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

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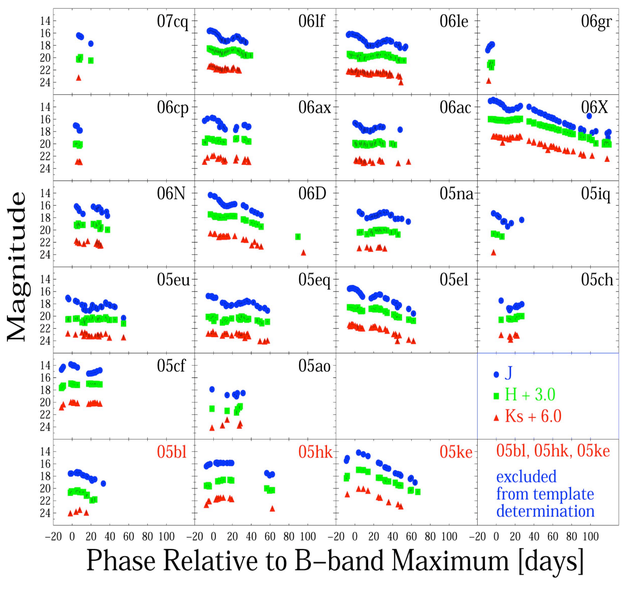
Abstract

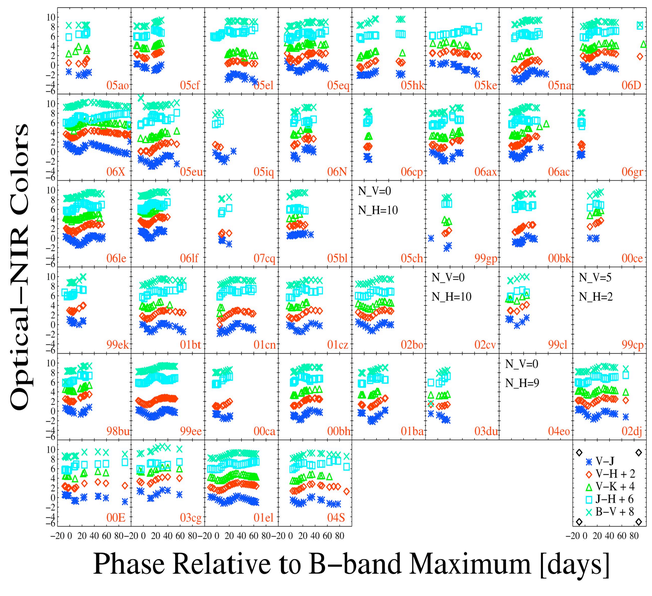
Extinction by dust and its degeneracy with intrinsic color variation is one of the dominant systematic errors in Type Ia supernova cosmology. Since extinction decreases toward longer wavelengths, and SN Ia are intrinsically most standard in the Near-Infrared, adding NIR data significantly reduces systematic extinction and distance errors derived from Optical data alone. Using the largest broadband set of low-z SN Ia light curves to date, we attempt to disentangle the effects of intrinsic color variation and dust extinction. Our current sample of ~40 SN Ia includes PAIRITEL 1.3m NIR data, FLWO 1.2m Optical data, and other data from the literature. We will add an additional ~40-60 PAIRITEL NIR SN Ia LCs by early 2010. We hope to estimate A_v and R_v for each SN in our sample and constrain the prior population distributions of A_v and R_v. By characterizing the extinction and dust properties of the low-z sample, we hope to inform current ground-based NIR work (e.g. CSP) and future Infrared space studies optimized for high-z SN Ia cosmology (e.g. JWST, JDEM).

SN Ia Light Curves and Color Curves

PAIRITEL, the robotic 1.3-m Peters Automated Infra Red Imaging TELescope at Mt. Hopkins, AZ, uses the same camera and filter set as the former 2MASS project, providing convenient photometric calibration from the 2MASS catalogue (Bloom et al. 06, Cutri et al. 03). Since January 2005, PAIRITEL has dedicated ~30% of its time (~2-3 hours a night) to follow up a nearby sample (z<0.04) of SN including 93 SN Ia, 21 of which are presented in Wood-Vasey, Friedman et al. 08 with ~40-60 more in *Friedman et al. 09 in prep*. Following Krisciunas et al. 04, 07, we confirm that SN Ia are excellent NIR standard candles, less sensitive to dust extinction than optical data (Wood-Vasey at al. 08, Mandel et al. 09, *Friedman et al. 09*). Hicken et al. 09 present CfA Optical observations for 185 SN Ia. UV data have also been observed for a subset of low-z SN Ia with the NASA *Swift* satellite (Brown et al. 08).



21 PAIRITEL NIR SN Ia Light Curves JHKs template LCs are constructed from 18 PTEL SN (above), 23 from Literature. 3 peculiar SN Ia: 05bl, 05hk, 05ke excluded from template. (**Wood-Vasey, Friedman et al. 08**).



BVJHK Color Curves for 40 SN Ia NIR data: PAIRITEL+Literature. Optical data: Mount Hopkins 1.2m+Literature. UV data not shown. ~40-60 more SN Ia with Optical+NIR data by early 2010. (**Friedman et al. 09, *in prep***).

References

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Jha et al. 2007, 659, 122J
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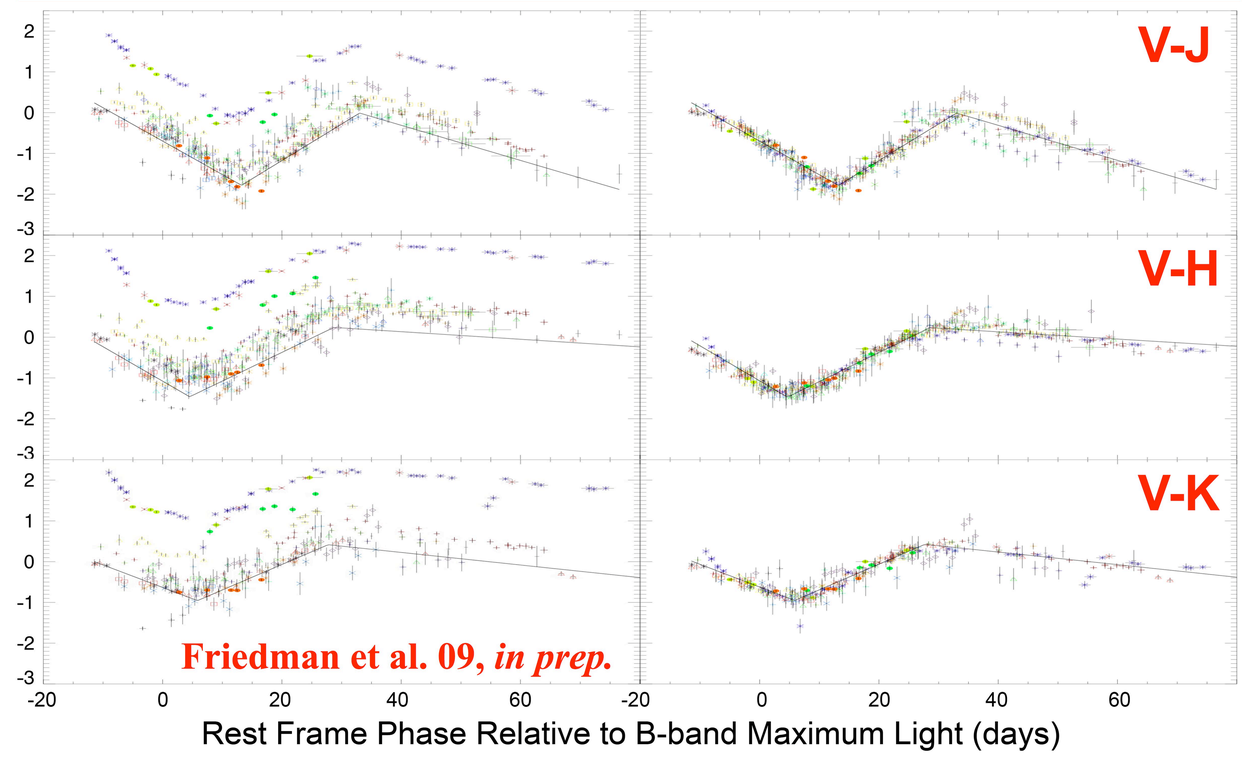
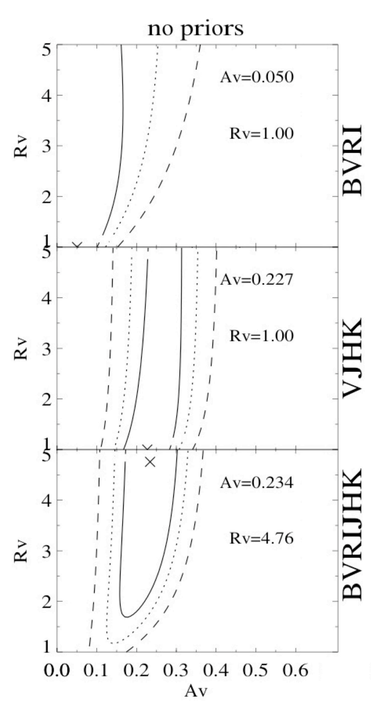
Estimating Optical-NIR Color Excesses

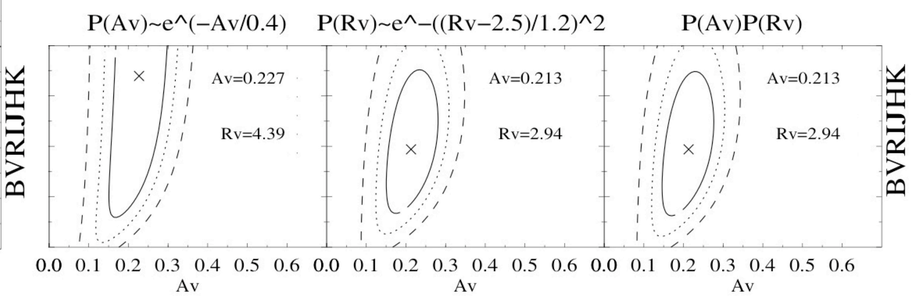


V-JHK Color Curves for 40 SN Ia. Color Excess E(V-JHK) estimated from offset to mean intrinsic color locus (black line). Variance of residuals constrains intrinsic color variation at each epoch. Corrected for time-dilation, MW extinction, K-corrected, no LC shape corrections.

Constraining Extinction, Dust Properties



A_v-R_v Estimates for SN05cf. (**left**) BVRIJHK color excesses (Wang et al. 2009) constrain extinction better than BVRI alone. With no priors, R_v hard to constrain for small A_v. *Uncertainties*: mean intrinsic color zero pt., intrinsic color variation, photometric errors. 68%, 95%, 99% probability regions shown. (**below**). Contours sensitive to R_v prior, less sensitive to A_v prior.



Future Work

As we expand our NIR/Optical data set (*Friedman et al. 09*), we attempt to model the prior distributions of intrinsic color and dust and use this information to find the most probable values of A_v and R_v for each SN. Our algorithm estimates the prior distributions by conditioning only on observed color data (i.e. no redshift data is used). Assuming the priors are known with perfect certainty, we can approximately compute the joint posterior distribution for A_v and R_v conditioned on the observed colors and priors. In related work, Mandel et al. 09 use an MCMC Gibbs sampling algorithm to compute the full joint posterior distributions of the means and variances of the NIR absolute magnitudes, conditioning only on NIR LCs and redshifts. Doubling the current sample will significantly improve our intrinsic color and dust inferences (*Friedman et al. 09*).

The CfA SN Program is supported by NSF Grant AST0205808 to Harvard U. A.S.F. acknowledges support from an NSF Graduate Research Fellowship and a NASA GSRP fellowship with Dr. Neil Gehrels (NASA/GSFC). PAIRITEL has been supported by a grant from the Milton Fund (Harvard U.). The camera is on loan from Prof. Mike Skrutskie at U. of Virginia.