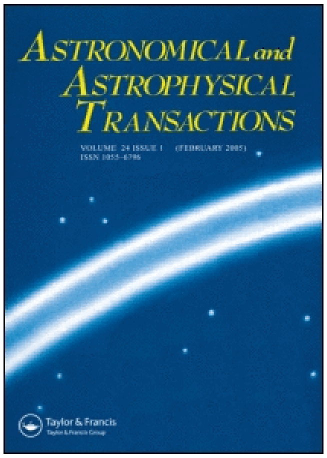

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Spectra of gamma-ray burst afterglows

A. Tolstov [a]; S. Blinnikov [a]
[a] Institute of Theoretical and Experimental Physics, Moscow, Russia

Online Publication Date: 01 December 2003
To cite this Article: Tolstov, A. and Blinnikov, S. (2003) 'Spectra of gamma-ray burst afterglows', Astronomical & Astrophysical Transactions, 22:6, 807 - 808
To link to this article: DOI: 10.1080/1055679031000148668
URL: http://dx.doi.org/10.1080/1055679031000148668

Astronomical and Astrophysical Transactions
Vol. 22, No. 6, December 2003, pp. 807–808

SPECTRA OF GAMMA-RAY BURST AFTERGLOWS

A. TOLSTOV* and S. BLINNIKOV

Institute of Theoretical and Experimental Physics, B. Cheremushkinskaja ul. 25, 117259 Moscow, Russia

(Received 14 November 2002)

Gamma-ray burst afterglows are believed to be described reasonably by synchrotron emission from relativistic blast waves at cosmological distances. We perform a detailed calculation using a full angle-, time- and frequency-dependent transfer equation and taking into account the effect of synchrotron self-absorption. The method developed for solving the transfer equation can be applied to the motion of a fluid with a Lorentz factor of up to 1000. We consider emission from the whole region behind the shock front and use the Blandford–McKee self-similar solution to describe the fluid behind the shock. We calculate the spectra and the light curves from a power-law distribution of electrons in an expanding relativistic shock and compare them with theoretical estimations.

Keywords: Gamma-ray bursts; Hydrodynamics; Relativity; Shock waves

We use a simple self-similar solution describing the explosion with a fixed amount of energy E_0 and propagation of a relativistic shock through a uniform cold medium (Blandford and McKee, 1976) and we limit the discussion here to the fully adiabatic case. We assume that a constant fraction ε_e of the shock energy goes into the electrons and the initial electron distribution is given by $N(\gamma_e) = K_0\gamma_e^{-p}$. We also assume that the magnetic energy density behind the shock is a constant fraction ε_B of the shock energy: $B^2 = 8\pi\varepsilon_B e$. The spectral emissivity and absorption coefficient is defined by synchrotron radiation (Rybicki and Lightman, 1979). The intensity I on the surface may be obtained by solving the radiative transfer equation in the comoving frame (Mihalas, 1980). We managed to solve the transfer equation numerically using a Runge–Kutta method with a global error control up to the Lorenz factor $\gamma \approx 1000$.

The flux density is given by

$$F_{0,\nu_0,t_{\text{obs}}} = \frac{2\pi}{D^2}\int_{\mu_{0,\,\text{min}}}^{1} \mu_0 R^2 I\left(r(\mu_0), \nu_0\left(\frac{\nu}{\nu_0}\right), \cos\delta\ (\cos\delta_0)\right)\left(\frac{\nu_0}{\nu}\right)^3 \mathrm{d}\mu_0,$$

where we omit the time dependence for short brevity, the subscript 0 is related to the observer frame, δ is the angle between the normal to the radiating surface and the direction toward the observer, D is the distance to the observer and μ_{min} can be obtained from

$$p'_\mu(1-\mu^2) - p(\mu - p) = 0.$$

Here $p = R/D$.

* Corresponding author. E-mail: t_alex@mail.ru

ISSN 1055-6796 print; ISSN 1476-3540 online © 2003 Taylor & Francis Ltd
DOI: 10.1080/1055679031000148668

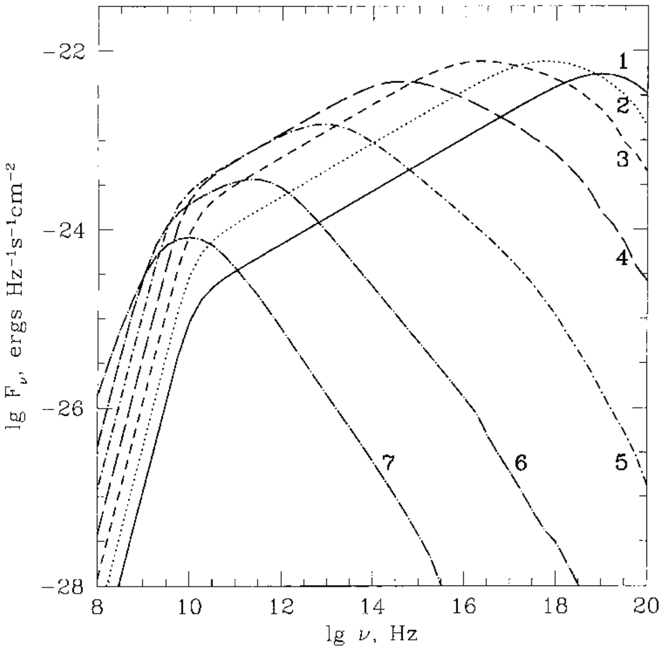

FIGURE 1 Synchrotron spectra of a relativistic shock with a power-law electron distribution at different times $t = 10^i$ s, $i \in \overline{1\ldots7}$.

In the calculation we use the following parameters: $E_0 = 10^{53}$ erg, $\varepsilon_e = 0.5$, $\varepsilon_B = 0.1$, $p = 2.5$ and $D = 10^{27}$ cm. The high value of energy refers to a spherically symmetric explosion, while in reality a gamma-ray burst (GRB) may be produced by a jet within a solid angle Ω; hence the total energy will be a factor of $\Omega/4\pi$ lower.

The main results of this calculation are summarized in Figure 1.

We have compared the calculated spectra with semianalytical estimates (Sari *et al.*, 1998; Granot *et al.*, 1999, 2001) for this simple problem and found that they are in good agreement with each other. This allows us to conclude that we have a workable method which is able to compute reliable spectra of GRBs and their afterglows in situations where simple analytical methods do not work (*e.g.* collisions of shocks).

References

Blandford, R. D. and McKee, C. F., 1976, Phys. Fluids 19, 1130.
Granot, J., Piran, T. and Sari, R., 1999, Astrophys. J. 527, 236.
Granot, J. and Sari, R., 2001, Astrophys. J. 568, 820.
Mihalas, D., 1980, Astrophys J. 237, 574.
Rybicki, G. B. and Lightman, A. P., 1979, Radiative Processes in Astrophysics, Wiley–Interscience, New York.
Sari, R., Piran, T. and Narayan, R., 1998, Astrophys. J. 497, L17.