Carnegie Supernova Project-II: The Near-infrared Spectroscopy Program*


NIR spectroscopy of Type Ia supernovae

Eric Hsiao 蕭亦麒
Florida State University
Nidia’s school of observing

• Good data is better than more data.
• Perfection in data taking is a virtue.
Carnegie Supernova Project

• **CSP-I (2004—2008):**
  - Build the low-redshift anchor for any Hubble diagram in a single, well-understood photometric system.

• **CSP-II (2011—2015):**
  - Observe SNe Ia in the Hubble flow to eliminate peculiar velocity errors. Phillips et al. (2018)
  - NIR spectroscopy to improve k-corrections and physics. Hsiao et al. (2018)
  - **Emphasis in the NIR!**
CSP-II NIR spectra

- 661 NIR spectra of 157 SNe Ia.
- 909 NIR spectra of all types.
- ~1 order mag increase in sample size.
- 77% of the NIR spectra taken with FIRE at (the real) LCO.
CSP-II NIR spectra

- 661 NIR spectra of 157 SNe Ia.
- 909 NIR spectra of all types.
- ~1 order mag increase in sample size.
- 77% of the NIR spectra taken with FIRE at (the real) LCO.

Nidia took one quarter of these spectra!
Why NIR?

Peak Magnitude

Peak Magnitude

$\Delta m_{15}(B)$

$M_B$

$B_0 - \mu$

$M_H$

$H_0 - \mu$

Phillips relation

dust extinction

optical

NIR

LC decline rate

Mandel et al. (2011)
Why NIR?

• Differences between normal and peculiar Ia’s are subtle in the optical.
• NIR probes deeper in the ejecta and shows drastic differences.

Hsiao et al. (2018)
Type Ia supernova

- **Unburned material**
  Premax C I 1.069, He I 1.083
  Marion et al. (2006), Hsiao et al. (2013, 2015), Boyle et al. (2017)

- **Boundary between C/O burning**
  Premax Mg II 1.093
  Wheeler et al. (1998), Hsiao et al. (2013)

- **Radioactive nickel**
  Postmax H-band break
  Wheeler et al. (1998), Hoeflich et al. (2002), Hsiao et al. (2013)

- **Stable nickel**
  Transitional and nebular phase [Ni II] 1.939

- **Companion signature**
  Postmax P-beta 1.282, He I 1.083
  Maeda et al. (2014), Sand et al. (2016), Botyanszki (2017)

- **Central density and B-field**
  Nebular phase [Fe II] 1.644
NIR spectroscopy of Type Ia supernovae

Eric Hsiao 蕭亦麒
Florida State University
Type II supernova

- NIR Paschen-γ region shows two distinct spectral type: strong and weak.

- Weak: weak features at 1.06 and 1.04μm. Prominent Sr II lines.

- Strong: strong feature at 1.06μm, no feature at 1.04μm. No strong Sr II lines.
Type II supernova

- What are the 1.06\(\mu\)m and 1.04\(\mu\)m lines?
- 1.04 shows up earlier than 1.06 and has a wide range of velocities.

---

Davis et al. in prep

Takats et al. (2014)
Type II supernova

<table>
<thead>
<tr>
<th>Name</th>
<th>Photometric</th>
<th>NIR Spectroscopic</th>
<th>Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Classification</td>
<td>Classification</td>
<td></td>
</tr>
<tr>
<td>SN2002hh</td>
<td>IIP</td>
<td>-</td>
<td>Pozzo et al. 2006</td>
</tr>
<tr>
<td>SN2004et</td>
<td>IIP</td>
<td>-</td>
<td>Maguire et al. 2010</td>
</tr>
<tr>
<td>SN2005cs</td>
<td>IIP</td>
<td>Weak</td>
<td>Pastorello et al. 2009</td>
</tr>
<tr>
<td>SN2008in</td>
<td>IIP</td>
<td>Weak</td>
<td>Takats et al. 2014</td>
</tr>
<tr>
<td>SN2009N</td>
<td>IIP</td>
<td>Weak</td>
<td>Takats et al. 2014</td>
</tr>
<tr>
<td>SN2009ib</td>
<td>IIP</td>
<td>Weak</td>
<td>Takats et al. 2015</td>
</tr>
<tr>
<td>SN2009md</td>
<td>IIP</td>
<td>-</td>
<td>Fraser et al. 2011</td>
</tr>
<tr>
<td><strong>SN2012A</strong></td>
<td>IIP</td>
<td>Strong</td>
<td>Tomasella et al. 2013</td>
</tr>
<tr>
<td>SN2012aw</td>
<td>IIP</td>
<td>Weak</td>
<td>Dall’Ora et al. 2014, Jerkstrand et al. 2014</td>
</tr>
<tr>
<td>SN2013by</td>
<td>IIL</td>
<td>Strong</td>
<td>Valenti et al. 2015</td>
</tr>
<tr>
<td>SN2013ej</td>
<td>IIL</td>
<td>Strong</td>
<td>Valenti et al. 2014</td>
</tr>
<tr>
<td>SN2017eaw</td>
<td>IIP</td>
<td>Weak</td>
<td>Rho et al. 2018</td>
</tr>
</tbody>
</table>

Davis et al. in prep
Type II supernova

- But remember in optical LCs, we see a continuum of plateau slopes from IIP to IIL.

Anderson et al. (2014)
Type II supernova

• Rejoice!

• There are NIR Type II spectral templates based on principal component analysis of CSP-II sample.

Davis et al. in prep
Take-home point

• SNe II in the NIR show distinct spectroscopic groups that largely correspond to the photometric classifications. (IIP=>weak, IIL=>strong)