The Carbon Footprint of Type Ia Supernova

MNRAS, submitted
arXiv: 1202.3788

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GSPS
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Modern SN Taxonomy

- Early-time spectrum (< 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, no Si, no H
  - II: H Balmer series

(Kasen, http://panisse.lbl.gov/~dnkasen/tutorial)
Type Ia Supernova

White Dwarf

Transferring Gas

Companion Star
A Photometric Detour

Lick Observatory SN Search (using KAIT)

SNe Ia light curves

(Ganeshalingam et al. 2010)
2011 Nobel Prize in Physics

Saul Perlmutter, Lawrence Berkeley National Laboratory & UC Berkeley

Brian P. Schmidt, Australian National University

Adam G. Riess, John Hopkins University & STScI

“For the discovery of the accelerating expansion of the Universe through observations of distant supernovae.”
SNe Ia, Let Me Count the Ways

White dwarf

Subgiant or main-sequence star

White dwarfs

Red giant

White dwarf
Spectral Features in SNe Ia

See also:
Berkeley SN Ia Program (BSNIP)

- 1298 spectra of 582 SNe Ia (z < 0.2)
- 20 years (1989-2008) of Lick + Keck
- Most have photometry (Ganeshalingam et al. 2010, ApJS, 190, 418)
- Consistent & reliable observations & data reduction
- Submitted (arXiv: 1202.2128, 1202.2129, 1202.2130)
- Data will be public & searchable online in Jan 2013
The Search for Spock Carbon

- 188 spectra of 144 SNe Ia
- < 4 days after maximum brightness
The Persistence of Memory Carbon

![Graph showing Cumulative Fraction of Spectra with CII vs Rest-Frame Phase (days)]

- Definite + Possible CII
- Definite CII
The Song Carbon Remains the Same

![Graph showing the distribution of SNe with different LC shapes and whether they include C II or not.](image)
A Horse Carbon of a Different Color
A Horse Carbon of a Different Color
Where’s the Beef Carbon?

$v(C \text{ II}) \approx 12,500 \text{ km/s}$

$v(Si \text{ II}) \approx 12,000 \text{ km/s}$
Burning Down the House Carbon

\[ M(C) \approx 2 - 30 \times 10^{-3} M_\odot \]

(\(\approx 96\%\) C burned)
Conclusions

- 188 BSNIP spectra of 144 SNe Ia searched (first ~3 weeks after explosion)
- 11% show definite C; 14% show possible C
- 1-in-3 chance of seeing distinct C feature in first ~2 weeks after explosion
- SNe Ia with and without C have same light curve shape (i.e., luminosity) distribution
Conclusions

• SNe Ia with C are *bluer* in the optical and NUV

• $v(C) \approx 1.05 \times v(Si) \Rightarrow C$ outside Si, but lots of mixing and turbulent/non-uniform burning

• C feature strengths $\Rightarrow M(C) \approx 2 -$ 30 $\times 10^{-3}$ $M_\odot$ ($\approx$ 96% C burned)

• Detection of very early ($\sim$ 1 week after explosion) *increase* in C strength predicted by model
DelMarBQ
Tonight
Be There