What Can Supernova Spectra Do For You?

Jeffrey M. Silverman
(jsilverman@astro.berkeley.edu)

Adviser: A. V. Filippenko

GSPS
29 April 2011
Outline

• SN Basics & Background
• SN Ia Low-z Spectral Data Set
• Measuring the Data
• Analyzing the Data
• Summary & Conclusions
Outline

- SN Basics & Background
- SN Ia Low-z Spectral Data Set
- Measuring the Data
- Analyzing the Data
- Summary & Conclusions
Why Study Exploding Stars?

- Nucleosynthesis and galactic chemical evolution & enrichment
- Induced star formation
- Stellar evolution
  - Binary systems including a WD
- Cosmology & the accelerating Universe
- Big explosions are awesome!
Big Questions I’m Asking

- How do spectral properties of SNe Ia relate to their photometric and host galaxy properties?
  - Can a model (or set of models) explain all our observations?
  - How accurate can SN Ia cosmology become using spectra + photometry + host galaxy?
  - For large-scale SN surveys and ones at high-z, can a single, low quality spectrum be used for “precision cosmology”?

  - PTF, Pan-STAARS, SkyMapper, LSST, WFIRST...
Modern SN Taxonomy

- Early-time
  (< 2 weeks past B-band maximum brightness):
  - Ia: Si II 6355 Å, no H
  - Ic: Si absent or weak, no H, no He
  - Ib: He I (e.g., 5876 Å), no Si, no H
  - II: H Balmer series

(Kasen, http://panisse.lbl.gov/~dnkasen/tutorial/)
SNe Ia Are Not All the Same

- Normal (~70%)
- SN 1991T-like overluminous (~9%)
- SN 1991bg-like underluminous (~15%)
A Photometric Detour

Calan/Tololo
SNe Ia

(Kim et al. 97)
A Cosmological Detour

Constitution Set of SNe Ia (Hicken et al. 09)

Residuals: \( \Omega_M = 0.27, \Omega_\Lambda = 0 \)

Best Fit: \( \Omega_M = 0.28, \Omega_\Lambda = 0.72 \)
Outline

• SN Basics & Background
• SN Ia Low-z Spectral Data Set
• Measuring the Data
• Analyzing the Data
• Summary & Conclusions
Berkeley SN Ia Program (BSNIP)

- 1298 spectra of 582 SNe Ia (z < 0.2)
- 20 years (1989-2008)
  - Lick 3m (+Kast)
  - Keck I & II (+LRIS, DEIMOS, ESI)
- Many SNe w/ companion photometry
- Consistent and reliable observations and data reduction
  - Only a few people have reduced all the data
- BSNIP I (data paper) in prep.
  - Data will be publicly available online.
Observational Stats

Number of Nights Observed:

(1) Alex Filippenko: 254
   (over 20 yrs → 12.7 nights/yr)

(2) Ryan Foley: 85

(3) Ryan Chornock: 82

(4) Jeffrey Silverman: 56
   (over 3 yrs → 18.7 nights/yr)

(5) Tom Matheson: 51

(6) Mohan Ganeshalingam: 46
Data Reduction Stats

- JS: 29.3%
- RF: 19.3%
- RC: 19.0%
- TS: 12.1%
- TM: 10.5%
- DL: 3.6%
- AB: 3.5%
- O: 2.7%
Spectral Classification of BSNIP

- Automated spectral classification of all BSNIP spectra using SN IDentification program, SNID (Blondin & Tonry 07)
- SNID correlates an input spectrum with a library of template spectra
- Created our own set of templates
- SNID classifications used in spectral analysis (discussed later in the talk)
Outline

• SN Basics & Background
• SN Ia Low-z Spectral Data Set
• Measuring the Data
• Analyzing the Data
• Summary & Conclusions
What to do with all these spectra?

• Measure spectral features! (BSNIP II)
  – Characterize shape of features
  – Quantify strength of features
  – Compare multiple features in a given spectrum
  – Contrast different subtypes of SNe Ia
  – Inspect temporal evolution of features
  – Correlate spectral features with LC and host galaxy properties and Hubble residuals
Spectral Features to Measure

The diagram illustrates a spectrum with various spectral lines labeled with elements such as Ca, Si, Mg, Fe, S, Si, and O. The x-axis represents rest wavelength ($\lambda_{\text{rest}}$) in angstroms (Å), ranging from 4000 Å to 10000 Å, while the y-axis represents the flux ($F_\lambda$) on a logarithmic scale.
Outline

• SN Basics & Background
• SN Ia Low-z Spectral Data Set
• Measuring the Data
• Analyzing the Data
• Summary & Conclusions
SN 2004dt

SN 2006X

SN 2002bo

pEW (A) of Si II λ6355

Velocity (10^3 km s^{-1}) of Si II λ6355

la-norm
HV
la-91T
la-91bg
Outline

• SN Basics & Background
• SN Ia Low-z Spectral Data Set
• Measuring the Data
• Analyzing the Data
• Summary & Conclusions
How do spectral properties of SNe Ia relate to their photometric and host galaxy properties?

- Compile huge database of spectra
- Measure spectral features
- Analyze spectral measurements
- Correlate spectral measurements with photometric measurements (LC properties and Hubble residuals)
How do spectral properties of SNe Ia relate to their photometric and host galaxy properties?

- Fold-in host galaxy properties to current analysis
- Compare to theoretical models
- Add late-time spectra?
Conclusions

- Can a model (or set of models) explain all our observations?
  - Perhaps.
  - Varying 1 or 2 ignition params might change density/temp/lum./$^{56}$Ni amount
  - Level of CS interaction may be responsible for extreme values
  - Adding viewing angle dependence (i.e. asymmetries) may explain a lot
Conclusions

• How accurate can SN Ia cosmology become using spectra + photometry + host galaxy?
  – Still under investigation.
  – Initial results indicate we can do slightly better than photometry alone by adding in spectra or host info
  – Stay tuned…
Conclusions

• For large-scale surveys and ones at high-z, can a single, low quality spectrum be used for “precision cosmology”?
  – Probably (still a work in progress).
  – EW(Si $\lambda$4000) correlates with LC decline rate & is relatively blue
    • Can be weak (Ia-91T) or blended (Ia-91bg)
    • Scatter in correlation & Hubble residuals
    • Perhaps other measurements can improve things more???
I’d Like To Thank:

- The Academy
- C. Beem
- B. Cenko
- J. Choi
- R. Chornock
- B. Cobb
- R. Foley
- M. Ganeshalingam
- M. George
- C. Griffith
- S. Jha
- M. Kandrashoff
- I. Kleiser
- K. Keating

- J. Kong
- J. Leaman
- N. Lee
- W. Li
- A. Miller
- E. Miller
- M. Modjaz
- M. Moore
- A. Morton
- R. Mostardi
- C. Norris
- D. Perley
- D. Poznanski
- C. Reuter
- F. Serduke
- K. Shapiro
- J. Shiode
- H. Simpson
- N. Smith
- M. Staley
- T. Steele
- S. Stuart
- B. Swift
- P. Thrasher
- X. Wang
- A. Wetzel
- P. Williams
- D. Wong