EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

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APPLICATION FOR OBSERVING TIME LARGE PROGRAMME PERIOD: **69**

To be submitted only to: proposal@eso.org
Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of COIs and the agreement to act according to the ESO policy and regulations, should observing time be granted

1. Title Panel: **A–4**

Distant type Ia SNe and Cosmology: Constraining the nature of the dark energy and assessing the importance of dust and evolution.

2. Abstract / Total Time Requested

TotalAmountOfTime: 7n/125h TotalNumberOfSemesters: 2

Over the last decade, the Supernova Cosmology Project has pioneered the use of the magnitude-redshift relation of Type Ia supernovae (SNe Ia) to measure cosmological parameters. Our analysis of 42 SNe Ia, at redshifts ranging from $z = 0.18$ to $z = 0.83$, indicates that the universe is dominated by an unknown form of dark energy and that, at the present epoch, the expansion of the universe is accelerating.

There are now two important directions to pursue with the SN Ia cosmology work: (a) filling in the SN Ia Hubble diagram to obtain a more complete and detailed expansion history of the universe and (b) refining and further testing SNe Ia as tools for cosmological measurements.

We propose to observe 10 SNe Ia over the redshift interval $z \in [0.5, 1.2]$ during periods 69 and 71 and to obtain final reference images for an additional 10 SNe Ia that were discovered in period 67. These observations will dramatically shrink the major-axis of the error ellipse in the $\Omega_M - \Omega_\Lambda$ plane, decoupling the measurements of Ω_M and Ω_Λ. Thus, this data set will provide a critical check on the curvature of the universe from the CMB anisotropy measurements. Furthermore, the observations will place constraints on the nature of the "dark energy" and *at the same time* assess systematic effects due to grey dust and evolution of SNe Ia properties.

3.

Run	Telescope	Instrument	Time	Month	Moon	Seeing	Sky Trans.	Obs.Mode
A	UT4	FORS2	3n	apr	d	$\leq 0.8''$	CLR	v
B	UT4	FORS2	20h	any	d	$\leq 0.8''$	CLR	s
C	UT4	FORS2	15h	apr	g	$\leq 0.8''$	CLR	s
D	UT4	FORS2	1n	any	g	$\leq 0.8''$	CLR	v
E	NTT	SUSI2	3n	apr	g	$\leq 0.8''$	PHO	v
F	UT1	FORS1	15h	apr	g	$\leq 0.8''$	CLR	s
G	UT1	ISAAC	25h	apr	n	$\leq 0.6''$	PHO	s
H	UT1	ISAAC	10h	apr	n	$\leq 0.6''$	CLR	s

4. Principal Investigator: **C. Lidman** (ESO-Chile, ESO, clidman@eso.org)

CoI(s): A. Goobar (Stockholm, S), G. Folatelli (Stockholm, S), G. Garavini (Stockholm, S), S. Nobili (Stockholm, S), R. Amanullah (Stockholm, S), R. Pain (LPNHE, CNRS-IN2P3 and Univ. Paris, F), P. Astier (LPNHE, CNRS-IN2P3 and Univ. Paris, F), I. Hook (Cambridge, UK), S. Perlmutter (LBNL, USA), G. Aldering (LBNL, USA), P. Nugent (LBNL, USA), R. Knop (Vanderbilt, USA)

5. Description of the proposed programme

A) Scientific Rationale:

The Supernova Cosmology Project has developed an approach to measuring cosmological parameters using the magnitude-redshift relation of SNe Ia (Goobar & Perlmutter 1995, Perlmutter et al. 1997, 1998, 1999). Our results based on 42 fully-analysed SNe with $0.18 < z < 0.83$ show that we live in a universe that is dominated by a unknown form of "dark energy" and that, at the present epoch, the expansion of the universe is accelerating (Perlmutter et al 1999). A Hubble diagram based on our HST and ground-based observations is shown in Fig. 1. For a flat universe, where the "dark energy" is due to the cosmological constant, we find $\Omega_M = 0.28^{+0.09}_{-0.08}$, and constrain the combination $0.8\,\Omega_M - 0.6\,\Omega_\Lambda$ to -0.2 ± 0.1 for any universe.

This evidence has been increasingly strengthened, both by tests and improvements of the supernova measurements and by independent, cross-cutting cosmological measurements. In particular, the recent balloon-based CMB measurements (Jaffe et al. 2000) have strongly indicated that the geometry of the universe is flat, reinforcing the evidence for an accelerating universe by eliminating the possibility of a low-density open universe (see Fig.2a).

There are now two important directions to pursue with the SN Ia cosmology work: (a) filling in the SN Ia Hubble diagram to obtain a more complete and detailed expansion history of the universe and (b) refining and further testing the SNe Ia as tools for cosmological measurements.

(a) FILLING THE HUBBLE DIAGRAM TO z=1.2: THE NATURE OF THE DARK ENERGY

We currently have the opportunity to obtain a Hubble diagram that will be of long-lasting value as a record of the expansion history of the universe over the last 10 billion years. The redshift range that we propose to populate ($0.5 < z < 1.2$) is aimed at addressing several of the most important scientific questions of our time.

First, it allows a determination of the curvature of the universe and decoupled measurements of Ω_M and Ω_Λ. While additional SNe Ia with $z < 0.85$ will improve the current statistical uncertainty by $\sqrt{N}$, additional SNe Ia beyond $z \sim 0.85$ can dramatically shorten the major-axis of the current Ω_M—Ω_Λ error ellipse (cf. Goobar & Perlmutter 1995 and Fig. 2). With these observations we will be able to rule out $\Omega_\Lambda = 0$ at better than 3σ. For a flat universe, Ω_M and Ω_Λ could be constrained to $\sim 6\%$. The resulting estimate of Ω_M, for *any* Ω_Λ, is still accurate to ± 0.15 in this simulation and would be a first check on the CMB measurements that indicate a flat geometry.

Second, the Hubble diagram out to $z \sim 1$ provides 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, $w \equiv p/\rho$. The current constraints on w are consistent with a very wide range of dark energy theories, including Einstein's Cosmological Constant (for which $w = -1$) (Perlmutter et al. 1999, Garnavich et al. 1998). The proposed data set, together with data now being analyzed, can tighten these constraints by 40%, potentially ruling out several contending theories if the current w value holds. Recent work by Weller and Albrecht (2000) has shown that dark energy theories can be further differentiated on the Hubble diagram at $0.3 < z < 1$ by their behavior *over the range* of z. This requires better photometry measurements than previously obtained in this redshift range (with 4-m telescopes).

(b) SNE IA SYSTEMATIC UNCERTAINTIES: GREY DUST AND EVOLUTION

Perlmutter et al (1997, 1999) provide extensive discussion of possible systematics in the measurement of Ω_M and 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 SNe Ia evolution and abnormal dust within, or even between, galaxies. To proceed with the SN cosmology studies, we have identified a series of refinements and tests that will "sharpen" this cosmological measurement tool, by addressing these two issues. This work seeks to take advantage of an almost unique characteristic of SNe Ia as cosmological tools: they can be studied individually by their light curves and time-varying spectra and hence calibrated individually, not simply statistically.

It is unlikely that dust, as we normally consider it, causes SNe Ia to be too dim. The effects of such dust would have already been apparent (Reiss et al. 2000, Perlmutter et al. 1999). This has led some to hypothesize the existence of grey dust (Aguirre, 1999; Aguirre & Haiman 2000), which would not have been detected in the current data sets. If grey dust were the cause of the dimming, then there are two ways it can be detected.

Firstly, the difference between the apparent magnitudes of SNe Ia in a model dominated by dark energy $(\Omega_M,\Omega_\Lambda) = (0.3, 0.7)$ and those in an open universe with dust becomes significant for SNe Ia with $z > 0.9$ (See Fig. 1). At $z = 1.2$, the difference amounts to 0.3 magnitudes, and this should be measurable with 5 well observed SNe Ia at these redshifts. During 2001 we discovered and followed two SNe Ia at z=1.1. In 1998 we discovered and followed one SNe Ia at z=1.20 (SN 1998eq). We now wish to observe another 2 SNe Ia at $z \approx 1.1$

5. Description of the proposed programme (continued)

during period 69.

Secondly, the ubiquitous nature of dust, even grey dust, is that it reddens. In one grey dust model (Aguirre, 1999), SNe Ia should be reddened by $E_{(\mathrm{B-I})} = 0.14$ magnitudes if dust were the cause of the dimming. Precise observations of several SNe at $z = 0.5$ in the near IR J band (rest frame I-band) and optical R-band (rest frame B band) should be able to detect this amount of reddening. During 2001 we observed two SNe Ia at z=1.1 in the IR J band. We now wish to obtain a reference images for the SN which is strongly blended with its host and to observe and two additional SNe Ia.

The evolution of type Ia SNe properties with redshift is also a potential pitfall. However, there is indirect evidence that evolution is not a major problem. Nearby SNe Ia are observed in a wide variety of galaxy environments, from massive ellipticals to star forming spirals. They all lie on the same peak-magnitude vs. stretch correlation, although there is some evidence that nearby SNe Ia in elliptical hosts lie in a different region of the peak-magnitude vs. stretch diagram to nearby SNe Ia in spiral hosts. It is expected that distant SNe Ia will also come from a similar variety of environments and that they will also lie on the same relationship. Thus, it is reasonable to expect that any evolution in type Ia progenitors can be accounted for by the peak magnitude vs. stretch relationship. However, indirect evidence is not as certain as direct observational proof. We will focus on two observational tests.

1) A spectral-feature luminosity indicator. The spectral ratios of Ca II and SiII show a tight relationship with the lightcurve timescale parameter (Fig 3a) 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. Measurement of these features for SNe Ia at $z \sim 0.5$ will allow a better than 3σ detection of evolutionary effects which could sufficiently alter the SN brightness to make the current datasets consistent with a flat, $\Omega_M = 1$ universe.

2) A UV metallicity indicator. Metallicity is an important parameter governing radiative transfer in SN photospheres, and thus it is important to develop a direct measure for metallicity in a given SN Ia. The positions of the iron-peak blends (Co and Fe of varying ionisations) at restframe ∼2890 and 3165 Å have FWHM of ∼100 Å and shift by 60 Å when going from 0.1 solar to 10 times solar metallicity (see Fig. 3b). Measurement of this shift is relatively insensitive to host-galaxy spectral contamination or reddening.

In the upper half of Fig 4. we show the spectrum of a SN 2000?? at $z = 0.54$. that was taken with FORS1 on UT1. As a comparison, in the lower half Fig. 4 we show the spectrum of a type Ia SN at $z = 0.55$ taken with EFOSC1 on the ESO 3.6m. The difference in the signal-to-noise ratio between the two spectra is a factor of 6. The VLT allows us to make the transition from qualitative statements, such as "It looks like a SN Ia," to quantitative measurements of line strengths and comparisons with nearby objects.

SN 2000?? appears to be a perfectly normal type Ia SNe that was observed about 5 days before maximum light (rest frame). During 2001, we observed SN 2001?? (z=0.55) with roughly the same S/N and it also appears to be a perfectly normal SNe Ia. As exciting as these spectra are, it will only be through the study of several SNe Ia at $z = 0.5$ that the question of evolution can be directly addressed. Our success with using the VLT to obtain the spectra of SN 2000?? and SN 2001?? has convinced us that obtaining moderate S/N spectra of 3-5 SNe Ia at z=0.5 is now feasible and necessary.

References

Aguirre, 1999, ApJ, 525, 593.
Aguirre & Haiman, 2000, ApJ, 532, 28.
Garnavich et al. 1998, ApJ., 509, 74.
Goobar & Perlmutter, 1995, ApJ, 450, 14.
Jaffe, A. H. et al, 2000, submitted Phys. Rev. Lett. (astro-ph/0007333)
Knop, R., et al., 2000, B.A.A.S., 197, 950.
Lidman, C, et al., 2000, Messenger, 101, 18.
Nugent et al., 1995, ApJ. Lett., 455, 147.
Perlmutter S. et al., 1997, ApJ, 483, 565.
Perlmutter S. et al., 1998, Nature, 391, 51.
Perlmutter S. et al., 1999, ApJ, 517, 565.
Riess A. G. et al., 2000, 536, 62.
Riess, A. G., et al., 2001, ApJ, in press.
Weller, J. and Albrecht, A., submitted to Phys. Rev. Lett.

B) Immediate Objective:

The aim is to use a sample of 20 type Ia SNe (with redshifts ranging from $z = 0.5$ and $z = 1.2$) to place constraints on the nature of the dark energy and to comprehensively evaluate and quantify the effects of grey dust and evolution. This is complex program that requires substantial amount of ESO time. During period 67,

5. Description of the proposed programme (continued)

we confirmed and obtained followup data for about 10 SNe with redshifts ranging from $z = 0.35$ to $z = 1.1$. We are now applying for time to obtain reference images for these SNe and to observe an additional 10 SNe Ia. For the SNe that will be discovered during period 69, we will need time for final reference images during period 71.

We plan to conduct three searches during period 69. The first two will use the MOSAIC camera on CFHT and SuprimeCam on Subaru to perform the classic *two epoch search* which has been used so successfully in the past. The third search will be a novel *rolling search* with the 12kx8k camera on the CFHT. The rolling search is different to the searches we have done in the past. We will monitor several fields for a few nights during each new moon period over four consecutive months. The advantage of this style of search is that there is much less need for optical follow-up time, as the the bulk of the lightcurve is obtained from the search data itself.

The observations are structured as follows:

Run A - Spectroscopic confirmation of SNe found in the Subaru and CTIO search runs

We require 3 visitor nights with FORS2. Two of these nights will be used to spectroscopically confirm candidates found with MOSAIC on the CTIO 4m and SuprimeCam on Subaru. We estimate that we will discover about 5 SNe Ia in the redshift interval $z \in [0.4, 0.8]$, 6 SNe Ia in the redshift interval $z \in [0.8, 1.0]$, and 5 SNe Ia with $z > 1$. These observations are essential. Only confirmed SNe Ia will be followed. We aim to follow 10 of them in the optical and observe 4 of them (2 at z=0.5 and 2 at z=1.1) in the IR.

The upgrade of the FORS2 CCD to a red sensitive CCD will mean that the VLT will be able to confirm the spectral type of SNe up to z=1.2 (Lidman et al. 2000).

The remaining night will be used to obtain moderate S/N spectra of three type Ia SNe at z=0.5. We currently have moderate S/N spectra of two z=0.5 SNe (SN 2000?? at z=0.543 and SN 2000?? at z=0.552).

Run B Spectroscopic confirmation of SNe found in the rolling search with CFHT.

We require 20 hours of service time with FORS2 to confirm candidates found in the rolling search with the 12kx8k camera on the CFHT. We expect to discover 15 SNe Ia with redshifts in the range $z \in [0.4, 1.2]$. Unlike the CTIO and SuprimeCam searches, the bulk of the lightcurve is obtained from the search data itself. Only the final light curve point, some 30 rest frame days after maximum, requires followup observations on a larger telescope (see run C).

Run C/D/E - Optical Lightcurves

Three NTT visitor nights, 15 hours of FORS2 service time and one night of FORS2 visitor time to monitor five SNe in the R, I and z bands and to obtain the final lightcurve point of 7 SNe from the rolling search on CFHT. The visitor night is essential and should be scheduled about 10 days after the SNe have been discovered. Constraints caused by scheduling or by the availability of operational staff may mean that this time could be scheduled for observations with an IR instrument. This data will be used to obtain the restframe B-band light curves and restframe $B - V$ colours of 5 SNe at $z = 0.5 - 0.8$. Optical observations of SNe with $z > 0.8$ can only be done with HST, for which we have been awarded 100 orbits. The light curve and colour allows us to calibrate the peak magnitude of SNe Ia and to place them on the Hubble diagram. This data, together with run G, will also be used to measure the restframe $B - I$ color and will allow us to test for the presence of grey dust.

Run F - Optical reference images for the SNe discovered in 2001

We require about 15 hours of FORS1 service time to obtain reference imageas for 8 SNe that were observed in 2001 in order to subtract the light of the underlying host galaxies.

Run G - IR magnitude at peak of 4 SNe Ia

Twenty five hours of ISAAC service time to measure the peak magnitudes of 2 SNe Ia at $z = 0.5$ and 2 SNe Ia at $z = 1.1$. For the SNe at $z = 1.1$, the rest frame V band corresponds to the near IR J-band. Together with data from the HST, this will be used to place these SNe on the Hubble diagram and indirectly test for the presence of grey dust. For the SNe at $z \approx 0.5$, the observed $R - J$ colour corresponds to rest frame $B - I$ and will allow us to test directly for presence of grey dust.

Run H - IR reference image for SN2001?? at $z = 1.12$

Ten hours of ISAAC time to obtain the reference image of the underlying host galaxy to be subtracted from the ISAAC images of SN 2001?? at z=1.12.

C) Telescope Justification: The observations consist of moderate S/N ($\approx 10 - 20$) observations of SNe that have magnitudes that range between 22.5 to 25 in R and 22 to 24 in J. For the bulk of the observations, only the VLT can obtain the S/N we require. For those observations that can be done on 4m class telescopes, we have requested the NTT.

D) Observing Mode Justification (visitor or service): Some of our observations require visitor mode, since we will have to observe within a specific time frame. Service mode observations cannot guarantee this no matter what priority the program has. Other observations, particularly the optical followup over six weeks and the IR imaging, which requires excellent seeing conditions, are best done in service mode.

5. Attachments (Figures)

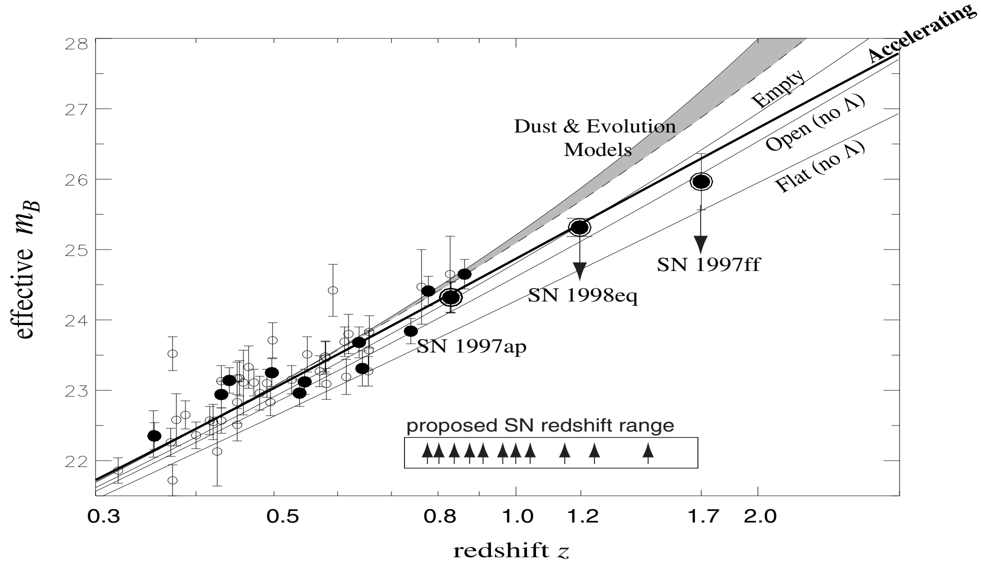

Fig.1 - Magnitude Redshift Relation

Fig. 1 The Hubble diagram for 42 high-z SNe, plotted as open circles (Perlmutter et al. 1999) and 11 more recently observed SNe, plotted as filled circles (Knop et al. 2000). The Einstein-de Sitter case $(\Omega_M, \Omega_\Lambda) = (1.0, 0.0)$ is strongly excluded by the current data. The "Open (no Λ)" case (0.28,0.00) indicates that some contribution from a cosmological constant is required for values of Ω_M favored by dynamical measurements. The magnitude difference between the best-fit world model (0.28, 0.72) and suitable ones with Ω_Λ=0 show redshift dependencies which would be very hard to mimic within the context of SNe evolution or grey dust hypotheses (the grey shaded region is an example model with uniform dust). By extending our survey to $z = 1.2$, the *shape* of the Hubble diagram alone would become sufficient evidence to support a cosmological constant. The preliminary magnitude estimates of our highest redshift SN, SN1998eq at $z = 1.2$ is suggestive but more analysis and more SNe Ia at this redshift are necessary.

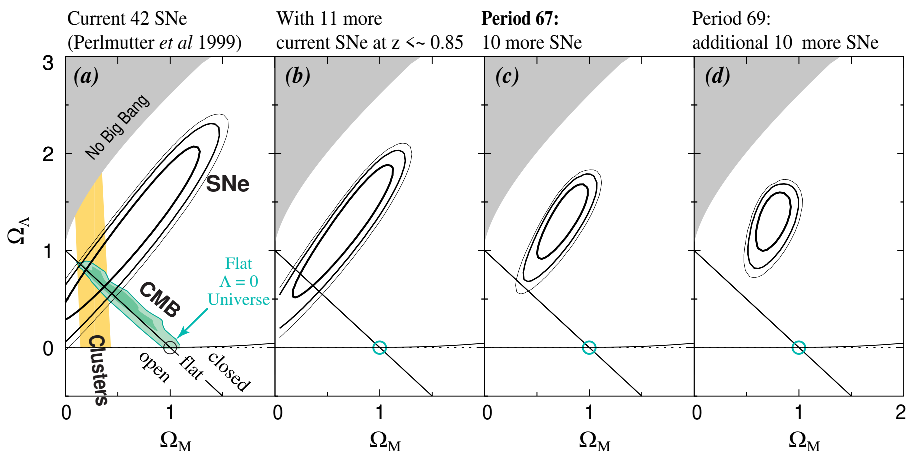

Fig.2 - Confidence regions

Fig.2: *(a)* 68%, 90%, and 99% confidence regions in the Ω_M—Ω_Λ plane from the 42 distant SNe Ia in Perlmutter et al. 1999. *(b)* Expected confidence region after including our additional 11 $z < 0.85$ SNe Ia currently under analysis. *(c)* Confidence region expected from the observations taken during period 67, including two SNe Ia at $z \sim 1.1$. *(d)* The confidence region after the proposed period 69 observations, which includes an 2 additional SNe Ia at z=1.2. These simulations show that our proposed program can check the curvature of the universe found by the CMB program; we dramatize the point by showing a scenario in which the universe is *not* flat, e.g., using the central Ω_m,Ω_Λ value of panel *(a)*.

5. Attachments (Figures)

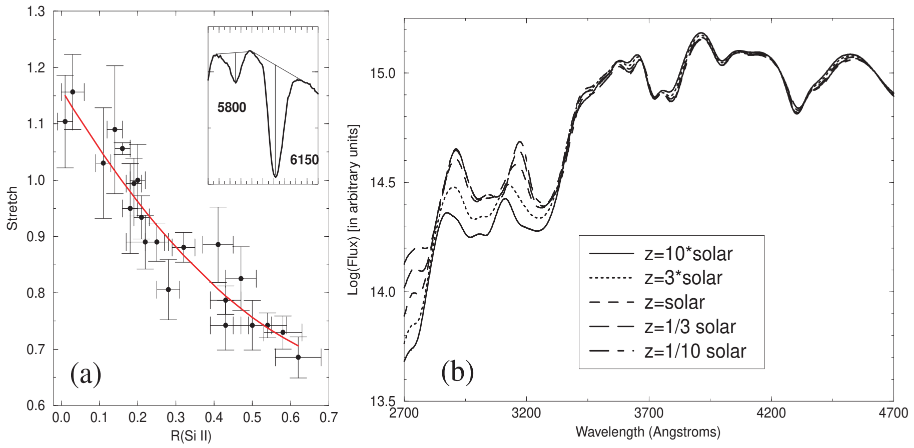

Fig.3 - Luminosity and metallicity indicators

Fig.3: (a) The tight relationship between the spectroscopic ratio $\mathcal{R}$(SiII) and the lightcurve timescale stretch for well-observed low-redshift SNe Ia (see N95 for a similar $\mathcal{R}$(CaII) plot). The inset shows how this spectral ratio is measured. (b) Maximum light spectrum synthesis models of W7 (a deflagration SN Ia model by Nomoto et al.) with varying metallicities in the outer C+O layer. Note the change in both the strength of several restframe UV features and the wavelengths of their minima (which we propose to measure for three $z \sim 0.5$ SN Ia).

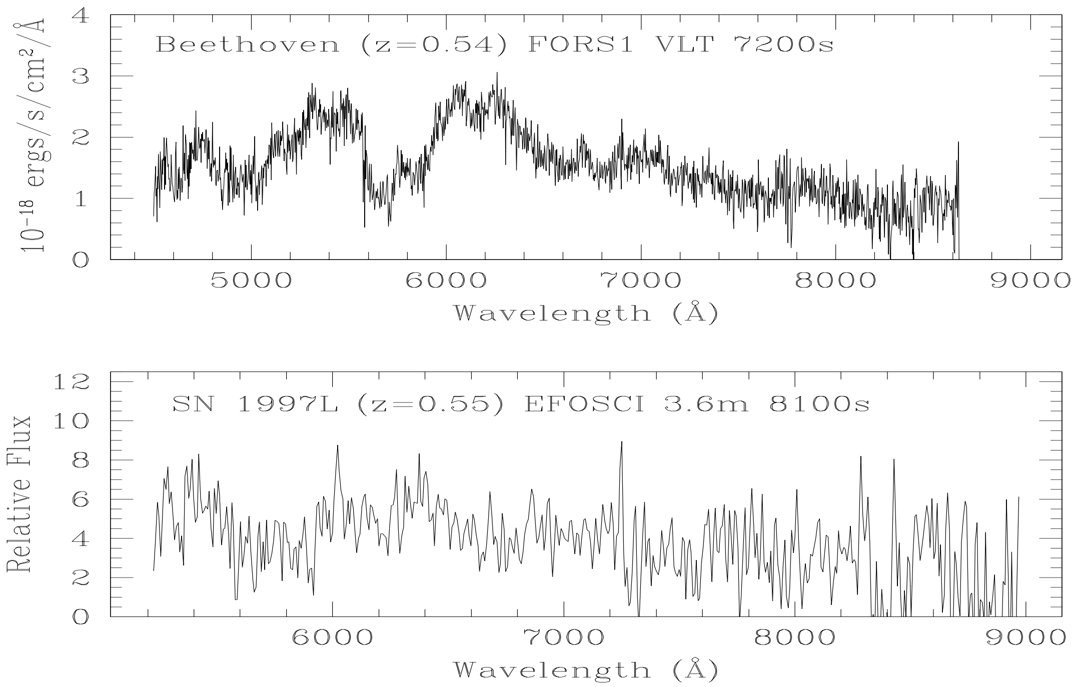

Fig.4 - SN 2000?? and SN 1997L

Fig.4: A comparison between the spectra that one can obtain of a distant SNe Ia with a 4m class telescope (SN 1997L) and a 8m class telescope (SN 2000??). The VLT allows us to make the transition from qualitative statements, such as "It looks like a SN Ia," to quantitative measurements of line strengths and comparisons with nearby objects.

6. Experience of the applicants with telescopes, instruments and data reduction

The Supernova Cosmology Project has repeatedly demonstrated its ability to

a) discover large numbers of high–z SNe Ia ($>$ 20 per observing run) while they are still on the rise,

b) obtain spectroscopic follow-up within a few days of discovery to confirm the SN type and redshift,

c) acquire ground-based and HST 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 $z = 1.20$.

We have been a frequent user of ESO facilities. During periods 58, 59, 60, 61, 62 and 63 over 60 distant and 13 nearby SNe Ia were observed by our group using the ESO 3.6m. During period 64, we used FORS1 to follow a SN Ia at $z = 0.85$. During period 65, we used ISAAC and FORS1 on UT1 to obtain detailed IR imaging and optical spectroscopic followup of a type Ia SN at $z = 0.54$ (Lidman et al, 2000). During period 67, we used FORS1 to discover 10 SNe, several of which were followed up with ISAAC, FORS1 and SUSI2. All of this data has been reduced and much of it published. It usually takes a bit more than one year after the initial discovery, the time when the final reference images are taken, to publish the results.

The PI, Aldering, Hook, Pain and Perlmutter are all experienced observers. The PI is a service observer at UT1 and UT2 and has observed over 200 nights since operations began. He is very experienced in all aspects of FORS1, FORS2 and ISAAC and is very knowledgeable in data reduction techniques. The co-Is of the proposal have all participated in our previous discovery and follow-up runs and are experts in faint object imaging, spectroscopy and data reduction.

A. Goobar and P. Nugent guide the group into designing the optimal observing strategy and developing tools to make best use of the data.

7. Resources available to the team, such as: computing facilities, research assistants, etc.

The Supernova Cosmology Group (SCP) is an international Collaboration that is spread over several countries.

In Sweden, the group, which consists of 1 senior researcher and 4 Phd students, is headed by A. Goobar. This group, together with I. Hook, will be responsible for reducing and analyzing the spectroscopic and imaging data.

In France, the group, which consists 2 senior researchers, 2 post-docs and 1 Phd student, is headed by of R. Pain. this group will co-ordinate the search and discovery run at the CFHT and they will perform the photometry.

In the USA the group, which consists of 4 senior researchers, 3 post-docs and 4 Phd students, is headed by S. Perlmutter. They will co-ordinate the search and discovery run at CTIO and they serve as the data center.

The SCP has extensive computing resources in the USA, Sweden and France.

The PI lives and works in Chile and will co-ordinate the ESO observations once the SNe have been discovered.

The Supernova Cosmology Group has a proven track record. To date, we have discovered and observed over 100 distant SNe Ia. In our most recent search and discovery run, 13 SNe Ia were discovered.

The current form does not specifically ask us to comment on the success of our period 67 request. Despite the somewhat inclement whether which halved the amount of time we could spend on spectroscopy, we were able to confirm 10 SNe, obtain moderate S/N spectra for one type Ia at z=0.552 (SN 2001??), obtain followup IR photometry of three SNe Ia (SN 2001?? at z=1.12, SN 2001?? at z=1.067 and SN 2001?? at z=0.671), obtain followup optical photometry on 10 SNe Ia and obtain a final IR reference image for SN 2000??.

Our original request was to observe 20 SNe Ia during periods 67, 69 and 71. With 10 SNe observed in period 67, we are asking time to complete the original request.

8. Special remarks

This is an international collaboration that uses the CFHT 12kx8k, the CTIO MOSAIC and the Subaru Suprime-Cam cameras to discover SNe Ia candidates, the VLT and the Keck telescope to spectroscopically confirm SNe Ia, the VLT, NTT and HST (100 orbits already awarded) to follow SNe over a period of two months. The key to our success has been that we have been able to get time on each of these facilities. No single telescope, no single observatory, including ESO, can hope to collect the data we wish to obtain. However, ESO facilities will play (and did play during period 67) the *key-role* in our observing campaign. *Without the requested time at ESO telescopes we will be unable to achieve any of the aims set out in the scientific rationale.*

The data we have collected thus far and the data we propose to collect will be used by four Phd students for their thesis.

Special scheduling constraint. The visitor mode observations require co-ordination with other observations at other telescopes. If time is awarded, please contact the PI before the schedule is made.

9. Justification of requested observing time and lunar phase

Lunar Phase Justification: For the spectroscopy with FORS2, dark time is essential. For the followup imaging in the optical, grey time is acceptable. For the IR observations, there is no restriction.

Time Justification: We have used v2.8 of the ETC. Unless explicitly stated we have assumed an IQ of 0.8 arc seconds and an airmass of 1.2.

Runs A) and B) A type Ia SNe at z=0.5 has R=22.5 at peak. With the 300V grism, the 1 arc second slit and the new CCD, we need about 1500 seconds to get a S/N of 5 . A type Ia SNe at z=1.2 has I=24.5 at peak. With the 200I grism, the 1 arc second slit and the new CCD, we can get a S/N of 3 (which is sufficient for SN typing) in 12,000 seconds. To confirm 10 SNe Ia, two of which will be at SNe Ia at z=1.2, and to obtain moderate S/N ($\approx$ 10) spectra on three SNe Ia at z=0.5, we need 3 nights in visitor (run A) and 20 hours in service (run B).

Runs C), D) and E) The following table lists the broad band magnitudes of a type Ia SNe $z = 0.5$ (R-band) and $z = 0.85$ (I-band and z-band) and the required exposure times.

Day past Max (obs frame)	0	10	20	30	40
z=0.5 (R-band)	22.4	22.7	23.3	23.9	24.6
SUSI2 Exp. time (S/N=20)	140s	230s	660s	1900s	6900s
z=0.85 (I-band)	23.2	23.4	23.8	24.4	25.1
FORS2 Exp. time (S/N=20)	500s	700s	1500s	4500s	16000s
FORS2 (z-band) Exp. time (S/N=20)	1800s	-	-	-	-

To observe 5 $0.5 < z < 0.85$ SNe Ia during 5 epochs and to obtain the colour of each of these SNe near maximum, we ask for 3 visitor nights with SUSI2, 1 visitor night on FORS2 and 8 hours of service time with FORS2. To obtain the final light curve point for 7 CFHT SNe Ia, we need 7 hours.

Run F) We plan to observe about 8 SNe that were observed in 2001. On average we will spend 1-2 hours per SN. With overheads, we will need about 15 hours.

Parts G) and H) To measure (S/N approx 15 in *reference subtracted image* and in 0.5 arc second seeing) the peak magnitude of 2 type Ia SNe at $z = 0.5$ (J=22.4), 2 type Ia SNe at $z = 1.2$ (J=23.9), and to take the reference image for SN2001?? at z=1.12, we need 35 hours with the Js filter and this includes overheads.

10. Applicant's publications related to the subject of this application during the past two years

A. Goobar, and L. Bergström, 2001, ApJ, Accepted, (see also astro–ph/0103489): Determining the Fraction of Compact Objects in the Universe Using Supernova Observations

M. Goliath, R. Amanullah, P. Astier, A. Goobar, and R. Pain, 2001, A&A Submitted (see also astro–ph/0104009): Supernovae and the Nature of the Dark Energy

E. Mörtsell, C. Gunnarsson, and A. Goobar, 2001, ApJ, Accepted (see also astro–ph/0105355: Gravitational Lensing of the Farthest Known Supernova SN1997ff.

A. Goobar, L. Bergström and E. Mörtsell, 2001, A&A Submitted: Measuring the properties of dust with high-redshift supernovae.

Goldhaber, G. et al., 2001, ApJ, 558, 359: Timescale Stretch Paramerterisation of Type Ia Supernova B-band Light Curves.

Reiss et al., 2001, astro-ph/0109070: Farthest Known Supernova: Support for an Accelerating Universe and a Glimpse of the Epoch of Deceleration.

Lidman, C., Goobar, A., & Pain, R. 2000, Messenger, 101, 18: Type Ia supernovae, cosmology and the VLT.

Bergström, L.,Goliath, M., Goobar, A., & Mörtsell, E., 2000 A&A, 358, 13: Lensing Effects in an Inhomogeneous Universe.

Aldering, G., Nugent, P., & Knop, R. 1999, AJ, 119, 2110: The Rise Times of High- and Low-Redshift Type IA Supernovae Are Consistent

Perlmutter S. et al., 1999, ApJ, 517, 565: Measurements of Ω and Λ from 42 High-Redshift Supernovae.

Gilliland, R., Nugent, P. & Phillips, M. M., 1999 ApJ, 521, 30: High-Redshift Supernovae in the Hubble Deep Field,

Perlmutter S. et al., 1998, Nature, 391, 51: Discovery of a Supernova Explosion at Half the Age of the Universe and its Cosmological Implications.

More than 100 discoveries of supernovae, reported in International Astronomical Union Telegrams and Circulars, including announcement of a $z = 1.2$ SNIa, IAUC 7046.

11. List of targets proposed in this programme

Run	Target/Field	α	δ	Equinox	Mag.	Diam.	Additional information
A	Type Ia SNe	00 00 00	-00 00 00	J2000	24		
B	Type Ia SNe	00 00 00	-00 00 00	J2000	24		
C	Type Ia SNe	00 00 00	-00 00 00	J2000	24		
D	Type Ia SNe	00 00 00	-00 00 00	J2000	24		
E	Type Ia SNe	00 00 00	-00 00 00	J2000	24		
F	Type Ia SNe	00 00 00	-00 00 00	J2000	24		
G	Type Ia SNe	00 00 00	-00 00 00	J2000	24		
H	Type Ia SNe	00 00 00	-00 00 00	J2000	24		

Target Notes: SNe will be found during a dedicated search run.

12. Scheduling requirements

1. Run Splitting

Run	splitting
C	1n,1n,1n

13. Instrument configuration

Telescope	Instrument	Parameter	Value or list
UT1	FORS1	IMG	R,I
UT1	ISAAC	SWI	Js
UT4	FORS2	IMG	R,I,z
UT4	FORS2	LSS	G200I, G300V+GG435
NTT	SUSI2	Imaging-filters	R,I