Scientific Justification

Type Ia supernovae are thermonuclear explosions of a white dwarf (WD) in a binary system. They have been proven as excellent distance indicators for constraining cosmological parameters and are major contributors to chemical enrichment. However, there are several open questions regarding the physics of the explosions that still need to be addressed, for eg. the mass of the progenitor or the companion star of the WD in the binary system. Late time Near Infrared (NIR) spectra of Type Ia supernovae offer a unique window into understanding their properties. Due to their faintness, very few objects have been spectroscopically followed up in the NIR at epochs close to a year after maximum light. A very small fraction of those have spectra at more than one epoch. SN2014J, which is the closest supernova in 4 decades, provides a great laboratory to obtain a time series of spectra to observe the evolution of the SN at late epochs.

In Spyromilio et al. [2004] (hereafter S04), the authors note that the line velocities for their two spectra of SN1998bu at +250 and +344 days are not the same, indicating a dependence of the nebular velocity on the epoch of observation. This is critical since nebular velocities have been used in studies to indicate a relation between the kinetic energy of the ejecta and the total energy from the ^{56}Ni decay (eg. Mazzali et al. [1998], Blondin et al. [2012], Silverman et al. [2013]). If there is an evolution in the line velocities then the late-time expansion velocity would be dependent on the exact epoch of measurement and hence, the results would need to be reconsidered. A time series at late epochs would allow us to place firm constraints on any such evolution

Recent studies by Maeda et al. [2010,2011] have found a correlation between the optical pseudo-colour and the nebular velocity, which they interpret as an indication that the ejecta are asymmetrically distributed. In the NIR spectra of SN1998bu, the emission lines appear broader and more skewered at later times which implies an asymmetric distribution of iron in the ejecta. Hence, for SN2014J, the late spectra in the NIR can shed light on the distribution of iron in the ejecta.

The Fe II lines in the NIR spectra at late times allow for an independent estimate of the iron mass. In S04, the authors show that the Fe II emission is consistent with the Fe^{+} mass from other methods, eg. the (pseudo-)bolometric luminosity at maximum. the evolution of the NIR spectrum provides direct evidence for Co to Fe decay. At late epochs, the flattening of the cooling curve and the exponential decline of the heating due to radioactivity combine to produce rapid cooling of the ejecta. This leads to a sharp decrease in the optical and NIR flux and is known as the Infrared Catastrophe (IRC; Axelrod 1980). The measurement of the iron mass at late times can shed light onto whether an IRC has occurred in the ejecta

The width of the Fe [II] 1.644 μm line is sensitive to the electron capture at early times which increases as a function of central density. Hence, an accurate measurement of the Fe [II] line width allows us to put firm constraints on the initial central density and therefore, on the total ejecta mass. This line width can also be used to constrain the magnetic field in the ejecta. Diamond et al. [2014] have used this to evaluate the magnetic field in SN2005df. They find evidence for a high initial magnetic field, however, due to the noise in the spectra, combined with low central density, they cannot rule out 0G. Observations of SN2014J with a higher signal to noise offer a prospect of improving upon those constraints.

A comparison of recently published late time observations of SN2011fe (at $> +$ 1000d) with earlier data (at $\sim +300$d) shows that the prominent Fe [III] feature at 4700 $\mathring{A}$ has almost completely faded away, indicating a significant change in ionisation (Taubenberger et al. [2015]). This evolution in the ionisation is a strong motivation to observe SNIa regularly at late epochs.

Since the Fe [II] lines at 1.25 and 1.64 μm arise from the same upper level, their ratio can be given by radiative transition rates. Hence, a comparison of the observed and expected ratios can give

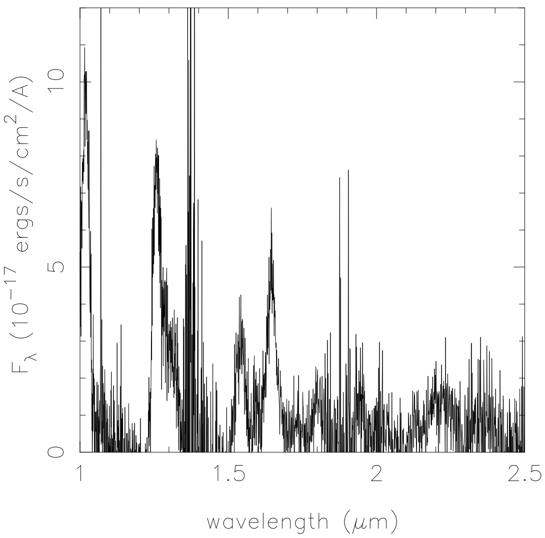


Figure 1: The NIR spectrum at +250 days for SN1998bu is shown from S04. We aim to improve upon the signal to noise and to observe the SN at later epochs.

an estimate of the extinction from the host galaxy dust. This provides an independent method to cross-check the extinction estimates from complementary early time data.

References

[Axelrod1980] Axelrod T. S., 1980, PhDT

[Diamond, Hoeflich, & Gerardy2014] Diamond T., Hoeflich P., Gerardy C. L., 2014, arXiv, arXiv:1410.6759

[Maeda et al.2011] Maeda K., et al., 2011, MNRAS, 413, 3075

[Maeda et al.2010] Maeda K., et al., 2010, Natur, 466, 82

[Spyromilio et al.2004] Spyromilio J., Gilmozzi R., Sollerman J., Leibundgut B., Fransson C., Cuby J.-G., 2004, A&A, 426, 547

[Taubenberger et al.2015] Taubenberger S., et al., 2015, MNRAS, 448, L48

Experimental Design

We propose to obtain 3 NIR spectra from the months of March to May. This will allow us to have a time series of spectra between $\sim + 400$ and $\sim +500$ days. A time series at these epochs will allow us to clearly discern whether there is any evolution in the line velocities at late epochs. Having 3 spectra will allow us to look at the line velocity evolution in the SN.

SN2014J is the nearest SNIa in close to 4 decades. Due to its brightness it offers a great opportunity to obtain high S/N late time observations which are not possible for other, more distant SNIa.

In order to study the late time properties of SN2014J, we have also proposed for photometric observations in the optical and NIR on the Himalayan Chandra Telescope (HCT). This will allow us to get a late time (pseudo)-bolometric light curve which can elucidate the configuration of the magnetic field in the ejecta. We will also we able to observe and time sample the late NIR light curve to understand the flattening in the JHK bands.

Technical Description

We would like 15 exposures of 120 seconds each per night. A total on source exposure time of 30 mins gives us an S/N of ~ 50 (see ITC pdf attached). For each such set of exposures, the acquisition time is 12 mins. Hence, in total we request for 1 hour for each night (using a conservative estimate for overheads), and a total of 3 hours for the period of March to May.

We would like to use the cross-dispersed mode in order to obtain a complete spectrum from 0.8 to 2.5 μm. Recently published observations of SN2005df (Diamond et al. [2014]) using GNIRS have also used cross-dispersion mode to get a complete spectrum from 0.8-2.4 μm.

The observations can be carried out during any phase of the moon. We would like to request clear nights for the observations. Details of the ITC are attached.

Band 3 Plan

Classical Backup Program

Justify Target Duplications

Publications

Taubenberger S., et al., 2015, MNRAS, 448, L48

Kerzendorf W. E., Taubenberger S., Seitenzahl I. R., Ruiter A. J., 2014, ApJ, 796, LL26

Maguire K., et al., 2014, MNRAS, 444, 3258

Use of Other Facilities or Resources

Previous Use of Gemini

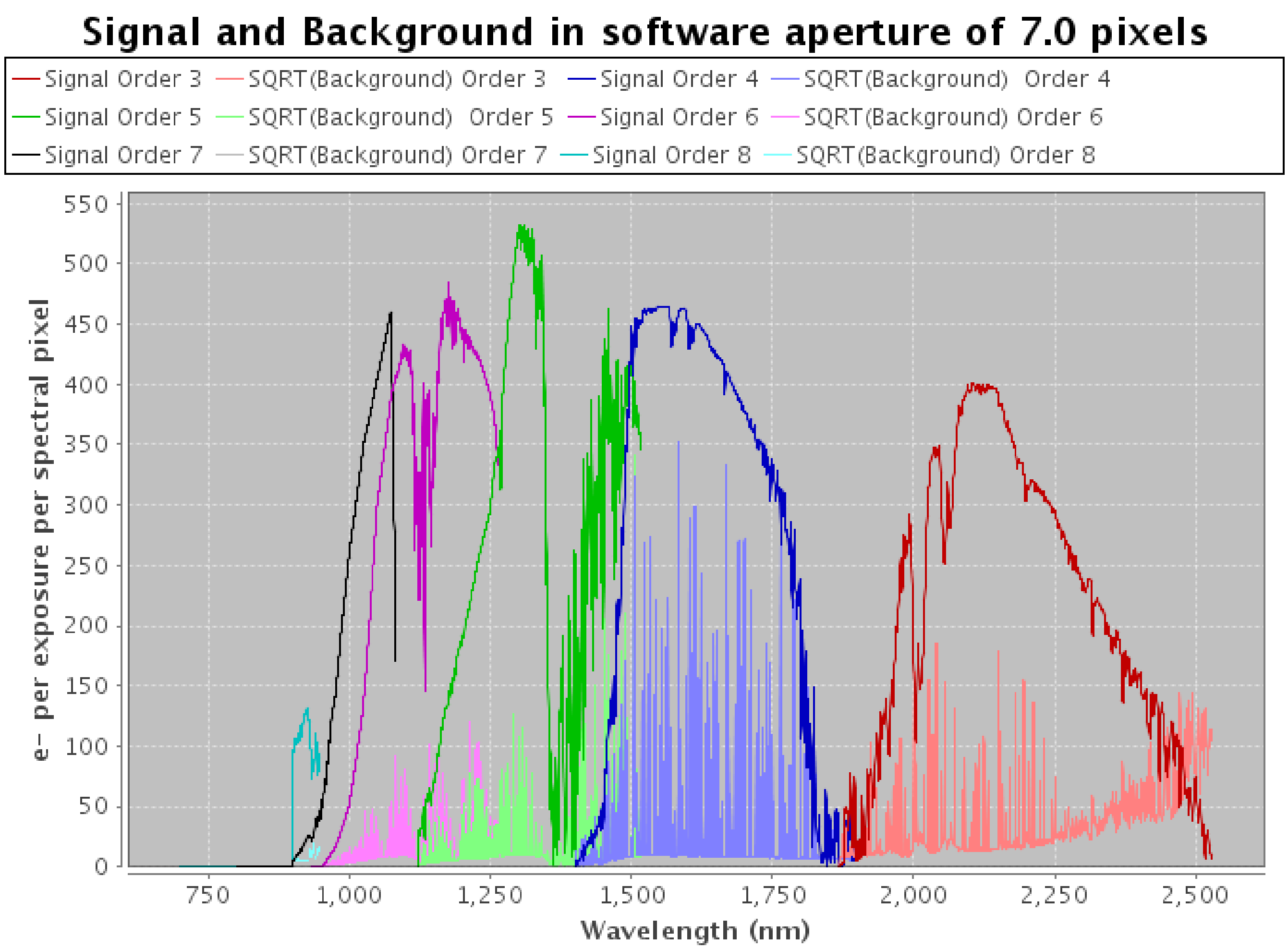
ITC Examples

Gemini Integration Time Calculator
GNIRS version 4.0

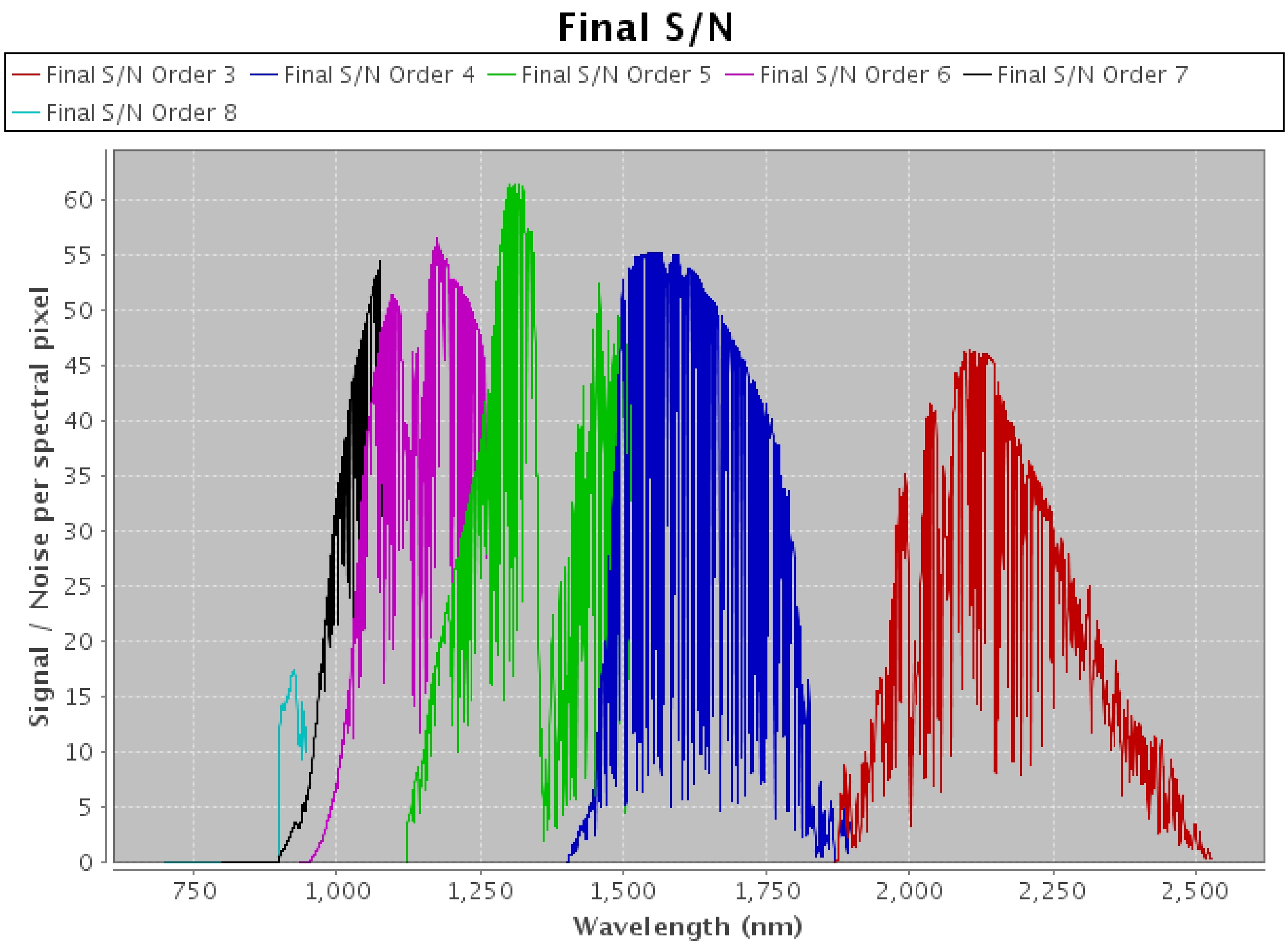
Click here for help with the results page.
software aperture extent along slit = 1.07 arcsec
fraction of source flux in aperture = 0.62
derived image size(FWHM) for a point source = 0.76arcsec

Sky subtraction aperture = 1.0 times the software aperture.

Requested total integration time = 1800.00 secs, of which 1800.00 secs is on source.



Click here for ASCII signal spectrum.
Click here for ASCII background spectrum.



[Click here for Final S/N ASCII data.]

Input Parameters:
Instrument: GNIRS

Source spatial profile, brightness, and spectral distribution:
The z = 0.0 point source is a 5000.0K Blackbody, at 16.55 mag in the J band.

Instrument configuration:
Optical Components:
- Filter: XD
- Cross-Dispersing Prism
- Fixed Optics
- Camera: 0.15arcsec/pix (Short Blue)
- Detector - 1K x 1K ALADDIN III InSb CCD
- Focal Plane Mask: slit0.675
- Grating: G32
- Read Noise: 10.0
- Well Depth: 90000.0

Central Wavelength: 1616.85 nm
Pixel Size in Spatial Direction: 0.15arcsec
Pixel Size in Spectral Direction(Order 3): 0.647nm
Pixel Size in Spectral Direction(Order 4): 0.485nm
Pixel Size in Spectral Direction(Order 5): 0.388nm
Pixel Size in Spectral Direction(Order 6): 0.323nm
Pixel Size in Spectral Direction(Order 7): 0.277nm

Pixel Size in Spectral Direction(Order 8): 0.242nm

Telescope configuration:
- silver mirror coating.
- side looking port.
- wavefront sensor: pwfs

Observing Conditions:
- Image Quality: 70.00%
- Sky Transparency (cloud cover): 50.00%
- Sky transparency (water vapour): 80.00%
- Sky background: 80.00%
- Airmass: 1.50

Frequency of occurrence of these conditions: 22.40%

Calculation and analysis methods:
- mode: spectroscopy
- Calculation of S/N ratio with 30 exposures of 60.00 secs, and 100.00 % of them were on source.
- Analysis performed for aperture that gives 'optimum' S/N and a sky aperture that is 1.00 times the target aperture.

Output:
- Spectra autoscaled.

Reference	Allocation	% Useful	Status of previous data