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Predictions of ECS and SSC models for flux-limited samples of γ-ray blazars *

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Abstract

The external Compton scattering (ECS) and synchrotron self-Compton (SSC) models make distinct predictions for the amount of Doppler boosting of high-energy γ-rays emitted by blazars. We examine how these differences affect the predicted properties of AGN samples selected on the basis of γ-ray emission. We create simulated flux-limited samples based on the ECS and SSC models, and compare their properties to those of identified EGRET blazars. We find that for small γ-ray-selected samples, the two models make very similar predictions, and cannot be reliably distinguished. This is primarily due to the fact that not only the Doppler factor, but also the cosmological distance and intrinsic luminosity play a role in determining whether an AGN is included in a flux-limited γ-ray sample. © 1999 Elsevier Science B.V. All rights reserved.

1. Introduction

A popular model for the production of high-energy radiation in AGNs involves inverse-Compton scattering of lower-energy photons up to γ-ray energies by highly relativistic electrons in the jet. There is still some uncertainty, however, regarding the source of the seed photons for this process. In the external Compton scattering (ECS) model [1,2], the seed photons are external to the jet (i.e., from the accretion disk and/or nearby regions), whereas in the synchrotron self-Compton (SSC) model [3,4], the seed photons originate in the jet itself.

These two models make distinct predictions for the behavior of the spectral energy distribution during a γ-ray flare, and in theory can be constrained by multiwavelength observations. Such observations are very difficult to carry out, however, and the results obtained so far have not ruled out either model [5].

The ECS and SSC models may also be potentially distinguishable via differences in their predicted amounts of γ-ray Doppler boosting [6]. In this paper we examine how these differences affect the observed properties of γ-ray selected blazar samples, and whether these models can be constrained by existing data on γ-ray-bright AGNs.

2. Method

All 42 of the identified γ-ray-bright AGNs in the second EGRET catalog [7] are strong, compact, flat-spectrum radio sources typical of the blazar class [8]. In a previous study [9], we examined the combined effects of Malmquist and Doppler bias on flux-limited

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Table 1
Predicted ranges of median parameter values for EGRET blazars

	5 GHz Flux [Jy]	Redshift	β_{app} h	Lorentz factor	View. ang. [deg.]	Doppler factor
ECS[a]	**1.5–2.5**	0.6–0.9	7–8	19–20	**1.0–1.3**	**32–34**
SSC[a]	**2.7–4.4**	0.4–0.7	6–8	15–18	**1.5–2.3**	**22–26**
ECS[b]	1.2–2.1	0.8–1.1	7–8	19–20	1.0–1.3	**33–36**
SSC[b]	1.9–3.9	0.5–0.8	7–8	18–19	1.1–1.5	**30–32**
EGRET[c]	2.6	0.9	...	...	...	...

[a] For γ-rays originating in a continuous jet.
[b] For γ-rays originating in a single blob.
[c] Median values for Mattox et al. EGRET blazar sample.

samples of blazars selected at radio wavelengths. We obtained good fits to the properties of the Caltech–Jodrell flat-spectrum AGN sample [10] using a simulated population having random jet orientations and a jet Lorentz factor distribution $N(\Gamma) \propto \Gamma^{-1.25}$.

We extend our simulations here to model the identified EGRET blazars, by assuming a simple scenario in which $L_{\gamma,\rm SSC} \propto L_{\rm radio}$, and $L_{\gamma,\rm ECS} \propto L_{\rm radio}\ \delta^{1-\alpha}$, where α is the γ-ray spectral index, and δ is the Doppler factor. In the case where the γ-rays are emitted by a single blob, rather than a continuous jet, the above Doppler boosting factors are increased by a factor of δ. We compare the properties of the brightest 42 γ-ray sources in the simulated populations predicted by both models.

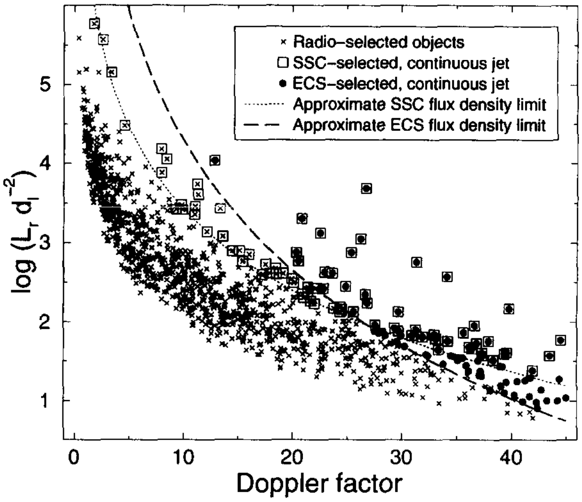

Fig. 1. Plot of "unbeamed" flux density vs δ for radio- and γ-ray-selected samples. The ordinate is equal to the intrinsic luminosity divided by the luminosity distance squared (in arbitrary units).

3. Results

Despite their large differences in Doppler boosting, the ECS and SSC models make very similar predictions for the EGRET blazars. In Table 1 we list the predicted range of median parameter values obtained from multiple Monte Carlo runs. Both models predict a large median Doppler factor and small median viewing angle, which suggests that the EGRET blazars should display a higher degree of flux variability and apparent bending than other blazars not detected by EGRET.

The similarities in the two model predictions are primarily due to the influence of cosmological distance and intrinsic luminosity on observed flux. The parameters which may be potentially distinguishable for the ECS and SSC models are indicated in boldface. However, additional simulations indicate that these become *indistinguishable* if there is more than ~ 0.5 magnitude of random scatter in the intrinsic γ-ray/radio luminosity ratio.

In Fig. 1 we plot the flux density a source would have in the absence of boosting versus its Doppler factor. Any source located to the right of the thick dashed line (barring a slight k-correction) has sufficient γ-ray flux to be detected by EGRET, according to the ECS model. The thin dotted line indicates the cutoff for the SSC model. The relatively large number of selected sources common to both models (located in the overlapping region) accounts for the similar median parameter values listed in Table 1.

More sensitive γ-ray surveys will not reduce the size of the overlapping region, as both curves will merely shift downwards. However, an increase in γ-ray sensitivity by a factor of $\sim$ 50–100 will enable many more low-δ sources to be selected by the SSC model (and high-δ sources by the ECS model), and potentially render the models distinguishable. A tight radio/γ-ray luminosity correlation is still required however.

4. Conclusions

We have used Monte Carlo methods to create simulated samples of γ-ray bright blazars detected by EGRET, according to the ECS and SSC models. We find that these models make very similar predictions for observable jet parameters, despite their large differences in Doppler boosting factors. This is primarily due to the strong influence of cosmological distance and intrinsic luminosity on observed γ-ray flux, and the relatively small size of the EGRET sample. Provided that there is a tight correlation between intrinsic radio and γ-ray luminosity in the blazar population, the ECS and SSC models are potentially distinguishable using more sensitive γ-ray AGN surveys.

References

[1] M. Sikora, M.C. Begelman, M.J. Rees, ApJ 421 (1994) 153.
[2] C.D. Dermer, R. Schlickeiser, ApJ 416 (1993) 458.
[3] S.D. Bloom, A.P. Marscher, ApJ 461 (1996) 657.
[4] L. Maraschi, G. Ghisellini, A. Celotti, ApJ 397 (1992) L5.
[5] R. Mukherjee et al., ApJ 490 (1997) 116.
[6] C.D. Dermer, ApJ 446 (1995) L63.
[7] D.J. Thompson et al., ApJS 101 (1995) 259.
[8] J.R. Mattox, J. Schachter, L. Molnar, R.C. Hartman, A.R. Patnaik, ApJ 481 (1997) 95.
[9] M.L. Lister, A.P. Marscher, ApJ 476 (1997) 572.
[10] G.B. Taylor et al., ApJS 107 (1996) 37.