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: 70.15000000000002 hours

PI total from all partners: 70.1 hours *(joint proposals)*

PI future time requested: 30.0 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

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

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. As demonstrated by our successful observations of a redshift=1.06 supernova in 2001B, 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 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) 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 cosmological measurements. In particular the recent balloon-based CMB measurements (Jaffe et al 2001) 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.1a). 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 and it is 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. 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 2002A, Lambda=0 could be ruled out at better than 3 sigma. 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 according to 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 high redshift, particularly z>1, will provide a direct test for such possible systematics. 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 (see Fig 2). The serendipitous measurements of SN1997ff (z=1.7) and our preliminary results for SN1998eq (z=1.2 but with better measurements than SN1997ff) are consistent with a no-dust, no-evolution interpretation, but are not sufficiently constraining by themselves.

THIS PROPOSAL

To use SNeIa for cosmological purposes, not only is the rest-frame optical lightcurve needed, but also a measurement of its colour at at least one epoch. This determines any reddening so that corrected rest-frame peak B and V magnitudes may be placed on the Hubble diagram and used for cosmology.

For redshifts around 0.8 these can be obtained from the ground, and we propose to measure GMOS i-band lightcurves (restframe B) for two SNe, and use GMOS z-band for restframe-V colour measurements at peak.

For higher redshift supernovae (z>1) 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 HST to accurately determine the rest-frame B-V color for one z>1 supernova. Without near-IR photometry, our highest redshift HST-observed SNe cannot be corrected for host galaxy extinction.

Our 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 Fig. 3). We now require a final NIRI "reference" image for this supernova in order to subtract off the contribution from its host galaxy.

These datasets, combined with redshift and supernova type confirmation from GMOS, provide all the information necessary to use the supernovae for cosmology.

Attachments:

Name	Source	Type
Figures	gem_sn_02a_figpage.ps	PS

Technical Justification

NIRI OBSERVATIONS:

We intend to use NIRI to observe one z>1 supernova close to peak brightness in the J band (rest-frame V at z=1.0-1.3). Meanwhile rest-frame B 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. We also intend to obtain a final "reference" NIRI image for the z=1.06 SN observed in May 2001 with NIRI (see Fig 3).

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, the J-band data at each epoch 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, assuming our "NIRI" constraints and 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 3). Observing one new supernova and the reference image for Satie will therefore require 87600s= 24.3hrs on target.

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, 0.75" slit.

EXPOSURE TIMES: Typical exposure times of 3600s each are sufficient for an initial 'screening' of 5 candidates in the magnitude range i=23-25. The final spectra can be smoothed heavily to reveal the supernova features (see Fig 3). The ITC gives a S/N of about 7 per smoothed spectral element in 1hr for a point source at i=24.0, assuming the setup above and our 'GMOS spec' constraints.)

We would then obtain detailed spectra on two candidates that appear to be likely z>1 Type Ia supernovae (either from those screened by GMOS or from elsewhere) in order to determine the type unambiguously and check for spectral peculiarities that indicate an unusual SNIa. These will require additional exposure times of 3 hrs each (for a total of 4hrs each) to provide spectra of similar quality to that in Fig 3 (note that this SN was unusual in having a very weak host galaxy so it was possible to obtain a clean spectrum in a relatively short time).

(b) GMOS Imaging

We aim to obtain optical lightcurves for two SNe at z~0.8 in i' (restframe B) and a measurement at peak in z' (restframe V)

INSTRUMENT SETUP: i, z filters, detector binned 2x2.

EXPOSURE TIMES: We require 5 points on the i-band lightcurve, each with S/N=20, plus one point at maximum in the z-band. A SN at z=0.8 has magnitudes approx [23.1, 23.3, 23.7, 24.3, 25.0] at days [0,10,20,30,40] relative to max in the observed frame. This requires exposure times of [480s,660s,1380s,4140s,14880s] respectively, plus 2820s for the z-band measurement at peak, a total of 6.7hrs. The corresponding total for a SN at z=0.75 is 5.3hrs. We therefore estimate that we need 12.0hrs to obtain lightcurves and colours for two SNe at z~0.8. The exact exposure times will be adjusted depending on the supernovae being followed.

OVERHEADS AND TOTAL TIME: The total exposure time requested above is 24.3hrs (NIRI imaging), 12.0 hrs (GMOS imaging) and 11.0 hrs (GMOS spectroscopy). The corresponding total times, including overheads, are (2*0.25 +24.3/0.75)=32.9hrs, (8*0.25 + 12.0/0.75)=18.0hrs and (5*0.5 + 11.0/0.75)=17.2hrs. Here we assume that obtaining GMOS spectroscopic flats to reduce the effects of fringing is included in the 25% overhead, and we also assume that the z and i images at peak can be obtained with the spectroscopy, removing the acquisition overhead for these. Finally 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 70.1hrs.

FUTURE TIME: NIRI and GMOS imaging time will be needed in semester 2003A to obtain 'reference' images once the SNe have faded, for subtraction of the host galaxy light from the supernova photometry.

DIVISION OF TIME BETWEEN TACS: This proposal is being submitted on behalf of the Supernova Cosmology Project to both the U.K. and 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. in approximately the proportion of partner shares, i.e. 46.7hrs (US) and 23.4hrs (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. The final selection of fields depends on the dates scheduled for searching but will be around 0 degrees declination in regions of low 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, about two weeks in the observer's 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 ("Satie")	13:57:11.95	+04:20:27.07	J=23.8 (depth to be reached)	17.5 hours
GSC0031200286 (wfs)	13:57:35.935	4:21:22.93	14.34 mag	separation 6.05
observing conditions: NIRI		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: NIRI		resources:		
SN3	13 00 00	00 00 00	(dummy target)	9.0 hours
GSC0495701179 (oiwfs)	13:00:07.366	-0:03:55.3	13.45 mag	separation 4.33
observing conditions: GMOS imaging		resources: GMOS imaging		
SN4	13 00 00	00 00 00	(dummy target)	9.0 hours
GSC0495701179 (oiwfs)	13:00:07.366	-0:03:55.3	13.45 mag	separation 4.33
observing conditions: GMOS imaging		resources: GMOS imaging		
SN2	13 00 00	00 00 00	J=23.8 (dummy target)	5.83 hours
Dummy OIWFS (oiwfs)	13:00:07.366	-0:03:55.3		separation 4.33
observing conditions: GMOS spec		resources: GMOS spec		
SN3	13 00 00	00 00 00	(dummy target)	5.83 hours
Dummy (oiwfs)	13:00:07.366	-0:03:55.3		separation 4.33
observing conditions: GMOS spec		resources: GMOS spec		
SN4	13 00 00	00 00 00	(dummy target)	1.83 hours
Dummy (oiwfs)	13:00:07.366	-0:03:55.3		separation 4.33
observing conditions: GMOS spec		resources: GMOS spec		
SN5	13 00 00	00 00 00	(dummy target)	1.83 hours
GSC0495701179 (oiwfs)	13:00:07.366	-0:03:55.3	13.45 mag	separation 4.33
observing conditions: GMOS spec		resources: GMOS spec		
SN6	13 00 00	00 00 00	(dummy target)	1.83 hours
GSC0495701179 (oiwfs)	13:00:07.366	-0:03:55.3	13.45 mag	separation 4.33
observing conditions: GMOS spec		resources: GMOS spec		

Resources

- Gemini North
  - NIRI

- Camera
  - f/6 (0.12 arcsec)
- Filter
  - Broad-Band
    - J (1.25 um)

- GMOS imaging (GMOS North)
  - Filter
    - i_G0302
    - z_G0304
  - 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
NIRI	50%	Any	80%	50%
GMOS spec	50%	50%	Any	50%
GMOS imaging	50%	80%	Any	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.

- 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.

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