1 Scientific Justification

The Hubble diagram for high-redshift Type Ia supernovae (SNe Ia) currently provides the most direct measurement of the expansion history of the universe – and hence the most direct evidence for an accelerating expansion. The "first generation" of SN Ia cosmology work developed a systematic approach to this measurement that led to astonishing results ruling out a flat, matter-dominated Universe (Riess et al. 1998; Perlmutter 1999). This indicated the presence of a new, unaccounted-for "dark energy" driving the cosmic acceleration.

One of the most pressing questions in cosmology now is: "What is the nature of this dark energy?" There is a fundamental difference between a Cosmological Constant and other proposed forms of dark energy – the former being equivalent to vacuum energy, as opposed to a slowly-varying scalar field (e.g., "dynamical Lambda" models such as quintessence). The distinction can be addressed by measuring the dark energy's equation-of-state parameter, $w = p/\rho$, where $w = -1$ corresponds to a Cosmological Constant – most scalar-field models predict $w > -0.8$. The importance of achieving a measurement where $\langle w \rangle = -1$ could be ruled out has led to a successful second generation of SN Ia cosmology studies: large multi-year multi-observatory programs with major commitments of dedicated time for "rolling searches", which find and follow SNe over many months of repeated wide-field imaging and identify them with coordinated spectroscopy.

The challenging second-generation goals are (1) to improve the constraint on $\langle w \rangle$ by building an order-of-magnitude larger statistical sample (i.e. ~ 500) of SNe Ia in the redshift range z=0.3-1.0 where $\langle w \rangle$ is best measured; (2) to study the transition to deceleration by building a significant sample of SNe Ia in the redshift range $z = 1 - 1.4$; and (3) to improve the systematic uncertainties by studying low-redshift supernovae in detail and comparing specific SN properties between low- and high-redshift. Fully exploiting samples from (1) and (2) to improve the *statistical* uncertainties will depend on (3) reducing the *systematics* correspondingly.

These goals require an ambitious effort on the part of the SN Ia community to build the necessary SN dataset, and we have constructed a coherent program to do this. We have developed the Nearby Supernova Factory to carry out (3), and are continuing our *HST* and Subaru programs to generate the $z > 1$ sample (2). To address (1) we are working with the Supernova Legacy Survey (SNLS) to generate the requisite large z=0.2–0.9 sample, and it is these SNe that are the target of this 2007A proposal. The first cosmological results using 71 SNLS SNe Ia are already published, with Keck playing a key spectroscopic role. When combined with BAO measures (Eisenstein et al. 2005), the recent SNLS measurements on $\langle w \rangle$ (Astier et al. 2006) give $\langle w \rangle = -1.023 \pm 0.090$ (statistical) ± 0.054 (identified systematic), and when combined with the 3rd year WMAP CMB data (Spergel et al. 2006) give $\langle w \rangle = -0.97^{+0.07}_{-0.09}$ (statistical). Despite these being the tightest published constraints on $\langle w \rangle$, they are still consistent with a very wide range of dark energy theories. By strategic Keck studies of larger samples to determine the value of $\langle w \rangle$, we aim to answer the key question: Is the dark energy something other than Einstein's Λ?

SNLS: An Unprecedented SN Ia Dataset to Measure Dark Energy

The Supernova Legacy Survey (SNLS; `http://cfht.hawaii.edu/SNLS/`) is an ambitious wide-field survey, utilizing an imager field four times larger than the next largest survey camera (at CTIO), with twice as much time devoted to the survey. Commenced in August 2003, the first year of data has already provided the tightest SN Ia cosmological results (Astier et al. 2006; Spergel et al. 2006). The full five-year SNLS dataset (see Technical Justification), when combined with a large sample of well-measured nearby SNe Ia from the Nearby SN Factory, will provide the major improvement in the determination of the dark energy parameters achievable over the next 5 years, achieving a $\sim$5% measurement of $\langle w \rangle$. It is important to note that these results assume a redshift precision of better than 1% and so spectroscopic redshifts are essential for all SNe Ia.

The Keck Observatory is the lead for the northern hemisphere spectroscopy of this landmark project. It is essential that each SN be identified, classified (within a week to ten days of its maximum brightness), and its precise redshift determined for this heavy investment in multi-color lightcurves to pay off in a Hubble diagram. The SNLS fields include the Extended Groth Strip (EGS) at +52d, for which a large aperture northern telescope is required.

Addressing Systematic Uncertainties with this Proposed Dataset The large SNLS sample is reducing statistical errors to the point where systematic errors will soon become the dominant source of error. Many potential sources of systematic error are well understood, and are easily modeled, e.g. gravitational lensing (Gunnarsson et al. 2006), k-corrections (Hsiao et al. 2006, Nugent et al. 2002), and Malmquist bias (Astier et al. 2006). Other potential systematics, such as possible evolution in the properties of SNe Ia or dust, are less well constrained. However, the large sample of consistently selected, multicolor, well-sampled, and uniform quality lightcurves provided by the SNLS are producing the first tests of these key systematics.

Ia evolution: Using SNLS data, Sullivan et al. (2006a; see Fig. 2a here) found that the SN Ia rate has two components – the "active" component has a rate proportional to the host galaxy star formation rate per unit mass, while the "passive" component traces the total stellar mass of the galaxy. Furthermore, the SNe Ia from star forming galaxies have broader lightcurves, on average, and therefore should be intrinsically brighter than SNe Ia from passive galaxies. As the star formation rate increases with redshift, the average properties of SNe Ia in any redshift bin should shift (Fig. 2b). However, first tests show that stretch correction appears to effectively remove any bias. By comparing SNLS SN Ia properties in different redshift bins, Conley et al. (2006; Fig 2c here) find no evidence for evolution in the properties of SNe Ia with redshift after stretch correction. Furthermore the rise-time of SNLS SNe ($19.67^{+0.54}_{-0.49}$ rest-frame days) is consistent with that of low-z SNe Ia (19.01 ± 0.18 days).

High-statistics subsamples: By dividing the sample into subsets based on host galaxy type (e.g., Sullivan et al. 2003), we are now able to begin comparisons of the nearly dust-free subset of SNe Ia (those in E/S0 or passive hosts) with the subset that has been corrected for extinction (those in star-forming spiral hosts). To do such tests at the required precision requires a large number of SNe Ia in each subgroup.

Multi-color lightcurves: SNLS is generating the first large high-redshift SN Ia dataset with complete color coverage throughout the lightcurves. This enables comprehensive extinction studies since all the SNe are sampled over a wide rest-wavelength baseline, thus breaking the degeneracy between dust and SN intrinsic color.

Spectroscopic tests: All SNLS SNe Ia are matched against a library of low redshift SNe Ia (Fig 3), allowing tests of whether the high redshift SNe show different average velocities or chemical compositions.

Conclusion. This continuing proposal focuses on the extraordinary science opportunities presented by the SNLS. The large increase in statistics for the mid-redshift range will enable major strides in our multi-semester campaign to build a well-measured SN Ia Hubble diagram. These data are crucial for studying cosmological parameters and dark energy, as well as refining evolution/dust checks on systematics. The conclusions of this second-generation SN study will provide our first chance to test whether dark energy is consistent with a Cosmological Constant, and will refine the use of large, well-studied SN Ia samples shaping future third-generation projects (e.g. *SNAP*), designed to probe the variation of w with time. With this program Keck will continue to play a leading role in this fundamental science.

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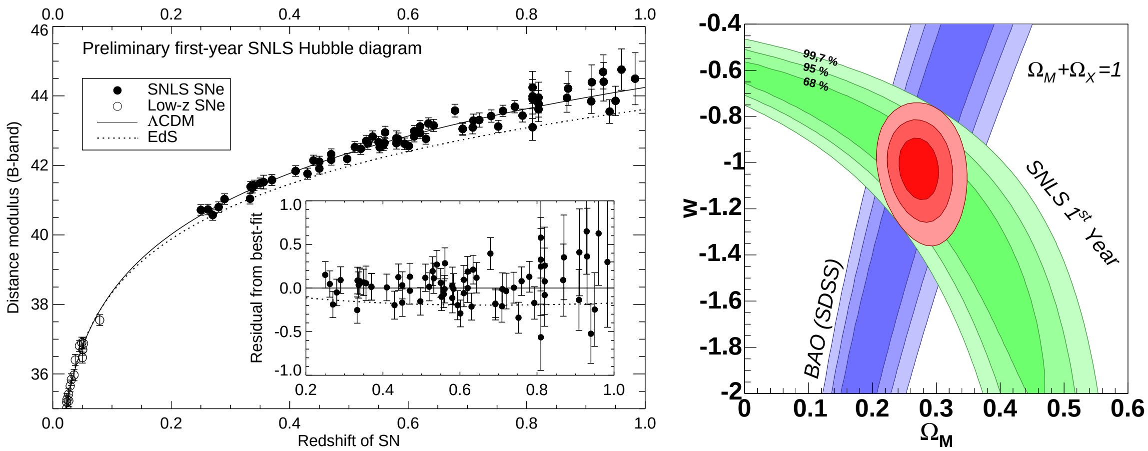
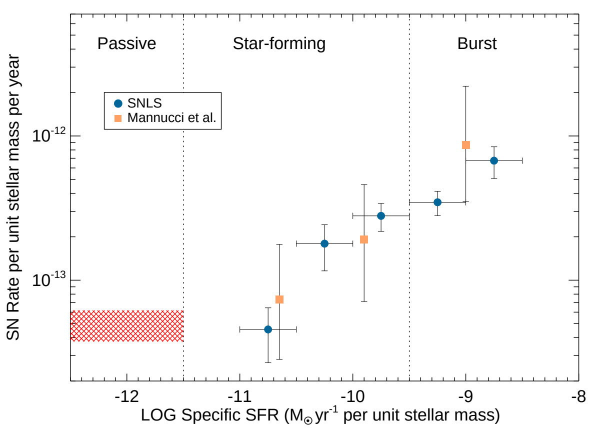
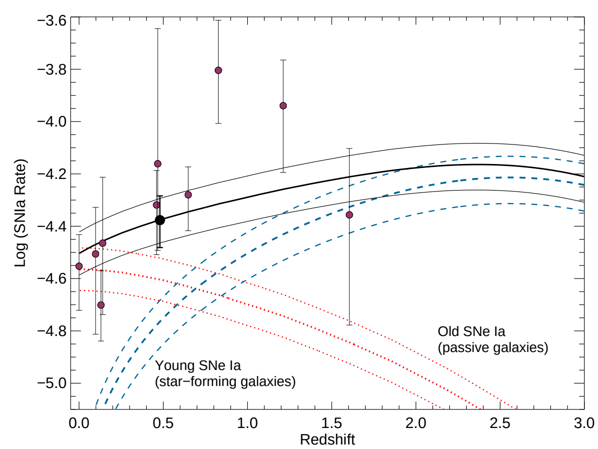


Figure 1: Current SNLS cosmological results. **Left:** The SN Ia Hubble diagram from the first full year of data (71 high-redshift SNe; Astier et al. 2006), only a quarter of the current SNLS sample, yet already the largest homogeneous SN sample. Inset shows the residuals from the best-fitting cosmology. The best-fit flat cosmology is Ω_M=0.263 ±0.042 (*stat*) ±0.032 (*sys*) (Astier et al. 2006). **Right:** Constraints in Ω_M versus w. Solid lines show the current 1, 2 and 3σ confidence limits. The current constraint is $w = -1.023$ ±0.090 (*stat*) ±0.054 (*sys*) when combined with the SDSS baryon acoustic oscillations result (Eisenstein et al. 2005). Similar results are obtained when SNLS is combined with the 3rd year WMAP data. The end-of-survey results will provide constraints on w of ±0.05 or better.





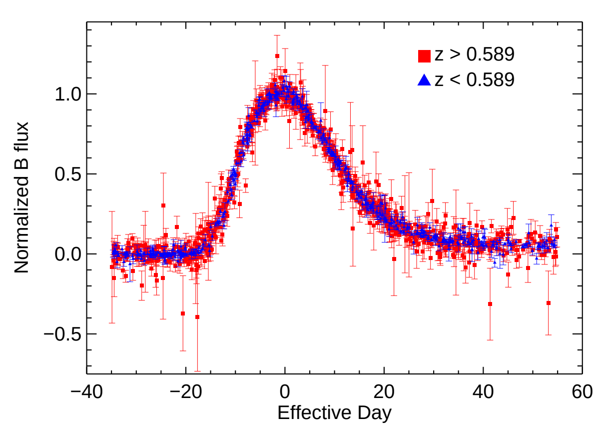


Figure 2: A selection of science results investigating systematics from the SNLS; Keck plays a crucial role in defining the datasets which allow tests for SN evolution such as those described here. **A) (above:)** The rate per unit stellar mass as a function of host galaxy type from Sullivan et al. (2006a). The SN Ia rate per unit mass is around ten times higher in strongly star-forming galaxies than in passive systems, a surprising result with implications for the nature of the SN Ia progenitor system. **B) (above right):** By modeling the SN Ia rate as the sum of an old and young progenitor component (Scannapieco & Bildsten 2005; Mannucci et al. 2005,2006) and combining with a knowledge of the cosmic star-formation history, the relative importance of each component evolves with redshift. Understanding the properties of each component will lead to an improved cosmological candle; SNLS is the ideal survey to perform this analysis. **C) (lower right):** Unprecedented early-time light-curve data allows a study of the rise-times of SNLS SNe Ia from Conley et al. (2006). Shown is the normalised and light-curve-width corrected rest-frame *B*-band SNLS SN Ia light-curves. The data allow a powerful internal consistency check: blue triangles are SNLS SNe at lower redshift, red squares those SNLS SNe at higher redshifts. The rise-times of the two samples are consistent. Furthermore, the consistency in the shape of the light-curves is spectacular across our entire redshift range.

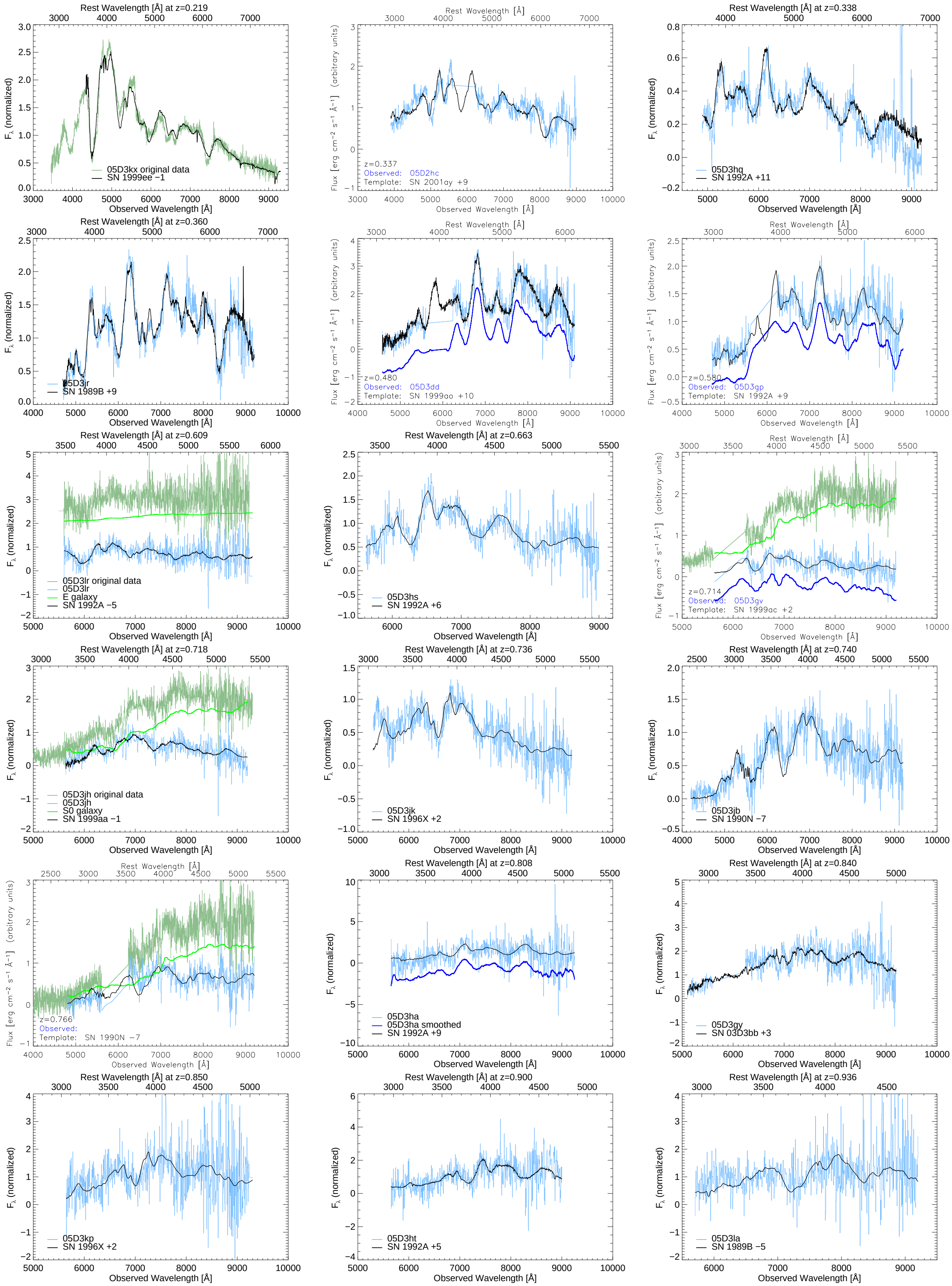


Figure 3: Spectra of SNLS SN candidates obtained during the 2005A Keck observing campaign. The light-blue lines show the data after host galaxy subtraction (if necessary), rebinned to 10Å. Overplotted in black are the best fit SN templates. The spectra are confirmed by Keck to be Type Ia SNe.

2 Progress to Date

We are using the CFHT Supernova Legacy Survey (SNLS) to obtain a significant increase in supernovae statistics at intermediate redshift *and* at the same time control their systematics. The SNLS commenced in June 2003, and, after three full years of survey operation, has located *and spectroscopically confirmed* nearly 300 well-sampled type Ia SNe with multi-epoch and multi-color light-curves. In particular the color information of the rising part of the lightcurve allows us to efficiently preselect candidates for spectroscopy (Sullivan et al. 2006b). The photometrically preselected sample of SN type Ia candidates is about 80% pure. Additionally, a SN redshift (which is typically good to within ± 0.01) and an estimated time of maximum is derived from the rising part of the lightcurve. This real-time light curve analysis makes the process of spectroscopic confirmation highly efficient (Howell et al. 2005; Sullivan et al. 2006b). SNLS routinely provides about 10 SN Ia candidates per field per month which require spectroscopic follow-up (see "Technical Justification" for details of the survey).

Our Keck 04A/05A/06A time allocations made an invaluable contribution to the co-ordinated SNLS follow-up, resulting in a major contribution to Astier et al. and the third-year cosmological analysis. We screened 15 SN candidates in 2004A, 21 in 2005A, and 21 in 2006A (poor weather severely affected our 2006A time with two of four nights effectively lost). All spectra are fully reduced using our custom-written software. Of the candidates from 2004A, 11 have been identified and 9 confirmed as SNe Ia. Of the 21 candidates from 2005A, 19 are identified and all are confirmed SN Ia (see Fig. 3). The 21 candidates in 2006A yielded 15 identifications and 12 SNe Ia (see "Status of Previously Approved Keck Programs"). The median redshift of the confirmed SNe Ia is 0.71. Note also that 33 of the SNe Ia confirmed by Keck were discovered in the EGS, making Keck the prime telescope to cover the EGS, only visible from the north.

As a direct result of the Keck allocation, SNLS was able to follow-up all candidates of interest during the allocated months, an essential step in the generation of a Hubble diagram. As the survey is a rolling search, reference images are already available for all of these confirmed SNe, and a large number of multi-color light-curves have already been measured (e.g., Astier et al. 2006). A novel approach to fit supernova light-curves has been developed which facilitates the use of full information of the available multi-color light curves (Guy et al. 2005). Using the SNLS data sample we found that the rest-frame-U band can produce a much tighter dispersion then previously anticipated. This is an important result as it allows extension of the redshift range of SNe that can effectively be observed and added to the Hubble diagram (Fig. 1; Astier et al. 2006).

Using the data from the first year, we have built a Hubble diagram extending out to z=1, with all distance measurements using at least two bands (Fig. 1). Systematics from potential SN evolution, Malmquist bias, spectral misidentification as well as photometric calibration are being investigated. Cosmological fits assuming a flat universe result in $\Omega_{\rm m} = 0.263 \pm 0.042(\text{stat}) \pm 0.032(\text{sys})$. If our first year's data set is combined with the recent measurement of baryon acoustic oscillations (Eisenstein et al., 2005), the constraints improve to: $\Omega_{\rm m} = 0.271 \pm 0.021$ (stat) $\pm\, 0.007$ (sys) assuming a flat ΛCDM model universe and $w = -1.023 \pm 0.090(\text{stat})$ $\pm\, 0.054$ (sys) for a universe with a constant equation of state w. With only 71 SN Ia, the resulting constraints on the cosmological parameters are already stronger than any other previous survey, illustrating the superb quality of the SNLS data sample.

The analysis of the third year data set is in progress. The improved statistics of this supernova sample will allow us to study and reduce the systematics further (e.g. by subdividing the sample). We expect to reach a level of combined statistical and systematic uncertainties that is below the currently quoted uncertainty for systematics alone.

3 Technical Justification

Supplementary Observations: The SN program of CFHTLS (SNLS), currently the largest ground-based SN survey, is a much larger program than our previous searches, and offers the unique opportunity to continue SNe Ia cosmological studies with greatly increased statistics and even greater reliability. SNLS is a well-established five-year rolling SN search program, observing four 1×1 deg^2 fields in Sloan g, r, i and z filters every 4 nights (observed frame; 2–3 nights rest-frame) during dark/gray time using MegaCam on CFHT. Each field is followed for 5 continuous months in every year. Exposure times of 20m, 30m, 60m and 60m per band per epoch provide SN discoveries and almost real-time well-sampled multicolor lightcurves for SNe Ia in the redshift range 0.2 to 1.0 (with discoveries up to $z \sim 1.2$). Photometric redshifts for host galaxies, combined with a sophisticated color screening of the SNe candidates (Sullivan et al. 2006b), allows SNLS to eliminate AGN and other variable non-SN sources from the spectroscopic target list. Further screening based on the real-time light-curves allow separation of candidates into probable type Ia and core-collapse (II, Ib/c) sub-groups. In any given month, 8-10 SN Ia candidates per field require spectroscopic analysis.

Clearly, in a survey of this magnitude, the spectroscopic time allocation required to follow all candidates exceeds the capacity of any one group or nation; consequently many large telescopes contribute to the substantial follow-up program. *In the "A" semesters, Keck plays a pivotal role in this follow-up campaign*, measuring redshifts and tell-tale SN Ia features for the highest redshift SNe Ia in the SNLS northern-most field — at this declination, a role only it can perform with the quickness and reliability to keep up with the high SNLS discovery rate.

Targets: All of the supernovae to be observed in this proposal will be discovered in the four SNLS survey fields, two of which are visible this spring. In particular, with Keck we will focus on the SNe discovered in the Extended Groth Strip (EGS) field at 14h18m+52d, where Mauna Kea telescopes must play a leading role in follow-up observations. We expect to have a target list of roughly 10 candidates per lunation for this field, most of which will be SNe Ia at $z > 0.4$ with a median $z \sim 0.7$. (Secondary fields at 10h00m+02d and 22h15m-17d will be observed when the primary field is not available.) This selection purity is another important advantage of the rolling SN search approach compared to classic 2-epoch SN searches.

Exposures: *All of our exposure times are based on our extensive experience of real Keck observations of high-z SNe.* Although the SNLS candidate weighting scheme selects against core-collapse SNe and AGN, inevitably some of these will pass through to our list of candidates, and so when estimating the number of SNe Ia we will confirm, we include a $\sim 20\%$ allowance for these interlopers. Under average conditions at Keck a SN Ia at $z \sim 0.5$ requires an exposure of about 30 min to produce a classification-quality spectrum. A SN Ia at $z \sim 0.9$ requires 3-4 30 min exposures to produce a reliable redshift and classification. The $z \sim 0.9$ SNe Ia are made difficult not only by the faintness of the SN, but by the increasing sky brightness and the loss of key SNe Ia spectral features in going to higher redshift.

Telescope Time Requested: There are two key requirements for the spectroscopic program to successfully exploit the SNLS — temporal coverage and speed. With Keck's aperture and sensitive spectrographs, and our specialized acquisition and real-time reduction methods developed for SN spectroscopy at Keck, we can obtain redshifts and spectral classifications for up to 10 SNe candidates per night out to $z \sim 1.0$. Thus, in one Keck night we can cover the majority of the higher-redshift SNe Ia the SNLS will produce in one field in one lunation. The clear focus at Keck will be on the 14h18m+52d field which has good visibility at Keck for four months.

Although many of the SNe will have spectra peaking at red wavelengths, important spectral features (e.g. metallicity indicators) extend down to observer-frame V-band. Therefore, these observations can not tolerate too much contamination from moonlight. In general we have found that we can observe at most 5 days from new moon before our program suffers significantly.

In total, obtaining the spectroscopy of this spring's SNLS SNe Ia's requires 4 nights on Keck during dark time in 4 consecutive months from February–May. We note that this SNLS spectroscopic follow-up campaign does not require the precise timing that was needed for our past $z \sim 0.5$ searches (and still required for our $z > 1$ searches) since the photometry of all the SN is obtained continuously. However, to coordinate with SNLS it is **important that the Keck scheduler consult with us prior to scheduling specific dates.**

Instrumentation: In the past we have used LRIS, DEIMOS, and ESI for our SN spectroscopy program. We have found that each of these instruments has specific advantages depending on the target redshift range and the supernova-campaign strategy. For the 2007A campaign we the request the LRIS spectrograph for all four nights. Its broader wavelength coverage (see Fig. 3) is the advantage for this program, since it is appropriate for a wider range of supernova redshifts. As in the highly successful 05A/06A LRIS campaigns, we will use the 400l/8500Å grating (cen=7500Å) in the red, and the 600/4000Å grism in the blue with the 5600Å dichroic.

Backup Program

Given the large commitment of queue-scheduled time for the SNLS we consider it next to certain that we will have a full schedule of SNe to observe on each of our nights. If transparency or seeing precludes spectroscopy at $z > 0.5$ we will observe the lower redshift SNLS SNe otherwise reserved for smaller telescopes. Under exceptionally bad weather conditions, we plan to observe nearby supernovae found by the SNfactory, which routinely finds a large number of good candidates.

Status of Previously Approved Keck Programs

Semester 2006B: Since the SNLS fall targets are visible at southern hemisphere observatories, we did not apply for Keck time in 2006B.

Semester 2006A: In 2006A 4 LRIS nights were awarded; 2 were completely lost to weather. In the remainder, we observed 21 candidates and confirmed 13 of these as SNe Ia and 5 as core-collapse SNe. 3 candidates remain unidentified and work continues on their reductions.

Semester 2005B: Since the SNLS fall targets are visible at southern hemisphere observatories, we did not apply for Keck time in 2005B.

Semester 2005A: In 2005A we were awarded 4 nights, in March, April, May and June, for SNLS follow-up. All observations where made with LRIS in long-slit mode. The March night had poor weather with strong winds, in which the seeing typically varied between 1.5 and 2 arc-seconds; no useful data were obtained. During the April night we observed 8 candidates, during the May night 7 candidates and during the June night 6 candidates. Of the 21 candidates observed during those three nights 19 where classified as Type Ia SNe with a median redshift of $z = 0.71$. This unprecedented high yield of SNe Ia can be attributed to our highly efficient pre-selection algorithm. The SNe Ia spectra are shown in Fig. 3.

Semester 2004B: Since the SNLS fall targets are visible at southern hemisphere observatories, we did not apply for Keck time in 2004B.

Semester 2004A: In 2004A we were awarded 3 nights, in March, April (both DEIMOS) and May (LRIS), for SNLS follow-up. The March night was completely lost due to poor weather conditions (note that even though March weather was exceptionally poor, the queue observed nature of SNLS ensured that candidates were still available in this month). For the April-DEIMOS run we observed 8 candidates in long-slit mode, and for the May-LRIS run a further 7 candidates. Our analysis indicated that 9 of these candidates are probable SNe Ia. During this semester, a trial collaboration with the DEEP team enabled us to observe 3 candidates on various DEEP EGS masks, resulting in one SN Ia, one SN II and one unidentified spectrum. We also developed a new capability for long-slit observers using DEIMOS. By placing reflective tape on either side of the slit on a special long-slit mask it becomes possible to acquire significantly fainter targets. We tested and demonstrated this capability in semester 2004A.

Semester 2003B: Since the SNLS fall targets are visible at southern hemisphere observatories, we did not apply for Keck time in 2003B.

Semester 2003A: In 2003A we were awarded 2 nights in May and 1 night in July for follow-up of SNLS supernova candidates. We concentrated on the SNLS field which encompasses the EGS. For both runs we observed with DEIMOS on Keck II in order to gain the experience needed to coordinate our follow-up with DEEP multi-object spectroscopy in the EGS. Conditions were marginal for the two nights in May, with excellent seeing accompanied by thick cirrus. During this run we demonstrated the feasibility of observing SNLS SNe in parallel with DEEP galaxy spectroscopy in the EGS. Conditions were good for the July run, and we were able to screen 5 high-redshift supernova candidates being followed by SNLS. As acquisition of faint targets is difficult with DEIMOS used in long-slit mode due to the low reflectivity of the long-slit mask, during this run we developed acquisition code patterned after our acquisition code for ESI.

Path to Science from Observations

As in the past, we will use spectral lines of the host galaxy to determine the redshift. These lines, whether seen in emission (e.g. OII 3727Å) or absorption (e.g. Ca II H & K), can be identified even when the SN and galaxy light are blended, because the galaxy lines are much narrower than the SN lines. (In cases where there is no significant light from the host, redshifts will come from the supernova spectrum itself.) The data are reduced using custom-written software, including an implementation of the B-spline sky subtraction technique and, for LRIS, fringe removal. The SN spectra are then smoothed on a scale of $\sim$ 20Å (after removing any lines due to the host galaxy and deweighting the spectral regions covered by OH lines) and compared with those of nearby SNe to ascertain the SN type (e.g. Fig. 3).

The Keck redshifts will be used along with rolling photometry from the SNLS to plot the Keck SNe Ia on the Hubble diagram. This requires that the light-curve time of maximum, peak flux, and width, be measured. The light-curve width is strongly correlated with the intrinsic supernova brightness, and is used to standardize SNe Ia. K-corrections — which we have developed using the spectra of low-z SNe Ia (Nugent et al. 2002) — must also be applied, followed by correction for dust extinction from the host galaxy and the Milky Way. The extinction correction requires a knowledge of the unreddened intrinsic SN colors, which we have determined from low-z SNe Ia in elliptical galaxies (and will improve with future low-redshift data) and do not result in overcorrection for extinction (as is the case for some other treatments in the literature). Once the SNe Ia have been standardized, we can solve for the confidence intervals for the cosmological parameters. We have and are continuing to develop extensive software to undertake such light-curve fitting, corrections, and parameter fitting.

The Keck spectroscopy will allow us to test for the effect on our cosmological fits due to any spectroscopically peculiar SNe Ia, and to set better limits on systematic uncertainties which could be caused by unrecognized spectroscopically peculiar SNe Ia. For our $z \sim 0.5$ (brighter) SN Ia where the host galaxy light does not significantly contaminate the SN spectrum, stronger tests, including comparison of the metallicity-dependent UV spectral features with our Cycle 9 and Cycle 11 *HST* UV spectra of nearby SNe Ia (from a separate program) will be possible.

Technical Concerns

Since our targets are faint, accurate offsetting is critical to take advantage of the narrow slit widths possible under the best seeing conditions. SNLS has developed sophisticated custom finder-chart tools (see `http://legacy.astro.utoronto.ca/makefinder.php`) to allow offsets from any nearby star to be calculated on-the-fly. There are no technical concerns with the searches, as SNLS comprises a dedicated team with extensive experience in finding and selecting SNe for spectroscopic follow-up with Keck. Real-time candidate lists are always available at `http://legacy.astro.utoronto.ca/cfhtls.php`

The Keck SN candidate spectroscopy runs must be coordinated with the SNLS search of the EGS, scheduled to start in January 2007, so *please contact us before scheduling any nights allocated to us at Keck!*

Experience and Publications

Our group has extensive experience with faint object spectroscopy on telescopes around the world and has had successful runs using LRIS, ESI, and DEIMOS on Keck for the last nine years. To reduce and analyze the spectra, our group has developed techniques that are specific to high-redshift supernova work. Our group has also developed extensive techniques for the photometry of high-redshift SNe against the bright background of their host galaxies. A list of relevant publications appears at the end of this document.

Resources and Publication Timescale

The LBNL supernova group consists of three UC professors (PI Perlmutter is now also a UC Berkeley faculty member), three permanent staff scientists, a scientist/project coordinator, four postdocs and three graduate students. The group uses the extensive computing facilities available at LBNL.

We note that one of the many advantages of the SNLS is that deep images are available which are uncontaminated by SN light i.e. are taken during the year *before* the SN explodes. Therefore, unlike in the past, we will not have to wait a year to obtain final reference images. This makes it possible to start final reductions and analysis shortly after the end of each month of observing.

Related Publications

(* = Keck data contributed to this publication.)

* The Rise Time of Type Ia Supernovae from the Supernova Legacy Survey, A. Conley et al., 2006, AJ in press, astro-ph/0607363

* Rates and properties of type Ia supernovae as a function of mass and star-formation in their host galaxies, M. Sullivan et al., 2006, ApJ in press, astro-ph/0605455

* The Type Ia Supernova Rate at z∼0.5 from the Supernova Legacy Survey, D. Neill et al., 2006, AJ 132, 1126

* The Supernova Legacy Survey: Ω_M, Ω_Λ, and w from the First Year Data Set, P. Astier, et al., 2006, A&A 447, 31

* Photometric Selection of High-Redshift Type Ia Supernova Candidates, M. Sullivan et al., 2006, AJ 131, 960

* Spectra of High-Redshift Type Ia Supernovae and a Comparison with their Low-Redshift Counterparts, I. M. Hook, et al., 2006, AJ 130, 2788

Spectroscopic Observations and Analysis of the Unusual Type Ia SN 1999ac, G. Garavini, et al., 2005, AJ 130, 2278

Restframe I-band Hubble Diagram for Type Ia Supernovae up to Redshift $z \sim 0.5$, S. Nobili et al., A&A, 437, 789 (2005).

Spectroscopic Observations and Analysis of the Peculiar SN 1999aa, G. Garavini, et al., 2004, AJ 128,387.

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* New Constraints on Ω_M, Ω_Λ, and w from an Independent Set of Eleven High Redshift Supernovae Observed with *HST*, R. A. Knop, et al., 2003, ApJ, 598, 102.

* Hubble Diagram of Type Ia Supernovae as a Function of Host Galaxy Morphology, M. Sullivan et al., 2003, MNRAS 340, 1057.

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