Radiative Transfer Analysis of SN2012fr Using SYNOW and Phoenix
A Detailed Spectral Study

Christopher Cain
Adviser: Dr. Eddie Baron

Homer L. Dodge Department of Physics and Astronomy
University of Oklahoma

July 27th, 2017
SN (SuperNova) 2012fr exploded in the Fornax Cluster, Member NGC 1365.
SN (SuperNova) 2012fr exploded in the Fornax Cluster, Member NGC 1365.

First observed October 26th, 2012.
SN (SuperNova) 2012fr exploded in the Fornax Cluster, Member NGC 1365.

First observed October 26th, 2012.

Identified as a Type Ia supernova. Unusually high-velocity Silicon II features were observed in the spectra.
Observations of SN2012fr cover times ranging from $-16$ days to $+120$ days with respect to maximum light.
Importance of Type Ia Supernovae

- Progenitors are near-Chandrasekhar Mass White Dwarfs.
Importance of Type Ia Supernovae

- Progenitors are near-Chandrasekhar Mass White Dwarfs.

- Spectroscopically homogeneous cosmological reference points ("standard candles").
Importance of Type Ia Supernovae

- Progenitors are near-Chandrasekhar Mass White Dwarfs.
- Spectroscopically homogeneous cosmological reference points ("standard candles").
- Explosion mechanism is not well-understood.
Homology - In an ideal, spherically symmetric supernova,

\[ \text{Ejecta Velocity} \propto \text{Radius} \]
Some Terms

- **Homology** - In an ideal, spherically symmetric supernova,

\[ \text{Ejecta Velocity} \propto \text{Radius} \]

- **Photosphere** - Opaque (optically thick) surface of the supernova.
Some Terms

- **Homology** - In an ideal, spherically symmetric supernova, Ejecta Velocity $\propto$ Radius

- **Photosphere** - Opaque (optically thick) surface of the supernova.

- **Detachment** - Separation of some element (e.g. Si II) from the photosphere in velocity space.
SYNOW (SYnthetic spectra NOW) is a radiation transfer simulation code for Type Ia supernovae.
SYNOW (SYnthetic spectra NOW) is a radiation transfer simulation code for Type Ia supernovae.

SYNOW accounts for multiple scattering.
SYNOW (SYnthetic spectra NOW) is a radiation transfer simulation code for Type Ia supernovae.

SYNOW accounts for multiple scattering.

Large free parameter space.
SYNOW produces synthetic spectra which can be matched to observed spectra to obtain parameter estimates.
SYNOW produces synthetic spectra which can be matched to observed spectra to obtain parameter estimates.
A time series of fits suggested detachment of Si II near maximum light.
A time series of fits suggested detachment of Si II near maximum light.
SYNOW Results (cont.)

A time series of fits suggested detachment of Si II near maximum light.
Phoenix

- Phoenix is a comprehensive simulation code that calculates the physics of radiative transfer in a model of a Type Ia supernova.
Phoenix

- Phoenix is a comprehensive simulation code that calculates the physics of radiative transfer in a model of a Type Ia supernova.

- Provides information about detailed physical structure, as well as synthetic spectra.
Phoenix

- Phoenix is a comprehensive simulation code that calculates the physics of radiative transfer in a model of a Type Ia supernova.

- Provides information about detailed physical structure, as well as synthetic spectra.

- Much closer to first-principles than SYNOW.
Phoenix: Objectives

- Confirm SYNOW velocities and temperatures using a “Toy Model”.
- Use a Type Ia model called W7 to further test these results.
- Modify W7 density and abundance structure to better reflect trends in SYNOW.
Phoenix: Objectives

- Confirm SYNOW velocities and temperatures using a “Toy Model”.

- Use a Type Ia model called W7 to further test these results.
Phoenix: Objectives

- Confirm SYNOW velocities and temperatures using a “Toy Model”.

- Use a Type Ia model called W7 to further test these results.

- Modify W7 density and abundance structure to better reflect trends in SYNOW.
Results: Toy Model

Fits were made for at several epochs starting with SYNOW velocities and temperatures.
Results: Toy Model

Fits were made for at several epochs starting with SYNOW velocities and temperatures.
Results: Toy Model

Fits were made for at several epochs starting with SYNOW velocities and temperatures.
Results: W7

These same epochs were fit using W7.
These same epochs were fit using W7.
Results: W7

These same epochs were fit using W7.
Modifying W7

- SYNOW provides qualitative information about density and abundance structure in a limited velocity range.
Modifying W7

- SYNOW provides qualitative information about density and abundance structure in a limited velocity range.

- Adjust W7 density profile to reflect SYNOW in that range.
Modifying W7

- SYNOW provides qualitative information about density and abundance structure in a limited velocity range.

- Adjust W7 density profile to reflect SYNOW in that range.

- Run Phoenix with modified density profile.
The modified density profile decays at a different rate at SYNOW velocities.
Preliminary Phoenix Results: Modified W7

Maximum light fits without (top) and with (bottom) the modified density profile.
Preliminary Phoenix Results: Modified W7

Maximum light fits without (top) and with (bottom) the modified density profile.
Conclusions

- SYNOW fits implied detached, high velocity Si II in a narrow range of velocities at later epochs.
Conclusions

- SYNOW fits implied detached, high velocity Si II in a narrow range of velocities at later epochs.

- Phoenix fits confirmed that Si II density falls off quickly.
Conclusions

- SYNOW fits implied detached, high velocity Si II in a narrow range of velocities at later epochs.

- Phoenix fits confirmed that Si II density falls off quickly.

- Working hypothesis: SN2012fr contains an optically thick, fast-moving Silicon shell that persists at late times.
Future Research

- Refine density modification procedure.
Future Research

- Refine density modification procedure.

- Develop procedure for modifying abundances using SYNOW results.
Future Research

- Refine density modification procedure.

- Develop procedure for modifying abundances using SYNOW results.

- Long term: Understand significance of SN2012fr in broader picture of Type Ia supernovae.
Acknowledgments

I’d like to thank:

- Dr. Eddie Baron, for helping me get over the many hurdles and challenges I encountered this summer.
I’d like to thank:

- Dr. Eddie Baron, for helping me get over the many hurdles and challenges I encountered this summer.
- Drs. Brad Abbott and Mike Strauss, for coordinating this REU program.
I’d like to thank:

- Dr. Eddie Baron, for helping me get over the many hurdles and challenges I encountered this summer.
- Drs. Brad Abbott and Mike Strauss, for coordinating this REU program.
- The Homer L. Dodge Department of Physics and Astronomy, for offering me this fantastic experience.
Acknowledgments

I’d like to thank:

- Dr. Eddie Baron, for helping me get over the many hurdles and challenges I encountered this summer.
- Drs. Brad Abbott and Mike Strauss, for coordinating this REU program.
- The Homer L. Dodge Department of Physics and Astronomy, for offering me this fantastic experience.
- The National Science Foundation, for funding this program.
I’d like to thank:

- Dr. Eddie Baron, for helping me get over the many hurdles and challenges I encountered this summer.
- Drs. Brad Abbott and Mike Strauss, for coordinating this REU program.
- The Homer L. Dodge Department of Physics and Astronomy, for offering me this fantastic experience.
- The National Science Foundation, for funding this program.
- Some of the computing for this project was performed at the OU Supercomputing Center for Education & Research (OSCER).
Thank You!