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γ-Ray Emission from the Extreme Blazar 1ES 0229 + 200

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Abstract. Based on the traditional Synchrotron Self-Compton (SSC) model, we consider a secondary γ-ray emission component to an extreme blazar 1ES 0229 + 200 for the multiwavelength radiation. By assuming a suitable electron spectra and Inter-Galactic Magnetic Field (IGMF), we obtained excellent fits to observed spectra of the source. This indicated that the observed excess GeV γ-rays emission can be explained by secondary γ-rays produced through inverse Compton scattering of $e^{\pm}$ pairs against Cosmic Microwave Background (CMB) photons.

Key words. Galaxies: active—BL Lacertae objects: individual (1ES 0229 + 200)—radiation mechanisms: non-thermal.

1. Introduction

It is believed that the primary TeV photons from distant TeV blazars should exhibit clear signs of absorption due to their interactions with the Extragalactic Background Light (EBL) to produce electron–positron ($e^{\pm}$) pairs (e.g., Nikishov 1962; Gould & Schreder 1966). In addition, $e^{\pm}$ pairs that are produced by γ–γ interaction process may produce a new γ-ray emission through inverse Compton scattering of these $e^{\pm}$ pairs against Cosmic Microwave Background (CMB) photons to GeV energy bands (Dai *et al.* 2002; Neronov *et al.* 2011). In this paper, we consider a secondary γ-ray emission component to an extreme blazar 1ES 0229 + 200 for the multiwavelength radiation. Throughout this paper, we assume the Hubble constant $H_0 = 70$ km s^{-1} Mpc^{-1}, the matter energy density $\Omega_M = 0.27$, the radiation energy density $\Omega_r = 0$, and the dimensionless cosmological constant $\Omega_\Lambda = 0.73$.

2. Model

In this model, both the primary photons produced in the source and secondary photons produced outside the source contribute to the observed high energy γ-ray emission. That is, the primary photons are produced in the source through the Synchrotron Self-Compton (SSC) process that uses a broken power-law function with a sharp cut off to describe the electron energy distribution in the radiation region (e.g., Katarzynski *et al.* 2001; Zheng & Zhang 2011; Zheng *et al.* 2011), and the secondary

Table 1. Modelling parameters for 1ES 0229 + 200.

Parameters	Values
Minimum Lorentz factor: $\gamma_{\rm min}$	3.5×10^4
Energy index: n_1	2.4
Broken Lorentz factor: $\gamma_{\rm break}$	5.9×10^6
Energy index: n_2	4.0
Maximum Lorentz factor: $\gamma_{\rm max}$	6.0×10^8
Density normalization coefficient: K [cm^{-3}]	1788
Size of the emission region: R [10^{17}cm]	1.8
Magnetic field: B [G]	2.6×10^{-3}
Doppler factor: δ	20
Intergalactic magnetic field: $B_{\rm IG}$ [G]	0.8×10^{-22}

photons are produced outside the source through inverse Compton scattering of $e^{\pm}$ pairs with cosmic microwave background, where $e^{\pm}$ pairs are produced through the interaction of TeV γ-rays emitted from the extreme blazar with the Extragalactic Background Light (EBL). We use the absorption optical depth which was deduced from the average EBL model by Dwek & Krennrich (2005), and we use the method given by Fan *et al.* (2004) (see for e.g., Yang *et al.* 2008) to calculate the secondary photons.

3. Application to 1ES 0229 + 200

The high frequency peaked BL Lac object 1ES 0229 + 200, at a redshift of $z = 0.14$, was discovered in the Einstein IPC Slew Survey (Elvis *et al.* 1992). H.E.S.S. observed results in 2005 and 2006 indicate that the source shows a hard intrinsic spectrum with high-energy peak of its spectral energy distribution above a few TeV (Aharonian *et al.* 2007). We applied the above models to 1ES 0229 + 200 multi-wavelength simultaneous observations and the modelling parameters are reported in

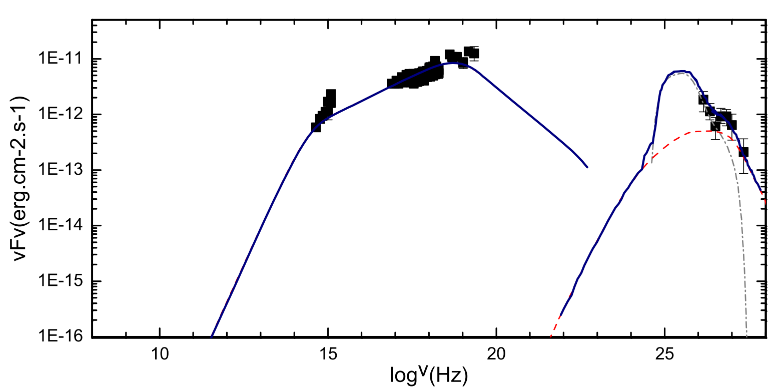

Figure 1. Comparisons of the predicted multiwavelength spectra with the observed data of 1ES 0229 + 200. The blue solid line, the red dashed line and the grey dash-dotted line represent the total radiation spectrum, primary radiation spectrum and secondary radiation spectrum, respectively. The observational data is taken from Kaufmann *et al.* (2011).

Table 1. Comparison of the predicted multiwavelength spectra with the observed data of 1ES 0229 + 200 are shown in Fig. 1. Assuming a suitable electron spectra and IGMF, we obtain excellent fits to the observed spectra of the source.

4. Discussion and conclusion

In this paper, assuming a suitable electron spectra and IGMF, we obtained excellent fits to the observed spectra of the source. This indicated that the observed excess GeV γ-ray emission can be explained by secondary γ-rays produced through inverse Compton scattering of $e^{\pm}$ pairs against CMB photons. Yang *et al.* (2008) accounted for possible GeV emission from TeV blazars. Their results indicated that the spectrum of the secondary γ-ray component is determined by IGMF, variation time and the flux level of TeV photons. In order to reproduce γ-ray emissions in our calculations, we adopted the IGMF strength as $B_{\rm IG} = 0.8 \times 10^{-22}$ G, and therefore, GeV γ-ray emission of the external component can dominate that of the source component. We argue that, if the flux of TeV photons is at a lower level, the fact that the source emission components are stronger than the secondary γ-ray component probably means that, in practice, TeV blazars do not show any significant secondary emission.

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