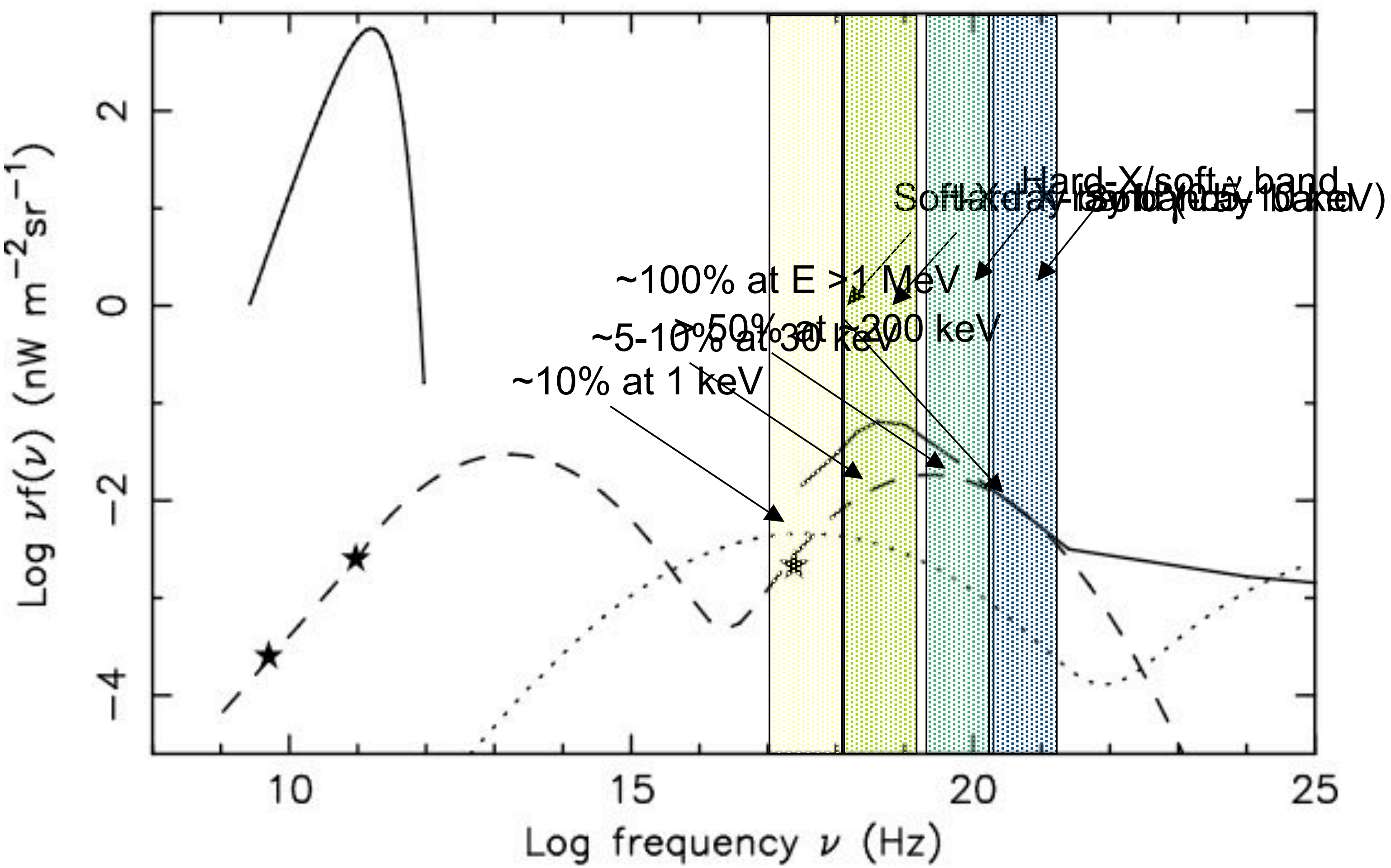
Microwave fluxes can be estimated from X-ray flux to within a factor ≤ 3.

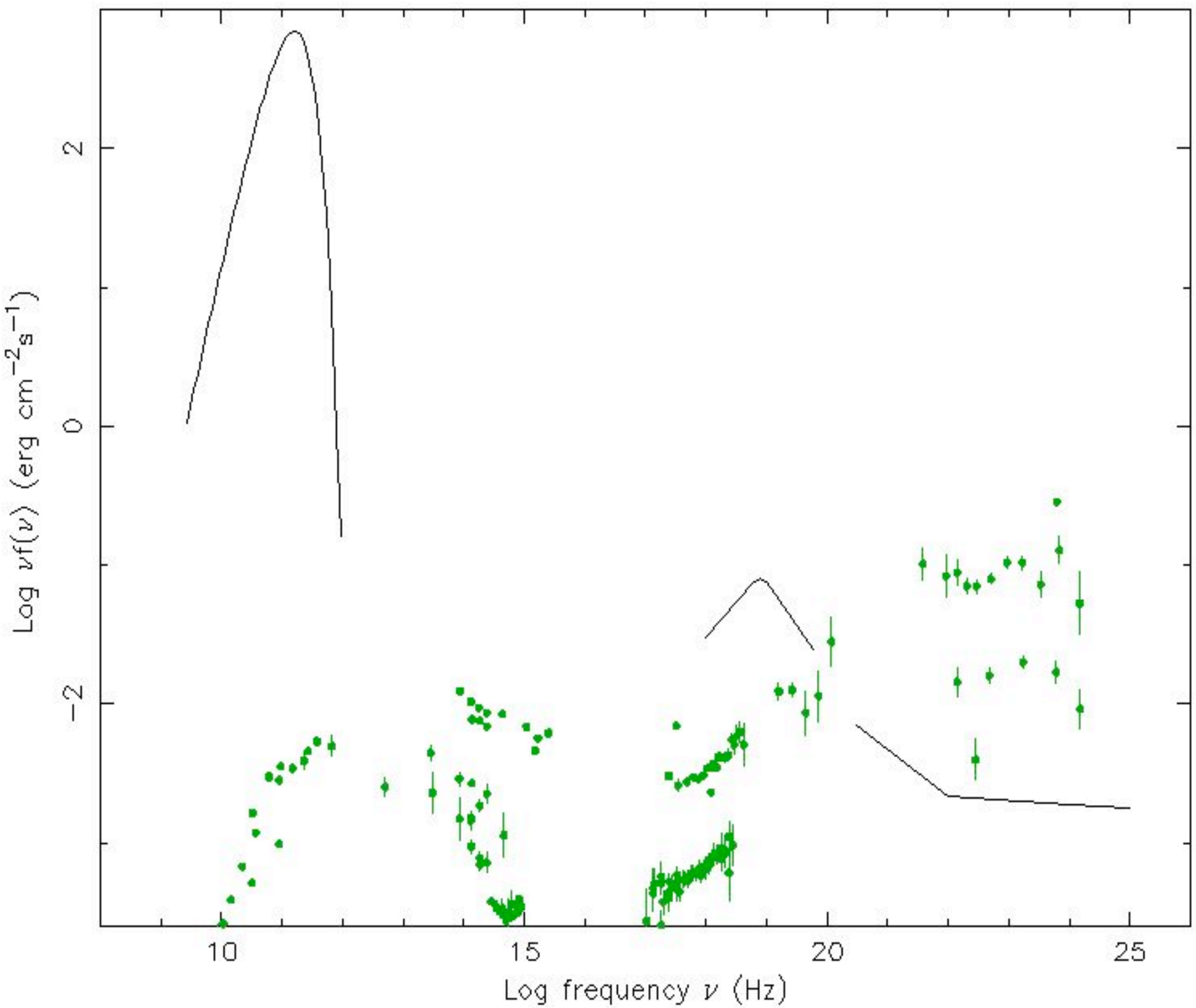
A ~10^{-15} erg/cm2/s all sky soft X-ray survey would detect ≈ 200,000 blazars + radio galaxies and could be used to clean WMAP and Planck CMB maps

From μ-wave to X-rays



$$I_{Blazar} = \int_{S_{min}}^{S_{max}} dS \cdot \frac{dN}{dS} \cdot S$$


Hard-X/soft γ band
~100% at E >1 MeV
~50% at ~200 keV
~5-10% at 30 keV
~10% at 1 keV
Log νf(ν) (nW m−2sr−1)
Log frequency ν (Hz)
2
0
−2
−4
10
15
20
25



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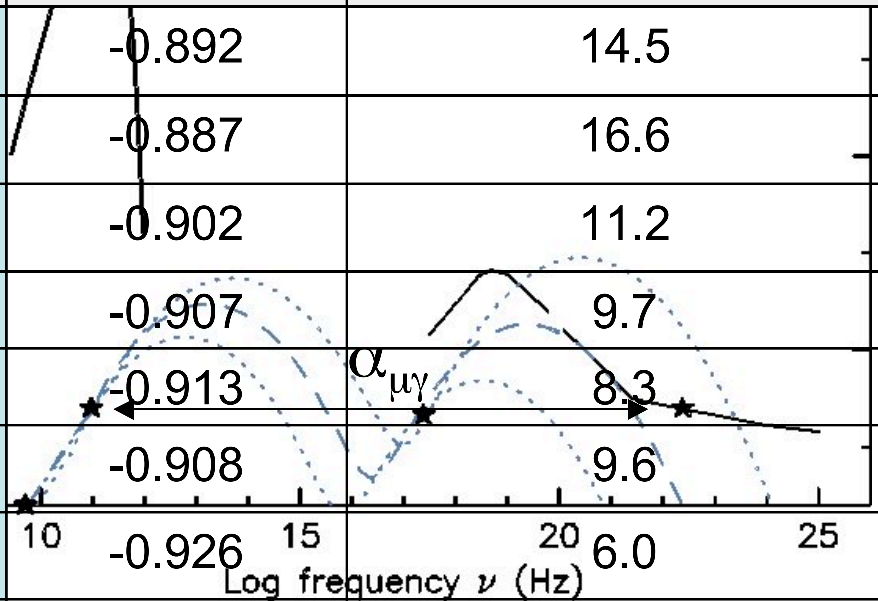
Radio — γ-ray flux ratio & duty cycle

Define a slope/trend: $$\alpha_{\mu\gamma} \equiv \frac{\log(F_{\mu} / F_{\gamma})}{\log(\nu_{\mu} / \nu_{\gamma})}$$

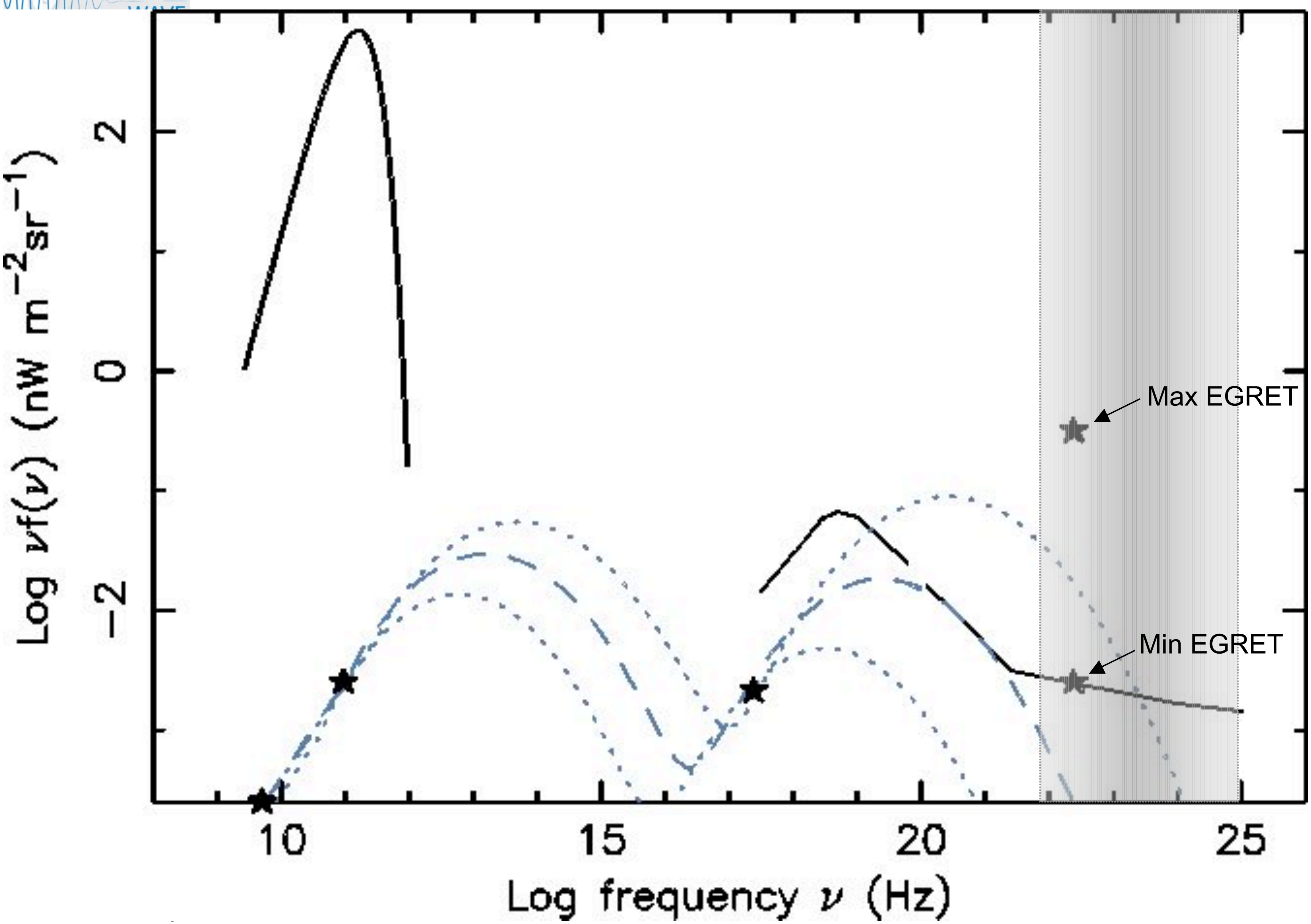
Blazar Name	$\alpha_{\mu\gamma}$	fγ-source/<γ–background> ($\alpha_{\mu\gamma background}$=-0.994)
BZQ J0204+1514	-0.892	14.5
BZU J0210-5101	-0.887	16.6
BZB J0339-0146	-0.902	11.2
BZQ J0423-0120	-0.907	9.7
BZQ J0455-4615	-0.913	8.3
BZQ J0457-2324	-0.908	9.6
BZU J0522-3627	-0.926	6.0
BZB J0538-4405	-0.892	14.4
BZQ J1256-0547 (3C 279)	-0.870	25.5

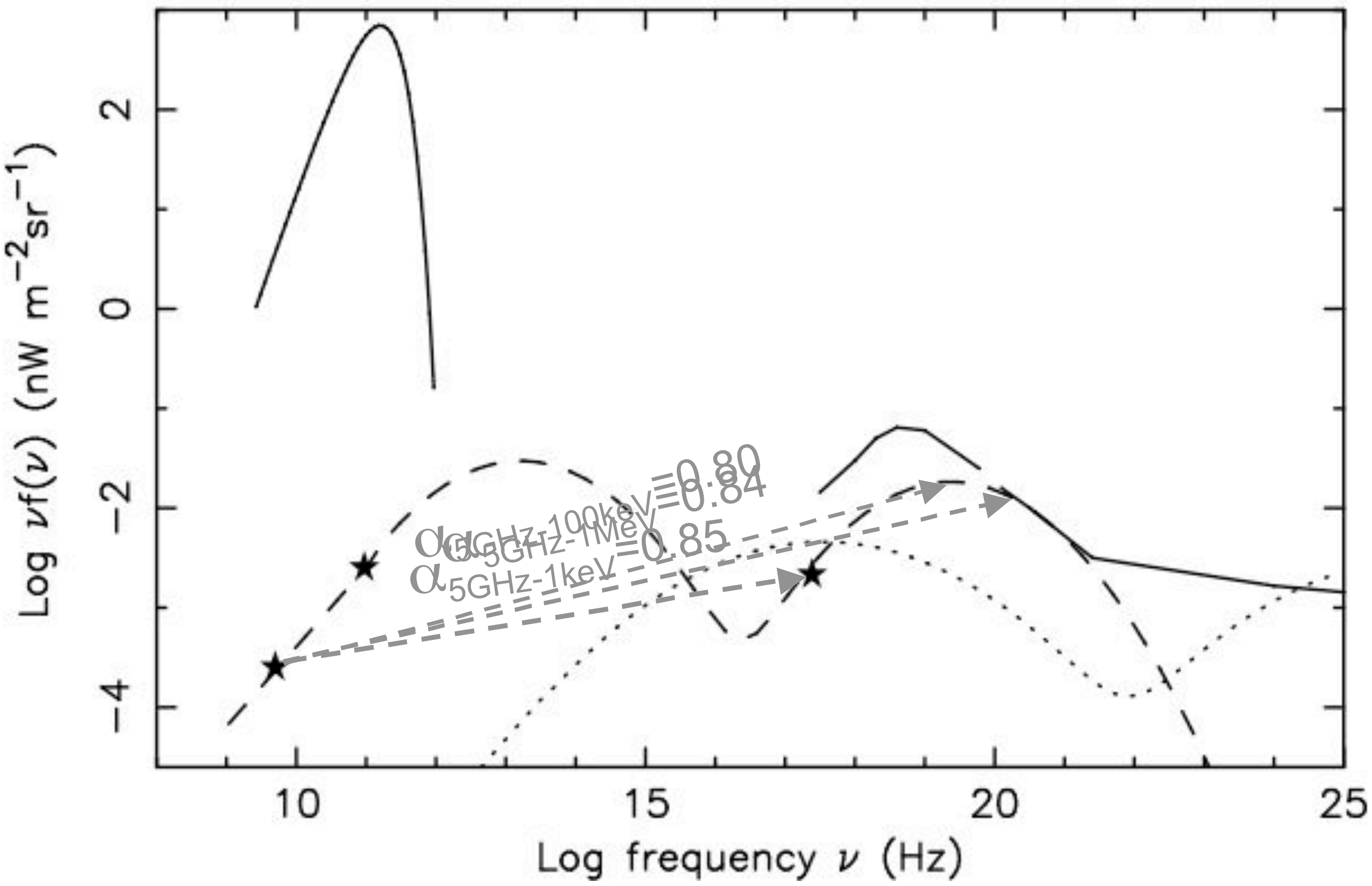


Duty cycle (%)
6.9
6.0
8.9
10.3
12.0
10.4
16.7
6.9
3.9

Table 2. The list and properties of all WMAP-detected Blazars associated to EGRET γ-ray sources

Blazar Name (1)	R.A. J2000.0 (2)	Dec J2000.0 (3)	Radio Flux 5GHz Jy (4)	WMAP flux 94GHz Jy (5)	EGRET flux >100 MeV 10^{-8} ph cm^{-2} s^{-1} (6)	$\alpha_{\mu\gamma}$ (7)	Duty cycle % (8)	EGRET name 3EG J (9)	WMAP catalog number (10)
4C15.05	02 04 50.3	15 14 10	3.073	1.6*	9-53	0.846-0.914	2-12	0204+1458	092
1Jy0208-512	02 10 46.2	−51 01 02	3.198	1.8	35-134	0.816-0.867	1-4	0210-5055	158
B2 0234+28	02 37 52.3	28 48 08	2.794	2.1*	11-31	0.877-0.917	5-13	0239+2815	093
CTA26	03 39 30.8	−01 46 35	3.014	3.2	13-178	0.827-0.926	1-17	0340-0201	106
PKS 0420-01	04 23 15.7	−01 20 32	4.357	3.9	9.3-64.2	0.873-0.946	4-29	0422-0102	110
1Jy0454-463	04 55 50.7	−46 15 59	1.653	3.8	5.5-22.8	0.911-0.966	11-47	0458-4635	151
1Jy0454-234	04 57 03.1	−23 24 51	1.863	2.7	8.1-14.7	0.915-0.938	13-23	0456-2338	128
PKS 0506-61	05 06 44.0	−61 09 40	1.211	1.1*	6-29	0.855-0.915	3-13	0512-6150	154
1Jy0537-441	05 38 51.3	−44 05 11	4.805	6.7	16.5-91.1	0.880-0.945	5-28	0540-4402	148
PKS 0735+178	07 38 07.3	17 42 18	1.812	1.7*	15-29	0.872-0.896	4-8	0737+1721	113
B2 0827+24	08 30 52.0	24 10 57	0.886	2.6*	16-111	0.837-0.911	2-11	0829+2413	112
S50836+710	08 41 24.4	70 53 40	2.342	1.2*	9-33	0.854-0.903	2-9	0845+7049	089
OJ 287	08 54 48.8	20 06 30	2.908	2.5	9.7-15.8	0.910-0.928	11-18	0853+1941	115
4C 29.45	11 59 31.7	29 14 43	1.461	2.1	7.5-163.2	0.814-0.931	1-19	1200+2847	111
PKS1221-82^a	12 24 54.3	−83 13 10	0.797	1.2*	11-36	0.850-0.895	2-7	1249-8330	178
1Jy1226+023	12 29 06.3	02 03 04	36.923	9.0	8.5-48.3	0.916-0.982	13-73	1229+0210	170
3C279	12 56 11.0	−05 47 19	11.192	19.0	15-250	0.882-1.000	5-100	1255-0549	181
PKS 1313-333	13 16 07.9	−33 38 59	1.093	1.3*	15-32	0.858-0.887	3-6	1314-3431	182
1Jy1406-076	14 08 56.4	−07 52 25	1.080	1.7*	10-128	0.815-0.912	1-12	1409-0745	203
1Jy1424-418	14 27 56.2	−42 06 19	2.597	1.5*	12-55	0.842-0.901	2-9	1429-4217	191
1Jy1510-089	15 12 50.4	−09 06 00	3.080	1.7	12.6-49.4	0.851-0.903	2-9	1512-0849	207
1Jy1606+106	16 08 46.0	10 29 07	1.412	3.1	21.0-62.4	0.865-0.907	3-10	1608+1055	009
DA 406	16 13 40.9	34 12 46	2.324	1.4	19-68.9	0.831-0.880	1-5	1614+3424	023
4C38.41	16 35 15.4	38 08 04	3.221	4.2	31.8-107.5	0.856-0.902	3-9	1635+3813	033
PMNJ1703-6212	17 03 36.2	−62 12 39	0.616	1.9*	14-53	0.853-0.904	2-9	1659-6251^b	198
S41739+522	17 40 36.9	52 11 42	1.699	1.2*	10-45	0.842-0.899	2-8	1738+5203	048
PKS 1814-63^c	18 19 34.9	−63 45 47	4.506	1.3*	14-27	0.864-0.889	3-6	1813-6419	200
PMNJ1923-2104	19 23 32.1	−21 04 33	2.885	2.1*	29**	0.880	5	1921-2015	008
PKS 2052-47	20 56 15.5	−47 14 37	2.026	1.3*	9-35	0.854-0.906	3-10	2055-4716	208
BL Lac	22 02 43.2	42 16 39	2.940	3.8*	9-40	0.890-0.947	7-29	2202+4217	058
PKS2209+236	22 12 05.9	23 55 39	1.123	1.3*	7-46	0.844-0.916	2-13	2209+2401	050
CTA102	22 32 36.3	11 43 50	3.967	3.1	12.1-51.6	0.873-0.928	4-18	2232+1147	047
1Jy2251+158	22 53 57.6	16 08 52	14.468	5.9	24.6-116.1	0.866-0.925	3-16	2254+1601	055
1Jy2351+456	23 54 21.6	45 53 03	1.127	1.7*	12-43	0.874-0.923	4-15	2358+4604	074


Max EGRET
Min EGRET
Log νf(ν) (nW m⁻²sr⁻¹)
Log frequency ν (Hz)
2
0
−2
10
15
20
25



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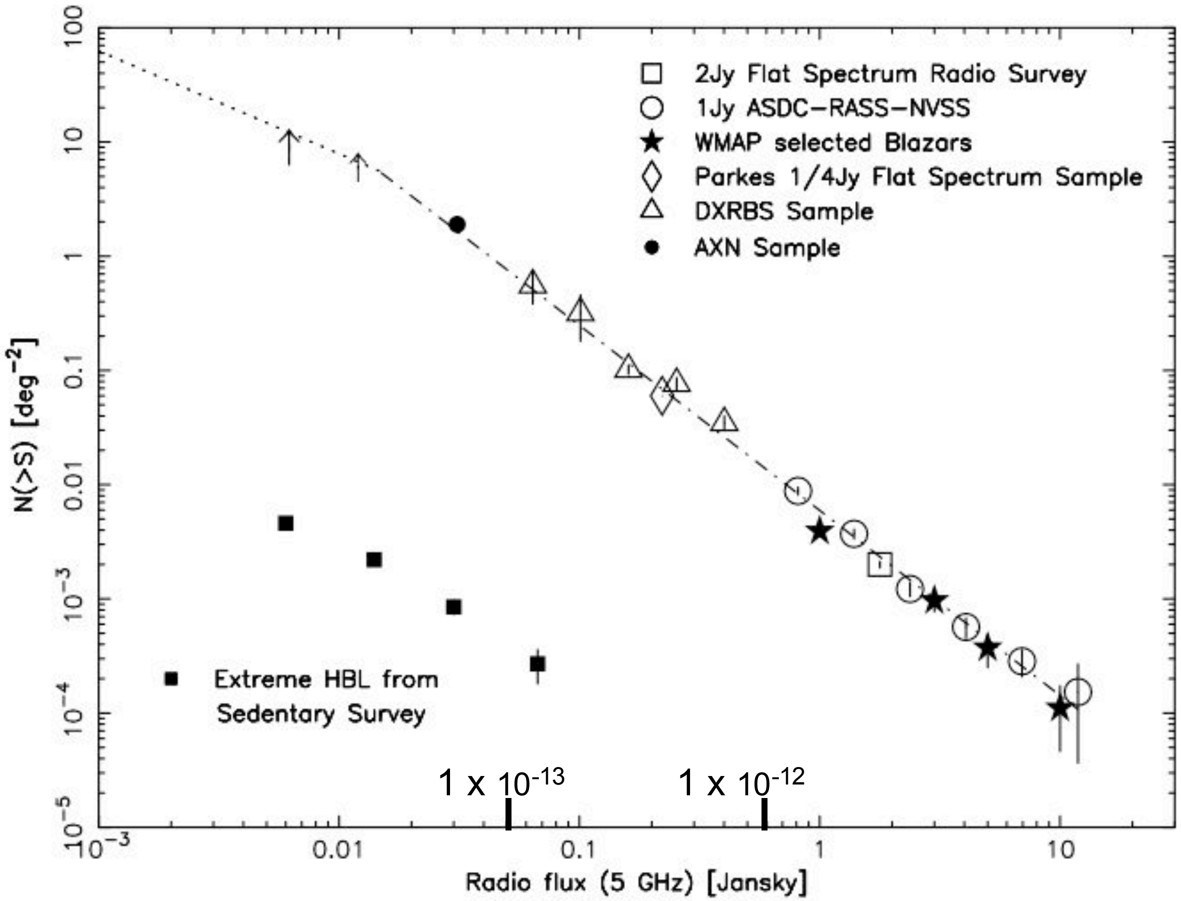
$$f_{1keV} = f_{5GHz} x 10^{-7.685\ \alpha_{5GHz\text{-}1keV}} = f_{5GHz} x\ 10^{-7.685x0.85}$$

$$f_{1keV}\ (\mu Jy) = 0.3\ x\ f_{5GHz}(Jy)$$

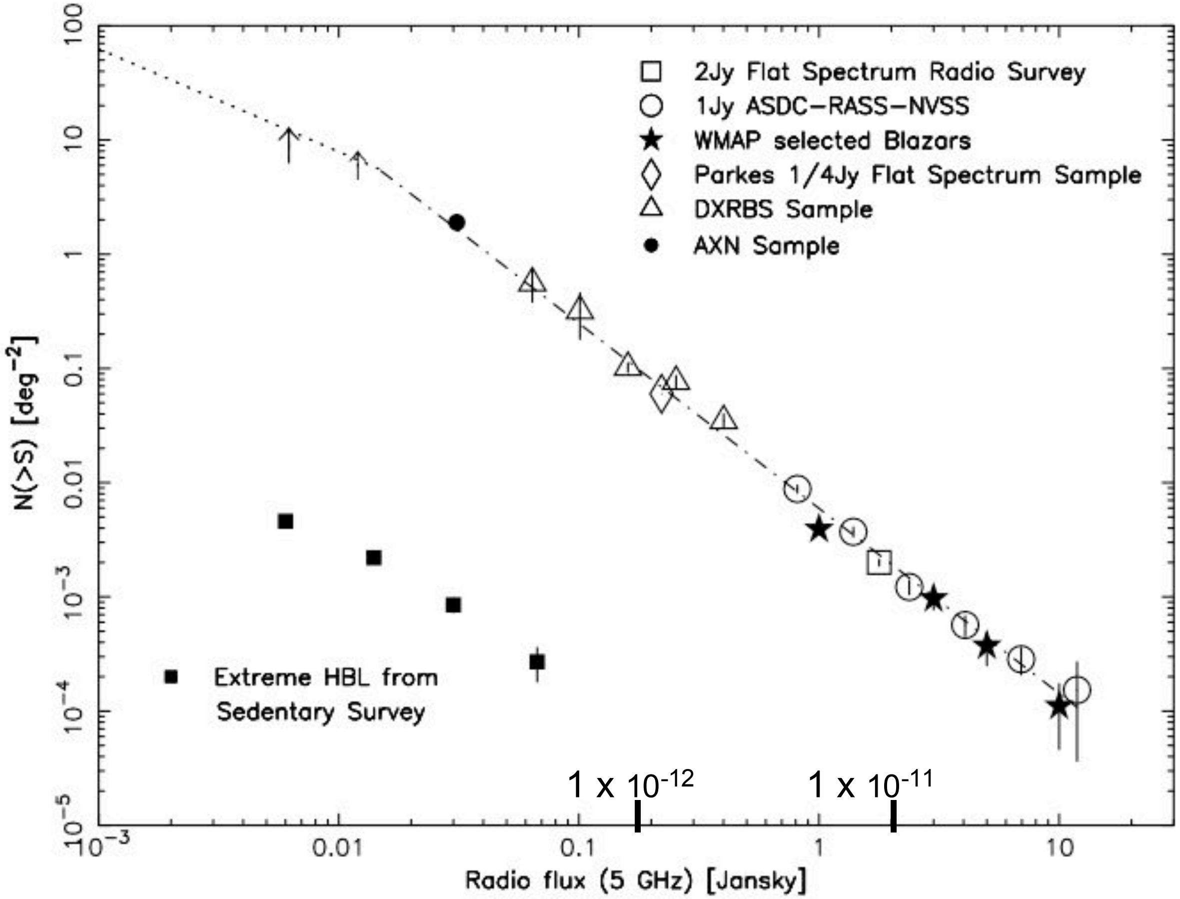
$$F_{0.1\text{-}2.4keV}\ (erg/cm2/s) = 2.4\ x\ 10^{-12}\ x\ f_{5GHz}(Jy)$$



$$f_{100keV} = f_{5GHz} x 10^{-9.685\ \alpha_{5GHz-1keV}} = f_{5GHz} x\ 10^{-9.685x0.80}$$

$$f_{100keV}\ (\mu Jy) = 0.017\ x\ f_{5GHz}(Jy)$$

$$f_{50-150keV}\ (erg/cm2/s) = 4.7\ 10^{-12}\ x\ f_{5GHz}(Jy)$$



First results from the Swift-BAT High-Latitude (15-150 KeV) survey

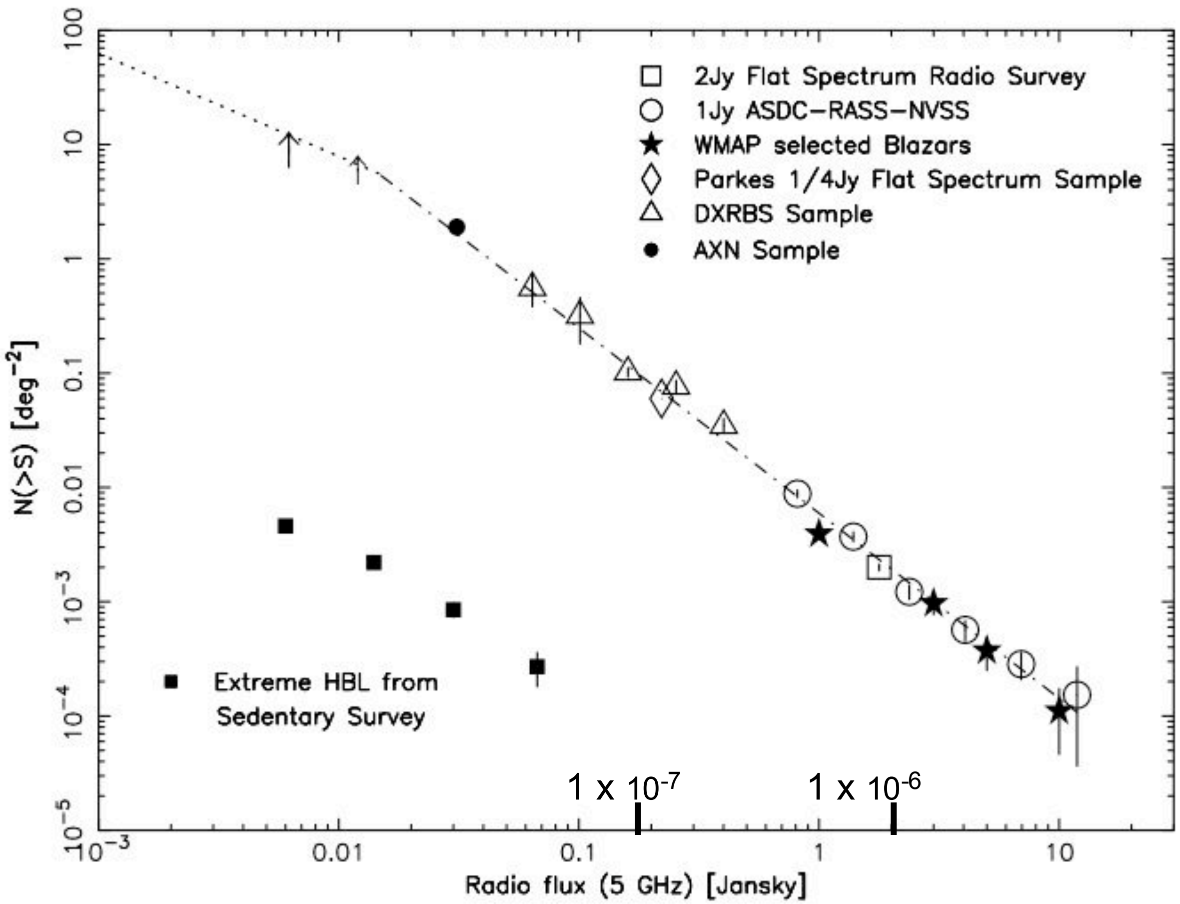
Markwardt et al. 2005, submitted

- Data from the 3 months of the Swift mission
- |bii| > 19 (~25,000 sq deg)
- Limiting sensitivity ≈ $3x10^{-11}$ erg/cm2/s
- 3-4 Blazars
- Radio-loud/non-thermal AGN >≈ 20% of all extragalactic sources
- Blazar redshift distribution seems very different than that of radio quiet (accretion powered) AGN
- Similar results from INTEGRAL

$$f_{1MeV} = f_{5GHz} x 10^{-10.685\ \alpha_{5GHz-1MeV}} = f_{5GHz} x\ 10^{-10.685x0.84}$$

$$f_{1MeV}\ (nJy) = 1.06\ x\ f_{5GHz}(Jy)$$

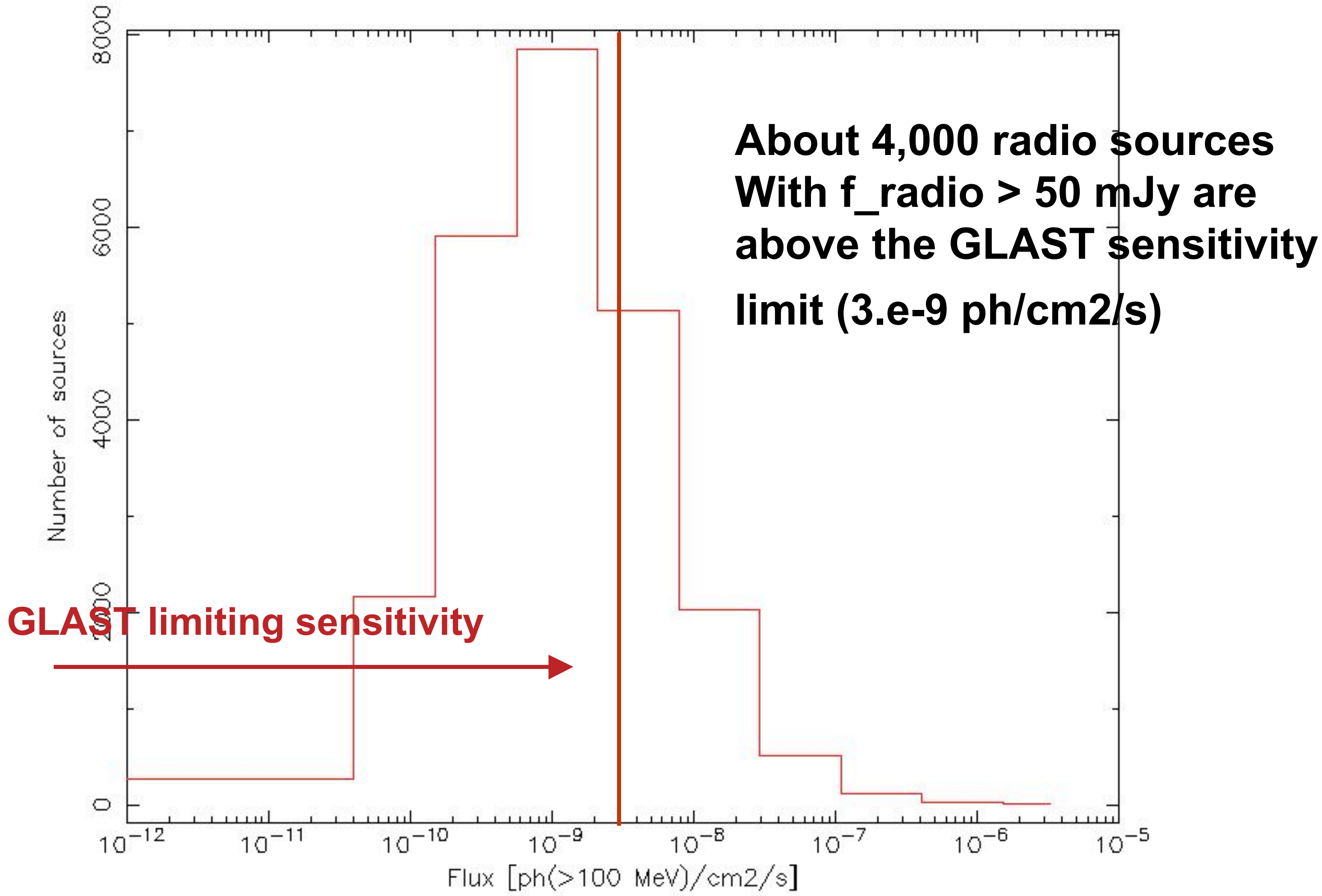
$$f_{3-10MeV}\ (ph/cm2/s) = 5.\ 10^{-7}\ x\ f_{5GHz}(Jy)$$



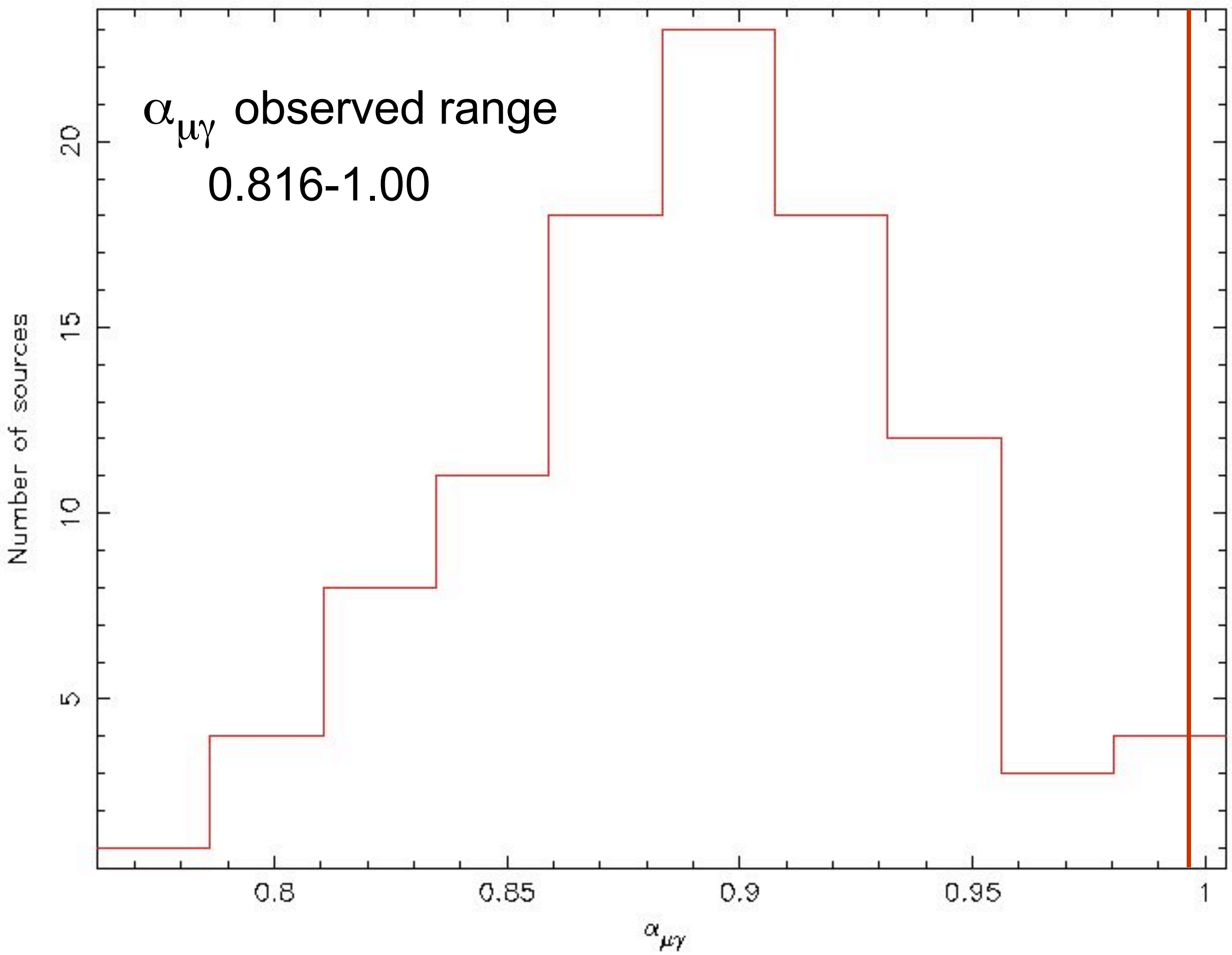
The high-energy gamma-ray band, GeV and beyond: blazar simulations

- Starts from a radio Luminosity function + Cosmological evolution
  - Monte Carlo simulation of redshift and radio luminosity
- Radio luminosity of each source is extrapolated to other energy bands (micro-wave, optical, X-ray, gamma-ray) based on SSC model + and randomized based on observed distributions.
- Gamma-ray flux simulated taking into account of duty cycle and Gamma Ray Background constraints (see Giommi et al. 2005 A&A in press, astro-ph/0508034)
- Sources are accepted above a set of flux limits (radio, opt , X-ray etc.)

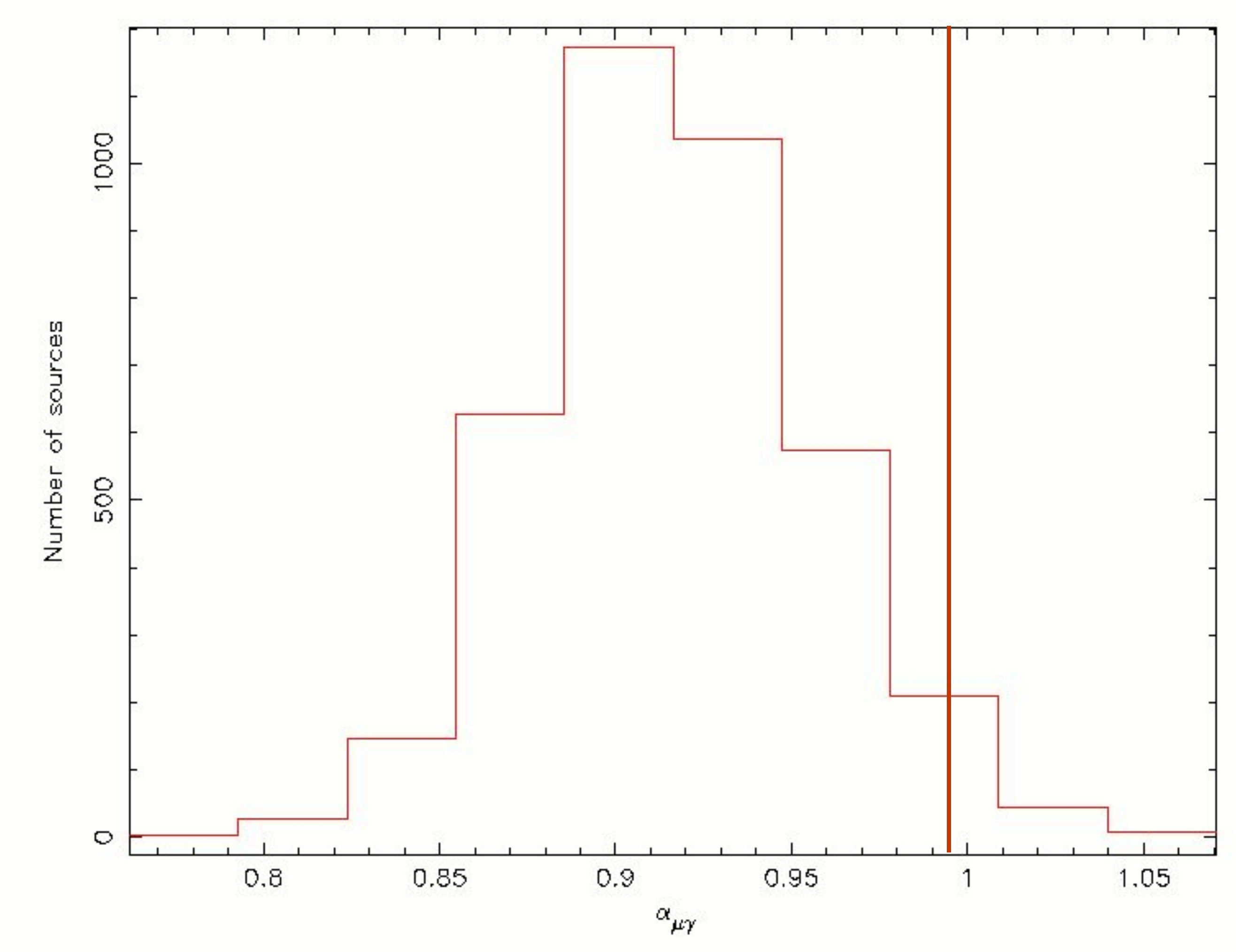
Predicted distribution of gamma-ray fluxes in a 50 mJy radio survey

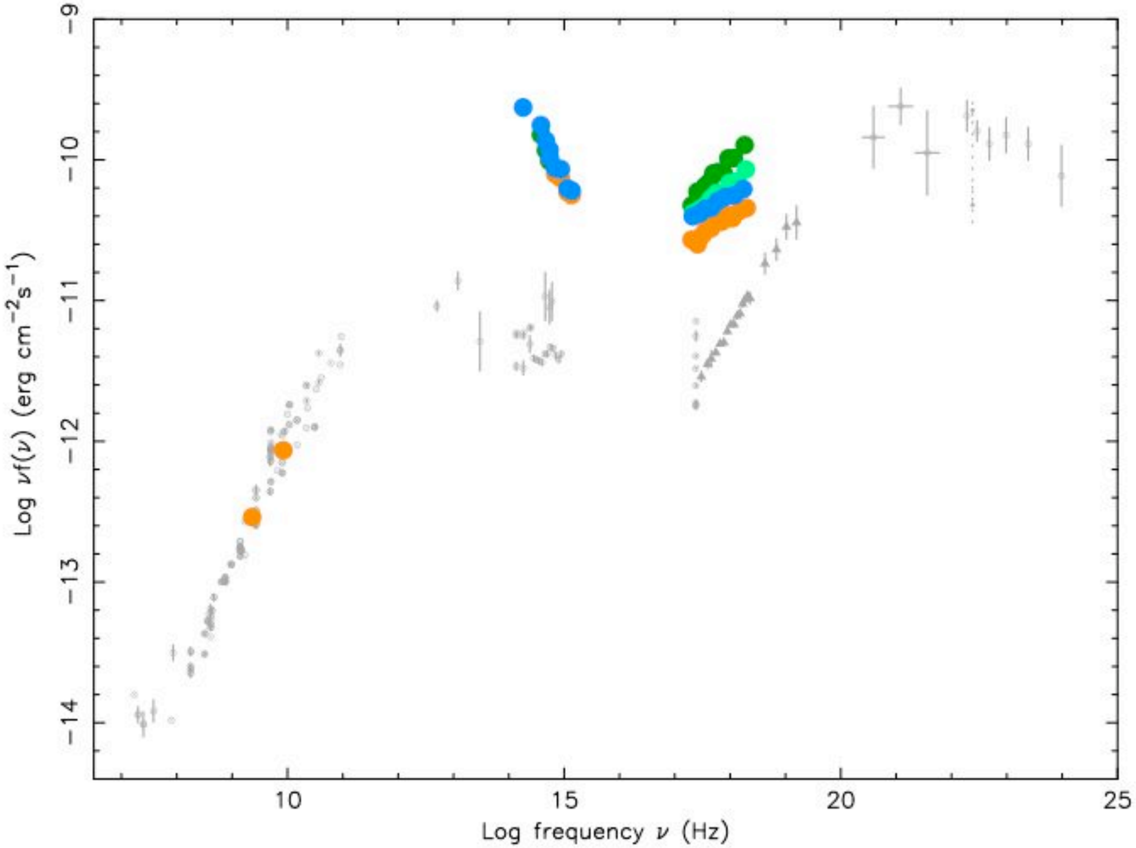


Expected distribution of microwave/gamma-ray spectral index ($\alpha_{\mu\gamma}$)
in the subsample of EGRET detected (f_γ>1x10^{-7} ph/cm2/s > 100 MeV)
in the 50 mJy simulated radio survey (110 Blazars)



Expected distribution of microwave/gamma-ray spectral index ($\alpha_{\mu\gamma}$)
in the subsample of GLAST detected ($f_\gamma > 3 \times 10^{-9}$ ph/cm2/s > 100 MeV)
in the 50 mJy simulated radio survey





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