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Type II-L Supernova SN 2019tua: Second Outburst in a Dwarf Galaxy

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Photometric observations of SN 2019tua, spanning 350 days of its evolution, show a linear light curve with a rate of brightness decline slower than for most SNe II-L. The maximum absolute magnitude of SN 2019tua, $M_R = -18\overset{\mathrm{m}}{.}0$, is close to the mean value for SNe II-L. SN 2019tua is the second type II SN in a dwarf galaxy UGC 11860. The two SNe were discovered with interval of 5 years, while the mean outburst SN frequency in such galaxies is about 1 event in 1300 years.

1 Introduction

Explosions of high-mass stars ($M >\sim 8M_\odot$) with hydrogen envelopes due to the gravitational collapse of their cores are classified as type II Supernovae (SNe). Barbon et al. (1979) proposed to divide SNe II into two major groups: SNe II-P, which have nearly constant luminosity for a time interval of ~ 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 parameters 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).

Explosions of two or more SNe in the same parent galaxy, which are called Supernova siblings, present special interest due to possibilities of exploring some characteristics of the host galaxies and testing distance estimation methods using SNe.

SN 2019tua (ATLAS19zjt, Gaia19ezc) in the galaxy UGC 11860 was discovered by ATLAS on 2019-10-31.33 UT at $m_c = 18\overset{\mathrm{m}}{.}72 \pm 0\overset{\mathrm{m}}{.}10$. The Supernova was offset by $2\overset{''}{.}3$ South, $7\overset{''}{.}3$ East from the center of its host galaxy, and was located at $\alpha = 21^{\mathrm{h}}58^{\mathrm{m}}00\overset{\mathrm{s}}{.}28, \delta = +24°15'57\overset{''}{.}1$, 2000.0 (Srivastav et al., 2019).

Spectra of SN 2019tua were obtained on 2019-11-01.38 UT at the Faulkes Telescope North, the best fit was found to SNe II at early phases. The expansion velocity was found to be about 17000 km s^{-1} from the Hα absorption and from the HeI 5876 Å line (Burke at al., 2019).

SN 2019tua is the second SN outburst in UGC 11860: five years earlier, SN ASASSN-14dq was discovered in this galaxy. ASASSN-14dq was a transitional event between the type II-P and type II-L SNe (Singh et al., 2018; Valenti et al., 2016).

The nearly simultaneous outbursts of two SNe are surprising because UGC 11860 is a low-luminosity type Sdm dwarf galaxy, its luminosity being only $\sim 1.5 \times 10^9 L_\odot$ (Singh et al., 2018). Using the mean values of SN frequency from Li et al. (2011), we can estimate the SN II rate for this galaxy as ~ 1 SN in 1300 years. Of course, the real time interval between the explosions of two SNe is unknown, but still we consider this a very rare event.

Table 1: $BVRI$ photometry of SN 2019tua

JD−2458000	B	σ_B	V	σ_V	R	σ_R	I	σ_I	Tel.
8809.10					15.41	0.05			M70
8815.96					15.40	0.03			M40
8816.29					15.43	0.04			M40
8817.00					15.44	0.04			M40
8817.06					15.43	0.05			M40
8838.97					15.91	0.02			M40
9033.50			19.27	0.06	18.32	0.03	18.02	0.03	K60
9047.48	20.10	0.07	19.55	0.04	18.52	0.03	18.16	0.04	K60
9050.47	20.15	0.08	19.51	0.05	18.48	0.04	18.17	0.04	K60
9057.44	20.25	0.07	19.55	0.07	18.52	0.04	18.16	0.05	K60
9058.46	20.44	0.06	19.57	0.04	18.53	0.02	18.26	0.03	K60
9067.44			19.82	0.06	18.66	0.03	18.46	0.04	K60
9079.51	20.74	0.06	19.94	0.05	18.78	0.03	18.63	0.07	K60
9085.39			19.90	0.08	18.79	0.04	18.66	0.07	K60
9103.29			20.36	0.06	19.09	0.06	19.12	0.06	K60
9116.24			20.88	0.05	19.44	0.03	19.32	0.07	K60
9129.39					19.47	0.06			K60
9146.27			21.20	0.10	19.93	0.05			K60
9163.31					20.27	0.04			K60

2 Observations and reductions

We obtained images of SN 2019tua in the R band with the 70-cm telescope in Moscow on 2019-11-21.6 UT. The observations with MASTER telescopes (Lipunov et al., 2010) were carried out at Tunka, Amur, SAAO. and OAFA sites. Unfiltered images were obtained on 5 epochs, from 2019-11-28 to 2019-12-21. Photometric monitoring at the 60-cm RC600 telescope of the Caucasus Mountain Observatory of Sternberg Astronomical Institute (Berdnikov et al., 2020), in the $BVRI$ bands, was performed between 2020-07-03 and 2020-11-09.

The standard image reductions and photometry were performed 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 subtracted using images of the host galaxy obtained at the RC600 telescope on 2022-05-30, when the SN had faded. The magnitudes of the local standard stars were taken from Singh et al. (2018). The unfiltered MASTER images were calibrated using the R-band magnitudes of local standards. The photometry is presented in Table 1, the identification of telescopes is given by the following codes: M70, the 70-cm reflector in Moscow; M40, 40-cm MASTER telescopes; K60, the 60-cm RC600 telescope of the Caucasus Mountain Observatory.

3 Results and conclusions

The light curves of SN 2019tua are presented in Fig. 1, we also plotted the magnitudes in Gaia G-band[2] and the discovery magnitude from ATLAS (Srivastav et al., 2019).

The maximum light was reached on about JD 2458812 with $R_{\max} \approx 15\overset{\mathrm{m}}{.}35$. After maximum, the brightness decline was nearly linear, with a rate 0.013 mag day^{-1} in the R

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

[2]http://gsaweb.ast.cam.ac.uk/alerts/alert/Gaia19ezc/

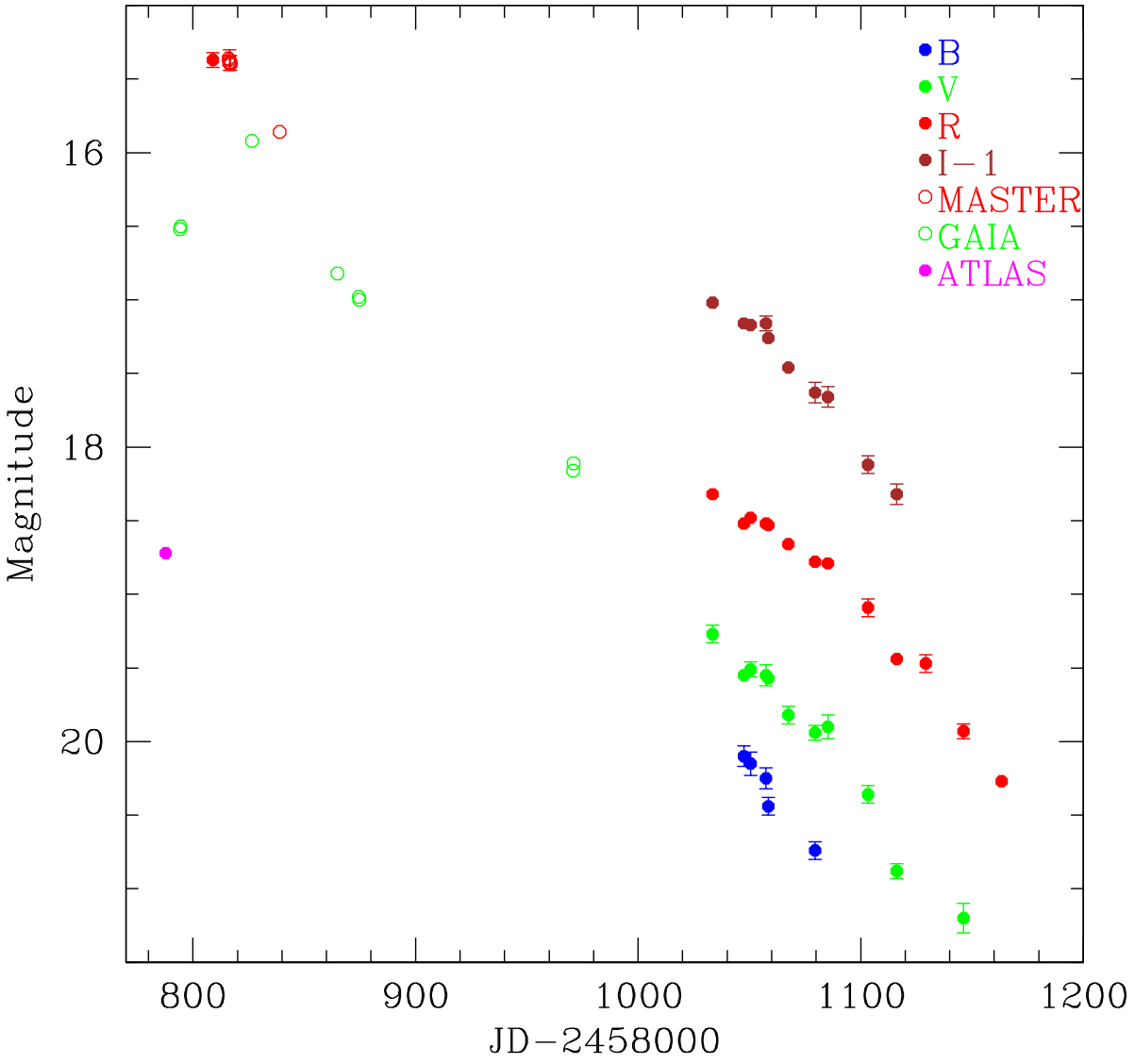

Figure 1: The light curves of SN 2019tua

band. Gaia G magnitudes demonstrated nearly the same rate, 0.015 mag day^{-1}. During the time interval of our continuous monitoring (JD 24589033–34589163), the rate of decline was 0.015 and 0.017 mag day^{-1} in the R and V bands, respectively. Thus, the linear phase of photometric evolution continued for about 350 days.

The absolute R-band light curve of SN 2019tua is presented in Fig. 2, it is compared with the light curve of ASASSN-14dq, which occurred in the same galaxy UGC 11860, and with five SNe II-L: 1998S, 2014G, ASASSN-15nx, 2016gsd, 2020mmz (Fassia et al., 2000, Bose et al., 2016, Bose et al., 2018, Reynolds et al., 2019, Tsvetkov et al., 2022).

We plotted the magnitudes from Singh et al. (2018) for ASASSN-14dq, and also an upper limit from images obtained at the MASTER Tunka telescope on 2014-07-01.66 UT, 7 days before discovery.

We accept the distance modulus $\mu = 33.25$ for UGC 11860 from Singh et al. (2018). We consider the extinction in the host galaxy to be negligible for both SNe, because the interstellar lines of NaI were not detected in the published spectra (Singh et al., 2018; Burke et al.. 2019). We also note that both SNe occurred at similar projected distances from the center of the host galaxy: 1.9 and 1.7 kpc for ASASSN-14dq and 2019tua, respectively. The projected distance between the sites of the two SNe is 2.4 kpc.

We applied to both SNe only the galactic extinction $E(B-V) = 0\overset{\mathrm{m}}{.}06$ according to Schlafly and Finkbeiner (2011). The distances and extinctions for the SNe from the comparison sample were adopted from the references above.

The maximum luminosities of SN ASASSN-14dq and SN 2019tua are similar, with SN 2019tua only $0\overset{\mathrm{m}}{.}3$ brighter. The shape of the light curves is different. ASASSN-14dq shows typical photometric evolution for a transitional event between types II-P and II-L: three phases with different rates of decline. The light curve of SN 2019tua exhibits monotonous decline. The comparison with the light curves of five SNe II-L shows that the decline rate of SN 2019tua is quite slow, at phase ∼300 days it is brighter than other SNe from the sample. Only SN 2016gsd has similar luminosity at that epoch, but at maximim it was $1\overset{\mathrm{m}}{.}7$ brighter than SN 2019tua. We also note that most SNe II-L and transitional objects show changes of decline rate, while for SN 2019tua it is quite monotonous. The absolute magnitude $M_{R\mathrm{max}} = -18\overset{\mathrm{m}}{.}0$ for SN 2019tua is very close to the mean value for SNe II-L according to Richardson et al. (2014).

The comparison of two type II SNe that occurred in the galaxy UGC 11860 reveals that they had quite different luminosity evolution, although their maximum absolute magnitudes were quite close to each other. Singh et al. (2018) applied the SCM method to ASASSN-14dq to estimate the distance for the host galaxy, the result was close to that derived from the galaxy redshift. We cannot apply the same method to SN 2019tua to verify its precision because of different nature of the light curve and insufficient set of observational data. Singh et al. (2018) did not reveal any peculiarity of the dwarf galaxy UGC 11860, we suppose that the nearly simultaneous outbursts of two SNe were rare occasional events.

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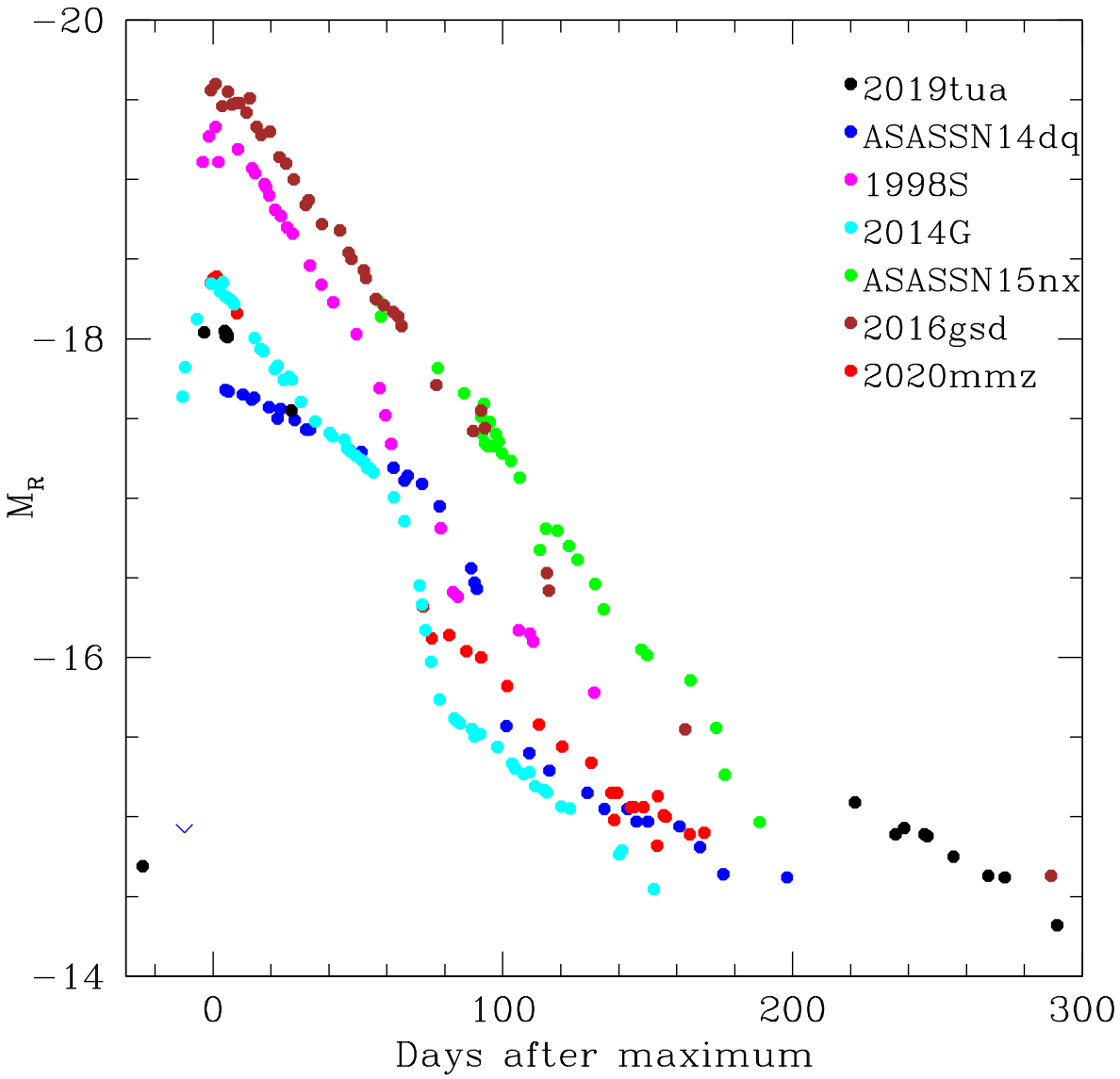

Figure 2: The absolute *R*-band light curve of SNe 2019tua, compared to those for ASASSN-14dq and five SNe II-L.

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