GEMINI OBSERVATORY

observing time request (HTML summary)

Semester: 2002A	**Gemini reference:** Not Available	**Partner reference:** Not Available
Observing mode: queue	**Instruments(s):** NIRI, GMOS North	**Partner ranking:** Not Available
PI time requested: 68.6 hours	**PI total from all partners:** 0.0 nights *(joint proposals)*	
PI future time requested: 35.0 hours	**PI minimum time requested:** 35.0 hours	
NTAC recommended time: 0.0 nights	**NTAC minimum recommended:** 0.0 nights	

Proposal submitted to: United Kingdom

Title: **Cosmology with High-Redshift Type Ia Supernovae**

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Abstract: *We now have the opportunity to obtain a Hubble diagram of Type Ia supernovae (SNeIa) that will be of longlasting value as a record of the expansion history of the universe. This record, based on SNeIa used as calibrated standard candles, directly constrains the cosmological parameters. NIRI on Gemini is capable of providing crucial near-IR data (rest-frame V band) for the highest redshift supernovae. Combined with coordinated optical observations at other observatories, in particular HST, these will provide powerful constraints on SNIa evolution and abnormal dust within or between galaxies. Meanwhile GMOS is capable of providing spectroscopic confirmation of the supernova's type*

and redshift, and optical lightcurves for faint supernovae. Accurate measurement of these high redshift SNe will dramatically shrink the major-axis of the error ellipse in the Omega_M--Lambda plane, decoupling the measurements of Omega_M and Omega_Lambda. This will provide the first check on the CMB measurements of a spatially flat universe, and unambiguously determine whether the universe contains vacuum energy. The Hubble diagram in this redshift range is the only currently feasible way to begin constraining the physics of the ''dark energy'' that is accelerating the universe's expansion.

Science Justification

The Hubble diagram for Type Ia supernovae (SNe Ia), extended to redshifts well beyond z=0.25 (Fig. 1), provides perhaps the most direct current measurement of the expansion history of the universe - and hence the most direct evidence for an accelerating expansion. The Supernova Cosmology Project developed an approach to this measurement (Perlmutter et al 1997, 1998, 1999) that resulted in a determination, based on 42 SNe with redshifts between 0.18 and 0.83, of Omega_M=0.28 (+0.09,-0.08) for a flat universe (Perlmutter et al 1999; see also Riess et al 1998).

This evidence has been increasingly strengthened, both by improvements of the SN 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 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) EXPLOITING A COSMOLOGY TOOL: FILLING A SN IA HUBBLE DIAGRAM TO z=1.2

Significant improvements are being made in the systematic uncertainties in SN measurements (see later in this proposal) and it is therefore now appropriate to reduce the statistical uncertainty by almost a factor of two - that is, by studying an additional 100 SNe Ia in the redshift range 0.5 - 1.3. This number could reasonably be expected to be found and spectroscopically confirmed with ground-based telescopes, and followed with accurate space-based optical photometry over the remaining lifetime of the HST. The study of these SNe is a key task to complete and we are therefore proposing a concerted effort in Semester 2002A to discover and study 15 SNe Ia, with the most distant to be followed with Gemini and 100 HST awarded orbits.

The supernovae at the high end of this redshift range (z>1) are the most challenging to study, but also have the largest scientific impact. First they allow a determination of the curvature of the universe and decoupled measurements of Omega_M and Omega_Lambda. While additional SNe Ia over the z~0.85 range of the current datasets will improve the current statistical uncertainty by square-root(N), additional SNe Ia beyond z=0.85 can dramatically shorten the major-axis of the current Omega_M-Omega_Lambda error ellipse (Goobar & Perlmutter 1995 and Fig. 1). After our proposed observations in semester 2001A, Lambda=0 could be ruled out at better than 3sigma. For a flat universe, Omega_M and Omega_Lambda could be constrained to about 6%. The resulting estimate of Omega_M, for any Omega_Lambda, 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 redshifts above 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 current constraints on the effective equation of state ratio (w=p/rho) 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.

(b) REFINING AND TESTING A COSMOLOGY TOOL: SNE IA SYSTEMATIC UNCERTAINTIES

Perlmutter et al (1997, 1999) provide extensive discussion of possible systematics in the measurement of Omega_M,Omega_Lambda; 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 SNIa evolution and abnormal dust within, or even between, galaxies. Well-measured SNeIa at z>1 will provide a direct test for such possible systematics. As shown in Fig.1, the form of the Hubble diagram at high-z expected for a Lambda-dominated universe would be hard to mimic by systematic effects such as intergalactic gray dust or evolution in SNIa peak magnitudes.

THIS PROPOSAL

To use SNe at z>1 for cosmological purposes, near-IR photometry is crucial since the rest frame B- and V-bands, where SNeIa are good calibrated standard candles, shift to the near-infrared. Our intention is to use Gemini J-band photometry, combined with data from other observatories to accurately determine the rest-frame B-V color for two z>1 supernovae (see technical case). This in turn determines any reddening so that corrected rest-frame peak B and V magnitudes may be placed on the Hubble diagram and used for cosmology. Without near-IR photometry, our highest redshift HST-observed SNe cannot be corrected for host galaxy extinction.

The most recent run, in 2001A, identified 17 SNe including 3 confirmed beyond z=1 (of which two were followed in detail). One of these, at z=1.06, was successfully observed with NIRI (see section on previous use of Gemini). We are now proposing to observe two more of the highest redshift supernovae with NIRI, plus use GMOS to observe 5 SNe spectroscopically and determine optical lightcurves for two SNe at z~0.85.

In summary, well measured SNeIa at high redshift are crucial for addressing the questions of the cosmological parameters, the curvature, and the identity of dark energy. The same SNe can serve double-duty by refining our checks on systematic effects such as dust and evolution.

Attachments:

Name	Source	Type
Figures	gem_sn_02a_figpage.ps	PS

Technical Justification

NIRI OBSERVATIONS:

We intend to use NIRI to observe two supernovae close to peak brightness in the J band (rest-frame V band at z=1.0-1.4). Meanwhile rest-frame B-band data will be obtained using HST 850LP observations, so that the rest-frame B-V colour can be determined. In addition the full rest-frame U-band light curve will be obtained using HST 814W (100 HST orbits are already allocated for this project), to determine the shape and time-of-maximum of the lightcurve. These datasets combined provide all the information necessary to use the supernovae for cosmology.

INSTRUMENT SETUP: NIRI f/6 camera, J-band filter.

EXPOSURE TIMES: We need to determine the rest-frame B-V colour with signal-to-noise ratio of 10. The noise will be dominated by the J-band (rest-frame V) measurement, and since this will involve subtracting a final J-band reference frame (to be obtained in a future semester), the current J-band data must reach a S/N of 14.

In the J-band, supernovae in the redshift range of interest have peak magnitudes of J=23.8. We have used the NIRI ITC with the following assumptions: median image quality (using the PWFS), median sky transparency, 80%-ile water vapour and sky background, airmass < 1.2. This gives an exposure time of 43800s, in good agreement with the results from the observations taken in 2001A on the z=1.06 SN 'Satie' (Fig 1). Two SNe will therefore require 87600s= 24.3hrs on target.

We request photometric conditions (median sky transparency or better).

GMOS OBSERVATIONS:

(a) GMOS Spectroscopy

We intend to obtain spectra of 5 supernova candidates close to peak brightness to confirm the SN type and obtain a redshift (usually measured from narrow lines in the galaxy spectrum)

INSTRUMENT SETUP: R400 grating, OG515 order sorting filter, lambda_c=740nm (gives a range of 530-950nm), detector binned 2x2.

EXPOSURE TIMES: Typical exposure times of 3600s each are sufficient for an initial 'screening' of 5 candidates in the magnitude range i=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 hrs each (total 4hrs). The final spectra can be smoothed heaviliy to reveal the supernova features (see Fig 2).

(b) GMOS Imaging

We aim to obtain optical lightcurves for two SNe at z~0.85 (higher redshift SNe require HST for optical observations).

INSTRUMENT SETUP: i filter, detector binned 2x2.

EXPOSURE TIMES: 6.4hrs are needed to obtain a full lightcurve (5 points) for a supernova at z=0.85 (peak mag=23.2) with S/N=20. We request 12.8 hrs to obtain 2 lightcurves. The exact exposure times will be adjusted depending on the supernovae being followed.

NOTE 1- THE GMOS TIMES ARE ESTIMATES BASED ON OTHER TELESCOPES AT THE MOMENT. A QUICK TEST OF THE GMOS ITC GAVE VERY SIMILAR ANSWERS TO THE VLT ESTIMATES)

NOTE 2- U.S. PROPOSAL CURRENTLY SAYS WE'RE DOING 5 SNE AT 0.3<Z<0.75.

We request photometric conditions (median sky transparency or better).

OVERHEADS AND TOTAL TIME:

The total on-source time requested above is 24.3hrs (NIRI) and 23.8hrs (GMOS). Following the guidelines on the NIRI and GMOS web pages of 15 mins per new target plus 25% of elapsed time used for offsetting etc (we include obtaining GMOS flats to reduce the effects of fringing in this estimate), the overheads are 17.8 hrs. We include a further 2 hours total to obtain NIRI photometric calibration for the two SN fields and a GMOS spectroscopic standard (only relative flux calibration is necessary). Suitable standards will be chosen once the target positions are known. The total request is therefore 66 hrs.

FUTURE TIME: An approximately equal amount of time will be needed in a future semester (2003A) to obtain 'reference' images once the SNe have faded, for subtraction of the host galaxy light from the supernova photometry (NIRI and GMOS imaging only). To maximise the effectiveness of our supernova search and follow-up campaigns, we are planning concerted efforts once per year, and will not be applying for Gemini time for this program next semester.

DIVISION OF TIME BETWEEN TACS: This proposal is being submitted on behalf of the Supernova Cosmology Project, and we are also applying for Gemini time for this program via the U.S. TAC (see proposal of Perlmutter et al "Cosmology with High-Redshift Type Ia Supernovae"). We request that the time be divided between the U.S. and U.K. allocations in approximately the proportion of partner shares, i.e. 44hrs (US) and 22hrs (UK).

TARGETS: The targets will be discovered in searches using the 12x8k camera on the CFHT telescope, the Mosaic camera on the CTIO 4m telescope and SuprimeCam on the Subaru telescope. The number of supernovae that can be studied in this campaign is limited by the follow up time available, and the searches are designed to cover the depth and area necessary to comfortably provide enough supernovae for the follow up stage. We have regularly demonstrated our ability to find and follow distant supernovae in this way over the last several years (See IAU Circulars by the SCP) including those at the highest redshifts(e.g. sn1998eq at z=1.2).

The final selection of fields depends on the dates scheduled for searching but will be around 0 degrees declination and will avoid regions of high galactic extinction.

TIME CRITICAL ASPECTS OF THE PROGRAM :

Although the observations are somewhat time-critical, we will be able to tell Gemini the window for follow-up well before the start of the semester.

The NIRI observations should take place within about a week of maximum light in the rest frame. Assuming the SNe are discovered a few days before maximum light, this gives a window of about 3 weeks in the observers frame. The GMOS spectroscopic observations should take place as soon as

possible after the search has been carried out, and the GMOS imaging observations will then be needed approximately every 10 +/-3 days.

Observation Details

Observation	**RA**	**Dec**	**Brightness**	**Total Time** *(including overheads)*
SN1	13 00 00	00 00 00	J=23.8 (dummy target)	17.5 hours
GSC0029801079 (wfs)	13:00:15.79	0:04:08.11	13.43 mag	separation 5.72
observing conditions: SN constraints		resources:		
SN2	13 00 00	00 00 00	J=23.8 (dummy target)	17.5 hours
GSC0029801079 (wfs)	13:00:15.79	0:04:08.11	13.43 mag	separation 5.72
observing conditions: SN constraints		resources:		
SN3	13 00 00	00 00 00	(dummy target)	8.8 hours
GSC0495701179 (oiwfs)	13:00:07.366	-0:03:55.3	13.45 mag	separation 4.33
observing conditions: SN constraints		resources: GMOS i		
SN4	13 00 00	00 00 00	(dummy target)	8.8 hours
GSC0495701179 (oiwfs)	13:00:07.366	-0:03:55.3	13.45 mag	separation 4.33
observing conditions: SN constraints		resources: GMOS i		
SN1	13 00 00	00 00 00	J=23.8 (dummy target)	5.6 hours
Dummy (oiwfs)				separation
observing conditions: SN constraints		resources: GMOS spec		
SN2	13 00 00	00 00 00	J=23.8 (dummy target)	5.6 hours
Dummy (oiwfs)				separation
observing conditions: SN constraints		resources: GMOS spec		
SN3	13 00 00	00 00 00	(dummy target)	1.6 hours
Dummy (oiwfs)				separation
observing conditions: SN constraints		resources: GMOS spec		
SN4	13 00 00	00 00 00	(dummy target)	1.6 hours
Dummy (oiwfs)				separation
observing conditions: SN constraints		resources: GMOS spec		
SN5	13 00 00	00 00 00	(dummy target)	1.6 hours
GSC0495701179 (oiwfs)	13:00:07.366	-0:03:55.3	13.45 mag	separation 4.33
observing conditions: SN constraints		resources: GMOS spec		

Resources

- Gemini North
  - NIRI
    - Camera
      - f/6 (0.12 arcsec)
    - Filter
      - Broad-Band
        - J (1.25 um)
  - GMOS i (GMOS North)
    - Filter
      - i_G0302
    - Disperser
      - Mirror
  - GMOS spec (GMOS North)
    - Focal Plane Unit
      - Longslit 0.75 arcsec
    - Disperser
      - R400_G5305
    - Filter
      - OG515_G0306

Observing Conditions

Name	Image Quality	Sky Background	Water Vapor	Cloud Cover
SN constraints	50%	Any	80%	50%

Scheduling Information:

Optimal dates:

Impossible dates:

Additional Information

Keyword Category: Extra Galactic

Keywords: Cosmological distance scale

Publications: Publications:

- Aldering G, Knop R., Nugent P., (2000) "The rise times of High- and Low- redshift Type Ia Supernovae are consistent", AJ, 119, 2110
- Perlmutter S. et al (1999) "Measurements of Omega and Lambda from 42 High-z Supernovae", ApJ, 517, 565
- Perlmutter S. et al, (1998) "Discovery of a supernova explosion at half the age of the Universe and its cosmological implications", Nature 391, 51.
- Kim A. et al (1996) "Implications for the Hubble constant from the first seven supernovae of z>0.35", ApJ, 473, 356

- Perlmutter S. et al (1997) "Measurement of the cosmological parameters Omega and Lambda from the first 7 supernovae at z>0.35", ApJ, 483, 565
- Pain R. et al (2001) : "The Type Ia Supernova Rate at Redshifts 0.35

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