Early Thermal X-Ray Emission from Long Gamma-Ray Bursts

SUZUKI, Akihiro (NAOJ)
SHIGEYAMA, Toshikazu (University of Tokyo)

Gamma-ray bursts (GRBs) are sudden appearance of gamma-ray point source on the celestial sphere. GRBs are divided into two groups, short and long bursts. Bursts with the duration longer (shorter) than 2 sec are classified as long (short) GRBs. Short GRBs are currently considered to originate from the merger of two neutron stars in a closed binary. Long GRBs are produced by an ultrarelativistic jet that launches as a result of the gravitational collapse of the iron core of massive stars, which is observationally confirmed by temporal and spacial coincidence between a special class of type Ic supernovae and long GRBs. Many problems, such as, radiation mechanisms of gamma-rays, jet injection, and so on, remain unsolved and discussed by a lot of researchers.

In this research [1], the dynamical evolution of an ultrarelativistic jet injected into the core of a massive star is investigated by two-dimensional relativistic hydrodynamic code developed by one of the authors (Figure 1). As a progenitor model, we adopted a Wolf-Rayet star with the mass of 14 $M_\odot$ and the radius of 4 $\times 10^{10}$ cm. Especially, we focus on the circumstellar medium (CSM) of the progenitor. Wolf-Rayet stars are considered to experience violent mass losing process prior to the gravitational collapse. Then, we calculate models with steady wind with the mass-loss rates 10^{-7}, 10^{-6}, 10^{-5}, 10^{-4}, and $10^{-3}\,M_\odot\,\mathrm{yr}^{-1}$ to investigate effects of the presence of dense CSM on the dynamics of the jet. In Figure 2, radial profiles of the velocity, the density, and the pressure along the inclination angle of 45° are compared for models with the mass-loss rates of 10^{-7} and $10^{-3}\,M_\odot\,\mathrm{yr}^{-1}$. In the dense CSM model, the reverse shock is formed and propagates in the ejecta. On the other hand, in the dilute CSM model, the rarefaction wave propagates in the ejecta.

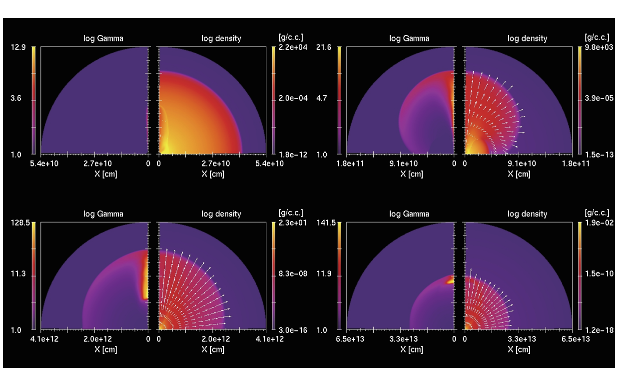

Figure 1: Results of relativistic hydrodynamical simulation of an ultrarelativistic jet emanating from a massive star.

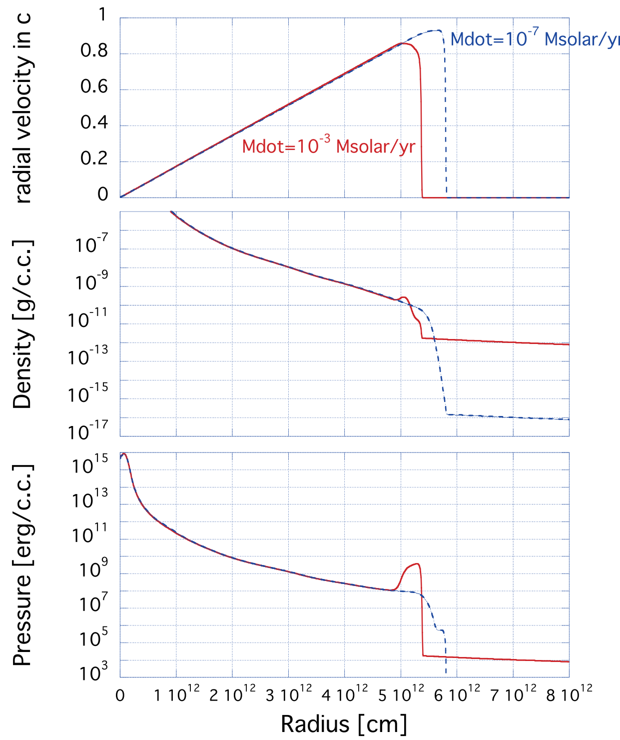

Figure 2: Radial profiles of the velocity (top), density (middle), and pressure (bottom) of the ejecta along the inclination angle of $\theta = 45°$. Solid and dashed lines correspond to dense and dilute CSM models.

Calculating the photospheric emission from the ejecta for each model, we found that the photospheric emission can explain properties of recently discovered thermal Xray emission from GRBs [2]. It may be possible that the circumstellar environment of massive stars that end their lives as GRBs can be probed by observing thermal X-ray emission.

References

[1] Suzuki, A., Shigeyama, T.: 2013, *APJ*, **764**, L12.
[2] Starling, R. L. C., Page, K. L., Pe'Er, A., Beardmore, A. P., Osborne, J. P.: 2012, *MNRAS*, **427**, 2950.