Local environment of SNLS5
Type Ia supernovæ

Matthieu Roman
Marc Betoule, Delphine Hardin
Cosmology with type Ia supernovæ

• We want standard candles...
  – *absolute magnitude* determined as an *empirical function* of light-curve’s shape
• ...to compute *luminosity distances*

\[
d_L(z) = (1 + z) \frac{c}{H_0} \int dz \left( \Omega_m (1 + z)^3 + \Omega_x \exp \left( \int_0^z dz' \frac{1 + w(z')}{1 + z'} \right) \right)^{-1/2}
\]
Cosmology with type Ia supernovæ

- We want **standard candles**...
  - *absolute magnitude determined as an empirical function of light-curve’s shape*
- ...to compute **luminosity distances**
- **Integrated expansion history**
- **Historical probe of discovery of accelerated expansion**

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*Perlmutter (1999)*
Standardization of the distance modulus

\[ \mu_B = m_B^* - M_B + \alpha \times \text{stretch} - \beta \times \text{color} \]

El-Hage (2014)
Standardization of the distance modulus

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El-Hage (2014)

Luminosity variation <15%
Light-Curves and Spectra

• Observables:
  – possibly redshift (spectrometry)
Light-Curves and Spectra

- **Observables:**
  - possibly redshift (spectrometry)
  - apparent flux (photometry)

- **Identification**

![Graphs showing light-curves and spectra](image-url)

- SNLS: 392 SNIa
- SDSS: 330 SNIa

24/03/16

Rencontres de Moriond - M. Roman
Joint Light-Curve Analysis (JLA)

- Collaboration btw SNLS, SDSS and low-redshift surveys
  - improved calibration accuracy
  - statistic-limited Hubble diagram

Betoule et al. (2014)
Joint Light-Curve Analysis (JLA)

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$w = -1.027 \pm 0.055$
$\Omega_m = 0.303 \pm 0.012$

$\omega_0 = -0.957 \pm 0.124$
$\omega_a = -0.336 \pm 0.552$
Going further in the standardization

- Environment of supernovæ evolve with redshift
Going further in the standardization

- **Environment** of supernovae evolve with redshift
- The **host stellar mass** can directly be estimated from galaxy luminosity
- It strongly correlates to HR residuals

*Sullivan et al. 2010*
Going further in the standardization

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Going further in the standardization

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- Mass-step for absolute magnitude

\[ M_B = \begin{cases} 
M_B^1 & \text{if } M_{\text{stellar}} < 10^{10} M_\odot, \\
M_B^1 + \Delta M & \text{otherwise.}
\end{cases} \]

Betoule et al. (2014)

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Going further in the standardization

- Environment of supernovæ evolve with redshift
- The host stellar mass can directly be estimated from galaxy luminosity
- It strongly correlates to HR residuals (JLA: 5σ)
- Mass-step for absolute magnitude
- The standardization is not better and the physical meaning remains unclear

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M_B^1 & \text{if } M_{\text{stellar}} < 10^{10} \, M_\odot, \\
M_B^1 + \Delta_M & \text{otherwise.}
\end{cases}
\]

\[\mu - \mu_{\text{DES}} \text{ (mmag)}\]

\[\log_{10}(M_{\text{stellar}}/M_\odot)\]

\[\text{SNLS} \quad \text{High Ia} \quad \text{D. Leman} \quad \text{SWOPE}\]

- Sullivan et al. 2010
- Betoule et al. (2014)
A first look at local host properties

- $\text{H}_\alpha$ as a tracer of **stellar formation**
- SNIa in locally **active** regions are **brighter**

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**Rigault et al. 2013**

**Nearby Supernova Factory**
Local environment of SNIa at all redshifts

• The measurement:
  – perform the local photometry of more than 700 host galaxies of SNIa from SNLS, SDSS and low-redshift surveys
Local environment of SNIa at all redshifts

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  – perform the **local photometry** of more than 700 host galaxies of SNIa from SNLS, SDSS and low-redshift surveys
  – probe the same size ($\approx 3$ kpc) at all redshifts
Local environment of SNIa at all redshifts

- The measurement:
  - perform the local photometry of more than 700 host galaxies of SNIa from SNLS, SDSS and low-redshift surveys
  - probe the same size ($\approx 3$ kpc) at all redshifts
  - compute rest-frame $U-V$ colours from observed magnitudes (fitting of galaxy spectral energy distribution)
Local environment of SNIa at all redshifts

• Correlations between local colour of SN explosion regions and Hubble diagram residuals
Local environment of SNIa at all redshifts

• Correlations between local colour of SN explosion regions and Hubble diagram residuals
  – $7\sigma$ significance assuming a bimodal distribution

$\Delta \mu = 0.1$

Roman et al. (2016, in prep.)
Local environment of SNIa at all redshifts

- Correlations between local colour of SN explosion regions and Hubble diagram residuals
  - $7\sigma$ significance assuming a bimodal distribution
  - more significant than stellar mass and galaxy colour (5$\sigma$)
  - valid for high and low redshift ranges

$\Delta\mu = 0.1$
Conclusions

- First analysis of local environment at all redshifts and for a large sample
- Strong hint that luminosity variations can be reduced
- Type Ia supernovæ can become a major cosmological probe again: dark energy, expansion rate
- LSST