Celestial Explosions: Geometrically Classifying Supernovae

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Motivation

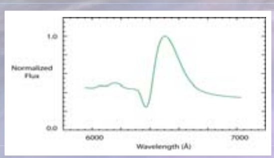
What are we studying?
Many supernovae (SNe), particularly those of Type IIn, show signatures of interaction with circumstellar material (CSM). We want to understand what these signatures can tell us about supernovae and their progenitor stars through unpolarized and polarized light. To do this, we compared a grid of models to the observed spectrum of SN 1997eg.

Why are we doing this?
We hope to be able to use numerical models to help interpret observations and constrain CSM geometries and other stellar parameters. This will help us to better understand the supernova explosion mechanism and draw connections between SNe and their progenitor stars.

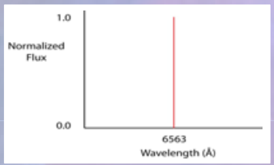
Background

We used three dimensional radiative transfer computer models to predict how polarized Hα emission line shapes correlate with various characteristics of the CSM, including geometry, optical depth, temperature, and brightness.

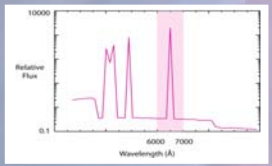
Our code, called *SLIP*, emits virtual, unpolarized photons from a central supernova source with a P Cygni profile in the Hα line; from a surrounding, stationary CSM composed of hydrogen; and from an ionized "shock" region interior to the CSM. The CSM also absorbs photons according to its temperature.



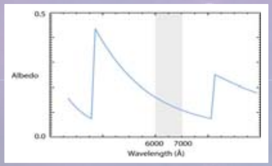
P Cygni profile arising from the expanding source



The narrow line emission arising from the nearly stationary shock region

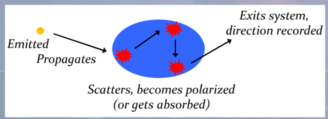


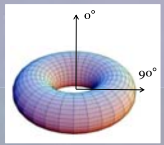
The hydrogen emission arising from the warm CSM



The albedo spectrum of the CSM

Once emitted, photons scatter in the CSM and become polarized via electron scattering. Outgoing photons are binned by viewing angle (each model contains data for all viewing angles).

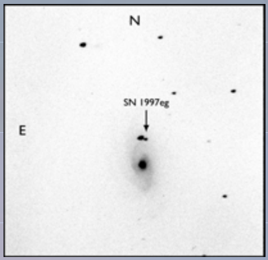




We created a grid of 108 numerical models simulating unpolarized and polarized Hα line profiles for different combinations of parameters.

Methods

As our observational comparison, we used data on SN 1997eg obtained from the Low-Resolution Imaging Spectrometer on the Keck telescope on December 20, 1997 (Hoffman et al. 2008).

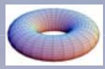


Parameter	Values Used
Geometry	Disk, Toroid, or Ellipsoid
Optical Depth	0.5, 1, or 2
Number of CSM Photons	0 or 0.1
Number of Shock Photons	0.01 or 0.2
Temperature	10,000 K, 20,000 K, or 50,000 K
Inclination Angle	0° - 90°

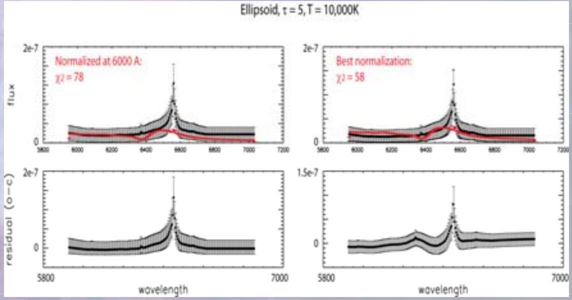
We created models with a spectral resolution of 5 Å. We then ran each model with enough photons to achieve a signal-to-noise ratio (SNR) ten times that of the observational data.


Disk


Ellipsoid


Toroid (a thinner version of the disk)

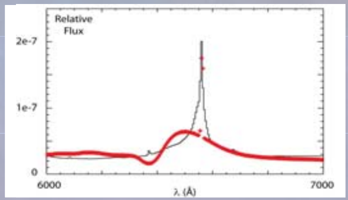
To compare the models to the observed data, we used a chi-squared analysis. To perform the actual chi-squared fit, we created multiple IDL routines.



First, we normalized a single model's data and the observed data at 6000 Å. We then made a chi-squared fit to determine how far off the model is from the observed data across the whole spectrum. We then moved the spectra with respect to one another to see if there are any better fits. Residuals, the difference between the model and the observed data, are able to be calculated and plotted from the program. From this information, we knew which normalization gave the smallest chi-squared value for that model.

Finally, we repeated this process for all the other models to find the best fit of the entire grid.

Results



We found that a disk geometry with a temperature of 20,000K at a viewing angle of ninety degrees was the best fit to the observed SN 1997eg data.

Parameter	Best Fit
Geometry	Disk
Optical Depth	0.5
Number of CSM Photons	0.1
Number of Shock Photons	0.2
Temperature	20,000 K
Inclination Angle	90°

These results are consistent with the analysis of Hoffman et al. (2008), who analyzed spectropolarimetric observations of SN 1997eg and proposed a model for the CSM that included a nearly edge-on equatorial disk.

Future Research

Our next step is to repeat the same method for models of polarized light. From previous research, it was found that many of the unpolarized models are degenerate, but including information from the polarized spectrum helps to break some of this degeneracy. *SLIP* creates the polarized models along with the unpolarized, but a better resolution is needed for comparison.

We will then mathematically describe the properties of these polarized line shapes to better understand the relationship of the model parameters to the resulting profiles.

Finally, we hope to use our models to predict future observations of supernovae interacting with their CSM. This may have implications for SN classification schemes and progenitor identification.

This research has been supported by the National Science Foundation, a Summer Research Grant from the University of Denver, and the REU program at Vanderbilt University

Background Image (Orion Nebula) from STScI

Ellipsoid Image from virtualmathmuseum.org Toroid and Disk Image from www.math.havard.edu

SN data courtesy A. Filippenko, UC Berkeley