The Absolute Brightness of Type Ia Supernovae in the Near-Infrared from PAIRITEL: Implications for the NASA/DOE Joint Dark Energy Mission

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Abstract

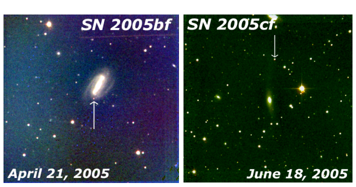
We present selected JHK band light curves (LCs) of Type Ia supernovae (SNe Ia) obtained from 2004-07 with the fully robotic 1.3m Peters Automated Infrared Imaging Telescope (PAIRITEL) at Mount Hopkins, Arizona. The data comprise a homogenous set of over 30 well sampled low redshift SNe Ia. Preliminary work suggests that SNe Ia may be superior standardized candles in the NIR vs. optical wavelengths, with combined optical/NIR data yielding significantly improved reddening measurements and distance estimates. If this is supported by future work, it will motivate designing non-cryogenic detectors sensitive beyond 1.7 μm for future satellites optimized for high redshift SNe Ia cosmology. This has strong implications for the mission design and cost of the planned NASA/DOE Joint Dark Energy Mission (JDEM).

Observations

The 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 its commissioning in October 2004, PAIRITEL has dedicated ~30% of its time (~2-3 hours a night) to follow up a nearby (z < 0.02) sample of 41 SNe Ia, ~30 of which will yield high quality, well sampled LCs. Simultaneous JHK$_s$ observations and nearly 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.

Name	epochs	Name	epochs	Name	epochs	Name	epochs
2004-05 (9)		2005-06 (20)		2005-06...		2006-07 (12)	
05m	8	05el	34	06D	27	06gr	7
05am	8	05M006	32	06E	28	06is	18
05ao	20	05eq	31	06N	31	06le	20
05ak	41	05eu	28	06X	77	06lf	18
05bl	23	05hf	21	06ac	37	06mq	21
05bo	19	05hk	19	06ax	15	07S	23
05cc	30	05iq	11	06az	21	07af	36
05cf	29	05ke	24	06bq	20	07bj	41
05ch	17	05ls	20	06cp	5	07bz	15
		05mc	46	06cz	4	07ca	14
		05na	36			07co	11
						07cq	5

False Color JHK$_s$ Images for SN 2005bf, SN 2005cf



Band	λ_{iso} (μm) z=0	λ(1+z) z=1	λ(1+z) z=2	A_λ/A_v
V	0.549	1.10	1.65	1.000
J	1.250	2.47	3.71	0.282
H	1.587	3.32	4.99	0.190
K	2.174	4.32	6.48	0.114

References

Aldering et al. 2007, AP, 27, 2-3, 213
Bloom et al. 2006, ASPC, 351, 751B
Cutri et al. 2003, 2MASS Catalogue
Krisciunas et al. 2004, ApJ, 602, 81
Krisciunas et al. 2005, ASPC, 339, 75
Krisciunas et al. 2007, AJ,133, 58-72
Lauer 2005, New Ast. Review, 49, 354

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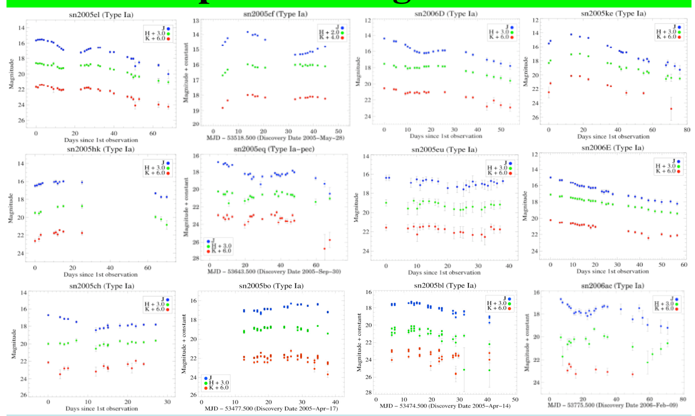
Sample JHK$_s$ Light Curves



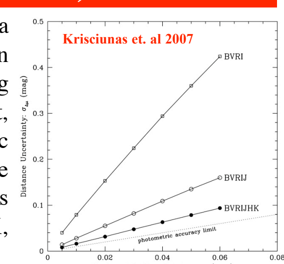
Selected PAIRITEL JHKs SNe Ia LCs: sn2005el, sn2005cf, sn2006D, sn2005ke, sn2005hk, sn2005eq, sn2005eu, sn2006E, sn2005ch, sn2005bo, sn2005bl, sn2006ac. (Wood-Vasey et al. 2007, Friedman et al. 2007 *in prep.)*

Type Ia *Standard Candles* in JHK$_s$

SNe Ia in the NIR may be superior distance indicators than in the optical bands. As a result, unlike optical Type Ia SNe, which are *standardizable* candles, IR SNe Ia appear to be essentially *standard* candles at the ~ 0.15-0.2 mag level or better (~7-9% in distance), depending on the filter (Krisciunas et al. 2004, 2005). Current PAIRITEL data includes ~30 well sampled SNe Ia in JHK$_s$, which will exceed the current published sample of < 20 LCs. Combined with the next 2-3 years of data, we expect a sample of ~60 SNe Ia, representing a homogeneous, high quality nearby training set to calibrate the Type Ia Hubble Diagram in the NIR.

Better Reddening Estimates, Distances

A combination of optical and NIR data yields significantly better distances than UBVRI data alone, mainly by improving the determination of extinction by dust, currently the most significant systematic distance error. Simulated distance modulus errors were improved by factors of 2.7 and 3.5 by adding J, and JHK, respectively. (Krisciunas et al. 2007).



Potential Impact on NASA JDEM

The preliminary implications of this work highlight the scientific value in extending the wavelength coverage of JDEM beyond 1.7 μm and as far as 6.5 μm, so that z~1-2 SNe Ia will have rest frame JHK light (~1.2-2.2 μm) redshifted into the detector's bandpass. For example, the SNAP and DESTINY satellites (Aldering et al. 2007; Lauer 2005), candidates for JDEM, are both designed with passively cooled detectors sensitive out to 1.7 μm. A detector optimized to observe z~2, rest-frame JHK (up to 6.5 μm) would almost certainly require cryogenics, thus substantially increasing the mission cost. A compromise JDEM with only J band capability (z~1, 2.5 μm) may balance scientific gain with cost.