Numerical models of collisions between core-collapse supernovae and circumstellar shells

Allard Jan van Marle^{1,2}
Nathan Smith^3
Stan Owocki^2
Bob van Veelen^4

1-Centre for Plasma Astrophysics, K.U. Leuven, Celestijnenlaan 200B, B-3001, Leuven, Belgium
2-Bartol Research Institute, University of Delaware, Newark, DE 19716, USA
3-Astronomy Department, University of California, 601 Campbell Hall, Berkeley, CA 94720, USA
4-Astronomical Institute, Utrecht University, P.O. Box 80,000, 3508 TA Utrecht, the Netherlands

Recent observations of luminous Type IIn supernovae (SNe) provide compelling evidence that massive circumstellar shells surround their progenitors. In this paper we investigate how the properties of such shells influence the SN lightcurve by conducting numerical simulations of the interaction between an expanding SN and a circumstellar shell ejected a few years prior to core collapse. Our parameter study explores how the emergent luminosity depends on a range of circumstellar shell masses, velocities, geometries, and wind mass-loss rates, as well as variations in the SN mass and energy. We find that the shell mass is the most important parameter, in the sense that higher shell masses (or higher ratios of M_shell/M_SN) lead to higher peak luminosities and higher efficiencies in converting shock energy into visual light. Lower mass shells can also cause high peak luminosities if the shell is slow or if the SN ejecta are very fast, but only for a short time. Sustaining a high luminosity for durations of more than 100 d requires massive circumstellar shells of order 10~M_sol or more. This reaffirms previous comparisons between pre-SN shells and shells produced by giant eruptions of luminous blue variables (LBVs), although the physical mechanism responsible for these outbursts remains uncertain. The lightcurve shape and observed shell velocity can help diagnose the approximate size and density of the circumstellar shell, and it may be possible to distinguish between spherical and bipolar shells with multiwavelength lightcurves. These models are merely illustrative. One can, of course, achieve even higher luminosities and longer duration light curves from interaction by increasing the explosion energy and shell mass beyond values adopted here.

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Email: AllardJan.vanMarle@wis.kuleuven.be