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Photometric observations of Supernova 2002hh

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Abstract

CCD VRI photometry is presented for SN 2002hh from 14 days after the outburst till day 347. SN 2002hh appears to be a normal type IIP supernova regarding both luminosity and the shape of the light curve, which is similar to SN 1999gi.

SN 2002hh was discovered on 2002 October 31.1 UT during the course of the Lick Observatory Supernova Search (Li, 2002). The Supernova is located at $\alpha = 20^{\rm h}34^{\rm m}44^{\rm s}.29, \delta = +60°07'19''.0$ (2000.0), which is $60''.9$ west and $114''.1$ south of the nucleus of the Scd galaxy NGC 6946, which has produced 7 other SNe. Spectra taken by Filippenko et al. (2002) on 2002 November 2 revealed it to be a very young, highly reddened type II SN. Broad, low-contrast Hα emission and absorption lines as well as strong, narrow interstellar NaI D absorption were present. The continuum was nearly featureless and very red. SN 2002hh was also detected as a source of radio and X-ray emission (Stockdale et al., 2002; Pooley and Lewin, 2002).

A detailed study of optical and infrared photometric and spectroscopic evolution for this object was presented by Pozzo et al. (2006). They concluded that SN 2002hh was a SN IIP (plateau), with early light curve similar to SN IIP 1999em, and that radioactive tails were well matched for these two SNe and SN 1987A. They adopted a two-component model for extinction with total $A_V = 5.2$ mag.

We observed SN 2002hh from 2002 November 13 till 2003 October 12 with different telescopes and detectors: the 60-cm reflector of the Crimean Observatory of Sternberg Astronomical Institute (C60) equipped with a SBIG ST-7 CCD camera; the 70-cm reflector in Moscow (M70) with a Meade Pictor416XT camera (a) or an Apogee AP47 camera (b); the 1.5-m reflector of the Maidanak Observatory (Md150) with a SITe 2000×800 LN cooled CCD camera.

An image of SN 2002hh obtained at Md150 on 2003 August 10 in the I band is shown in Fig. 1, where the local standard stars are marked. The magnitudes of these stars (reported in Table 1) were measured on 11 photometric nights mostly in 2004–2005, when observations of SN 2004et in the same galaxy had been carried out. VRI magnitudes of these stars were also derived by Pozzo et al. (2006), and the mean differences between the two data sets and their dispersions are: $\overline{\Delta V} = 0.015$; $\sigma_{\Delta V} = 0.01$; $\overline{\Delta R} = -0.008$; $\sigma_{\Delta R} = 0.01$; $\overline{\Delta I} = 0.053$; $\sigma_{\Delta I} = 0.027$. We may conclude that the agreement is good. Photometric measurements of the SN were made relative to the local standard stars using PSF-fitting with IRAF† DAOPHOT package. On nights with bad seeing, images of the SN and the nearby bright star overlapped, and it was necessary to subtract the image of this star using the task SUBSTAR in DAOPHOT.

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The color terms for transformation of instrumental magnitudes vri to the standard $VRcIc$ system were derived from observations of standard fields for C60 and M70 and from photometry of local standards for Md150. The resulting color terms are $K_v = -0.007$; $K_r = -0.48$; $K_i = -0.27$ for C60; $K_r = -0.35$; $K_i = -0.31$ for M70a; $K_r = -0.46$; $K_i = -0.37$ for M70b; $K_r = 0.12$; $K_i = 0.0$ for Md150.

The photometry of SN 2002hh is presented in Table 2, and the light curves are shown in Fig. 2, where the data from Pozzo et al. (2006) as well as magnitude estimates at discovery and the prediscovery upper limit from Li (2002) are also plotted. At the plateau stage, the agreement between the two data sets is quite good, although our R and I filters at C60 and M70 do not match the standard system well. Only in the I band there is evidence for some systematic difference, our magnitudes being about 0.15 mag brighter.

We obtained images on two dates (2003 March 3 and March 26) that are in the gap of Pozzo et al. (2006) data. At the exponential decline stage, our I magnitudes from Md150 are in a very good agreement with the results of Pozzo et al. (2006), while in the R band our magnitudes are systematically brighter by about 0.18 mag. This difference is likely due to different response curves of the equipment applied to an object with a very red color and emission-dominated spectrum. This is also the reason for our magnitudes from M70 to be brighter than from Md150; the latter should be given greater weight as their errors are smaller and the color system closer to the standard one.

We estimated the rate of decline at the exponential tail by fitting a straight line to the data from Md150: 0.0073 ± 0.0003 mag day^{-1} in R and 0.0094 ± 0.0004 mag day^{-1} in I. The result for the I band is close to that by Pozzo et al. (2006), but they found a significantly larger rate in R: 0.011 mag day^{-1}. We suppose that the difference is due to larger errors of magnitudes by Pozzo et al. (2006) at the late stage. We can also estimate the drop of brightness from the plateau to the onset of the exponential tail: $1\overset{\mathrm{m}}{.}4$ in R and $1\overset{\mathrm{m}}{.}6$ in I.

We found that the light curve of SN 1999em was not a good match to the data for SN 2002hh, as the brightness decline between the plateau and the exponential-tail onset was significantly smaller for SN 2002hh. Among the well-studied IIP Supernovae with normal luminosity, SN 1999gi was probably the best match, although considerable differences can be seen in Fig. 2, where we plotted the light curves of SN 1999gi according to Leonard et al. (2002) and our own unpublished data. While in the I band the match is very good, the magnitude difference between the plateau and the onset of final decline in R and V is greater for SN 1999gi.

Taking the extinction from Pozzo et al. (2006) and the host galaxy's distance of 5.9 Mpc (Karachentsev et al., 2000), we obtain the absolute magnitude at maximum light $M_V = -16.7$, close to the mean value for SNe IIP (Richardson et al., 2002).

We conclude that SN 2002hh is a normal type IIP supernova, with the light curve similar to SN 1999gi, especially in the I band. Our photometry confirms the results of Pozzo et al. (2006), but we obtain slightly different magnitudes and rate of decline in the R band at the epoch 200–340 days after the explosion.

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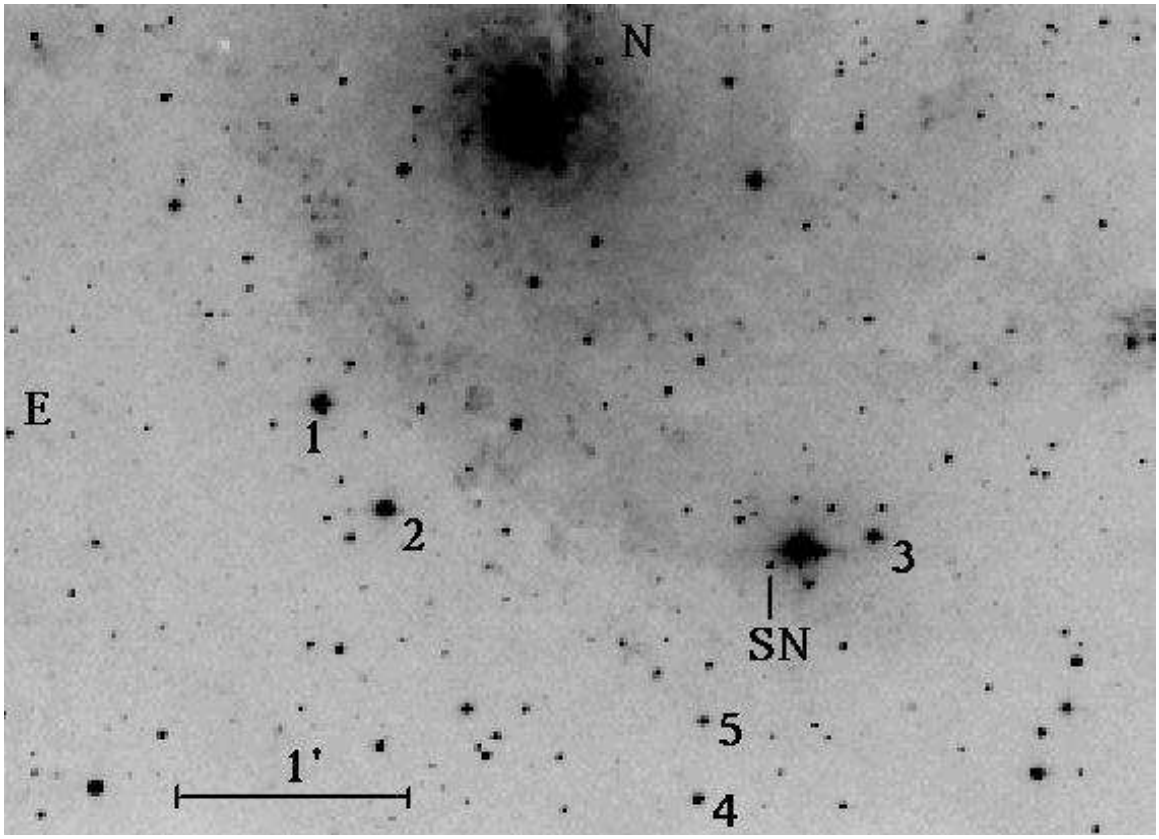

Figure 1. SN 2002hh and local standard stars

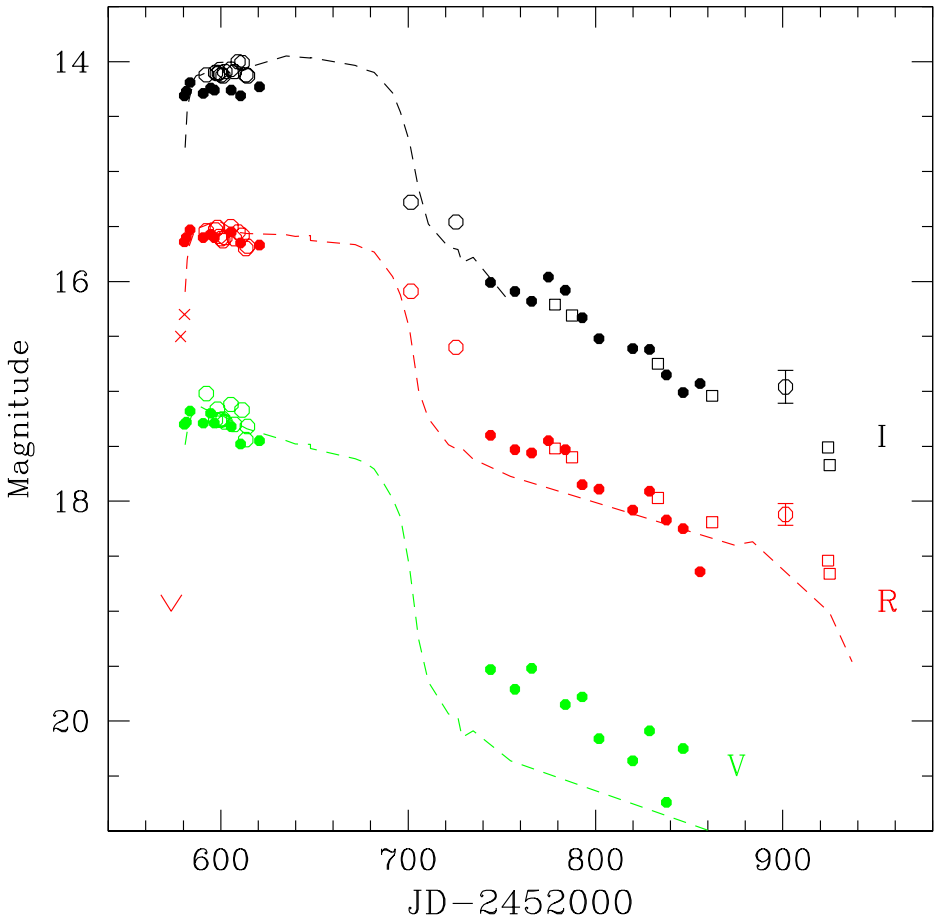

Figure 2. *VRI* light curves of SN 2002hh. Circles are our data from C60 and M70; squares, from Md150; dots show photometry by Pozzo et al. (2006); crosses and the 'v' mark are for discovery estimates and the prediscovery limit from Li (2002). Error bars for our magnitudes are plotted only when they exceed the size of a point. The dashed curves are the light curves of SN 1999gi

Table 1: Magnitudes of local standard stars

Star	U	σ_U	B	σ_B	V	σ_V	R	σ_R	I	σ_I
1	14.60	0.08	14.30	0.01	13.56	0.01	13.14	0.03	12.75	0.02
2	14.78	0.03	14.51	0.02	13.77	0.01	13.35	0.03	12.96	0.02
3	15.92	0.03	15.59	0.03	14.76	0.01	14.22	0.04	13.85	0.03
4			16.62	0.05	15.86	0.01	15.35	0.04	15.00	0.03
5			17.58	0.05	16.46	0.06	15.74	0.04	15.17	0.02

Table 2: Photometry of SN 2002hh

JD 2452000+	V	σ_V	R	σ_R	I	σ_I	Telescope
592.31	17.02	0.07	15.54	0.03	14.12	0.03	C60
597.21	17.26	0.06	15.53	0.07	14.10	0.04	C60
598.23	17.16	0.05	15.51	0.04	14.11	0.04	C60
599.24	17.26	0.05	15.59	0.04	14.10	0.04	C60
600.20	17.26	0.05	15.61	0.05	14.12	0.04	C60
601.17	17.25	0.08	15.63	0.05	14.13	0.07	C60
602.18	17.28	0.05	15.60	0.03	14.09	0.03	C60
605.38	17.12	0.09	15.50	0.04	14.07	0.04	C60
607.26	17.30	0.08	15.61	0.05	14.09	0.05	C60
609.32			15.55	0.04	14.00	0.05	C60
611.38	17.17	0.07	15.58	0.04	14.01	0.07	C60
613.39	17.44	0.05	15.70	0.03	14.12	0.03	C60
614.27	17.32	0.07	15.68	0.05	14.13	0.04	C60
701.50			16.09	0.05	15.28	0.04	M70a
725.54			16.60	0.07	15.46	0.04	M70a
778.44			17.52	0.03	16.21	0.02	Md150
787.46			17.60	0.03	16.31	0.02	Md150
833.38			17.97	0.04	16.75	0.02	Md150
862.27			18.19	0.03	17.04	0.02	Md150
901.44			18.12	0.11	16.96	0.16	M70b
924.13			18.54	0.03	17.51	0.02	Md150
925.10			18.66	0.03	17.67	0.02	Md150