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Photometric observations of the type IIn Supernova 2016ehw

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Abstract

CCD $BVRI$ and unfiltered photometry is presented for the type IIn Supernova 2016ehw. The object reached maximum with $R_{max} = 15.4$ mag and absolute magnitude $M_R = -18.1$ mag on JD 2457547. The brightness in the R band declined by 3.1 mag during 170 days of observations. The rate of decline increased at the phase about 80 days past maximum. Comparison of the light and color curves of SN 2016ehw to those of well-studied type IIn SNe shows that this SN is quite typical for its class considering photometric evolution and maximum luminosity.

1 Introduction

A large fraction of massive stars explode at the end of their lives due to the gravitational collapse of their cores; such events are recognized as core-collapse supernovae (CCSNe). Type II SNe are hydrogen-rich CCSNe; a fraction of these objects exhibit signatures of ejecta interaction with circumstellar matter (CSM), such events are classified as SNe IIn (see, for instance, Schlegel, 1990). SNe IIn are characterized by relatively high maximum luminosity due to the energy input from interaction between ejecta and CSM, they exhibit diversity of photometric evolution because of different structure of CSM and parameters of the ejecta.

In this paper, we present the results of our photometric observations of a bright type IIn Supernova, SN 2016ehw.

The MASTER-Amur auto-detection system (Lipunov et al., 2010) discovered a transient source at $\alpha = 08^{\rm h}36^{\rm m}37\overset{\rm s}{.}5, \delta = +73°35'04\overset{''}{.}8$ on 2016-06-04 16:14:44.427 UT. The unfiltered magnitude of the object was $15\overset{\rm m}{.}9$. The reference images without the source were obtained on 2016-05-25 20:01:44 UT with unfiltered $m_{lim} = 18.6$ at the MASTER-Kislovodsk telescope. The object was located in $19\overset{''}{.}53$ from the center of a barred spiral galaxy PGC024209 (MCG+12-8-47) (Vladimirov et al., 2016). The SN was independently discovered by Gaia on 2016-07-20.31 and designated Gaia16avr, the photometric observations in the Gaia-G band continued till 2017-02-18[1].

The Open Supernova Catalogue[2] reported classification of the SN as type IIn and the redshift of the host galaxy $z = 0.012$.

[1]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia16avr/
[2]https://sne.space/sne/SN2016ehw/

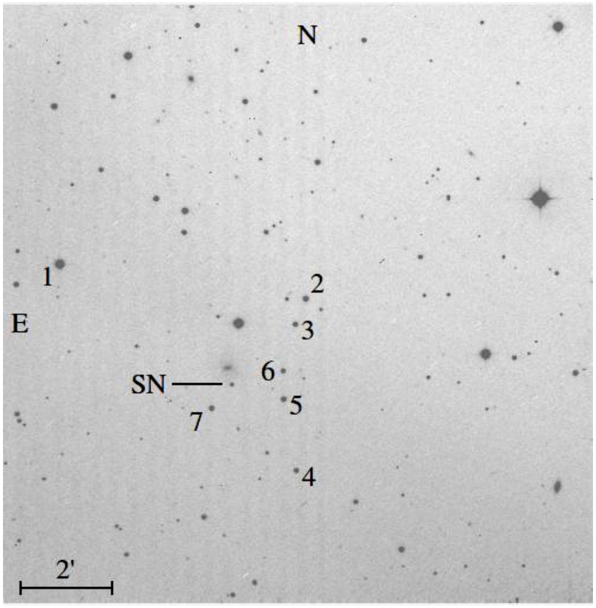

Figure 1. SN 2016ehw and local standard stars. The image was obtained with the 60-cm telescope in the R band.

2 Observations and reductions

We carried out photometric observations of SN 2016ehw in the $BVRI$ bands from 2016-08-29 to 2016-11-28 with the 60-cm reflector of the Crimean Observatory of Sternberg Astronomical Institute (SAI). The observations with MASTER telescopes were carried out at Kislovodsk, Tunka, and Amur sites (Lipunov et al., 2010). Unfiltered images (designated further as W-band ones) were obtained from 2016-06-04 to 2016-10-13, observations with $BVRI$ filters were carried out between 2016-06-06 and 2016-07-04.

The standard image reductions and photometry were made using IRAF[3]. Photometric measurements of the SN were made relative to local standard stars using PSF fitting with the IRAF DAOPHOT package. The unfiltered frames were reduced using the R-band magnitudes of local standards. The surface brightness of host galaxy at the location of the SN was low and did not affect the measurements, so the subtraction of galaxy background was not necessary. The image of SN 2016ehw with local standards is shown in Fig. 1. The magnitudes of the stars were calibrated on 3 nights in November 2016, when the Landolt (1992) standards were observed. They are presented in Table 1.

The results of our photometry of SN 2016ehw are reported in Tables 2, 3, and 4.

3 Results and conclusions

The light curves are shown in Fig. 2. The upper limit on 2016-05-25.8 (JD 2457534.3) and the first observations demonstrate clearly that the SN was discovered on the rising part of its light curve. The maximum light was reached on JD 2457547±1 (2016-06-07) with $W = 15.25 \pm 0.05$. The unfiltered magnitudes are in a good agreement with the R-band observations later than JD 2457570, but for earlier time, the W magnitudes may be brighter due to the blue color of the SN. On JD 2457546.39, the R-band magnitude

[3]IRAF is distributed by the National Optical Astronomy Observatory, which is operated by AURA under cooperative agreement with the National Science Foundation.

Table 1: Magnitudes of local standard stars for SN 2016ehw

Star	B	σ_B	V	σ_V	R	σ_R	I	σ_I
1	12.73	0.02	12.25	0.02	11.93	0.01	11.67	0.02
2	15.65	0.05	14.95	0.03	14.50	0.03	14.11	0.01
3	16.21	0.02	15.53	0.03	15.11	0.03	14.71	0.02
4	16.63	0.02	15.80	0.02	15.30	0.02	14.89	0.03
5	16.39	0.03	15.45	0.02	14.91	0.02	14.39	0.02
6	17.15	0.08	16.12	0.03	15.54	0.03	15.04	0.05
7	16.45	0.07	15.60	0.02	15.02	0.02	14.52	0.02

Table 2: Observations of SN 2016ehw with the 60-cm telescope

JD 2457000+	B	σ_B	V	σ_V	R	σ_R	I	σ_I
631.57	18.27	0.11	17.08	0.03	16.39	0.03	16.08	0.03
632.58	18.15	0.10	17.10	0.05	16.41	0.05	16.09	0.03
634.49	18.29	0.06	17.15	0.03	16.46	0.03	16.12	0.03
635.56	18.35	0.06	17.23	0.03	16.48	0.03	16.18	0.03
636.54	18.35	0.05	17.29	0.03	16.53	0.03	16.22	0.03
638.55	18.50	0.06	17.30	0.03	16.51	0.04	16.23	0.04
640.56	18.56	0.06	17.36	0.03	16.57	0.03	16.28	0.03
642.57	18.62	0.06	17.41	0.03	16.65	0.03	16.35	0.03
645.55	18.75	0.06	17.54	0.03	16.73	0.03	16.41	0.03
646.56	18.80	0.06	17.62	0.03	16.79	0.03	16.45	0.03
704.50			19.42	0.05	18.27	0.04		
711.47			19.74	0.07	18.47	0.04	18.15	0.07
713.49			19.77	0.09	18.60	0.04	18.27	0.04
714.38			19.54	0.07	18.56	0.04	18.36	0.06
715.58					18.56	0.06	18.30	0.08

was by 0.18 ± 0.06 mag fainter than the unfiltered one, so we may expect the R-band maximum magnitude to be about 15.43 ± 0.07 mag.

The brightness decline after maximum in the W and R bands was linear with the rate 0.014 mag/day until JD 2457630, then the rate increased to 0.026 mag/day. Gaia observations show that such decline continued for at least 100 days after the end of our observations.

The absolute R-band light curve of SN 2016ehw is presented in Fig. 3, the light curves of eight SNe IIn are plotted for comparison. The distance modulus $\mu = 33.5$ for SN 2016ehw was computed based on the reported redshift and $H_0 = 73$ km (s Mpc)$^{-1}$, and we used galactic extinction $A_R = 0.06$ from the NED database[4]. The data on eight SNe IIn were taken from Turatto et al. (1993), Rigon et al. (2003), Pastorello et al. (2002), Kankare et al. (2012), Hicken et al. (2017), Germany et al. (2004), Tsvetkov (2008), Tsvetkov et al. (2016).

The comparison shows that SN 2016ehw is quite a typical object of the class IIn, concerning the maximum luminosity and the shape of the light curve. It is best matched by SNe 1988Z, 1995G, 1999E, and 2009kn.

The color curves for the same objects are compared in Fig. 4. The colors of all the SNe were corrected only for the galactic reddening. The best match for the color curves of

[4]https://ned.ipac.caltech.edu/

Table 3: Observations of SN 2016ehw with the MASTER telescopes in $BVRI$ bands

JD 2457000+	B	σ_B	V	σ_V	R	σ_R	I	σ_I
546.39	15.68	0.06	15.55	0.04	15.49	0.04	15.64	0.08
555.39							15.46	0.06
558.39					15.57	0.07	15.57	0.09
561.39					15.54	0.06	15.40	0.07
570.40	16.51	0.07	15.97	0.05	15.62	0.04		
572.40	16.51	0.08	15.94	0.04	15.66	0.04		
573.40	16.58	0.08	15.98	0.04	15.66	0.04		
574.40	16.57	0.06	15.98	0.04	15.73	0.04		

Table 4: Unfiltered observations of SN 2016ehw with the MASTER telescopes

JD 2457000+	W	σ_W	JD 2457000+	W	σ_W
544.17	15.55	0.06	562.39	15.46	0.05
544.17	15.56	0.07	563.39	15.46	0.05
546.38	15.30	0.05	563.39	15.55	0.05
546.38	15.32	0.04	564.39	15.42	0.04
547.43	15.27	0.04	564.39	15.46	0.07
547.43	15.24	0.04	569.41	15.49	0.04
548.39	15.30	0.03	569.41	15.52	0.03
548.39	15.30	0.04	570.39	15.59	0.04
549.39	15.28	0.04	572.39	15.57	0.04
549.39	15.31	0.03	573.39	15.62	0.03
550.39	15.31	0.04	574.39	15.62	0.03
550.41	15.30	0.04	576.39	15.70	0.04
554.55	15.33	0.04	576.39	15.68	0.03
554.55	15.36	0.04	577.39	15.69	0.04
555.39	15.31	0.04	578.42	15.71	0.03
556.39	15.36	0.04	578.42	15.70	0.04
557.39	15.39	0.05	579.39	15.71	0.04
557.39	15.38	0.04	579.39	15.74	0.03
558.39	15.43	0.06	580.39	15.74	0.04
558.39	15.42	0.05	580.39	15.71	0.04
559.39	15.41	0.04	585.30	15.81	0.07
559.39	15.39	0.04	585.31	15.80	0.07
560.39	15.42	0.04	588.19	15.78	0.10
560.39	15.45	0.04	597.16	16.01	0.07
561.39	15.43	0.04	643.13	16.73	0.10
561.39	15.48	0.04	674.65	17.79	0.11
562.39	15.48	0.04			

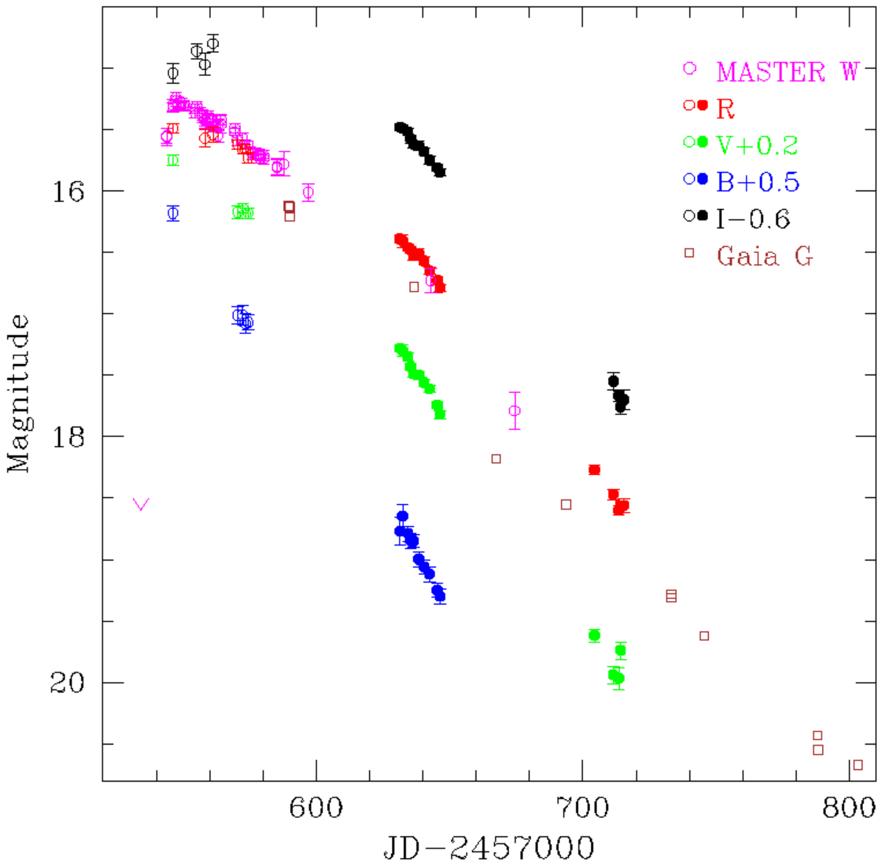

Figure 2. The light curves of SN 2016ehw. Dots show the data obtained with the 60-cm telescope, circles are the results from the MASTER telescopes.

SN 2016ehw is SN 2009kn. The shape of the color curves is quite similar for most of the objects, but the $(B-V)$ color curve for SN 2009kr exhibits quite a different shape. The comparison allows us to suppose that most of the SNe, including SN 2016ehw, suffered little extinction in their host galaxies. The presence of extinction may be suspected for SN 2009kn and, perhaps, SN 1999E. We also note that the $(V-R)$ color of SN 2016ehw at late stage was significantly redder that for all the other objects.

We conclude that SN 2016ehw is a quite typical SN IIn, its maximum luminosity and the shape of its light and color curves are similar to those for many other SNe of this class.

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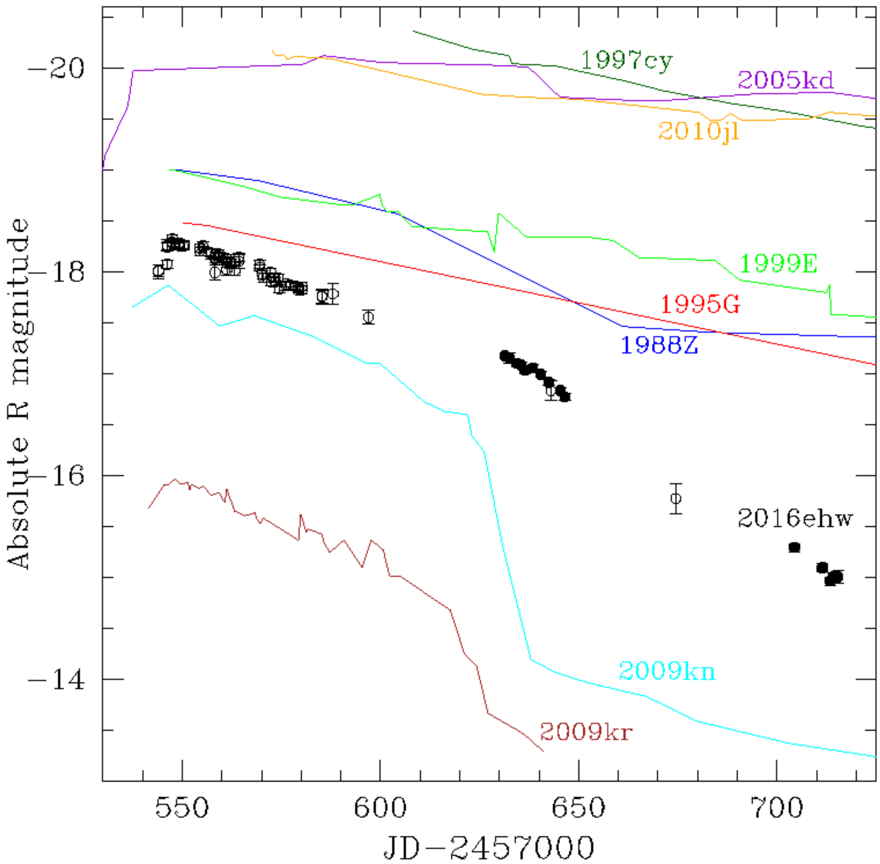

Figure 3. The absolute R-band light curves of SN 2016ehw compared to those for eight SNe IIn. Black dots and circles represent data from the 60-cm telescope and MASTER telescopes, respectively.

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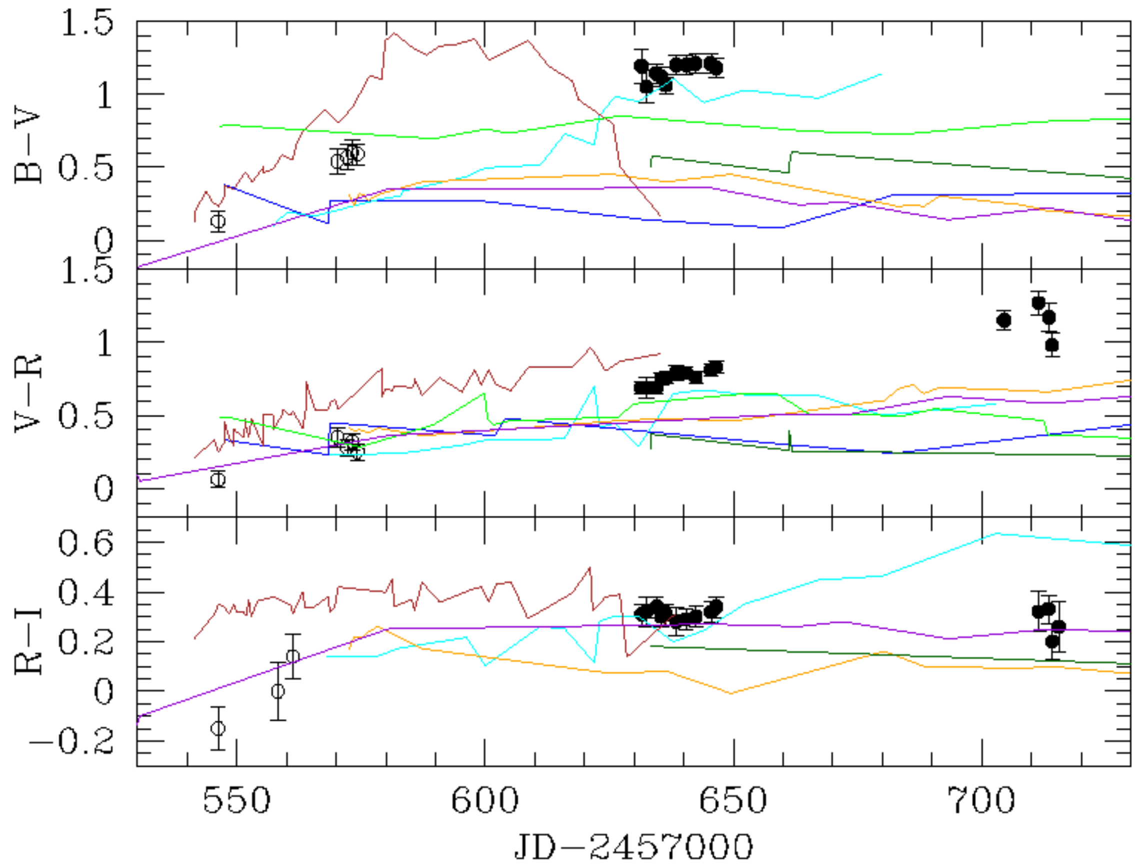

Figure 4. The color curves of SN 2016ehw compared to those for eight SNe IIn. The color coding is the same as in Fig. 3.