Hydrodynamical evolution of internal shocks in relativistic outflows

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The internal shock scenario is one of the most promising models to explain the observational feature of relativistic outflows as in gamma-ray bursts, and blazars. Most of the previous works, a simple inelastic collision of two point mass (e.g., Piran 1999) have been employed and little attention has been paid to hydrodynamical processes in the shell collision. However, it is obvious that, in the case of relativistic shocks, the time scales in which shock and rarefaction waves cross the shells are comparable to the dynamical time scale of Δ/c where Δ is the shell width measured in the shell comoving frame and c is the speed of light.

Hence, we study hydrodynamical effects of two colliding shells, the simplified models of the internal shock. The detail is shown in Kino, Mizuta & Yamada (in prep.) and the explanation of the special relativistic hydrodynamical code is expressed in Mizuta, Yamada & Takabe (2003). In this proceeding, we quantitatively show the main results of our recent work.

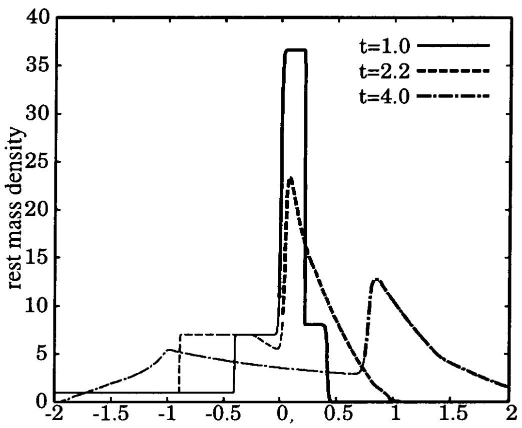

Figure 1: Rest mass density profiles in the case of equal mass shell where $\Gamma_r/\Gamma_s = 8$. The shell split feature appears by the rarefaction wave propagations.

Here we pay attention to the interesting case of a pair of shells with the same rest mass ("*equal mass*"). In Fig. 1, we show the case

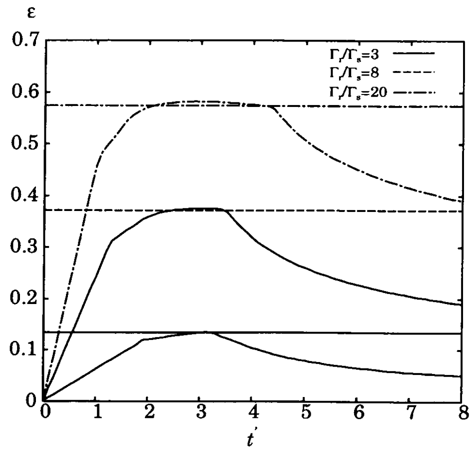

Figure 2: The conversion efficiency of the bulk kinetic energy to the internal energy.

of $\Gamma_r/\Gamma_s = 8$ where Γ_r and Γ_s are the Lorentz factors of the rapid and slow shells measured in ISM frame, respectively. We find that the density profiles are significantly affected by the propagation of rarefaction waves and show that a split-features at the contact discontinuity of two shells. We also find that the shell edge expands at a few ten percent of the speed of light after the collision. The conversion efficiency of the bulk kinetic energy to internal energy is also evaluated and the numerical result is presented in Fig. 2. Analogy of two point mass case, we define the efficiency as

$$\epsilon(t') \equiv \frac{\text{internal energy}}{\text{initial kinetic energy}} \quad (1)$$

In Fig. 2, we compare the numerical results with widely-used two point mass apploximation. Due to the rarefaction wave propagations, the efficiency is surpressed compared with the a simple inelastic collision model.

References

Kino, M., Mizuta, A., & Yamada, S., 2003 *in prep.*

Piran, T. 1999, Phys. Rep, 314, 575

Mizuta, A., & Yamada, S., & Takabe., 2003, ApJ, (in press)