Formation of the SN1987A Ring due to Magnetic Pressure

M. Mori[1], H. Washimi[2] and S. Shibata[3]

[1]Nagoya University, Japan; [2]Shonan Institute of Technology, Japan;
[3]Yamagata University, Japan

Several weeks after the explosion of supernova (SN) SN1987A, the UV flash of the SN illuminated a ring-like structure in the circumstellar material at about 0.65 ly from the SN. The interaction between the stellar winds from the SN progenitor is considered to be the candidate for the formation of the circumstellar structure. In the case that the stellar winds are spherically symmetric, the interaction should result in a shell-like structure. However, Washimi, Shibata & Mori (1996) show that the magnetic field in the winds causes an anisotropy which leads to the formation of a ring-like structure. When the fast wind of the blue supergiant phase of the progenitor sweeps up the surrounding slow wind of the red-supergiant phase, the magnetic field as well as the wind material are piled up in the interaction region. Since the magnetic energy increases in proportion to the square of the amplitude, the magnetic field exhibits its effect prominently at the interaction region; due to the magnetic pressure force the material at lower latitudes is compressed into a ring-like structure. It is suggested that this magnetic process can also explain the newly observed pair of rings of the SN1987A nebula. We note that the idea of a magnetic field effect is consistent with the radio observation of a supernova remnant, detected by Staveley-Smith et al. (1992) at about 1200 days after the explosion. This radio emission is explained by the collision of the supernova blast wave with the shocked blue wind. This position corresponds to the averaged expansion speed of the supernova ejecta ~ 0.08 ly which is consistent with the estimation by Shigeyama and Nomoto (1990). The estimated magnetic-energy density by the minimum-energy argument is $\sim 4 \times 10^{-8} f^{-4/7} N m^{-2}$, where f is the fractional volume of the radiating acceleration region, suggesting a magnetic field of a few milli-Gauss or more (Chevalier 1992). This field intensity is consistent with an intensity of $\approx 2 \cdot 10^{-4}$ Gauss obtained between the reverse shock and the contact surface shown, if one takes into account a further enhancement of the field due to the sweeping-up process by the supernova blast wave. When the SN ejector collides with the ring at the end of this century or at the beginning of the next one, we can also expect more intense radio emission at rather middle and high latitudes where the magnetic intensity is greater, rather than at the equator where the ring-like structure is located.

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