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Photometric observations of type II Supernova 2019osl

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We present photometric $BVRI$ observations of type II SN 2019osl covering 177 days. We determine the dates and magnitudes at maximum light and estimate interstellar extinction by comparison of its color curves with that for a sample of SNe II. The maximum absolute magnitude $M_V = -17\overset{\mathrm{m}}{.}9$ is about $1\overset{\mathrm{m}}{.}2$ brighter than the mean value for SNe II. The host galaxy UGC 3115 is classified as a lenticular galaxy, but we show that this classification is erroneous, because the images of the galaxy from Pan-STARRS survey clearly reveal a spiral structure.

1 Introduction

Type II Supernova (SN II) outbursts result from the core collapse of hydrogen-rich massive stars ($M >\sim 8M_\odot$). The lifetime of such stars is less than 10^8 years, that is why they occur in the galaxies with active star formation. Barbon et al. (1979) suggested a division of SNe II into two major groups: SNe II-P, which have nearly constant luminosity for ~ 100 days after maximum, and SNe II-L, which are characterized by linear decline (in magnitudes) after maximum. When more data had become available, objects with intermediate characteristics between SNe II-P and II-L were also found, and it was supposed that these classes presented the utmost cases of a continuous distribution (Anderson et al. 2014). The studies of light curves of SNe II are important for improving the classification scheme for these SNe.

SN 2019osl was discovered by ATLAS on 2019 August 26.57 UT with brightness $16\overset{\mathrm{m}}{.}8$ in "orange" filter. The position of the transient was $\alpha = 04^{\mathrm{h}}38^{\mathrm{m}}54\overset{\mathrm{s}}{.}33$, $\delta = +18^\circ50'10\overset{''}{.}23$ (J2000), the offset from the center of the host galaxy UGC 3115 was $5\overset{''}{.}9$ West, $10\overset{''}{.}2$ South (Tonry et al. 2019).

A spectrum was obtained at the Faulkes Telescope South on August 27.75 UT, the blue continuum with appearing broad hydrogen features suggested a young type II Supernova (Hiramatsu et al. 2019).

The host galaxy UGC 3115 has redshift 0.01085 and is classified as a lenticular galaxy in the RC3 catalog (de Vaucoulers et al. 1991). The rate of star formation is very low in lenticular galaxies, that is why the outburst of SN II in such a galaxy is a rare event which deserves special attention.

2 Observations and reductions

Photometric CCD observations of SN 2019osl in the $BVRI$ bands were performed with the 60-cm telescope of the Crimean Astronomical Station of Sternberg Astronomical Institute (SAI CAS), the 1-m telescope of Simeiz observatory of Institute of Astronomy, Russian Academy of Sciences (Nikolenko et al. 2019), and the 70-cm SAI telescope in Moscow.

Table 1: *BVRI* photometry of SN 2019osl

JD−2458000	*B*	*V*	*R*	*I*	Tel.
724.46	17.44 (0.06)	16.77 (0.04)	16.44 (0.04)	16.08 (0.04)	C60
725.24	17.41 (0.04)	16.75 (0.03)	16.39 (0.03)	16.12 (0.04)	C60
726.52	17.41 (0.03)	16.79 (0.03)	16.42 (0.04)	16.13 (0.04)	C60
732.54	17.46 (0.05)	16.84 (0.03)	16.45 (0.03)	16.16 (0.03)	C60
733.48	17.65 (0.04)	16.91 (0.04)	16.54 (0.05)	16.18 (0.04)	C60
741.57	17.78 (0.08)	16.98 (0.05)	16.53 (0.05)	16.25 (0.05)	C60
742.45	17.99 (0.05)	17.03 (0.03)	16.53 (0.03)	16.20 (0.03)	C60
743.44	18.05 (0.08)	16.98 (0.05)	16.57 (0.04)	16.25 (0.05)	C60
745.56	18.19 (0.11)	17.05 (0.05)	16.65 (0.05)	16.22 (0.05)	C60
780.47		17.66 (0.04)	16.94 (0.03)	16.41 (0.04)	S100
789.47	19.24 (0.13)	17.70 (0.04)	16.97 (0.04)	16.34 (0.03)	C60
790.35	19.36 (0.11)	17.73 (0.04)	16.87 (0.04)	16.38 (0.04)	C60
793.40	19.56 (0.09)	17.72 (0.04)	16.98 (0.03)	16.50 (0.03)	C60
795.29		17.68 (0.12)	17.02 (0.10)	16.36 (0.12)	C60
803.31		17.83 (0.07)	16.94 (0.07)		C60
804.35	19.66 (0.17)	17.91 (0.05)	17.05 (0.03)	16.53 (0.03)	C60
805.47	19.52 (0.16)	18.00 (0.06)	17.09 (0.05)	16.47 (0.05)	C60
806.30	19.50 (0.13)	17.99 (0.04)	17.07 (0.04)	16.51 (0.05)	C60
810.34	19.61 (0.14)	18.00 (0.06)	17.17 (0.06)	16.57 (0.05)	S100
901.18			19.39 (0.06)		M70

The standard image reductions and photometry were made using IRAF[1]. Photometric measurements of the SN were made relative to local standard stars using PSF fitting with the IRAF DAOPHOT package. The galaxy background was found to have negligible effect on most of our images; in rare cases when background subtraction was eligible, we used the images of the host galaxy retrieved with the Pan-STARRS image cutout service[2].

The image of SN 2019osl and local standard stars is presented in Fig. 1 (left panel). The stars were calibrated using Pan-STARRS[3] database, the *gri* magnitudes were converted to the Johnson–Cousins *BVRI* magnitudes using relations from Jester et al. (2005) and Kostov & Bonev (2018).

The right panel of Fig. 1 shows the image of the host galaxy from the Pan-STARRS survey, the location of SN is indicated by a white circle. The image in the *r* filter demonstrates that UGC 3115 is a spiral galaxy with a bar: two spiral arms are clearly seen emerging from the tips of the bar. SN 2019osl is located near the inner end of the bar. We conclude that classification of UGC 3115 as a lenticular galaxy is erroneous and the outburst of SN II in this galaxy is not surprising.

The photometry of SN 2019osl is presented in Table 1, the identification of telescopes is given by codes: M70 is the 70-cm reflector in Moscow, C60 is the 60-cm telescope of SAI CAS, S100 is the 1-m telescope of Simeiz observatory. Errors are in parentheses.

[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://ps1images.stsci.edu/cgi-bin/ps1cutouts

[3]https://catalogs.mast.stsci.edu/panstarrs/

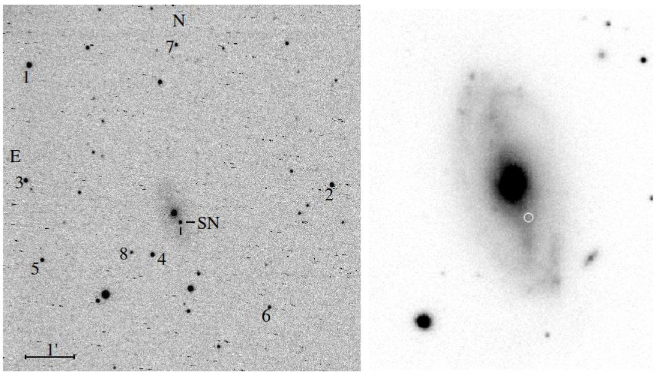

Figure 1.
SN 2019osl and local standard stars (left panel), r-band image of UGC 3115 from Pan-STARRS (right panel).

3 The light and color curves

The light curves for SN 2019osl are presented in Fig. 2. We plot our data, and also discovery magnitude and last non-detection upper limit from ATLAS (Tonry et al. 2019), magnitudes in the Gaia G band[4] and in the w-PS1 filter as reported by the TNS[5].

The magnitude estimate at discovery and non-detection 8 days earlier indicate fast rise to maximum, which occurred on JD 2458724 in $BVRI$ bands. The maximum magnitudes are $B_{\rm max} = 17^{\rm m}_{.}4$, $V_{\rm max} = 16^{\rm m}_{.}75$, $R_{\rm max} = 16^{\rm m}_{.}4, I_{\rm max} = 16^{\rm m}_{.}1$, with errors about $0^{\rm m}_{.}1$. The light curves show constant brightness decline for a time interval of about 100 days after maximum. The rates of decline in the $BVRI$ bands are, respectively, 0.03, 0.0147, 0.0078, 0.0048 mag d^{-1}, with uncertainties about 10%. The decline rate in the V band is close to the mean value for SNe II, which is 0.0127 mag d^{-1} according to Anderson et al. (2014).

Our last magnitude estimate in the R band and the data from Gaia and Pan-STARRS show that, at the time interval JD 2458870–950, the SN was on the linear tail phase, with rate of decline close to that expected from the radioactive decay of ^{56}Co to ^{56}Fe. The fast brightness drop from the first linear phase to the tail occurred in the interval JD 2458815–870 but was not covered with observations. The phase from maximum till the start of fast decline is usually called a “plateau”, although, for SN 2019osl and many other type II SNe, the brightness is not constant but declines slowly.

The color curves for SN 2019osl are presented in Fig. 3, they are compared with the color curves for several type II SNe with light curves similar to those of SN 2019osl: SNe 2014G, 2018zd, 2020tlf, 2022prv, 2023ixf (Bose et al. 2016; Jacobson-Galan et al. 2022; Tsvetkov et al. 2022; Zhang et al. 2020; Zimmmerman et al. 2024; Tsvetkov et al. 2024ab).

The color curves of the SNe from comparison sample were aligned by the epoch of V-band maximum and shifted vertically for best match with the data for SN 2019osl.

If the extinction for SNe from comparison sample is known, we can use the shifts of the color curves to estimate extinction for SN 2019osl. The data on comparison SNe were taken from the papers cited above, and the mean value for extinction of SN 2019osl from comparison with the five SNe from our sample is $E(B-V) = 0^{\rm m}_{.}48 \pm 0^{\rm m}_{.}05$. The extinction

[4]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia19emq/
[5]https://www.wis-tns.org/object/2019osl

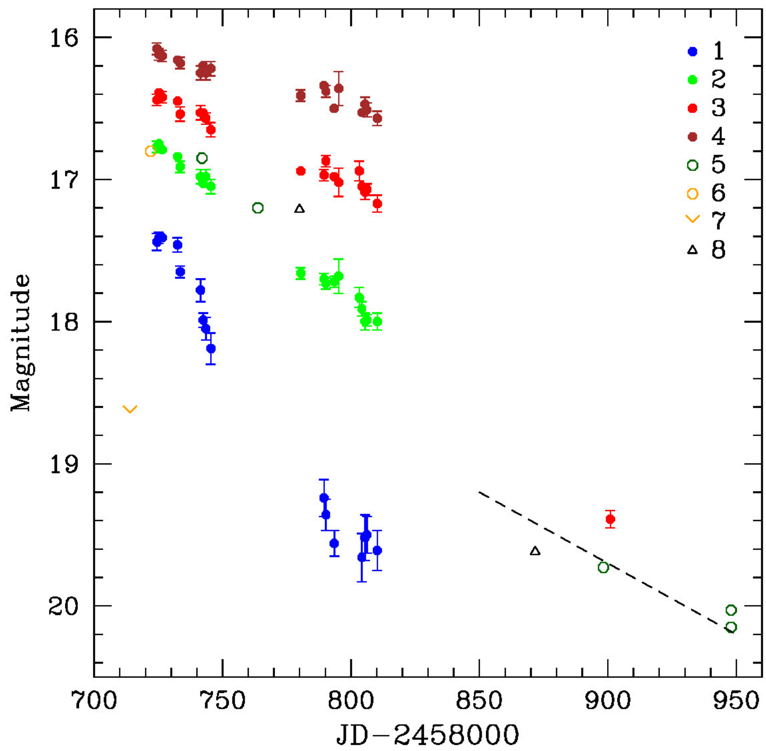

Figure 2.
The light curves of SN 2019osl. 1,2,3,4: our B, V, R, I magnitudes; 5: data from Gaia; 6, 7: magnitude estimate at discovery and upper limit in the "orange" ATLAS filter; 8: magnitudes in the w-PS1 filter. The dashed black line shows the brightness decline rate expected from radioactive decay of ^{56}Co.

in the Galaxy is $E(B-V)_G = 0\overset{m}{.}33$ (Schlafly & Finkbeiner 2011), so the extinction in the host galaxy is $E(B-V)_{\rm gal} = 0\overset{m}{.}15$.

The shape of the color curves is similar for all the displayed objects, all color indices are gradually increasing with time.

The distance to the host galaxy of SN 2019osl was calculated from its redshift, corrected for the motion relative to the cosmic microwave background as reported by NED[6], using $H_0 = 73$ km s^{-1} Mpc^{-1}; the distance modulus is $\mu = 33.2$.

Using the values of distance and extinction derived above, we obtain the absolute magnitudes of SN 2019osl at maximum: $M_B = -17\overset{m}{.}77$, $M_V = -17\overset{m}{.}94$, $M_R = -17\overset{m}{.}98$, $M_I = -17\overset{m}{.}92$. The mean maximum absolute magnitude in the V band for SNe II, according to Anderson et al. (2014), is $\overline{M_V} = -16\overset{m}{.}74$, so SN 2019osl is about $1\overset{m}{.}2$ brighter than the average SN II.

The light curve of SN 2019osl in absolute R-band magnitudes and comparison with the light curves for five SNe II is presented in Fig. 4. The sample of SNe II is the same as for comparison of the color curves, the data for these SNe were taken from the papers cited above. All presented SNe have similar maximum luminosity in the range from $-17\overset{m}{.}8$ to $-18\overset{m}{.}3$. The shape of the light curves for the first 60 days after maximum is also quite similar. The differences are in the length of the "plateau" stage and the luminosity at the final linear decline. SN 2012ixf is the best match to SN 2019osl, although the length of the "plateau" for SN 2023ixf is shorter.

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

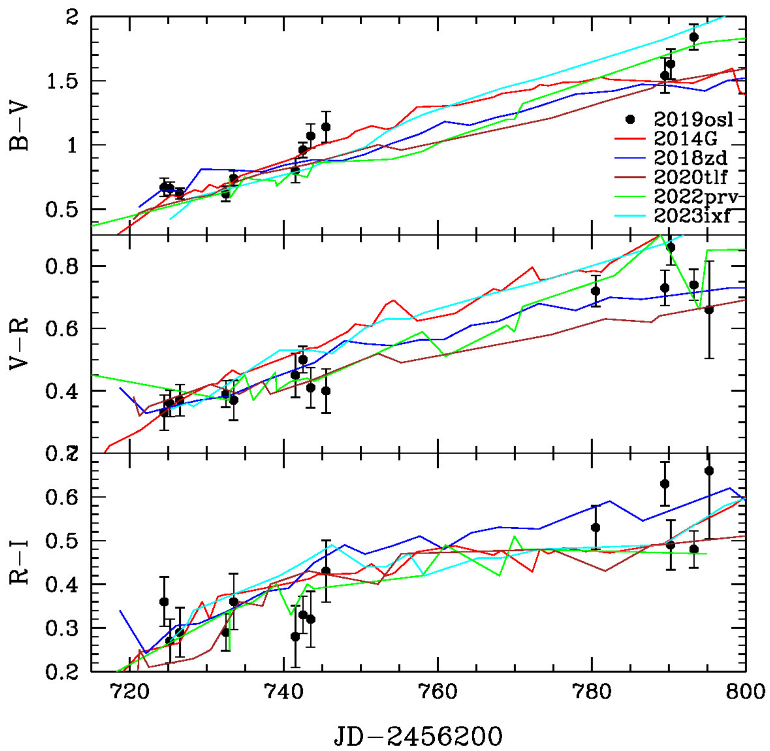

Figure 3.
The color curves of SN 2019osl and comparison with those for five SNe II.

4 Conclusions

The results of our observations, combined with the data from the literature, allowed us to determine the date of maximum brightness and magnitudes at maximum light for SN 2019osl, to study its light and color curves. The photometric evolution of SN 2019osl can be divided into three stages: nearly linear decline after maximum, fast drop, and final linear tail. The first stage is usually called "plateau", although, in this case, the luminosity is not constant. The rate of decline at this stage is close to the mean value for SNe II. The maximum luminosity of SN 2019osl is about $1\overset{m}{.}2$ brighter than for average SNe II. The light and color curves of SN 2019osl after maximum are matched by those for SNe 2014G, 2018zd, 2020tlf, 2022prv, 2023ixf, although significant differences in the length of the "plateau" and in luminosity on the final tail are revealed for these objects. The outburst of SN II in a lenticular galaxy seemed surprising, but we show that the classification of the host galaxy is erroneous and it demonstrates spiral structure.

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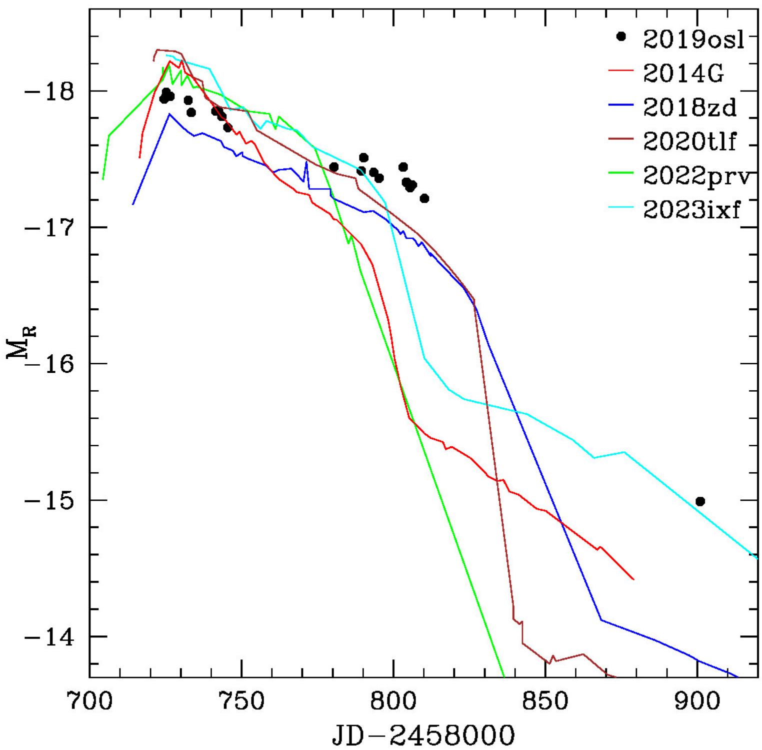

Figure 4.
The light curve of SN 2019osl in absolute R-band magnitudes and comparison with those for five SNe II.

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