Type Ia Supernovae are Good Standard Candles in the Near-Infrared: Evidence From PAIRITEL

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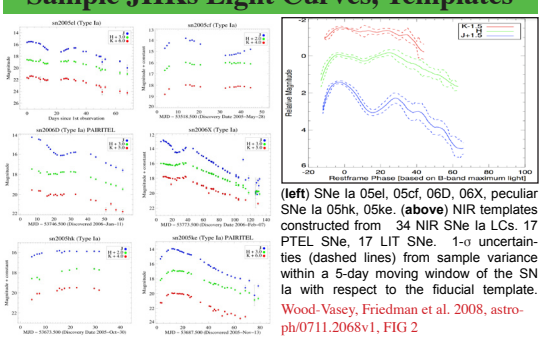
Abstract

We have obtained 1065 near-infrared (NIR; JHK_s) measurements of 19 Type Ia supernovae (SNe Ia) using PAIRITEL, the 1.3-m Peters Automated Infra Red Imaging TELescope at Mount Hopkins, Arizona. These data double the number of well-sampled NIR SNe Ia light curves and strengthen the evidence that SNe Ia are excellent standard candles in the NIR, even without correction for light-curve shape or for reddening. We construct fiducial NIR templates for normal SNe Ia from our sample, excluding only the two known peculiar SNe Ia, SN2005hk and SN2005ke. The H-band absolute magnitudes in this sample of 17 SNe Ia have an uncorrected intrinsic RMS of only 0.14 mag, as small as the scatter in luminosity distance measurements based on optical light curves *after* corrections for light-curve shape and dust absorption. Combining the homogeneous PAIRITEL measurements with 17 SNe Ia from the literature, these 34 SNe Ia have standard H-band magnitudes with an RMS scatter of 0.15 mag. We present a nearby NIR Hubble diagram that shows no correlation of the residuals with light-curve properties. However, future samples that account for optical and NIR light curve shapes, absorption, spectroscopic variation, or host-galaxy properties will likely improve the use of SNe Ia as distance indicators.

Observations

The robotic PAIRITEL 1.3m telescope, formerly used in the 2MASS project, uses the same camera and filter system, providing convenient photometric calibration from the 2MASS catalogue (Bloom et al. 2006, Cutri et al. 2003). Since January 2005, PAIRITEL has dedicated ~30% of its time (~2-3 hours a night) to follow up a nearby ($z < 0.02$) sample of 47 SNe Ia, 19 of which are presented in Wood-Vasey, Friedman et al. 2008, astro-ph/0711.2068v1. Simultaneous JHK_s observations and nightly cadence allow for densely sampled light curves reaching $K_s <$ 17 mag, from as many as ~15 days before max. to ~50 days past max., covering the first two IR peaks.

Sample JHKs Light Curves, Templates



(**left**) SNe Ia 05el, 05cf, 06D, 06X, peculiar SNe Ia 05hk, 05ke. (**above**) NIR templates constructed from 34 NIR SNe Ia LCs. 17 PTEL SNe, 17 LIT SNe. 1-σ uncertainties (dashed lines) from sample variance within a 5-day moving window of the SN Ia with respect to the fiducial template. Wood-Vasey, Friedman et al. 2008, astro-ph/0711.2068v1, FIG 2

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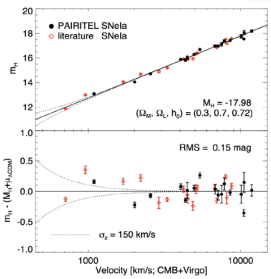
H-Band Hubble Diagram



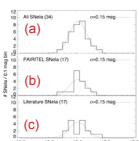
m_H vs. z and residuals vs. z (with respect to ΛCDM)

RMS dispersion
34 SNe: (0.15 mag)
17 PTEL SNe: (0.14 mag)
17 Other SNe: (0.15 mag)

Plotted uncertainties from fit to H-band template from 34 SNe Ia (excluding peculiar velocities)

Wood-Vasey, Friedman et al. 2008, astro-ph/0711.2068v1 (FIG 5)

Type Ia H-Band Standard Candles

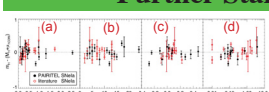


Histograms of H band absolute magnitudes at time of B-band max light (ΛCDM, ho = 0.72)

(a) 34 SNe Ia
(b) 17 PAIRITEL SNe Ia
(c) 17 literature SNe Ia

(dotted line) Overlaid σ=0.15 Gausian, normalized to # of SNe Ia

Further Standardization



Hubble Diagram Residuals vs…
(a) χ^2/DOF of each SN to Template
(b) # of H-band LC points
(c) LC shape parameter Δ
(d) measured optical extinction

Hubble Diagram residuals insensitive to χ^2/DOF of SN fit to template, even with few data points. PTEL + LIT distributions show weak dependence of residuals on optical LC shape, extinction.

Future Work, Impact on NASA JDEM

Our work confirms that nearby SNe Ia are excellent NIR standard candles. NIR data are also less sensitive to dust extinction and combined optical and NIR data result in improved measurements of extinction and distance (Krisciunas et al. 2007). As such, rest-frame NIR should be strongly considered for future space missions optimized for SNe Ia cosmology. For example, the SNAP (Aldering 2004) and DESTINY satellites (Lauer 2005), candidates for the NASA/DOE Joint Dark Energy Mission (JDEM) mission, are both currently designed with detectors sensitive out to 1.7 μm, which will only detect rest-frame H -band light (1.6 μm) out to z~0.1. Only a detector capable of observing rest-frame H-band at z~0.5-2 could take full advantage of the superb SN Ia rest frame H-band standard candle. Prior to JWST, the astronomical community should discuss the costs and benefits of a JDEM mission with the required sensitivity from 2-5μm.

References

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