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Nearby SuperNova Factory

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The Nearby SuperNova Factory (*SNFactory*) is a project to discover and obtain detailed light curve and spectral observations for over 300 nearby type Ia supernovae (SNe Ia) during the period 2003-2007. The primary goal of the *SNFactory* will be to determine those properties of SNe Ia affecting their use for cosmology.

1 Introduction

The *SNFactory* project has been initiated by scientist at LBNL in the United States; LPNHE (Paris) , IPNL (Lyon) and CRAL (Lyon) in France. The *SNFactory* will concentrate on Type Ia supernovae (SNe Ia), the type which have recently been used to determine that the expansion of the universe is accelerating[1]. The *SNFactory* will lay the foundation for the next generation of experiments to measure the expansion history of the Universe. It will discover and obtain light curve spectrophotometry for $\sim$ 300 Type Ia supernovae in the low-redshift end of the smooth Hubble flow.

2 Science goals

The *SNFactory* science goals are :

- to anchor the low red-shift SN Ia hubble diagram.
- to calibrate/measure technical quantities needed for the analysis of high red-shift SNe Ia.
- to improve the quality and the understanding of the SNe Ia as distance indicator.

If the last point is the main objective of the project the two other points should not be neglected, they will strongly improve the precision on the cosmological parameters extracted from a given set of high red-shift SNe Ia.

2.1 Anchoring the low red-shift Hubble diagram

The luminosity distance to a Type Ia SN is given by:

$$d_L^2 \equiv \frac{L}{4\pi f} = \left[\frac{c(1+z)}{H_o} F\left(z, \Omega_M, \Omega_\Lambda\right)\right]^2 \tag{1}$$

Observations provide the red-shift, z, and the observed SN flux, f. L is the intrinsic SN flux and $F\left(z, \Omega_M, \Omega_\Lambda\right)$ is a function of z, the red shift, Ω_M, the normalized mass-density, and Ω_Λ, the normalized vacuum-energy density. Eq. 1 can be recast in a form convenient from an experimental viewpoint:

$$f = \frac{LH_o^2}{4\pi c^2(1+z)^2} F\left(z, \Omega_M, \Omega_X\right)^{-2} \tag{2}$$

From a cosmological perspective, we are interested in F, Ω_M and Ω_X, while the product LH_o^2 is an unknown nuisance parameter which must be marginalized over in order to extract the cosmological parameters. However, for $z \sim 0$ Eq. 2 simplifies to:

$$f_{|z\sim 0} \sim \frac{LH_o^2}{4\pi (cz)^2} \tag{3}$$

Thus, observations of nearby supernovae can significantly improve the determination of the cosmological parameters by strongly constraining the nuisance product, LH_o^2. For example the extraction of Ω_M and Ω_Λ from the CFHT/SNLS data [a] can benefit from the usage of $\sim$ 200 nearby SNe Ia : the statistical error on Ω_M (Ω_Λ) decreasing from 0.12 (0.37) to 0.06 (0.10) respectively.

2.2 Extinction and K-factor corrections

The standard method of correcting for extinction by dust in the galaxies hosting Type Ia SNe relies on the observed fact that dust scatters blue light more than red light. Thus, the colors of extincted objects are redder than they would be without extinction. Observations of stars of known color and brightness in the Galaxy, and the Large and Small Magellenic clouds suggests a fairly consistent relation between the amount of reddening and the amount of extinction. For rest frame B-band light the amount of dimming is roughly 4× the change in the flux ratio between the B-band and the V-band.

Correction of SN brightnesses for dust extinction involves a comparison of a measurement of the color at maximum light of a new SN with maximum light colors of SNe Ia which are extinction-free (e.g., those in elliptical galaxies, which are mostly free of dust). The change in color must be multiplied by the above factor of 4 to obtain the extinction-corrected brightness.

The current uncertainty in the intrinsic (dust-free) colors of SNe Ia is not negligible. Only about 10% of all host galaxies are elliptical, so the number of calibrating SNe Ia is small. Moreover, few of those SNe Ia are in the smooth Hubble-flow, where the effects between SN color and brightness due to dust and intrinsic luminosity can be separated. As a result, the uncertainty in the intrinsic SN Ia colors is one of the dominant uncertainties in the current cosmology measurements.

Because SNe Ia will be at different red shifts, in the rest frame of the SN any filter used to obtain an image will not exactly match the standard B-band filter. Therefore, the brightness of a SN Ia will be affected by spectral features which are either included or excluded due to filter mismatch. The correction for this effect — referred to as the K-correction — requires knowledge of the SN spectrum and the photon response of the instrument. For high-redshift SNe Ia

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[a] CFHT/SNLS will collect from the ground $\sim$ 700 SNe Ia with $0.3 < z < 0.9$ between the years 2003-2008

the spectrum is usually only available from around the time of maximum light, whereas each photometry point along the SN light-curve requires its own K-correction. Thus, the appropriate spectrum to be used for K-corrections at other epochs on the light-curve must be inferred from the spectra of low-redshift analogs. The choice of the best analog relies on comparison of the maximum-light spectra and the colors of the low- and high-redshift SNe. The better the analog, the better the accuracy of the K-correction. For some types of SNe Ia observed at red shifts where the filter match to B-band is particularly bad, the errors in the K-corrections can alter the inferred corrected peak brightness by several percent. With the spectral time series that the *SNFactory* will obtain for all 300 SNe Ia, the K-corrections for the low-redshift SNe will be **zero**, since the product of the B-band filter response and the SN spectrum can be calculated directly.

Thus, a large sample of SNe Ia spectral template and the improved knowledge of the SN Ia intrinsic color, have the power to significantly improve the results from supernova cosmology experiments.

2.3 SNe Ia classification and study

The main goal of this program, on top of providing a better understanding of the SN Ia physics, will be to reduce the luminosity dispersion for sub-classes of SN Ia and to estimate the systematics on the luminosity associated to each SN Ia in such sub-classes. As shown figure 1 the measurement of SN Ia spectra at different epochs will give a direct access to the physics involved in the light emission by the supernovae. For this reason the SN Ia are able to provide a controlled distance indicator: we cannot imagine to have a variation in the intrinsic flux emitted by the SN Ia without a change in the physics parameters of the SN Ia explosion. The *SNFactory* giving access by its spectro-photometric observations to these parameters will open a new area in the understanding of the SN Ia physics.

3 The *SNFactory* project

The *SNFactory* program will collect 300 nearby SN Ia ($0.03 < z < 0.08$) and do a detailed study of the spectral evolution of each SN Ia: 10-15 spectra of spectro-photometric quality between 15 days before and 45 days after maximum in the spectral range 320-1000nm.

The *SNFactory* will search for supernovae using CCD images obtained by JPL's Near Earth Asteroid Team (*NEAT*). A proof-of-concept search conducted using two nights of *NEAT* data found 4 confirmed supernovae. *NEAT* has since expanded its operation to include a 1.2-m telescope (at the 10,000 ft summit of Haleakala, Hawaii) working 18 nights per month. In addition, since this search covers large portions of the sky irrespective of known galaxies, it will be rid of the biases to which pointed searches are subject due to their reliance on existing galaxy catalogs. *NEAT* has recently quadrupled its capacity, with a second 1.2-m telescope operating at Mt. Palomar with a large CCD camera, so we expect to discover several supernovae per week. Each patch of sky will be revisited frequently. This will enable early discovery – and hence early light curve coverage – and help eliminate Malmquist bias.

Traditionally supernovae have been followed with *BVRI* photometry, and spectra beyond the initial confirmation spectrum are rare. The *SNFactory* will change all that. Using a integral field unit[2] on a two-channel (blue 3500-5700Å& red 5300-10000Å) optical spectrograph with a resolution of respectively 4.5 Å and 6.6 Å, the *SNFactory*'s **S**uper**N**ova **I**ntegral **F**ield **S**spectrograph (*SNIFS*, under construction at CRAL) equipped with LBNL's red-enhanced CCD's, will allow spectroscopy of supernovae at all epochs. Because these spectra will be spectrophotometric, *UBVRIZ* photometry can be synthesized from these spectra, without the uncertainties due to photometric color terms and K-corrections (see figure 2). *SNIFS* will retain one advantage of

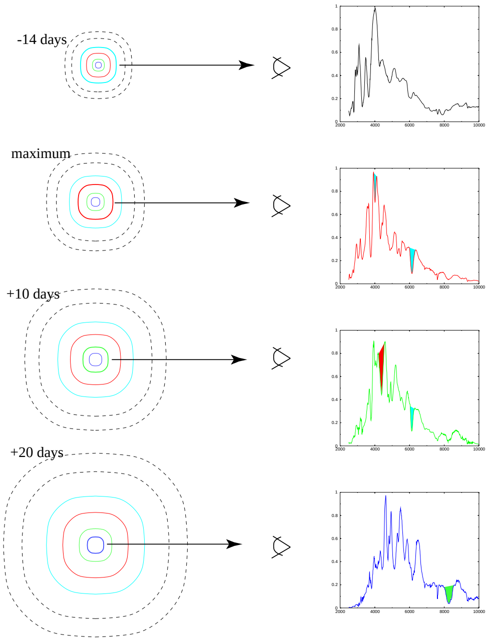

Figure 1: *As the ashes of the SN Ia explosion expand with time, the light collected is sensitive to the composition (spectral features) and the speed (width of the spectral features) of deeper and deeper layers of the SN Ia. By observing such time series the* SNFactory *project will improve our understanding of the SN Ia explosion.*

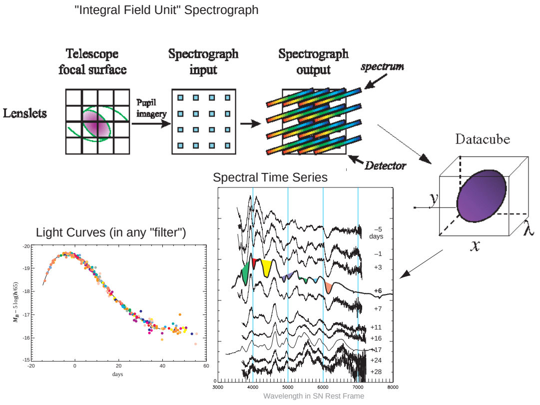

Figure 2: SNIFS *principle: the SN and surrounding galaxy is sampled by a 15 × 15 micro-lens array covering a field of 6” × 6”. A spectra is produced with the light collected by each lenses. From the data cube produced (= measured intensity for a given position in the field of view and a given wave length), a photometric spectra of the SN Ia is extracted. It should be noticed than an IFU allow spectro-photometric measurement. This is not the case of spectra obtained with a simple slit as the fraction of the spectered object masked by the slit is unknown. The SN Ia spectra obtained at different epoch, integrated in a given wave length domain, will allow to produce the SN Ia light curve in any filter.*

the traditional approach, which allows surrounding field stars to be used for flux scaling when conditions are non-photometric, by also having an imager which integrates on the field immediately surrounding each supernova and having the exact same exposure as the integral field unit. The primary follow-up for the *SNFactory* will be performed at the University of Hawaii's 2.2-m telescope, located on the summit of Mauna Kea. Mauna Kea has excellent atmospheric stability producing some of the best image quality attainable from the ground. The *SNFactory* has arranged for observation with *SNIFS* 20% of the time on the 2.2-m, to be allocated as the 2nd half of the night on every first and third night of a five-night cycle.

4 Conclusion

After the cosmology at 50%, measurements at the 10% level are underway. The percent level is the goal for this decade, the “dark energy” study, energy at the origin of the universe acceleration, is at this price. The Nearby SuperNova Factory is an essential step to fulfill this scientific goal. The *SNfactory* will revolutionize all phases of experimental work on supernovae. The rate of discovery for Hubble-flow supernovae will exceed the current rate by an order of magnitude, the discovery biases will be lessened (and traceable), and the quality and quantity of follow-up data will exceed that of current programs by a large factor. With such data, it is expected that great strides can be made in improving supernovae as cosmological distance indicators.

References

1. S. Perlmutter *et al.*, Ap. J. **517**, 565 (1999).
2. Bacon, R. *et al*A&AS **113**, 347 (1995).