BLAZAR CONTRIBUTION TO NON-THERMAL COSMIC BACKGROUNDS

- blazar properties
- a new deep radio logN - logS
- blazar contribution to non-thermal cosmic backgrounds
- ROXA catalog

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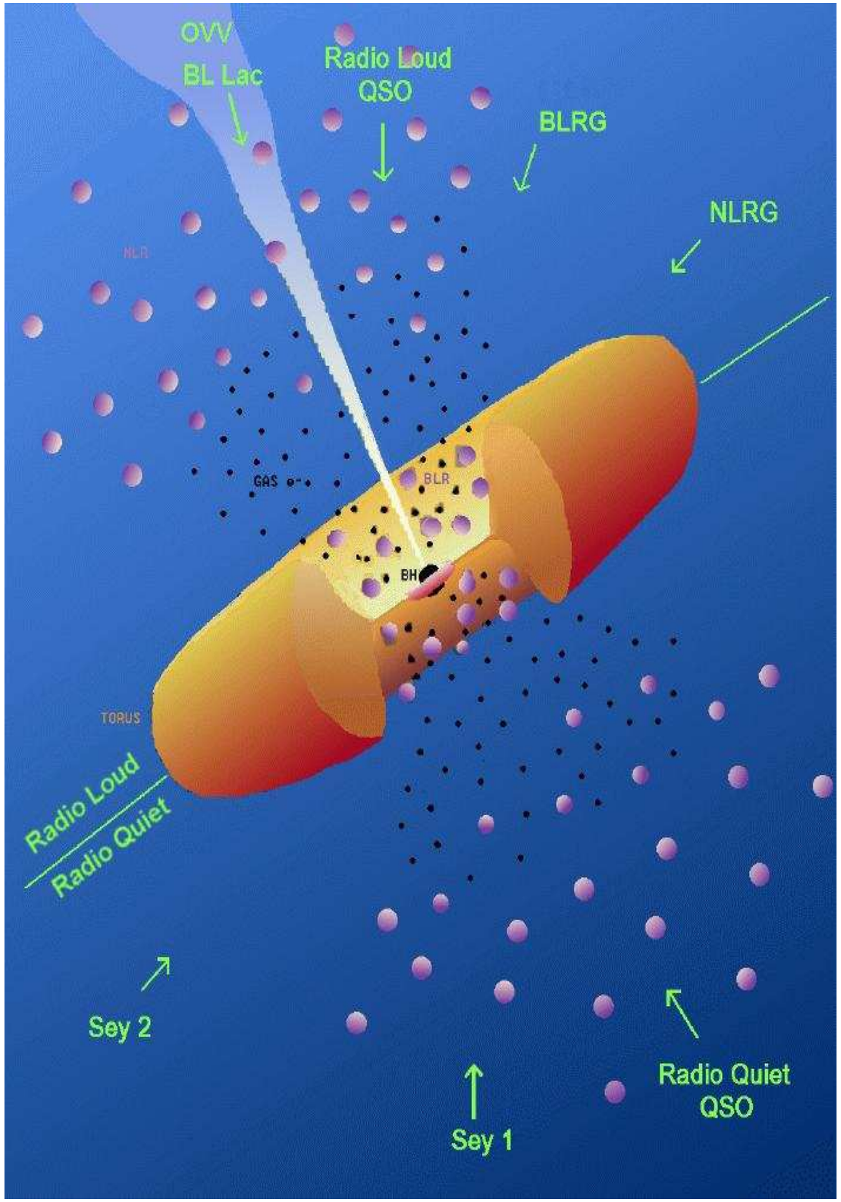
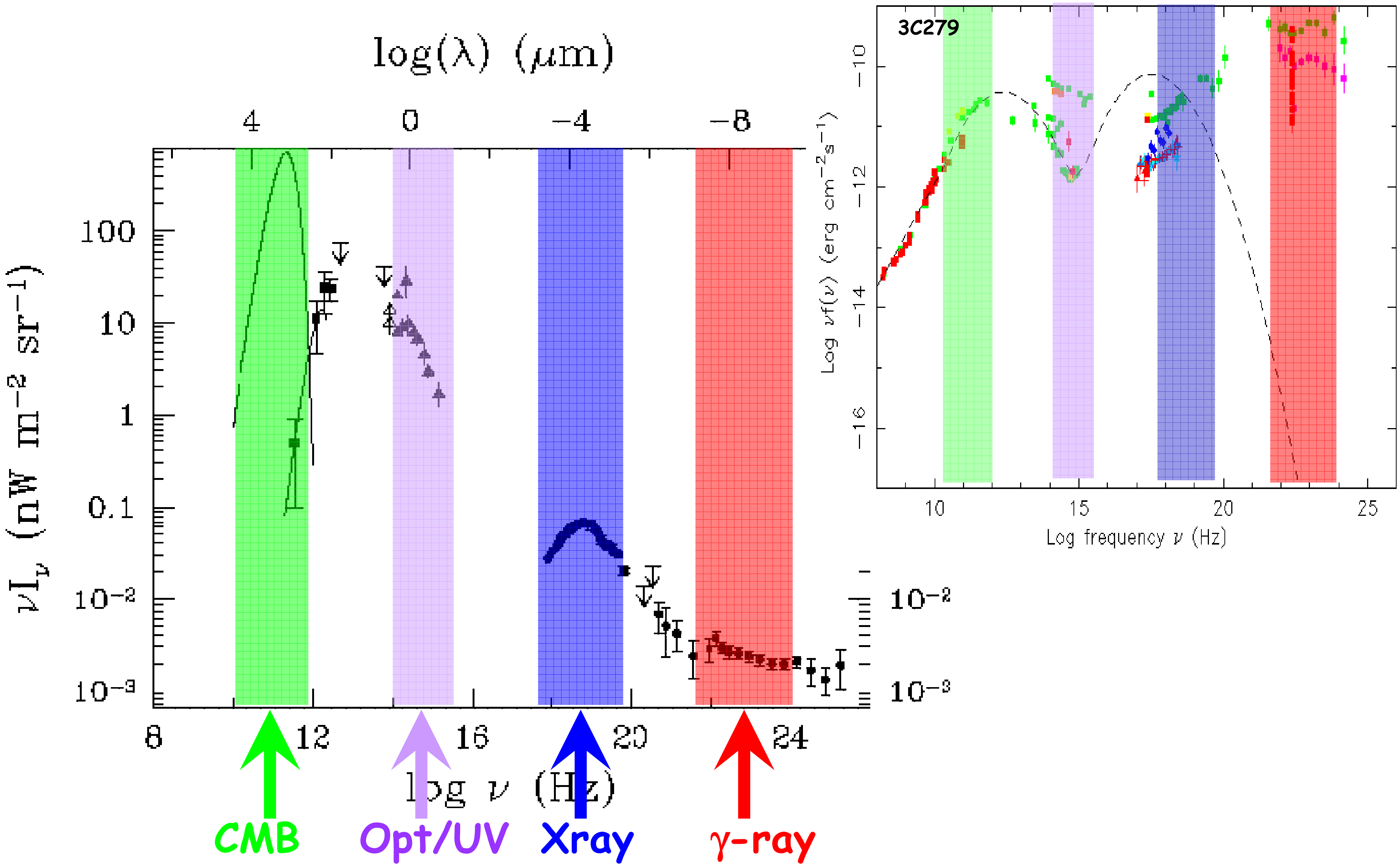
Properties of blazars



They represent a rare class of objects, making up considerably less than 5% of all AGN:

- ✓ jets at relatively small ($\leq$ 20-30°) angles with respect to the line of sight;
- ✓ smooth, broad band, non thermal continuum, covering the whole electromagnetic spectrum (radio to γ-rays) with $L \sim 10^{49}$ erg s^{-1};
- ✓ radio and compact morphology (core flux >> extended flux) and flat spectrum (radio spectral index $\alpha_r \leq 0.5$);
- ✓ rapid variability (large $\Delta L / \Delta t$);
- ✓ high and variable optical polarization;
- ✓ superluminal motion in sources with multiple-epoch Very Large Baseline Interferometry (VLBI) maps;
- ✓ in the gamma rays, they are the most abundant component within the high galactic latitude population of sources.

Blazars & Cosmic Backgrounds



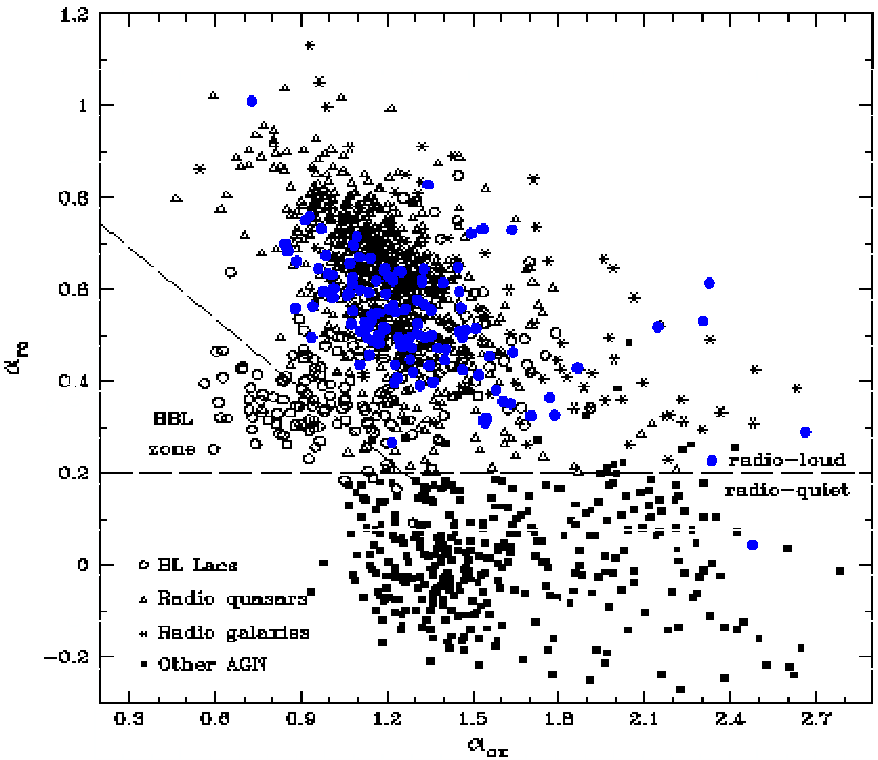
Extragalactic Cosmic Backgrounds - CMB

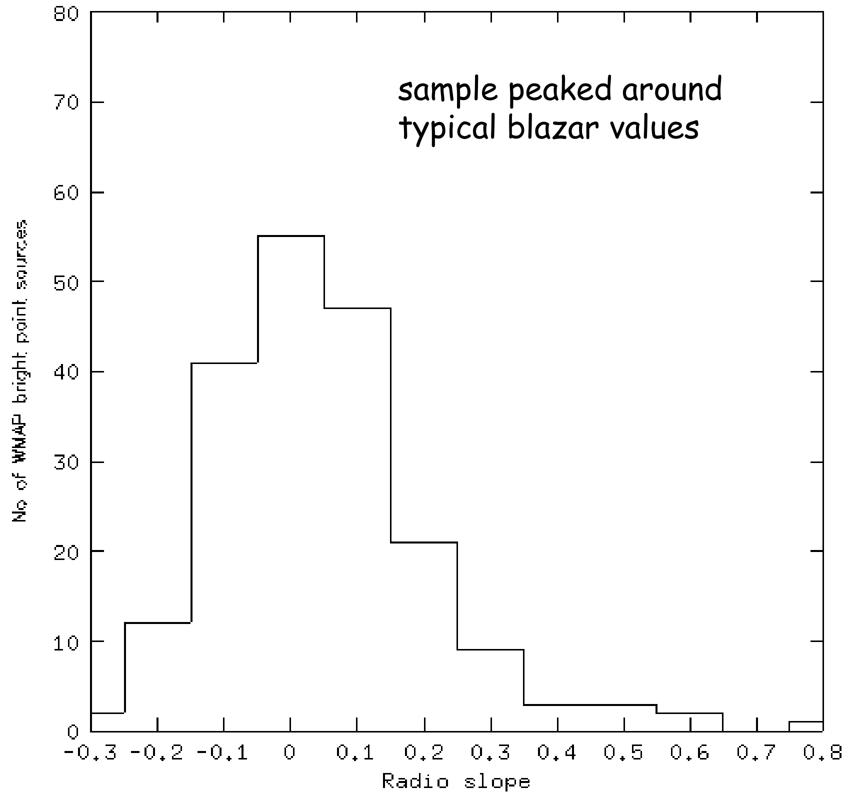
- Primordial photons redshifted to microwave frequency due to the Universe expansion
- We observe these photons as CMB
- Tiny inhomogeneities in the early universe left their imprint on the CMB in the form of small anisotropies in its temperature
- These anisotropies contain information about basic cosmological parameters (e.g. total energy density and curvature of the universe)
- Anisotropies on small angular scales (< 2°) are enhanced by oscillations of the photon-baryon fluid before decoupling
- In a spherical harmonic expansion of the CMB temperature field, the angular power spectrum specifies the contributions to the fluctuations on the sky coming from different multipoles l, each corresponding to the angular scale $\theta=\pi/l$

CMB T fluctuation have been measured and studied from l < 20 with COBE, BOOMERanG, MAXIMA, DASI, CBI, VSA and recently WMAP up to l ~ 800.

Results are consistent with a cold dark matter model in a flat universe , as favoured by standard inflationary models.

The α_{ox} - α_{ro} diagram: WMAP bright sources



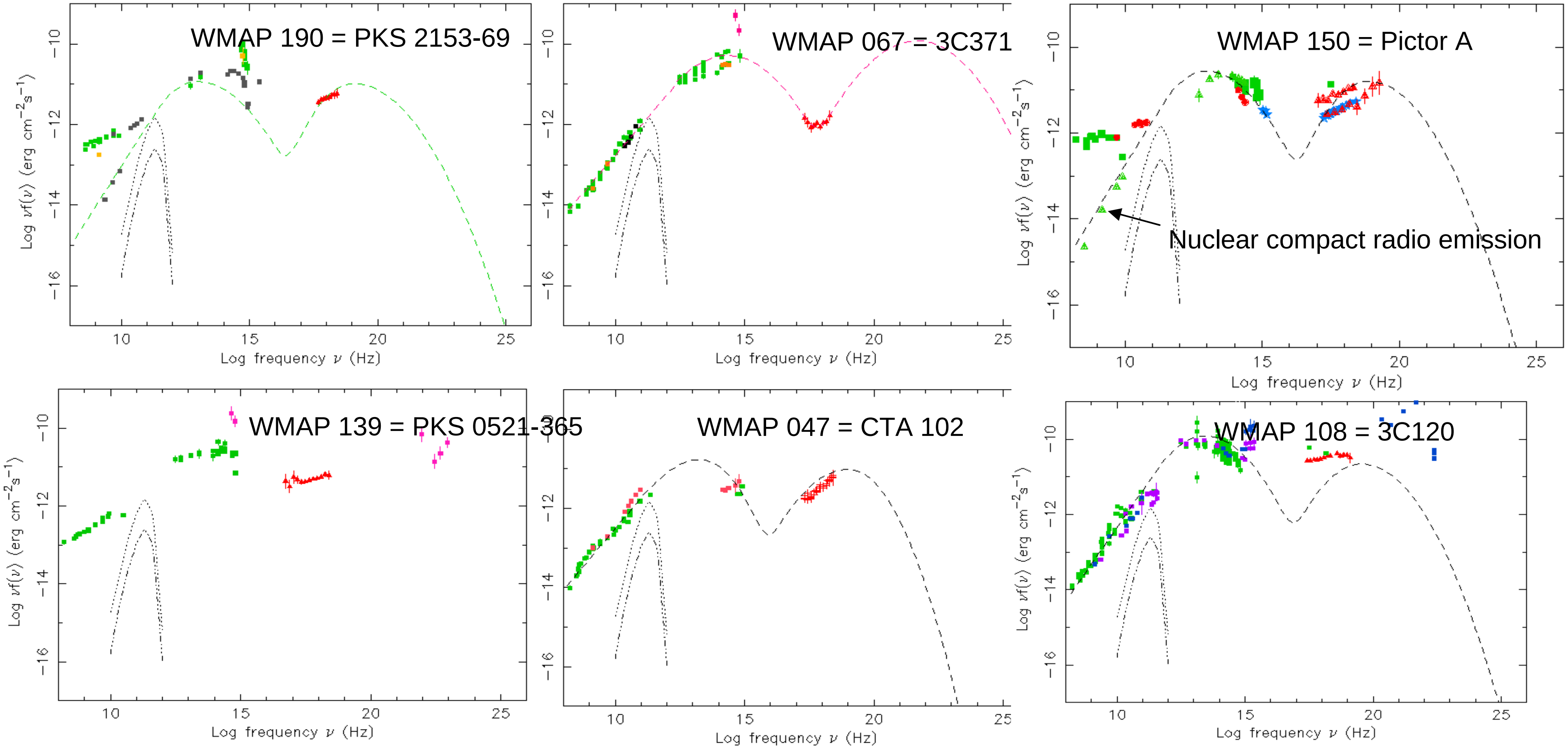


- 141 FSRQs
- 23 BL Lacs
- 13 Radio galaxies
- 5 Steep Spectrum QSOs
- 2 starburst galaxies
- 2 planetary nebule

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

The vast majority of bright WMAP foreground sources are blazars

WMAP SEDs



Spectral distribution of typical CMB temperature fluctuations [300 (·········) and 50 (·—·) μK]

Giommi&Colafrancesco 2004 A&A 414,7

A new deep blazar radio logN - logS

A new deep radio logN - logS combining several radio and multi-ν surveys.

to push the radio limit to fluxes significantly below 50 mJy at 5 GHz it is necessary to reach X-ray sensitivities proportionally deeper.
To this purpose we searched for serendipitous NVSS radio sources in XMM-Newton EPIC-pn X-ray images.

We took into account of flux ratios in different energy bands and of observed broad-band SEDs.

The radio surveys were carried out at 3 different observing frequencies: 1.4, 2.7 and 5 GHz :

- all flux densities converted to a common frequency, 5 GHz
- spectral slope assumed to be α_r=0.25 ($f \propto \nu^{-\alpha}$) [the average value in all our samples]

ASDC-XMM serendipitous blazar survey (AXN)

1220 EPIC-pn fields processed,
847 of which at |b| > 20
188 EPN good non-overlapping exposures:

- no bright extended targets
- full window mode
- deepest observation in case of multiple exposures
- dec > - 40°

Central 5 arcmin around field center excluded

0.14 deg²/field -> 26.3 deg² total

No. of sources	space density sources/deg	Flux (mJy) (1.4GHz)	Flux (mJy) (5.GHz*)
50	1.9±0.3	50	31
107	> 4.0	20	12
149	> 5.6	10	6

* assuming $\alpha_r = 0.4;\ f(\nu) \propto \nu^{-\alpha}$

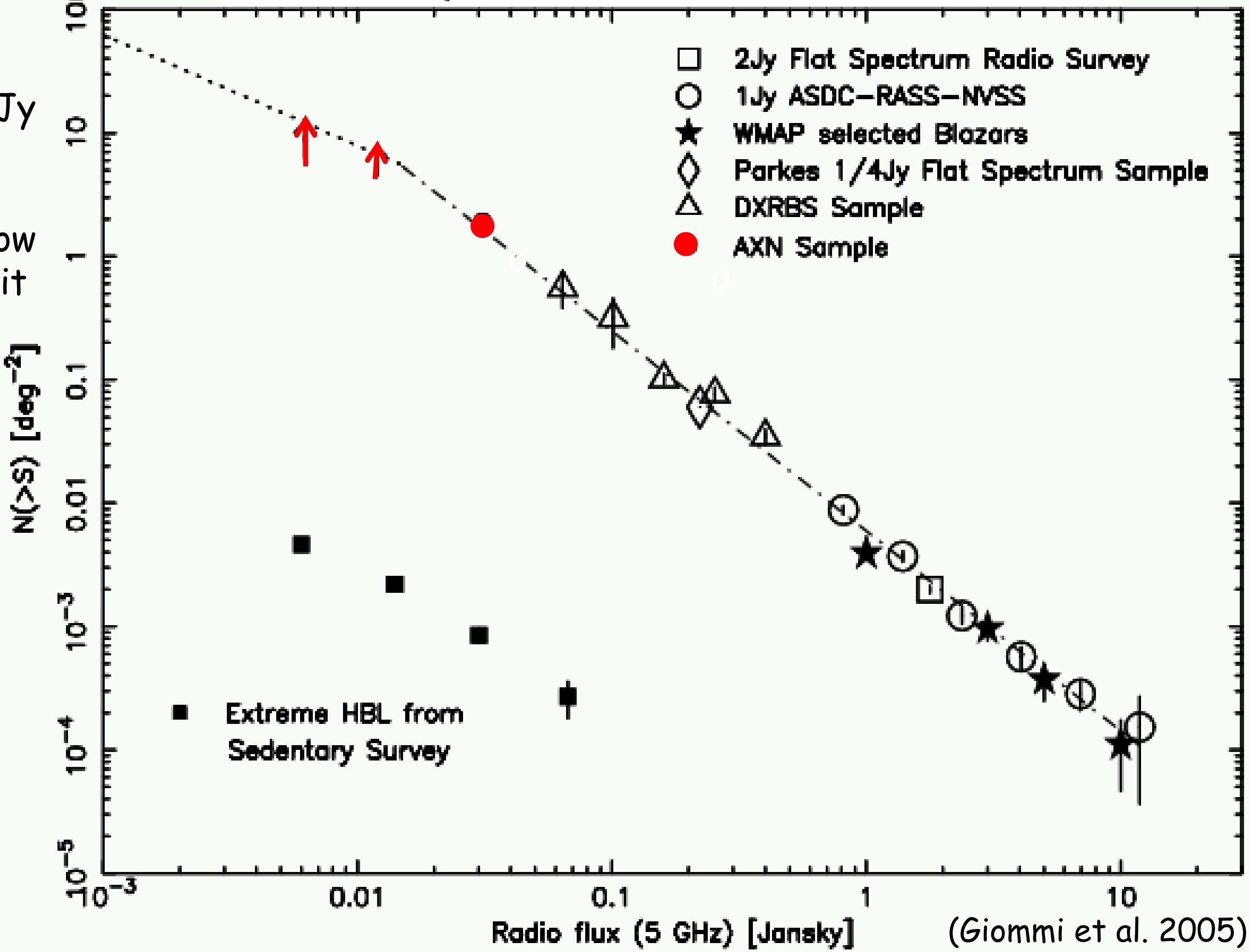
(Cavazzuti, in prep)

A new deep blazar radio logN - logS

$$N(>S) = \begin{cases} 5.95\ 10^{-3} \times S^{-1.62} & S > 0.015\ Jy \\ 0.125 \times S^{-0.9} & S < 0.015\ Jy \end{cases}$$

lower limit at 6 mJy and 12 mJy:

> 50% blazars below the sensitivity limit of XMM images.



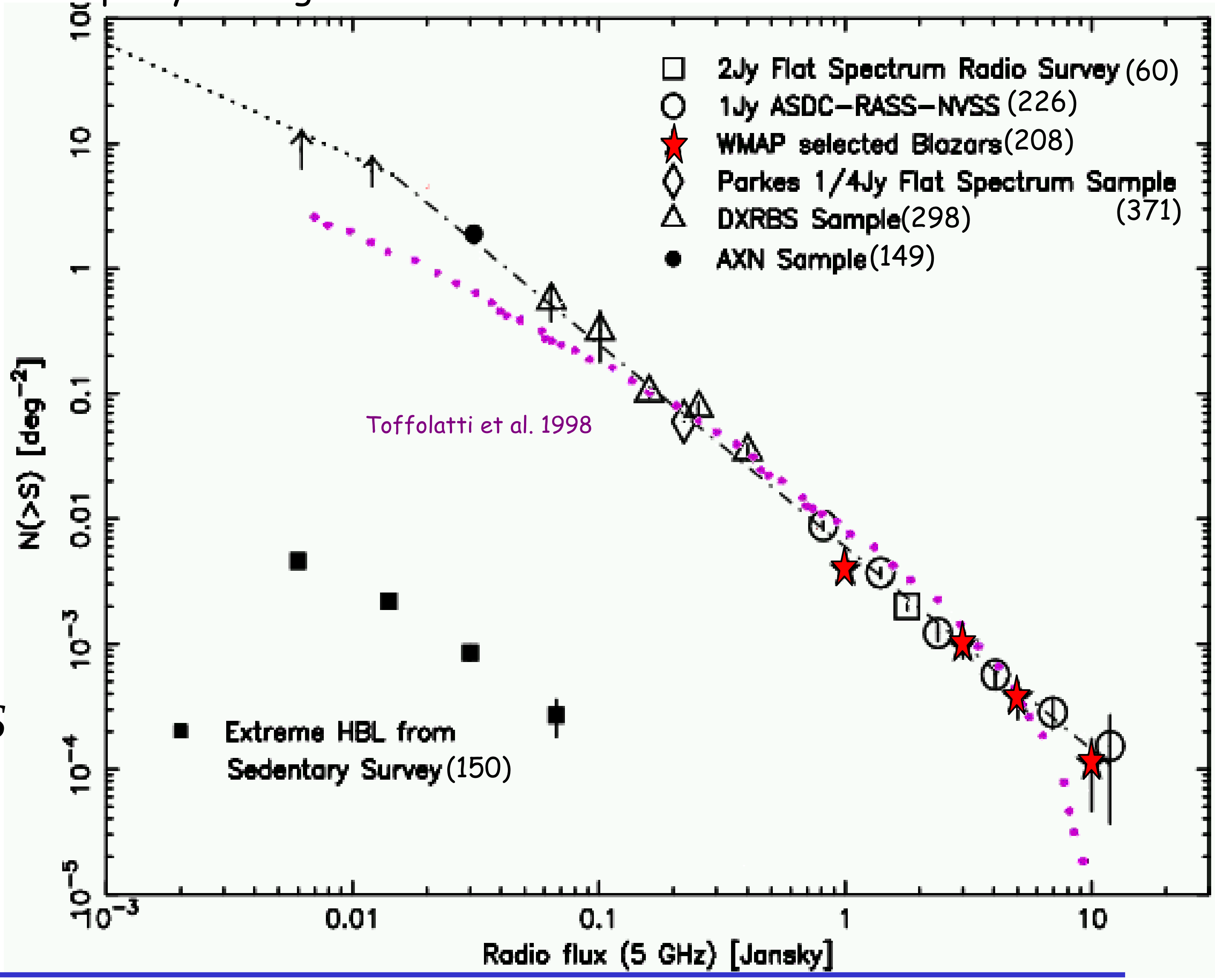
(Giommi et al. 2005)

Contribution to the CMB

It is steeper than that of flat spectrum radio sources previously used to estimate the contamination of CMB maps by extragalactic sources.

integrated radio flux due to a population of discrete sources in the flux range S_{min} - S_{max}

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



Contribution to the CMB

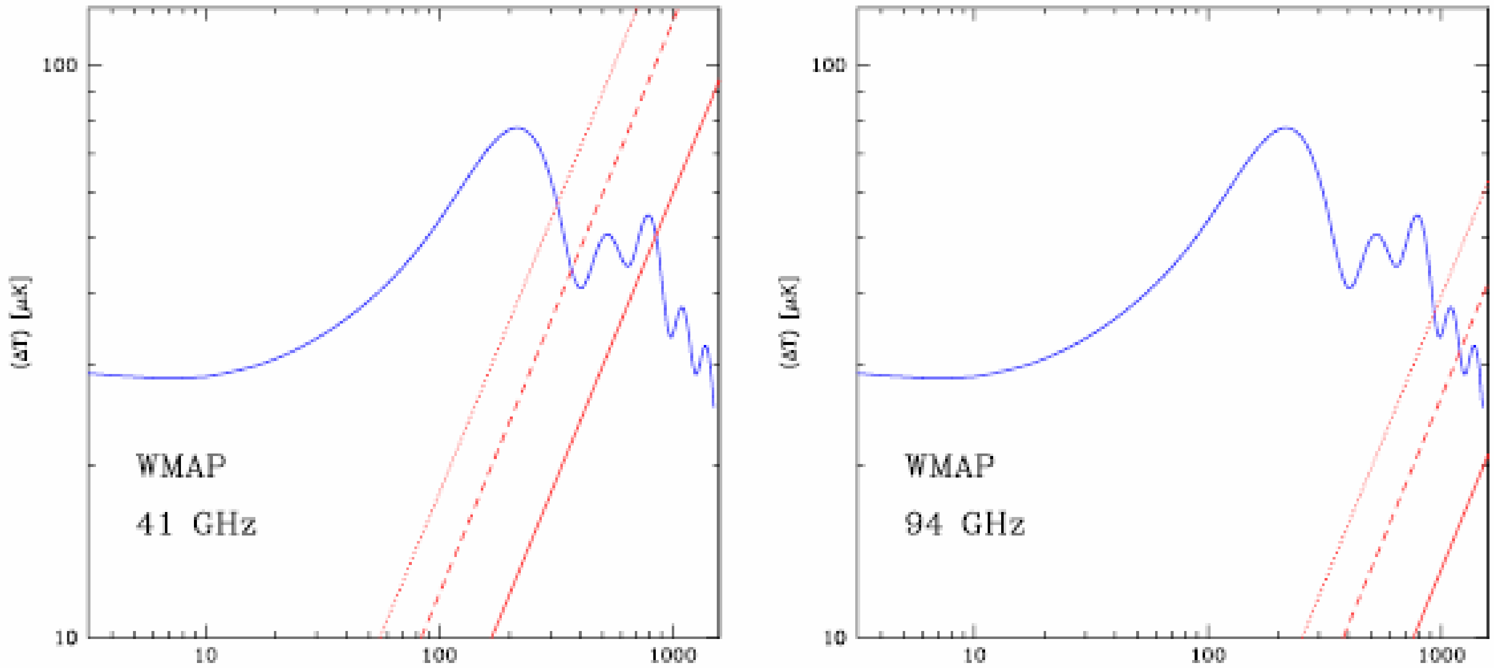


Fig. 4 The contribution of blazars to the CMB fluctuation spectrum in the WMAP 41GHz (left panel) and 94 GHz (right panel) channels, as evaluated from the LogN-LogS given in Fig. 1 (solid line). We also show the angular power spectrum for the blazar population by adding an estimate of the possible contribution of radio sources with steep-spectrum at low radio frequencies which flatten at higher frequencies (dashed line). The dotted line also includes the effect of spectral and flux variability. Although this additional contamination may be substantial a precise estimation can only be done through simultaneous high resolution observations at the same frequency. A typical CMB power spectrum evaluated in a ΛCDM cosmology with $\Omega_m = 0.3, \Omega_\Lambda = 0.65, \Omega_b = 0.05$ which best fits the available data is shown for comparison.

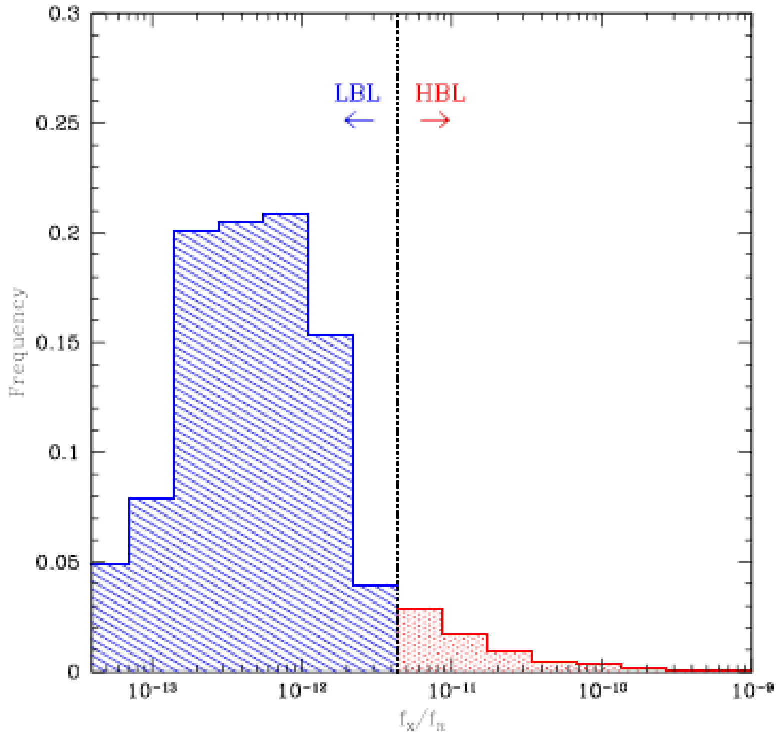
(Giommi et al. 2005)

Contribution to the CXB - soft X

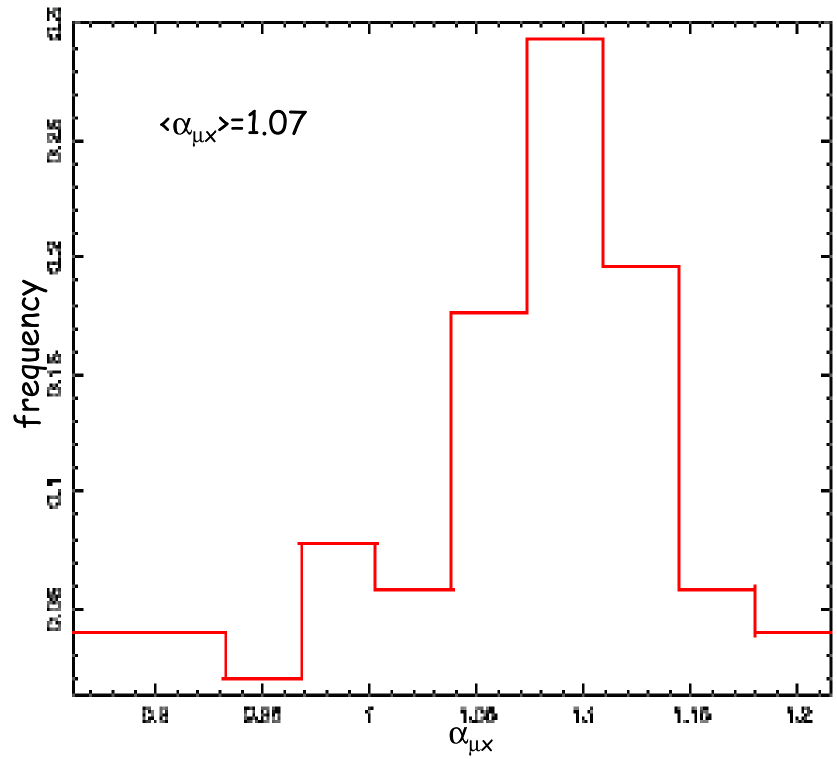
a) converting the radio flux intensity S into X-ray flux using the observed distribution of F_x/F_R flux ratios

b) converting the blazar contribution to the CMB into X-ray flux

$$\alpha_{\mu x} = \frac{Log(f_{1keV} / f_{94GHz})}{Log(\nu_{1keV} / \nu_{94GHz})}$$



F_x/F_R distribution of blazars estimated from the 1Jy ASDC-NVSS-RASS and the Sedentary surveys (~ 2000 LBL and HBL)



the distribution of the spectral slope between μwave and X-ray from the sample of WMAP blazars for which X-ray measurements are available (only LBL)

Contribution to the CXB - soft X

a) total Blazar contribution = 2.7×10^{-12} erg cm^{-2} s^{-1} deg^{-1} in the Rosat 0.1-2.4 keV energy band. Assuming an average blazar $\alpha_x = 0.7$ the flux converts to 2.6×10^{-12} erg cm^{-2} s^{-1} deg^{-1} or 11% of the CXB (estimated to be 2.3×10^{-11} erg cm^{-2} s^{-1} deg^{-1})

b) from $\alpha_{\mu x}$ we get $f_{1keV} = 1.4 \times 10^{-7} \times f_{94GHz}$
Integrated blazar emission @94GHz ~ 7.2×10^{-6} CMB_{94GHz} and $CXB_{2-10keV} \sim 2.3 \times 10^{-11}$ erg cm^{-2} s^{-1}==> f_{1keV} ~ 3.9% CXB
Because of the $\alpha_{\mu x}$ distribution is for LBL only and that HBL make 2/3, the total contribution to CXB scales to about 12%

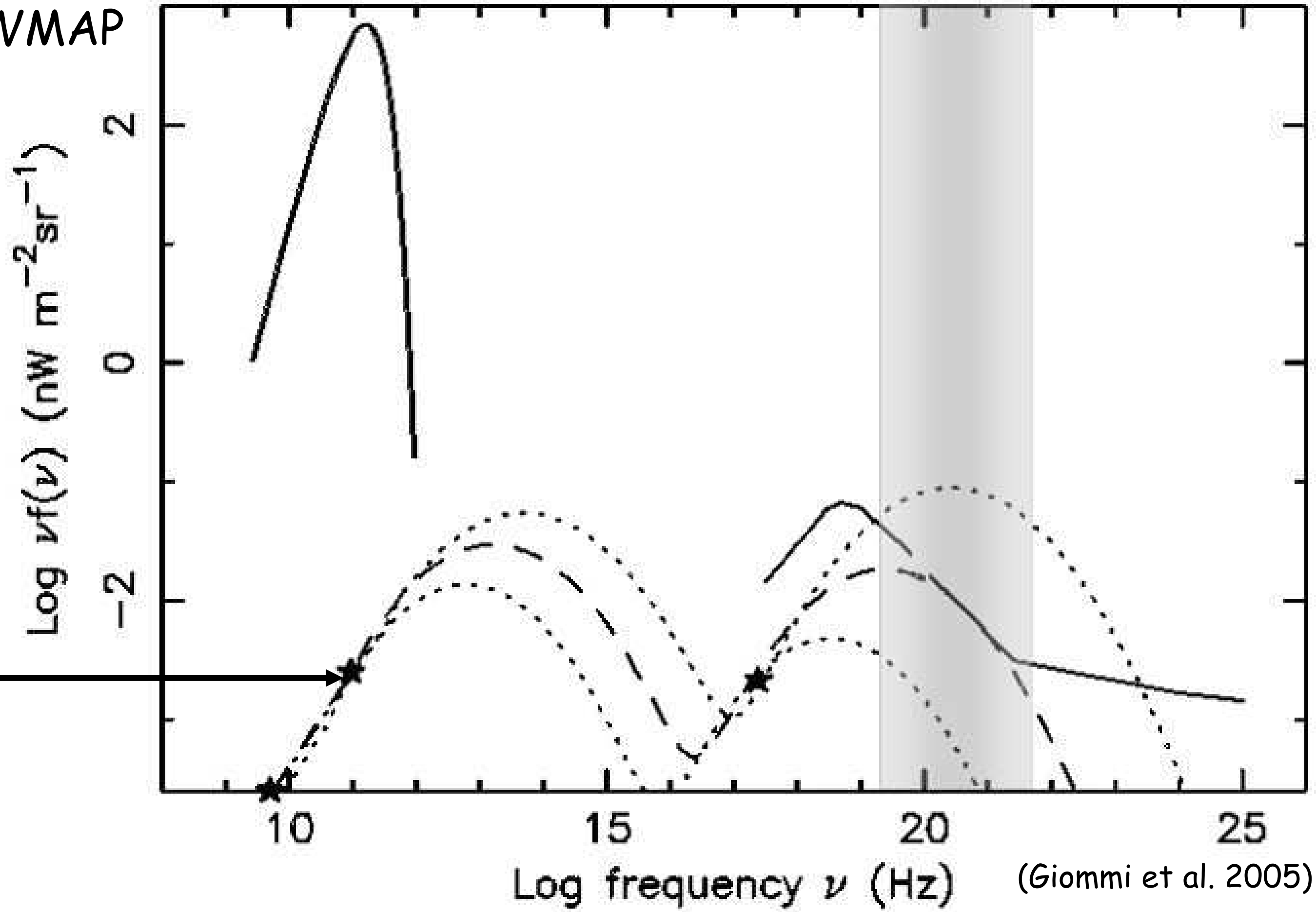
both in good agreement with radio loud AGN content ~ 13% in the XMM bright serendipitous survey

Contribution to the CXB - hard X/soft γ

1. consistent with integrated flux @ 94 GHz
2. radio slope ~ $\langle\alpha_r\rangle$ WMAP
3. $\alpha_{\mu x}$ ~ $\langle\alpha_{\mu x}\rangle$ WMAP

$8\cdot 10^{-6}\,CMB$

$$I_{Blazars} = \int_{0.1mJy}^{1Jy} S$$



(Giommi et al. 2005)

μwave bkg: 2.725 °K black body, X bkg: Perri&Giommi 2000 A&A, γ bkg: Sreekumar et al 1998 ApJ

Contribution to the CXB - hard X/soft γ

low: synchrotron $\nu_{peak} = 10^{12.8}$ Hz
medium: synchrotron $\nu_{peak} = 10^{13.5}$ Hz
high: synchrotron $\nu_{peak} = 10^{13.8}$ Hz

Log(ν_{peak}) of WMAP blazars and other catalogs peak ~ 13.5

⬇

blazar may be responsible for a large fraction of the hard X-ray/soft γ-ray bkg compatible with IC tail of LBL objects

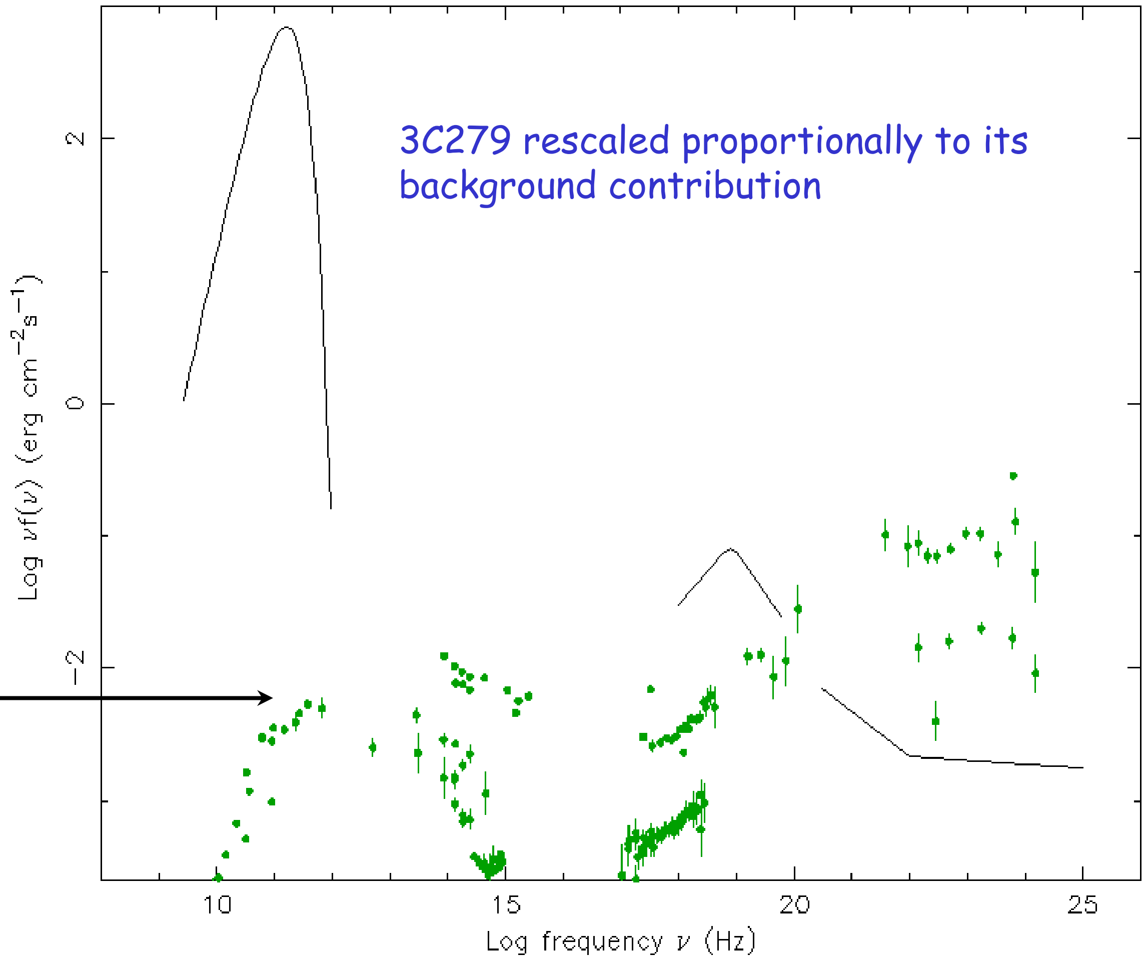
Contribution to the EGRB

Extrapolation of representative SED from the blazar contribution to the CMB

$$\langle S_{blazar} \rangle_{94GHz} \approx 8 \cdot 10^{-6} CMB$$

either these sources are not representative of their class of blazars, despite the contribution to the CXB is consistent with average value, or their duty cycle at γ-ray frequency is very low

$8 \cdot 10^{-6} CMB$



μwave bkg: 2.725 °K black body, X bkg: Perri&Giommi 2000 A&A, γ bkg: Sreekumar et al 1998 ApJ

μwave - γ ray flux ratio and duty cycle

$$\alpha_{\mu\gamma} = -\frac{Log(f_{94GHz} / f_{100MeV})}{Log(\nu_{94GHz} / \nu_{100MeV})}$$

$$Log\frac{\nu_{\mu(94GHz)}}{\nu_{\gamma(100MeV)}} = -11.41$$

$$\frac{f_{\gamma_s}}{f_{\gamma_{bkg}}} = 10^{(\alpha_{\mu\gamma_s} - \alpha_{\mu\gamma_{bkg}})\times 11.41}$$

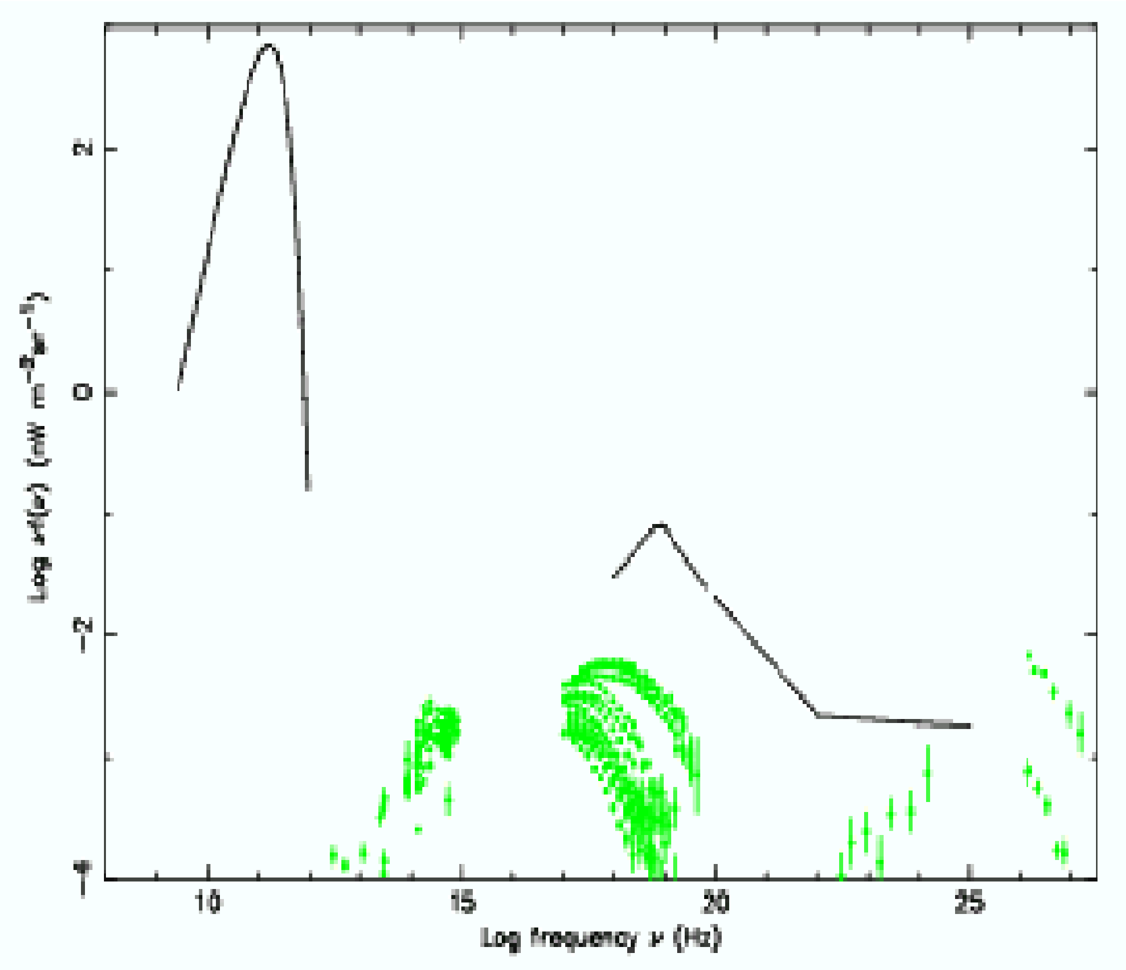
Blazar Name (EGRET sources)	$\alpha_{\mu\gamma}$	fγ-source/<fγ-bkg> ($\alpha_{\mu\gamma 100\% bkg}$ = **0.994**)
BZQ J0204+1514	0.892	14.5
BZU J0210-5101	0.887	16.6
BZB J0339-0146	0.902	11.2
BZQ J0423-0120	0.907	9.7
BZQ J0455-4615	0.913	8.3
BZQ J0457-2324	0.908	9.6
BZU J0522-3627	0.926	6.0
BZB J0538-4405	0.892	14.4
BZQ J1256-0547 (3C 279)	0.870	25.5

Strong variability at γ-ray energies is very common.

Plausible scenario for EGRB: mixture of IC radiation produced by LBL during strong flares and perhaps a less variable component due to the still rising part of the Compton spectrum in HBL objects

Contribution to TeV energy band

MKN421 scaled to 1/1000 of the total blazar contribution to the CMB since the radio logN-logS of extreme HBL like this source (in the Sedentary Survey) is about 1/1000 of the LogN-LogS of all blazars.



μwave bkg: 2.725 °K black body, X bkg: Perri&Giommi 2000 A&A, γ bkg: Sreekumar et al 1998 ApJ

Candidate blazar catalog: selection of the sample

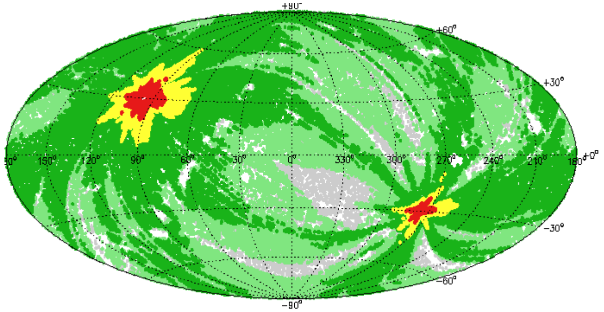
Cross-correlation between NVSS (radio) and RASS (X-ray) surveys.

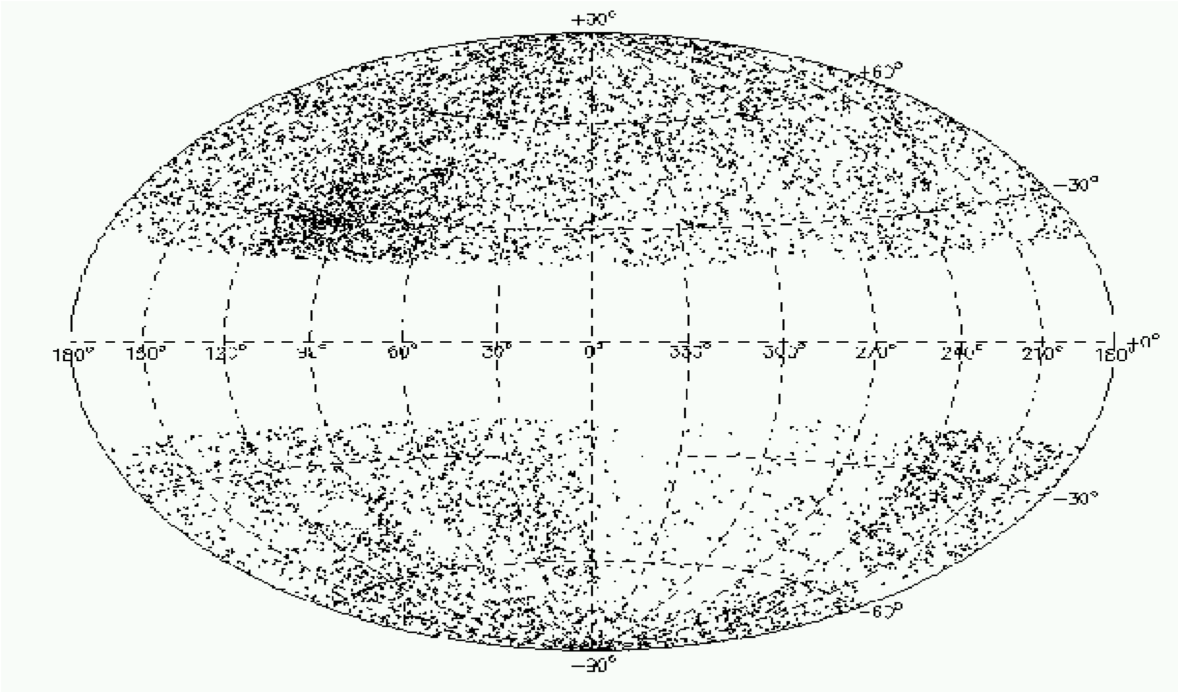
Optical magnitudes from GSC2
(assuming Jmag < 19.5 when no counterpart is found in GSC2)

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

Over 7600 Blazar candidates (500 of which are included in the catalogue of known Blazars)

RASS (galactic coordinates)





Radio - Optical - X ray Asdc Catalog (ROXA)

Object type	N	%
BL Lac	230	28.1
FSRQ	237	28.9
HSFRQ	4	0.5
BL Lac/FSRQ	7	0.9
BL Lac candidate	15	1.8
Confirmed blazars	**493**	**60.2**
R.G./BL Lac	34	4.2
R.G./FSRQ	2	0.25
R.G./Pol	2	0.25
Radio Galaxies	24	2.9
SSRQ	107	13.1
QSO RL	118	14.4
NELG	14	1.7
BLRG	5	0.6
Others	20	2.4
TOTAL	**819**	**100**

~ 60% confirmed blazars
(286 ~ 58% new ID)
~ 14% are candidate blazars
(no radio slope)
~ 18% are SSR QSOs
~ 8% other AGN types

~ 5700 objects are expected to be blazars

(Turriziani, Cavazzuti, Giommi in prep)

Complement to the Sowards-Emmerd (2005) work, who used a mono-ν approach to select radio sources and than optically identify them. They are sensitive to LBL objects.
Our multi-ν approach is sensitive to HBL objects, because we used an X-ray selection criteria.

Conclusions - contribution to cosmic background light

- blazar emit non-thermal radiation all along the e.m. spectrum

- despite the low space density, in some energy bands they are the dominant population in the extragalactic sky

➡ a deep understanding of the blazar contribution to the cosmic background light is becoming an increasing necessity as the μ-wave, the γ-ray and the TeV bands are about to be explored by a new generation of astronomy satellites and ground-based Cherenkov telescope

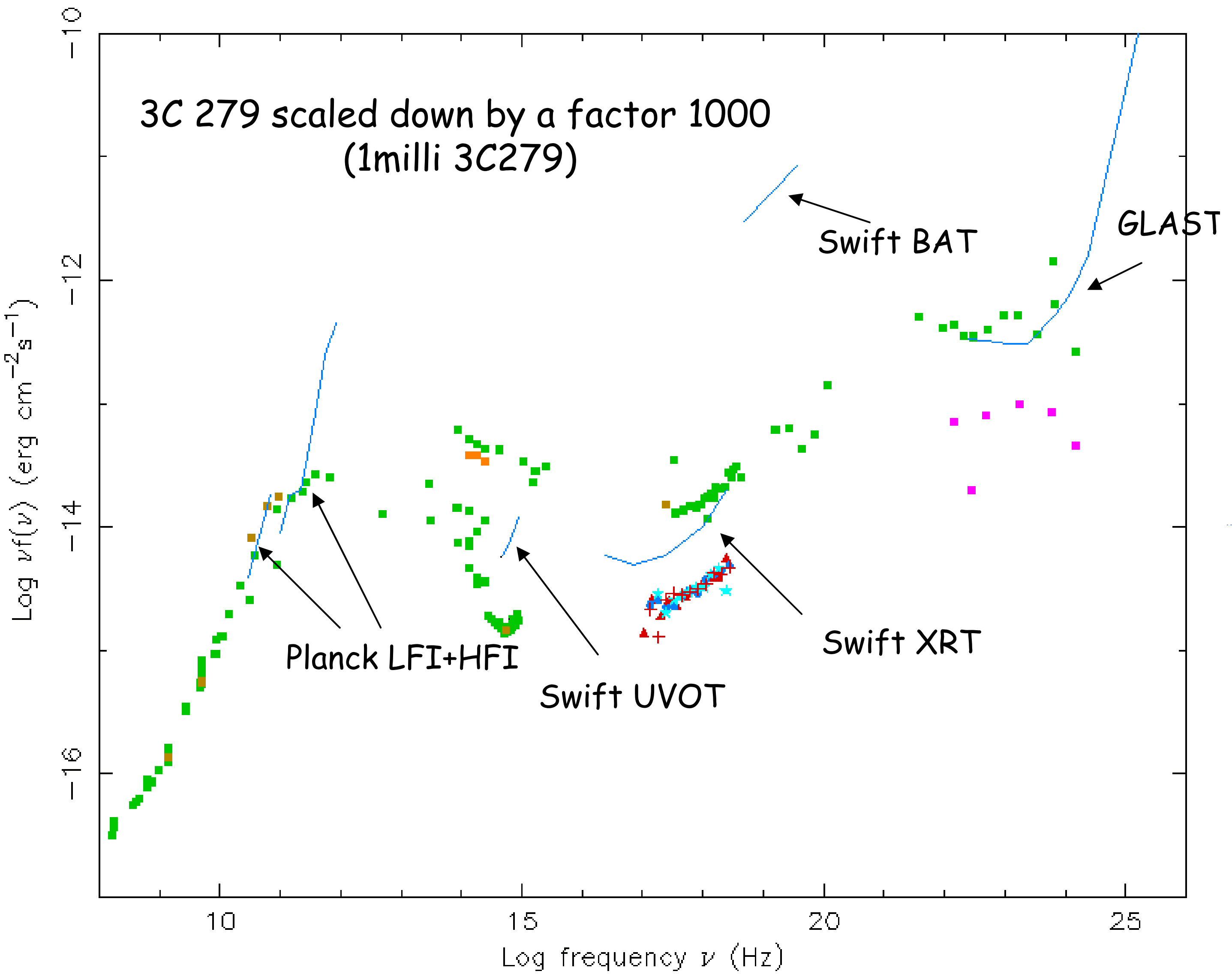
The overall cosmic background energy has two well understood components:

1. the primordial Black Body emission peaking at the μ-wave frequencies
2. the X-ray apparently diffuse emission arising from the accretion onto super-massive B.H. in AGN integrated over the cosmic time

Blazars add a third non-thermal component that

- at low ν contaminates the CMB fluctuation spectrum and complicates its interpretation while
- at high ν dominates the extragalactic background radiation

Conclusions - next generation of μ-wave and γ-ray satellites



Conclusions - next generation of μ-wave and γ-ray satellites

This hypotetical 10 mJy LBL blazar is:

- ✓ at the limit of the Planck sensitivity,
- ✓ detectable with deep Swift exposure (or less deep XMM and Chandra obs) and
- ✓ detectable by GLAST during strong flares.

the new blazar radio logN - logS predicts a space density of > 5 objects per square degree with flux above 10 mJy

⬇

Planck should detect ~ 100.000 - 200.000 blazars in the ~ 30.000 square degree high galactic latitude sky

➡ important to remove as much as possible this contaminating component

an all-sky survey with limiting sensitivity of a few 10^{-15} erg cm^{-2} s^{-1} in the soft X-ray band would detect a large majority of blazars above the Planck limiting sensitivity and therefore allow the construction of a database including over 100.000 blazars with flux measurements at radio, μ-wave and X-ray frequencies.

THANKS !!!