Investigating the possibility of constructing a model-free SDSS II SN Ia training set

J. Mosher[1], M. Sako[1], J. Holtzman[2], J. A. Frieman[3], R. Kessler[4], P. Garnavich[5], S.W. Jha[6], B. Dilday[6], SDSS-II Collaboration

[1]University of Pennsylvania; [2]New Mexico State University; [3]Fermi National Accelerator Laboratory; [4]The University of Chicago; [5]University of Notre Dame; [6]Rutgers University.

INTRODUCTION

For type Ia supernovae to continue to play a key role in the quest to improve our understanding of dark energy, systematic uncertainties must be understood and reduced. Some of the most important systematic uncertainties include k-correction uncertainties, host galaxy extinction uncertainties and photometric calibration uncertainties. In evaluating the training set suitability of the 84 SDSS II Supernova Survey Ia's with $z < 0.15$ and passing basic cosmology cuts, we touch upon each of these issues.

To use these SNe as a traditional training set we need to k-correct them to rest frame and be able to estimate host galaxy extinction coefficients for each.

We would prefer to be able to make these corrections with minimal use of models.

Because all SDSS II SNe were imaged with a single well-calibrated telescope, the photometric systematic uncertainties are minimal.

In this work we evaluate rest frame light curves created from two different k-correction methods, and discuss our ability to extract reliable host galaxy extinction information from our data set.

DIFFERENT K-CORRECTION METHODS, DIFFERENT RESULTS

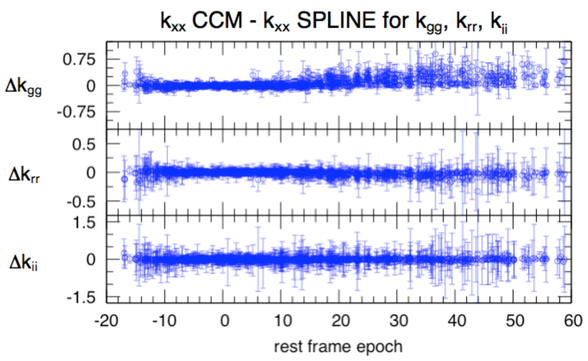
SED Templates: *Hsiao*	+	Photometry: *observed*	+	Color Adjustment: *CCM* vs. *spline*

Two different color adjustment techniques were implemented:

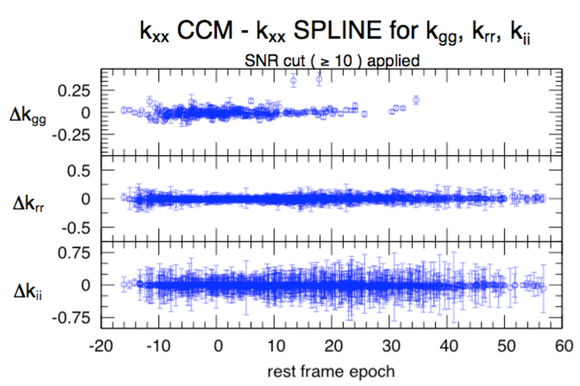
1. Extinction law, e.g. the use of CCM by Nugent et al. (2002), which matches the template to a single color, redward of the band of interest.
2. Spline interpolation (e.g. Hsiao et al. 2007), which matches the template to at least two colors, redward and blueward of the band of interest.

Purpose:

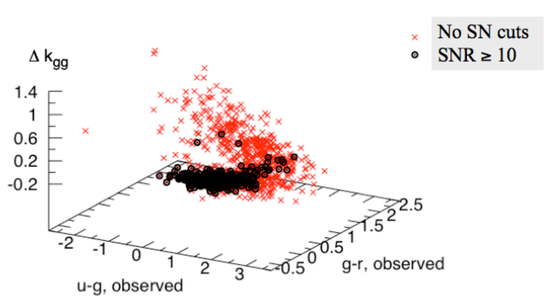
Avoid models or fits, but use the fact that ugriz magnitudes were acquired nearly simultaneously so that interpolation to get mags for color adjustments is unnecessary.



CCM and spline techniques are consistent in the r and i bands, but different at late times in the g band. Differences imply spline g light curve will be ~ 0.1 magnitude dimmer than a CCM g light curve for rest frame epochs between 30 and 50 days.



Applying a signal to noise cut of SNR ≥ 10 results in disappearance of most of the late time u band data necessary for the spline color adjustment.

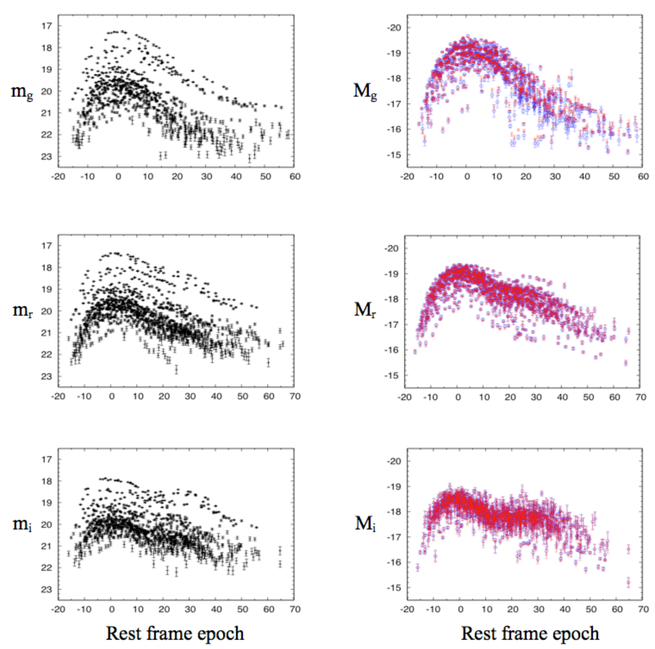


Large k-correction differences occur when u-g is smaller than ~0.5 mags and g-r is redder than ~0.75 mags, a combination of colors that is quite different from the Hsiao template at late times.

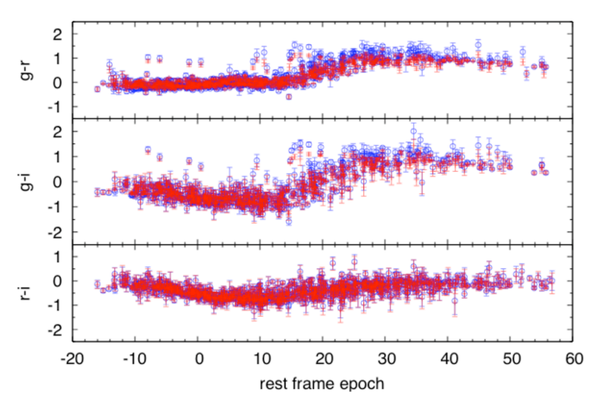
Possible sources of difference between CCM and spline k-correction methods include:

- *accuracy of input u-band photometry*. Observed photometry is noisy; this is especially true for the u band, and is a major drawback to our approach. It may be necessary to use fits and/or templates in the u band in order to distinguish between noise and color differences.
- *spline difficulties*. One major advantage of the CCM color adjustment method is that it is always smooth and local. Spline color adjustments are sensitive to edge effects, and if significant color adjustment is necessary, can distort the shape of the template.
- *shape of the template in blue portion of the spectrum*. If the template does not reflect the mean in a particular spectral region, for a particular epoch, k-corrections will be systematically affected.

REST FRAME LIGHT CURVES



To mitigate noise while retaining some late time data, light curves have been calculated using a photometry subset for which observed g, r, and i magnitudes are either less than 21.5 or have magnitude errors less than or equal to 0.2 . No restrictions have been placed on u band magnitudes. MWG extinction corrections were made with SFD dust maps, the CCM extinction law, and color-adjusted Hsiao templates. Distance modulus was calculated with ΛCDM cosmology. No host galaxy corrections have been applied. Light curves with CCM (red) and spline (blue) k-corrections are both shown. Observed light curves (black) are shown for reference.

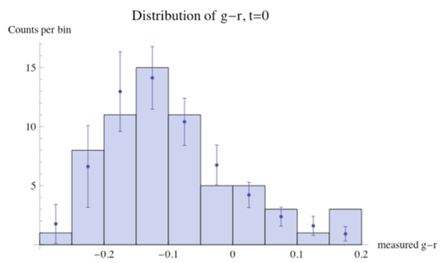


Color curves for MWG extinction corrected rest frame photometry. CCM (red) and spline (blue) r-i curves are almost identical whereas the spline g-r and g-i curves are redder at late times than their CCM counterparts.

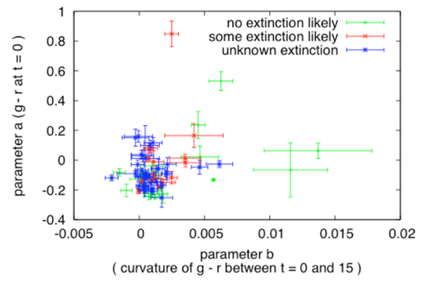
PRELIMINARY HOST GALAXY EXTINCTION ESTIMATES

Peak g-r data was fit to extract intrinsic color and extinction information:

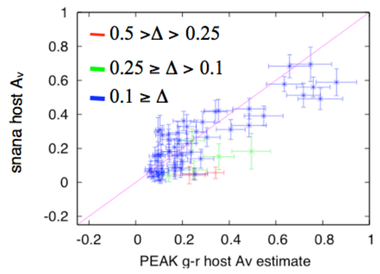
1. Simple parabola fit used to get g-r(t=0) and width-luminosity parameter information for each supernova.
2. After cutting SNe with high likelihood of being intrinsically red, use remaining g-r(t=0) information to estimate host extinction for each SN.



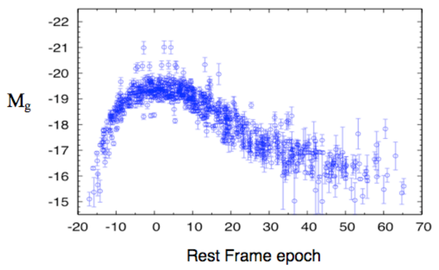
A histogram of peak g-r colors has been overlaid with the best fit probability predictions (including only data from the 63 SNe with enough data between rest frame epochs -5 and 15 to be fit, and passing a color cut). The fit is adequate for g-r < 0.15, but diverges by more than 2 σ for the reddest objects.



Peak time data is fit with parabola of form $g\text{-}r = a + b\,t^2$. Intrinsically dim SNe have g-r color curves that increase more rapidly with time, allowing them to be separated from the rest, as per Phillips et al 1999. All but one SN with $b > 0.004$ also has SNANA luminosity parameter $\Delta > 0.5$. (the exception is 8151, a known spectroscopic peculiar) The SN we expect to be less extincted, due to their host galaxy type or their separation from the galactic center, are intrinsically dim or within two σ of the mean $(g\text{-}r)_0$.



A comparison of peak g-r host extinction estimates with SDSS II light curve fitter host galaxy A_v. By excluding supernovae with $b > 0.004$ all SNe with $\Delta > 0.5$ have been excluded. In general, our host galaxy extinction estimates are higher than the SNANA estimates.



Results:

1. We were able to obtain host galaxy extinction estimates for 63 of the 84 light curves being studied.
2. The peak Av technique displayed here requires cutting SNe likely to be intrinsically dim. This is not ideal.
3. It seems likely that our extinction estimates are too large (see host galaxy corrected light curve above) . Tweaking of method is possible, but using late time data would be preferable.

CONCLUSIONS & FUTURE WORK

This work describes preliminary steps taken to evaluate low redshift SDSS II SN Ia data for use as a light curve fitter training set. Without the use of models, we were able to k-correct and derive host galaxy extinction estimates for 64 of our supernovae.

Our study shows that k-correction color adjustment methods, spline and CCM, give different results in g band: k corrections need more study. Steps should be taken to determine whether the observed discrepancy is real, or an artifact of our choice of observed photometry or spline technique. If the discrepancy is likely to be real, then it will be necessary to determine which method is correct: this will involve compiling a reasonably large set of high-quality Ia late-time spectra with observed frame coverage of 3000 – 7000 Angstroms.

Our color analysis of g-r near peak is consistent with others' observations that g-r at this epoch depends on intrinsic color as well as extinction. Using the secondary fit parameter b to remove intrinsically red object allowed us to make host galaxy extinction estimates for a subset of our SNe, However, it seems that these estimates are still biased to the red for the intrinsically dimmer SNe that remained. A quantitative evaluation of the quality of these estimates , via residuals of a Hubble diagram, and some tinkering with fit forms and epochs, should be carried out before making a final determination of the suitability of this method. The results of our k-correction examination will have some bearing here: if CCM proves to be adequate, we will have more late-time g-r data to work with and it may be possible to directly compare peak time and late time (Lira type) extinction estimates.

REFERENCES

Cardelli, J.A., Clayton, G.C., & Mathis, J.S., 1989, ApJ, 345, 245
Frieman, J.A. et al. 2008, AJ, 135, 338
Holtzman, J. et al. 2008, AJ, 136, 2306
Hsiao, E.Y., Conley, A., Howell, D.A., et al. 1996, AJ, 112, 2398
Jha, S., Riess, A.G., & Kirschner, R.P. 2007, ApJ, 659, 122
Kessler, R. et al. 2009, (preprint)
Lira, P. 1995, M.S. thesis, Univ. Chile
Nugent, P., Kim, A., & Perlmutter, S. 2002, PASP, 114, 803
Phillips, M.M., Lira, P., Suntzeff, N.B., Schommer, R.A., Hamuy, M., & Maza, J. 1999, AJ, 118, 1766
Riess, A.G., Press, W.H., & Kirschner, R.P. 1996, ApJ, 473, 88
Sako, M. et al 2008, AJ, 135, 348
Schlegel, D.J., Finkbeiner, D.P., & Davis, M. 1998, ApJ, 500, 525
Zheng, C. et al. 2008, AJ, 135, 1766