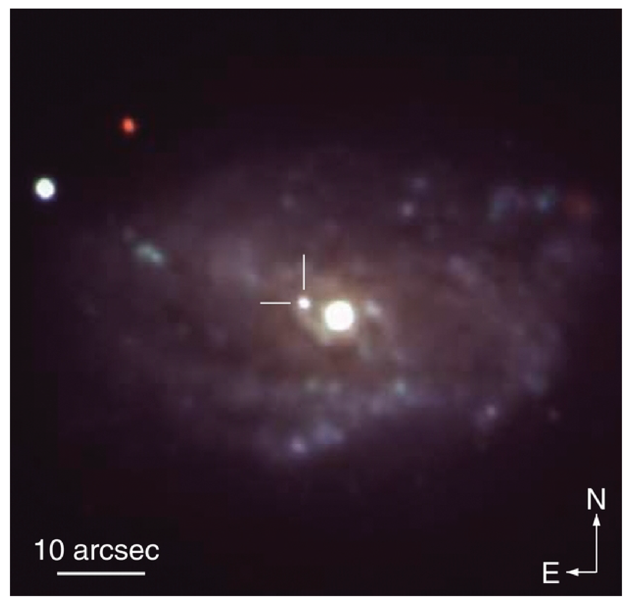
The Supernova Spectropolarimetry Project: Evolution of asymmetries in the very luminous Type Ib SN 2012au

Jennifer L. Hoffman[1], Nathan Smith[2], Jon Mauerhan[2], Christopher Bilinski[2], Luc Dessart[3], Leah N. Huk[1], Douglas C. Leonard[4], Peter A. Milne[2], Paul S. Smith[2], & G. Grant Williams[5]

Polarization data support a jetted explosion and may reveal an equatorial structure that dissipates over time.



Day 334 image taken with MMT (from Milisavljevic et al. 2013, ApJ, 770, L38)

BACKGROUND

SN 2012au was a luminous, energetic, slowly evolving SN Type Ib. It reached its peak brightness of M_R = -18.7 on 2012 Mar 21. It ejected 3–5 $M_\odot$ and had a kinetic energy output of ~ 10^{52} erg.

Spectral properties and high expansion velocities suggest that 2012au may be an intermediate object between normal SNe Ib and SLSNe or GRB-SNe.

Its light curve and spectra both suggest aspherical and/or non-uniform ejecta. Spectropolarimetric observations provide independent evidence for such geometrical asymmetries.

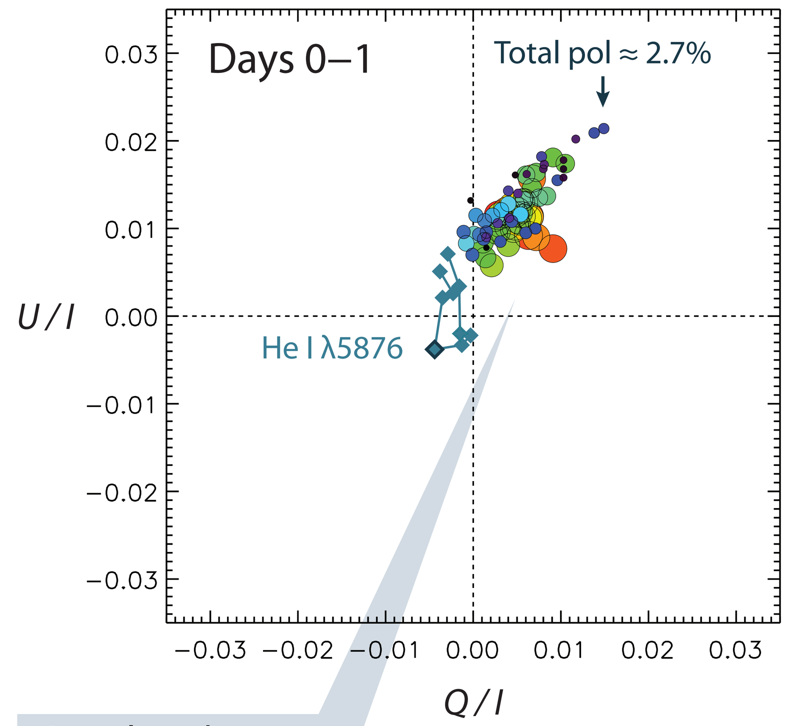
OBSERVATIONS

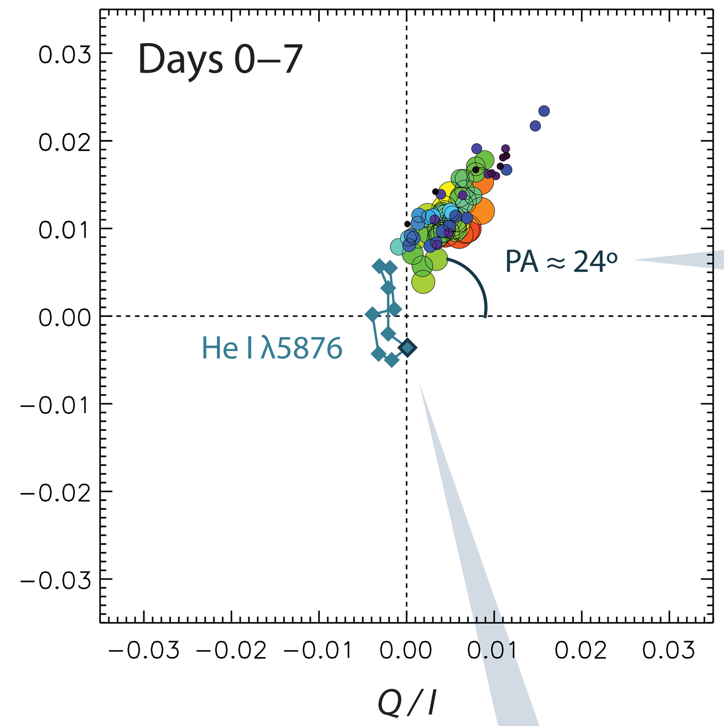
We observed SN 2012au with the SPOL spectropolarimeter 6 times at 3 Steward Observatory telescopes. We display a subset of the results here, including one high-resolution spectrum obtained at the MMT. For simplicity, we have combined several epochs together.

Epoch	Telescope	Comments
Days 0–1	90″ Bok	4 exposures
Days 0–7	90″ Bok	9 exposures
Days 35–40	61″ Kuiper	5 exposures
Days 57–67	61″ Kuiper	3 exposures
Day 69	MMT	spectrum only
Days 86–91	61″ Kuiper	3 exposures

REFERENCES

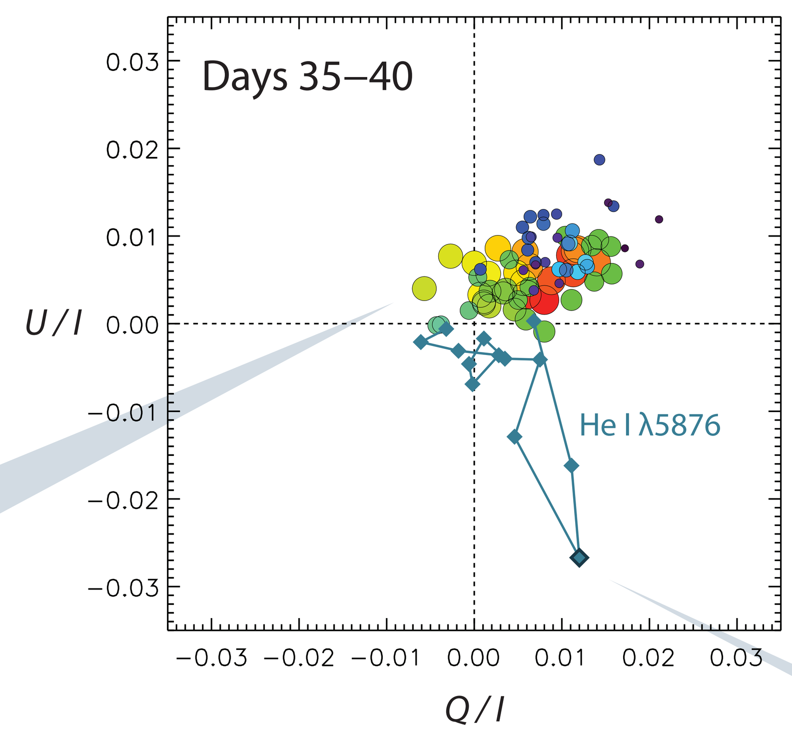
Howerton et al. 2012, CBET, 3052, 1
Kamble et al. 2013, arXiv:1309.3573
Milisavljevic et al. 2013, ApJ 770, L38
Takaki et al. 2013, ApJ 772, L13



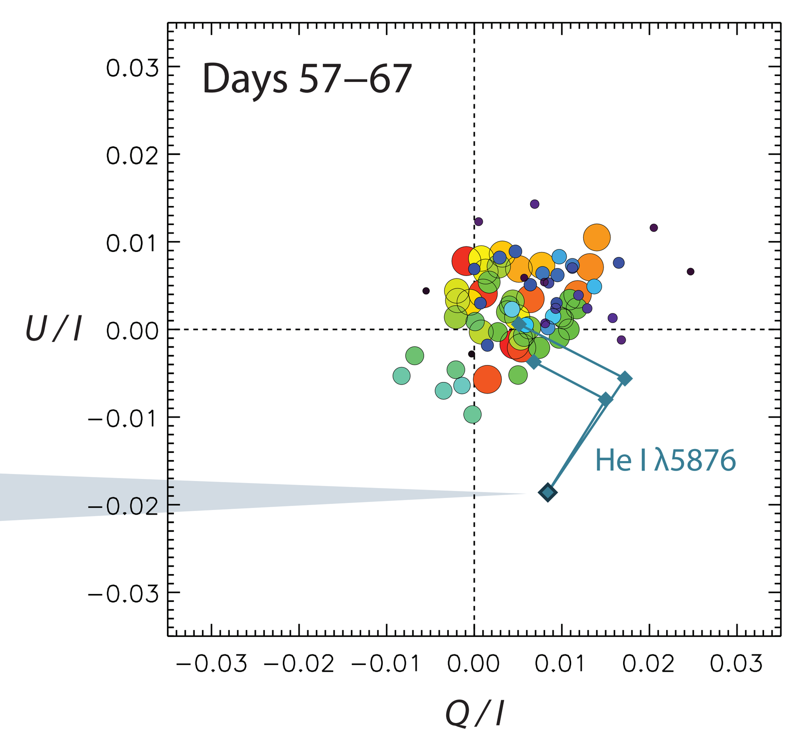


Q-U plots depict total polarization as distance from the origin and position angle as ½ the angle from the +*Q* axis. Linear behavior indicates a well-defined system axis.

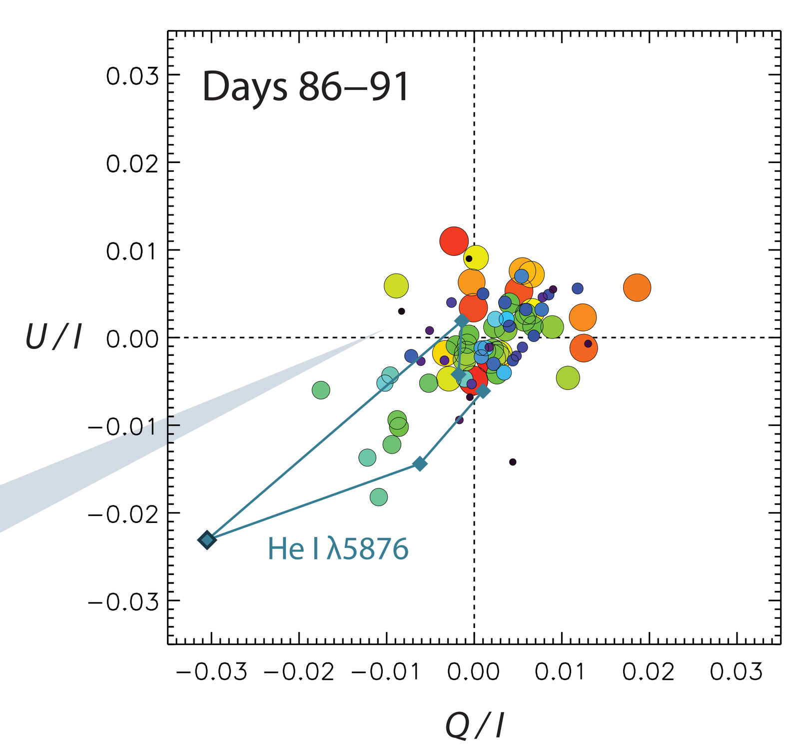
Crossing the origin results in a 90° PA flip, often associated with a disk-jet structure. (This conclusion depends on ISP being very small.)



Data have been deredshifted. Continuum points are binned to 50 Å and shown with point size and color proportional to wavelength. Error bars are smaller than the points.



The He I λ5876 line is defined from -13,000 km/s to -8600 km/s and overplotted in 10–20 Å bins with connected diamonds. Darker points represent the velocity bin corresponding to ≈ -10,000 km/s.



No interstellar polarization (ISP) has been removed, but the later-time continuum points scatter around 0, suggesting ISP is negligible.

RESULTS / DISCUSSION

The ejecta were aspherical at early times.
⇒ Possible jet signature

In the first week, the position angle of the continuum is constant with wavelength at ≈24°. It drops to ≈16° by Days 35–40 and becomes less well defined at later times.

This behavior is consistent with the previously proposed 2-component ejecta. It may also suggest a jet-driven explosion with inner ejecta more spherical than the outer.

The He I λ5876 line has a high-velocity polarized component at early times.
⇒ Associated with jet or aspherical outer ejecta

The flux minimum shifts from -14,000 to -10,000 km/s over time. In polarization, the feature initially has minima at both these velocities, but later the high-velocity polarization signature disappears.

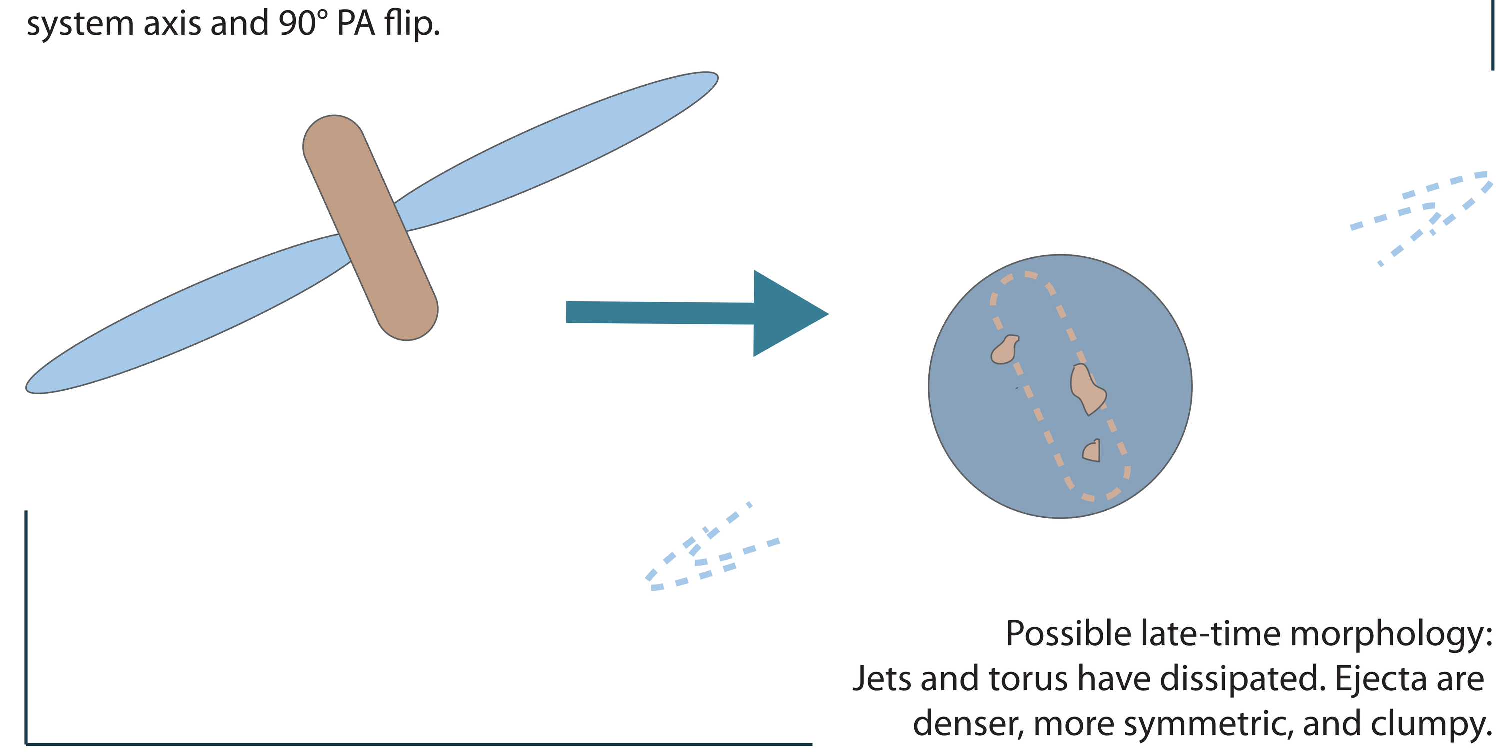
The -14,000 km/s helium feature is likely associated with the jetlike ejecta component, since its PA is similar to that of the continuum.

A polarized He I λ5876 component at -10,000 km/s persists throughout our data.
⇒ Equatorial structure, dissipating at late times

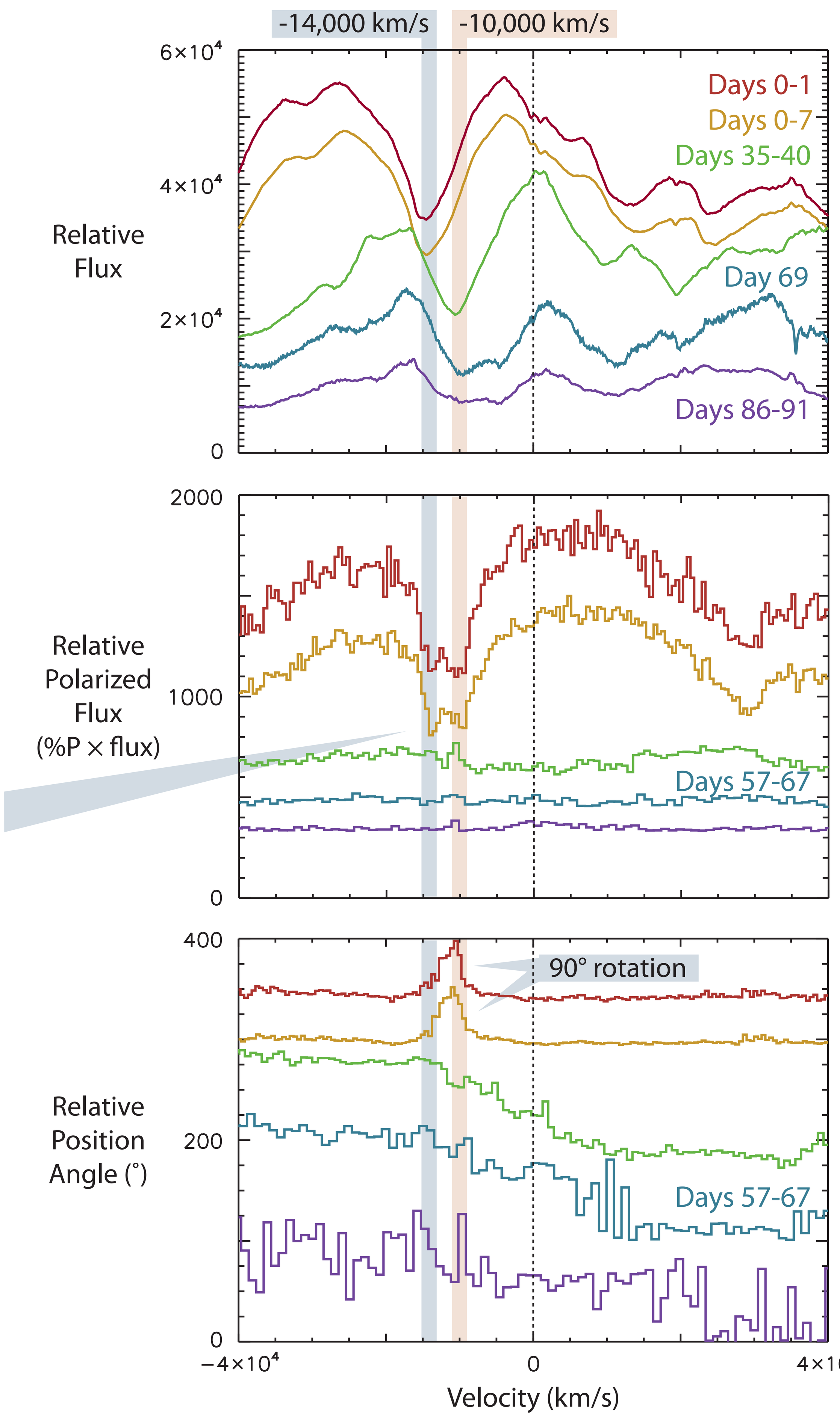
The largest excursions in polarization and PA consistently occur at -10,000 km/s in all observations. The PA of this component is initially 90° different from the continuum, but changes dramatically over time.

In the first 2 epochs, this feature suggests an equatorial torus or ring orthogonal to the jet. Over time, this structure may dissipate or be overrun, leaving blobs of He or Ni that block changing regions of the inner ejecta. (This interpretation depends on ISP being negligible.)

Possible early-time morphology: Jets and torus create well-defined system axis and 90° PA flip.



Possible late-time morphology: Jets and torus have dissipated. Ejecta are denser, more symmetric, and clumpy.



NEXT STEPS

Constrain ISP with probe star observations.

Break down epochs into individual spectra to look for shorter-timescale changes.

Analyze spectropolarimetric data obtained with SPOL at MMT on Day 26 and Day 296. Very late-time observations will reveal whether asymmetries persist deep into the nebular phase.

Use radiative transfer modeling to quantify proposed scattering geometries.

Investigate other line behavior (Hα, Ca II, etc.).

Compare with spectropolarimetric behavior of other SNe Ib/Ic.

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AAS Extras!

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