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Photospheric thermal radiation from GRB collapsar jets

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Abstract. Photospheric thermal radiation components from gamma-ray burst (GRB) jets are estimated based on relativistic hydrodynamic simulations of jet propagation. The light curves and spectra are derived, considering viewing angle effects. The light curves exhibit several seconds time variability and the luminosity is as large as that of GRB prompt emission. For observers at a viewing angle of several degrees the spectra below the peak energy are much softer than that of Planck distribution and close to typical GRB spectrum. Whereas the spectra for observers at small viewing angle are hard and close to Planck distribution. Numerical Amati and Yonetoku relations are reproduced.

Keywords. gamma-ray burst, hydrodynamics, numerical, radiation mechanisms: thermal

1. Introduction

The radiative mechanism of the GRB prompt emission is not fully understood. If the central engine produces a fireball, strong photospheric thermal radiation is expected during jet propagation into circum-stellar matter. The spectrum of the GRB prompt emission is a broken-power law. The νF_ν spectrum has a peak energy (E_p). The spectral index below the peak energy is typically unity which is much softer than that of single temperature Planck distribution. Recently thermal radiation components have been found in the spectrum of the GRB prompt emission, i.e., GRB090902B (Ryde *et al.* (2010), Zhang *et al.* (2011), and Ryde *et al.* (2011)), and GRB0909026B (Serino *et al.* (2011)).

The luminosity and spectrum of the photospheric thermal radiation from collapsar jets are derived theoretically by Pe'er & Ryde (2011), assuming steady and spherical outflow profile. Lazzati *et al.* (2009), Mizuta *et al.* (2011), Lazzati *et al.* (2011) and Nagakura *et al.* (2011) derived light curves of photospheric thermal radiation components from numerical relativistic hydrodynamic simulations. The luminosity is high enough to explain the prompt emission of typical GRBs. In this report, we show the results of photospheric thermal radiation, considering viewing angle effects.

2. Model, Methods, and Results

2D relativistic hydrodynamic simulations on jet propagation from collapsars have been performed, assuming axisymmetry and equatorial plane symmetry. Numerical methods and jet model are the same as those used in Mizuta *et al.* (2011), except the radial computational domain is extended to $r = 3\times10^{13}$ cm. The model 16TI which is developed by Woosley & Heger (2006) is employed as a progenitor star. Duration of the injection is 30 or 100 s.

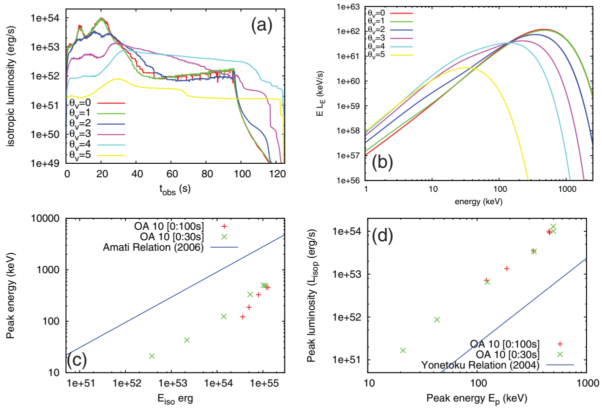

Figure 1. Light curves (a) and spectra (b) for different viewing angle (θ_{v}) observers (100 s injection model). $E_p - E_{\mathrm{iso}}$ (c) and $E_p - L_{\mathrm{iso}\,p}$ (d) plots with Amati and Yonetoku relations.

Figure 1(a) shows light curves of the photospheric thermal radiation for different viewing angles (θ_{v}) (100 s injection model). The luminosity quickly increases for small viewing angle and the light curves exhibit a few second time variability. On the other hand, the luminosity is not so high at viewing angles of several degrees. Fig. 1(b) shows spectra of photospheric thermal radiation for different viewing angles (100 s injection model). The spectrum below the peak energy is a power law and the indices for small viewing angles are $1 \sim 2.6$, while the indices for several degrees viewing angles are $1 \sim 1.5$, which is softer than that of single temperature Planck distribution. The isotropic radiation energy and peak energy are shown in Fig. 1(c). The isotopic peak luminosity and peak energy are shown in Fig. 1(d). Both plots show good correlations and reproduce the trend of Amati and Yonetoku relations, although absolute values do not match (numerical Amati and Yonetoku relations).

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