Rayleigh-Taylor (RT) 不安定性の成長による物質混合の３次元シミュレーション。

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1 Model

We performed high resolution 3D simulation of RT instability in the supernova envelope with AMR scheme. Primordial structure of our expanding supernova envelope is obtained from the established spherical model of SN1987A (Shigeyama 1990) and we started 3D AMR simulation from $t = 100\,\mathrm{s}$ model of spherical simulation. The simulation box is defined to be a cubic box of $0 \leq x \leq 1$, $0 \leq y \leq 1$, and $0 \leq z \leq 1$ and the explosion occurs at the origin, i.e., $(x, y, z) = (0, 0, 0)$. The boundary condition for the 3 planes of $x = 0$, $y = 0$, and $z = 0$ is reflecting one and that for the rest 3 planes of $x = 1$, $y = 1$, and $z = 1$ is free. We started our simulation with levels 5 - 11 FTT method (effective 2048^{-3} resolution). The specific heat ratio γ is assumed to be 4/3.

2 Compare 3D pertubation with 2D pertubation

At first, we input 3D perturbation as $V = v_r(1 + \epsilon\cos(m\theta)\cos(m\phi))$ and 2D perturbation as $V = v_r(1 + \epsilon\cos(m\phi))$ (where v_r is radial velocity at $t = 100\,\mathrm{s}$, ϵ $(= 0.05)$ is perturbation amplitude, and m $(= 20)$ is wavelength parameter) inside shockfront and compared their results. As like the growth rate of RT instability in 2 layers models simulation (see e.g., Noro et al. 2002), the mixing length (the height of mushroom like structure) obtained by inputting 3D perturbation is about 1.3 times larger than that of 2D perturbation

3 Perturbation Amplitude Parameter

We input perturbation as $\delta V = v_r \epsilon \cos(20\theta)\cos(20\phi))$ at $t = 100\,\mathrm{s}$ and carried out this survey for various perturbation amplitudes such as ε = 0, 1, 5, 10, 15, 20 and 30 %. Fig. 1 shows the final velocity of the interface between He and H layers against perturbation amplitude. When $\varepsilon \geq 0.1$, the final velocity is larger than the observed expansion velocity ($3000km/s \sim 4000km/s$). The final velocity increases linearly during $\varepsilon \leq 0.15$. But it saturates when $\varepsilon \geq 0.15$.

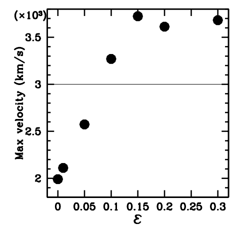

図 1: The final velocities vs perturbation amplitude ε.

we failed to reproduce observed high velocities with 5% perturbation. However there is no reason to limit on the direction of the perturbed motion to the radial direction. Since the turbulence inside the shock front is expected, initial perturbation could have random velocity component. Then, at some where, the combination of random components may result into congregated perturbation. We simulated such situation by changing the direction of perturbed velocity component artificially in order to concentrate four wave length components into one and its final velocity is 3510km/s. Similar situation would be taken place when the magnetic field converges the supernova explosion as like Balsala (2001) proposed or when the rotation effect plays similar role.

References

Shigeyama, T., and Nomoto, K., 1990, APJ, 360, 242.

Noro, A., Ogawa, T., Ohta, T., Miyaji, S., and Yamashita, K., 2002, IPSJ Symposium Series, 4, 9.