The Supernova Spectropolarimetry Project: Results from Multi-Epoch Observations of the Type IIb SN 2011dh

A rare type-IIb class supernova with an HST detected progenitor and multi-epoch spectropolarimetric observations.

Abstract

The Supernova Spectropolarimetry Project is a recently formed collaboration between observers and theorists that focuses on decoding the complex, time-dependent spectropolarimetric behavior of supernovae (SNe) of all types. Using the CCD Imaging Spectropolarimeter (SPOL) at the 61° Kuiper, the 90° Bok, and the 6.5-m MMT telescopes, we obtain multi-epoch observations of each target, aiming to construct the most comprehensive survey to date of supernovae in polarized light.

Preliminary results from the SNSPOL project provide support for the increasingly popular hypothesis that many supernovae are aspherical explosion events. Thus far, we have observed 27 different SNe, many over multiple epochs, over the course of the last three years. While the history and evolution of these events is often studied with photometric and spectroscopic information, most supernovae are not studied with the combined advantage that spectropolarimetric data provides. The use of polarimetry allows us to probe the extent of the asphericity of the explosions while the use of spectropolarimetry allows us to characterize this asphericity across a variety of chemical species individually and as a function of velocity. Modern 3-D model simulations favor an explosion mechanism that is often inherently asymmetric in nature. Here, we showcase some of our initial results for the nearby type-IIb SN 2011dh that demonstrate the unique in formation that spectropolarimetric observations provide.

Observations

The observations described here were obtained using the CCD Imaging Spectropolarimeter SPOL (Schnitt et al.) on the 61° Kuiper 90° Bok, and 6.5-m MMT telescopes. Our typical configuration uses the 600 lines/mm grating in first order with a 51° long slit. The width of the aperture is chosen to be between 1° and 5° depending on the SN position in the host. Our typical wavelength coverage is 4000-7500Å with a resolution of ~20Å. A standard Hoya L38 blocking filter is used to avoid second-order contamination for λ<7600Å. A rotatable semi-achromatic half-wave plate is used to modulate incident polarization and a Wollaston prism in the collimated beam separates the orthogonally polarized spectra onto a thinned, anti-reflective-coated 800×1200 pixel SITe CCD. The efficiency of the wave plate as a function of wavelength is measured and corrected for by inserting a fully-polarizing Nicol prism into the beam above the slit. A series of four separate exposures that sample 16 orientations of the wave plate yield two independent, background-subtracted measures of each of the normalized linear Stokes parameters, q and u. Several such polarization sequences of each target are obtained each night and combined, with the weighting of the individual measurements based on photon statistics.

Results

Below, we showcase some of the results from the type-IIb SN 2011dh. The spectropolarimetric data were acquired in 2 different epochs. Data were acquired on multiple nights for each epoch and combined. The dates listed—June 14, 2011 and July 28, 2011—are the start dates of each epoch of observation. The flux spectrum along with the calculated Q, U, and θ values are displayed for both epochs. We also show q-u plots for the entire observed spectrum. Photometry after the explosion event is available in a number of bands (BVRI).

The polarization signal from a supernova is thought to come from electron scattering in the case of an aspherical photosphere and from the interstellar polarization (ISP). Line absorption and emission features also affect the polarization signal, producing what should appear as an inverse P Cygni profile in our polarization spectrum. After controlling for the ISP, we thus find that the remaining signal suggests varying levels of asphericity in the photosphere at different wavelengths.

Prior to SN 2011dh, only 2 other type-IIb SNe had been observed with spectropolarimetric data (2001ig and 2008ax), making this a largely unstudied class of object with this information. HST archival images allowed for the detection of progenitor systems in case of 2008ax and 2011dh (Crockett et al., Maunder et al. 2011), while a blue supergiant companion was found at the location of 2001ig’s explosion after the fact. This gives us the unique opportunity to study a rare class of event in which we have powerful information about both the progenitor systems and the nature of the explosion asymmetry.

Epoch 1 begins 15 days post explosion and Epoch 2 begins 59 days post explosion.

The wavelength range 4500-7500Å is plotted in bins of size 28Å with physical color corresponding roughly to wavelength.

An ISP value of Q = -0.2%, U = 0.4% was chosen based on the depolarization of Hα in Epoch 1. This value of the ISP is not in agreement with an estimate solely based on reddening, suggesting that there are variations in the reddening law (Sahu et al.).

Image of SN 2011dh in M51 taken by the Palomar 48-inch Telescope (taken from Arcavi et al.).

Photometry acquired by the Mount Laguna Observatory 40” telescope is available in the BVRJ bands as labeled (Image credit to Julienne Sumandal). Dates are set relative to maximum brightness, which occurred roughly ~20 days after explosion in the visual bands. The absolute peak magnitude of SN 2011dh in the V band was -17.123 (Sahu et al.).

The flux spectrum for SN 2011dh with 4Å size bins.

Epoch 1 shows strong depolarization of the Hα absorption feature, much as in the case of 2001ig (Maunder et al. 2007).

While the Hα depolarization is essentially gone by epoch 2, other spectral lines show evidence of depolarization at this phase.

We acknowledge support from NSF/AST Grant 1210599

References


Christopher Bilinski1, G. Grant Williams2, Paul S. Smith1, Nathan Smith1, Peter A. Milne1, Jennifer L. Hoffman3, Leah N. Huk3, Douglas C. Leonard4, Luc Dessart5

1Steward Observatory
2MMT Observatory
3University of Denver
4San Diego State University
5Laboratoire Lagrange, CNRS