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SNANA: A PUBLIC SOFTWARE PACKAGE FOR SUPERNOVA ANALYSIS

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ABSTRACT

We describe a general analysis package for supernova (SN) light curves, called SNANA, that contains a simulation, light curve fitter, and cosmology fitter. The software is designed with the primary goal of using SNe Ia as distance indicators for the determination of cosmological parameters, but it can also be used to study efficiencies for analyses of SN rates, estimate contamination from non-Ia SNe, and optimize future surveys. Several SN models are available within the same software architecture, allowing technical features such as K-corrections to be consistently used among multiple models, and thus making it easier to make detailed comparisons between models. New and improved light-curve models can be easily added. The software works with arbitrary surveys and telescopes and has already been used by several collaborations, leading to more robust and easy-to-use code. This software is not intended as a final product release, but rather it is designed to undergo continual improvements from the community as more is learned about SNe. We give an overview of the SNANA capabilities, as well as some of its limitations. Interested users can find software downloads and more detailed information from the manuals at http://www.sdss.org/supernova/SNANA.html.

Subject headings: supernova software

1. INTRODUCTION

It has long been recognized that type Ia supernovae (SN Ia) are a reasonably homogeneous class of events, with similar light curves, colors, and spectra. After accounting for correlations between light-curve shape (usually the width or decline-rate), color, and luminosity, SNe Ia provide relative distance modulus estimates with a dispersion of only $\sim 15\%$ (Phillips 1993). There are many approaches to characterizing the correlations that are used in fitting observed light curves, and the most commonly used methods are shown in Table 1. A typical model includes a combination of template light curves and spectra, along with variable parameters (e.g., stretch and color) that modify the templates to match the observed light curve. The model templates themselves are derived by a "training" procedure involving well-observed SNe. Each light-curve fitting method has been implemented with different software, making comparisons between the models difficult. Comparison of light-curve simulations based on the different models is even more of a challenge, since there are no standard codes or methods.

The analysis of recent SN Ia survey data has shown that the determination of cosmological parameters is now limited by systematic uncertainties (Astier et al. 2006; Wood-Vasey et al. 2007; Kessler et al. 2009) associated with the light-curve fitting methods. To make progress in overcoming these limitations, there is a need for reliable and reproducible analysis software that can be shared among different SN groups aiming to improve or replace these methods. Even in cases where different groups use the same light-curve fitting method, they may use different versions of the software, again complicating comparisons. Moreover, a comparison of different analysis methods can be complicated by subtle differences in analysis details such as the treatment of selection criteria and K-corrections. Unraveling these differences calls for a single, well-documented analysis framework with clear software version control. In addition, such a framework can naturally incorporate detailed Monte Carlo simulations that are required to quantify the impact of survey selection efficiencies on light-curve fitting and cosmological inference. Such simulations can also be used to investigate sources of intrinsic SN Ia brightness fluctuations that result in scatter in the Hubble diagram beyond that caused by photometric errors.

To address these issues and thereby improve the availability, quality, and reproducibility of SN analyses, we have developed a publicly available analysis software package called SNANA. This package contains a light-curve fitter, Monte Carlo simulation, and cosmology fitter. These tools incorporate existing SN light-curve models (Table 1), and are easily adaptable to new or improved models. A description and comparison of the MLCS2K2 and SALT–II methods is given in § 5 of Kessler et al. (2009). The stretch-templates can represent Ia or non-Ia SNe, and can therefore be applied to any type of SN.

The SNANA software package was originally developed

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and used for the analysis of the SDSS-II SN sample (Frieman et al. 2008; Kessler et al. 2009), but the need to plan for future SN surveys, such as the Dark Energy Survey (DES[10]) and Large Synoptic Survey Telescope (LSST[11]), led to a publicly available package. Additional motivation for public-use software is described in Weiner et al. (2009). This paper describes the capabilities of SNANA, which are rapidly evolving with the needs of larger SN samples. A manual, installation instructions, and the software are available from our website.[12]

There are three basic principles in the design of SNANA. First, each light-curve model is defined in a separate function that is used in both the light-curve fitter and in the simulation. This ensures that the fitter and simulation are synchronized with the same underlying model, and it also allows for anyone to provide a new SN model by simply providing a new function. If the underlying model describes SNe Ia in the rest-frame, then a standard K-correction utility is used based on the choice of spectral template and filter bandpasses. The underlying SN model can also describe SNe Ia in the observer frame, and thus bypass the K-correction utility. The second principle allows for the simulation of any survey by using a standard "observing conditions" library (§ 2) that describes the cadence, seeing, atmospheric transparency, and readout noise. The third principle is to allow a new survey to be added without making code modifications.

TABLE 1
SN MODELS AVAILABLE IN SNANA.

model (reference)	comment
MLCS2K2 (Jha et al. 2007)	$UBVRI$ + K-corr
MLCS2K2-IR (this paper)	$UBVRIYJHK$ + K-corr
SALT–II (Guy et al. 2007)	rest-frame flux vs. λ & epoch
Δm_{15} (Prieto et al. 2006)	$BVRI$ + K-correction
stretch (Goldhaber et al. 2001)	rest-frame mags + K-corr
two-stretch[a] (Hayden et al. 2009)	rest-frame mags + K-corr
non-Ia (this paper)	II(P,L,n), Ib, Ibc

[a]Two-stretch splits the template at peak brightness, and stretches each part separately.

2. SIMULATING SN LIGHT CURVES

Ideally, survey simulations would be based on artificial SNe embedded into survey images at the pixel level. While survey images are available within a collaboration, they are typically not available to the community. Even if survey images were available, full image-level simulations would require a large amount of computing to perform the many variations that are needed to study systematic uncertainties or to optimize a future survey. We have instead developed a fast light-curve simulation that is based upon actual survey conditions and that therefore accounts for non-photometric conditions and varying time intervals between observations due to bad weather. At each survey epoch and sky location, the simulation uses the measured observing conditions to generate realistic light curves that can be analyzed in exactly the same way as the data.

The observing conditions for a survey is stored in a text file called a "SIMLIB," an example of which is shown in Fig. 1. A simulated SN flux is generated for each "MJD" corresponding to an observation. The quantity ZPTAVG relates the magnitude (m) to observed flux (F) in CCD counts by the relation $F = 10^{-0.4(m-\texttt{ZPTAVG})}$; ZPTAVG therefore accounts for the atmospheric transparency, exposure time, and the efficiency of the telescope, CCDs, and filters. To optimize a future survey, the exposure time can be independently varied to avoid re-making the SIMLIB with different ZPTAVG values.

The CCD readout noise and sky-noise are determined by the CDD-NOISE and SKYSIG parameters (per pixel) summed in quadrature over an effective aperture (A) based on PSF-fitting,

$$A = 2\pi \frac{\left[\int PSF(r) r dr\right]^2}{\int [PSF(r)]^2 r dr} \ . \quad (1)$$

For a PSF described by a Gaussian (σ = PSF1 in Fig. 1), the effective aperture is $4\pi\sigma^2$. The simulation accounts for non-Guassian tails in the PSF by including a second Gaussian function parametrized by PSF2 and PSF2/1-RATIO. For the SDSS-II SN simulation, the inclusion of non-Gaussian tails increases the total noise by about 10% compared to the single-Gaussian approximation for the PSF. The quantity ZPTSIG reflects the spread in zeropoints from an ensemble of standard stars, and is used to introduce additional photometric dispersion.

For a small survey field, the SIMLIB needs just one sequence of observations since the conditions within a small field are likely to be uniform. For a large field, such as the 300 square degree field of stripe 82 in the SDSS-II SN Survey (Frieman et al. 2008), a SIMLIB can contain thousands of observation sequences to account for the variations across the field. Whether SN collaborations use SNANA or not, it would be useful if all SN survey teams create appropriate SIMLIB files and make them available along with data releases. The current SNANA package includes SIMLIBs for the SDSS-II (Kessler et al. 2009), ESSENCE (Wood-Vasey et al. 2007), SNLS (Astier et al. 2006), and HST (Riess et al. 2007) surveys, as well as estimates for future surveys including the DES (Bernstein et al. 2009) and LSST surveys. For completed SN surveys, the generation of a SIMLIB is straightforward to extract from the observations. To study future surveys, the SIMLIB generation is typically based on extrapolating previous observations at a similar site, and including observing gaps due to the moon and telescope operations. The reliability in predicting a SIMLIB for a future survey is crucial to the reliability of the simulation results.

The simulation begins with the generation of SN properties based on the selected model from Table 1, typically choosing a shape-luminosity and color parameter. The color parameter can represent host-galaxy extinction (A_V) for models such as MLCS2K2, or it can reflect an agnostic relation between the supernova color and its peak brightness (i.e, for models like SALT–II). The parent distributions of these parameters are currently based on a nearly complete sample of SDSS-II SNe as described in §7 of Kessler et al. (2009). The shape and color parameters, along with other internal model (training) pa-

[10] http://www.darkenergysurvey.org
[11] http://www.lsst.org/lsst
[12] http://www.sdss.org/supernova/SNANA.html

```
SURVEY: SDSS     FILTERS: ugriz   TELESCOPE:  SDSS
USER: John Q SN     HOST: sdssdp47.fnal.gov
COMMENT: 'Extract random RA,DECL : year=2005'
BEGIN LIBGEN  Tue Jul 22 15:08:41 2008

# ---------

LIBID: 1
RA: 26.430172  DECL: 0.844033  NOBS: 42  MWEBV: 0.026  PIXSIZE: 0.40

                       CCD  CCD         PSF1 PSF2 PSF2/1
      MJD     ID FLT GAIN NOISE SKYSIG (pixels)  RATIO ZPTAVG ZPTSIG
S: 53616.383  405 u  1.47  4.48   4.83 1.89 3.69 0.225  27.42  0.018
S: 53616.383  405 g  4.05  4.25   4.04 1.85 3.61 0.247  28.29  0.023
S: 53616.383  405 r  4.72  4.25   5.28 1.64 3.62 0.142  28.17  0.012
S: 53616.383  405 i  4.64 12.99   6.95 1.60 3.81 0.103  27.80  0.038
S: 53616.383  405 z  3.48  4.70   6.91 1.74 3.75 0.131  26.48  0.013
S: 53622.395  552 u  2.17  5.75   3.26 1.66 3.42 0.146  26.95  0.016
S: 53622.395  552 g  4.03  5.45   4.09 1.58 3.31 0.107  28.38  0.021
S: 53622.395  552 r  4.89  4.65   5.00 1.46 3.55 0.065  28.14  0.011
S: 53622.395  552 i  4.76 10.71   6.43 1.53 3.65 0.075  27.83  0.036
S: 53622.395  552 z  4.69  5.16   4.91 1.43 3.35 0.068  26.10  0.009
S: 53626.359  625 u  1.47  4.48   4.60 1.71 3.62 0.116  27.49  0.033
S: 53626.359  625 g  4.05  4.25   4.40 1.83 3.50 0.282  28.22  0.095
S: 53626.359  625 r  4.72  4.25   5.87 1.64 3.65 0.112  28.18  0.042
S: 53626.359  625 i  4.64 12.99   6.54 1.47 3.56 0.070  27.82  0.040
S: 53626.359  625 z  3.48  4.70   6.73 1.64 3.88 0.110  26.49  0.012
etc ...
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FIG. 1.— Example excerpt from a SIMLIB for the SDSS-II SN Survey.

rameters such as light curve templates and spectral surfaces, are used by the light curve model to determine the rest-frame magnitude at each epoch. To study potential biases from evolving SN properties, an arbitrary redshift dependence can be assigned to the parent distributions of the shape and color parameters, as well as to the model parameters that relate shape and color to intrinsic brightness (e.g., SALT–II α, β, and host-galaxy dust parameter R_V). The simulation also includes "intrinsic smearing" options to introduce additional scatter in the Hubble diagram residuals.

K-corrections similar to the method in Nugent et al. (2002) are used to transform rest-frame model magnitudes to observer-frame magnitudes in the telescope system. For most applications the spectral templates from Hsiao et al. (2007) are used to determine the K-corrections, but the SNANA software allows for using any spectral template. For the final step in the simulation, the SIMLIB is used to translate the ideal above-atmosphere magnitudes into observed fluxes and uncertainties. As explained in §6 of Kessler et al. (2009), the simulation for each survey accounts for search-related efficiencies; in particular, the spectroscopic efficiency is based on the discrepancy between the observed and simulated redshift distribution. The quality and flexibility of the simulation is illustrated in Figs. 2-3, which show data-simulation comparisons for the measured flux and its uncertainty for four different surveys. For the flux-uncertainty comparison (Fig. 3), there are some discrepancies that may be due to a mis-interpretation of the noise determination from the image-subtraction pipeline.

Although supernova-based cosmology results have all used rest-frame SN Ia models of optical ($UBVRI$) light curves, there is a growing interest in obtaining infrared light curves in order to reduce the effect of host-galaxy extinction. To study such possibilities in future surveys, rest-frame infrared light curves can be simulated using an extended version of MLCS2K2 in which light curve templates for $YJHK$ have been constructed based on recent observations from PAIRITEL (Wood-Vasey et al. 2008).

To study the determination of SN Ia photometric redshifts (photo-Z), the simulation includes a host-galaxy photo-Z library (HOSTLIB) so that the host-galaxy photo-Z can be used as a prior in a photo-Z fit. The HOSTLIB is not created by SNANA, and therefore the HOSTLIB must be created externally from either another simulation, or from a photo-Z analysis of host-galaxies with spectroscopic redshifts. The SNANA simulation simply finds a host galaxy with a redshift matching the SN redshift, and stores the host-galaxy photo-Z to be used by the light curve fitter.

To estimate SN Ia sample contamination, the simulation can generate non-Ia SN light curves. While the Type Ia light curve models are based on a parametric equation or photometric templates, there are no such models for non-Ia types. To allow for a large diversity of non-Ia SNe, the simulation uses a library of spectral templates that specify the SN flux as a function of epoch and wavelength. A spectral template can be a smoothed average based on an ensemble of SNe, or a template can correspond to a particular (well-observed) supernova where a composite spectrum is warped to match the observed photometric colors. Since the spectral templates are interpolated to cover all wavelengths and epochs, only well-sampled photometric light curves are used. The current library contains composite and individual templates for types IIP, IIn, Ib, and Ibc. The simulation of the non-Ia

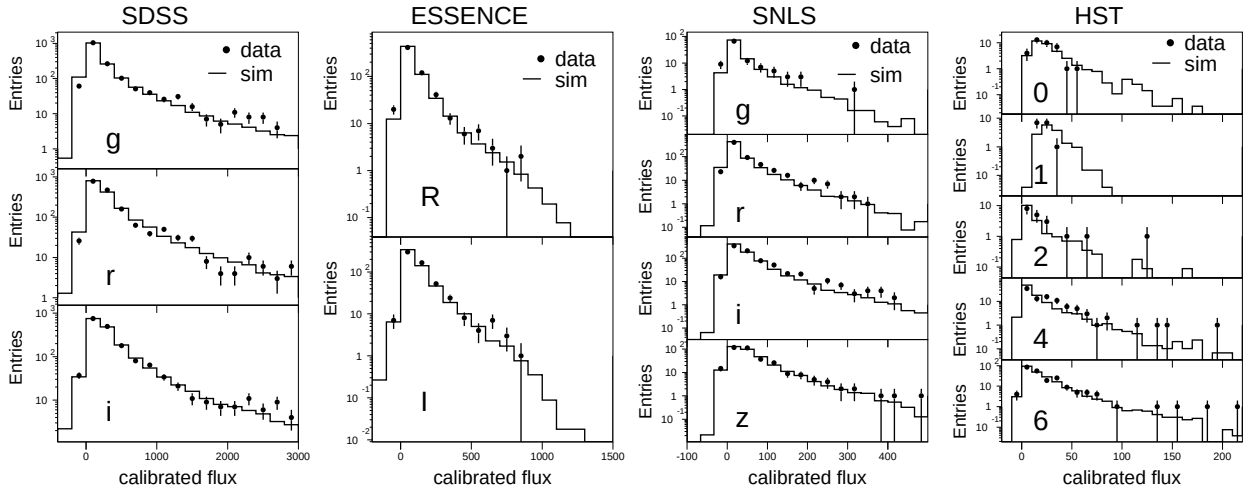

FIG. 2.— Comparison of flux distributions for data (dots) and simulations (histograms) for SDSS-II, ESSENCE, SNLS, and HST. The observer-frame passband is indicated on each plot (HST filter symbols are 0 =NIC-F110W, 1 =NIC-F160W, 2 =ACS-F606W, 4 =ACS-F775W, 6 =ACS-F850LP). Each simulated distribution is scaled to have the same total number of entries as the data. The calibrated flux is $10^{-0.4\cdot\mathrm{mag}+11}$.

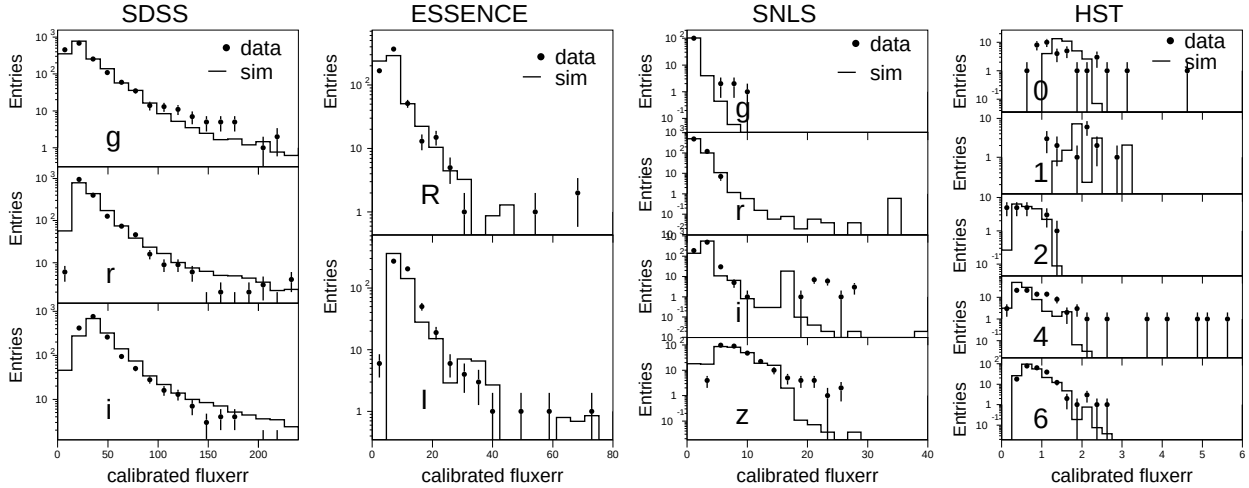

FIG. 3.— Data-simulation comparison of the flux uncertainty. See Fig. 2 caption for details.

diversity will gradually improve as more well-observed non-Ia light curves become available. A limitation of SNANA is that there is currently no utility to convert non-Ia light curves into spectral surfaces.

A trigger simulation is included to mimic algorithms that are used to discover SNe Ia in real time. Although the offline selection criteria should in principle be more stringent than the search trigger, it may be useful to use the simulation to make more rigorous crosschecks. The trigger simulation is also useful to anticipate SN discovery rates in the design of future surveys. The trigger simulation is based on user-supplied efficiency tables that depend either on observed magnitudes or on the signal-to-noise ratio (SNR). These efficiency tables could be made, for example, by injecting fake SNe into real images, and then passing these images through the object-finding pipeline. Since a discovery typically requires observations in multiple filters and/or multiple epochs, one can specify arbitrary detection logic. For example, the SDSS-II SN Survey required a detection in at least two of the *gri* filters, and required a detection at two or more epochs; this logic is simulated by specifying the trigger to be "2 gr+ri+gi."

A more difficult aspect of the trigger is the target selection for spectroscopic observations. Since spectroscopic selection is based on human decisions and telescope availability, there is no clear software algorithm to describe this part of the efficiency. As described in § 6.2.1 of Kessler et al. (2009), the observed and simulated redshift distributions can be used to empirically determine the spectroscopic selection efficiency. After all quantifiable sources of inefficiency are included in the simulation, the simulated redshift distribution will typically not match that of the data. In the specific case of Kessler et al. (2009), the observed redshift distribution always has a deficit at higher redshifts compared to the simulation, and this deficit is assumed to be a result of the spectroscopic efficiency (ϵ_{spec}). In general, ϵ_{spec} depends on two types of parameters. The first set of parameters are those determined by the simulation (denoted $\vec{x}_{\mathrm{sim}}$), such

as intrinsic or observed brightness, host-galaxy extinction, and host-SN separation. The second set of parameters (denoted $\vec{x}_{\rm model}$) are those introduced by the analysis team based on their knowledge of survey operations, or in some cases based on a guess. A simple example is $\epsilon_{\rm spec} = \exp[-(r-r_0)/\tau_r]$, where $\vec{x}_{\rm sim} = r$ is the observed r-band magnitude, and $\vec{x}_{\rm model} = \{r_0, \tau_r\}$ are the model parameters. The $\vec{x}_{\rm model}$ parameters are determined by solving

$$\int d\vec{x}_{\rm sim}\,[N_{\rm SIM}(z_i,\vec{x}_{\rm sim})\epsilon_{\rm spec}(z_i,\vec{x}_{\rm sim},\vec{x}_{\rm model})] = N_{\rm DATA}(z_i)\ , \quad (2)$$

where $N_{\rm DATA}(z_i)$ is the number of observed SNe, after all selection criteria, in the redshift bin centered at z_i, and $N_{\rm SIM}(z_i,\vec{x}_{\rm sim})$ is the number of simulated SNe in the same redshift bin and within the integration cell denoted by $d\vec{x}_{\rm sim}$. SNANA can be used to determine $N_{\rm SIM}(z,\vec{x}_{\rm sim})$ and $N_{\rm DATA}(z)$, but the extraction of $\vec{x}_{\rm model}$ requires specific software that is currently not part of SNANA. It may be convenient to determine the model parameters in redshfit bins, $\vec{x}_{\rm model}(z_i)$, and then fit each parameter to a smooth function of redshift. With each new definition of $\vec{x}_{\rm model}$ parameters, the SNANA simulation is easily modified to compute $\epsilon_{\rm spec}(z,\vec{x}_{\rm sim},\vec{x}_{\rm model})$. Finally, we note that the precision in determining $\epsilon_{\rm spec}$ is limited by the precision in the SN rate as a function of redshift.

3. LIGHT CURVE FITTING

The light curve fitting program is appended to an underlying program that reads SN light curves and applies user-defined criteria to select a subset of SNe and epochs. Users can append other fitters or other analysis programs to the underlying program. This structure ensures a uniform definition of selection requirements that can be shared among users.

The SNANA light curve fitter treats data and simulated samples in exactly the same way. Available models are shown in Table 1. Models that describe SNe in the rest-frame all use the same algorithms for host-galaxy extinction and K-corrections. The standard fit assumes a well-known spectroscopic redshift, and then fits for shape and color parameters. For the MLCS2K2 model, each fit returns four parameters: epoch of peak brightness (t_0), shape-parameter (Δ), host-galaxy extinction (A_V), and a distance modulus (μ). For other similar models, the shape-parameter Δ is replaced by the corresponding parameter, such as stretch or Δm_{15}. Observer-frame infrared light curves ($YJHK$, HST, etc ...) can be fit with any model at redshifts that correspond to the rest-frame optical region of the model. For MLCS2K2, the rest-frame model includes $YJHK$. Example light curve fits in the optical and infrared (using the MLCS2K2 model) are shown in Figs. 4-5.

For surveys that cannot obtain a spectrum for all SNe, there are two photo-Z fit options. The MLCS2K2 model is used here for illustration. The first method, called a "constrained photo-Z fit," is designed to identify SN Ia that do not have a spectroscopic redshift: uses include SN rate measurements and targeting host-galaxy redshifts for unconfirmed SNe Ia. In this 4-parameter fit, the redshift is a fitted parameter and the distance modulus is constrained (calculated) so that the observed luminosity of the SN corresponds to a particular cosmology: $\mu = \mu(z,\Omega_{\rm M},\Omega_\Lambda,w)$ where $\Omega_{\rm M},\Omega_\Lambda,w$ are fixed by the user. The second method, called a "cosmology-photoZ"

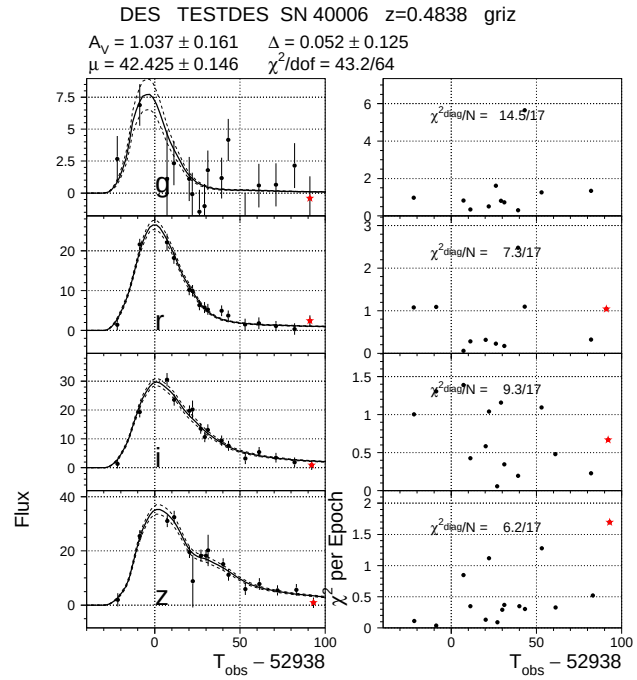

FIG. 4.— As part of a study to optimize the DES-SN Survey, SNANA-MLCS2K2 light curve fits (left) are shown for a simulated SN Ia at redshift $z = 0.48$ with host-galaxy extinction $A_V \sim 1$. The observer filter (g, r, i, z) is indicated on each panel. Solid dots with error bars are the measurements and uncertainties, stars indicates measurements outside the specified epoch range, solid curve is the best-fit model, and dashed curve indicates the model uncertainty. The right panels show the residual χ^2 maps that are useful for identifying outliers.

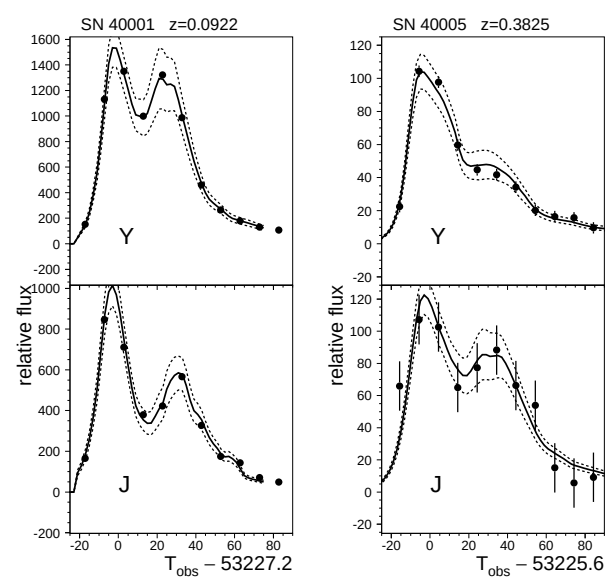

FIG. 5.— As part of a study to observe DES-supernova fields in the infrared with VISTA (Visible and Infrared Survey Telescope for Astronomy: www.vista.ac.uk), SNANA-MLCS2K2 light curve fits are shown for simulated SNe Ia at redshifts shown above each panel. The observer filter (Y, J) is indicated on each panel. Symbols and curves are defined in the Fig. 4 caption.

fit, involves fitting for both the redshift and distance modulus: the five fitted parameters are μ, z, t_0, Δ, A_V. A potential difficulty with the 5-parameter cosmology-photoZ fit is CPU time: the marginalization (see § 5) takes a few minutes per fit, so studying a sample of 10^4 SNe Ia requires about a CPU-month of resources.[13] In addition to these photo-Z methods, the host-galaxy photo-Z can be used as a prior to help constrain the redshift. For simulated SNe Ia in the Dark Energy Survey (DES), Fig. 6 shows the difference between the fitted photo-Z ($Z_{\rm phot}$) and true redshift ($Z_{\rm true}$). As expected, including the host-galaxy photo-Z as a prior results in a smaller scatter in $Z_{\rm phot} - Z_{\rm true}$.

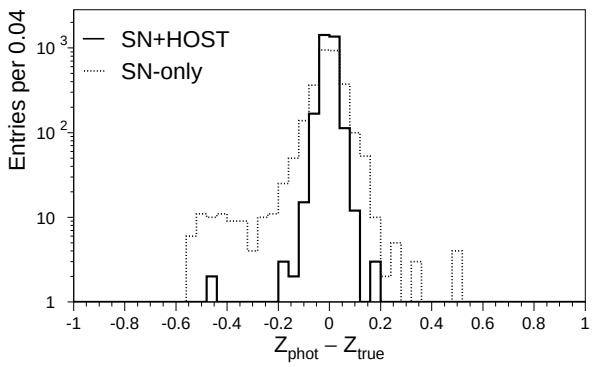

FIG. 6.— Distribution of $Z_{\rm phot} - Z_{\rm true}$ from a study of the DES-SN Survey in a scenario in which spectroscopic redshifts are not available. $Z_{\rm phot}$ is the SN photometric redshift obtained with the MLCS2K2 method. Dashed histogram is based solely on the SN photometric light curve, and the solid histogram includes the host-galaxy photo-Z as a prior.

All fitting methods use MINUIT[14] to obtain parameter values that minimize the data-model χ^2. There is also an option to obtain marginalized parameter estimates[15] at the expense of taking more CPU time, particularly for the 5-parameter cosmology-photoZ fit. The interaction between fitting and selection requirements introduces a subtle caveat in selecting measurements within a specific epoch range relative to the time (t_0) of maximum brightness. The epoch range is not well defined before the fit, making the epoch selection ambiguous. The SNANA light curve fitter handles this situation by performing two fit iterations. In the first iteration, the epoch range is very wide. The first estimate of t_0 is then used to define the epoch-window for the second iteration. The star in Fig. 4 indicates a measurement that was rejected in the second iteration because it is outside the user-specified epoch window.

The light-curve fitter includes the capability to determine interpolated fluxes and uncertainties at any epoch. The uncertainty accounts for covariances among the model parameters. This interpolation is useful to compare observed magnitudes with synthetic magnitudes based on spectra, and to compare magnitudes from multiple telescopes that observe the same SN at different times.

4. COSMOLOGY FITTER

SNANA includes a basic cosmology fitter that reads a table of redshifts and distance moduli generated by the light curve fitter, and then determines cosmological parameters w and $\Omega_{\rm M}$ within the framework of the Friedmann-Robertson-Walker model. Priors on the cosmology parameters can be included from measurements of Baryon Acoustic Oscillations and the Cosmic Microwave Background. Covariances from peculiar velocities (Hui & Greene 2006) can be incorporated into the fitter, which effectively downweights the most nearby SNe.

To study more exotic cosmology models, such as time-dependent dark energy and non-zero curvature, there is another fitter based on Monte Carlo Markov Chains.

5. SOFTWARE OVERVIEW

The SNANA software is written primarily in C and fortran, and makes extensive use of the CERN library (CERNLIB) for fitting, creating plots, and for a graphical interface. For analysis features that appear to be specific to a particular data sample or light curve model, there is always an effort to integrate such features in a general manner that can be used more broadly. For example, the use of priors and marginalization that are associated with the MLCS2K2 method have been integrated into SNANA so that they can be used on any light curve model. In addition to the SNANA simulation and fitters, there is an increasing library of software tools for comparing results, translating formats, plotting, sorting, generating a SIMLIB, and converting χ^2 grids into contours. Although the code is stored in a CVS repository for the developers, the public code is released in incremental versions (e.g., v7_07) with release notes documenting the changes.

In anticipation of very large SN surveys in the near future, significant attention has been paid to processing speed. The simulation generates more than 10 light curves per second. The light curve fitter takes about 1 second per light curve for the minimization, but the marginalization can take 10-100 seconds depending on the number of fit parameters and the number of integration bins.

6. CONCLUSION

There are currently about a dozen SN-related analyses that make use of SNANA, and users include students, postdocs, and faculty. This broad usage has greatly helped to improve the reliability and usability of the software package. Experts, nonexperts, and small groups can participate using software that they could not write on their own, and new ideas can be tested with minimal overhead. Since the current SN fitting models are based on externally performed training procedures that cannot be duplicated, there is an urgent need to develop turn-key SN training programs. Scientists interested in studying SN light curves are invited to use and make contributions to SNANA.

[13] Processing times are based on an Intel i686 2.8 GHz processor.
[14] http://wwwasdoc.web.cern.ch/wwwasdoc/minuit/minmain.html
[15] http://pdg.lbl.gov/2009/reviews/rpp2009-rev-probability.pdf

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