NOAO Observing Proposal *Survey proposal* **Panel:** *For office use.*
Date: March 14, 2002 **Category:** Cosmology

A Rolling Search for High-Redshift Supernovae

PI: Robert A. Knop **Status:** P **Affil.:** Vanderbilt University
Department of Physics and Astronomy, VU Station B 351807, Nashville, TN 37235-1807 USA
Email: r.knop@vanderbilt.edu Phone: (615)322-6165 FAX:

CoI: Saul Perlmutter **Status:** P **Affil.:** Lawrence Berkeley National Laboratory
CoI: Greg Aldering **Status:** P **Affil.:** Lawrence Berkeley National Laboratory
CoI: Peter Nugent **Status:** P **Affil.:** Lawrence Berkeley National Laboratory
CoI: Eric Smith **Status:** T **Affil.:** Vanderbilt University
CoI: Isobel Hook **Status:** P **Affil.:** University of Oxford/Gemini Observatory
CoI: Gerson Goldhaber **Status:** P **Affil.:** University of California at Berkeley

Nicolas Regnault
Shane Burns
Rene Ortman
Eugene Commins
D. Andy Howell
Lifan Wang
Rachel Gibbons
Anthony Spadafora
Alex Conley
Michael Wood-Vasey
Dan Kasen
Robert Vogel
Ariel Goobar
Reynald Pain

Abstract of Scientific Justification *(will be made publicly available for accepted proposals)*:
We propose a survey which will use the Mosaic camera on the CTIO 4m telescope in a "rolling search" for supernovae at redshifts $z < 0.8$. In addition, the survey will use the KPNO 4m telescope to obtain spectra of many of the supernovae discovered at $z < 0.45$, for purposes of identification and measurement of the redshifts. The search will image 7.2 square degrees of the sky with Mosaic for several days each month for four months each year. By the end of the five-year survey, we will have ~ 360 supernovae with high-quality lightcurves, all with multiple measurements while the lightcurve is still rising. This will dramatically improve our measurement of the cosmological paramters Ω_M and Ω_Λ, and will begin to address the nature of the dark energy. This survey will also provide the ideal data set for addressing and limiting potential systematic errors in supernovae at $0.3 < z < 0.8$, which is of great importance since it is supernovae at that redshift range on which the evidence for dark energy current rests. The supernoave observed by this survey will have lightcurves equivalent in quality to those discovered with a traditional two-epoch high-redshift supernova search and followed with HST.

Summary of observing runs requested for this project

Run	Telescope	Instrument	No. Nights	Moon	Optimal months	Accept. months
1	CT-4m	MOSAIC	70	dark	Sep - Dec	Sep - May
2	KP-4m	MARS	45	grey	Sep - Dec	Sep - May
3						
4						
5						
6						

Scheduling constraints and non-usable dates *(up to four lines).*

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

Type Ia Supernovae as Cosmological Tools

In the last five years, measurements of SNe Ia discovered at redshifts $0.3 < z < 0.9$ have provided substantial evidence that the expansion of the universe is currently accelerating, and that the cosmological constant Ω_Λ has a positive value. SNe Ia are uniquely powerful cosmological tools because they are both very bright, and thus visible at great distances, and consistent enough to be used as calibrated standard candles. The Supernova Cosmology Project (SCP) led by Saul Perlmutter developed the technique to find large numbers of these supernovae in batches. The SCP and the High-Z team led by Brian Schmidt (now led by Chris Stubbs) have each independently produced consistent measurements of Ω_M and Ω_Λ (Perlmutter, 1999; Riess 1998). Together with measurements of the Cosmic Microwave Background which indicate the Universe is flat (Balbi, 2000; Melchiorri, 2000), supernovae provide estimates of the cosmological parameters $\Omega_M \simeq 0.3$ and $\Omega_\Lambda \simeq 0.7$.

The evidence for the presence of some kind of "dark energy" with an equation of state $p/\rho = w < -0.6$ (where $w = -1$ would represent a cosmological constant or vacuum energy) is one of the most important astronomical discoveries in the last decade. Measurements of high-redshift SNe Ia may be taken further to begin to address the properties of the dark energy by refining the measurement of w by both increasing the statistics at the current redshift range and pushing the observations out to higher redshift. Figure 3, discussed below, shows the striking improvement in the statistical limits on the cosmological parameters, as well as on the equation of state of dark energy, yielded by this survey.

Because the current evidence for dark energy rests on SNe Ia at redshifts z=0.3–0.9, it is crucial that we better understand these objects. An NOAO survey using the Mosaic camera on the 4m CTIO telescope is perfectly suited to address the two primary plausible sources of potential systematic error in SNe Ia: evolution, and the effects of dust extinction. Evolution of the supernova population is best addressed by high-quality measurements of SNe at low ($z < 0.1$) and high redshifts, including a good measurement of the rise of the lightcurve for supernovae in both samples (Aldering 2000). The possible effects of dust extinction on supernovae include the effects of "gray dust" (ref) and concerns about the estimations of the effects of standard host-galaxy reddening on the current set of supernovae (ref). Grey dust may best be addressed by observing supernovae in the optical and infrared wavelengths at a range of redshifts (including $z < 1$ and $z > 1$), so as to have strong measurements of supernovae across the epochs of both acceleration and deceleration. Host galaxy extinction is best addressed by obtaining a large sample of well-observed supernovae at the redshifts on which the current cosmological results rest. Good color measurements of this large sample will allow high-quality direct estimates of E(B-V) from dust extinction. Moreover, with a sufficiently large sample, enough ($\sim 1/8$) will be in elliptical galaxies, allowing an estimation of the cosmological parameters from a statistically significant set of supernovae unlikely to be affected by host galaxy dust extinction; discovery of $\gtrsim 300$ SNe Ia in all hosts would therefore provide a sample *entirely hosted in elliptical galaxies* which is equivalent in size to the set of supernovae which provide today's measurement of dark energy. This survey will address these issues by providing high-quality color and lightcurve measurements of supernovae at the redshift range that provides our best evidence today for dark energy.

This Survey: a Rolling Search for Supernovae

This proposed survey will use the Mosaic wide-field imager on the CTIO 4m Blanco telescope in a "rolling search" to discover and produce high-quality lightcurves of $\sim$ 360 (or something) SNe Ia at $z < 0.8$ over the five-year duration of the survey. The survey will be run by the SCP, whose members have extensive experience coordinating major multi-month and multi-telescope supernova search-and-follow-up surveys, including comparable scale projects at the CTIO 4m telescope. In addition, this survey requests 9 nights of time each year on the KPNO 4m Mayall telescope using the MARS spectrometer to perform spectroscopic confirmation and redshift measurements of SNe at redshifts $z < 0.5$. Equipped with LBNL red-sensitive CCDs (ref), this instrument is ideal for this work. Other follow-up time will be applied for separaterly, and will emphasize the supernovae at higher redshifts. ☑

In contrast to traditional "two epoch" high-redshift supernova searches (where images from a reference and a search run are subtracted from each other), this survey will image the same target fields repeatedly to two depths in R and I for four months; the nature of the search runs are described in detail in the technical description section. In addition, deep B and V images will be obtained once of each field for purposes of obtaining photometric redshifts.

The great advantage of this mode of search is that the same telescope time is used for discovery and for high-quality lightcurve measurements; for supernovae at the primary target redshifts, no additional photometric followup is necessary (as it is for a two-epoch search). Moreover, since the same fields are observed at every epoch, there will be observations of the rise of the supernova lightcurve which are taken *before discovery.* The survey will produce an unprecedented number supernovae with photometric observations starting at the epoch of the explosion in addition to excellent post-maximum lightcurve measurements. Multiple points on the lightcurve before discovery, together with BVRI photometric redshifts of host galaxies, will allow better discrimination of candidates for further spectroscopic followup, thereby increasing the "hit rate" and efficiency of use of that time.

Figure 1 shows the expected supernova discoveries over the course of this survey, in redshift bins of width 0.1. A primary set of $\sim$ 270 supernovae out to $z = 0.6$ will have R-I color uncertainties less than 0.05 magnitudes; 90 additional supernovae out to $z = 0.8$ will have R-I color uncertainties in the range 0.05–0.1. Another $\sim$ 100+ supernovae will be discovered at redshifts another 0.1–0.3 beyond $z = 0.8$; those supernovae will require additional photometric followup from larger or space-based telescopes, which will be applied for separately from this telescope.

Figure 2 shows a simulated lightcurve from this survey for a SN Ia at $z = 0.45$ in one of the "shallow" fields of this survey, together with data for a supernova at a similar redshift observed with the Hubble Space Telescope (HST). The quality of the lightcurve is such that this survey by itself will provide estimates of a supernova's peak magnitude, light curve width, and R-I color which are *equivalent in quality* to those of a supernova discovered using a traditional search and followed with the HST. This survey will produce lightcurves of this quality for every supernova out to a redshift of $z \sim 0.6$ in the "shallow" fields, and out to $z \sim 0.7$ in the "deep" fields. This will greatly improve the confidence limits on Ω_M and Ω_Λ, and on the equation of state parameter w; Figure 3 shows the improvement in the statistical errors on the cosmological parameters. Moreover, because the coverage of the lightcurves will be more complete (especially before maximum light) than is possible with supernovae discovered in a traditional survey and followed with HST, these data will be better for calibrations, corrections, and evolutionary tests which rely on the shape of the lightcurve. The sample of $\sim$ 270 supernovae with excellent measurements of R-I (good to $\lesssim$ 0.05 magnitudes) will allow us to directly address the issues of dust extinction discussed above.

Redshifts and spectral confirmation will be obtained through a combination of the KPNO 4m time being requested for this survey, and by additional telescope time for which the SCP applies each year. Experience indicates that 3–4 supernovae at $z < 0.5$ may be spectrally confirmed by a 4m telescope during the course of one night. Nine nights on the KPNO 4m, divided into three nights during the each of the last three months of the survey, would be sufficient to confirm most of the supernovae discovered at z <0.4–0.5 each year. The SCP will use its other observing resources to confirm many of the remaining supernovae, both at these redshifts and at higher redshifts.

Relation to Other Supernova Surveys

The SCP and other teams are currently engaged with other supernova surveys; this survey would be complementary with the others. The Supernova Factory (ref) is aimed at discovering a large number of supernovae at redshifts $z < 1$, which will be used as calibrator objects for supernovae at higher redshifts. The CFLS survey at CFHT (*how should we state the SCP's relationship??*), as well as ongoing searches at Subaru in collaboration with Momoru Doi, are designed primarily to find supernovae at higher redshifts of $z > 1$. This survey will discover supernovae at the intermediate redshift range. The CTIO 4m telescope is the ideal instrument for discovering supernovae at this range, and as stated above this is the range in which it is currently most important to understand and limit systematic errors on high-redshift supernovae.

Looking further ahead, this survey coupled with the others mentioned will help build the necessary understanding of systematic and statistical properties of SNe Ia so as to make the best use of the SNAP satellite mission, which if approved will be launched in $\sim$ 2010and will discover and follow thousands of supernovae

Other Astronomical Uses

Although the timing of the observations are optimized for the measurement of SN Ia lightcurves, at the end of each year the survey will have very deep BVRI measurements of in 7.2 square degrees. The total summed time in R and I will provide a S/N=10 limiting magnitude of 25.7 in R and 25.2 in I in the 2.4 square degrees of "deep" fields; it will be 0.5 magnitudes less deep in the 4.8 square degrees of "shallow" fields. The B and V observations obtained for photometric redshifts will round out the data set for deep BVRI fields. These fields will be chosen to be contiguous; although this is not necessary for the supernova work, it will maximize their value for other uses. Fields will be repeated for two years (thereby providing deep final references for supernovae discovered at the beginning of the previous year), and then shifted, thus doubling the total area of sky observed by the end of the survey. By the end of the 5-year survey, there will be deep BVRI images of a contiguous 14.4 square degree region of the sky, ideal for cluster searches and SZ measurements.The SCP has collaborated in the past with other groups who used their search data for cluster searches and weak lensing measurements. The much greater depth, areal coverage, and consistency of these data will make them far more useful. (Help: other uses I should mention?)

The survey will also have direct educational uses. The PI, R. Knop, is proposing an astronomical lab course at Vanderbilt University which will be based around high-redshift supernova searches. Although the course will primarily rely on pre-existing data, the timing of the course and the survey may allow the students to become involved in the search and participate in one of the most exciting current groundbreaking astronomical research projects.

References

Aldering, G., Knop, R., and Nugent, P., 2000, AJ, 119, 2110.
Balbi, A., *et. al.*, 2000, ApJ, 545, 1.
Melchiorri, A., *et. al.*, 2000, ApJ, 536, 63.
Perlmutter, S., *et. al.*, 1999, ApJ, 517, 565.
Riess, A., *et. al.*, 1998, AJ, 116, 1009.
van Dokkum, P., 2001, PASP, 113, 1420.

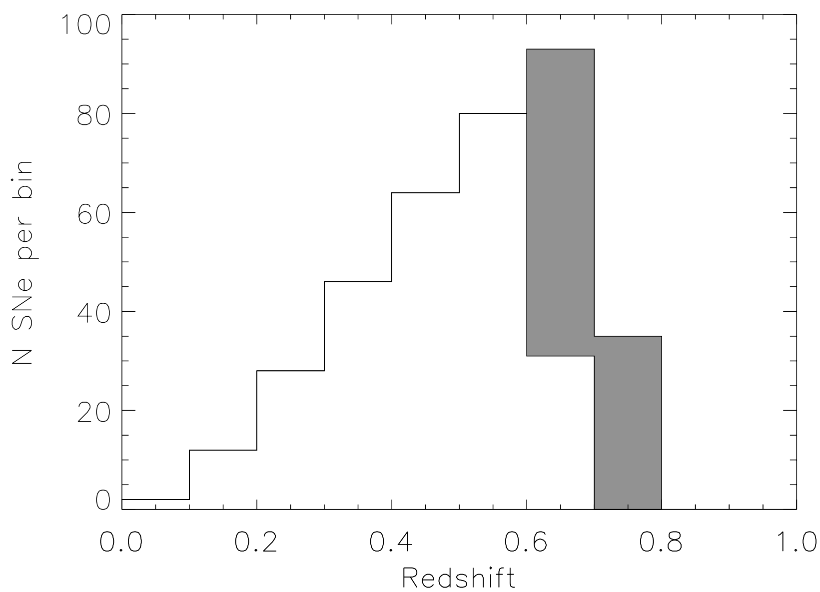

Figure 1: Predicted number of supernovae discovered by five years of the survey in fields to two depths. Open bars represent supernovae with observed R-I color uncertainties better than 0.05 magnitudes; solid bars have R-I color uncertainties in the range 0.05–0.10 magnitudes.

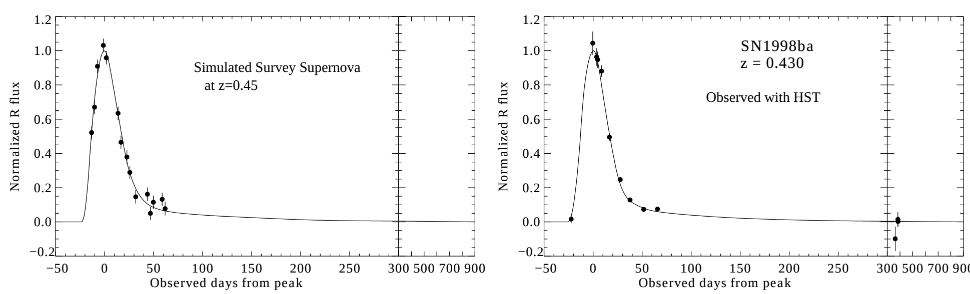

Figure 2: Left, a simulated lightcurve of a SN Ia at z=0.45 produced by the observations in the "shallow" field of this survey, discovered in the second month of the survey, assuming observations every three days and that each day has a 25% chance of being lost to weather. Right, the measured lightcurve from a supernova discovered at $z = 0.43$, observed with WFPC2 on HST.

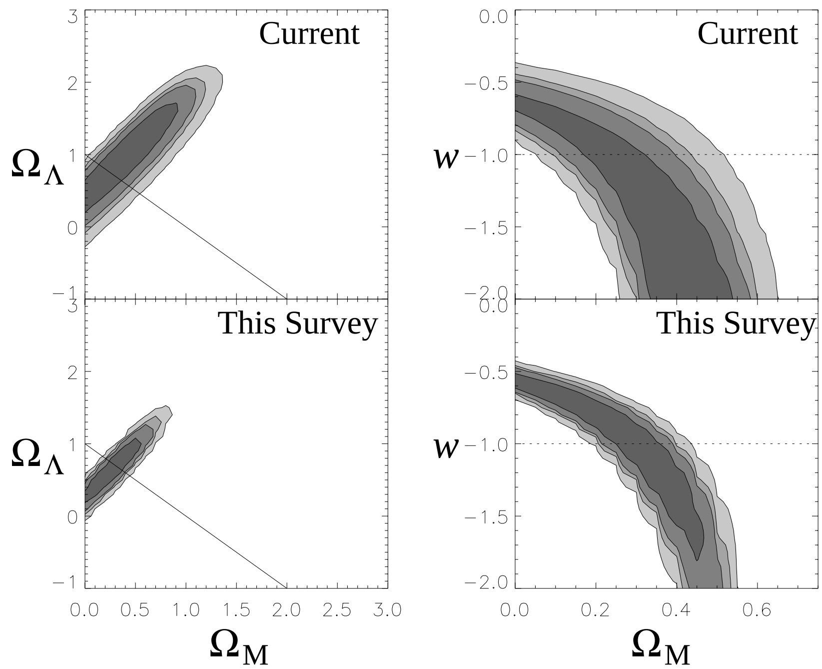

Figure 3: Simulated 68%, 90%, 95%, and 99% confidence limits on cosmological parameters from 360 high-redshift supernovae at $z < 0.8$ discovered by this survey. All plots explicitly include statistical errors due to host galaxy correction and measured uncertainties in E(B-V). On the left are the limits on the mass density Ω_M and the cosmological constant Ω_Λ. On the right are the joint limits on Ω_M and the equation of state parameter w for dark energy, under the assumption that the universe is flat. The upper plots show the SCP's current limits, including the results from 10 supernovae discovered at CTIO in 1997-1998 and followed with the HST, are shown in outline on each plot. The lower plots include only the high-redshift supernovae of this survey, plus an assumed 40 supernovae at $z < 1$. (In practice, many more supernovae at $z < 0.1$ will be available from the Supernova Factory (ref ??).)

Management Plan *Describe the overall plan for conducting the proposed survey, including the experimental design, survey deliverables, staffing requirements, and a list of all observing runs requested for this survey. See the Survey Program instructions for details.*

The PI of this project, R. Knop, together with his research team at Vanderbilt University, will have as their primary research activity the performance and management of this search and related observations. They will be supported by the rest of the international SCP collaboration, including particularly the supernova team at Lawrence Berkeley National Laboratory (LBNL), which includes five research scientists, four post-docs, three graduate students, and other support personnel. At Vanderbilt University, the SCP has accesses to substantial computing resources including the VAMPIRE Beowulf cluster. Access to the LBNL's National Energy Research Scientific Computing (NERSC) supercomputing center provides more than sufficient computing resources, together with support manpower, for the analysis of the data as well as subsequent storage and dissemination. The resources of NERSC, for example, will allow us to apply the computationally expensive LAcosmic routine (van Dokkum, 2001) to the images prior to the image subtraction during a search. That, and combining images from subsequent nights, will allow the search to succeed even without performing cosmic-ray splits during one night of observing (which is expensive in telescope time, as it reduces the R-band exposure time in the "shallow" fields to less than twice the 100s readout time of the Mosaic camera). ✓

R. Knop is in the process of applying for external funding to support travel as well as a post-doc and/or 2–3 graduate students to work on this survey. Even in the absence of direct support for the members of the SCP at Vanderbilt University, the Supernova team at LBNL (funded by the DOE) as well as the rest of the SCP is committed to the success of this survey, and will provide travel money, manpower, and equipment to ensure that it succeeds. R. Knop has been the primary researcher responsible for coordinating the actual search during SCP campaigns of recent years, and has been the primary maintainer of the search software. As such, he is uniquely qualified to manage this rolling supernova search.

This project will take advantage of the survey data pipeline being developed by the Data Products Group led by Chris Smith at CTIO. This pipeline will produce overscan, bias, and flatfield corrected images from Mosaic at CTIO. These flatfielded images will then be transferred to computers at LBNL and Vanderbilt, where they will be combined and subtracted using the extremely successful SCP search software which has been used to discovered supernovae at CTIO and other telescopes over the last several years. This survey will be an excellent test of both the pipeline of the Data Products group, as well as in the efficient use of data produced by that group. It will rely on the Data Products Group to provide flatfielded images in a timely manner, and will then quickly turn these flatfielded images into supernova discoveries which will be reported in IAU circulars, as well as observed spectroscopically by other telescopes and published in the astronomical literature. Furthermore, this survey will serve as a testbed for involvement of LBNL's NERSC supercomputing center in the National Virtual Observatory (NVO) project.

The impact of the survey on NOAO resources will be modest. The SCP will send one or two observers to CTIO around new moon each month to perform the observations during each half-night of the survey. Past experience indicates that there will be more than sufficient network bandwidth to send one half-night's worth of flatfielded data over the course of one night. While the use of the network connection will be intermittently high, the survey will not need significant bandwidth to the USA for more than (conservatively) ~ 10 hours every three to four nights. An additional observer will be sent to KPNO to perform spectroscopic observations during the nights of those runs.

The runs requested are listed at the end of this section. Please note, however, that the exact timing of the runs flexible, as discussed in detail in the Technical Description for the CTIO 4m Mosaic runs.

The SCP is aware that the High-z team is also proposing a large supernova survey. If both proposals are given time, the SCP expects and hopes to coordinate with the other team to ensure that the two surveys are run in the most efficient manner so as to maximize the scientific benefit of both. For instance, if one team has additional observing time at other telescopes during the time of the other team's survey, the second team might give higher-redshift candidates requiring additional observations to the first time, thereby benefiting both teams as well as the scientific knowledge of the community.

Observing Runs Requested for Each of the Five Years of this Project

Semester	Telescope	Instrument	# of Nights	Moon	Acceptable Months
200xB or A	CTIO-4m	Mosaic	3.5	dark	Sep or Jan
200xB or A	KPNO-4m	MARS	3	grey	Sep or Jan
200xA or B	CTIO-4m	Mosaic	3.5	dark	Oct or Feb
200xA or B	KPNO-4m	MARS	3	grey	Oct or Feb
200xA or B	CTIO-4m	Mosaic	3.5	dark	Nov or Mar
200xA or B	KPNO-4m	MARS	3	grey	Nov or Mar
200xA or B	CTIO-4m	Mosaic	3.5	dark	Dec or Apr

Use of Other Facilities *Describe how the proposed observations complement data from non-NOAO facilities. For each of these other facilities, indicate the nature of the observations (yours or those of others), and describe the importance of the observations proposed here in the context of the entire program.*

The SCP is an international collaboration involved in a number of projects related to supernova cosmology. Each year it applies for observing time at a number of national observatories, as well as the observatories of the University of California (including the 10m Keck telescopes). These resources will be used to spectrally confirm and measure the redshifts of those additional supernovae not observed spectrally at the KPNO 4m, and at higher redshifts. The SCP has demonstrated over the last decade that it is capable of quickly turning around supernova discoveries into fruitful followup observations, and that it has the manpower, computing, and telescope resources to make the best use of these discoveries.

Release of Data *Describe the timeline and mechanism for the release of data subsets, the complete dataset, and catalogs to the astronomical community.*

The individual images will be archived and made available to the public as a part of the work of the Data Products Group at CTIO. The SCP will release all of the images to the public at the end of the four-month period of the survey each year. In addition, deep co-added, cosmic-ray rejected, and calibrated images which combine data throughout all of the nights of the survey will be made available over the Internet from LBNL (and NOAO, if they wish to mirror these images). LBNL's connectivity to the Internet is sufficient to provide access to any subset of the data to any astronomer in North America. The SCP will develop a web interface and search engine providing easy access to the specific data, which will include information about depth, image quality, and exposure time for each frame available.

(NOTE: How soon should we make this data available? We could have it out within days or weeks, but we might want to sit on it until the end of each four-month period.) ☑

Previous Use of NOAO Facilities *List allocations of telescope time on facilities available through NOAO to the PI during the past 2 years, together with the current status of the data (cite publications where appropriate). Mark with an asterisk those allocations of time related to the current proposal. Please include original proposal semesters and ID numbers when available.*

Demonstrated Successes: Over the past few years we have discovered and studied >100 SNe (~ 80 at CTIO) at redshifts $z = 0.03$–1.20. We have followed each of these SNe with photometry over the light curve (beginning before or at maximum light in almost every case) and spectroscopy near peak for most. Almost all of our SNe are Type Ia since SNe Ia are typically 2 magnitudes brighter than the other types. Eighteen SNe Ia have been observed by the HST. Nineteen others formed the core of the Spring 1999 Nearby Campaign (a campaign to study low-redshift, $z < 0.1$, SNe Ia). The results have been published in Perlmutter *et al.*, 1997, Perlmutter *et al.*, 1998, and Perlmutter *et al.*, 1999, Knop *et al.*, 2000, Goldhaber *et al.*, 2001, Pain *et al.* (submitted), and additional papers are in preparation.

Spring 2002a SNe Ia Search: Six nights have been scheduled for the CTIO-4m/Mosaic for a "two-epoch" search. In addition, confirmation and follow-up time has been scheduled for Gemini-N/GMOS (35 hours), Gemini-N/NIRI (35 hours), and WIYN (5 nights).

Spring 2001a SNe Ia Search: We were awarded 3 nights in March 2001 and 3 nights in April 2001 at CTIO-4.0m/Mosaic for the Spring 2001 SNe Ia search, as well as 2 nights at WIYN/MIMO and 35 hours at Gemini/NIRI for the follow-up. The search campaign was a striking success, as more than 17 SNe Ia have been discovered in the redshift range $z = 0.35$–1.1, and HST follow-up photometry was triggered for five of the highest redshift SNe. Although half of the WIYN time was lost due to bad weather conditions, this telescope allowed us to gather good 3rd epoch points for the SNe Ia detected in the redshift range $z = 0.35$–0.55. Observations of the most distant SNe Ia —$z \sim 1.055$ detected with CTIO/MOSAIC and $z \sim 1.12$ detected at CFHT/12x8k— have been carried out at Gemini/NIRI. Because of cancellation of the queue this program was not carried out in queue mode. However it was used as a test program for NIRI SV (broadband imaging mode with the f/6 camera). About 12 hours of useful data were obtained in this way, approximately half of our original request (when overheads are taken into account). The data quality is good, and the images are currently being reduced (see figure 3). Final analysis awaits acquisition of final reference images (proposed here) of the SN's underlying host galaxy.

UV Observations of Nearby Type Ia Supernovae: The program "UV Observations of Nearby Type Ia Supernovae" was successfully carried out this past spring at several ground-based facilities and HST. The spectra of Hubble-flow SNe Ia observed from HST and from the ground were taken at weekly intervals over a range in time starting slightly before maximum light and extending to +30 days. These observations were aimed at accomplishing the following three goals: (1) Calibration of the rest frame UV light curves of SNe Ia and an assessment of their potential use as distance indicators through UV light curve shape analyses. (2) Improvement in our understanding of the physics of SNe Ia, metallicity/evolutionary effects and correlations between peak brightness and UV spectral features. (3) Calibration of the SNe Ia previously observed by HST at high-redshift.

$\boxed{\star}$ CTIO 0.9-m Apr/May 01 We were awarded 2 nights on the CTIO 0.9-m for the photometric screening of the nearby supernova candidates and initial UBVRI photometry. Both nights were good and the data is currently being analyzed.

$\boxed{\star}$ CTIO 1.5m Apr/May 01 We were awarded 3 nights on the CTIO 1.5-m for follow-up photometric observations of the supernovae, particularly concentrating on U-band photometry. All of the nights were good and the data is currently being reduced.

$\boxed{\star}$ YALO Apr/May 01 We were awarded ~ 20 hrs on the YALO 1.0-m for the BVI photometric follow-up of the 2 HST observed supernova candidates. The light curves from these observations are almost completely reduced.

☆ KPNO 2.1-m Apr/May 01 We were awarded 6 nights on the KPNO 2.1-m for both spectroscopic screening of supernova candidates and spectroscopic follow-up of our HST supernova. All nights were good and we issued reports of supernova discovered/classified in IAUC's: 7612, 7614, 7618, 7640.

☆ KPNO 4.0-m Apr/May 01 We were awarded 1 night on the KPNO 4.0-m which was used for late-time spectroscopic follow-up of the HST observed supernovae. The red observations have been reduced.

Detection and Observation of Nearby Type Ia Supernovae: To control the systematic errors affecting the $(\Omega_m, \Omega_\Lambda)$ measurements it is necessary to gather as much information as possible on the intrinsic properties of SNe Ia. In particular, measuring the intrinsic colors of SNe Ia with good precision allows for the correction for absorption by dust. Also studying the spectral evolution of SNe Ia helps to constrain theoretical models of these objects. Such studies are only possible on nearby SNe Ia, $z < 0.15$. In Spring 1999, we undertook a large nearby supernova search in collaboration with other groups. More than 50 SNe were discovered, among which 19 were SNe Ia in the nearby Hubble flow discovered near maximum (Aldering 2000). Papers are near submission on the overluminous SN Ia SN1999aw and on the hypernova SN1999as; analysis of the balance of the dataset is underway. CTIO and KPNO instruments played a key role in the photometric and spectroscopic follow-up of these events, as follows:

☆ CTIO 4-m Mar/Apr 00 We were awarded four nights for final reference spectra of SNe from the very successful Spring 1999 Nearby Campaign. Substantial time was lost over the four nights due to technical problems at the telescope. Final reference spectra (i.e. after the SN has faded) and improved host-galaxy redshifts were obtained for 10 SNe. Additionally, three SNe were confirmed in IAUCs.

☆ CTIO 1.5-m Feb/Apr 00 We were awarded six nights for final $UBVRI$ photometry reference points for SNe from the Spring 1999 Nearby Campaign. We obtained final references (i.e. after the SN has faded) for 15 SNe.

☆ KPNO 4-m Apr 99 We were awarded two nights at the KPNO 4-m to obtain spectral time series for SNe Ia discovered as part of the Nearby Campaign. On the first of these nights we successfully obtained spectra for 14 SNe Ia from the total sample of 19 SNe Ia which had intensive follow-up. The second of these nights was unusable due to strong winds.

☆ KPNO 2.1-m Apr 99 We were awarded four nights to obtain $UBVRI$ photometry of Nearby Campaign SNe Ia. Half of this time was lost due to clouds or strong winds.

☆ CTIO 1.5-m Mar/Apr 99 We were awarded seven nights to obtain $UBVRI$ photometry of Nearby Campaign SNe Ia. Most of this time was usable, and the resulting photometry was reduced after the final references were taken in Spring 2000.

☆ CTIO 0.9-m Mar/Apr 99 We were awarded four Director's Discretionary nights during bright time to obtain $UBVRI$ photometry of the brighter Nearby Campaign SNe Ia. Most of this time was usable, and the photometry is now reduced.

☆ CTIO 4-m Mar 99 We were awarded four nights to screen and obtain spectral time series for nearby supernova discovered as part of the Spring 1999 Nearby Campaign. With the CTIO 4-m we screened the bulk of the 40 SNe discovered in this Campaign, and obtained over half of the spectral time-series data for the Campaign. The discoveries from CTIO were reported in IAUC's 7128 (SN1999as), 7130 (SN1999aw, SN1999ax, SN1999ay), 7131 (SN1999az, SN1999ba, SN1999bb), 7134 (SN1999be, SN1999bf), and 7136 (SN1999bi, SN1999bj, SN1999bk, SN1999bl, SN1999bm, SN1999bo, SN1999bp). Along with the other SNe discovered in the Campaign, this is the largest number of spectroscopically confirmed SNe ever discovered in such a short period of time.

Detection and Observation of High-z type Ia Supernovae:

⋆ CTIO 4-m Apr 99: We were awarded two nights for final photometric followup at the CTIO 4-m to provide high quality reference images in both R and $I-$ for most of the high-z SNe discovered in the previous two semesters. Both nights were clear, but half of the first night was lost to computer problems. Analysis of the SNe lightcurves for which final reference images were obtained has been presented in Knop *et al.* (2000). The photometry has been combined with HST photometry to obtain new constraints on the cosmological parameters, which agree well with the previous results, as shown in Figure 2b from Knop *et al.*, (2000).

⋆ CTIO 4-m Dec 98/Jan 99: We were awarded five nights of final photometric followup at the CTIO 4-m to provide high quality reference images in both R and $I-$ for most of the high-z SNe discovered in the previous two semesters. All but one of these nights was clear, and the resulting data went into the Knop *et al.*, (2000) analysis.

⋆ CTIO 4-m Mar 98/Apr 98, Keck Apr 98: On this our third run with the BTC we were able to discover > 20 high-z SN candidates at CTIO, 13 of which were spectroscopically confirmed including 8 SNe Ia observed with multi-color photometry with HST. Using the final reference images from the following year's observing runs (above two items), the photometry analysis of these SNe was completed, combining both ground-based and HST data (Knop *et al.* 2000).

Why CTIO? *(For CTIO proposals only.) Explain why access to the southern hemisphere is needed to achieve your scientific goals.*

Observing Run Details for Run 1: CT-4m/MOSAIC

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for WIYN-2hr, WIYN-SYN, YALO, and Gemini runs).*

Because the search runs at Mosaic each year are identical, this section describes all of those runs. We are propsing each year to perform four runs of seven half-nights, spaced by three nights, centered around the new moon of four successive months. ACTUALLY, we aren't. We're proposing something else, which will be in a table that I will write later. This is a total of 3.5 nights per month, or 14 nights (28 half-nights) per year of the survey. Over five years, the survey will use 70 nights (140 half-nights) of time with Mosaic on the CTIO 4m telescope.

The exact timing and nature of the Mosaic runs at CTIO is flexible; the SCP is open to negotiation with the CTIO staff on when the survey would best fit their schedule. For example, the survey will still succeed with some modification to the schedule of seven half-nights each spaced by three nights. The only real requirement is that a large enough equatorial target field far from the plane of the galaxy (i.e. with Galactic extinction E(B-V)$<\sim 0.03$) be observable over the four months of the survey. Ideally, fields would be equatorial so that follow-up from telescopes in both hemispheres (including the time requested on the KPNO 4m for this survey) will be possible. However, if necessary, the survey could work in the "wrong" half of the night in a field of very negative declination (in which case the survey would not include spectroscopic time at KNPNO).

Two ideal periods of time for this survey would be September–December, and January–April. This survey may also make use of the "off half" of some of the nights of the existing SuperMacho survey, by overlapping the end of their period with the beginning of our period (or vice versa); this would require no sacrifice in data quality for either program, since one would naturally want the end of the night while the other would naturally want the beginning of the night. Note, however, that as mentioned above this survey benefits greatly from data as many as 8 or 9 days after new moon, whereas the SuperMacho survey only takes data within 3–4 days of full moon; thus, although a large degree of overlap with SuperMacho nights would be possible in the first or last month of the survey, complete supernova measurements will require observations $\pm 7--9$ days before and after each new moon. Observing for a period of 15–18 days each month ensures that *every* supernova which explodes in the surveyed area during the survey gets a measurement of the lightcurve with a point no more than ~ 5 rest-frame days from maximum light both before and after the time of maximum; a greater gap around full moon would lead to supernovae "lost" due to not having a measurement close to maximum light.

The survey proposes to use half-nights: for an equatorial field, this would be the second half of the night for the first two months, and the first half of the night for the second two months, so as to minimize the airmass to the chosen target fields. Fields will be observed in the R and I bands at each epoch, which are the wavelengths most useful for SNe Ia at $0.3 < z < 0.8$. Six "deep" fields (2.4 square degrees) would be observed to a limiting magnitude of 24.0 (with S/N=10) in R and 23.5 in I. Twelve "shallow" fields (4.8 square degrees) would be observed to a limiting magnitude of 23.5 in R and 23.0 in I. These observations require 4.5 hours of time, including a 100s readout time for each exposure. The "deep" fields will provide excellent measurements of supernovae out to redshifts of 0.7, and the "shallow" field to redshfits of 0.6; additional supernovae up to ~ 0.1 beyond this will have useful lightcurves. These chosen depths maximize the number of cosmologically useful supernovae discovered without sacrficing too much time to overhead reading out the CCDs as a result of very short exposure times.

In addition, at the beginning of the survey each year the target fields would be observed to a depth of 24.0 or 24.5 (for "shallow" and "deep" fields respectively) in B and V, requiring an additional night of observations. These will allow BVRI photometric redshifts, as well as classification from the color information, of host galaxies of discovered supernovae. This will also enhance the value of the data set for other scientific uses. ✓

Image reductions will be performed by the data pipline of the Data Products Group at CTIO, and will be transferred to LBNL and Vanderbilt where the extremely succesful SCP search software will process it and detect and measure supernoave.

Instrument Configuration

Filters:	Slit:	Fiber cable:
Grating/grism:	Multislit:	Corrector:
Order:	$\lambda_{\rm start}$:	Collimator:
Cross disperser:	$\lambda_{\rm end}$:	Atmos. disp. corr.:

R.A. range of principal targets (hours): 8 to 9

Dec. range of principal targets (degrees): -5 to +5

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

Observing Run Details for Run 2: KP-4m/MARS

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for WIYN-2hr, WIYN-SYN, YALO, and Gemini runs).*

DUMMY FILE - FROM 2002A GMOS (GMOS Spectroscopy: We aim to obtain spectra of 5 SNe Ia candidates to confirm the SN type and obtain a redshift. Typical exposure times of 3600s each are sufficient for an initial screening of 5 candidates in the magnitude range 23–25. More exposure time would then be spent on two candidates that appear to be likely $z > 1$ type Ia supernovae —either from those screened by GMOS or from elsewhere. These will require additional exposure times of 3 hours each. Note that the final spectra can be smoothed heavily to reveal the supernova features (Fig. 3).

The total on-source time requested is 11 hours. Following the GMOS web page guidelines, we add 30 minutes per new target, plus 25% of elapsed time to take into account the overheads. Here, we assume that obtaining the I-band flats to reduce the effects of fringing is included in the 25% overhead. We therefore require 17.2 hours for the GMOS spectroscopy observations.

(b) GMOS Imaging: GMOS will also be used to obtain lightcurves for two SNe Ia discovered in the redshift range $z \sim 0.7$–0.85 —higher redshift SNe Ia require HST for optical observations.

Exposure Times and Overheads: We intend to obtain 5 i' points —rest frame B— and 1 z point —rest frame V— around maximum, with a S/N ratio of 20. The table below presents representative exposure times for a $z \sim 0.8$ SNIa observed at GMOS. It shows that obtaining a lightcurve takes about 6.75 hours per supernova. The corresponding time for a $z = 0.75$ SN Ia is 5.3 hours. Therefore, the total on-source time requested is 12 hours. Adding 25% of elapsed time, plus 15 minutes per visit to take into account the overheads, we therefore request 18 hours on GMOS. We also assume that the z and i images at peak can be obtained with the spectroscopy, removing the acquisition overhead for these. The target table summarizes the photometric observations we plan to carry out at GMOS.

Day Observer Frame	I-Mag	Z-Mag	S/N [I]	S/N [Z]	Exp. I[s]	Exp. Z[s]	Total
0	23.1	23.1	20	20	480	2820	3300
10	23.3	—	20	—	660	—	660
20	23.7	—	20	—	1380	—	1380
30	24.3	—	20	—	4140	—	4140
40	25.0	—	20	—	14880	—	14880

Summary: We will use Gemini/GMOS for the spectroscopic confirmation of 5 SNe, including 2 at a redshift $z > 1$, and the follow-up of two SNe Ia discovered in the redshift range $z = 0.7$–0.8. We request 35.2 hours (US+UK) in May and June for this purpose.

Instrument Configuration

Filters:	Slit:	Fiber cable:
Grating/grism:	Multislit:	Corrector:
Order:	λ_{start}:	Collimator:
Cross disperser:	λ_{end}:	Atmos. disp. corr.:

R.A. range of principal targets (hours): 3 to 4

Dec. range of principal targets (degrees): -5 to +5

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*

NOAO observing proposal LaTeX macros v2.6.