PRELIMINARY SUPERNOVA
3YEAR COSMOLOGY RESULTS

SN-Cosmology analysis team, on behalf of DES-SN working group


Anais Möller

Rencontres de Moriond
March 2018
DARK ENERGY SURVEY

- 5-year survey, started 2013

- DES uses four primary probes
  - Galaxy clusters
  - Weak lensing
  - Large Scale Structure
  - Type Ia SNe

- Photometric survey
  - DES-wide
    - 5000 sq. degrees covered 10 times (grizy)
  - DES-deep
    - 10 DES fields (30sq. degrees) imaged weekly (griz)
TYPE I A SUPERNOVAE

- extremely bright
  - (detect to $z \sim 2$)
- “common”
- homogeneous spectral and photometric properties

- are standardisable candles
- allows us to measure distances
COSMOLOGY WITH SNE Ia

740 SNe Ia from 7 surveys

- direct measurement of cosmic expansion
- Geometrical probe only other probes are a combination of geometry and growth of structure.
COSMOLOGY WITH SNE IA

Equation of state parameter

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Density</th>
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<tr>
<td>$p_i = w_i \rho_i$</td>
<td>$w_\gamma = \frac{1}{3}$</td>
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- Non-relativistic particles: $w_M \sim 0$
- Relativistic particles: $w_\gamma = \frac{1}{3}$
- Cosmological constant: $w_\Lambda \equiv -1$

DARK ENERGY

$w_{DE}(a) = w_0 + w_a (1 - a)$

Changes with scale factor (or time)

Cosmological Constant

$w_0 = -1; w_a = 0$
Anais Möller (ANU)
### DES 3-YEAR SAMPLE: SNe Ia

<table>
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<th>$w_{\text{Err}}$ (stat + sys)</th>
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<tr>
<td>DES SN</td>
<td>0.02 &lt; z &lt; 0.85</td>
<td>206 SNe After Cuts</td>
</tr>
<tr>
<td>External Low z (CFA,CSP)</td>
<td>z &lt; 0.10</td>
<td>128 SNe After Cuts</td>
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INGREDIENTS FOR SN COSMOLOGY

Type Ia supernovae
1. find SNe
2. classify type Ia SNe
3. redshifts
4. distances

Cosmology analyses
1. biases
2. systematics
INGREDIENTS FOR SN COSMOLOGY

Type Ia supernovae

1. find SNe
2. classify type Ia SNe
3. redshifts
4. distances

Difference imaging
INGREDIENTS FOR SN COSMOLOGY

Difference imaging

\[ \text{search} - \text{template} = \text{difference} \]

Kessler et al.
Goldstein et al. 2015

SN candidate
INGREDIENTS FOR SN COSMOLOGY

Type Ia supernovae

✓ find SNe
2. classify type Ia SNe
3. redshifts
4. distances

spectra
INGREDIENTS FOR SN COSMOLOGY

Spectra
INGREDIENTS FOR SN COSMOLOGY

Spectra

Anglo-Australian Telescope

2dF

- 392 2dF Fibres
- 2.1 degrees

Perfect match with DECam!
INGREDIENTS FOR SN COSMOLOGY

Spectra

Real time SNe Typing & redshift
INGREDIENTS FOR SN COSMOLOGY

Spectra

Real time SNe Typing & redshift

Host galaxy redshifts

Galaxies that hosted a transient

- targeted - 6450
- qop > 2 - 4859 objects
- qop > 3 - 3984 objects

qop=3 95% correct

95% GAMA limit
75% VIPERS limit
INGREDIENTS FOR SN COSMOLOGY

Spectra

Real time SNe
Typing & redshift

Host galaxy redshifts
& more

14,693 redshifts

AGN
Transient
SN Host

BrightGal
ClusterGal
LRG
Photo-z
RadioGal

Childress et al. 2017
INGREDIENTS FOR SN COSMOLOGY

Type Ia supernovae
✓ find SNe
✓ classify type Ia SNe
✓ redshifts
4. distances

photometry-> light curves

Distance modulus:
\[ \mu_B = m_B^* - M_B + \alpha \times_1 - \beta C \]

derived from fit to SNIa light curve
can be constrained using cosmo fits
INGREDIENTS FOR SN COSMOLOGY

Photometry

Scene modelling photometry

Fit flux - True flux

True flux

FAKE SN on Images

True magnitude

Photometric distance bias <1%

*This is a 3mmag systematic per band
INGREDIENTS FOR SN COSMOLOGY

Photometry

Calibration

Repeated measurements of thousands of Tertiary Standard Stars

\[ \sigma_{\text{cal}} = \sqrt{\sigma^2 - \sigma^2_{\text{phot}}} \]

Burke et al. 2017

Calibration systematic 6mmag
INGREDIENTS FOR SN COSMOLOGY

Type Ia supernovae

✓ find SNe
✓ classify type Ia SNe
✓ redshifts
✓ distances
INGREDIENTS FOR SN COSMOLOGY

Type Ia supernovae

✓ find SNe
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Cosmology analyses

1. biases
2. systematics
INGREDIENTS FOR SN COSMOLOGY

Biases

Simulations: SNANA

Selection effects and light-curve fitting

e.g. Selection effects

- Model: spectroscopic follow-up
- Include DIFFIMG & Spectroscopic efficiencies in simulations
- Simulations are then used to correct distance bias for cosmology analysis
COSMOLOGY ANALYSES

Systematics

Categories:
- Calibration (20 low-z bands + 4 DES bands)
- SNela Light-curve Model
- Distance Bias Corrections: e.g. peculiar velocities
- Milky Way Extinction

→ Total 58 Sources of Systematic Uncertainty

CosmoMC with full covariance matrix → Cosmological Parameters

Full testing suite with rigorous unblinding criteria using 100 simulated datasets.
COSMOLOGY ANALYSES

Blinded!

- CosmoMC: JLA-like
  - B. Zhang

- CosmoMC: Pantheon-like using BBC, unblinded December 22nd, 2017
  - D. Brout

- Steve-o: New hierarchical Bayesian model for Supernova Cosmology
  - S. Hinton
COSMOLOGY ANALYSES

Beams with Bias Corrections

- Redshift bin averaged Hubble diagram
- Covariance (stat+sys) is $N_z \times N_z$ (different from usual $N_{SN} \times N_{SN}$)

CosmoMC

- Fit cosmological model with Planck CMB priors

Kessler et al. 2017

![Graph showing Distance Bias Correction vs. Redshift](image)
**DES 3YR PRELIMINARY RESULTS!**

CosmoMC + **Beams with Bias Corrections**
WHAT IS NEXT?

JLA-like analysis
Applying JLA-like method to DES 3 year sample

Steve-o: A hierarchical Bayesian model for Supernova Cosmology
Simultaneous measurement of high level parameters as well as cosmology (S.Hinton et al.)

Inverse Distance Ladder $H_0$ Measurement with BAO Anchor
Similar to $H_0$ analysis using JLA sample (Aubourg et al. 2015, Macaulay et al. in prep)

Reduce Calibration Sys. with Low-z Sample measured with DECam
Pilot program in Y5 to follow-up externally discovered SNeIa

Full 5 Year Dataset Analysis
Spectroscopic and photometric supernovae.
## WHAT IS NEXT?

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<td>DES 5YR photo</td>
<td>~2000</td>
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THANK YOU!

DECam builders
DES shift-takers
Data processing
OzDES
Calibration