INTERNATIONAL TIME PROGRAMME

Ω and Λ through supernovae

1. Scientific Outline

1.1. BROAD SCOPE

The project presented here aims to provide in a short term an accurate determination of the cosmological parameters through the use of supernovae. A number of key issues just at the core of cosmology are addressed in this project. A precise determination of Ω_M and Ω_Λ is our most important goal. Evaluation of rates of supernovae will shed light into the nature of their progenitors, and serve as a test to the presence of a non-zero cosmological constant. Further inspection of our images can provide information on rates of events like GRB afterglows, lenses, among others, which will be analyzed by our group.

1.2. SPECIFIC SCOPE

In 1999–2000 we want to complete the study of the systematic uncertainties in our determination of Ω_M and Ω_Λ. To solve these uncertainties, and fully exploit the results already obtained and those to come, we need to build up a more consistent sample of SNe Ia light curves and spectra at z$\simeq$ 0.15–0.2, as will be explained below. As a result of this campaign the luminosity function of SNe Ia will be determined, and new photometric and spectroscopic luminosity indicators investigated. With better lightcurve templates and spectral time series at all optical wavelengths (especially prior to maximum light), any possible source of unaccuracy will be revealed. This is why the aim of the project shifts now to the 2.5–4.2m aperture range of telescopes, making it a project ideal for La Palma. The application presented here to La Palma ITP comes at the final but most definitive moment in the long path undertaken to determine the cosmological parameters through supernovae.

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Tasks:

(1) observer (2) data reduction (3) interpretation

- No previous time awarded
- Telescopes to be used:

WHT, INT, JKT, NOT

- Instrumentation:

WHT: ISIS (spectroscopy, 3000–9000 Å, at $\sim$ 6 Å), Aux. Camera (imaging)
INT: WFC (R imaging over $\sim$ 30 x 30 arcmin, UBVRI imaging)
NOT: ALFOSC (spectroscopy), HiRAC (imaging, photometry)
JKT: CCD imager with SITe

- Scheduling (see Justification)

2. Scientific Proposal

Recent results from the study of Type Ia supernovae (SNe Ia) have reinforced the prospects of using these objects to measure the cosmological parameters, based on the treatment of SNe Ia as *calibrable candles* rather than as straight *standard candles*, through the relationship between the shapes of their light curves and their luminosity at maximum (Riess et al. 1996; Perlmutter et al. 1997; see references in Ruiz–Lapuente et al. 1997). Indeed, the detection and follow–up of large numbers of nearby ($z \leq 0.1$) SNe Ia in specifically designed observational campaigns, has made possible to go beyond the controversial idea that SNe Ia were standard candles. Those SN are now seen as a single *family* whose members can be identified by the widths of their light curves (Phillips et al. 1993; Hamuy et al. 1995; Riess et al. 1996). Such a new use of SNe Ia is now being confirmed as one of the best methods to determine the cosmological parameters and most relevant projects in cosmology at the moment (Peebles 1998).

The above considerations have inspired an intensification of the study of SNe Ia in the perspective of using them to measure the cosmological parameters H_0, Ω_M, and Ω_Λ (Hamuy et al. 1995; Riess et al. 1996; Goobar & Perlmutter 1995). In order to carry out those ambitious programs, SNe Ia at high z must be detected and studied, in order to compare them with the nearby sample.

Various means have been used to determine the intrinsic (relative) luminosities of SNe Ia from their lightcurves. Based on early results from the Calan–Tololo survey, Phillips et al. (1993) showed that the quantity Δm_{15}, which measures the brightness difference from maximum to 15 days after maximum, was correlated with intrinsic luminosity. Hamuy et al. 1996a confirmed this correlation (with a slightly different slope) for all but the reddest (most reddened?) SNe Ia from the Calan-Tololo survey. Riess et al. (1996) used a different approach based on templates with different lightcurve shapes. The Supernova Cosmology Project has used a method, close in spirit to Δm_{15} , in which all SNe Ia lightcurves at each bandpass can be fitted by a template which is simply stretched in time about the date of maximum light. The amount of stretching, S, has been found to correlate with intrinsic luminosity for the 18 SNe Ia from the Calan-Tololo survey discovered within 5 days of maximum (for SNe Ia discovered later after maximum, the date of maximum is not well determined). This procedure is demonstrated in Figure 1.

The scatter remaining after this correction and reddening corrections are applied can be as small as ~ 0.1 mag. However, the Supernova Cosmology Project has found some high–z SNe Ia which have S values that are smaller or larger than those of the Calan–Tololo SNe. In order to improve our stretch-based description of SNe Ia lightcurves, well–studied lightcurves of nearby SNe Ia are needed covering a wider range in S. These SNe Ia must be distant enough that peculiar velocities do not affect the determination of their relative distances,i.e., assuming pure Hubble flow. Also lightcurves with much more data prior to maximum for various stretch SNe Ia are needed to make templates covering the range of lightcurve dates we now have for high–z SNeIa.

The abovementioned width–luminosity relationship has been observed in SNe Ia produced in galaxies of different Hubble types, thus posessing stellar populations of diverse ages and types, too. This is allowing us to study systematic effects of SN luminosity with host galaxy type.

Rates are another important piece of science to obtain through this project. The slope of the rate increase depends on which systems are the actual progenitors of the SNe Ia (Ruiz–Lapuente, Burkert, & Canal 1995). Considering that the star formation rate has been higher in the past (peaking at z $\sim$ 1–2) than now, we have made theoretical predictions of the number of SNe Ia per unit mag, square degree, and year to be expected for different progenitors and different models of the Universe (Ruiz–Lapuente & Canal 1998), and we are now comparing the results with the observational data obtained by Pain et al. (1996, 1998). Rates in the redshift space z $\sim$ 0.15–0.2 will be determined with this project.

2.1. THE NEED FOR A BETTER NEARBY SAMPLE

For the past several years the Supernova Cosmology Project has exploited Type Ia supernovae as standard candles to probe the geometry of the universe. The Supernova Cosmology Project has used Keck, other ground–based, and HST data to demonstrate that SNe Ia observed over a large redshift range measure the cosmological parameters Ω_M and Ω_Λ far better than has ever been done before (Perlmutter et al. 1998a, 1998b). Figure 2 shows the Hubble diagram using our 40 first high–z SNe discovered through March 1997 along with 18 SNe from the Calan-Tololo SNe survey (Hamuy et al. 1996b). Figure 3 shows the constraints placed on Ω_M and Ω_Λ from the best fit to the Hubble diagram of Figure 2.

The statistical uncertainties in the measurement of Ω_M–Ω_Λ from the 40 SNe Ia shown in Figs 2 & 3 are small enough now that systematic uncertainties must be examined even more closely. One of the largest potential sources of systematic uncertainty stems from our reliance on the low–redshift SNe Ia dataset from the Calan–Tololo SN survey (Hamuy et al. 1993, 1996a, 1996b) to anchor the low-redshift portion of the Hubble diagram *and* to define the relation between intrinsic SN luminosity and lightcurve shape. The Calan-Tololo survey was conducted by blinking photographic plates so its selection function and biases (i.e. Malmquist bias) are difficult to quantify. This makes it difficult to assess whether or not the statistical properties of nearby and distant supernovae are the same. Trends amongst the the Calan-Tololo SNe, such as the presence of smaller stretch SNe at higher redshift, surprising little extinction for most SNe, and a dependence between peak color and luminosity (unrelated to extinction: Tripp 1998), calls for some caution in generalizing conclusions based on the Calan-Tololo SNe Ia. The small number of other SNe Ia for which good data are available is not suitable because they are either too nearby to be in the Hubble flow, heavily reddened, unpublished,etc. Moreover, few well-observed SNe Ia have been discovered before maximum, meaning that the date of maximum, and pre-max portions of template lightcurves we use to fit the high–z SNe are not as well determined as we would like. Good U–band lightcurves for use as templates are especially hard to come by, yet we have rest-frame U–band data from HST for high–z SNe Ia in need of a U–band template.

In order to make full use of the hard-won data on higher redshift supernovae, our understanding of the empirical properties of SNe Ia need to be verified and refined, and their selection biases quantified. This can best be accomplished through the systematic study of the large, homogeneous sample of nearby SNe Ia we expect to find in our survey. These SNe will be discovered using the same search methods and software that has proved so successful in finding distant SNe *on demand.* This will enable the statistical properties of the new nearby sample and existing and future distant samples to be compared directly. This dataset will also be extremely valuable for modeling SNe explosions.

2.2. THE NEARBY SUPERNOVA SURVEY AND FOLLOW UP AT THE INT

The basic outline of the survey is as follows. During dark time in February 1999 we will use wide-field CCD mosaics at the INT 2.5-m to do a survey at z $\simeq$ 0.15–0.2. The survey will cover 30 deg^2 by scanning 10 deg^2 per night in blocks of three nights two consecutive new moons (February month). The survey is optimized to find SNe Ia at redshift $z \sim 0.15$ by exposing 10–15min in R with the WFC at the 2.5m INT. A fraction of them will

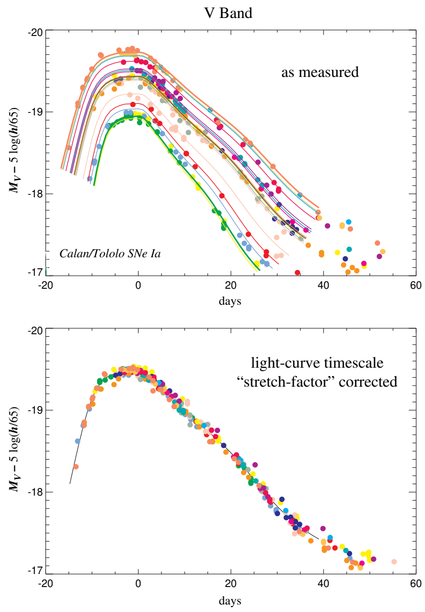

Figure 1. V-band lightcurves for nearby SNe Ia from Hamuy etal. 1996b. The upper panel shows lightcurves for individual SNe Ia, with absolute magnitudes derived assuming pure Hubble flow and $H_o = 65$ km/s/Mpc. Template lightcurves from Leibundgut et al. (1991) have been fit to the lightcurve for each SNe. Note that the brighter SNe have lightcurves which are broader and decline more slowly. Also notice that very few of these SNe have data well before maximum light. The lower panel shows the superposition of these data after using a linear correction for stretch, S, and scaling the time axis (with maximum at t = 0) by the same stretch-factor. We have found that the lightcurves for a given filter for most SNe Ia can be represented by a single stretched template. We have also found that this stretch factor is linearly proportional to the intrinsic luminosity (in magnitudes).

be approximately 10 days before maximum. The survey will also find other types of SNe, as well as some SNe Ia already past maximum, which will be screened out based on spectra taken at the WHT and NOT shortly after discovery. SNe Ia still on the rise (as determined from photometric follow-up and spectroscopic dating) will be imaged every 5 days for approximately two months, using the scheduled time at the JKT telescope. Spectra will also be obtained periodically ($\sim$ once per week) using the WHT and the NOT. This is a self–contained programme since it allows to perform search and follow–up in a three–four months period using the night–time telescopes at La Palma.

Thus, unlike most on-going SNe searches, **all of the searching and follow-up for this survey is concentrated in four consecutive months in 1999, allowing the telescope time for the entire program to be**

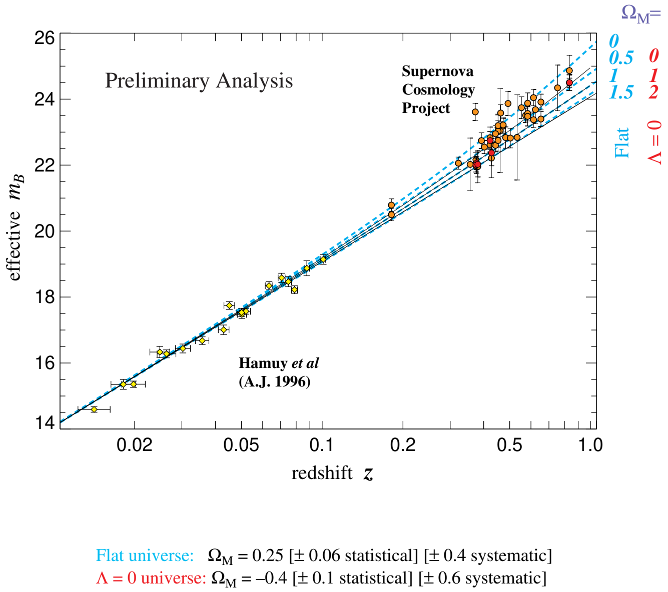

Figure 2. Hubble diagram based on the preliminary analysis of 40 high–redshift Type Ia supernovae. The low-redshift SNe Ia are those from Hamuy et al. (1996a), from the Calan–Tololo search used to calibrate the high-redshift SNe Ia.

classically scheduled. Given the fact that the INT Wide Angle Survey (Mc Mahon 1998: http://www.ast.cam.ac.uk/rgm/), among other several astrophysical objects will discover SNe Ia, this ITP programme can also help to do the follow up (spectroscopically and photometrically) of their objects, enlarging up to 20-25 the number of SNe Ia for which a complete database will be obtained with the observing time. It is important to notice that this INT Wide Angle Survey does only survey (search) for objects and has no follow–up associated with it.

All the SN data will be searched electronically, allowing the discovery efficiencies from each telescope/detector combination to be determined through computer simulations. Follow-up photometry will utilize UBVRI filters redshifted to the mean redshift ($z \sim 0.15$) of the sample. The faintest SNe will have $B \sim 20$ at maximum light, hence the need for spectroscopic follow-up on large telescopes. The purpose of the follow–up is to obtain as good a coverage as possible to allow the proper classification of the SN Ia among the family (by accurately determining their light curves) and to produce a meaningful nearby sample for use in the determination of the cosmological parameters.

The well-sampled lightcurves resulting from this intensive follow-up campaign will allow a much better determination of lightcurve properties and how they are related to intrinsic luminosity. Very few nearby SNe have good data prior to maximum light, so these lightcurves will open new avenues of study of both the empirical and theoretical properties of SNe. Because most of our high-z SNe have been discovered before maximum (typically by ~ 10 days), so these early, well-sampled lightcurves can be used to create superior templates for use with high-z SNe.

2.3. SPECTRAL TIME SERIES AT THE WHT AND NOT

Spectroscopic follow–up with the 4.2m WHT and 3.5 m NOT plays a key role in this project. Shortly after the discovery period during dark time (ours and from the Wide Field Angle Survey), we expect to have $\sim 20-25$ SNe candidates for which spectroscopy is needed to confirm them as SNe, measure their redshifts, and determine their SNe types. For those that are SNe Ia, better S/N spectra will then be required to spectroscopically date them (cf. Figure 4 for an example of the change in SNe Ia features as the explosion ages) and to estimate their intrinsic luminosities using various line indices (e.g. from Si and Ca; see Riess et al. 1998, for more details). For some brighter SNe Ia, we may be able to measure Na I (5890,5896Å), and possibly K I 7699Å, absorption (expected to have $EW \sim 0.0$–0.5Å) and thereby constrain host galaxy extinction independent of SNe colors. The spectra will also be used to develop more accurate K-corrections (Kim et al. 1996), which are needed to convert the observed photometry of high–z SNe Ia to standard passbands. Wide spectral coverage is especially important for this purpose, since high-z photometry often uses unusual bandpasses (e.g the 4000Åwide F110W filter on NICMOS). The ISIS spectrograph at the WHT is particularly well suited for this program since it enables efficient coverage of most of the optical spectrum.

In order to screen ~ 20 SNe candidates, and obtain more detailed spectra for ~ 15 of them, we need 5 nights on the 4.2m WHT/3.5m NOT just after the discovery period (second new moon in February). We estimate from past experience, along with the specific properties of the ISIS spectrograph + 4.2m combination, that screening observations will require 30 minutes per SN, and that better quality spectra will require roughly 100 minutes per SNe. With the inclusion of 10% overhead this leads to our request for 5 nights on the first month between WHT and NOT. It is crucial to obtain this initial spectroscopic follow-up as soon as possible after discovery to determine the properties of SNe Ia before maximum, and to concentrate follow-up at WHT and NOT on the most interesting SNe as soon as possible after the discovery moon (second new moon Feb). We note that the additional nights given by the ITP at the WHT and NOT are easy

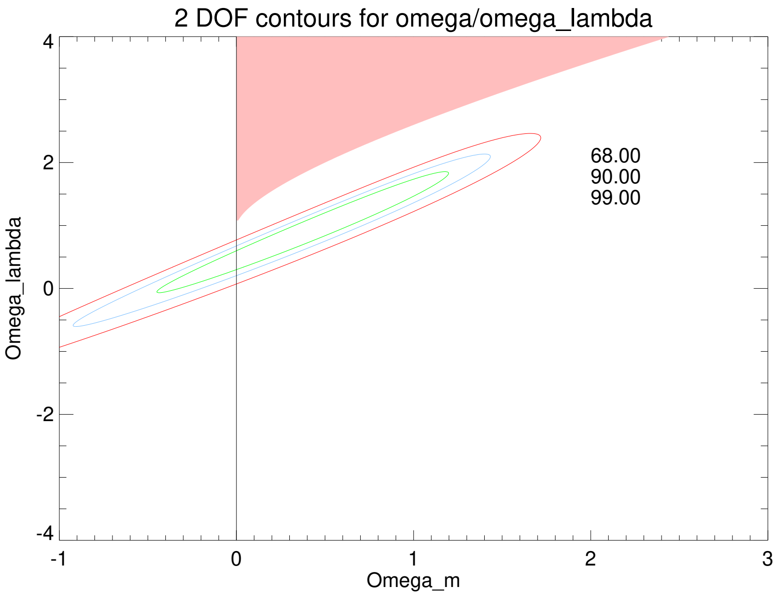

Figure 3. Contours showing the confidence region for Ω_M and Ω_Λ resulting from a preliminary analysis of over 40 SNe Ia, including 1997ap at $z = 0.83$ from Perlmutter et al. 1998a. Shown are the 68%, 90%, and 99% confidence regions for an unconstrained fit for Ω_M and Ω_Λ. The grey region is excluded by the Big Bang, while the region $\Omega_M < 0$ is unphysical. Note that these contours are for 2 degrees of freedom; the confidence regions for e.g., Ω_Λ at a given Ω_M are different (smaller for a given confidence level).

to schedule since they will be equispaced along the following 3 months in dark/grey time. They will serve to create the spectral series of the SNe Ia discovered.

2.4. RELATION TO THE Z $\simeq$ 1 AT KECK

This proposal is designed to obtain better "calibration" data on nearby Type Ia supernova which will allow a more accurate and robust treatment of the high-redshift data obtained as part of the Supernova Cosmology Project we have been conducting for the past several years on Keck. Although both programs are important for utilizing SNeIa for cosmology, they are independent projects which can proceed on their own.

The scientific results of these and previous SNe discovery, follow-up, and analysis campaigns have been quite extraordinary. The addition of one SN, SN1997ap discovered in March 1997, to the seven previously published SNe for the first time closed off the confidence regions in the Ω_M, Ω_Λ plane and provided the first unconstrained estimates for Ω_M and Ω_Λ separately (i.e., without the assumption of a flat universe). Keck spectroscopy and HST imaging of 1997ap also demonstrated that this distant SN Ia looked and behaved just like nearby SNe Ia. These results were reported by Perlmutter et al. in the Jan 1, 1998 issue of *Nature*.

3. Management of the programme

The Supernova Cosmology programme has already a trajectory of succesful collaboration and management of the different tasks. The tasks developed include observations, data reduction, data evaluation and interpretation, development of different theoretical aspects related to the project and evaluation of the global results of interest to cosmology. Data reduction is done without delay and publications are written by the authors.

We can forsee a most fruitful use of the awarded observing time, which will extend even beyond the main goal to a set of very interesting side projects.

We plan to organize four meetings during the year of awarded ITP:

• Jan 1999: preparation meeting before the start of the observations

• April 1999: after discovery runs, mid-time progress meeting

• Dec 1999: end of the project meeting, review of the goals achieved, plans for publication

• Dec 2000: conference at the Canary Islands

4. Targets for observation

The searches of SNe Ia at high z are centered in clusters and "empty" fields tiled next to each other, all near $\delta = 0\ ^0$ and spread over the R.A range that is visible through the months February–June (if the programme is shifted to September then the targets will be those visible from September–December). Previous discovery runs have found 11/12 SNe/each run. "Discovery time" will be done at the first and second new moon since the beginning of International Time. Follow up will be regularly scheduled at the various telescopes at La Palma.

Target SN for this proposal would come from candidates discovered during search at INT. Above you find, as an example, a set of SNe Ia discovered at z $\simeq$ 0.3 during the spring semester. In the present proposal the search will be optimized for z=0.15 and brighter objects will be found.

TABLE 1. Targets for observation

SN	z	decline: $\Delta m_{15}{}^*$	SN Type	m_R
SN 1992bi	0.458	0.47	SNIa	22
SN 1994H	0.374	0.91	SNIa	21.4
SN 1994al	0.42	1.17	SNIa	22.4
SN 1994F	0.35	2.04	SNIa	22.1
SN 1997aj	0.58	1.39	SNIa	23.8
SN 1997am	0.42	1.04	SNIa	22.9
SN 1997ap	0.83	1.03	SNIa	24.2

$*$ Number of magnitudes of decline in 15 days

5. Technical justification

5.1. THE 2.5-M ISAAC NEWTON TELESCOPE

The **Wide Field Camera** (WFC) on the **2.5-m INT** will be used for the *initial SNe search*, and thereafter for *followup photometry.*

In the **search mode** we will survey $\approx$30 deg^2 by scanning 10 deg^2/night during three consecutive nights. The camera has an $\approx$0.28 deg^2 field. Thus $\approx$35 exposures per night of 10min each in the R band are required. Rates of SNe Ia at z=0.3, as determined by Pain et al. (1996) are 20 SNe Ia/sq deg/yr/0.5mag. For 1 night and integrating for 6 half magnitudes this implies a rate of 0.33 SNe Ia/sq deg/night between mag 18 and 21. Thus by surveying 30 deg^2, we will obtain 10 SNe Ia. 35 exposures of 10 min each in R will mean $\approx$6 hours of integration. Allowing for overheads associated with readout (to be reduced to 40 sec in 1999), and standard calibration fields, the full 8-10 hour night is required.

For the **follow up** photometry of the newly discovered SNe we obtain broadband U,B,V,R,I photometry of the SNe Ia at z$\sim$0.15-0.2 discovered during the "discovery time". The purpose is to obtain as good a coverage as possible to allow the proper classification of the SN Ia among the family (by elucidating their light curves) and to produce a meaningfully significant sample for use in the determination of the cosmological parameters.

To obtain good quality photometry of the supernova we will require exposures of 10-15 min duration for an object of $m_R \sim 18$–21 mag in V, R and I. In U and B 15 min exposures will be required. Thus in one night we could image some 6–8 SNe Ia at the INT. Thus, the requested INT time will give one point in the light curve of 6–8 SNe Ia each week. The JKT will complement these observations by providing data on the brighter objects, and also by providing supplementary photometric calibration data for the observed fields.

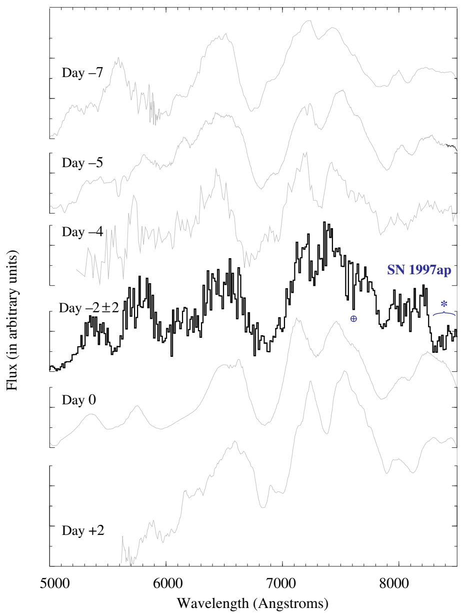

Figure 4. Spectrum of SN 1997ap at z=0.83 compared with the spectra of nearby SNe Ia. (Nature, Jan 1 issue)

A number of standards covering different air-masses should be observed for calibration purposes (a set of 4–5 photometric fields would be enough). For non-photometric nights, the INT data would be calibrated on a relative scale to field stars. Photometric calibration could be provided at a later date from short exposures of the field using either the JKT or INT during photometric nights.

5.2. THE 4.2-M WILLIAM HERSCHEL TELESCOPE

The WHT would be used primarily for spectroscopic confirmation of the SNe discovered by the INT. ISIS (both arms) would be used to obtain spectra of the SNe at high z discovered during the *discovery time* period in the week previous to the new moon. The spectra would be obtained as close to the maximum light as possible to allow an accurate classification of the SNe to be made (within the dispersion of family types) and a proper use of the sample in the determination of the cosmological parameters.

ISIS would be used at a spectral resolution of 2.5-3 Åin the blue arm and 6Å in the red arm over the full spectral range of ∼3000–9000 Å(using the R300B grating in the blue arm and the R158R grating in the red arm, with the 6100Å dichroic). In order to eliminate contamination from the background light of the host galaxy, spectra of the contiguous host galaxy background would also be obtained.

Good quality spectrum (SN > 20 per pixel) of a supernova ($m_V \approx 18$–21) would require two exposures of 50 minutes each. For the brightest SNe two exposures of 25 minutes each would be sufficient. For phase where the supernovae will be faintest (the limit is $m_V \sim 23$ mag), we would use three 50 minute exposures (leading to a S/N of ∼5 per pixel). Thus, in optimal conditions, during a single night we will collect spectra of 6–10 SNe discovered. A number of standards covering different air-masses should be observed for spectro-photometric calibration purposes (a set of 2–3 standards would be sufficient).

The WHT with ISIS will also be used one grey or dark night per week for the three months following discovery, for spectroscopic monitoring of up to 9 of the newly discover SNe. The spectroscopic coverage would be as above.

5.3. THE 2.5-M NORDIC OPTICAL TELESCOPE

The smaller aperture 2.5-m NOT would be employed for **spectroscopic identification** of the brighter SNe, and therafter for **followup photometry**. Its good image quality would be exploited for photometry of SNe situated close to a strong underlying galaxy.

We would use ALFOSC, the Faint Object Spectrograph Camera, equipped with a Loral 2048×2048 CCD, for the *spectroscopic studies*. Grisms 6 (range of 3200–5500Å at a resolution of 3.9Å) and 8 (range of 5800–8300Å at a resolution of 3.0Å) would be employed. For a m_V target of 19, integration times of order 50 minutes would be needed to give S/N > 25 per pixel.

The HiRAC Camera would be employed for the *imaging programme*. Similar integration times and filter sets would be used as with the INT WFC. The fine pixel scale (0.11 arcsec/pixel, with a field of 3.7 arcmin) and good image quality of the NOT (0.4–0.5 arcsec) means that this imager will be ideal for photometry of those SNe that are situated close to an underlying galaxy (which might otherwise compromise the photometry of the SNe).

5.4. THE 1.0-M JACOBUS KAPTEYN TELESCOPE

The JKT would be employed for followup photometry of the brighter SNe. It would also be used for photometric calibration of fields previously observed with the INT, NOT and JKT during non-photometric conditions.

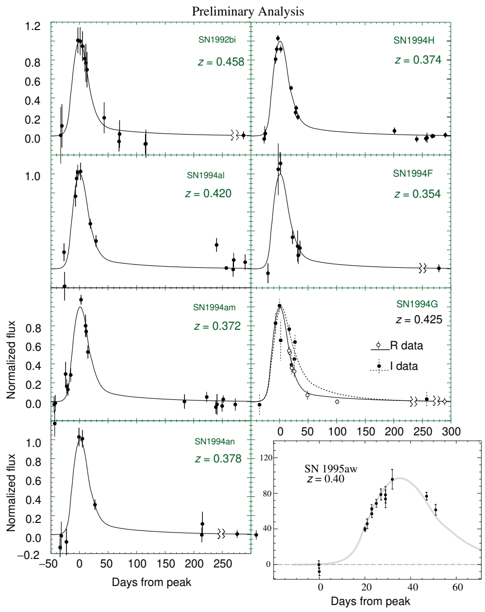

Figure 5. Light curves of supernovae at high redshift. In order to obtain precise values for Ω_M and Ω_Λ, the rate of decline of the SN light curve (stretch S) has to be determined. If we consider SNe Ia to be calibrable candles through measurement of the decline of the light curve, the internal dispersion in luminosity is reduced down to $\sigma = 0.1$ *mag* only. Lacking such measurement, the dispersion is 4 times larger and the use for cosmological measurements becomes much poorer.

The CCD imager would be used together with the SITe 2048×2048 CCD if available (giving a $\approx 11 \times 11$ arcmin field. Exposure times of typically 20 minutes in the R band would be needed to obtain good S/N (> 50) for objects down to R magnitudes of 21.

5.5. THE CARSLBERG AUTOMATIC TRANSIT CIRCLE

The CAMC has recently been upgraded with a CCD imaging camera (see http://www.ast.cam.ac.uk/ dwe/SRF/camc.html for details). Data from this will be used to determine the grey extinction term for each nights data.

6. Scheduling and Breakdown of Observing Time

The general outline of the programme would be to schedule the discovery period in February/March. Then followup observations would be scheduled in the following four months.

6.1. THE DISCOVERY PERIOD OBSERVATIONS

The zero time imaging would be carried out with the WFC of the INT just after the new moon in February 1999 (e.g. 19 Feb. 1999). In **three dark nights** the WFC would survey some 30 square degrees of sky in the R band.

The same fields would be observed for **3 dark nights** with the INT's WFC in R just before the following new moon in March 1999 (e.g. 12 Mar. 1999). We expect that of the new SNe discovered, some 10 will be of type SN Ia.

6.2. CLASSIFICATION OF THE SNE AFTER DISCOVERY

In order to select those SNe of Type Ia for subsequent photometric monitoring, spectra would be obtained of the new objects. The WHT and NOT would be employed. **Five dark nights** would be required in the dark period of March 1999 after the discovery imaging on *both* the WHT+ISIS and NOT+ALFOSC.

6.3. PHOTOMETRIC FOLLOWUP

Photometric monitoring of the SNe would be carried out with the INT+WFC and NOT+HiRAC. The allocation of one dark night and six grey nights on each would be scheduled in three, two night periods in April, May and June for followup photometry. The six nights of bright time on each would be scheduled in May to enable zeropoints and calibrations of the fields to be obtained.

The JKT telescope dark time would be scheduled in two night slots in two periods, one per month in March, April to track the brighter SNe. The grey (six nights) and bright time (six nights) on each would be scheduled equally in April, May to carry out calibration photometry of the observed fields.

6.4. SPECTROSCOPIC FOLLOWUP

In order to generate time series spectra of the newly discovered Type Ia SNe, the WHT with ISIS would be employed for 1 dark or grey night every one–two weeks for the three months after discovery (until the field becomes unobservable at the end of June 1999). This would require the **remaining dark night** of WHT time and **six grey nights**.

The whole programme runs for four consecutive months. There is flexibility in the starting time. We prefer to start in Feb 1999. But we leave as other possible dates March 1999, or even (worse for our preferences, but still possible) September 1999. For this later case, the observations should be scheduled in a similar way to previously described but taking as zero–point the first new moon in September.

7. Further science

The science to be done with the observations collected will also include:

1. The determination of rates of SNe Ia at medium z. As mentioned before this gives a unique possibility to derive information on the progenitors of SNe Ia and cosmological constant (Ruiz–Lapuente & Canal 1998).

2. Study of the evolution of properties of SNe Ia at medium and high z.

3. Statistics of GRB afterglows and their correlation with supernovae.

4. Lensing and derivations of constraints on the inhomogeinities of mass distribution in the Universe.

5. Role of SNe Ia in the chemical enrichment at high z.

6. Study of bulk motions by determining distances to nearby SNe Ia.

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