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PHOTOMETRY OF PECULIAR TYPE IA SUPERNOVA SN2005HK

Jessica C. Carter[1]
Department of Physics and Astronomy, Valdosta State University, Valdosta, GA 31698
and
Mark Leising
Department of Physics and Astronomy, Clemson University, Clemson, SC 29634

ABSTRACT

BVRI photometry of the peculiar Type Ia supernova SN2005hk is presented, with emphasis on late-time observations. Results are derived by performing aperture photometry on images taken with the Bok and Mayall telescopes. Instrumental magnitudes are calibrated with published magnitudes of stars in the frames. The light curve presented demonstrates that this particular supernova is classified as "peculiar" due to its deviation from the standard light curve of Type Ia Supernovae. The late light curves appear quite flat, though some questions about our analysis, subtraction of the underlying galaxy in particular, remain.

Subject headings: supernovae: general — supernovae: individual (SN2005hk)

1. INTRODUCTION

Type Ia supernovae (SNe Ia) are the thermonuclear explosions of white dwarf stars. They occur when a white dwarf in a binary star system accretes sufficient mass from its companion star, typically a red giant, to reach nearly the Chandrasekhar mass limit of 1.4 $M_{\odot}$. In its death throes, the formerly carbon-oxygen white dwarf ejects a layer of carbon and oxygen at a speed of 10^9 cm/s, followed by ejecta of silicon, sulfur and calcium. At the center of the ejecta is radioactive nickel, ^{56}Ni, with a core of stable iron-peak elements.

These explosions are of great importance to astronomers for cosmological studies, they are major producers of iron in the universe and provide much of the heating of the interstellar medium. Given that most SNe Ia are of comparable absolute magnitudes and share similar light curves, they prove themselves useful as standard candles for measuring distances on vast extragalactic scales. Studies at early times yield information on the total energy output, while late-time studies ($\geq$150 days) of light curves and spectra provide information on the orientation of the supernova's magnetic field as well as composition of its core (Stritzinger & Sollerman 2007). Continued observations of their spectra and improvements to models of their light curves will help us understand these explosions better, and possibly make them more reliable as standard candles.

Type Ia supernovae are often characterized as "normal" or "peculiar." Peculiar SNe Ia usually are designated so because they deviate from the normal light curves as either having sub-luminous or super-luminous peak brightnesses. Their ejecta velocities are usually slower than that of normal SNe Ia. Late-time spectral observations differ greatly, showing permitted lines of Fe II, Ca II, and Na I, rather than forbidden lines of Fe II, Fe III, and Co III. Such is the case of SN2005hk, which Sahu et al. (2008) describes as having a slower decline rate in its light curves compared to normal supernovae SN1994D and 2003du. We present in this paper photometric observations of SN2005hk in comparison to the light curve of a typical SNe Ia.

Electronic address: jccarter@valdosta.edu; lmark@clemson.edu
[1] Southeastern Association for Research in Astronomy (SARA) NSF-REU Summer Intern

2. OBSERVATIONS AND IMAGE PROCESSING

SN2005hk was observed in *BVRI* bands with the 2.3-m Bok telescope and the 4-m Mayall telescope, both of Kitt Peak National Observatory (KPNO) of Tuscon, Arizona. The Bok telescope was equipped with the 90″ Prime Focus Wide-Field Imager, a mosaic of four 4k×4k CCDs with a field of view of 1.16° × 1.16°, corresponding to a plate scale of 0.45″/pixel. The Mayall telescope was equipped with "MOSAIC", a collection of eight 8k×8k pixel CCDs with a field of view of 4′ × 4′, and a plate scale of 0.26″/pixel.

The images were zero and dark subtracted, and flattened with the `ccdproc` task in IRAF. Once the images were processed, aperture photometry was performed using the tasks `qphot`, `mknobsfile`, `mkconfig`, `fitparams`, and `invertfit`. The aperture used only slightly larger than the FWHM of the stellar profiles, because of the nearby structure of the host galaxy. System photometry parameters were calculated from measurements of the local standard stars whose properties were determined by Sahu et al. (2008).

3. DATA

The derived magnitudes of SN2005hk on selected nights are presented in Table 1. In each of the graphs of Figures 1–4, the diamonds represent the light curve of 1992A, a "normal" SNe Ia that was studied by Hamuy et al. (1996). The squares in each graph represent 2005hk; the normal template light curves have been shifted vertically to fit by eye.

Figures 1-4 depict SN2005hk reaching peak magnitude in B-band slightly ahead of a "normal" SN Ia. Its light curve decline rate is slower than that of most SNe Ia, suggesting slower expansion and longer diffusion times of the photons produced near the peak of the light curve. The flat late light curves possibly suggest that this su-

TABLE 1
Photometric Observations of SN2005hk

Date	B	Error (B)	V	Error (V)	R	Error (R)	I)	Error(I)
2005 Nov 7	15.920	0.003	15.971	0.009	15.917	0.006	15.551	0.012
2005 Nov 8	15.856	0.003	15.897	0005	15.691	0.002	15.768	0.005
2005 Nov 13*	16.022	0.069	15.739	0.050	15.631	0.034	15.577	0.051
2005 Dec 8*	18.600	0.019	17.076	0.010	16.501	0.017	16.106	0.009
2005 Dec 12*	18.758	0.033	17.237	0.024	16.646	0.025	16.251	0.018
2006 Jan 12*	19.204	0.031	17.920	0.014	17.501	0.011	17.142	0.027
2006 Oct 12	21.484	0.015	...	...	...	...	...	...
2006 Oct 22	20.625	0.023	19.602	0.014	19.072	0.012	18.362	0.021
2006 Dec 20	20.921	0.039	19.602	0.018	19.191	0.019	...	...
2007 Jan 24	...	...	19.222	0.029	18.721	0.024	...	...

References. — * Observations from Sahu et al. (2005)

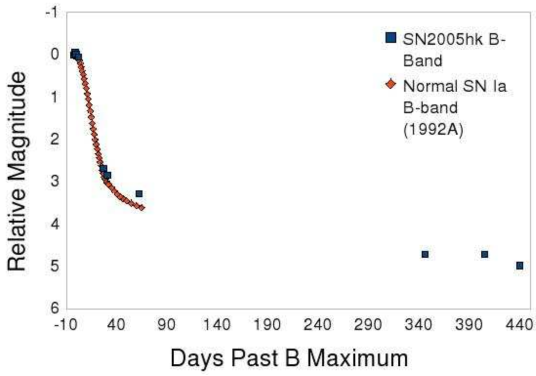

Fig. 1.— *B*-band light curve of normal SN 1992A in comparison to *B*-band of 2005hk; *B*-band of 2005hk includes data from Sahu et al. (2008). The graphs have been arbitrarily vertically shifted to best fit by setting the maximum brightness as zero, which occurs at day zero. Note how 2005hk appears to be super-luminous in comparison to 1992A, a normal-type SN studied by Hamuy et al. (1996)

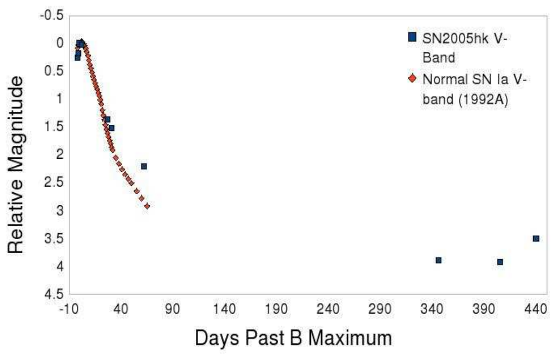

Fig. 2.— *V*-band light curve of 1992A in comparison to *V*-band of 2005hk; *V*-band of 2005hk includes data from Sahu et al. (2008). The graphs have been arbitrarily vertically shifted for best fit by setting the maximum brighness as zero, which occurs at day zero. The graph of 1992A is provided by Hamuy et al. (1996).

pernova may have a more tangled magnetic field. If the magnetic field of a SN becomes tangled, positrons remain trapped within the supernova, increasing the possibility that they will collide with and lose their kinetic energy to other particles. The energy released in a collision is in the form of atomic ionization and excitation, which lead to the emission of line photons. Thus a supernova with a tangled magnetic field produces a late light curve with

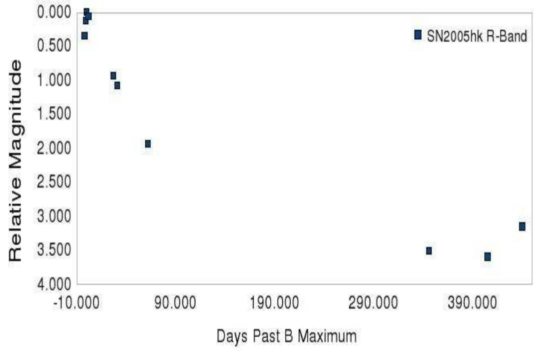

Fig. 3.— *R*-band light curve of 2005hk (including observations from Sahu et al. (2008); graph has been arbitrarily shifted for best fit by setting the maximum brightness as zero, which occurs at day zero. No template of 1992A available for comparison.

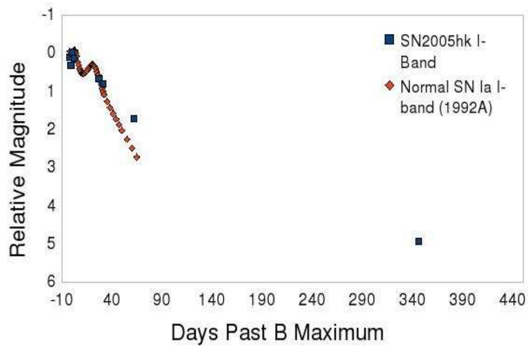

Fig. 4.— *I*-band light curve of 1992A (Hamuy et al. 1996) in comparison to *I*-band of 2005hk; the graphs have be arbitrarily vertically shifted for best fit by setting the maximum brightness as zero, which occurs at day zero. *I*-band data of 2005hk includes observations from Sahu et al. (2008).

a slower decline than that of a normal SN Ia (Stritzinger & Sollerman, 2007).

4. CONCLUSION

Due to its light curve's deviance from the standard model of a SN light curve, 2005hk can be reasonably assumed to be peculiar, in comparison to normal SNe. The deviation of SN2005hk's light curve from the typical SN pattern is more apparent in late-time observations. While a normal SN Ia light curve would display a "steepening" (rapid decay rate) at this time and eventually radiate only in the infrared, SN2005hk continues to emit a substantial amount of visible light in late-time observations. Use of aperture photometry to calculate the magnitude of the supernova produced reasonable results, but our calculations can be improved by subtracting the light from the host galaxy before performing photometry to ensure that our aperture does not include counts from the structured galaxy. Subtraction images with the SN gone can now be obtained. Additional errors in accuracy of the measurements may be due to lack of sufficient standard stars to calculate instrumental magnitudes, as many of the standard stars in the late deep exposures were saturated.

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