Highlights of Astronomy, Vol. 13
International Astronomical Union, 2003
O. Engvold, ed.

Extragalactic Binaries as Core-Collapse Supernova Progenitors

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Core-collapse supernovae (SNe) come in a variety of subtypes. The SNe II-plateau (II-P) show a long plateau in their light curves, as well as classical P Cygni Balmer line profiles in their spectra. The SNe II-linear (II-L) show a linear decline in their light curves after maximum, and the blue absorption trough in the Balmer lines is missing, leaving only broad emission profiles. The SNe II-narrow (IIn) show a narrow profile atop a broad base to the Balmer emission. The SNe Ib exhibit no hydrogen lines, but prominent He lines instead. The SNe Ic also show no H, but also weak or no He, with their spectra dominated by intermediate-mass elements. The SNe IIb start out appearing as SNe II(P), but in time evolve spectrally to resemble SNe Ib, with a later resumption of broad Balmer profiles, as in the case of SN 1993J (see Filippenko 1997 for a review of SN types). The progression from SNe II-P, II-L, IIn, IIb, Ib, through Ic may be due to the degree of stripping of the H-rich stellar envelope. Binary star systems are likely the progenitors of many core-collapse SNe. In fact, we might expect $\gtrsim$ 40–50% of all such SNe to arise from binaries (e.g., De Donder & Vanbeveren 1998).

Observational evidence supports the binary nature of the progenitors of some core-collapse SNe. One constraint on the binary nature of SNe Ib/c may come from their centimeter-wavelength radio emission. This synchrotron emission arises as the SN blastwave interacts with a dense, pre-SN wind-established, circum-stellar medium (CSM), leading to particle acceleration and compression of magnetic fields. In the case of SNe Ib/c, any dense CSM may require the presence of an interacting binary companion (Van Dyk et al. 1992; although see Chevalier 1998; yet also see Chevalier 2002). However, the association of two extreme SNe Ic, 1998bw and 2003dh, with long-duration γ-ray bursters implies, if the collapsar model is correct (e.g., MacFadyen & Woosley 1999), that some SNe Ic may arise from (single) very massive stars, possibly in the Wolf-Rayet phase. This is consistent with SNe Ib/c possibly being preferentially associated with massive star formation regions (Van Dyk et al. 1999), implying that SNe Ib/c arise from more massive progenitors than SNe II, further supporting the Wolf-Rayet model.

Various anomalies of and the famous circum-stellar ring structure around the peculiar Type II-P SN 1987A in the LMC can be explained by an accreting or merging binary system (e.g., Podsiadlowski 1992). The SN IIb 1993J in M81 has been proposed to be a binary KO I + OB? system (e.g., Aldering, Humphreys, & Richmond 1994). The radio emission for this SN implies a CSM density profile shallower than expected for a spherically symmetric progenitor wind, which might occur as a result of binary interaction. It is not clear from recent

https://doi.org/10.1017/S1539299600016324 Published online by Cambridge University Press

HST ACS images of a now much fainter SN 1993J that the blue companion has been detected.

The ~8% modulations in the radio light curves for the Type II-L SN 1979C in M100 imply a quasi-periodic, ~ 1575 d, variation in the pre-SN wind. This suggests that the progenitor was in a highly-eccentric, long-period ($P \sim 4000$ yr), interacting, massive (10 $M_\odot$ + 15 $M_\odot$) VV Cephei-like (RSG+OB) binary system (Weiler et al. 1992), This picture is supported by a full 2-D hydrodynamic simulation of the system (Schwarz & Pringle 1996). Similar bumps and dips in the radio light curves for the Type IIb SN 2001ig in NGC 7424 (Ryder et al. 2003), a SN quite similar to SN 1993J, imply modulations in the wind with $P \sim 600$ yr; this is generally far longer than stellar pulsation time scales, but is perhaps consistent with thermal pulse (C/He flashes) periods in 5–10 $M_\odot$ asymptotic giant branch stars. However, such time scales are also consistent with modulation in the colliding winds in an interacting WR+OB binary system.

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