The Circumstellar Structure and Massive Progenitors of Interacting Supernovae

OR, How can we probe stellar mass loss after the supernova?

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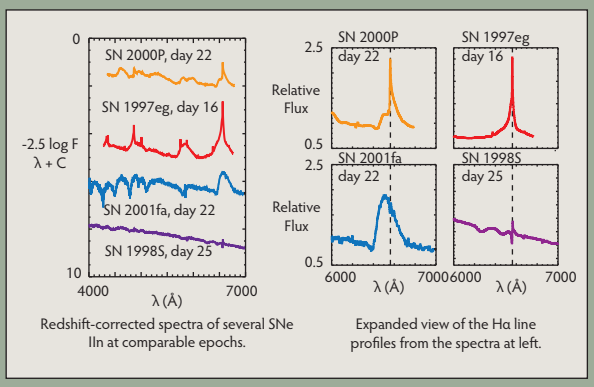
1. Some supernovae show signatures of interaction with dense pre-existing circumstellar material.

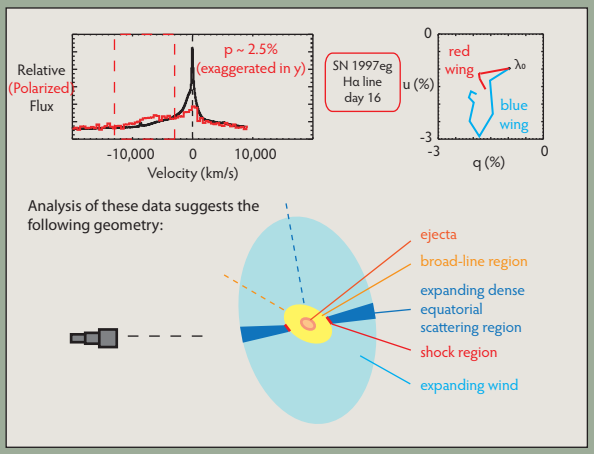


Redshift-corrected spectra of several SNe IIn at comparable epochs.

Expanded view of the Hα line profiles from the spectra at left.

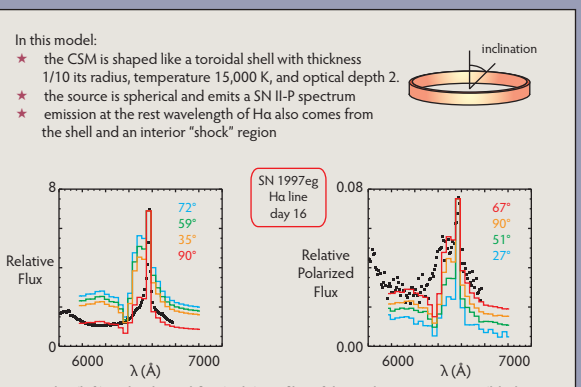
These "interacting supernovae" are also called Type IIn supernovae. They normally show strong, narrow hydrogen Balmer emission lines in their spectra. Aside from these emission lines, however, the category is heterogeneous. The wide variation in spectra, light curves, and radio/X-ray brightness among these objects may reflect differing characteristics of their circumstellar material. Because this CSM is formed by pre-supernova stellar winds, studying interacting supernovae can probe the mass-loss history of the most massive stars.

2. Polarization measurements give clues to the circumstellar geometry of these objects.



Spectropolarimetry distinguishes direct light from scattered light and constrains the shape and orientation of scattering regions. The example above is for the Type IIn SN 1997eg. Enhanced blue wings in the polarized Balmer lines suggested that the receding side of the expanding disk-like scattering region was obscured. Loop-like shapes (instead of straight lines or knots) across emission line profiles in the Stokes *q*-*u* plane implied that the emission and scattering regions were misaligned to one another.

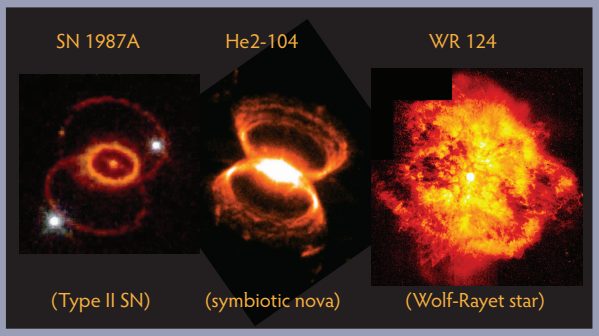
3. Numerical modeling helps interpret the polarimetry and constrain system parameters.



Flux (left) and polarized flux (right) profiles of the Hα line in SN 1997eg (black squares) compared with model results (colored lines) at various inclination angles.

Monte Carlo radiative transfer models predict the total and polarized flux profiles arising from different ejecta-CSM geometries. I have constructed model grids to investigate how different system parameters affect the shape of the Hα line. In the example above, the Hα profiles of SN 1997eg are well fitted by a model with a circumstellar toroidal shell, but the total and polarized flux profiles imply different inclination angles. This supports the finding of misaligned structures in the system (§ 2). A near-stationary shocked region inside the CSM appears to be important in creating the narrow "spikes" in the polarized flux profiles of this and other SNe IIn.

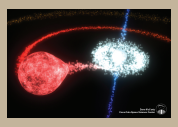
4. Comparing these CSM geometries with those of massive stars can link SNe with progenitors.



A better understanding of the structures surrounding interacting SNe will allow us to draw connections with massive star wind geometries. For example, misaligned components like those in SN 1997eg may imply a progenitor with unstable, convection-driven mass loss. Further studies combining polarimetry with numerical modeling promise to illuminate the nature of stellar mass loss at cosmological distances and in a variety of galactic environments.

THE FINE PRINT:
SNe IIn spectra are from Filippenko, private communication. SN 1997eg data are from Hoffman et al. 2007, astro-ph/0709.3258. HST image credits: (SN 1987A) C. Burrows, ESA/STScI, and NASA; (He2-104) R. Corradi, M. Livio, U. Munari, H. Schwarz, and NASA; (WR 124) Y. Grosdidier, A. Moffat, G. Joncas, A.Acker, and NASA. This research was supported by the National Science Foundation and by the National Energy Research Scientific Computing Center.

Also ask me about X-rays in β Lyr!



For detailed references and acknowledgments, please see other side...

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Acknowledgments

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