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TEMPORAL VARIABILITY OF THE GRB LIGHT CURVE

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Abstract. The variability of Gamma Ray Bursts (GRBs) light curves at the beginning of GRB event can bring us information about the nature of the hidden 'inner engines'. Here, we will present a numerical model which can synthesize light curves in the first phase of GRB. At the beginning we assume that an 'inner engine' creates a large number of small mass shock waves which are expanding isotropically and after short period of time (a couple of seconds) disappearing in the surrounding media. This process causes creation of a massive shock wave which interacts with surrounding media and produces the GRB afterglow. The peaks in the light curve arise in the moment of mutual shocks interaction. We have modeled light curves from a given dynamics, by assuming synchrotron radiation mechanism.

1. MODEL

In order to explain a temporal variability of the light curve we propose the following scenario. In the first phase of explosion, central engine creates a large number of small mass highly collimated shocks which are expanding isotropically. These shocks have high Lorentz factors with different magnitudes, so the faster shocks can catch the slower ones - this is known as the internal model (Kobayashi, Piran and Sari, 1997; Fenimore and Ramirez-Ruiz, 1999; Piran, 2000). When interaction happens a number of radiating particles for faster shock sharply increases, as well as the velocity of particles, creating a pulse in the GRB light curve. Duration of the pulse depends on the width of the shocks and on its Lorentz factor, with typical values of several tens of milliseconds. Since the masses of shocks are relatively low (few orders lower than mass of the afterglow shock), they have short live times and suddenly disappear in surrounding media. But the central engine makes them repeatedly in the initial phase. They accelerate particles of the inter-stellar medium (hereafter ISM) around the GRB center, and together create one bigger, more massive shock, which continues to spread. Then starts the second phase of GRB, with creation of the afterglow.

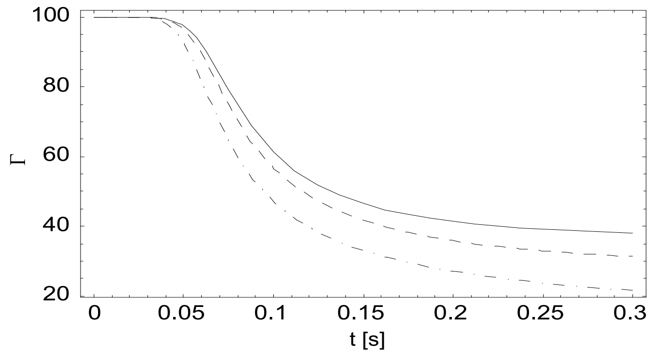

Figure 1: Evolution of Lorentz factor for a time of collision.

If the shock wave on his way, encounter another, the slower one, this event will increase the number of radiating particles. Mathematically, we may represent this density disturbance with a Gaussian function, where the width on the half maximum b represents the width of the slower shock, and intensity of the Gaussian a represents the slower shock number density. The equation we used have a following form:

$$n = n_0 \left(\frac{R_0}{R}\right)^s (4\Gamma + 3) \left(1 + a \cdot \exp\left[-\left(\frac{R - R_c}{b}\right)^2\right]\right) \tag{1}$$

where R_c and R_0 are the distance to the place of shock wave creation and the shock wave interaction, respectively. The n_0 is the density of the ISM (interstellar medium), and Γ is the Lorentz factor of the shock wave. The width of shock wave is given by Blandford and McKee (1976) and it is mainly in a range from $10^{12} - 10^{13}$ cm, depend on the relative velocity of the shock waves. This range may be broadened to higher values to include effect of grouping (superposition) of shock waves, then the maximal width of such composed shock is $\sim 10^{14}$ cm. Let us briefly describe the physical scenario of these processes. As we mentioned above, the number of small shocks is created by the central engine. They are colliding with each other and created pulses, but if some of shocks are not in collision, it will create a background radiation. If a collision is not enough intensive - low density shocks - pulses will be very small or will not be created at all. However, if collision include a broader and slower shocks with higher density, the produced pulse will be very intensive. This present main mechanism to explain high variability of the light curve.

That conformation of light curve is probably the result of specific distribution of ISM around the GRB center. It can be explained by the superposition of slower shock waves which have lost much of its energy, but stay in shock wave form. The presented model may simulate this situation with specific parameter values. In that case we were forced to change parameters a and b to acquire wider and low density barrier. Results of such analyze are not presented here in this paper and could be the subject of another research.

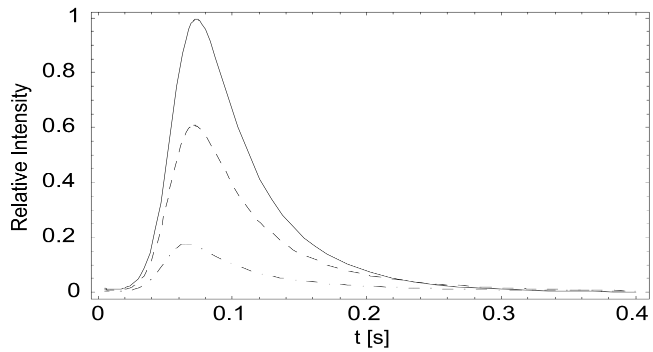

Figure 2: The shape of the typical GRB pulse given for three different values of ejected mass M_{ej}.

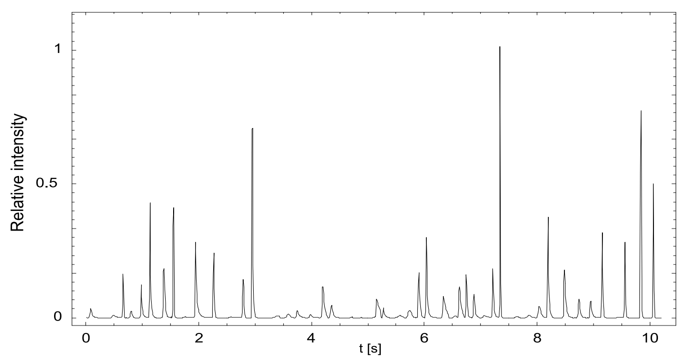

Figure 3: Synthesized temporal variability in the first 10 sec.

References

Blandford, R.D. and McKee, C.F.: 1976, *Physics of Fluids*, **19**, 1130.
Fenimore, E.E., Ramirez-Ruiz, E.: 1999, *Astron. Astrophys. Suppl. Series*, **138**, 521R.
Kobayashi, S., Piran, T., and Sari, R.: 1997, *Astrophys. J.*, **490**, 92.
Piran, T.: 2000, *Phys. Reports*, **333**, 529.