Type Ia Supernova Cosmology with the Dark Energy Survey

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For the DES SN working group
SN 2012fr in NGC 1365

DES First Light Imaging 2012 September 12

Discovery 2012 October 27

NASA Astronomy Picture of the Day 2012 November 24

Image Credit & Copyright: Martin Pugh
# DES Supernova Members

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Outline

• DES Supernova program at a glance
• Science Verification Data (Dec 2012 – Jan 2013)
• Looking Forward ...
  – Photometric Calibration
  – Spectroscopic follow-up strategy & photometric typing
Lightning SN Ia cosmology review

Distance Modulus vs. Redshift

Cluster Search (SCP)
Amanullah et al. (2010) (SCP)
Riess et al. (2007)
Tonry et al. (2003)

Contreras et al. (2010)
Hicken et al. (2009)
Kowalski et al. (2008) (SCP)
Jha et al. (2006)
Riess et al. (1999)
Krisiunas et al. (2005)
Hamuy et al. (1996)
Lightning SN Ia cosmology review

No Big Bang

SNe

BAO

CMB

Flat

\( \Omega_m \)

\( \Omega_A \)

-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0

0.0
0.1
0.2
0.3
0.4
0.5

w

\( \Omega_m \)
# DES Supernova Survey at a glance

<table>
<thead>
<tr>
<th>Dark Energy Survey</th>
<th>Current Major Survey (SNLS: Megacam @ CFHT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Type Ia SNe</td>
<td>~3500 (Photometric typing)</td>
</tr>
<tr>
<td>Redshift range</td>
<td>up to z ~ 1.2 (deep z band)</td>
</tr>
<tr>
<td>Fields</td>
<td>10 pointings @ 3 deg(^2) (8 “shallow”, 2 “deep”)</td>
</tr>
<tr>
<td>Cadence</td>
<td>~5 day cadence over 5 months</td>
</tr>
<tr>
<td>Spectroscopic Follow-up</td>
<td><strong>Subset</strong> of candidates observed by 4-10m class telescopes</td>
</tr>
</tbody>
</table>
Key advances

- **Statistics**: split SNe into subsets to better understand astrophysical systematics
- **Deep z-band**: better systematic control at high-z
## Shallow & Deep Fields

<table>
<thead>
<tr>
<th>Filter</th>
<th>Limiting Mag (Shallow)</th>
<th>Limiting Mag (Deep)</th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>24.9</td>
<td>25.6</td>
</tr>
<tr>
<td>r</td>
<td>24.3</td>
<td>25.4</td>
</tr>
<tr>
<td>i</td>
<td>23.9</td>
<td>25.1</td>
</tr>
<tr>
<td>z</td>
<td>23.7</td>
<td>24.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Filter</th>
<th>Exp time (Shallow)</th>
<th>Exp time (Deep)</th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>3 min</td>
<td>10 min</td>
</tr>
<tr>
<td>r</td>
<td>2.5 min</td>
<td>20 min</td>
</tr>
<tr>
<td>i</td>
<td>3.3 min</td>
<td>30 min</td>
</tr>
<tr>
<td>z</td>
<td>6.6 min</td>
<td>60 min</td>
</tr>
</tbody>
</table>

`~15 min`  `~2 hrs`

DES 5-year SN Ia redshift distribution
DES Simulated Light curves
DES SN fields

Observe SN fields when:

- Predicted seeing > 1.1 arcsec
- Time since last observation > 7 days
DES SN fields: ancillary data
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Science Verification: SN Candence

16 days

DEEP
Science Verification: Supernovae

$z = 0.241$

DES12C3a

(642239)
Science Verification: Supernovae

$z = 0.241$

DES12C3a (642239)

Spectroscopically confirmed by AAT
Science Verification: Supernovae

$z = 0.21$

DES12C2a
(619935)
Science Verification: Supernovae

$z = 0.243$

DES12C1b

(636359)
Science Verification: Supernovae

\( z = 0.303 \)

DES12C1a

(636909)
Science Verification: Supernovae

$z = 0.26 \pm 0.01$

(photo-z from SN lightcurve)

(635230)
Science Verification: Supernovae

$z = 0.806$

from host spec-z (VVDS)
Improving Candidate Selection

<table>
<thead>
<tr>
<th>期间</th>
<th>总候选</th>
<th>人工标记为有趣</th>
</tr>
</thead>
<tbody>
<tr>
<td>重新处理</td>
<td>408,304</td>
<td>7,219</td>
</tr>
<tr>
<td>SV</td>
<td>585,664</td>
<td>3,184</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>过滤器</th>
<th>对象ID</th>
<th>搜索</th>
<th>模板</th>
<th>剔除</th>
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<tbody>
<tr>
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<td>![图像]</td>
<td>![图像]</td>
<td>![图像]</td>
</tr>
</tbody>
</table>
Random forest candidate selection

Receiver Operating Characteristic: DES SNe (Pixel Level)

- $mtry = 2$, $nodesize = 2$, $ntree = 10$
- $mtry = 2$, $nodesize = 2$, $ntree = 100$
- $mtry = 20$, $nodesize = 2$, $ntree = 10$
- $mtry = 20$, $nodesize = 2$, $ntree = 100$
- $mtry = 40$, $nodesize = 2$, $ntree = 10$
- $mtry = 40$, $nodesize = 2$, $ntree = 100$
- $mtry = 43$, $nodesize = 2$, $ntree = 10$
- $mtry = 43$, $nodesize = 2$, $ntree = 100$
- $mtry = 100$, $nodesize = 2$, $ntree = 10$
- $mtry = 100$, $nodesize = 2$, $ntree = 100$

90% classification rate, 3.8% false positive rate
SV data: summary

- Refined subtraction pipeline now in place
- Machine Learning will be in place reducing scanning load
- Deep reference images from SV
- Data looks good; lots of SNe; analyses in progress (even with preliminary photometry)
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Photometric Calibration

- Leverage overall DES calibration plans
  - DECal plans and other atmospheric monitoring systems
  - Spectroscopic observations of white dwarfs
- Direct Calibration Chain
Photometric Calibration

- As direct as possible
- Redundant chains
- Anchor calibration to chain established for SNLS & SDSS

- Additional observations of CALSPEC standards
  - Observe standards at same airmass as SN fields
  - Field stars in each field directly calibrated to CALSPEC
HST CALSPEC standards
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Spectroscopic follow-up

SN Classification: Photometric classification with a “random” spectroscopic training sample

- 8-meter telescopes: training sample and host-less SNe
- 4-meter telescopes: host spectra for redshifts

AAOmega/2dF on AAT field-of-view perfectly matched with DECam

OzDES: 100 nights/5 years

Lidman et al. 2012

Median magnitudes: 23.18, 22.33 and 21.93
Photometric Typing

- Photometric typing is our biggest new challenge
- magnitude-limited survey gives you ~75% Type Ia SNe
- Typing systematics: a matter of understanding the distribution of core-collapse SNe that look “kinda like” Type Ia
- Type Ia's are not a perfectly uniform sample anyway – need to understand distributions very well
- An opportunity looking forward to LSST

Summary

- DES Supernova program at a glance
  Nice advance over current SN sample; main high-z SN survey over next 5 years

- Science Verification Data
  (Dec 2012 – Jan 2013)
  Data look good; ready to start survey in two weeks(!)

- Looking Forward ...
  - Photometric Calibration
    Robust, multi-faceted plan for calibration
  - Spectroscopic follow-up strategy & photometric typing
    Nearly complete spectroscopic redshifts; optimistic about photometric typing
Random Forest

SNR Distribution for Real DES SNe

- **Classified Real**
- **Classified Bogus**

SNR values range from 0.0 to 1000.0.
Cosmology constraints

$w_a$ vs $w_0$

DES+SDSS+LowZ SNe
Incl. DETF Stage II Prior
plus Planck

$w(a)$ vs Redshift

Stage II only
Stage II + SN (with sys)
Stage II + SN (no sys)