

Optical polarimetry of SN 2004bv[★]

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Abstract. We report *R* band imaging polarimetry of SN 2004bv in NGC 6907 on June 19.299 (UT middle of observation), i.e., two weeks after maximum. We have obtained $[0.11 \pm 0.02]\%$ at position angle $118^\circ.7$ for the observed polarization. The average foreground polarization from field objects was estimated to be $[0.12 \pm 0.02]\%$ at PA $163^\circ.4$, consistent with the low reddening towards the SN. Spectroscopy reported elsewhere does not show the Na I D line in the SN spectrum suggesting that the interstellar polarization in the host galaxy is negligible. If this is the case, the data are consistent with SN 2004bv being close to spherically symmetric. The estimated *R* magnitude at the time of the observations was 14.5 mag. An upper limit to the SN *H* magnitude on June 20.259 (UT) was 13.9 mag. The role that small and medium-sized telescopes may play in studying the symmetry and time evolution of SN explosions is pointed out.

Key words. polarization – supernovae: individual: SN 2004bv

1. Introduction

SN 2004bv was discovered by Nakano et al. (2004) on May 24.70 (UT) located $3''.8$ West and $20''.7$ South of the center of NGC 6907. Spectroscopy near maximum brightness (Li et al. 2004) showed that it is a Type Ia supernova (SN). Li et al. (2004) point out that SN 2004bv resembles SN 1991T (Filipenko et al. 2004) and SN 1999aa (Li et al. 2004).

Polarimetry is a powerful tool to help to understand the geometry of SN explosions. A bi-modal trend is now accepted with Type Ia SNs having low or null polarization and core collapse SNs (Types II, Ib and Ic) showing significant polarization (Wang 1996). This trend implies that Type Ia SNs are close to having spherically symmetric geometry while core collapse SNs are non-spherically symmetric. Nevertheless, in the past few years exceptions to this Type Ia pattern appeared (Howell et al. 2001; Wang et al. 1997, 2003, 2004, 2005). New polarimetric data are hence needed to clarify this picture.

In this letter we present optical linear polarization measurements in the *R* band of SN 2004bv obtained nearly two weeks after the optical maximum. The observations and data reduction are presented in Sect. 2 and a comparison of our results with previous works, along with final comments, are in Sect. 3.

2. Observations

The observations were made using IAGPOL, the IAG imaging polarimeter (Magalhães et al. 1996), at the *f*/13.5 Cassegrain focus of the 0.6m IAGUSP telescope. It is sited at the

Observatório do Pico dos Dias (OPD), Brazil (latitude -22°). When in linear polarization mode, the polarimeter uses a rotatable, achromatic half-wave retarder followed by a calcite Savart plate. This provides two images of each object in the field, separated by 1mm (corresponding to $25''.5$ at the telescope's focal plane) and with orthogonal polarizations (see Fig. 1). One polarization modulation cycle is covered for every 90° rotation of the waveplate. The polarimeter is highly efficient and photon-noise limited for point sources. The simultaneous imaging of the two beams allows observing under non-photometric conditions and at the same time the sky polarization is practically canceled. Additional details about this polarimeter can be found in Magalhães et al. (1996), Pereyra (2000) and Pereyra & Magalhães (2002).

The data were collected on June 19.299 (UT at the middle of the observation). The measurements were made using a standard *R* filter with a 1024×1024 CCD, covering an area of $\sim 10' \times 10'$. A sequence of eight waveplate positions separated by $22^\circ.5$ was used. The integration time per waveplate position was 5 min and the total observing time was $(5 \times 8 =) 40$ min.

For the data reduction process, we follow the procedure indicated in Pereyra & Magalhães (2002) using the PCCDPACK package (Pereyra 2000), written for the IRAF¹ environment. Correction to convert the resulting instrumental polarization position angle to the equatorial system was found from observations of polarized standard stars taken on the same night. The instrumental polarization, obtained from observations of

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[★] Based on observations obtained at the *Observatório do Pico dos Dias*, LNA/MCT, Itajubá, Brazil.

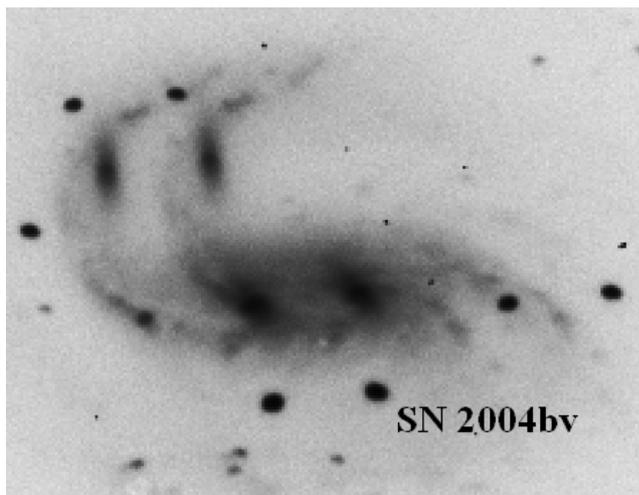


Fig. 1. Image of the SN 2004bv field obtained with the IAGPOL polarimeter in R filter on June 19.299. Each object has two images, each orthogonally polarized to the other, due to the polarimeter's calcite prism. The supernova is located $3'8$ West and $20'7$ South of the center of NGC 6907. North is to the top and East is to the left.

unpolarized stars, was smaller than 0.04%, a typical value for the polarimeter/telescope combination. No correction for instrumental polarization was hence applied to the data.

The effect on the data of the sky gradient induced by the host galaxy was checked using different and increasing sky annulus (between $3'6$ and $42''$). Then, the average (weighted by the errors) linear observed polarization (P) and the polarization position angle (θ , measured from north to the east) for SN 2004bv, itself measured with an aperture radius of $3''$, were $P = [0.11 \pm 0.02]\%$ and $\theta = 118'7$. The polarization 95% confidence interval for this polarimetric signal-to-noise is $[0.07, 0.15]\%$ (Simmons & Stewart 1985). From field stars (see Sect. 2.1 below), the estimated SN R magnitude at the time of the observations was found to be 14.5 mag.

Images in the H ($1.65 \mu\text{m}$) band were obtained on June 20.259 (UT) with the same telescope and the observatory's near-IR CamIV camera. The total integration time for this infrared data was 5 min. Five frames dithered by $30''$ were used to generate the sky frame. Individual frames were sky-subtracted, flat-fielded, aligned and added before the photometry procedures. An upper limit of 13.9 mag for the SN was obtained.

2.1. Foreground polarization

The Galactic foreground polarization for SN 2004bv was estimated using field stars on the same CCD frames. The PCCDPACK package provides the polarization of each object in the CCD frames, as well as the error-weighted average Stokes parameters (Q and U) for all the objects considered. We take these parameters as the average foreground polarization towards the supernova.

The objects used (Fig. 2) were USNO A-2.0: 0600-42605819, 0600-42615316 and 0600-42617305. Their average polarization was measured to be $P = [0.12 \pm 0.02]\%$;

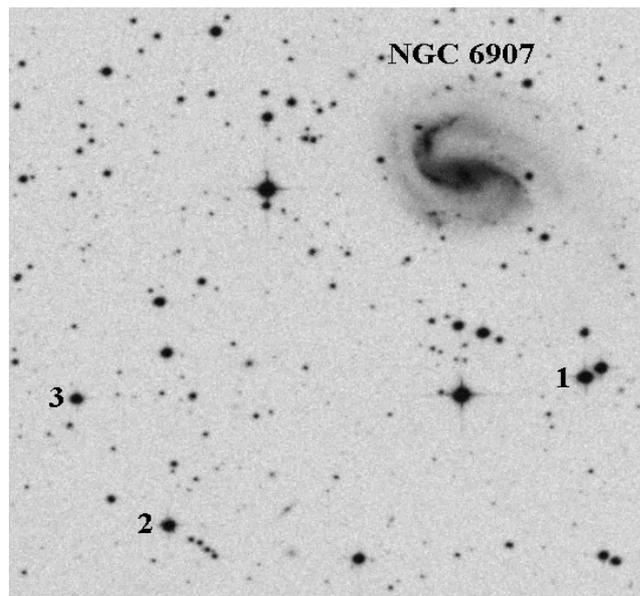


Fig. 2. Field objects around NGC 6907 used to calculate the Galactic foreground polarization towards SN 2004bv: (1) USNO A-2.0 0600-42605819; (2) USNO A-2.0 0600-42615316; (3) USNO A-2.0 0600-42617305. This DSS2 Red image covers ($\sim 9' \times 9'$). North is to the top and East is to the left.

$\theta = 163'4$. This measurement is below the expected maximum polarization ($\sim 9E(B-V)$, Serkowski et al. 1975) towards the supernova if a Galactic reddening is assumed ($E(B-V) = 0.064$, Schlegel et al. 1998). This small $E(B-V)$ towards the host galaxy NGC 6907 ($l = 18^{\text{h}}9$, $b = -30'8$) is thus consistent with the negligible Galactic foreground polarization we found.

Li et al. (2004) do not report Na I D line in the spectrum and the low polarization for SN 2004bv would indicate also that the interstellar polarization in the host galaxy is negligible. As a check, we measured the galaxy nucleus with an aperture radius of $1.8''$ and found it to be polarized at a level of $[0.26 \pm 0.07]\%$ at PA $155'2$. This value, and especially its polarization angle, is very close to the Galactic foreground polarization found above. Hence, the data are consistent with SN 2004bv being close to spherically symmetric.

An updated light curve for SN 2004bv is shown in Fig. 3. We included the R and H magnitude obtained by us at the time of our observations. The last ones are consistent with a Type Ia SN \sim two weeks after the optical maximum (\sim Jun. 04).

3. Comments

As pointed out in Sect. 1, in general most Type Ia SN with polarimetric data ($\sim 15\%$ of total Type Ia SNs) present low (observed or intrinsic) polarization. Examples of this pattern are SN 1972E (0.35%), SN 1981B (0.41%), SN 1992A (0.3%), SN 1994D (0.3%), SN 1994ae (0.3%), and, SN 1995D (0.2%), (Wang et al. 1996); and, SN 2002el ($< 0.2\%$), (Wang 2002). This low polarization indicates that the explosions in Type Ia SNs are preferentially spherically symmetric. The negligible optical polarization value obtained by us for SN 2004bv seems to be consistent with this overall trend.

