Lines and Loops:
Polarized Spectra Reveal Three-Dimensional Supernova Structure

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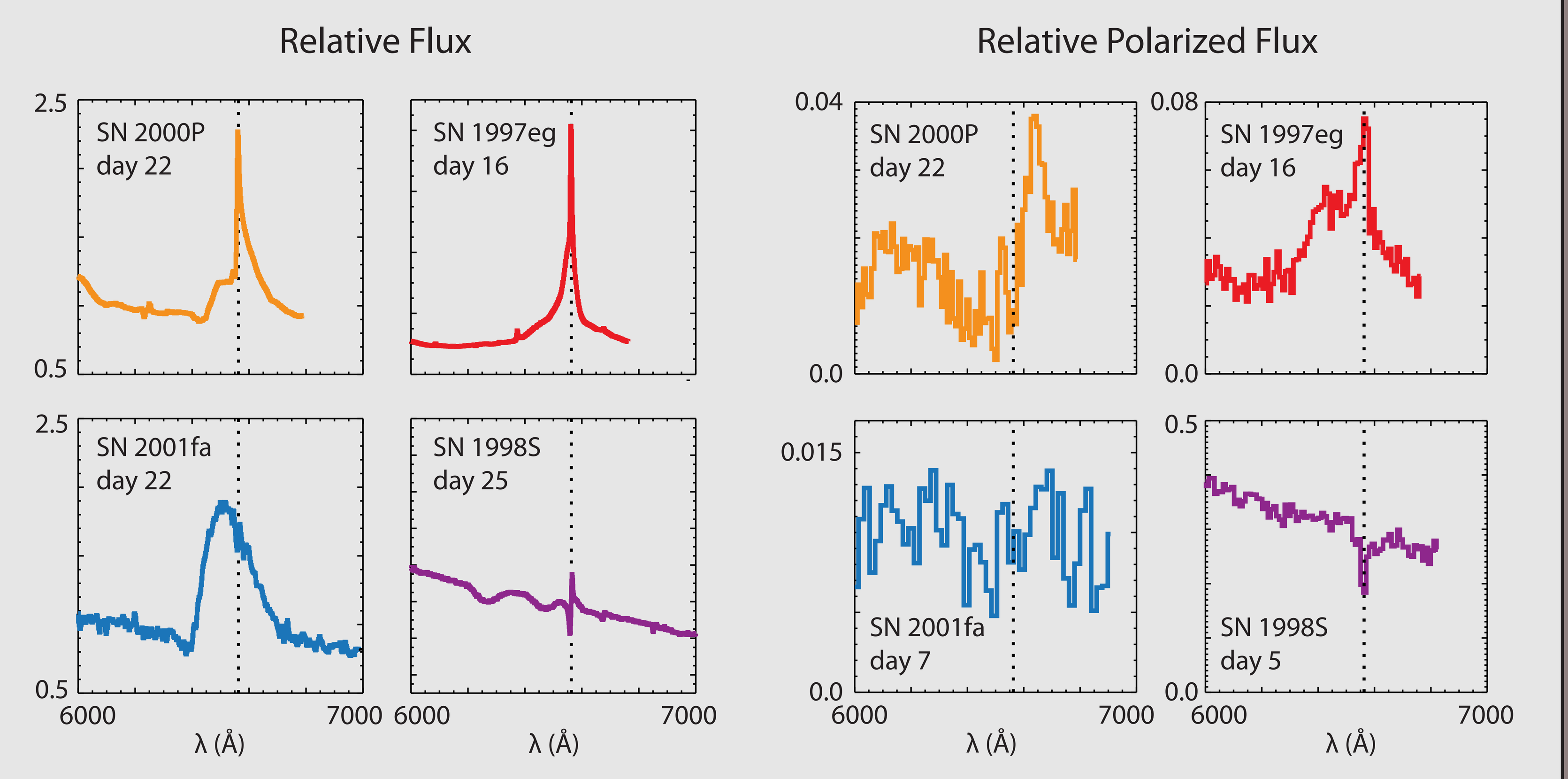
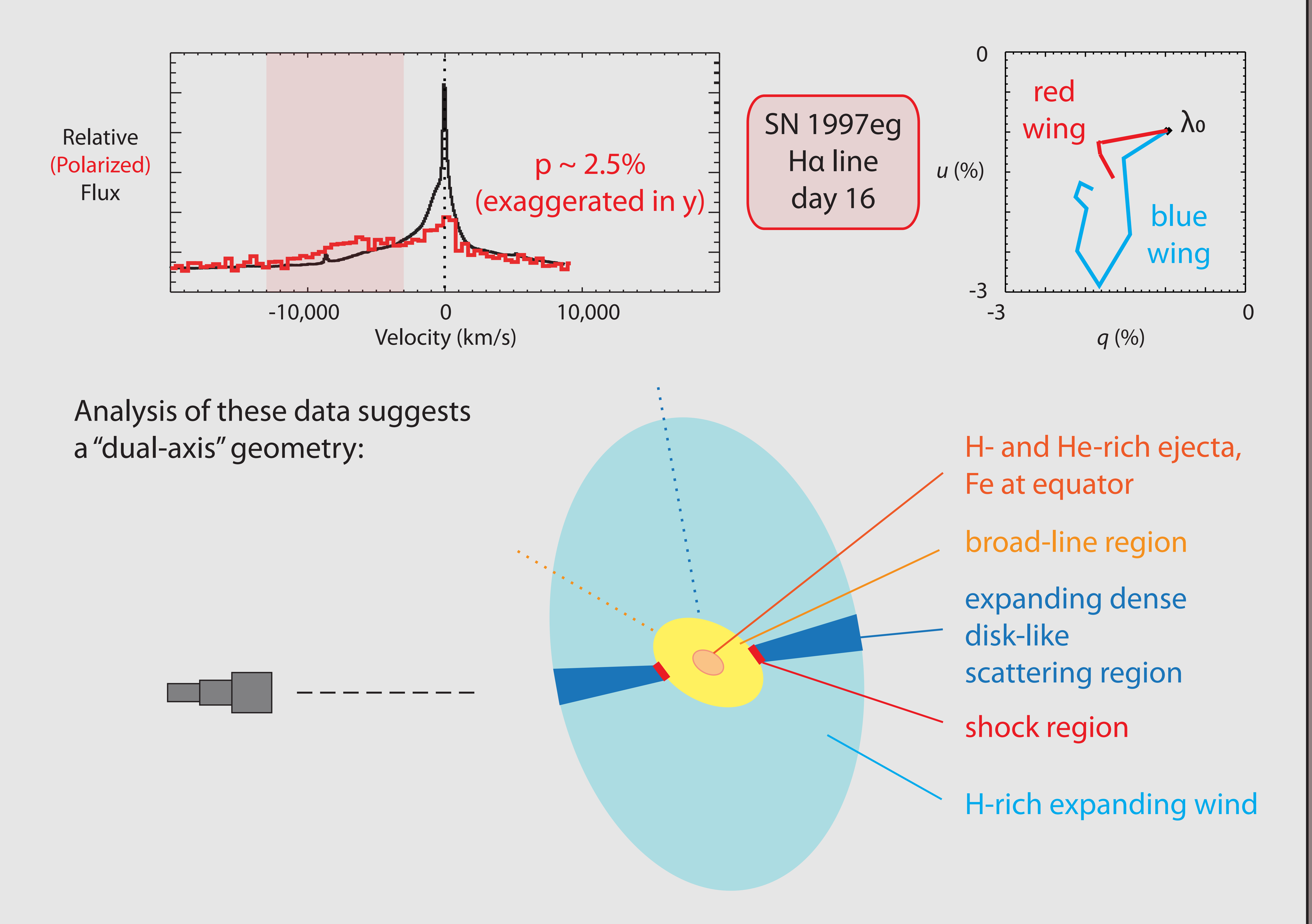
1. Some core-collapse supernovae are surrounded by dense pre-existing circumstellar material.



Hα line profiles of several SNe IIn at comparable epochs.
Both the flux and the polarized flux profiles vary widely between objects.

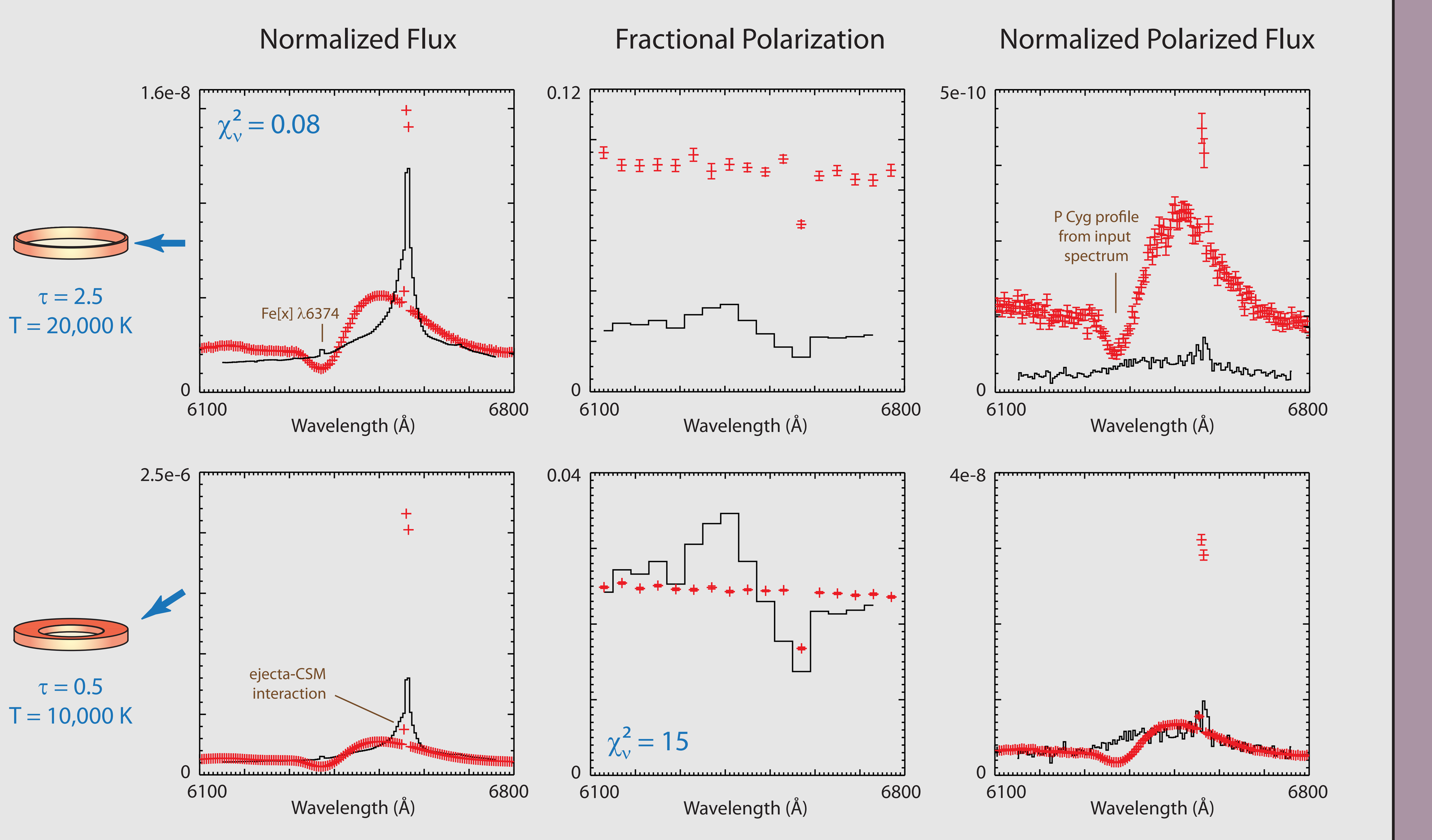
These "interacting supernovae," also called Type IIn supernovae, show strong, narrow hydrogen Balmer emission lines in their spectra. However, the category is heterogeneous, with wide variation in flux and polarization spectra, light curves, and radio/X-ray brightness among these objects. Such variations 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. Analysis of polarized line profiles gives clues to the circumstellar geometry of these objects.



Spectropolarimetry constrains the shape, orientation, and composition of circumstellar scattering regions. In 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 across emission line profiles in the Stokes *Q-U* plane implied that the emission and scattering regions were misaligned to one another, suggesting a progenitor with unstable, convection-driven mass loss rather than a binary system. Analysis of other polarized lines revealed that the ejecta contained H, He, and Fe, while the wind was composed mainly of hydrogen with a mass of ~10 M_{sun} (consistent with an LBV eruption).

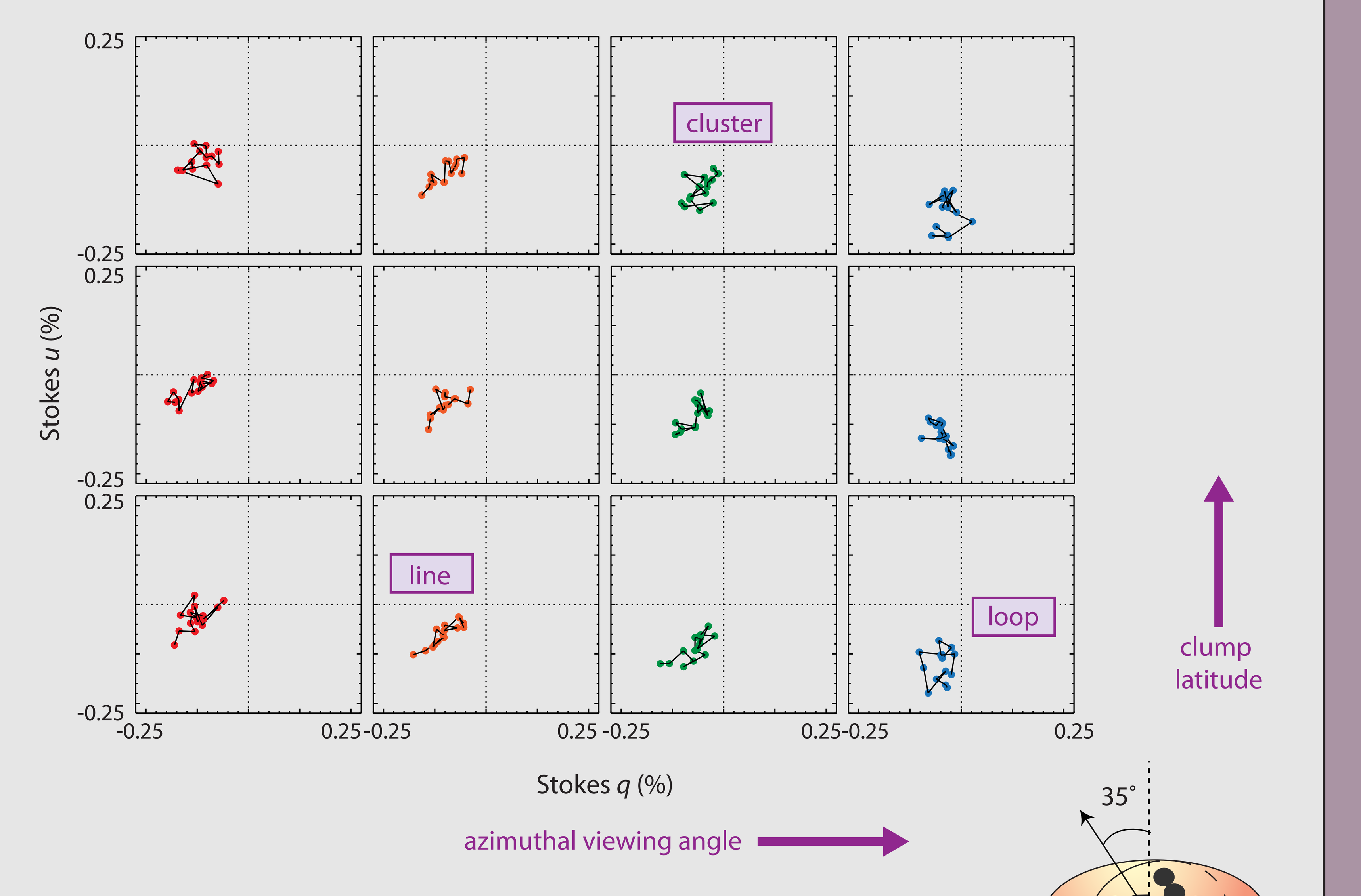
3. Numerical models provide diagnostics connecting CSM characteristics with line profiles...

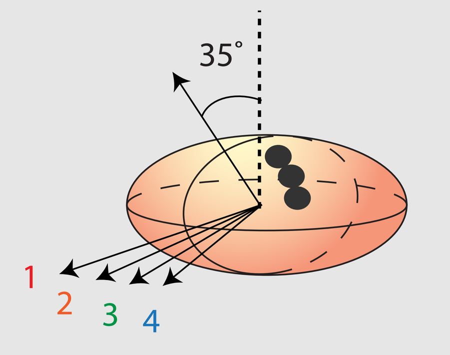


Profiles of the Hα line in SN 1997eg at day 16 (black lines) compared with two Monte Carlo models (red points). The upper model yields the best fit to the flux profile of all the models in our grid, but produces too little polarization. The lower model yields the best fit to the polarization profile and also fits the flux fairly well, but does not match the central "spike". Models do not yet include interaction between the ejecta and CSM, which likely gives rise to the intermediate-width "shoulder" in the observed data.

Monte Carlo radiative transfer models predict the (polarized) line profiles arising from different CSM geometries. In the example above, the difference in viewing angle between the best fit in total light and the best fit in polarized light supports the picture of multiple axes in SN 1997eg.

4. ... and with signatures in the *Q-U* plane.





Sample model investigating *Q-U* traces created by a dense, Hα-absorbing clump above an ellipsoidal scattering region. Wavelength range is the same as in the above simulations; data are binned to 60 Å.

Using a large grid of these models, I am also conducting a detailed study of the mysterious *Q-U* loops seen in a wide variety of SNe. Quantifying these loops' formation will help constrain the geometry, density, and temperature of the components of the circumstellar environment as a function of time during the SN's evolution.

A better understanding of the wind structures surrounding SNe IIn will help link them with potential progenitors in our own galaxy. Thus, developing spectropolarimetric diagnostics by matching data with models can 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. 2008, ApJ, 688, 1186. Sweden aurorae photo credit: P-M Hedén (Clear Skies, TWAN). This research has been supported by the National Science Foundation. Special thanks to DU research assistants Leah Huk, Cheridan Harris, and Charee Peters.

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