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The light curves of type Ia Supernova 2008gy

D. Yu. Tsvetkov¹, P. Balanutsa¹, E.S. Gorbovskoy¹, D.A. Kuvshinov¹, A.V. Krylov¹, T. Kopytova², T. Kryachko³, S. Korotkiy⁴

¹ Sternberg Astronomical Institute, University Ave., 13, 119992 Moscow, Russia

² Ural State University, Ekaterinburg, Russia

³ Astrotel Observatory, Karachay-Cherkessia, Russia

⁴ Ka-Dar Scientific Center and Public Observatory, Moscow, Russia

Abstract

CCD *BVRI* photometry is presented for the type Ia supernova 2008gy. The light curves match the template curves for a fast-declining SN Ia, but the colors appear redder than average, and the SN may also be slightly subluminal. SN 2008gy is found to be located far outside the boundaries of the three nearest galaxies, each of them has a nearly equal probability to be the host galaxy.

SN 2008gy was discovered by P. Balanutsa on unfiltered CCD images taken with a 335-mm telescope near Moscow on October 30.99 UT. This telescope is a part of the large “MASTER Robotic Net” (Lipunov et al. 2010). The new object was located at $\alpha = 3^{\text{h}}10^{\text{m}}00^{\text{s}}.96$, $\delta = +19^{\circ}13'23''.1$ (J2000.0), which is $23''$ west and $6''$ north of the center of PGC 1584648 (Lipunov 2008). Confirmation images were taken by Kryachko and Korotkiy (2008) on November 2.94 UT with an 80-mm refractor at Karachay-Cherkessia, Russia. Folatelli et al. (2008) reported that they had obtained spectra (range 340–602 nm) of SN 2008gy with the New Technology Telescope (+EFOSC2) at La Silla on November 19.0–19.1 UT. The spectrum of SN 2008gy shows it to be a type-Ia supernova, two to three weeks after maximum light, at a redshift of 0.029.

SN 2008gy was imaged again with the 335-mm telescope near Moscow on November 7.73 UT. The photometric monitoring of the SN in *BVRI* filters was carried out at the 60-cm reflector of the Crimean Observatory of Sternberg Astronomical Institute between 2008 November 9 and November 25. All image reductions and photometry were made using IRAF¹.

The image of SN 2008gy obtained at the 60-cm reflector in the *R* band is shown in Fig. 1. It is evident that the SN is located in a group of three galaxies, which are labeled G1, G2, G3. We searched the NED² and Hyperleda³ databases and found out that G1 is PGC 1584648, G2 is PGC 1584876, and G3 is IC 1890. Only for IC 1890 is the redshift known, it is 0.03412. The value reported for SN 2008gy differs by 1500 km/s from this estimate, which seems larger than possible peculiar velocities of galaxies in a group or the velocity of the presupernova inside its host galaxy. However, the redshift uncertainty for SN 2008gy was not announced, and it can possibly account for most of this difference. We calculated the angular distances from the SN to the three galaxies on our CCD frames, respectively for G1, G2, G3: $21''.1$, $37''.0$, $61''.9$. If we assume that the redshift 0.029 corresponds to the distance for SN 2008gy and adopt the distance modulus $\mu = 35.4$, as reported in NED, the linear projected distances of the SN from the centers of the galaxies are 12.2 kpc, 21.3 kpc, 35.7 kpc. According to these data, G1 is the most

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

²<http://nedwww.ipac.caltech.edu>

³<http://leda.univ-lyon1.fr>

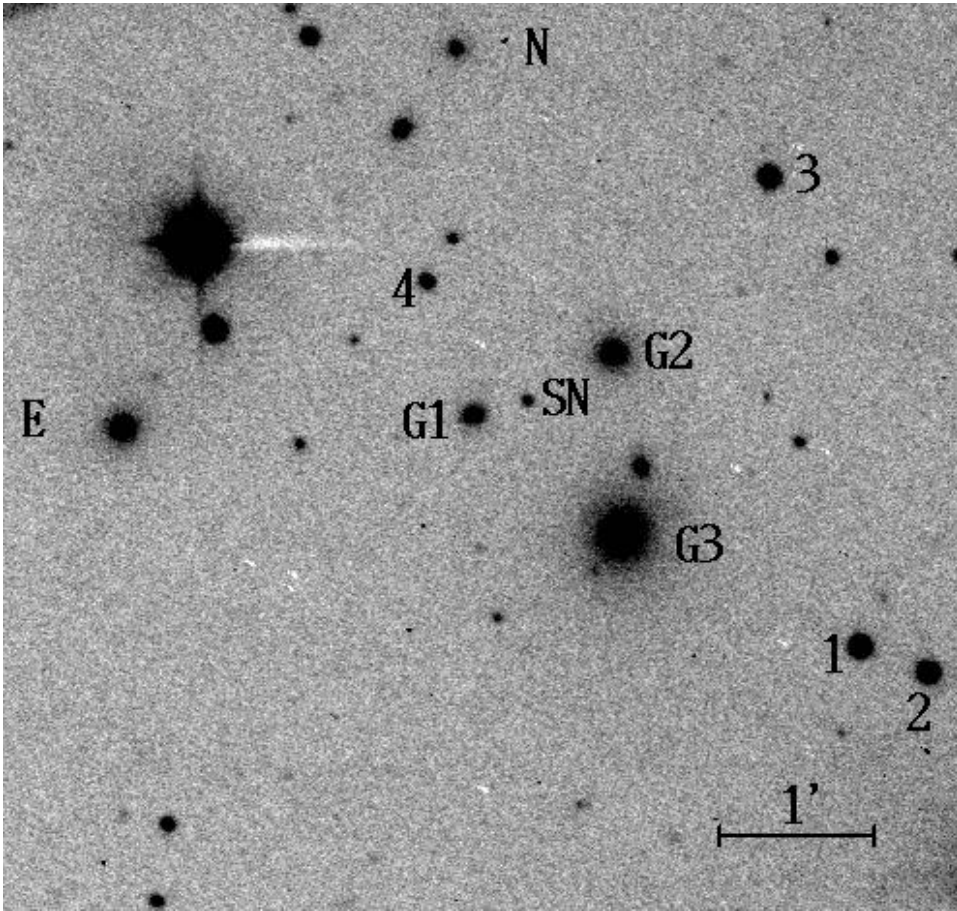


Figure 1. SN 2008gy, the nearest galaxies, and the local standard stars.

likely host galaxy. But other galaxies are significantly brighter and larger, and the relative projected radial distances, defined as angular separation divided by the isophotal radius of the galaxy, for the three galaxies are 2.27, 1.74, 2.06. Thus, from this point of view, G2 is the most likely host galaxy, and G1 is the least probable host. Taking into account that the projected distances are the lower limits to the spatial separations, we conclude that there is nearly equal probability for SN 2008gy to belong to any of the three galaxies, or to be located in the intergalactic medium.

The local standard stars are also marked on Fig. 1. The magnitudes of these stars are reported in Table 1, they were calibrated on four photometric nights in November. It is clear that the galaxy background has no effect on the photometry of SN 2008gy. The magnitudes of the SN were derived by PSF fitting relative to a sequence of local standard stars. We used the R magnitudes to calibrate the unfiltered CCD frames obtained at the 335-mm and 80-mm telescopes.

The results are presented in Table 2 and the light curves are shown in Fig. 2.

The data are best fitted by the light curves of moderately fast-declining SN Ia 1994D (Richmond et al. 1995). From this fit, we estimate that maximum light was reached around JD 2454775 (November 4) with $B_{max} = 17.7$, $V_{max} = 17.3$, $R_{max} = 17.0$. The color curves are shown in Fig. 3. The colors of SN 2008gy are significantly redder than for SN 1994D, approximately by 0^m44 in $(B - V)$ and 0^m22 in $(V - R)$. The galactic extinction for SN 2008gy is $E(B - V)_{gal} = 0^m16$, $A_B^{gal} = 0.7$, $A_V^{gal} = 0.54$, according to NED. We cannot

Table 1: Magnitudes of local standard stars

Star	B	σ_B	V	σ_V	R	σ_R	I	σ_I
1	15.46	0.01	14.71	0.01	14.30	0.01	13.94	0.01
2	15.31	0.02	14.72	0.01	14.34	0.02	14.00	0.01
3	15.15	0.02	14.50	0.01	14.11	0.01	13.72	0.02
4	18.38	0.26	17.01	0.02	16.19	0.03	15.38	0.03

Table 2: Photometric observations of SN 2008gy

JD 2454000+	B	σ_B	V	σ_V	R	σ_R	I	σ_I	Tel.
770.49					17.11	0.13			335-mm
773.44					16.96	0.04			80-mm
778.23					17.27	0.08			335-mm
780.46	17.83	0.07	17.36	0.05	17.26	0.03			600-mm
781.42	18.18	0.05	17.58	0.03	17.41	0.03			600-mm
782.39	18.17	0.11	17.56	0.05	17.43	0.05			600-mm
786.33	18.62	0.06	17.84	0.03	17.75	0.05	17.44	0.17	600-mm
789.38	19.20	0.09	18.02	0.02	17.86	0.03			600-mm
795.26	19.81	0.08	18.36	0.02	17.92	0.03	17.51	0.10	600-mm
796.20			18.42	0.04	17.79	0.05			600-mm

expect any significant extinction in the parent galaxy because the SN is located outside the boundaries of all possible host galaxies. So, we suppose that SN 2008gy is intrinsically redder than SN 1994D at the phase of early decline by about 0^m28 in $(B - V)$ and 0^m11 in $(V - R)$. Assuming $\mu = 35.4$ and correcting only for the galactic extinction, the absolute magnitudes of SN 2008gy are $M_B = -18.4$, $M_V = -18.6$. We may suggest that the rate of early decline for this SN is not much different from that for SN 1994D, $\Delta m_{15}(B) \approx 1.35$, and then the luminosity of SN 2008gy at maximum is significantly fainter than can be expected from the relations of M_B and M_V versus $\Delta m_{15}(B)$ as presented by Hicken et al. (2009). However, the distance modulus corresponding to the redshift of IC 1890 is by 0^m35 larger, and with absolute magnitudes brighter by 0^m35 mag SN 2008gy fits quite well to the relation between maximum luminosity and rate of decline. Thus, we cannot make a definite conclusion on the luminosity of SN 2008gy, but its intrinsic red color is much more probable.

The possible lower luminosity and red color may be connected with the location of the SN far away from the host galaxy, where the characteristics of stellar population may be different from those closer to the galaxy center (see e.g. Sullivan et al. 2010 and references therein).

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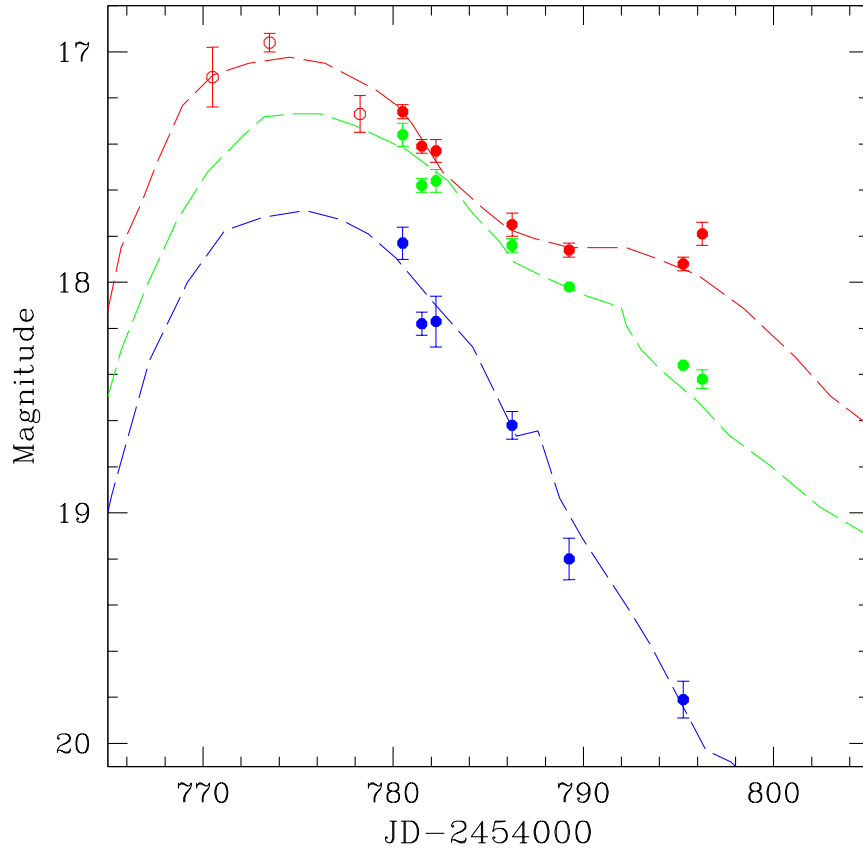


Figure 2. The light curves of SN 2008gy in the B (blue), V (green) and R (red) bands. Dots show data obtained at the 60-cm telescope, circles are for the unfiltered frames exposed at the 355-mm and 80-mm telescopes. The dashed curves are the light curves of SN 1994D.

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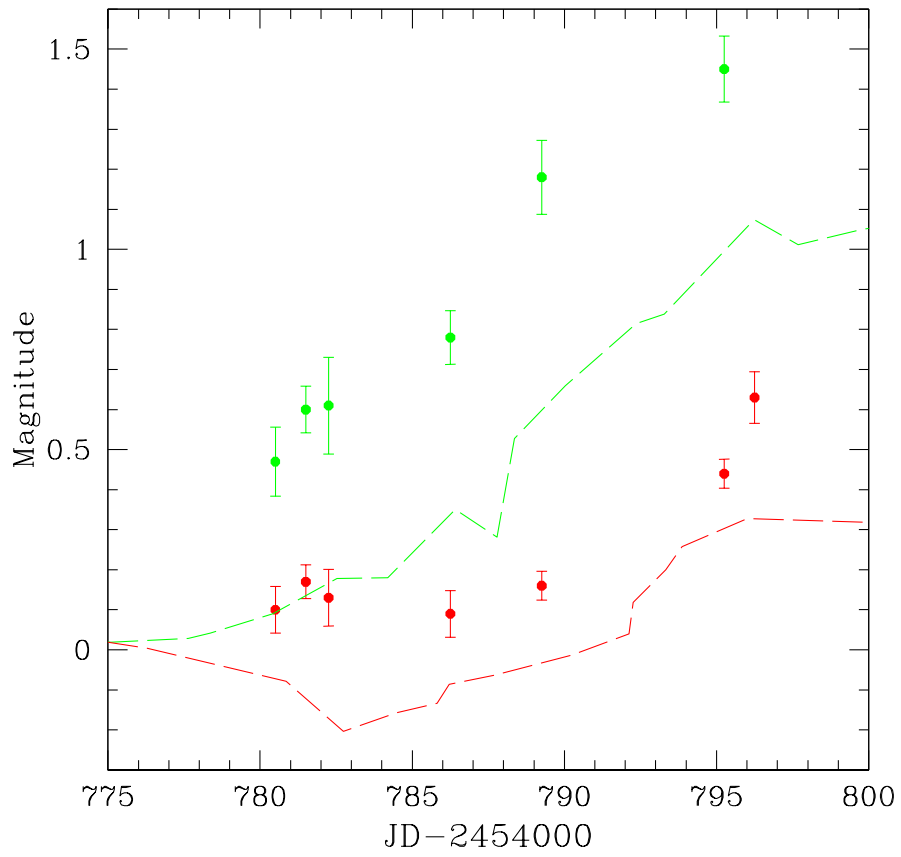


Figure 3. The $(B - V)$ (green) and $(V - R)$ (red) color curves for SN 2008gy. The dashed curves are the color curves of SN 1994D.