



# Diffusion spectra of ultrarelativistic unevenly moving shell radiation

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## Abstract

We consider the dependence of diffusion spectra on acceleration and deceleration of the shell, which can be caused by the interaction of the shell with the environment, on the duration of the action of the gamma-ray burst (GRB) source and on the period of its action. With periodic action of the GRB source, a second maximum appears in the diffusion spectra at high frequencies. The closest to typical value of the low-energy spectral index is obtained for a decelerating shell with a duration of action of the GRB source not less than the diffusion time; the values of the high-energy spectral indices for the decelerating shell correspond to typical ones.

**Keywords** Gamma ray: bursts · Radiation mechanisms: thermal · Ultrarelativistic shell · Radiation diffusion equation

## 1 Introduction

Gamma-ray bursts (GRBs) spectra display a wide variety of both spectral and temporal behavior Teegarden (1998), Meszaros et al. (2002). The Band function matches the shape of most GRB spectra Axelsson and Borgonovo (2015), Li (2022). It is a smooth combination of two power laws (with low- and high-energy indices  $\alpha$  and  $\beta$  respectively). To describe the spectra of GRBs, in addition to the Band function, the ISSM function Yassine et al. (2020) and the COMP function Li (2022) are also used. At the same time, photospheric (thermal) component is observed in a large number of GRBs Pe'er (2015). The spectral composition and direct radio interferometric measurements of the afterglow dimensions allow us to conclude that the source of GRBs is ultrarelativistic plasma Kumar and Zhang (2015), Abdalla et al. (2019).

Previously, the radiative transfer equation in a relativistically expanding shell was obtained in the diffusion approximation, their solution for natural initial data was obtained and applied to the initial radiation of GRBs. It was shown that the initial stage of a GRB in the photon-thin case can be described by radiation diffusion in an ultrarelativistically

expanding shell Ruffini et al. (2013); the time interval during which it is still possible to use the diffusion approximation increases with increasing depth inside the shell according to a law close to a quadratic function; when approaching the diffusion time, the value of the limiting depth inside the shell for using the diffusion approximation increases, and the value of the radiation intensity decreases; during the main radiation of the photon-thin shell, the diffusion approximation is valid for most of the shell Siutsou and Kurhuzava (2021).

The radiation of an ultrarelativistically expanding shell was also considered in the case where the initial energy distribution in the shell depends on the depth inside it according to a linear law. In this case, the effective temperature and the instantaneous spectrum of the GRB at the initial moment of time, as well as the time-integrated spectrum at high frequencies, depend on the slope of the initial energy distribution function. The low-energy spectral index is the same for any initial energy distribution in the shell and is equal approximately +2; the high-energy spectral index increases with increasing slope of the function corresponding to the initial energy distribution in the shell and has values between  $-2$  and  $-14$ . This makes it possible to explain a large number of GRBs with a typical Band spectrum using our model. Siutsou and Kurhuzava (2023)

Some other functions of the initial energy distribution inside the shell were also considered Kurhuzava (2024a). For parabolic initial energy distributions inside the shell, the diffusion spectra depend on the initial energy distribution inside the shell only in the frequency region near the flux peak.

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