The Nearby Supernova Factory: Data and Science Overview

Kara Ponder
kponder@berkeley.edu
Computational Data Science Fellow
UC Berkeley / LBL
Overview of SNfactory

- Worldwide collaboration (US, France, Germany, China)
- UH 2.2 m Telescope with SNIFS
- Integral Field Spectroscopy (IFU)
- Dominated by targets from dedicated, unbiased SN searches
- Spectrophotometric time series of over 300 SNeIa
- Wavelength coverage: 3200 - 10,000 Å
- Median number of epochs: 14
- $0.02 < z \lesssim 0.08$
Overview of SNfactory

- Worldwide collaboration (US, France, Germany, China)
- UH 2.2 m Telescope with SNIFS
- Integral Field Spectroscopy (IFU)
- Dominated by targets from dedicated, unbiased SN searches
- Spectrophotometric time series of over 300 SNeIa
- Wavelength coverage: 3200 - 10,000 Å
- Median number of epochs: 14
- $0.02 < z \lesssim 0.08$
First Comprehensive Data release expected early 2020 with:
- 927 Supernova
- 577 SNe Ia
- 45 Standard Stars

Note: Pie charts show full database not necessarily release statistics.
Science with SNfactory data

Recent and Upcoming Papers

- Comprehensive Data Release:
  - Pipeline
  - w-Cosmology
  - Calibration
  - SNIFS
  - SN Search
- SNEMO - Saunders et al. (2018)
  - arXiv:1810.09476
- SUGAR - Leget et al. (accepted)
  - arXiv: 1909.11239

- SN 2011by + 11fe - Xiaosheng Huang
- Third Color Parameter - Alex Kim
- Manifold Twins - Kyle Boone

Talks at SCAM

- SNEMO - Ben Rose
  - Wed 2:00 PM - 2:20 PM
- SNEMO - Sam Dixon
  - Wed 2:20 PM - 2:40 PM
- SUGAR - Florian Mondon
  - Wed 2:40 PM - 3:00 PM
- SNfactory Calibration - Greg Aldering
  - Thurs 9:00 AM - 9:20 AM
- Host Galaxy Studies - Mickael Rigault
  - Thurs 4:20 PM - 4:40 PM
Comparing SN 2011by & SN 2011fe

Xiaosheng Huang

References:

- Huang + SNfactory (2017)
- Pereira + SNfactory (2013)
- Fakhouri, Boone + SNfactory (2015)
- Foley & Kirshner (2013)
- Foley et al (2018)
We have shown spectrophotometric “twins” have per-object RMS ~ 0.08 mag

SN 2011by and SN 2011fe are spectrally similar

Cepheid-based distances have suggested they are not photometric twins at 4σ, i.e. they have different brightnesses (Foley+2018)

SNfactory observed
- 11by at 7 phases
- 11fe at 32 phases

Using the extinction curve from Fitzpatrick (1999), we simultaneously fit for E(B-V), R_V, and the difference in distance modulus (Δμ). As in Huang++(2017).
Comparison between “twins” SN 2011fe and SN 2011by

- Accounting for twins dispersion lowers tension to $2.6\sigma$
- Not really twins at early phases causing error in relative phase determination
- Removing -10 day LC point shifts relative phase by 1 day
- RMS is 2x better and results in more dust
- Lowers the Cepheid and twins tension to $1.8\sigma$

Results
($\Delta\mu =$ distance modulus difference)

Slides from Xiaosheng Huang
Evidence for Third Color Parameter

Alex Kim
Modeling SN Ia Colors

- Broad-band (UBVRI) synthesized magnitudes at peak

- Fitting this linear model...

- ... yields $\alpha$ and $\beta$ consistent with the Fitzpatrick (1999) dust model

\[
\begin{pmatrix}
\hat{U} \\
\hat{B} \\
\hat{V} \\
\hat{R} \\
\hat{I}
\end{pmatrix} = \Delta \hat{I} +
\begin{pmatrix}
c_{U} \\
c_{B} \\
c_{V} \\
c_{R} \\
c_{I}
\end{pmatrix}
+ \begin{pmatrix}
\alpha_{U} \\
\alpha_{B} \\
\alpha_{V} \\
\alpha_{R} \\
\alpha_{I}
\end{pmatrix} + \begin{pmatrix}
\beta_{U} \\
\beta_{B} \\
\beta_{V} \\
\beta_{R} \\
\beta_{I}
\end{pmatrix}
\]

$\alpha$ and $\beta$ (solid) and Fitzpatrick model (dashed) span the same plane in color space.

Slides from Alex Kim
Add One More Latent Color Parameter to the Model

- $\alpha$ and $\beta$ still consistent with the Fitzpatrick dust model
- New color vector $\varphi$ detected at high signal-to-noise (>99% confidence)
- New SN color parameter "p" is correlated with host mass at 2$\sigma$

\[
\begin{pmatrix}
\hat{U} \\
\hat{B} \\
\hat{V} \\
\hat{R} \\
\hat{I}
\end{pmatrix} = \Delta \bar{I} + \begin{pmatrix}
c_{\bar{U}} \\
c_{\bar{B}} \\
c_{\bar{V}} \\
c_{\bar{R}} \\
c_{\bar{I}}
\end{pmatrix} + a \begin{pmatrix}
\alpha_{\bar{U}} \\
\alpha_{\bar{B}} \\
\alpha_{\bar{V}} \\
\alpha_{\bar{R}} \\
\alpha_{\bar{I}}
\end{pmatrix} + b \begin{pmatrix}
\beta_{\bar{U}} \\
\beta_{\bar{B}} \\
\beta_{\bar{V}} \\
\beta_{\bar{R}} \\
\beta_{\bar{I}}
\end{pmatrix} + p \begin{pmatrix}
\phi_{\bar{U}} \\
\phi_{\bar{B}} \\
\phi_{\bar{V}} \\
\phi_{\bar{R}} \\
\phi_{\bar{I}}
\end{pmatrix}
\]
Manifold Twins

Kyle Boone

References:
- Fakhouri, Boone + SNfactory (2015)
Mapping SN Ia Diversity with Manifold Learning

- Using manifold learning we can parametrize the diversity of the spectra of SNe Ia at maximum light.
- We find that 3 nonlinear components are required (versus SALT2 which only uses 1 linear component: x1)
- Dispersion at 0.082 mag*  

* for training dataset
Using Manifold Twins significantly reduces correlations with host properties.

SALT2 Hubble residuals have a bias of up to 0.3 mag when comparing to areas of Component 1 parameter space.

SALT2 is missing some SNe Ia diversity!
Thank you

Summary:

- SNfactory expecting a comprehensive data release early 2020.
- Many science talks this week using its data!

- Good “twins” still have some variation: Xiaosheng Huang xhuang@lbl.gov
- Several projects indicate that SALT2 is not covering the full diversity of SNeIa.
  Some proposed solutions to this include:
  - Additional color terms: Alex Kim agkim@lbl.gov
  - Non-linear correlations: Kyle Boone kyboone@uw.edu (Look for Thesis Talk at AAS Winter 2020)
SNfactory Collaborating Institutions

- Physics Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA, 94720
- Universite de Lyon, F-69622, Lyon, France; Universite de Lyon 1, Villeurbanne; CNRS/IN2P3, Institut de Physique Nucleaire de Lyon
- Centre de Recherche Astronomique de Lyon, Universite Lyon 1, 9 Avenue Charles Andre, 69561 Saint Genis Laval, France
- Sorbonne Universite, Universite Paris Diderot, CNRS/IN2P3, Laboratoire de Physique Nucleaire et de Hautes Energies, 4 Place Jussieu, Paris, France
- Department of Physics, Yale University, New Haven, CT, 06250-8121
- Max-Planck-Institut fur Astrophysik, Karl-Schwarzschild-Str. 1, D-85748 Garching, Germany
- Tsinghua Center for Astrophysics, Tsinghua University, Beijing 100084, China
- Institut fur Physik, Humboldt-Universitat zu Berlin, Newtonstraße 15, 12489 Berlin, Germany