Cosmic Fireworks: When Stars Explode

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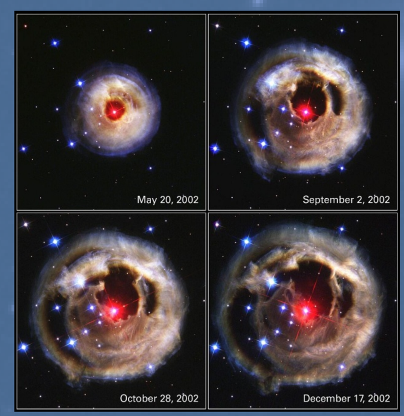
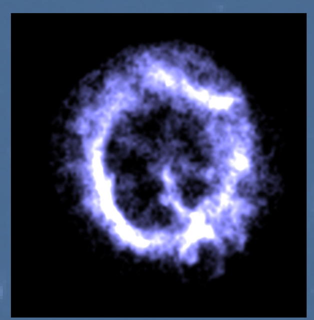
Definitions

Supernovae – exploding stars
Circumstellar Material (CSM) – clouds of hydrogen gas that surround supernovae
Ellipsoid and Toroid – two shapes that we set up the CSM as in our models
Photons – virtual light particles in the computer program

Motivation



Without supernovae,
we would not have all the elements that we see on the periodic table
we would not understand the life cycle of stars



What are we studying?
We want to understand what the CSM can tell us about supernovae and their progenitor stars

Why are we doing this?
We hope to be able to use observations to constrain CSM geometries and other stellar parameters .
This should help astronomers interpret new supernova observations to investigate the characteristics of pre-supernova stars

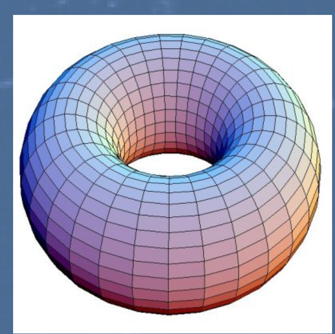
Methods

We are using three dimensional computer models to predict how hydrogen-alpha line shapes correlate with various characteristics of the CSM

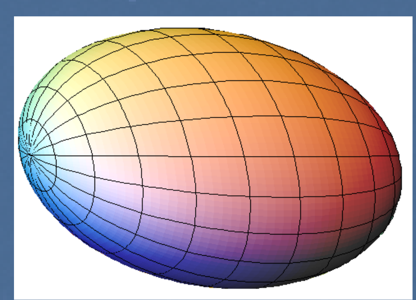
Our computer code simulates how light particles (photons) interact with the CSM on their way to our telescopes
Each of our models contains data for all viewing angles

We create graphs from the data that we collect

We compare the results of different models to see how changing the input parameters changes the line shape



Toroid



Ellipsoid

Supernova data: left panels are courtesy A. Filippenko (UC Berkeley). Top right panel is from Hoffman et al. 2008, Astrophysical Journal, 688, 1186. Bottom right panel is from Leonard et al. 2000, Astrophysical Journal, 536, 239
Ellipsoid Image from virtualmathmuseum.org
Toroid Image from www.math.havard.edu
Supernova images from Physics Central (X-ray image), Isaac Newton Group of Telescopes (V838 Mon), and Imperial College of Astrophysics (Supernova in Galaxy).
Background image (Hubble Ultra Deep Field) from ESA.

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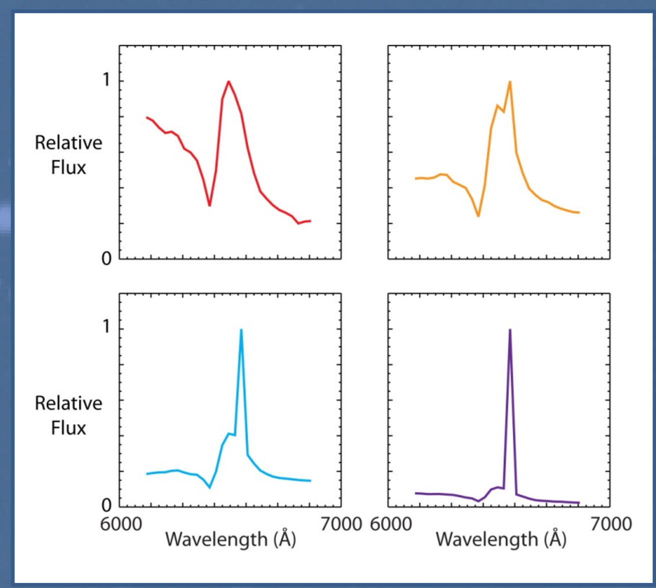
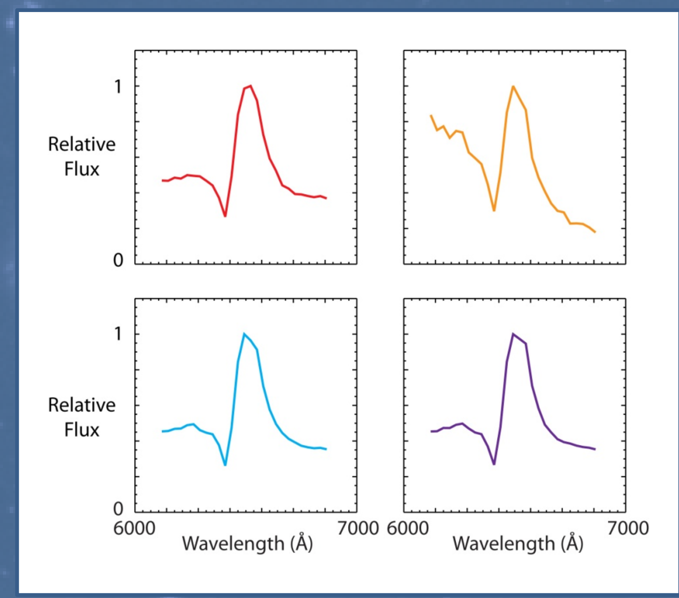
Results

What parameters are we changing?
Geometry – the shape of the CSM surrounding the supernova
Optical Depth – how opaque the CSM is
Number of CSM photons – how many photons came from the CSM itself, as a fraction of how many came from the star
Number of shock photons – how many photons came from the "shock" region inside the CSM, as a fraction of how many came from the star
Temperature – the temperature of the gas in the CSM

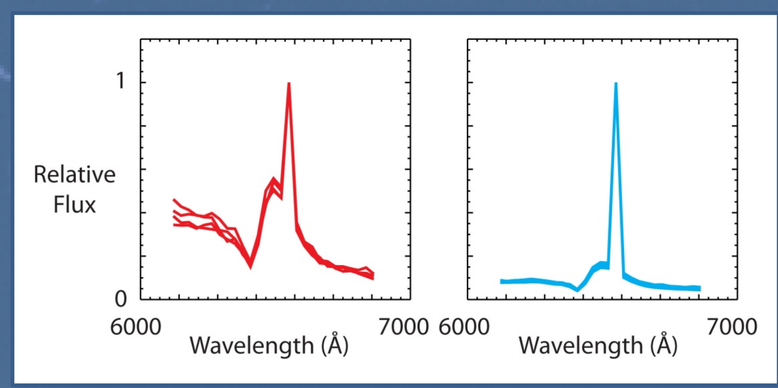
Parameter	Values We Used
Geometry	Ellipsoid or Toroid
Optical Depth	0.5 or 1
Number of CSM Photons	0.0 or 0.1
Number of Shock Photons	0.01 or 0.2
Temperature	10,000 K or 20,000 K



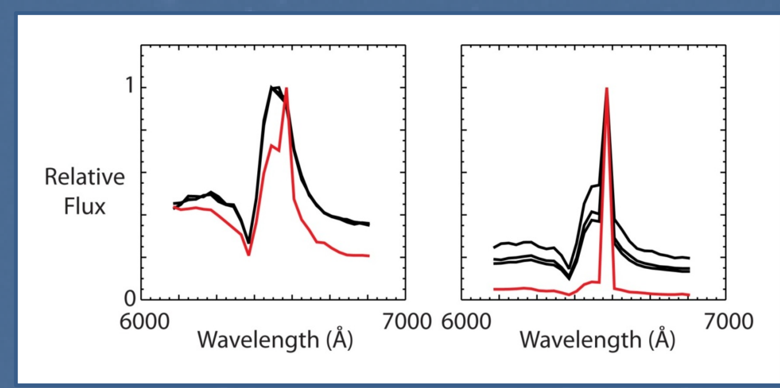
The image to the left shows the wide variety of line shapes that are produced from various runs.



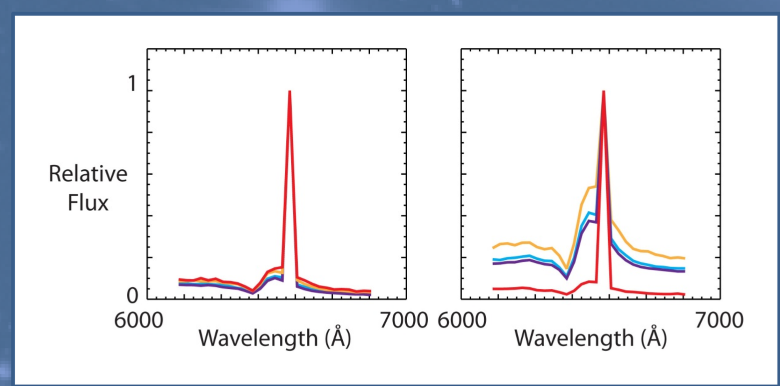
Even though the images on the left all have varied parameters, you can see the line shapes are very similar. This shows the degeneracy that still exists in our model.



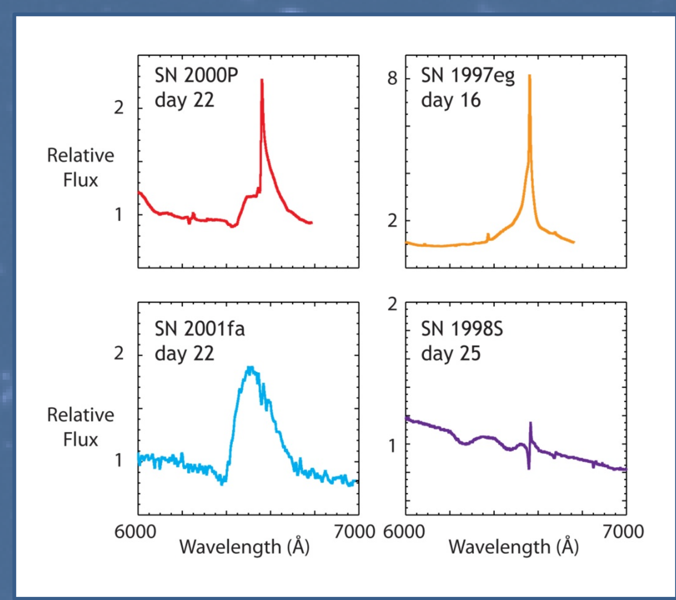
These two runs are the same except for temperature. Both are ellipsoid geometry. The left is 10,000K and the right is 20,000K.



The only difference in the runs above is the number of shock photons. The red shows an edge-on profile. We see that as shock photons increase, it produces a stronger narrow line at all viewing angles.



The two runs above are the same except for geometry (left - ellipsoid and right - toroid). The various colors show the different viewing angles. The ellipsoid shows that there is little difference in flux for each viewing angle, whereas the toroid has a variety of curves depending on the viewing angle.



On the left we see actual data from Type IIn supernovae. Many of these lines look similar to the ones produced by our model.

Conclusions and Future Research

Seeing different line shapes could help us distinguish CSM geometries and orientation, but more work is needed to resolve the degeneracy of some models
The models we made use unpolarized light. Models could also be made using polarized light
We will continue to compare our models with observed supernova lines to see if the models can explain the actual line shapes