A Figure of Merit for Blazar-like Source Identification in the γ-ray Energy Band

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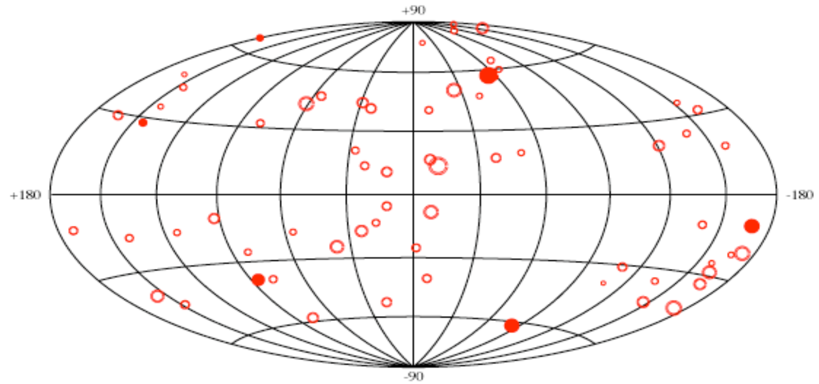
Blazars in γ-rays

Radio loud AGN:
- Emission from radio to TeV
- Highly variable (at all ν)
- Highly polarized
- Radio core dominance
- Superluminal speeds

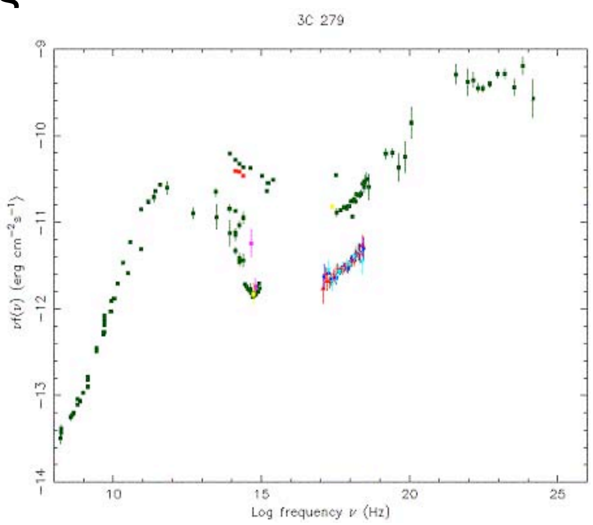
Blazars: AGN observed at a small angle wrt the jet
~ 5% of all AGN

Blazars are the **dominant population of extragalactic point-like sources** at:

- Microwave frequencies (LBL)
- γ-rays (LBL)
- TeV energies (HBL)

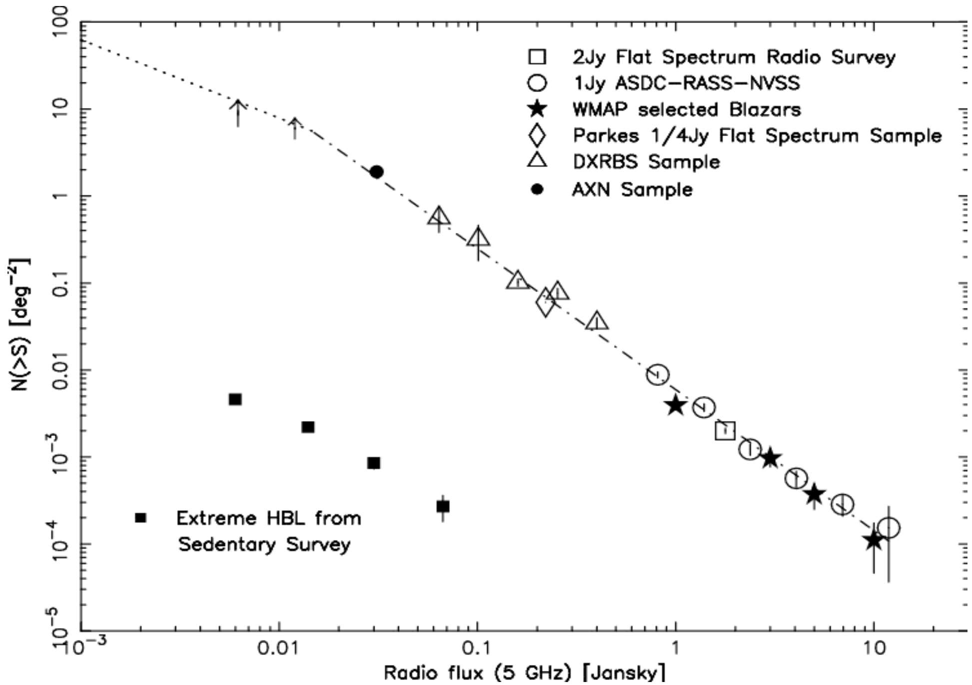


- ~ 130 high confidence Blazar from 3rd EGRET catalog at E >100 MeV
- ~20% BL Lacs, ~80% FSRQs
- ~13 Blazars @ TeVs



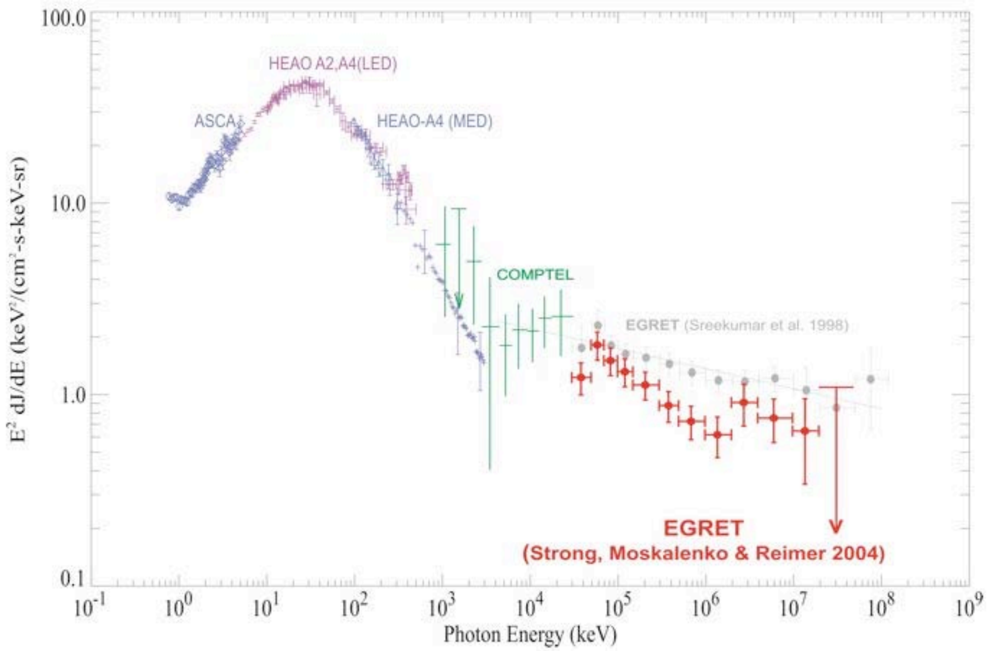
Observational Constraints

Blazar radio LogN-LogS



Radio (5GHz) LogN-LogS of Blazars built combining several radio and multifrequency surveys
(Giommi et al 2006)

Diffuse Extragalactic Cosmic γ-ray Background (CGB)



F_{diff}(E>100 MeV) outside the galactic plane:

~ 1.45 10^{-5} ph cm^{-2} s^{-1} sr^{-1} (Sreekumar et al. '98)

~ 1.14 10^{-5} ph cm^{-2} s^{-1} sr^{-1} (Strong et al. 2004)

Blazars & Cosmic Backgrounds

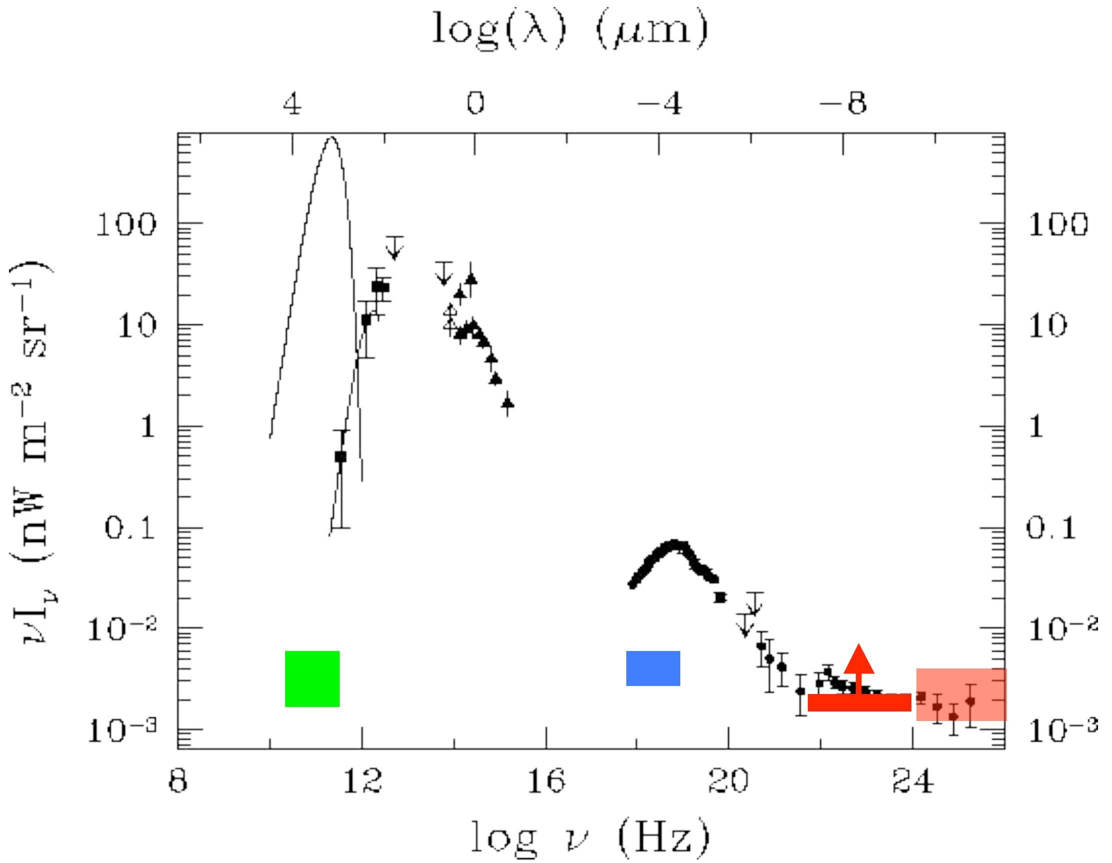
Blazar contribution to the
Cosmic Background Brightness:

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

CMB foregrounds
~ $20 \cdot 10^{-6}$ I_{CMB} @ 40 GHz
~ $8 \cdot 10^{-6}$ I_{CMB} @ 94 GHz

CXB X-rays ~ 10%

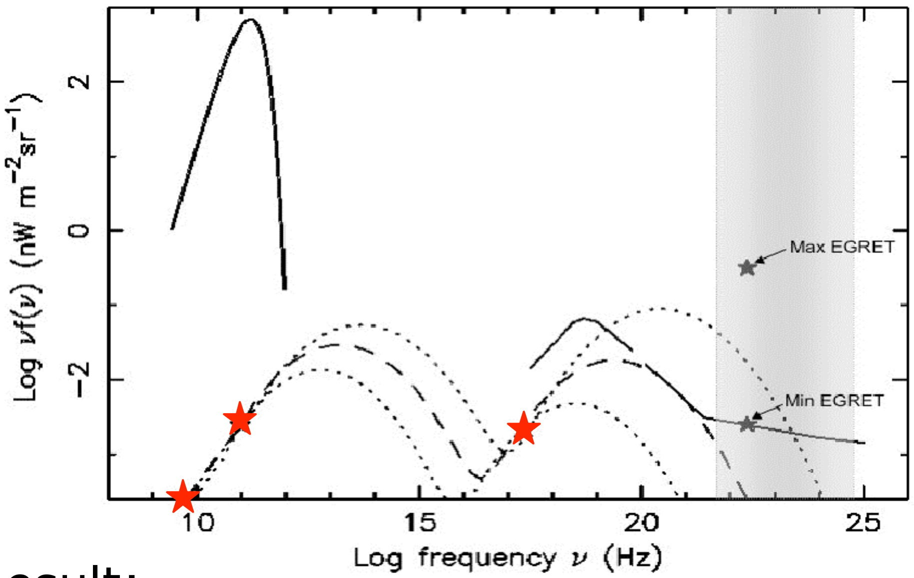
CGB γ-rays > 80 - 100 % (?)

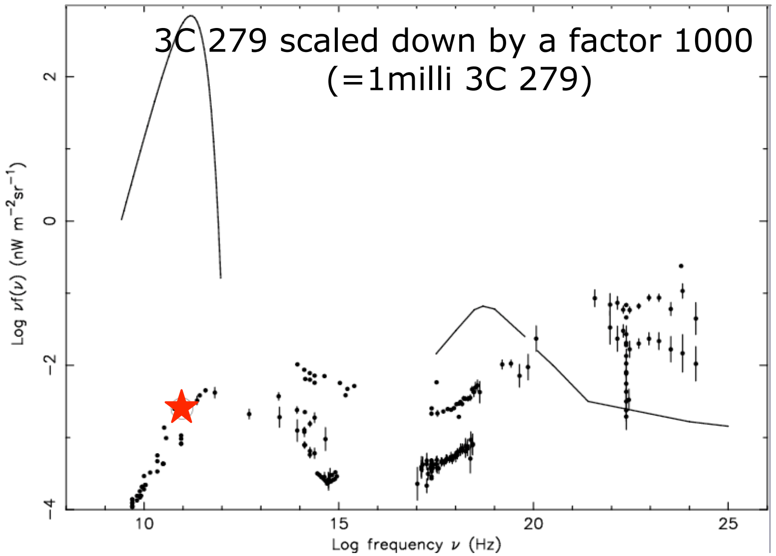


The Method: estimate of the LBL Blazar contribution to CGB

Hard X-ray/Soft γ-ray : SSC constrained in 3 points (★) by $F_{diff,blazar}$(94GHz), $\alpha_{r,\mu}$, $\alpha_{\mu,x}$, $\alpha_{\mu,\gamma}$

γ-ray : Scale typical EGRET LBL-blazar SEDs (3C 279), interpreted by simple SSC models, to the integrated blazar flux intensity at CMB energies (★)





Giommi et al 2006

Result:

Either sources SSC-LBLs (like 3C 279) are not representative of blazars contributing to the CGB, despite CXB contribution consistent with other estimates, or their duty cycles @ γ-rays is low

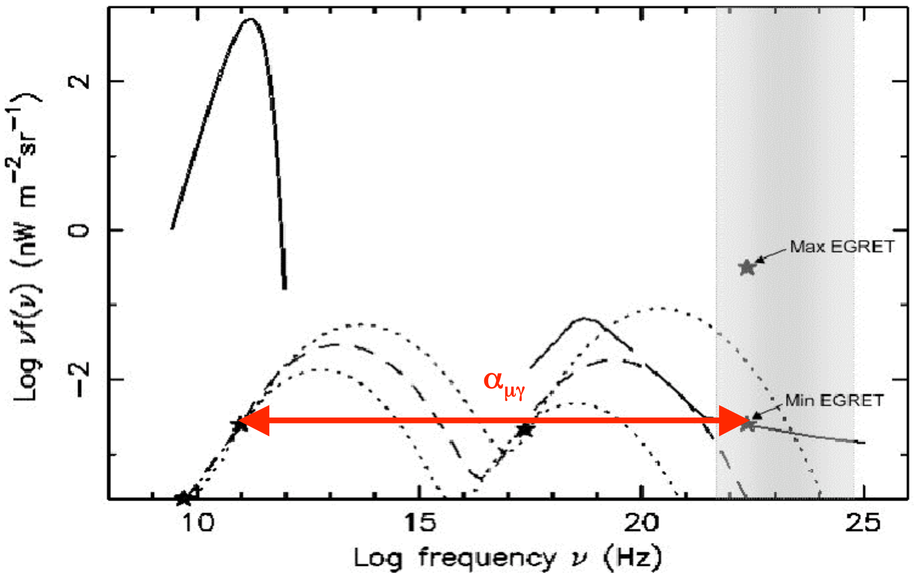
$\alpha_{\mu\gamma}$ and Duty Cycle

Define a μ-wave to γ-ray index:

$$\alpha_{\mu\gamma} \equiv -\frac{\log\left[f_\mu(94GHz)/f_\gamma(100MeV)\right]}{\log(\nu_\mu/\nu_\gamma)}$$

Limiting value: $(\alpha_{\mu\gamma})_{100\%CGB}=0.994$

This is the value of an hypotetical source that would produce 100% of the CGB if representative of the class. Any **source with $\alpha_{\mu\gamma}$ < 0.994** shoud have a **duty cycle lower than 100%** in order not to overproduce the extragalactic diffuse γ-ray background.



$$Duty\ Cycle \equiv \frac{100}{10^{11.41(0.994-\alpha_{\mu\gamma})}}$$

Duty cycle > 100% => source always visible (also in low state)

where: $\log\left(\nu_\mu(94\,GHz)/\nu_\gamma(100\,MeV)\right) = 11.41$

Samples: WMAP bright source catalogs

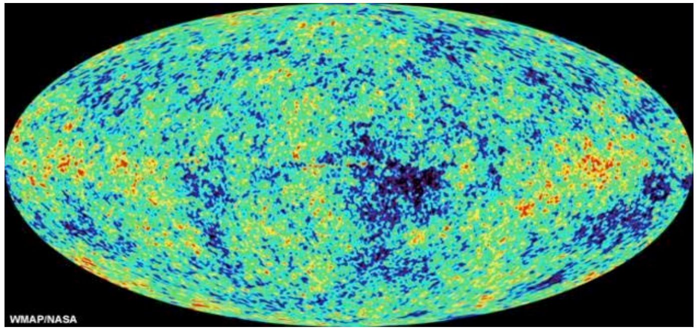
WMAP 1st yr

208 bright sources: 85-90% Blazars

- **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)

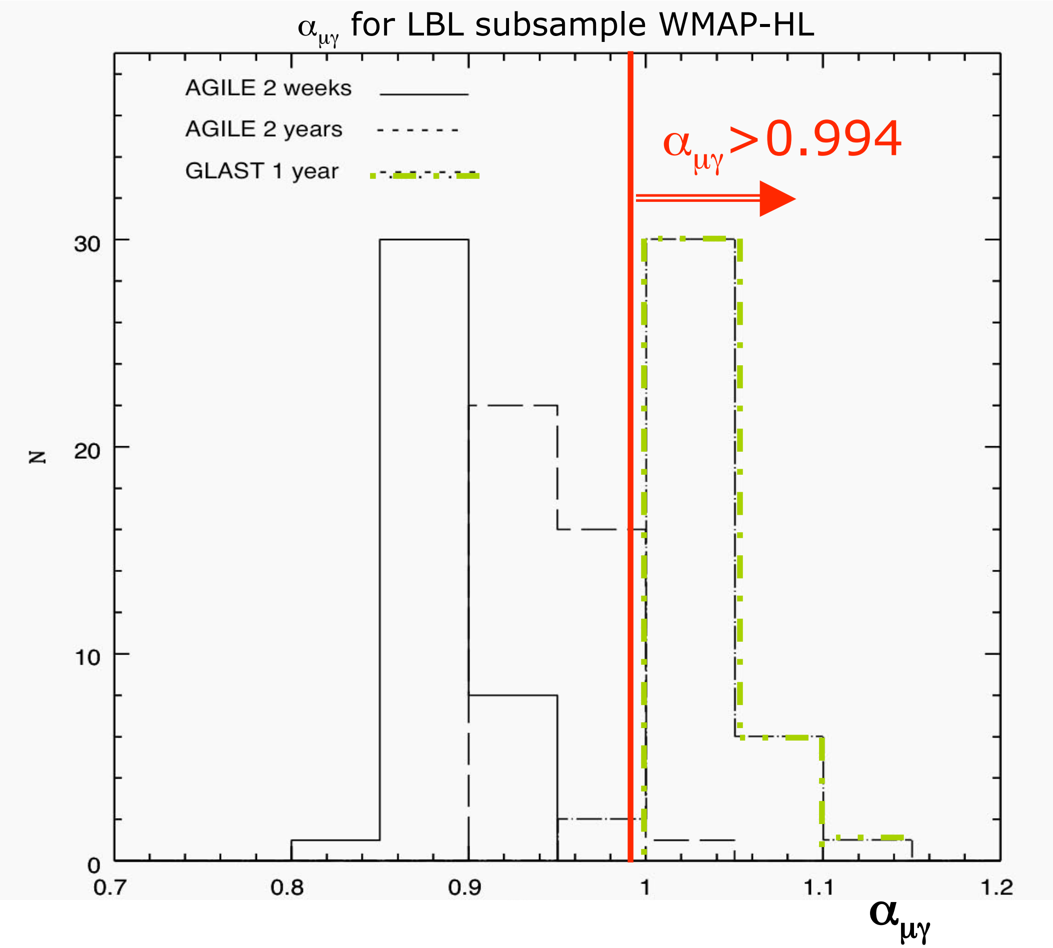
WMAP catalog web page@ASDC on:
http://www.asdc.asi.it/wmap/

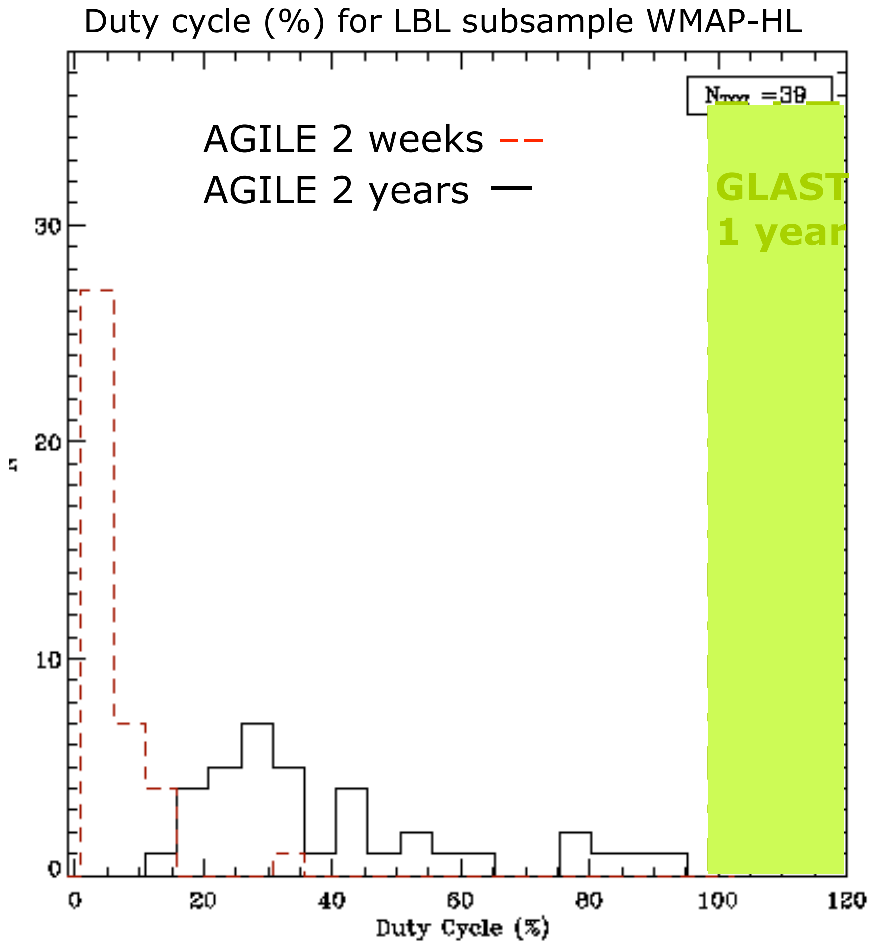


WMAP LBL Blazars at high latitude |b| > 30° with measured flux values @ 94GHz:

Total of 39 LBL sources

WMAP 1st yr, |b| > 30





$\alpha_{\mu\gamma} = 0.84 \Leftrightarrow 2\%$ duty cycle, $\alpha_{\mu\gamma} = 0.90 \Leftrightarrow 10\%$ duty cycle

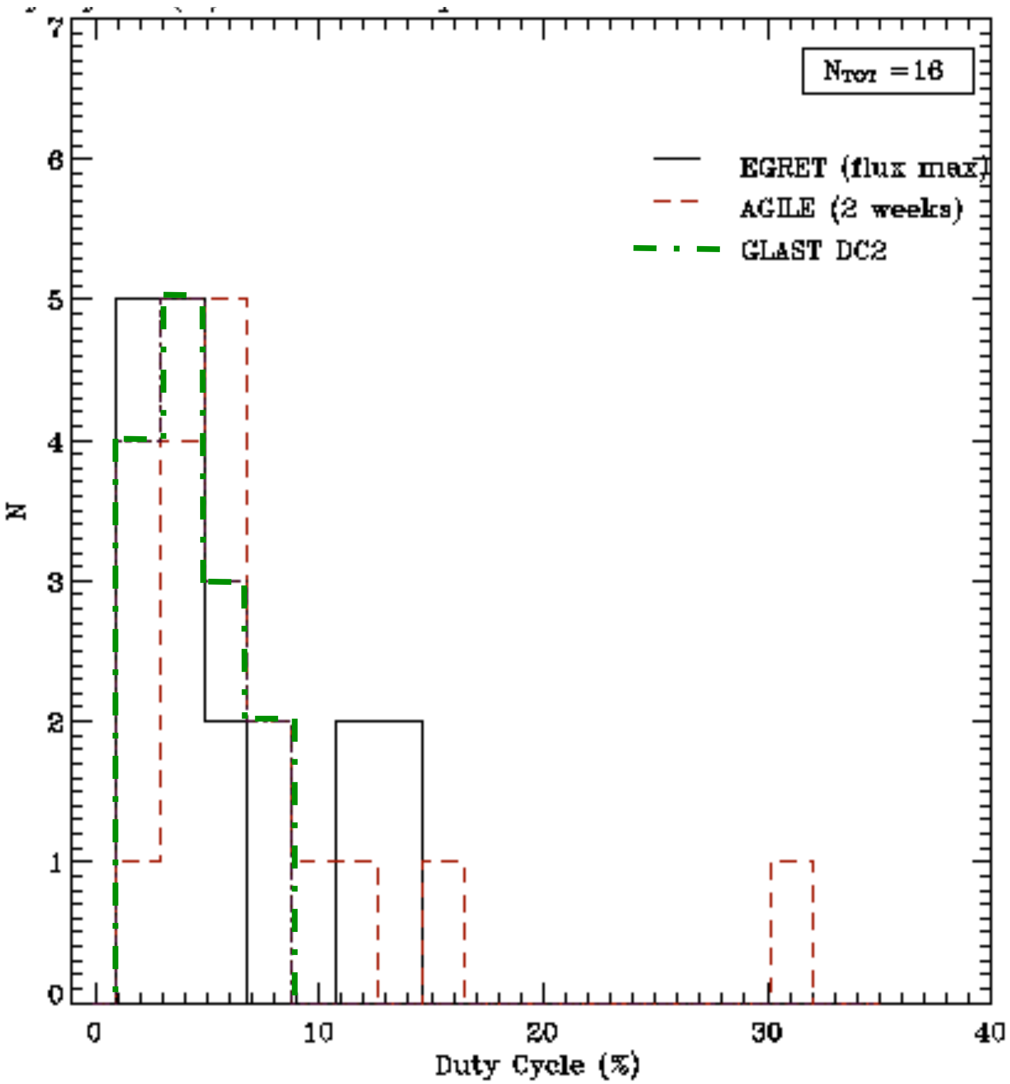
$\alpha_{\mu\gamma}$ >0.994 corresponds to **> 100% duty cycle: no bkg constraints (visible also in low state)**

Comparison of allowed Duty Cycles (%) corresponding to:

- Maximum γ-ray flux observed by EGRET (———)
- AGILE limiting sensitivity of one typical pointting (-----)
- GLAST DC2 55 days simulated flux values (– · –)

EGRET and DC2 data correspond to sources with **high γ-ray flux levels**, with **low duty cycle** allowed (**in the range 1%-15%**) in order not to overproduce the extragal bkgr (assuming that each source is representative of the entire LBL Blazar population).
Sources in such high state could also be detected by AGILE in just one pointing (~15 gg).

Results for 16 WMAP 1st yr sources with EGRET counterpart:



WMAP 3rd year bright source catalog
+ sources with no 94 GHz measured flux
+ Medium Latitude analysis

Our **new sample** is composed by LBL sources from the **new WMAP 3rd yr catalog** (**323** bright sources: **194 FSRQ, 38 BL Lac**)

+ sources with no 94 GHz measured flux. For these sources we estimate the 94 GHz flux from fluxes available at other frequencies (61, 41, 33, 23 GHz) in accordance with $F_{94GHz}=F(\nu)(94/\nu)^{-0.25}$

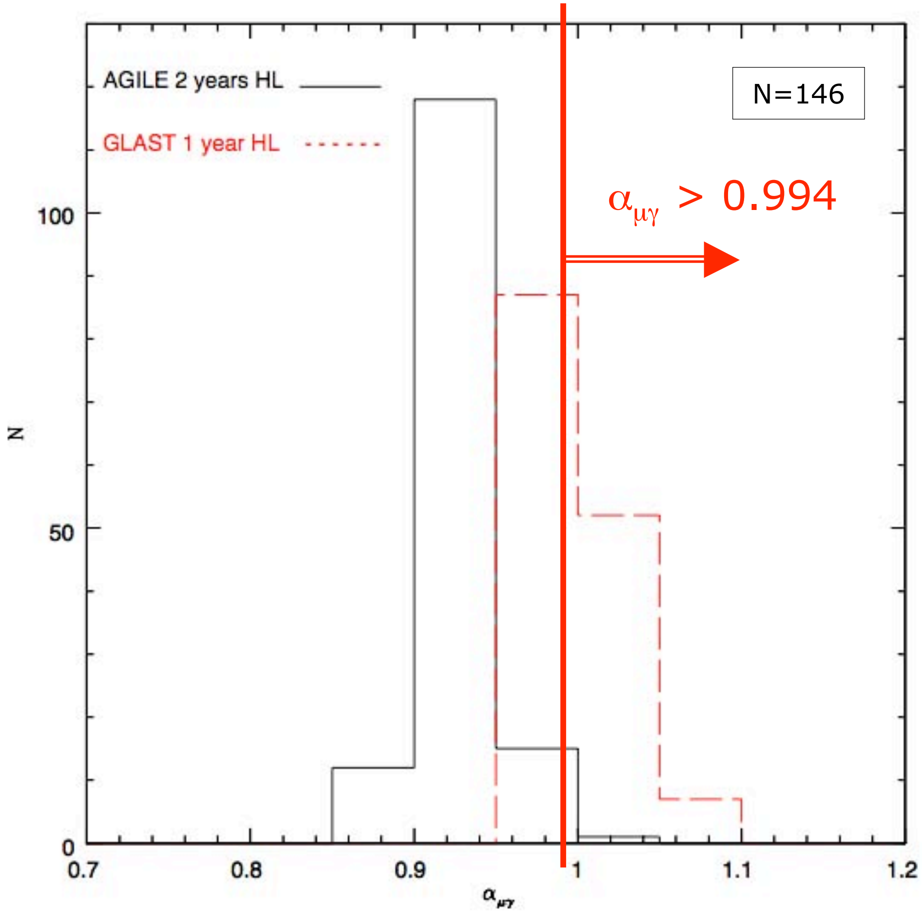
- Total of **146 High Latitude LBL** sources (previous: 39 sources)

+ Medium Latitude sources (ML) **10° <|b|< 30°, l > 30°**

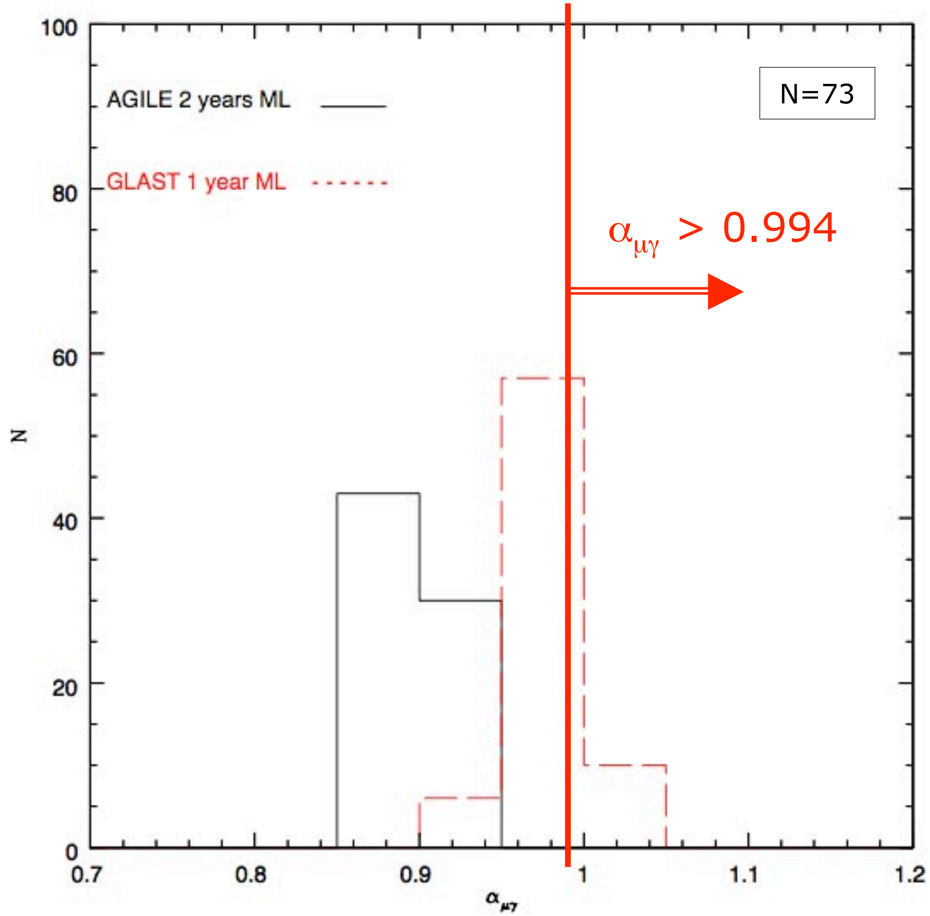
- Total of **73 Medium Latitude LBL** sources

$\alpha_{\mu\gamma}$ WMAP 3rd yr catalog

High Latitude |b| > 30

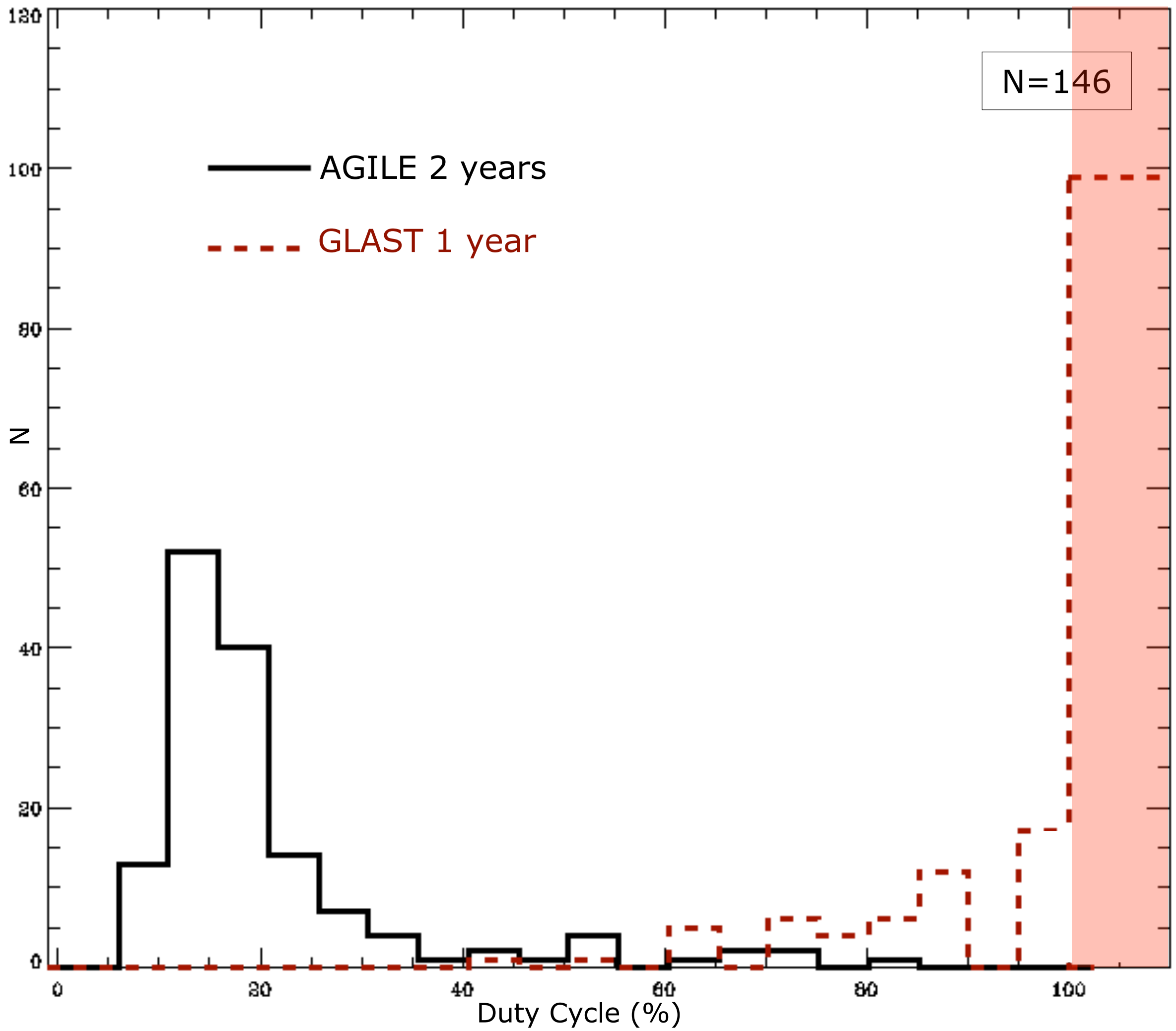


Medium Latitude 10 < |b| < 30



$\alpha_{\mu\gamma}$ **>0.994** corresponds to **> 100% duty cycle: no bkg constraints**

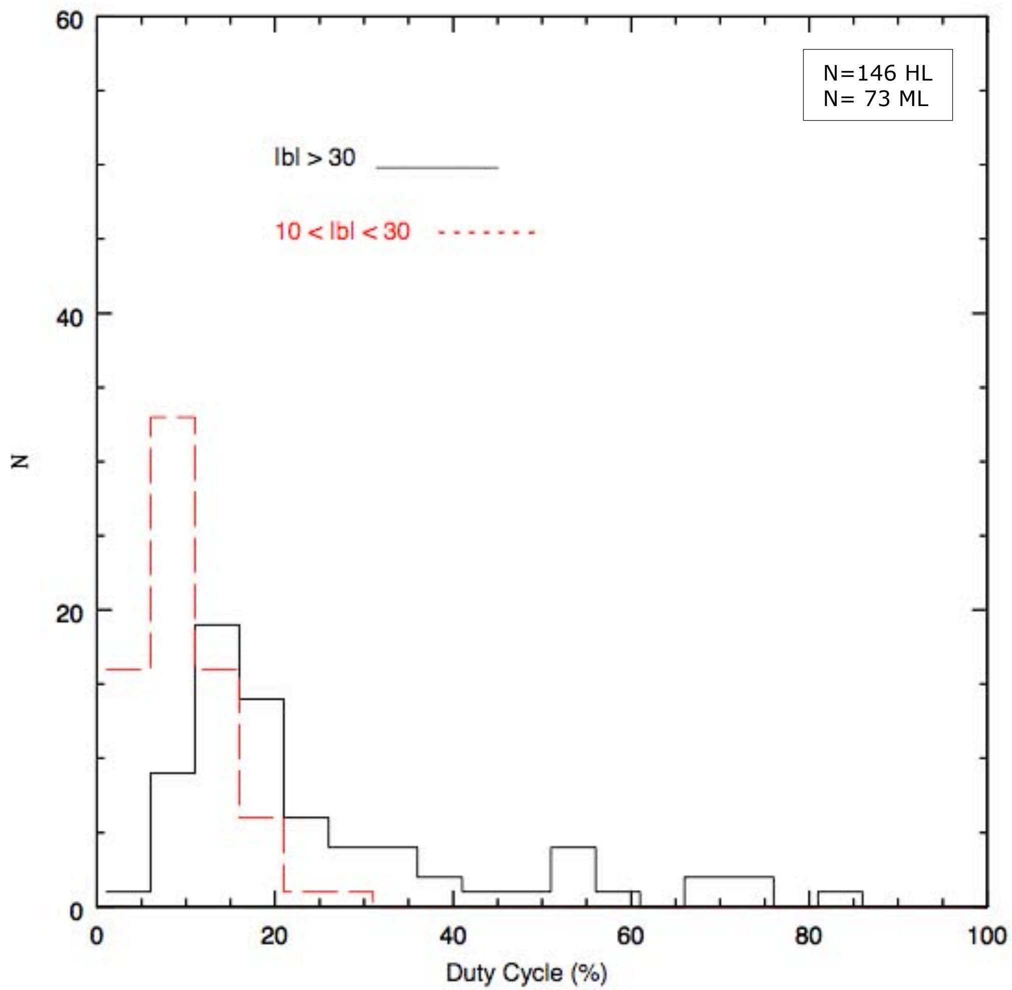
Duty Cycle at High Latitude (|b| > 30)



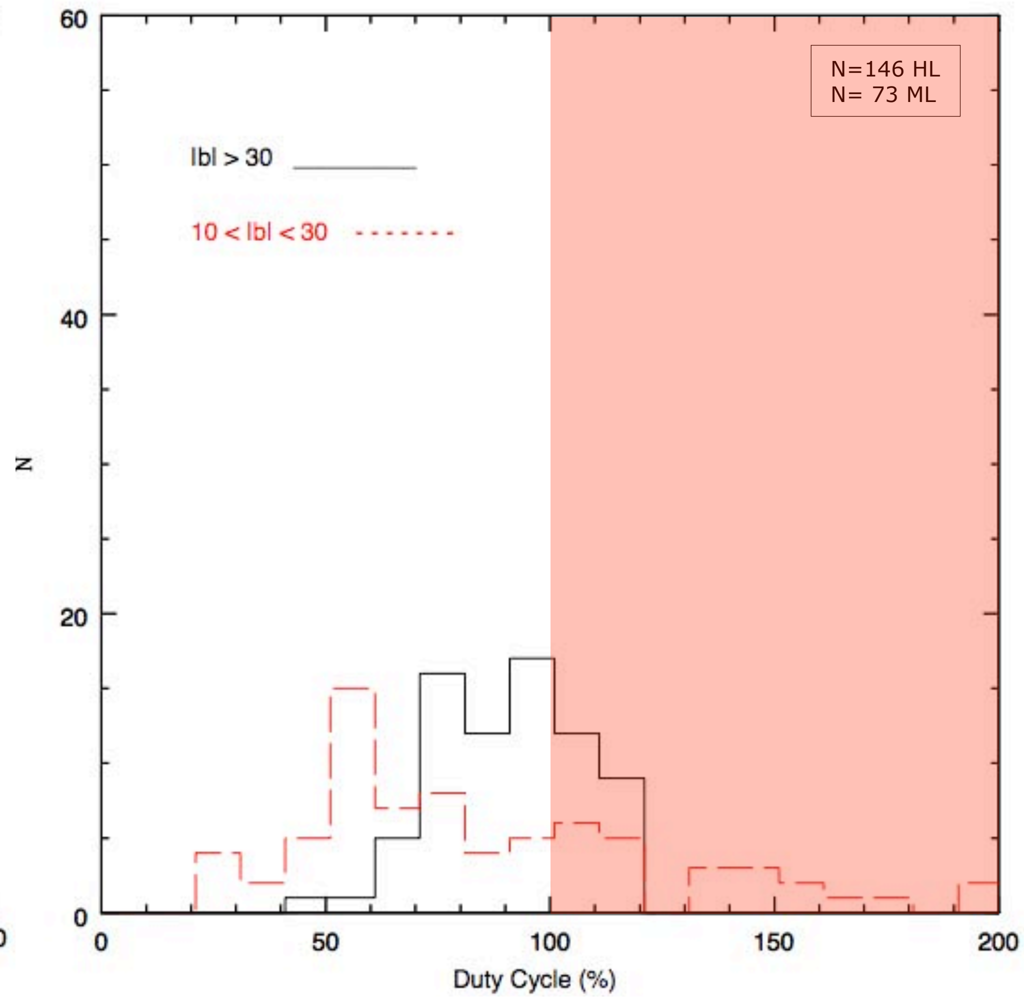
duty cycle > 100% : source always visible

Comparison between Duty Cycles at High and Medium Latitudes

AGILE 2 years



GLAST 1 year



Conclusions

Method to foreseen the possibility to detect a known blazar in the next γ-ray experiments (new parameter in the ASDC web pages)

- WMAP 1st yr (F_{94} measured) ⇔ consistency ⇔ WMAP 3rd yr (F_{94} measured + F_{94} extrapolated)

- Extrapolated F_{94GHz} => lower duty cycle

  ⇓

  fainter sources => high state to be detected

- Medium latitudes: less sensitivity => high state to be detected

Preliminary Results

- GLAST in one year would be able to detect all WMAP-HL sources in the sample also in a low-flux steady state with no bkg constraints

- AGILE in two years would be able to detect a few WMAP-HL sources with no duty cycle constraints such as 3C 273, 3C 279,... (3C 446, 1Jy2255-282 why not seen by Egret? Low exposure pointings?) and all other sources in the sample with duty cycle bigger than ~ 20%

- AGILE in one pointing of ~ 2 weeks would detect sources in flaring state with duty cycle in the range ~1%-15%

AGILE & GLAST Sensitivities

$$S(E_i) = \frac{n^2 + \sqrt{n^4 + 8n^2 F_{diffuse}(E_i) A_{eff}(E_i)\ T\ 2\pi\left(1 - cos\ \theta^{68\%}_{PSF}(E_i)\right)}}{2f A_{eff}(E_i)\ T\ \Delta E_i} \quad \mathrm{ph\ cm^{-2}\ s^{-1} MeV^{-1}}$$

[2] Pittori et al., in preparation (2007)

n=5, (a threshold condition ~ 5σ)

$\Delta E_i \sim E_i$

any other efficiency factors =1 (to give an estimate of limiting sensitivity values for both instruments)

effective area

PSF 68% containment radius (the acceptance solid angle value for diffuse background evaluation)

The corresponding fraction of accepted signal photons is f=0.68.

AGILE sensitivity at high latitute (HL: |b|>30°) for two exposure times:

T = 10^6 s ~ 2 weeks (a typical AGILE pointing)

T= 2 yr (nominal lifetime of the mission)

GLAST HL-sensitivity is evaluated for T= 1 yr.