1 Scientific Justification

The Hubble diagram for Type Ia supernovae (SNe Ia), extended to redshifts well beyond $z = 0.25$ (Fig. 1), provides the most direct current measurement of the expansion history of the universe—and hence the most direct evidence for an accelerating expansion. The "first generation" of supernova cosmology work developed a systematic approach to this measurement (Perlmutter *et al.* 1997, 1998, 1999) that resulted in a determination, based on 42 SNe at $0.18 < z < 0.83$, of $\Omega_M = 0.28^{+0.09}_{-0.08}$ for a flat universe (Perlmutter *et al.* 1999; see also Riess *et al.* 1998). These measurements indicate the presence of a new, exotic "dark energy" component that can cause acceleration, posing a key problem for fundamental particle physics. This conclusion is strongly supported by current CMB measurements of the curvature of the universe.

The importance of this surprising physics problem has lead to a new second generation of supernova cosmology studies: large multi-year multi-observatory programs with major commitments of dedicated time for "rolling searches," which can 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 determine the dark energy's average equation-of-state ratio, $w \equiv p/\rho$, by building an order-of-magnitude larger statistical sample (i.e. $\sim$500) of SNe in the redshift range $z = 0.3 - 0.8$ where this average w is best measured; (2) to study the transition to deceleration by building a first significant sample ($\sim$15) of SNe Ia in the redshift range $z = 1 - 1.4$; and (3) to improve the systematic uncertainties for the supernova cosmology measurements by studying specific properties of selected SNe from both redshift ranges. Fully exploiting the large samples from (1) and (2) to improve the *statistical* uncertainties will depend on (3) reducing the *systematic* uncertainties correspondingly.

These goals clearly require an ambitious effort on the part of the SN Ia community to build up the necessary SN dataset. We are working with the new Magacam CFHT Legacy Survey to begin to generate the large $z = 0.3 - 0.8$ sample (the target set of this current 2003A proposal), and with the Subaru SDF and SXDF surveys and HST surveys to generate the $z > 1$ sample (the target set of the previous 2002B proposal). By strategic Keck studies of these samples, we aim to answer the key question: Is the average w equal to -1, the value for Einstein's Cosmological Constant?

Studying the Dark Energy Requires SN Ia at Intermediate z

The SN Ia redshift-magnitude diagram in the redshift range $z = 0.3 - 0.8$, (where dark energy dominates over dark matter) is one of the only known ways to constrain the physics of the dark energy that apparently is accelerating the universe's expansion. The simplest measurement to characterize this dark energy is the effective equation-of-state ratio, $w \equiv p/\rho$ averaged over the redshifts from the observer to the source. As shown in Figure , the current constraints on average w are consistent with a very wide range of dark energy theories, including Einstein's Cosmological Constant (Perlmutter *et al.* 1999, Garnavich *et al.* 1998).

The full five-year CFHTLS dataset, when combined with a large sample of well-measured nearby SNe that will, for example, be available from the Nearby Supernova Factory, will provide a major improvement in the determination of the dark energy parameters. Fixing $w = -1$, 1-σ errors on (Ω_M, Ω_Λ) of (0.06, 0.10) can be achieved. Alternately, assuming a flat universe errors on (Ω_M, w_{avg}) of (0.07, 0.18) can be achieved. Even with the first few years' statistics from this survey, we will be able to see evidence for a non-Cosmological Constant dark energy if its average w is more than 0.1 away from -1. It is important to note that these results assume a precision on z of better than 1% and so a spectroscopic redshift measurement is needed for all SNe.

An Unprecidented SN Ia Dataset to Build a Hubble Diagram
The CFHT Legacy Survey is the most ambitious of the planned wide-field surveys, with an imager field 4 times larger than the next largest survey camera (at CTIO), and twice as much time devoted to the survey. The Legacy Survey will be performed with the new MegaCam prime focus camera and will cover four 1x1 deg^2 MegaCam fields with the filter set (g', r', i', z'), sequenced over five years at an average rate of 5.25 nights per lunation. Each semester there will be five sequential runs per field. Dscribed in more detail below (see Technical Justification), the five-year goal of the SN program of the survey (the SNLS) is to discover and follow ~ 600 well measured SN IA in the redshift range $0.3 < z < 0.9$.

The Keck Observatory will take the lead for the northern hemisphere spectroscopy of this landmark project. It is essential that each supernova be identified, classified (within a few weeks of its maximum brightness), and its precise redshift determined for this heavy investment in multi-color lightcurves to pay off in a Hubble diagram. Note that the Legacy Survey fields include the "Groth Strip" (14h17m, +52), for which a northern hemisphere observatory is required, and this may allow a possible simultaneous synergy with the DEEP project; see Technical Details.

Addressing Systematic Uncertainties with this Proposed Dataset
Perlmutter *et al.* (1997, 1999) provide extensive discussion of possible systematics in the measurement of Ω_M, Ω_Λ; we find that uncertainties due to K-corrections, gravitational lensing amplification, and Malmquist bias, are quite small compared to the statistical error. Remaining sources of systematic uncertainty that we showed are unlikely, but possible, are SN Ia evolution and abnormal dust within, or even between, galaxies. The proposed Legacy Survey data set will allow new tests and constraints on several of these key systematics.
Multi-color Lightcurves. The rolling search with multiple filters will generate the first SN Ia dataset with complete color coverage throughout the lightcruves. This will enable more comprehensive extinction studies than previously possible, and will allow the Keck spectra to be photometrically calibrated. The calibrated spectra are key to hunting for evolution indicators such as the UV flux – metallicity relation (see Figure ?).
High-statistics Subsamples. Figure ? shows a pilot study test that we have recently completed (see Sullivan et al. 2002, and Progress To Date), in which the sample of 42 SNe was divided into subsamples from different host galaxy types. This is an important first test of evolutionary and dust effects that will differ in different host galaxy environments. The Legacy Survey will allow us to perform such tests on many more constrained differing subsamples of supernovae, each containing a large statistical sample.
A spectral-feature luminosity indicator, as a "backup program." [[[SHORTEN THIS PARAGRAPH]]]The spectral feature ratios of Ca II and of Si II show a tight relationship with the lightcurve timescale parameter (Fig 4a) and may therefore be used as an alternative luminosity indicator (Nugent *et al.* 1995). These spectral ratios have not yet been exploited at high-z. As described below in the Technical Justification section, measurement of these features for a SN Ia at $z \sim 0.5$ will provide a sensitive test of evolutionary effects. This is also an ideal backup program, since when fewer SNe are available from the rolling search, longer exposure times can be used.

Conclusion. [[[SHORTEN THIS TOO.]]] This proposal focuses on the unusual science opportunities presented beginning with the Semester 2003A by the CFHT Legacy Survey.

With the large increase in statistics in the mid-redshift range, we hope to make major strides in our ongoing multi-semester campaign to build a well-measured SN Ia Hubble diagram. These data are crucial for addressing the questions of the cosmological parameters, the curvature, and the identity of dark energy. They also serve double duty by refining our evolution/dust checks on systematics. This second-generation of supernova studies provides our first chance to test if the dark energy is consistant with the Cosmological Constant; its conclusions and refinements in the use of large, well-studied SN Ia samples will shape an eventual proposed third-generation project such as SNAP that might get to probe for changes in wq. I With this proposal, Keck will play the crucial northern hemisphere spectroscopy role for this fundamental science.

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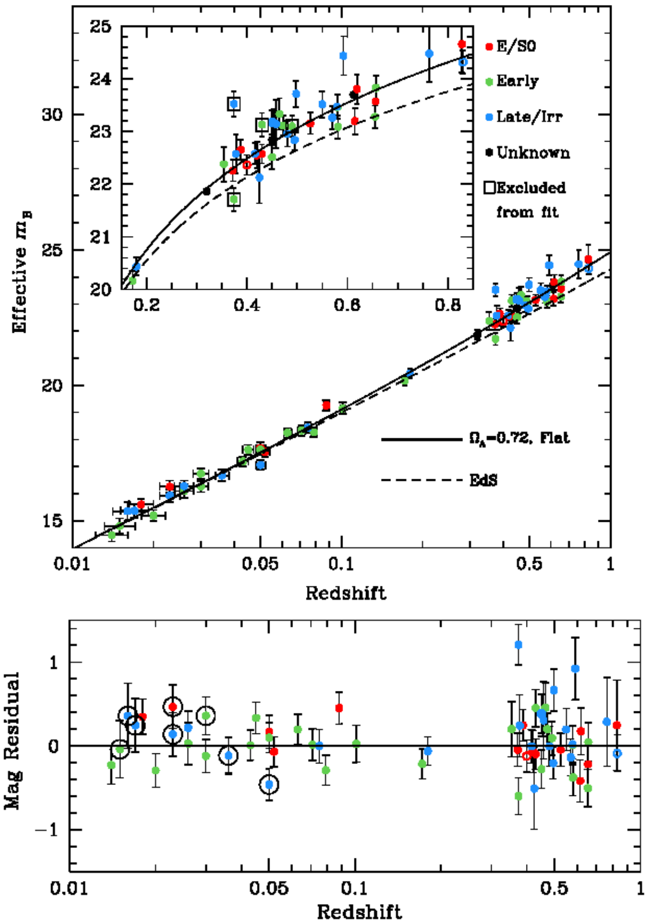

Figure 1: UPPER PANEL: The stretch-corrected SNe Ia Hubble diagram for the SCP (Perlmutter *et al.* 1999) dataset plotted according to the class of the host galaxy. The inset shows the high-redshift SNe, the main panel the Hubble diagram for the entire sample. Boxed points show SNe excluded from the P99 solution. LOWER PANEL: The residuals from the adopted cosmology ('fit-C' of P99) for both high and low-redshift SNe. Circled points discriminate between CfA SNe and Calan-Tololo SNe. In both panels unfilled circles denote galaxies with a less secure type-classification. (See Sullivan *et al.* (2002)

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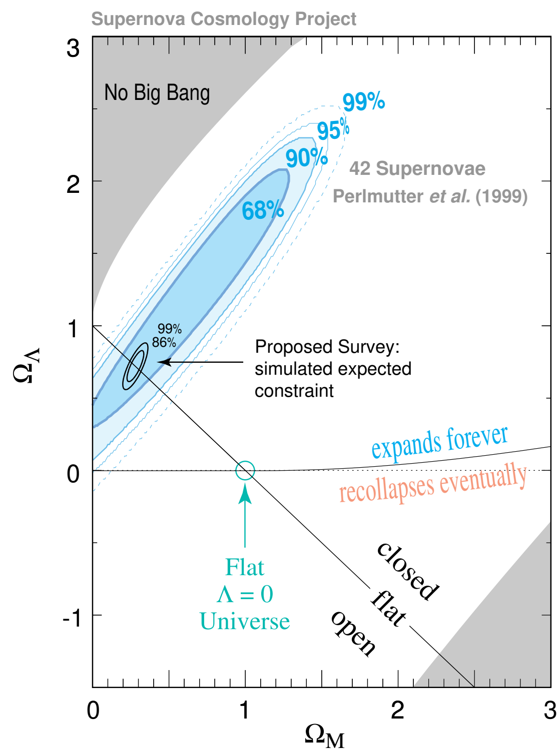

Figure 2: [caption here]

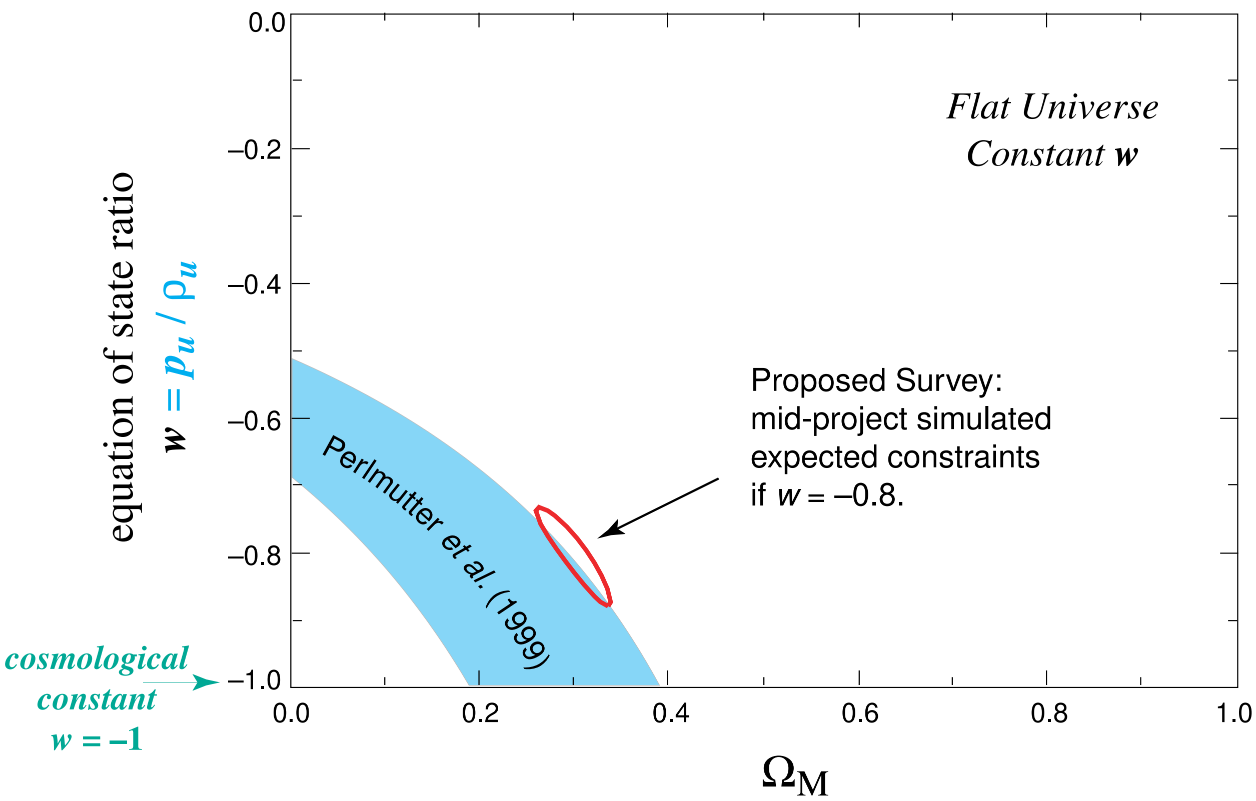

Figure 3: [caption here]

2 Progress to Date

Significant samples of well-studied SNe Ia at the higher redshifts are the key ingredients to further progress on the measurement of cosmological parameters. We have now built up the foundations for this work, and have begun collecting the relevant supernovae. The foundation-work began in October 1998 with our very successful pilot study using Keck imaging and spectroscopy in order to demonstrate that SNe Ia up to $z = 1.2$ could be found and studied using existing facilities. SN 1998eq at $z = 1.200$ was the key discovery from this run, and we obtained its complete I-band and J-band light curves using HST (Aldering *et al.* 1998, 2001). ($z = 1.2$ is still the highest-redshift for which there is spectroscopic confirmation of a Type Ia. See Fig. 3b.) Since then we have successfully transferred the *searches* to smaller telescopes, such as CFHT and CTIO—and, most recently, Subaru (Doi *et al.* 2001) — with wide-field imagers which give a larger $A \cdot \Omega$ product than LRIS. The Keck spectroscopy runs of 1999B, 2000A, 2001A, and 2002A, demonstrated that the resulting high-z SNe can be efficiently targeted and studied. The most recent run, 2002A, identified 21 SNe, while the previous run, 2001A, had identified 17 SNe. The 2002A run yielded two SNe with $z > 1$, while the previous year yielded three.

After the most recent supernovae (and those proposed here) fade and their lightcurves can be constructed, their data points will fill in the sparse/empty regions of the Hubble diagram beyond $z \sim 0.7$ (See Fig. 1). The lower-redshift regions have now been much better measured with the data from the four semesters prior to fall 1998. Keck spectra were obtained for all four sets of discoveries while the SNe were near maximum light, and eleven of these SNe were observed by the HST with both NICMOS and WFPC2. As shown in Figures 1 and 2b, the cosmological results from the eleven SNe (Knop *et al.* 2000, 2001) are in close agreement with results from the first supernova results (Perlmutter *et al.* 1999) that gave direct evidence for a cosmological constant. (A detailed discussion of the results from all previous Keck runs is presented later: we have now discovered ~ 120 SNe using these techniques, with a redshift distribution between 0.2 and 1.2, peaking at $z \sim 0.6$.)

Beyond these Hubble-diagram-cosmology presentations and publications, this year we have also been presenting and publishing results based on this project's Keck measurements on the study of SN Ia variations over time/redshift. Sullivan *et al.* (2002, submitted) presented new results on the Hubble Diagram of SN Ia as a function of host galaxy morphology that demonstrated that host galaxy extinction is unlikely to systematically dim distant SN Ia in a manner that would produce a spurious cosmological constant. The internal extinction implied is small, even for late-type systems ($A_V < 0.3$), and the cosmological parameters derived from those SNe Ia hosted by presumed dust-free early-type galaxies are consistent with our previous determination of a non-zero Λ. This result was based on Keck ESI spectroscopy and HST STIS "snapshot" images of SNe spanning the range $0 < z < 0.8$.

Pain *et al.* (2002) studied the changing SN Ia rates in the redshift range $z \sim 0.65$. Additional papers now in progress include a determination of the rates of SNe Ia at even higher redshifts, $z > 1$, and an analysis constraining metallicity variations and evolution from our SNe Ia spectra. NB: The previous papers from this program are discussed below.

3 Technical Justification

Feasibility: We have repeatedly demonstrated our ability to *a)* discover large numbers of high–z SNe Ia, *b)* obtain spectroscopic follow-up to confirm the SN type and redshift, *c)* acquire light curve photometry, and *d)* analyze the data to obtain peak magnitudes and measure Ω_M and Ω_Λ. We have demonstrated this capability out to $z = 1.20$. The SN program of CFHTLS (SNLS) is a much larger program than our previous searches with the CFHT, and offers us the opportunity to continue SNe Ia cosmological studies with greatly increased statistics and even greater reliability.

The SNLS is a rolling SN search which will observe four 1×1 deg^2 fields in Sloan g, r, i, z every 2-3 nights for 5 months per semester using MegaCam on CFHT, beginning in February 2003. The exposures of 15m, 30m, 60m and 30m per band will provide the discovery and well-sampled multicolor lightcurves for SNe Ia in the redshift range 0.3 to 0.9 (with discoveries up to $z \sim 1.2$). Photometric redshifts for host galaxies and color screening of the SNe candidates will allow SNLS to eliminate AGN and $z > 0.9$ SNe from the spectroscopic target list. Keck's role will be to measure the redshifts and tell-tale SN Ia features, especially for the highest redshift SNe Ia in the CFHTLS northern field — a role only it can perform with the quickness and reliability to keep up with the 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 made in the Groth Strip field at 14h18m+52d. We expect to have a target list of roughly 15 objects per lunation, most of which will be SNe Ia at $z > 0.5$. This selection purity is another important advantage of the rolling SN search approach compared to a classic 2-epoch SN search.

Exposures: *All our exposure times are based on experience with real Keck data for high-z SNe.* Although our observing technique and candidate weighting scheme select against SNe II and AGN's, some of these pass through to our list of candidates, and so when estimating the number of SNe Ia we will confirm, we include a $\sim 10\%$ 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 4-5 30 min exposures to produce a reliable redshift and a classification somewhere between probable and certain.

Telescope Time Requested. There are two key requirements for the spectroscopic program to succesfully exploit the SNLS — temporal coverage and speed. With Keck's aperture and sensitive spectrographs, and our specialized acquisition and reduction methods developed for SN spectroscopy at Keck, we can obtain redshifts and spectral classifications for up to 15 SNe candidates per night out to $z \sim 0.9$ Thus, in one Keck night we can cover the majority of the higher-redshift SNe Ia the SNLS will produce in one lunation. SNLS will operate for 5 months this semester, meaning that there a 4 lunations which need to be covered after accounting for edge effects (i.e. elimnation of SNe with only partial lightcurves which occur at the beginning and end of the 5 month period.)

Although many of the SN 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.

Therefore, obtaining the spectroscopy of this spring's SNLS SNe Ia's requires 4 one-night runs on Keck during dark time in early March, early April, late April, and late May.

We note that this SNLS spectroscopic follow-up campaign does not require the precise timing 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 automatically. However, since this is the first semester of SNLS and MegaCam is still untested it is **important that the Keck scheduler consult with us prior to scheduling specific dates.**

Instrumentation. In the past we have used both LRIS and ESI for our SN spectroscopy program. At the highest redshifts we have found that ESI is superior for our purposes, primarily because the high resolution of ESI separates out the night sky lines, allowing them to be excised from the data before smoothing to identify SNe and galaxy features. However, we have also seen that DEIMOS is producing excellent sky subtraction, and might be competitive with ESI (with poorer OH suppression but better throughput). Moreover, since SNLS observations are planned for the Groth Strip — one of the DEEP program's target fields — we are discussing with the DEEP team the possibility of obtaining Groth Strip galaxy spectra in parallel with the SN observations requested here.

At this time, for 2003A we will request the ESI spectrograph for all 4 nights. Subject to the outcome of our discussions with the DEEP team, we may request a switch to DEIMOS for some or all of our nights. It is most efficient for us to stick with a limited number of instruments during the semester given that we will have isolated one-night runs (and already have real-time observing and analysis software that we are now using with ESI). However, if scheduling pressure on Keck II is severe we would consider LRIS as a backup choice.

Backup Programs

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 of $z > 0.5$ we will observe the lower redshift SNLS SNe otherwise reserved for smaller telescopes. In addition, we are pursuing studies of the host galaxies of SNe we have discovered in the past in order to understand the relationship between SN Ia properties and global properties (metallicity, morphology, etc.) of the hosts. Several of these programs, such as measuring the gas-phase metallicity of the host of the hypernova SN 1999as using the [NII]/Hα ratio, determining the colors of the $M_B \sim -11$ host galaxy of SN 1999aw, or measuring the age and metallicity of the nearby ($z = 0.054$) Hubble-flow elliptical host galaxy of SN 1999av with high-resolution high S/N spectroscopy, can be carried out as back-up programs.

Status of Previously Approved Keck Programs

Semester 2002B: Four Keck II/ESI nights have been scheduled for November 2002.
Semester 2002A: We were awarded six nights for ESI spectroscopy of SNe from our spring 2002 search campaign which consisted of a "rolling" search at CFHT (a pilot-study for the SNLS) as well as "classical" searches at Subaru and CTIO. Essentially all the Keck time was lost due to bad weather, with the dome closed for most of the nights. Of our three nights in April, we were able to use about one half night. We observed two CFHT SNe (at $z \sim 0.3$) and two Subaru candidates (at $z = 0.56$ and $z = 0.88$). The three nights in May were completely lost due to weather.

Semester 2001A: In this highly successful six-night run we used one night of LRIS + Keck I and five nights of ESI + Keck II to obtain specta of 17 SNe, including three SNe Ia at $z > 1$. Our strategy of observing for six nights in one semester paid off, as we were able to use the three poorer seeing (~ 1 arcsec) nights and one cirrusy night to confirm brighter targets, and use the two better seeing nights to study SNe at $z > 1$. The Keck spectra allowed us to classify the SNe, obtain redshifts, and select the highest redshift targets for HST. In addition, the spectra are being compared to low redshift SNe Ia to test for the effects of evolution in the high-z sample. This run also gave us extensive experience with ESI, enabling us to refine our reduction techniques to best exploit ESI's advantages (and compensate for small remaining problems).
Semester 2000A: The highlight of this two-night run at Keck was spectroscopy of 2000fr, supernova candidate (from our CFHT search) that turned out to be a Type Ia SN at $z = 0.54$ at a very early phase in its light curve (only ~ 6 days after explosion). This early discovery allowed us to begin an intensive monitoring campaign to study the supernova in great detail, including near-IR imaging with ISAAC on the VLT. This data set allows us to make a detailed comparison with nearby Type Ia supernovae to check for signs of evolution or extinction by dust (Nobili *et al.* (2001)). These results have encouraged us to pursue detailed spectroscopy of another $z \sim 0.5$ SN Ia.
Semester 1999B: Three nights were awarded for the second week of October, 1999. The time was used for spectroscopy of candidate SNe that were discovered in a search at CFHT earlier that month. Out of the 10 candidates discovered, we were able to observe 6 of them, and two of those were found to have $z \sim 0.9$.
Semester 1999A: One night was awarded, and was not usable.
Semester 1998B: Three nights were awarded for a pilot study to find very high-z SNe. Two nights were used for imaging and one for spectroscopy, resulting in three Type Ia SNe with $z = 1.2$, 0.84 and 0.11. The SN with $z = 1.200$ (1998eq) is (still) at the highest redshift that Type Ia SNe have yet been confirmed (IAUC 7046). The discovery of this supernova demonstrates that it is feasible to find and obtain spectra for Type Ia events even for redshifts $z > 1$. The two highest redshift SNe from this run, both of which were discovered close to maximum light, were observed in I-band and J-band with HST WFPC2 and NICMOS.
Semesters 1997B and 1998A: In December 1997 and March 1998 we carried out searches using the BTC on the CTIO 4-m. The resulting SN candidates were observed spectroscopically with Keck on approximately 4 usable nights (over the two semesters). A total of 36 candidates were observed and 26 were confirmed as Type Ia, with mean redshifts of approximately 0.6–0.7. These were followed-up from the ground with CTIO-4m, WIYN, ESO 3.6m, WHT and INT telescopes, and 11 of these were also followed photometrically with HST using WFPC2 and NICMOS. The corresponding final reference images have been obtained for these SNe and the results presented in Knop *et al.* (2001).
Earlier Semesters: Final host galaxy images have been obtained for nearly all the SNe discovered prior to the above semesters. These SNe have been analyzed and formed the basis of the analysis presented in Perlmutter *et al.* (1999), which highlights the evidence for a cosmological constant. Nine additional papers based on our Keck work describe (i) the first measurements of cosmological parameters based on the first seven SN discoveries (Perlmutter *et al.*, 1997); (ii) a measurement of the rate of Type Ia SNe at $z \sim 0.4$ (Pain *et al.*, 1996), (iii) the rate of Type Ia SNe at $0.35 < z < 0.85$ (Pain *et al.*, 2002), (iv) constraints on the spatial variation of the Hubble constant from our data (Kim *et al.*, 1997), (v) a study of the timescale stretch parameterization of type Ia supernova B-band light

curves (Goldhaber *et al.*, 2001), (vi) the use of SN spectra for the determination of subtype and age of SNe Ia (Riess *et al.*, 1998), (vii) results on the $z = 0.83$ supernova 1997ap, and implications for cosmological measurements (Perlmutter *et al.*, 1998), (viii) the consistency of rise times measured for low and high-z supernovae (Aldering *et al.*, 2000), (ix) that our evidence for a non-zero cosmological constant is independent of host galaxy morphology. (Sullivan, *et al.*, 2002).

Research is in progress which will result in additional papers. These include (i) a determination of the rates of SNe Ia at $z > 1$, (ii) an analysis constraining metallicity variations and evolution from our SN spectra, and (iii) new limits on the cosmological parameters and possible systematics (grey dust or evolution) from SN 1998eq at $z = 1.20$. All these papers use the results from Keck spectroscopy obtained as part of our supernova cosmology program. A number of papers on these topics have also appeared in conference proceedings.

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 SN spectra are smoothed on a scale of $\sim$ 20Å (after removing any lines due to the host galaxy – and in the case of ESI – deweighting the spectral regions covered by OH lines) and compared with those of nearby SNe to ascertain the SN type.

The Keck redshifts will be used along with follow-up photometry from the Subaru Observatory Large Project 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 — must also be applied, followed by correction for dust extinction from the host galaxy and the Galaxy. 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 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 extensive software to undertake such light-curve fitting, corrections, and parameter fitting.

The spectra will also be used to directly test the hypothesis that distant SNe are spectroscopically similar to nearby SNe, as was done for SN 1997ap (See Fig. 3 and also Perlmutter *et al.* (1998)). In most cases, the host galaxy light significantly contaminates the SN spectrum, and therefore a template spectrum of the host galaxy at the supernova site will eventually be obtained for at least one or two of these cases. This will be subtracted from the original (SN + galaxy) spectrum. (We are also examining the use of cataloged galaxy spectra for this purpose.) With these final reduced SN spectra, we will measure key spectral features, such as the locations of the UV iron-peak lines, and the luminosity indicators, $\mathcal{R}$(CaII) and $\mathcal{R}$(SiII), for spectra with sufficient S/N (such as the $z \sim 0.5$ SN Ia we will target). The effect on our fits in the $\Omega - \Lambda$ plane due to any spectroscopically peculiar SNe Ia can be tested and used to set better limits on systematic uncertainties which could be caused by unrecognized spectroscopically peculiar SNe Ia. For our $z \sim 0.5$ SN Ia, stronger tests, including comparison of the UV spectral features with our Cycle 9 (and requested Cycle 11)

HST UV spectra of nearby SNe Ia (from a separate program), and detailed $\mathcal{R}$(CaII) and $\mathcal{R}$(SiII) measurements will be possible.

Technical Concerns

Since the targets are faint, accurate offseting is critical to take advantage of the narrow slit widths possible under the best seeing conditions. On our last ESI run we found that comparing guider image captures with our deep search images allowed for better offsets than standard offseting from a single bright star since the slit position relative to numerous field objects could be determined with high accuracy. Monitoring of the frames also allowed us to compensate for changes in atmospheric refraction as well as the very small flexure of the guider camera. Therefore, we will request that the night assistant continuously run the save-to-disk option for the guider. This can impact disk-space on the summit.

There are no technical concerns with the searches as we have developed, tested, used an extensive image analysis software suite which makes it possible to compare the images of all $100,000$ galaxies in the fields searched to their images on the earlier nights within 24 hours, to find the SNe before maximum light, and to identify the precise coordinates for follow-up spectroscopy and additional photometry.

The Keck SN candidate spectroscopy runs must be coordinated with the "rolling search" run to be scheduled for the Subaru Observatory Large Program, 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 and/or ESI on Keck each semester (or - more recently - combined pair of semesters) for the last five years. To reduce and analyze the spectra, our group has developed techniques that are specific to high-z supernova work.

Our group has also developed extensive techniques for the photometry of high-z 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 group consists of three permanent staff scientists, one professor, a scientist/project coordinator, four postdocs and three graduate students. By 2002B the group will grow, with the addition of two new postdocs. The group uses the extensive computing facilities available at LBNL. In addition, collaborators in the US, Sweden, France, Chile and the U.K. are actively participating in the project. Publication of the results will occur somewhat more than a year after discovery of the SNe; it is necessary to wait for the SNe to fade before template images of the host galaxies, and the derivation of accurate light curves, can be obtained. If there is insignificant host light, we can occasionally publish sooner: SN1997ap was discovered in March 1997, and a paper describing the data and results from that supernova was published by *Nature* in January, 1998. The results from the first 42 SNe (data obtained from Spring 1995 to Spring 1998, including final follow-up photometry on the Spring 1997 SNe) was published in *ApJ* in Fall 1999.

Publications

(* = Keck data contributed to this publication.)

* Hubble Diagram of Type Ia Supernovae as a Function of Host Galaxy Morphology, M. Sullivan *et al.*, submitted for publication in MNRAS.

* The distant Type Ia supernova rate, R. Pain, *et al.*, 2001, astro-ph/0205476, accepted for publication in the Astrophysical Journal.

K-corrections and Extinction Corrections for Type Ia Supernovae, Peter Nugent, Alex Kim, Saul Perlmutter, 2002, PASP 114, 803.

*The Distant Type Ia Supernovae Rate, R.Pain, *et al.*, presented at the January 2002 AAS meeting.

*Verifying the Use of Type Ia Supernovae as Probes of the Cosmic Expansion, R.Ellis, *et al.*, presented at the January 2002 AAS meeting.

*Ω_M and Ω_Λ from 11 HST-Observed Supernovae at z=0.36-0.86, R.Knop, *et al.*, presented at the January 2002 AAS meeting.

*NICMOS Photometry of High Redshift Supernovae, S.Burns, *et al.*, presented at the January 2002 AAS meeting.

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Results from a Deep Supernova Search at Keck, G. Aldering, *et al.*, 2002, in preparation

Type Ia Supernovae and Host Galaxy Extinction, E. Commins, *et al.*, 2002, in preparation

The Host Galaxies of Type Ia Supernovae at High Redshift, G. Aldering, *et al.*, 2002, in preparation

Supernova Discoveries In IAU Circulars

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