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# INFLUENCE OF BARRIER FORM ON THE SHAPE OF THE GRB LIGHT CURVE PULSES

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**Abstract**. In this contribution we investigated the influence of shape of barrier formed by the material ejected by the decelerated shock waves, on the light curve pulses. This research is done in the frame of the internal shock wave model which is broadly accepted to explain evolution and mutual interaction of relativistic shock waves in the first phase of gamma ray bursts. We have used the model which we develop in earlier work to follow the evolution and interaction of single shock wave. In order to investigate evolution of hydrodynamical parameters, as well as the effects on radiation which create light curve pulse, we replace the Gaussian profile of barrier with more suitable. Comparation and discussion with observational results is also presented.

## 1. INTRODUCTION

The internal shock wave scenario is widely accepted as a unique model for explanation of observed temporal variability of the GRB light curve (Piran, 2005). This scenario is connected with the first phase of GRB event. It proposes that GRB core generate vast number of relatively small mass shock waves with different velocities. Mechanism for creation of shock waves is based on a differential motion of ejected material, with the jump created on its front. When two of such shocks with different velocities collide and merge in one, the pulse in the light curve is created. Detailed model for treating of this scenario has been developed and explained in literature, see for example Kobayashi et al. 1997, Simić et al. 2007, etc.

In the paper mentioned above (Simić et al. 2007) we propose formation of the so-called density barrier, created by the accumulation and grouping of the ejected and slowed material of the shock shells. When newly created incoming fast shock wave interact with density barrier it produce pulse in the light curve with a different width and height. This is the main mechanism for explaining the observed significant differences in duration and intensity of light curve pulses. It follows from this prediction that the shape of the density barrier has a mayor influence on the form of the pulses in light curve.

In this paper, we want to investigate this influence by assuming the different shapes of the barrier. In the paragraph 2, we give mathematical interpretation and used formulas, in paragraph 3. the results are presented, and in the last paragraph 4. we presented the conclusion and final discussion.

## 2. MODEL

The model we use here is established and presented in the paper published by Simić and coauthors (Simić et al. 2007 - hereafter SP07). All basic equations are the same as in SP07, so here we will not repeat these. The change we did is connected with equation 5 in SP07, which is rewritten as:

$$n = n_0 \left( \frac{R_o}{R} \right)^s (4\Gamma + 3) f(q_1, q_2, ...) \tag{1}$$

where the last member of former equation describe shape of a density barrier. We take three different forms of it in order to test the influence of barrier profile on the shape of the light curve pulses. Used forms of the barrier are presented in Figure 1. and described by equations (1) to (3) for delta function, gaussian and slow-rise rapid-decay (hereafter SRRD) profile, respectively.

$$f(q_1, q_2, ...) = \begin{cases} a, & R_{\min} \le R \le R_{\max} \\ 1, & R < R_{\min} \,\&\, R > R_{\max} \end{cases} \tag{2}$$

$$f(q_1, q_2, ...) = \left( 1 + a \cdot \exp\left[ -\left( \frac{R - R_c}{b} \right)^2 \right] \right) \tag{3}$$

$$f(q_1, q_2, ...) = \begin{cases} a \left( \dfrac{R}{R_o} \right)^{n+2}, & R \le R_c \\ b \cdot \exp\left[ -k \left( \dfrac{R}{R_o} \right)^m \right], & R \ge R_c \end{cases} \tag{4}$$

The parameters *a* and *b* determine the height and width of the density barrier. Additional free parameters in Eq. (4) are for description of the slope of function $f(q_1, q_2, ...)$ and must be calculated in a way to avoid discontinuity at the point $R_c$. Some of used parameters have a constant values, for example $R_o$ distance of shocks origin (we use $R_o = 5\times10^{13}$cm) and *s* index of the density distribution in the domain where we observe the shock evolution (we use $s = 0$ for homogenous environment). The shapes of barrier used are presented in Fig. 1, where we can see they have same position of central part located around $R = 1.15\times10^{14}$cm. In addition, the width at the half maximum is equal for the first two functions, and slightly lower for the third function. All three functions are of the same height, scaled to one.

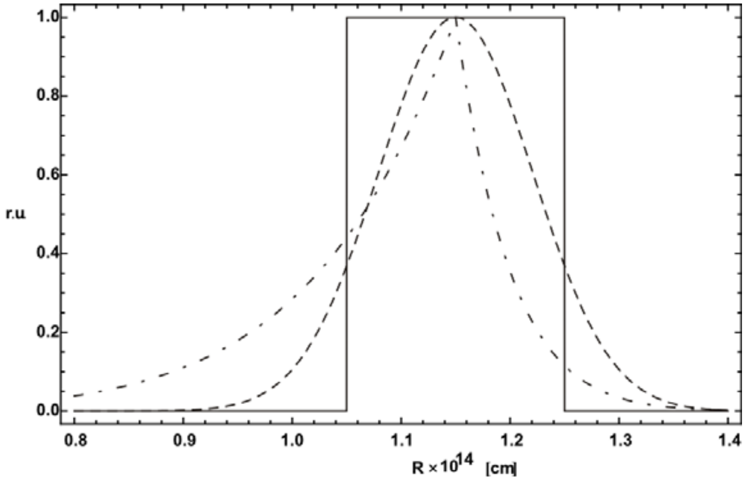

**Figure 1:** Shapes of three different density barrier used. Full line present delta like function, dashed line Gaussian and dash-doted line SRRD profile.

## 3. RESULTS AND DISCUSSION

The results of calculations for one interaction are presented in Figs. 2. and 3, where we can see the evolution of Lorentz factor, mass as well as position of shock wave, for three different forms of density barrier. We can see slight difference between separate cases. For example in the first case of delta-like function it is easy to notice a point of sharp discontinuity at the higher and lower part of curve. In other two cases decrease of $\Gamma$ and increase of $m_s$ and $R$ is presented with smooth curves. Also we can notice same trend of evolution for all tree cases, with small exeption for evolution of mass $m_s$. Namely, in the case of SRRD barrier profile, there is a smaller increase of mass compared to the other two cases. This could be explained in the contest of used function (Eq. 4), for this one has rapid decay after central maximum value, resulting in lower particle density.

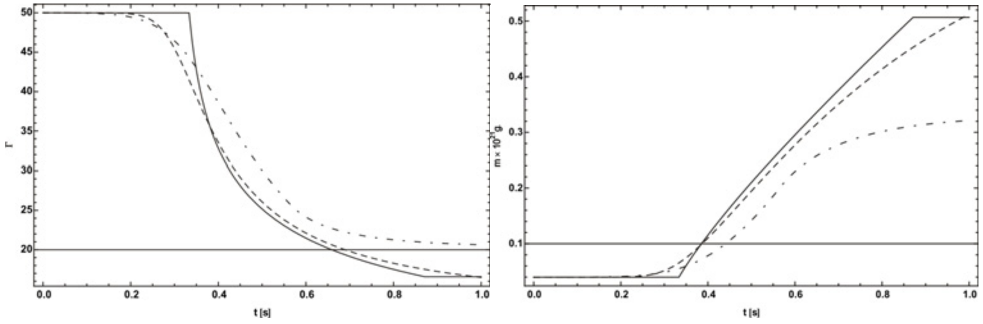

**Figure 2:** Evolution of appropriate Lorentz factors (left) shock shell mass (right). Types of lines are same as in Fig. 1.

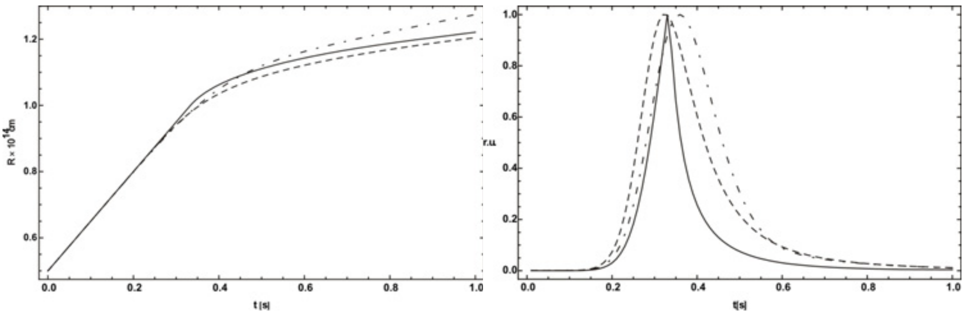

**Figure 3:** Evolution of distance of shock wave from GRB center (left) and shapes of sinthetized pulses given in the relative units for appropriate barrier form (right). Types of lines are same as in Fig. 1.

Finally, for synthetised GRB light curve pulse we get curves presented in Fig. 3 - right. They are given in relative units for easiest mutuall comparison. With the full line we describe the first case of delta-like function. That is idealised case which do not occure in real scenario. That is why it slightly deviate mostly in pulse widht from others two, presented with dashed line (Gaussian) and dash-doted line (SRRD). However, it is easy to notice the FRED (*fast rise slow decay*) profile of pulse in this case, which is also noticalble in the case of Gaussian barrier. In the thrid case of SRRD profile, the synthetised GRB light curve pulse is more symetric, without FRED behaviour. That could be explained with the shape of used barrier in the SRRD case, where number density of radiating particles, slowly increase and than rapidly decrease, what compensate in complete FRED property observed in the GRB light curves. The reason for use of this type of function is that barrier formed by merging and acumulation of shock waves can be well described with it. At the front of such moving density perturbation the particles number is always highest. In front of and behind the barrier center density of material decrease, more rapidly in the first case, so used SRRD profile is approximately appropriate for real situation.

In this paper we tested influence of different forms of barrier on the shape of GRB light curve pulses. The obvious results is that in all tree used cases the trend of changing is almost the same. There is a slight difference observed in the case of SRRD profile, where the FRED law is suppresed. Also, in the first case of delta-like function produced pulses are thiner then in the other two. On the basis of conducted research we can claim that in the case of two shock wave interaction the barrier profile is most likely described by the function in Eq. (4) what produce more symetric pulses. Contrary, when we have collision of fast shock wave with the slow or non-moving thicker barrier, the Gaussian profile is more appropriate. This interaction produce asymetric pulses with the FRED law more pronounced.

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## References

Kobayashi, S., Piran, T. and Sari. R.: 1997, *Astrophys. J.*, **490**, 92.
Piran, T.: 2005, *RvMP*, **76**, 1143.
Simić, S., Popović, L. Č., Andersen, M. I. and Chrinstensen, L.: 2007, *A&SS*, **309**, 173.