Blazar duty-cycle at $\gamma$-ray frequencies: constraints from extragalactic background radiation and prospects for AGILE and GLAST

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Abstract We take into account the constraints from the observed extragalactic $\gamma$-ray background to estimate the maximum duty cycle allowed for a selected sample of WMAP Blazars, in order to be detectable by AGILE and GLAST $\gamma$-ray experiments. For the nominal sensitivity values of both instruments, we identify a subset of sources which can in principle be detectable also in a steady state without over-predicting the extragalactic background. This work is based on the results of a recently derived Blazar radio LogN-LogS obtained by combining several multi-frequency surveys.

Keywords Blazar · AGN · Extragalactic background

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1 Introduction

Blazars are the dominant population of extragalactic sources at microwave, $\gamma$-rays and TeV energies. They represent 5–8% of all AGNs and are powerful sources emitting a continuum of electromagnetic radiation from a relativistic jet viewed closely along the line of sight. The large observed variety of Blazar Spectral Energy Distributions (SEDs) can be reproduced, at least in first approximation, by simple Synchrotron Self Compton (SSC) emission model, composed of a synchrotron low-energy component that peaks between the far infrared and the X-ray band, followed by an Inverse Compton component that has its maximum in the hard X-ray band or at higher energies, and may extend into the $\gamma$-ray or even the TeV band. Those Blazars where the synchrotron peak is located at low (~infrared) energy are usually called Low energy peaked Blazars or LBL, while those where the synchrotron component reaches the X-ray band are called High energy peaked Blazars or HBL. Blazars may also be subdivided in BL Lacertae types (BL Lacs ~20% of all Blazars), characterized by strong non-thermal emission with no or very weak emission lines and in Flat Spectrum Radio Quasars (FSRQs ~80%) which share the strong non-thermal emission of BL Lacs but also show intense broad line emission. LBL sources, mostly FSRQ and few BL Lacs, are the large majority among Blazars and are usually discovered in radio surveys, while HBL objects all of BL Lac type, are preferentially found in X-ray flux limited surveys.

Despite the relatively low space density of Blazars, their strong emission across the entire electromagnetic spectrum makes them potential candidates as significant contributors to extragalactic Cosmic Backgrounds. Giommi et al. (2006) have recently re-assesed the Blazar contribution to the microwave (CMB), X-ray (CXB), $\gamma$-ray (CGB) and TeV Cosmic backgrounds based on a new estimation of the Blazar radio LogN-LogS, assembled combining several radio and multi-frequency surveys. It was shown that Blazars add a non-thermal component to the overall Cosmic Background that at low frequencies contaminates the CMB fluctuation spectrum. At higher energies (E > 100 MeV) the estimated Blazar collective emission over-predicts the extragalactic background by a large factor, thus implying that Blazars not only dominate the $\gamma$-ray sky (cfr. Padovani et al. 1993), but also that their average duty cycle at these frequencies must be rather low.
In this paper we analyze a sample of WMAP detected Blazars and we estimate the maximum duty cycle allowed, taking into account the constraints from the observed extragalactic γ-ray background, in order to be detectable by AGILE and GLAST for the nominal sensitivity values of both instruments.

2 Observational constraints and blazar γ-ray duty cycle

The integrated Blazar intensity at microwave frequencies has been computed by using an updated radio LogN-LogS and it has been extrapolated to the hard X-rays and soft γ-rays by using simple SSC models for the SEDs (Giommi et al. 2006). Figure 1 shows the CMB, CXB and CGB observed levels, depicted as simple solid lines, together with three SEDs from a simple homogeneous SSC models. The SED parameters are constrained to

- Be consistent with the expected integrated flux at 94 GHz,
- Have the $\alpha_{\mu x}$ slope equal to the mean value of the WMAP Blazars ($\alpha_{\mu x} = 1.07$),
- Possess a radio spectral slope equal to the average value of the WMAP microwave selected Blazars.

The three curves, forced to pass through the three star symbols graphically representing the three constraints listed above, are characterized by three different synchrotron $v_{\text{peak}}$ values.

From Fig. 1 we see that a high value of $v_{\text{peak}}$ over-predicts by a large factor the observed hard-X-ray to soft γ-ray Cosmic Background, whereas a too low value of $v_{\text{peak}}$ predicts a negligible contribution. The case $\log(v_{\text{peak}}) = 13.5$ Hz predicts 100% of the Hard-X-ray/Soft γ-ray Cosmic Background. Since the $\log(v_{\text{peak}})$ values of Blazars in the 1JyARN survey and WMAP catalog peak near 13.5 and range from 12.8 to 13.7 within one sigma from the mean value,

![Graph representing observational constraints and blazar γ-ray duty cycle](image)

Fig. 1 The possible contribution of LBL Blazars to the Hard X-ray soft γ-ray Background (shaded area). The three SSC curves correspond to different $v_{\text{peak}}$ values ($\log v_{\text{peak}} = 12.8, 13.5$ and $13.8$), constrained as described in the text.

The data presently available indicate that Blazars may be responsible for a large fraction, possibly 100% of the Hard-X-ray/Soft γ-ray Cosmic Background.

Blazars are the large majority of the extragalactic γ-ray (E > 100 MeV) identified sources detected by the EGRET experiment. In order to estimate Blazar contribution to the γ-ray Cosmic Backgrounds, one can analogously scale the full SED of EGRET detected LBL Blazars, such as that of the well known blazar 3C279, to the integrated Blazar flux intensity at CMB energies. In Fig. 2 we show the SED of 3C279 scaled so that its flux at 94 GHz matches the cumulative emission of the entire Blazar population (star symbol).

From Fig. 2 one can see that while at X-ray frequencies the contribution to the CXB ranges from a few % to over 10% in the higher states, the predicted flux at γ-ray frequencies ranges from about 100% to several times the observed Cosmic Background intensity. This large excess implies that either 3C279 is highly non representative of the class of Blazars, despite the contribution to the CXB is consistent with other estimates, or its duty cycle at γ-ray frequencies is very low. The same approach can be followed with other Blazars detected at γ-ray frequencies. In all EGRET detected WMAP Blazars the SED of LBL Blazars over-predicts the CGB by a large factor.

We define a microwave to γ-ray slope as

$$\alpha_{\mu\gamma} = \frac{\log(f_{94\,\text{GHz}})}{\log(f_{100\,\text{MeV}})},$$

and a limiting value: $\alpha_{\mu\gamma}^{100\% \, \text{CGB}} = 0.994$ which is the value of an hypothetical source that would produce 100% of the CGB if representative of the class.

Any source with $\alpha_{\mu\gamma} < 0.994$ should have a duty cycle lower than 100% in order not to overproduce the extragalactic diffuse γ-ray background.

![Graph showing possible contribution of LBL Blazars to the Hard X-ray soft γ-ray Background](image)

Fig. 2 The CMB, X-ray and γ-ray cosmic backgrounds with superimposed the SED of the Blazar 3C279 scaled as described in the text.