GEMINI OBSERVATORY

observing time request (HTML summary)

Semester: 2002B

Gemini reference: Not Available

Instruments(s): NIRI, GMOS North

Observing mode: queue

Time awarded: Not Available

Partner reference: Not Available

Partner ranking: Not Available

NTAC recommended time: 0.0 nights

NTAC minimum recommended: 0.0 nights

Proposal submitted to: United Kingdom

...also submitted to... United States *(joint proposals)*

PI time requested: 26.7 hours

PI minimum time requested: 1.0 hours

PI future time requested: 0.0 nights

PI total from all partners: 80.2 hours *(joint proposals)*

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

Principal Investigator: **Isobel Hook**

PI institution: University of Oxford, Department of Physics, Astrophysics, Nuclear and Astrophysics Laboratory,Keble Road,Oxford,OX1 3RH,United Kingdom

PI status: PhD/Doctorate

PI phone / fax / e-mail: +1 808 974 2521 / +1 808 935-9235 / ihook@gemini.edu

Co-investigators:
Robert Knop: Vanderbilt University, r.knop@vanderbilt.edu
Saul Perlmutter: Lawrence Berkeley National Laboratory, saul@lbl.gov
Greg Aldering: Lawrence Berkeley National Laboratory, galdering@lbl.gov
Eric Smith: Vanderbilt University, eric.a.smith@vanderbilt.edu
Ariel Goobar: University of Stockholm, Sweden, Ariel.Goobar@physto.se
Chris Lidman: European Southern Observatory, clidman@eso.org
Richard McMahon: University of Cambridge, rgm@ast.cam.ac.uk
Peter Nugent: Lawrence Berkeley National Laboratory, penugent@lbl.gov

---

Abstract: *Type Ia supernovae (SNe Ia) have provided direct evidence for an accelerating universe and for the existence of a ''dark energy'' driving that expansion. During the next few years SNe Ia observations will begin to address the properties of this dark energy. We propose to use GMOS and NIRI on Gemini to observe supernovae at two redshift ranges: 0.4<z<0.7 and z~1.0. These measurement will determine the equation of state of the dark energy, and will also allow us to set more stringent systematic limits on the current supernova data. With GMOS, we will obtain spectra of 30 supernovae at z<0.7 discovered as part of the Tololo Rolling Supernova Search (TRSS), and of another two SNe at z~1.*

These spectra will confirm the identity of candidates as SNe Ia and will measure redshifts. In addition, following our success with a SNIa at z=1.06 during semester 2001A, we will obtain J-band photometry with NIRI of two SNe at z~1. These will be used in tandem with HST and Subaru z-band measurements tc provide rest-frame B-V colours, which are necessary for measuring, and correcting for, any extinction by dust.

Science Justification

The Hubble diagram for Type Ia Supernovae (SNe Ia) provides 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 (SCP) 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 ~ 0.3 for a flat universe (Perlmutter et al. 1999; see also Riess et al. 1998); balloon-based CMB measurements have strengthened the evidence for an accelerating universe by indicating that the geometry of the universe is flat, ruling out the possibility of a low-density open universe.

Further measurements of high-redshift supernovae hold promise in two areas. First, over the next few years it will be possible to begin to address the properties of the ‘‘dark energy’’ which is driving the expansion of the universe, by measuring w, the equation of state (pressure/density); a value of w=-1 would indicate vacuum energy, or a cosmological constant. In a few years, sufficient supernova data at a range of redshifts together with independent constraints on Omega_M from, e.g. large scale structure, it will be possible to measure w to approximately five times better accuracy than can be done today. Figure 1 shows the improvements in the cosmological parameters with these proposed observations, and what we expect to be able to achieve in five years. Indeed, in the example shown (where the simulated value of w is -0.8), we would be able to rule out vacuum energy.

Secondly, more and better measurements of supernovae will allow us to minimize the effects of systematic errors on the results. For example, the effects of host galaxy dust extinction may be addressed with high-quality color measurements of a large quantity of supernovae. The effects of ‘‘grey dust’’ are addressed by obtaining measurements of supernovae at intermediate (z<1) and high (z>1) redshifts, thereby looking into the epochs of both acceleration and deceleration.

THIS PROPOSAL

The observations in this proposal will measure supernovae at two redshift regimes. First, we will use GMOS on Gemini to obtain spectra of supernovae at 0.4<z<0.7 produced by the Tololo Rolling Supernova Search (TRSS) for High-Redshift Supernovae (proposed as a NOAO survey project by Knop et al.), which will be relying on this proposed time in order to confirm the identifications as SNeIa and measure the redshifts of the higher-z supernovae discovered. The expected improvements on the cosmology due to this five-year survey (implicitly including redshifts obtained by this proposal) are shown in Figure 1. This proposed Gemini spectroscopy of SNe at 0.4<z<0.7 will allow the TRSS to achieve its goals both in measuring w and setting limits on the effects of supernova evolution and host galaxy extinction.

A new feature of the TRSS survey is that it will address evolution by measuring the rise-time of high-redshift supernovae to ~0.7 days (Aldering, Knop & Nugent 2000)-- which will require spectroscopic redshift measurements to take into account the effects of time dilation. According to the models of Dominguez et al. (2001) this will allow us to constrain evolution in the mean peak SN brightness between low- and high-redshift to within 0.07mag. (Photometric redshifts will help us screen candidates to make our use of GMOS more efficient, but are not precise enough for a ~3% measurement of a supernova lightcurve rise time.) Likewise, the R-I colors produced by the survey will allow a measurement of a shift in the mean extinction between high- and low-redshift supernovae as low as 0.015mag.

In addition, we have the rare opportunity to take advantage of a large, deep imaging survey on Subaru: the ‘‘Subaru Big Project,’’ a campaign which will obtain multi-filter images of the Subaru/XMM deep field using 14 nights with SuprimeCam. This project will obtain ~8 faint (I~24.5) candidates, of which about 6 should be z>1 SNeIa. Supernovae at these highest redshifts are the most challenging to follow; however, they have a large scientific impact. They provide the greatest leverage in decoupling measurements of Omega_M and Omega_Lambda, thereby shortening the long axis of the confidence ellipse which results from measurements of supernovae at z<1 (see Figure 1). Second, they are at a high enough redshift that observing them allows us to look back to the era of deceleration. Observations of supernovae at z>1 together with intermediate redshifts of z<1 provide a complete picture which can clearly distinguish an accelerating cosmological expansion from systematic effects. Three confirmed z>1 SNeIa will be observed by HST in the z’-band. We request time with GMOS on Gemini to obtain redshifts and type confirmations for two of these very faint candidates. Photometric redshifts available for many of the host galaxies will help to select probable SNe~Ia in the target redshift range. These most distant supernovae also require measurements in the infrared, since rest-frame B- and V-band, where supernovae are best understood as standard candles, are redshifted out beyond wavelengths of 1 micron. We propose to carry out these J-band observations with NIRI on Gemini.

Attachments:

Name	Source	Type
sn_02b_figpage.ps	sn_02b_figpage.ps	PS

Technical Justification

We propose to use GMOS for spectroscopy and NIRI for infrared imaging to obtain spectra and lightcurves of supernovae in two regimes: 0.4<z<0.7 and z >~ 1.

GMOS OBSERVATIONS

TARGETS: The proposed TRSS would proceed over four months one semester each year for five years, using the Mosaic camera to simultaneously find and obtain high-quality lightcurves of >300 supernovae at z<0.7. We propose to use GMOS on Gemini to complete the identification and measurement of redshifts of supernovae out to z~0.7 which are too dim for the KPNO4m and MMT time proposed as part of TRSS. During the first semester of TRSS this will amount to ~30 supernovae at 0.4<z<0.7, where SNeIa have peak I-band magnitudes between 22 and 23. Host galaxy photometric redshifts and points on the rise of the supernova lightcurve will allow us to both improve the odds that a given candidate will be a SNIa, and to ensure that we are observing near maximum light.

GMOS EXPOSURE TIMES: For the 30 $z<0.7$ SNe a typical exposure time of 1800s per object is sufficient for a screening observation to confirm supernova type and measure a precise redshift. Including 25% overhead and 30 min. to acquire each object, this totals 35 hours of GMOS time.

In addition, we propose to obtain spectra of 2 faint (I~24.5) candidates which will be at z~1. The Subaru Big Project will find up to ~8 such candidates, of which ~6 should be $z>1$ SNeIa. Three confirmed $z>1$ SNeIa will be sent to HST for z'-band observation. We request time with GMOS on Gemini to obtain redshifts and type confirmations for two of these very faint candidates. These will require on-source exposures of 3.5 hours each with GMOS; adding 25% overhead and 30 minutes of acquisition for each object totals 10.3 hours. Figure 2 shows a smoothed Keck spectrum of SN2001hb, a supernova at z=1.055, at a quality similar to what we expect to be able to achieve with GMOS.

In total, we request 45.3 hours of GMOS spectroscopy observations. All observations will use a 0.75'' slit, the R400_G5305 grating, and the OG515 order sorting filter.

NIRI OBSERVATIONS

For the supernovae discovered at $z>1$ by the Subaru Big Project, the rest-frame V-band light is shifted out beyond 1micron; observations in the J-band filter are necessary in order to measure a rest-frame B-V color and correct for host galaxy extinction. Spectra of these candidates will be obtained with GMOS (above) and with the Keck telescope; z-band followup (corresponding to the rest-frame B-band) will be performed with ACS on HST and/or SuprimeCam on Subaru. We propose to use NIRI on Gemini to measure 2 SNeIa in the J-band at $z>1$. The uncertainty in rest-frame B-V will be dominated by this J-band measurement. We will measure the J-band magnitude to a S/N of 14, thereby giving us S/N 10 in the final measurement once a host galaxy reference image is subtracted. Figure 2 shows our successful NIRI observations from Spring 2001 of SN2001hb at z=1.055, of a similar quality to the proposed observations.

NIRI EXPOSURE TIMES: As described above, the current J-band data must reach a S/N of 14. In the J-band, SNeIa in the redshift range of interest are predicted to have peak magnitude of J = 23.8. To estimate the required exposure time we have used the NIRI ITC with the following assumptions: median image quality (using the PWFS but not the OIWFS since we are using the f/6 camera), median sky transparency, 80%-ile water vapor and sky background, and airmass < 1.2. This gives an exposure time of 43800 seconds, in good agreement with the results from the observations taken in semester 2001a on the z = 1.06 SN2001hb (Fig. 2). Two supernovae will require 87,600s = 24.3 hours on target.

NIRI OVERHEADS Following the guidelines on the NIRI web page of 15 minutes per new target plus 25% of elapsed time used for offsetting etc., the total overheads would be 8.6 hours. We include an additional 2 hours to obtain photometric calibration for the two SN fields. Suitable standards will be chosen once the target positions are known. At this stage we include photometric calibration time as an overhead on top of the target exposure time. The total NIRI request is therefore 34.9 hours.

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 by Knop 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. NIRI 23.3 hours (US) and 11.6 hours (UK); GMOS 30.2 hours (US) and 15.1 hours (UK). Total = 53.5 hrs (US) and 26.7 (UK).

TIME CRITICAL ASPECTS OF THE PROGRAM :

Although the observations are somewhat time-critical, the window for observations is known well in advance. The NIRI observations should take place within about a week of maximum light in the rest frame, about two weeks in the observer's frame.

The TRSS will proceed over a period of four months (September through December), with supernovae being discovered and coming to maximum light throughout the period. GMOS spectroscopy of the target objects will be spread over several nights around dark time during each of the first three months of TRSS.

Observation Details

Observation	RA	Dec	Brightness	Total Time *(including overheads)*
TRSS_1to30 (dummy target)	00 00 00	00 00 00	i=23	35.0 hours
GSC0525300332 (oiwfs)	23:59:59.782	-0:03:55.66	11.30 mag	separation 3.93
observing conditions: GMOS spect		resources: GMOS spect		
Sub_SN1 (dummy target)	00 00 00	00 00 00	24.5	5.15 hours
GSC0525300332 (oiwfs)	23:59:59.782	-0:03:55.66	11.30 mag	separation 3.93
observing conditions: GMOS spect		resources: GMOS spect		
Sub_SN2 (dummy target)	00 00 00	00 00 00	24.5	5.15 hours
GSC0525300332 (oiwfs)	23:59:59.782	-0:03:55.66	11.30 mag	separation 3.93
observing conditions: GMOS spect		resources: GMOS spect		
Sub_SN3 (dummy target)	00 00 00	00 00 00	24.5	17.45 hours
GSC0525300113 (wfs)	23:59:40.046	-0:03:07.42	12.78 mag	separation 5.89
observing conditions: NIRI imaging		resources: NIRI imaging		
Sub_SN4 (dummy target)	00 00 00	00 00 00	24.5	17.45 hours
GSC0525300113 (wfs)	23:59:40.046	-0:03:07.42	12.78 mag	separation 5.89
observing conditions: NIRI imaging		resources: NIRI imaging		

Resources

- Gemini North
  - NIRI imaging (NIRI)
    - Filter
      - Broad-Band
        - J (1.25 um)
    - Camera
      - f/6 (0.12 arcsec)

- GMOS spect (GMOS North)
  - Disperser
    - R400_G5305
  - Focal Plane Unit
    - Longslit 0.75 arcsec
  - Filter
    - OG515_G0306

Observing Conditions

Name	Image Quality	Sky Background	Water Vapor	Cloud Cover
NIRI imaging	50%	80%	80%	50%
GMOS spect	50%	50%	Any	50%

Scheduling Information:

Synchronous dates:

Optimal dates:

Impossible dates:

Additional Information

Keyword Category: Extra Galactic

Keywords: Cosmological distance scale

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.
- 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 -0.85, submitted to ApJ.
- G. Goldhaber, et al, (2001), Timescale Stretch Parameterization of Type Ia Supernova B-Band Light Curves, Astrophysical Journal, 558, 359
- R. Knop, et al, (2000), Latest Cosmological Results from Type Ia Supernovae, Bulletin of the American Astronomical Society, 197, 950
- A. Goobar et al, (2000), The acceleration of the Universe: measurement of cosmological parameters from type Ia supernovae, Physica Scripta, T85, 47.
- R. Pain, I. Hook, S. Perlmutter, et al., (1996) , The Type Ia supernova rate at z~0.4, Astrophysical

Journal, 473, 356

- R.Knop, et al, (2001), New Limits on Cosmological Parameters Omega_M and Omega_Lambda from HST Observations of Eleven Supernovae at Redshifts z=0.36-0.86, in preparation
- Supernova 2001ay in IC 4423, Circular 7612, P.Nugent, G.Aldering, I.Hook, S.Perlmutter, L.Wang
- Supernovae 1999bi, 1999bj, 1999bk, 1999bl, 1999bm, 1999bn, 1999bo, 1999bp, 1999bq, Circular 7136, Supernova Cosmology Project.

Allocations:

Reference	**Time**	**% Useful**	**Comment**
GN2001A-Q-10	12.0 hours	50	This was a joint proposal with GN2001A-Q-16 (submitted to the U.S. TAC) to observe distant supernovae with NIRI. Both were ranked highly and the full amount of requested time (35hrs) was awarded by the respective TACs. 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, approximately half of our original request (when overheads are taken into account). We intend to obtain a final reference image for this SN with NIRI in semester 02B.
GN2002A-Q-30	12.0 hours		This was a joint proposal with GN2002A-Q18 (submitted to U.S. TAC) for GMOS observations of distant supernovae. The time has not yet been used.
GN2002A-Q-31	12.0 hours		This was a joint proposal with GN2002A-Q37 (submitted to U.S. TAC) for NIRI observations of distant supernovae. The time has not yet been used.
GN2002A-Q-75	6.5 hours		This was a joint proposal with GN2002A-Q9 (submitted to Candian TAC) for GMOS spectroscopy of z>5 QSO candidates. The UK allocation is in band 4 and the time has not yet been used.

Proposal Contents

Summary
Investigators
Abstract
Science Justification
Technical Justification
Observation Details
Allocation Committee Comments
Additional Information