Disentangling Intrinsic Color Variation and Dust Extinction of Type Ia Supernovae With Near-Infrared, Optical, and Ultraviolet Photometry

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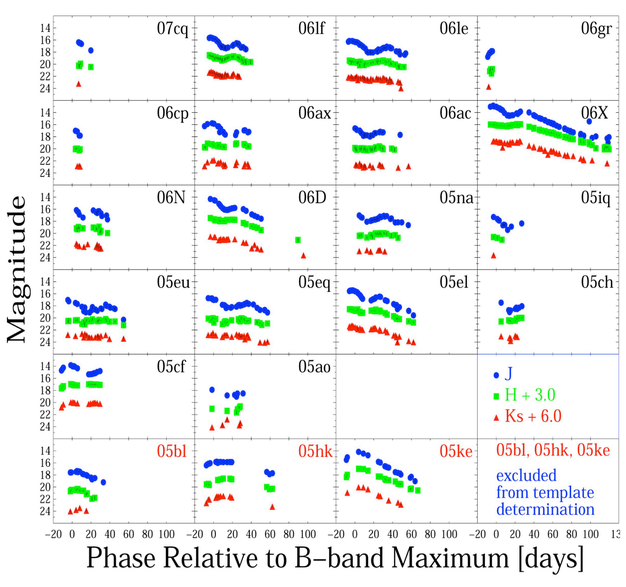
Abstract

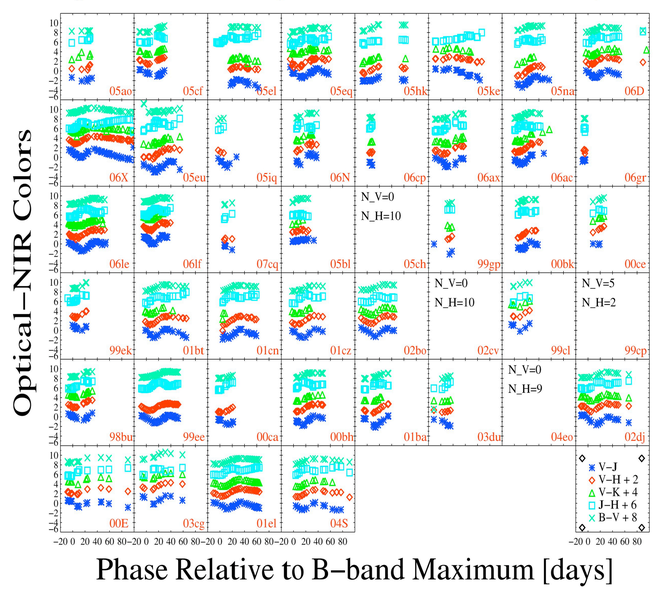
We attempt to disentangle the relationship between intrinsic color variation and extinction by dust in Type Ia supernovae (SN Ia) using the largest broadband set of SN Ia light curves to date. Our sample of ~60 low-redshift light curves includes Near-Infrared (NIR) data from the PAIRITEL 1.3m, Optical data from the FLWO 1.2m, and Ultraviolet data from *Swift*, along with other Optical and NIR data from the literature. Extinction by dust is currently the dominant systematic error in SN Ia cosmology. Adding NIR data significantly reduces systematic distance errors derived from Optical data alone. Since SN Ia are also intrinsically more standard at NIR wavelengths than Optical wavelengths, this work motivates future Infrared space studies optimized for high redshift SN Ia cosmology (e.g. JWST, JDEM). Infrared observations of Type Ia Supernovae will thus be crucial to optimally constraining the history of cosmic expansion.

SN Light Curves and Color Curves

PAIRITEL, the robotic 1.3-m Peters Automated Infra Red Imaging TELescope at Mount Hopkins, Arizona, 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 ($z < 0.04$) sample of SN including 76 SNe Ia, 21 of which are presented in Wood-Vasey, Friedman et al. 2008 with ~20 more in Friedman et al. 2009 *in prep*. Simultaneous JHKs observations and nightly cadence allow for densely sampled light curves. We also obtain concurrent optical observations with the Mt. Hopkins 1.2-m (Hicken et al. 2009 *in prep.*). Ultraviolet data for a subset of these SN have been obtained by the NASA *Swift* satellite, (Brown et. al. 2008)



21 PAIRITEL NIR SN Ia Light Curves JHKs template LCs constructed from 18 PTEL SN (above), 23 from Literature. 3 peculiar SN Ia: 05bl, 05hk, 05ke excluded from template. (**Wood-Vasey, Friedman et al. 2008**).



BVJHK Color Curves for 40 SN Ia NIR data: PAIRITEL+Literature. Optical data: Mount Hopkins 1.2m+Literature. UV data not shown. ~60 SN with Optical+NIR data in preparation. (**Friedman et al. 2009, *in prep***).

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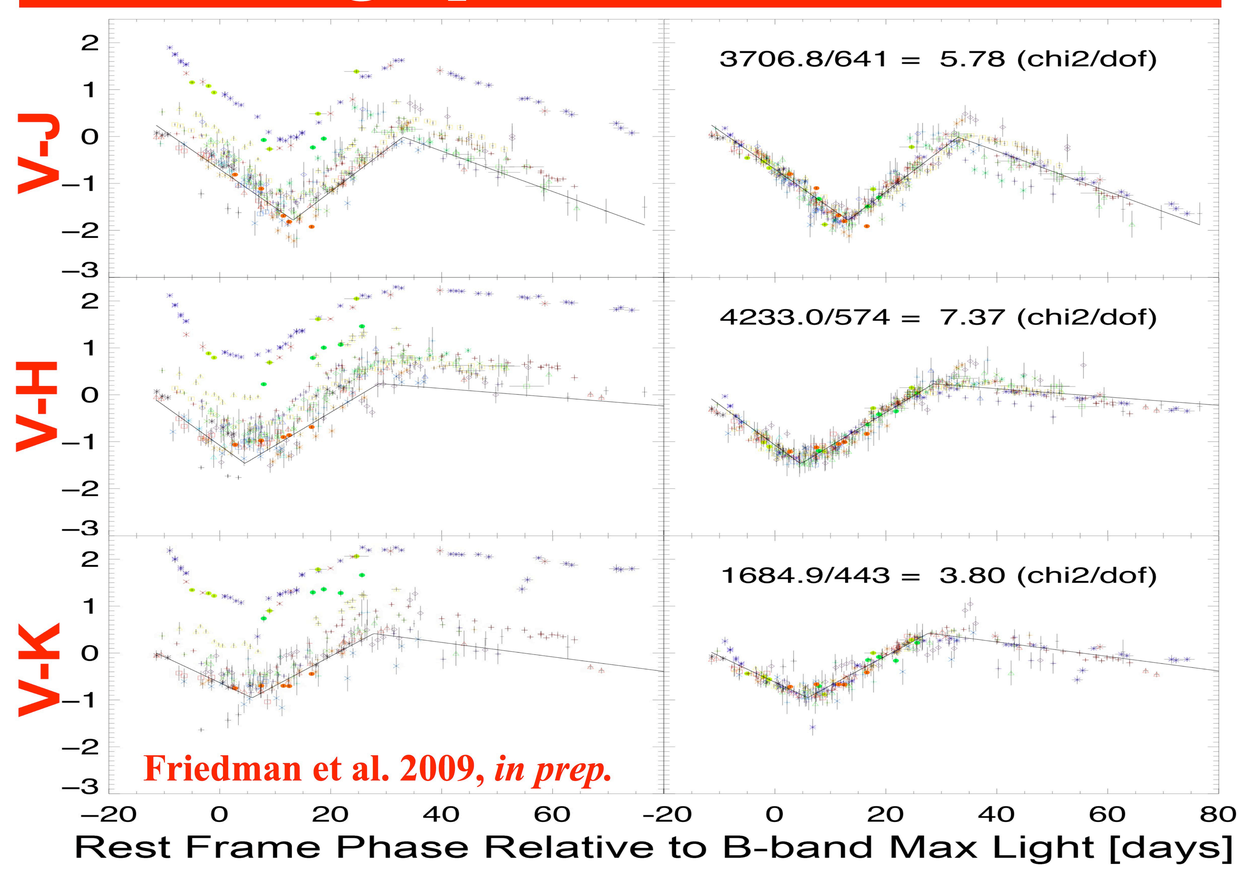
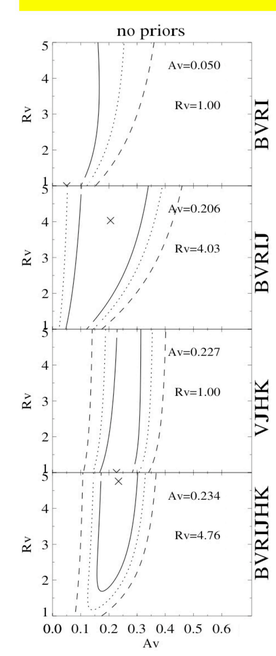
Estimating Optical-NIR Color Excesses

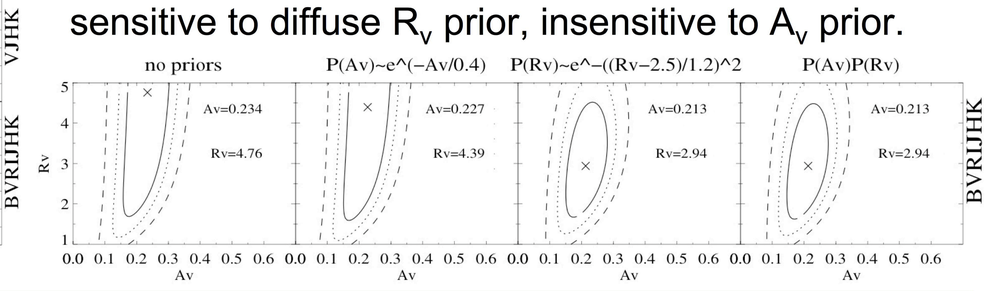


V-JHK Color Curves for 40 SN Ia. Color Excess E(V-JHK) estimated from offset to fiducial unreddened locus (black line). Variance of residuals measures intrinsic color variation at each epoch. Corrected for time-dilation, MW extinction, K-corrected, no LC shape corrections.

Constraining Extinction, Dust Properties



A_V-R_V Contours for sn2005cf. (**left**) BVRIJHK Color Excesses constrain Extinction Av~0.23, better than BVRI alone. Host Galaxy Dust parameter R_V harder to constrain for A_V<0.5. Dominant errors from intrinsic color variation, zero point of unreddened locus, photometry. 68%, 95%, 99% confidence regions shown. (**below**) Effect of priors. Contours very sensitive to diffuse R_V prior, insensitive to A_V prior.



Future Work, Impact on NASA JDEM

Following Krisciunas et al. 2004, 2007, we confirm that nearby SN Ia are excellent NIR standard candles, less sensitive to dust extinction than optical data (Wood-Vasey at al. 2008, Mandel et al. 2009 *in prep*, Friedman et al. 2009 *in prep*). Combined optical and NIR data give improved measurements of extinction and distance. As such, Rest-frame NIR should be strongly considered for future space missions optimized for SN Ia cosmology. The SNAP (Aldering 2004) and DESTINY satellites (Lauer 2005), candidates for the NASA/DOE Joint Dark Energy Mission (JDEM) mission, both currently have detectors designed out to 1.7 μm, which will detect rest-frame H-band light (1.6 μm) only out to z~0.1. Only a 2-5 μm detector designed for rest-frame H-band at z~0.5-2 can take full advantage of the NIR SN Ia standard candle. Goal: Measure w to 1-3%. Prior to JWST, the astronomical community should discuss the costs and benefits of a JDEM bandpass out to 2-5 μm.