Abstract

We test different physically motivated models for the spectral shape of the $\gamma$-ray emission in a sample of 128 blazars with known redshifts detected by Fermi-LAT at energies above 50 GeV. The first nine years of LAT data in the energy range from 300 MeV to 2 TeV, as analysed to determine the spectral energy coverage of 2FHL blazars in our sample. We compare these spectral data to four leptonic models for the production of $\gamma$-rays through inverse Compton scattering of electrons with different spectral shapes. In the first three models we consider Compton scattering in the Thomson regime with different acceleration mechanisms for the electrons. In the fourth model we consider Compton scattering by a pure power law distribution of electrons with spectral curvature due to scattering in the Klein-Nishina regime. The majority of blazar $\gamma$-ray spectra are preferentially fit with either a power law with exponential cut-off in the Thomson regime or a power law electron distribution with Compton scattering in the Klein-Nishina regime, while a log-parabolic with a low-energy power-law and broken power-law spectral shape in the Thomson regime appear systematically disfavoured, which is likely a consequence of the restriction to pure Thomson scattering which we imposed on those models. This finding may be an indication that the $\gamma$-ray emission from FSRQs in 2FHL is dominated by Compton scattering of radiation from the dusty torus, while in the case of BL Lac objects, it is dominated by synchrotron self-Compton radiation.

1.1 Thomson Regime Models (Continued...)

3.1.3 First-order Fermi acceleration with different cooling/cooling times

Broken power-law (BPL) electron distribution, yielding

$$n_{\gamma} = \frac{1}{2\pi} \frac{\lambda}{\sqrt{2\pi}} \exp \left( -\frac{\lambda^2}{2} \right) \left( \frac{1}{1+b} \right)^{1+b/2}$$

where $\lambda = h\nu/2\pi$ is the dimensionless energy, with $h$ Planck's constant, $\nu$ is the electron mass, and $b$ is the speed of light. The $\gamma$ is the Lorentz factor, $\gamma_0$ is the dimensionless target photon energy, $\nu_0 = (1+\beta^2)^{1/2}/2$, is the lower integration limit resulting from the minimum Lorentz factor that can scatter the target photons to a given $\nu$, and $\nu = \nu_0(\gamma_0/\gamma)$.

Fitting Methodology

The highest-energy peak of the extrapolated light curve model of Dominguez et al. [2012] with a $\gamma$-minimization routine.

Models fitted with a $\gamma$-minimization routine.

3.1.4 First-order Fermi acceleration with different cooling/cooling times

Broken power-law (BPL) electron distribution, yielding

$$n_{\gamma} = \frac{1}{2\pi} \sqrt{2\pi} \frac{\nu}{\sqrt{2\pi \beta}} \exp \left( -\frac{\nu^2}{2\beta} \right) \left( \frac{1}{1+b} \right)^{1+b/2}$$

where $\nu = h\nu/2\pi$ is the dimensionless energy, with $h$ Planck's constant, $\nu$ is the electron mass, and $b$ is the speed of light. The $\gamma$ is the Lorentz factor, $\gamma_0$ is the dimensionless target photon energy, $\nu_0 = (1+\beta^2)^{1/2}/2$, is the lower integration limit resulting from the minimum Lorentz factor that can scatter the target photons to a given $\nu$, and $\nu = \nu_0(\gamma_0/\gamma)$.

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Models fitted with a $\gamma$-minimization routine.

3.1.5 First-order Fermi acceleration with different cooling/cooling times

Broken power-law (BPL) electron distribution, yielding

$$n_{\gamma} = \frac{1}{2\pi} \sqrt{2\pi} \frac{\nu}{\sqrt{2\pi \beta}} \exp \left( -\frac{\nu^2}{2\beta} \right) \left( \frac{1}{1+b} \right)^{1+b/2}$$

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Models fitted with a $\gamma$-minimization routine.

3.1.6 First-order Fermi acceleration with different cooling/cooling times

Broken power-law (BPL) electron distribution, yielding

$$n_{\gamma} = \frac{1}{2\pi} \sqrt{2\pi} \frac{\nu}{\sqrt{2\pi \beta}} \exp \left( -\frac{\nu^2}{2\beta} \right) \left( \frac{1}{1+b} \right)^{1+b/2}$$

where $\nu = h\nu/2\pi$ is the dimensionless energy, with $h$ Planck's constant, $\nu$ is the electron mass, and $b$ is the speed of light. The $\gamma$ is the Lorentz factor, $\gamma_0$ is the dimensionless target photon energy, $\nu_0 = (1+\beta^2)^{1/2}/2$, is the lower integration limit resulting from the minimum Lorentz factor that can scatter the target photons to a given $\nu$, and $\nu = \nu_0(\gamma_0/\gamma)$.

Fitting Methodology

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Models fitted with a $\gamma$-minimization routine.

Conclusion

- Stochastic acceleration (a log-parabolic electron distribution with a low-energy power-law) or first-order Fermi acceleration with different cooling/cooling regimes (a broken power-law electron distribution) does occur, then scattering does not occur in the Thomson regime.
- Radiation-reaction limited-first order Fermi acceleration (a power-law with an exponential cut-off electron distribution) in the Thomson regime is important for BL Lacs, FSRQs, variable, non-variable, and other types of blazars (but there is a degeneracy in the model). Scattering in the Klein-Nishina regime is important for non-variable blazars and FSRQs.
- Synchrotron radiation seems to be the main source of target photons in the case of SGP & HSP blazars, while IR photons from the dust torus might be the main target photon source in the case of FSRQs.

References