THREE DIMENSIONAL HYDRODYNAMICAL SIMULATION OF TYPE II SUPERNOVA

—— *Mixing and Fragmentation of Ejecta* ——

MIKIO NAGASAWA
National Astronomical Observatory
Mitaka, Tokyo 181
Japan

ABSTRACT. Adiabatic supernova explosions of polytropic stars are investigated by a three dimensional Smoothed Particle Hydrodynamics. The evolution of thermal point explosions is almost spherically symmetric in a global sense, but they are found to be unstable against Rayleigh-Taylor instabilities. The typical unstable wavelength, which grows in the nonlinear stage, is comparable to the thickness of the spherical shell. As a result, we find a porous density structure on the expanding shell. These results suggest the clumpiness of the ejecta of supernova explosions. The accompanying mixing motion in the expanding shell can explain the rapidly rising light curve of SN1987A. Because it may mix up the energy source ^{56}Ni towards the outer layers of supernovae.

1. Introduction

In hydrodynamical studies of supernova explosions, there have been several suggestions that expanding spherical shells are unstable against non-spherical perturbations. The deflagration fronts in Type I supernovae are not always spherical but showed finger-like shapes (Müller and Arnett 1986) . Tomisaka and Ikeuchi (1983) studied the stability of spherical shells against the non-radial perturbations and found that there are Rayleigh-Taylor instability modes for short wavelength perturbations.

Recently there are several observations which suggest non-spherical motion in the ejecta of SN1987A. The first is the observation of large linear polarizations, which suggests that the supernova ejecta itself is not spherical but prolate or oblate with a certain aspect ratio (Barret 1987) . The other is the observation of X-ray from SN1987A. It is suggested that the ^{56}Ni is mixed toward the surface due to convection or Rayleigh-Taylor instability (Itoh et al. 1987) .

D. McNally (ed.), Highlights of Astronomy, Vol. 8, 213–214.

https://doi.org/10.1017/S1539299600007796 Published online by Cambridge University Press

2. Numerical Models

There have been several simulations of axially symmetric explosions (Bodenheimer and Woosley 1983) . In such restricted systems, some important non-axisymmetric instability modes may have been omitted from the beginning. We try to study supernova explosions including non-axisymmetric modes (Nagasawa et al. 1988) .

We have developed our SPH code to be able to solve the energy equation to treat the adiabatic problem with arbitrary equation of state, not restricted for polytropic gas. Our code has resolutions fine enough to study the criterion for gravitational instabilities or to simulate the analytic shock solutions. (Nagasawa and Miyama 1987) . We solved the adiabatic explosion of polytropic stars. Because of the large explosion energy, self-gravity during the explosion has been neglected.

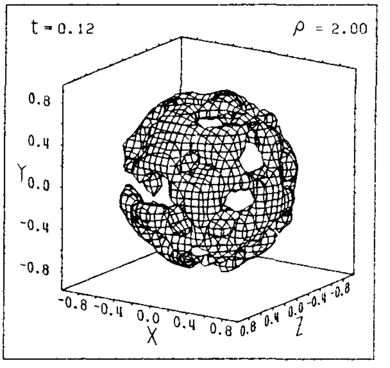

Fig.1. The 3D equidensity surface shows the void structure although the general motion is a spherical expansion.

3. Results

Thermal point explosions induce spherical shell expansions similar to that in one dimensional calculations and the Rayleigh-Taylor instability raises the density fluctuations in that shell. First in the linear stage, the small size of fluctuations appear on the contact discontinuity. The typical unstable wavelength, in the nonlinear stage, is comparable to the thickness of the spherical shell. The initial fluctuation is introduced as a numerical noise when we construct the 3-D equilibrium spheres by relaxation. The ejected gas, observed with a certain density level, seems very clumpy. The efficiency of the disruption does not increase with the explosion energy because the fast expansion has a shorter time before the break-up beyond the initial radius. The convection between shock front and contact discontinuity causes effective mixing in the shell. While, due to the phase cancellation of complicated fragments, there is no dominant contribution to the degree of polarization.

References

Barret, P., 1987. *ESO Workshop on SN1987A*, 174.

Bodenheimer, P., and Woosley, S., 1983. *Asrtrophys. J.* , **269**, 281.

Itoh, M., Kumagai, S., Shigeyama, T., Nomoto, K., and Nishimura, J., 1987. *Nature*, **330**, 233.

Müller, E., and Arnett, W.D., 1986. *Asrtrophys. J.* , **307**, 619.

Nagasawa, M., and Miyama, S.M., 1987. *Prog. Theor. Phys.*, **70**, 747.

Nagasawa, M., Nakamura, T., and Miyama, S.M., 1988. *Publ. Astron. Soc. Japan*, **40**, No.6.

Tomisaka, K., and Ikeuchi, S., 1983. *Publ. Astron. Soc. Japan*, **35**, 187.