PSN J07285387+3349106 IN NGC 2388: AN EXTREMELY RAPIDLY DECLINING LUMINOUS SUPERNOVA

TSVETKOV, D. YU.; VOLKOV, I. M.; PAVLYUK, N. N.

Sternberg Astronomical Institute, M.V. Lomonosov Moscow State University, Universitetskij pr.13, 119992 Moscow, Russia, e-mail: tsvetkov@sai.msu.su

Supernova in NGC 2388 was discovered by Lick Observatory Supernova Search (LOSS) on 2015 February 13.338 UT at an unfiltered magnitude of 16.9. The variable was designated PSN J07285387+3349106 when it was posted at the Central Bureau's TOCP webpage. The new object was located at RA=7:28:53.87, DEC=+33:49:10.6 (2000), which is 5″E and 2″N from the center of the host galaxy. Spectroscopic observation on 2015 February 18.79 UT was reported by Ochner et al. (2015). The spectrum was almost featureless, with strong interstellar Na I D absorption, which allowed to estimate a reddening value of $E(B-V) \approx 1$ mag. Unresolved emission lines of He I (587.6 and 706.5 nm) were detected, and a black-body temperature of about 15300 K was inferred for the transient. The characteristics were consistent with those of a very young core-collapse SN, and a tentative classification as Type Ibn SN was suggested for the object.

We performed photometric observations of PSN J07285387+3349106 in the $BVRI$ bands with the 0.7-m reflector in Moscow (M70), equipped with Apogee AP-7p CCD camera, and the 1.0-m reflector of Simeiz Observatory (S100) with FLI PL09000 CCD. First images were obtained on February 17, and the last ones were collected on March 17, 2015. The standard image reductions and photometry were made using IRAF[1]. Photometric measurements of the SNe were made relative to 6 nearby local standard stars using PSF-fitting with IRAF DAOPHOT package. The BV and $g'r'i'$ magnitudes of these stars were taken from the AAVSO Photometric All-Sky Survey (Henden et al., 2012; hereafter, APASS). The RI magnitudes were computed using relations presented by Munari[2]. Besides, on one photometric night we calibrated VR magnitudes of the local standards using data from the M70 telescope. The agreement between the APASS data and our calibration was excellent, confirming the reliability of the calibration. Subtraction of the host galaxy background was necessary for reliable photometry, because the SN occurred in one of the spiral arms of the galaxy and close to the nucleus. As the SN was practically undetectable in the images obtained on March 17, we used these frames to subtract the galaxy background from the images collected in February, when the SN was bright. For the images obtained in March we used the SDSS[3] images for subtraction. We plan to obtain new deep images of the host galaxy with our telescopes and improve the quality

---

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

[2]https://13378703316991552715.googlegroups.com/

[3]http://www.sdss.org

of subtraction. The instrumental magnitudes were transformed to the standard Johnson-Cousins system using linear colour equations. The photometry for the SN is presented in Table 1, the light curves are shown in Fig. 1.
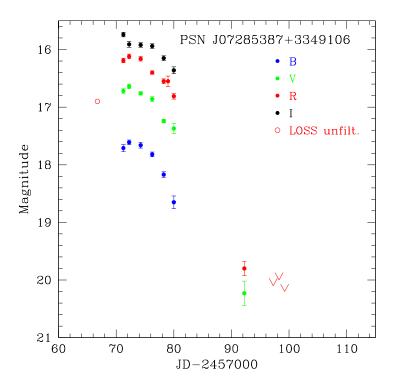

Figure 1. The $BVRI$ light curves for PSN J07285387+3349106.

The maximum light in the BVR bands was reached at about JD 2457072-73 (February 18-19), and perhaps some days earlier in the I band. The magnitudes at maximum are $B_{max} = 17.6$, $V_{max} = 16.65$, $R_{max} = 16.15$, with about ± 0.1 mag uncertainty . The red colour of $(B - V) \approx 1$ mag at maximum confirms the high value of interstellar reddening reported by Ochner et al. (2015). For the first week past maximum the brightness declined quite slowly, but then a very fast decline occurred. We can approximately estimate the values of brightness decline for the first 15 days after peak (Δm_{15}), which are usually used to describe the rate of photometric evolution for SNe Ia and SNe of other types with similar light curve shapes: $\Delta m_{15}(V) \approx 2.6$, $\Delta m_{15}(R) \approx 2.5$. Such high values were observed only for three among all well-studied SNe: SN 2002bj (Type Ib)(Poznanski et al., 2010), 2005ek (Ic)(Drout et al., 2013) and 2010X (Ic-pec)(Kasliwal et al., 2010).

Fig. 2 presents comparison of the R-band light curve of PSN J07285387+3349106 with the light curves for the three fastest declining SNe listed above and also with the type Ibn SN 2010al (Pastorello et al., 2015), and one of the fastest decliners among SNe Ic SN 1994I (Richmond et al., 1996). The left panel compares the shape of the light curves which are normalized to the peak. It is shown that the R-band light curve of PSN J07285387+3349106 near maximum is matched by that for SNe 1994I, 2002bj and 2010X, while SN 2005ek has sharper peak, and for SN 2010al the peak is much broader. The fast decline after the peak is similar for SNe 2002bj, 2005ek, 2010X and PSN J07285387+3349106.

The right panel shows the absolute magnitude light curves. We accepted the following

Table 1: *BVRI* photometry of PSN J07285387+3349106

JD − 2457000	B	σ_B	V	σ_V	R	σ_R	I	σ_I	Telescope
71.22	17.71	0.06	16.72	0.04	16.19	0.04	15.74	0.04	M70
72.31	17.61	0.04	16.64	0.04	16.12	0.04	15.91	0.05	S100
74.31	17.66	0.05	16.76	0.03	16.16	0.04	15.92	0.04	S100
76.39	17.82	0.04	16.86	0.04	16.40	0.03	15.94	0.04	S100
78.28	18.17	0.05	17.24	0.03	16.55	0.04	16.15	0.04	S100
79.15					16.55	0.09			M70
80.16	18.65	0.11	17.37	0.09	16.81	0.05	16.36	0.06	M70
92.22			20.23	0.21	19.80	0.12			M70
97.27					>20.1				M70
98.26					>20.0				M70
99.24					>20.2				M70

values of distance moduli and total extinction A_R for the SNe used for comparison: SN 1994I: 29.62, 1.05; SN 2002bj: 33.48, 0.2; SN 2005ek: 34.12, 0.44; SN 2010X: 34.0, 0.4; SN 2010al: 34.27, 0.15. For PSN J07285387+3349106 we adopted a distance modulus of $\mu = 33.84 \pm 0.15$ from the NED database, which is calculated from the redshift of the galaxy, corrected for Virgo and Great Attractor infall, with $H_0 = 73$ km/sec/Mpc. We adopted Galactic extinction $A_R = 0.13$ (Schlafly & Finkbeiner, 2011) and the host galaxy interstellar reddening $E(B-V) = 1$ mag from Ochner et al. (2015). To calculate absolute magnitudes we need the value of $R_V = A_V/E(B-V)$. It is well known that for SNe R_V may differ from the standard Galactic value of 3.1, and can be as low as ~ 1.5, especially for SNe with high $E(B-V)$ (see e.g. Tsvetkov et al., 2014; Wang et al., 2008). So we calculated absolute magnitudes using two values of R_V: 3.1 and 1.5. It is difficult to estimate uncertainty of the data on the host galaxy extinction, as Ochner et al. (2015) does not provide such information. Assuming this uncertainty to be about 10%, and adding in quadratures the errors of distance modulus (± 0.15) and peak magnitude (± 0.1) we derive uncertainty of absolute magnitude ~ 0.3 mag. The right panel plot demonstrates that with $R_V = 3.1$ PSN J07285387+3349106 reaches peak magnitude of $M_R = -20.15$ mag and is definitely much brighter than all other SNe of our sample. If $R_V = 1.5$, than the maximum luminosity of PSN J07285387+3349106 $M_R = -18.8$ mag is close to that for SNe 2010al and 2002bj, it is higher than for SN 1994I by about 0.8 mag, and exceeds that for SNe 2005ek and 2010X by about 1.8 mag.

We conclude that PSN J07285387+3349106 belongs to a rare class of extremely fast declining SNe and is similar to SNe 2002bj, 2005ek and 2010X regarding the shape of the light curves. The estimate of the peak luminosity for a heavily reddened SN depends strongly on the presently unknown value of R_V. We show that even if R_V is close to the minimal observed value, PSN J07285387+3349106 still belongs to the brightest objects among SNe of similar classes.

PSN J07285387+3349106 may represent an extreme case of fast declining SNe, combining very fast decay and high maximum luminosity. Unfortunately, it is now too faint for our instruments, and we want to attract attention of all interested observers to this object. We should note that for SNe 2002bj, 2005ek and 2010X there are practically no data on the radioactive tail of the light curve. PSN J07285387+3349106 presents the opportunity to obtain such data for the first time for a SN of this class. Observations at largest telescopes are needed to help reveal the nature of this object and for all class of

fast declining SNe.

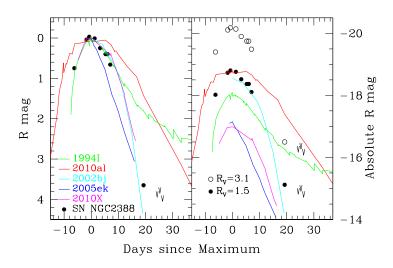**Figure 2.** Comparison of the *R*-band light curves for PSN J07285387+3349106 with those for 5 SNe.

References:

Drout, M. R., Soderberg, A. M., Mazzali, P. A., et al., 2013, *ApJ*, **774**, 58

Henden, A. A., Levine, S. E., Terrell, D., Smith, T. C. & Welch, D., 2012, *J. AAVSO*, **40**, 430

Kasliwal, M. M., Kulkarni, S. R., Gal-Yam, A., et al., 2010, *ApJ*, **723**, L98

Ochner, P., Benetti, S., Pastorello, A., et al., 2015, *ATel*, **7105**

Pastorello, A., Benetti, S., Brown, P. J., et al., 2015, *MNRAS*, **449**, 1921

Poznanski, D., Chornock, R., Nugent, P. E., et al., 2010, *Science*, **327**, 58

Richmond, M. W., VanDyk, S. D., Ho, W., et al., 1996, *AJ*, **111**, 327

Schlafly, E. F. & Finkbeiner, D. P., 2011, *ApJ*, **737**, 103

Tsvetkov, D. Yu., Metlov, V. G., Shugarov, S. Yu., Tarasova, T. N., & Pavlyuk, N. N., 2014, *CoSka*, **44**, 67

Wang, X., Li, W., Filippenko, A.V., et al., 2008, *ApJ*, **675**, 626