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Temporal Evolution of GRB Spectra: Leptonic and Hadronic

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Abstract. As the Fermi observatory has revealed, the GRB light curves show variant behaviours in different energy bands. Especially, the onset of GeV emission tend to lag that at lower energy. Various models to explain the GeV-delay, including early afterglow models or hadronic models, have been proposed. We have developed a time-dependent code for emission processes with one-zone approximation. The temporal evolution of GRB spectra is discussed based on leptonic inverse Compton and hadronic cascade models. This offers important predictions for future observations such as CTA.

Keywords. gamma rays: bursts, radiation mechanisms: nonthermal, cosmic rays

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1. Introduction

Most of the GRB spectra peak around the MeV range, and are well fitted by the usual Band function. In the standard picture, this component is explained by synchrotron emission from accelerated electrons, while alternative models have been proposed such as photospheric emission. The recent detection of GeV photons with *Fermi*-LAT has opened up the possibility of constraining such models. In some objects *Fermi* has also found in the GeV energy range additional spectral components (Abdo *et al.* 2009a,b, Ackermann *et al.* 2011, 2011). Moreover, the onset of the GeV emission tends to be delayed relative to the onset of the main MeV emission (Abdo *et al.* 2009c).

The photon statistics above the GeV range provided by *Fermi* are not sufficient to distinguish between the internal or external origin (Ghisellini *et al.* 2010, Kumar & Barniol Duran 2010) of the high-energy emission. However, it is expected that future multi-GeV observations with atmospheric Cherenkov telescope arrays such as CTA will drastically improve the data quality, owing to their large effective area. Lightcurves and spectral evolution measurements expected from such telescopes should provide critical information on the GRB physics. To discriminate between the emission models, detailed temporal-spectral evolution studies for various situations (e.g. Pe'er 2008, Vurm & Poutanen 2009, Daigne *et al.* 2011) are needed.

2. Leptonic and Hadronic Lightcurves

In our recent studies (Asano & Mészáros 2011, 2012), the temporal-spectral evolution of the prompt emission of GRBs is simulated numerically for both leptonic and hadronic models (e.g. Böttcher & Dermer 1998, Gupta & Zhang 2007, Asano *et al.* 2009a,b, 2010). We consider internal dissipation regions in possible models for explaining the delayed onset of the GeV emission. The numerical code can follow the evolution of the particle energy distributions in a relativistically expanding shell. For sufficiently weak magnetic fields, leptonic inverse Compton (IC) models can reproduce the few seconds delay of the onset of GeV photon emission observed by *Fermi*-LAT, due to the slow growth of the target photon field for IC scattering. However, even for stronger magnetic fields, the GeV delay can be explained with hadronic models, due to the long acceleration timescale of protons and the continuous photo-pion production after the end of the particle injection. While the FWHMs of the MeV and GeV lightcurves are almost the same in one-zone leptonic models, the FWHM of the 1-30 GeV lightcurves in hadronic models are significantly wider than those of the 0.1-1 MeV lightcurves. The amount of the GeV delay depends on the importance of the Klein-Nishina effect in both the leptonic and hadronic models. The amounts of escaped neutrons in our simulations are within the acceptable range for acting as UHECR sources. Since we have adopted large Γ and R values in order to simulate GRBs where GeV photons can escape from the source, the resultant neutrino spectra are hard enough to avoid the current flux limit constraints from IceCube (Abbasi *et al.* 2012). Our hadronic model also predicts a delayed onset of the neutrino emission, which is more pronounced than the corresponding GeV photon delay. If neutrinos are eventually observed, this point can also be directly tested. The quantitative differences in the lightcurves for various models may be further tested with future atmospheric Cherenkov telescopes such as CTA.

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