Statistical Analysis of Spectropolarimetric Models of SN 1997eg

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Background

Supernovae (SNe) classified as Type IIn possess strong, narrow emission lines, which indicate the presence of dense, ionized circumstellar material (CSM). This CSM generates from progenitor mass loss episodes prior to explosion. Reverse analysis of the polarized line profiles through model comparison allows us to extract information about the circumstellar material (CSM) and progenitor wind. Modeling the emission lines that arise from the interaction of a type IIn supernova with its surrounding CSM allows us to constrain its characteristics and assist in identifying any likely type IIn Sne progenitors.

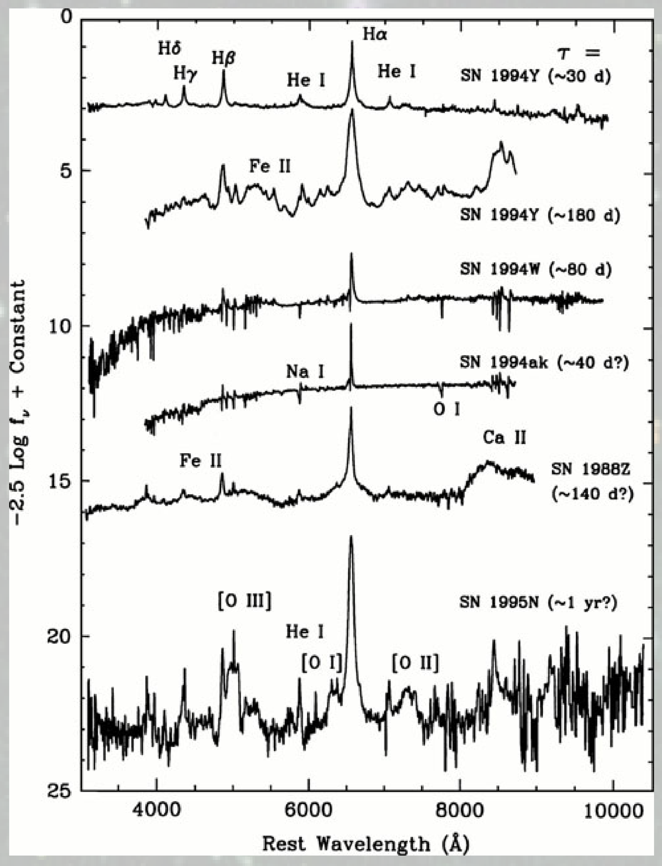
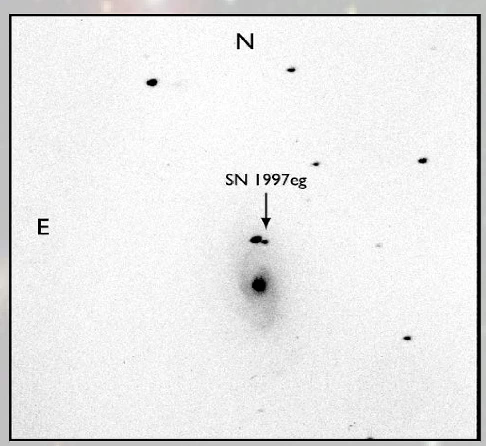


Figure 1: Spectral subtypes of core collapse supernovae

Introduction

Multi-epoch spectropolarimetric data were obtained for SN 1997eg using the Keck and Lick observatories, (Hoffman et al. 2008). The full spectral progression (Figure 2) of SN 1997eg spanning over a year of observations



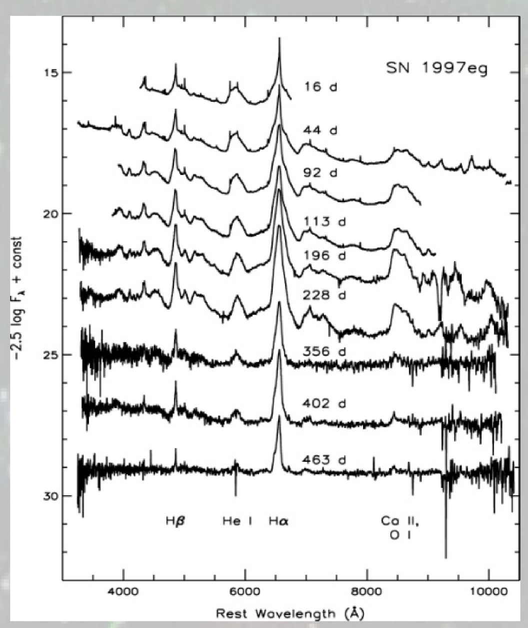


Figure 1 (above): *I*-band image of SN 1997eg and its host galaxy, NGC 5012 (Filippenko et. al. 2001). Figure 2 (right): Spectral evolution of SN 1997eg (Hoffman et al. 2008)

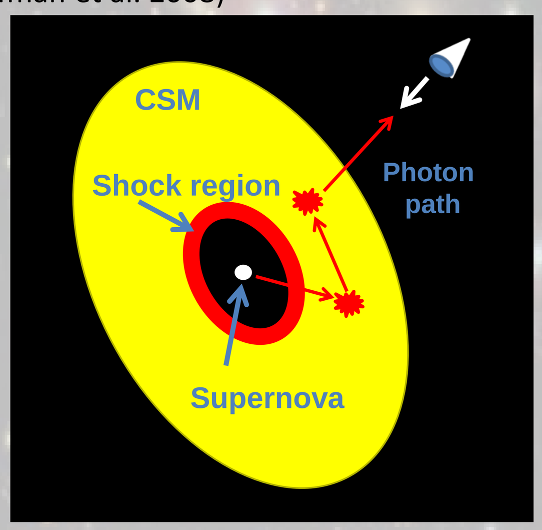


Figure 3: Path of a photon through the SLIP code

In the code, photons originate from a central supernova "source", a warm stationary CSM composed of hydrogen, and an ionized "shock" region interior to the CSM (figure 3). The CSM both scatters and absorbs photons.

A numerical 3-dimensional radiative transfer code called *SLIP* (Supernova LIne Polarization), developed by Jennifer Hoffman at the University of Denver, is used to investigate how CSM characteristics and viewing angle may influence the shape of hydrogen-alpha emission lines in both unpolarized and polarized light. *SLIP* tracks photons as they scatter through model CSM arrangements of varying optical and physical parameters.

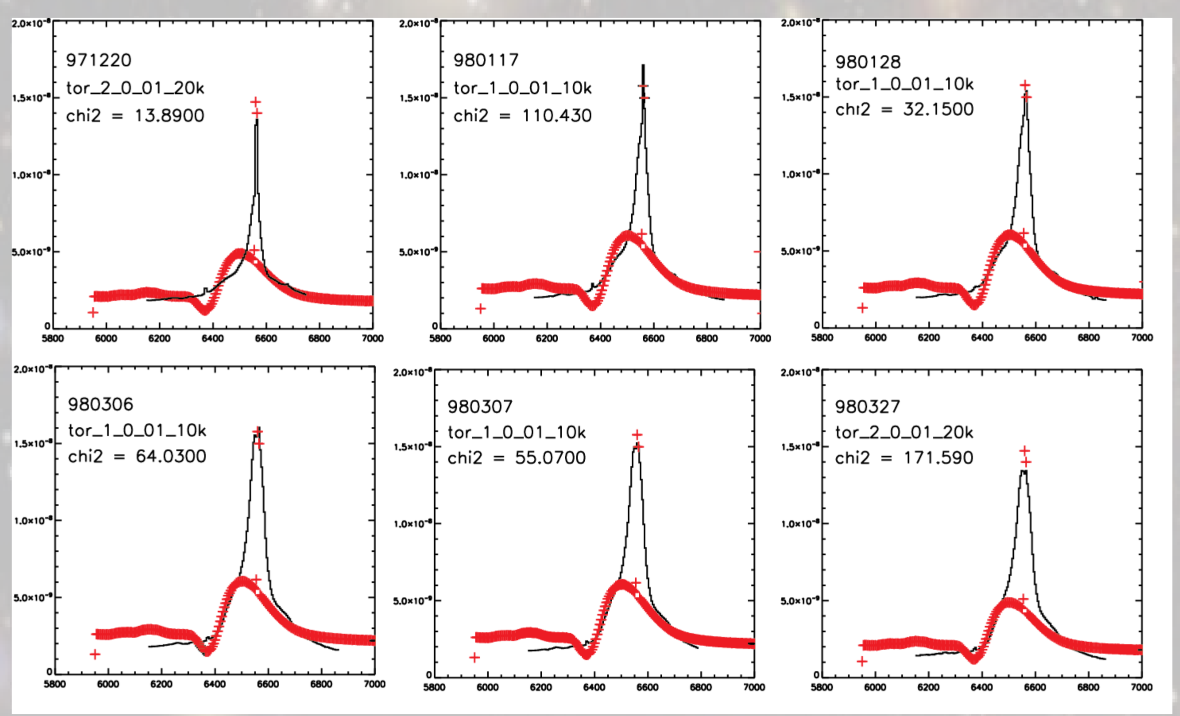


Figure 4 (left): Previous multi-epoch results from comparison of 1997eg with total flux spectra indicated a toroid at 20000k and a high optical depth.

We first used *SLIP* to create a grid of 300 models using only the total light spectra between 6000 Å and 7000 Å as seen from 12 different viewing angles. Our initial comparisons of the total light model grid with the H-alpha line profiles of SN 1997eg,suggested an optically thick disk-like scattering region viewed nearly edge on and becoming brighter over time.

Acknowledgments

This research has been supported by the National Science Foundation (AST 0807477) , a Summer Research Grant from the University of Denver, and the REU program and Prof. Keivan Stassun at Vanderbilt University

SN data courtesy A. Filippenko, UC Berkeley.

Methods

Before performing the χ2 fitting procedure, we first matched and normalized the spectra. Each set of model data was trimmed in wavelength to match the size of the observed 1997eg data for each epoch . We initially normalized the observed spectrum to the model spectrum at the bluest point. Finally, we shifted the model spectrum vertically (i.e., scaled the flux data) with respect to the observed flux data. To carry out the simultaneous fit, we concatenated the total flux and polarized flux vectors together by adjusting the wavelength vector to simulate two adjacent lines.

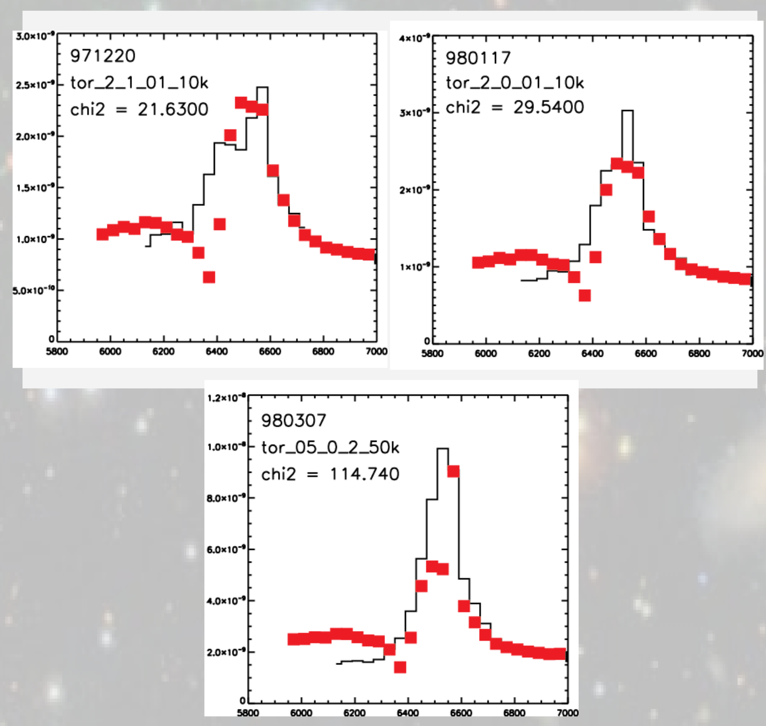


Figure 6: Group of best fitting toroid models (red) plotted with all three epochs of 1997eg polarized flux spectra (black).

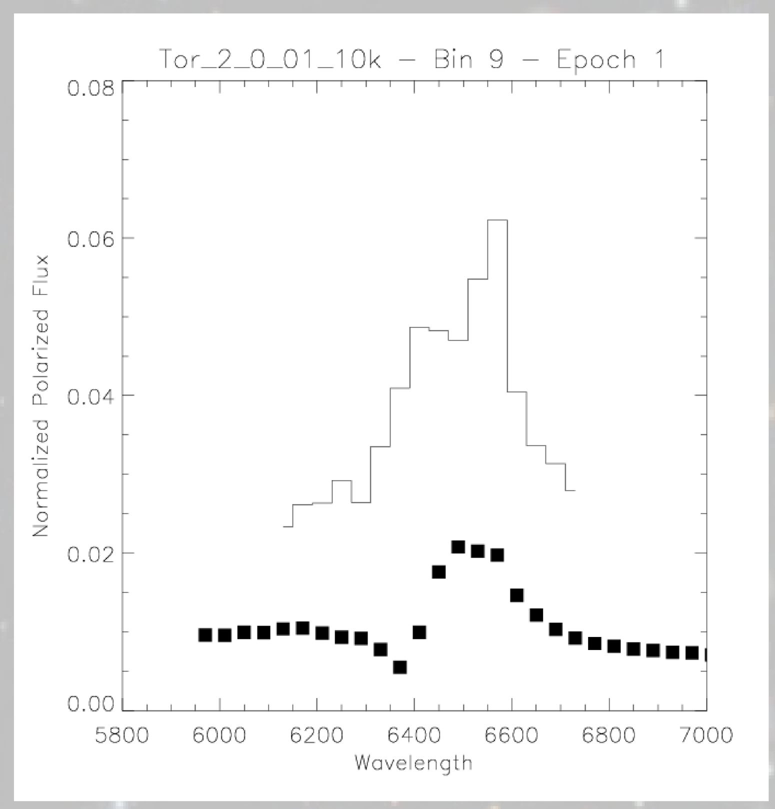


Figure 5: Model polarized flux spectra (squares) vs 1997eg polarized flux spectra (line). Wavelength is binned at 40 A.

Because each comparison has a different number of degrees of freedom, we present the results as reduced χ^2. Our number of degrees of freedom is *N-n*, where *N* is the number of wavelength elements and n=2 reflects the single "location parameter" introduced by model flux scaling. Using this method to test the observed data against each model and viewing angle in our grid, we calculated the χ^2 and reduced χ^2 value. Models with reduced χ^2 more than 3σ from the central *N-n* value do NOT arise from a parent population that looks like the model.

Results

In general, the reduced χ^2 values are most sensitive to viewing angle, with the statistically significant models lying in two valleys between angle bin groups 8 and 11. The viewing angle dependent trend is consistent across changes in both temperature and optical depth. This confirms our previous notion that in cases where CSM characteristics are well known from prior analysis, line profile fitting with *SLIP* can be used to determine the viewing angle about a toroidal CSM configuration. Behavior of fits for disks and ellipsoids behave similarly to that of toroids, with most notable dependence on viewing angle, ellipsoids having most significant models at slightly lower viewing angles between bins 4 and 7.

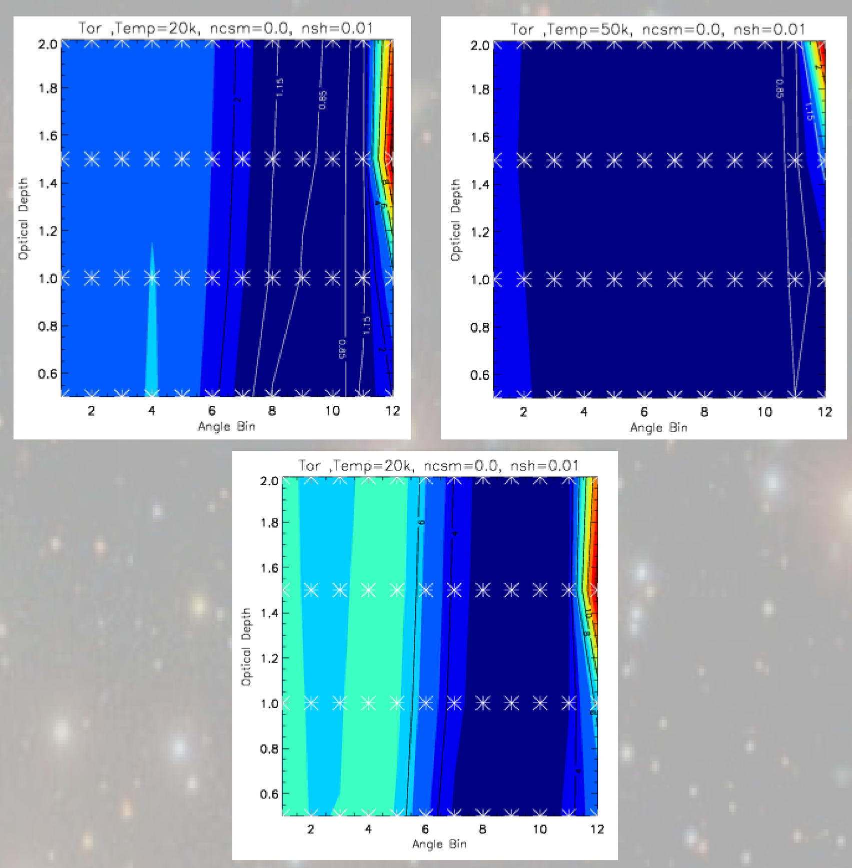


Figure 7: Best fitting model groups for total flux spectra, epochs 1-3

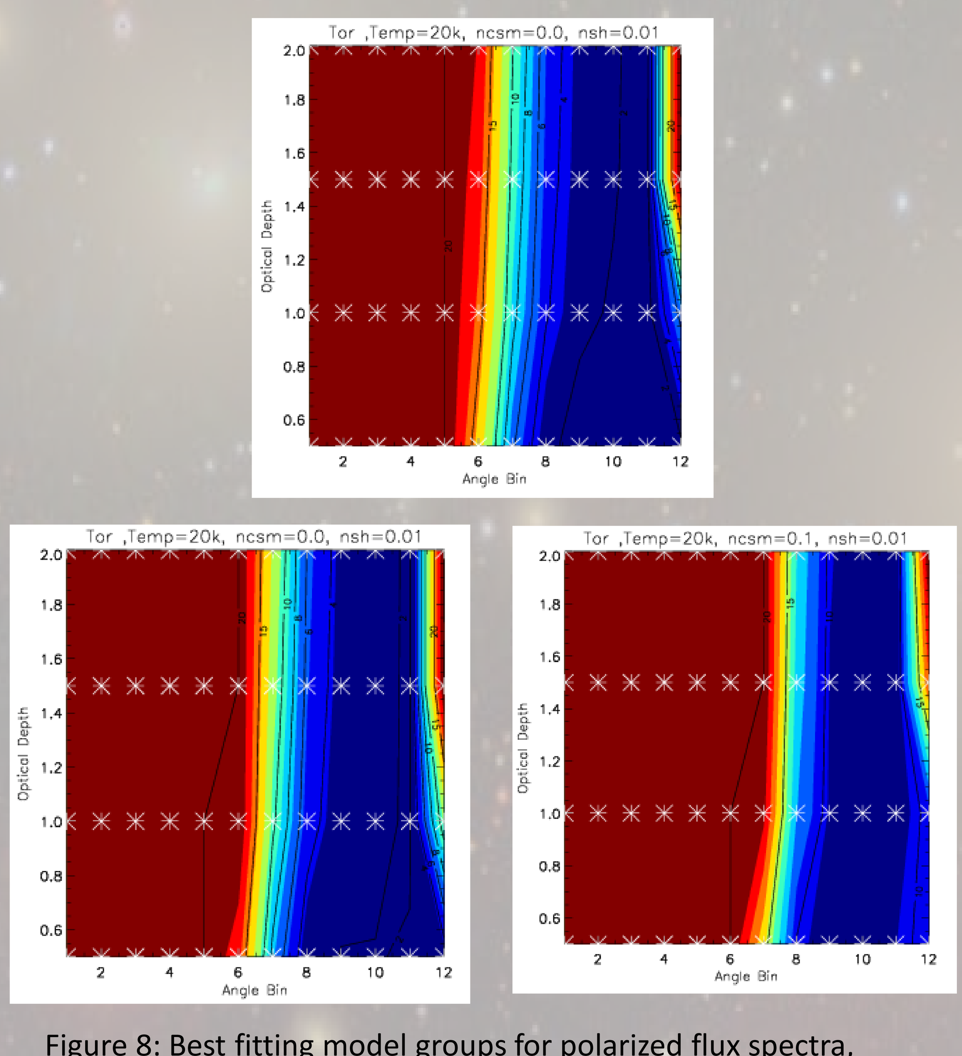


Figure 8: Best fitting model groups for polarized flux spectra, epochs 1-3

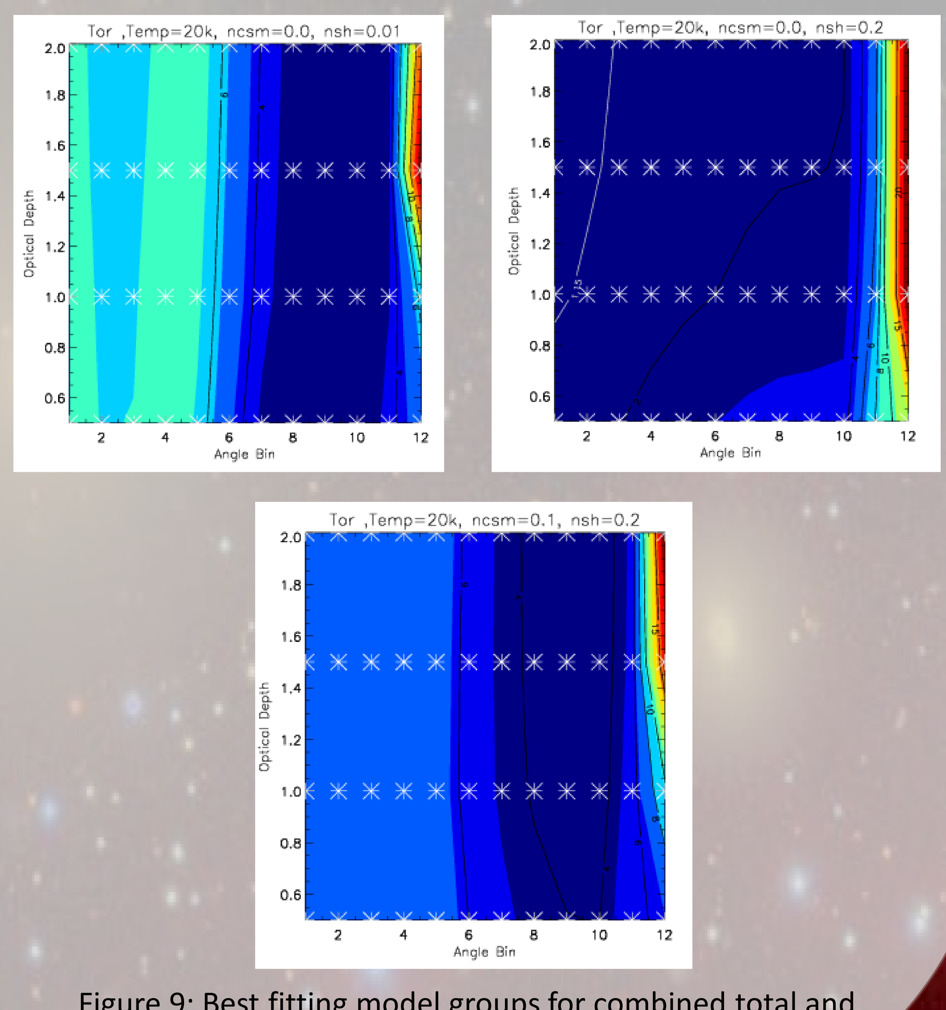


Figure 9: Best fitting model groups for combined total and polarization spectra, epochs 1-3

Future Work

We plan to continue statistical verifcation of our model fits by implementing a Komolgorov-Smornov test. We also plan to expand the model analysis to include more epochs of data, different spectral lines, and spectra of other type IIn supernovae.

SLIP does not currently account for more complex behavior such as the expansion of the ejecta or the CSM. We plan to augment the code to include these other phenomena.