

# V5852 Sgr: an unusual nova possibly associated with the Sagittarius stream

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## ABSTRACT

We report spectroscopic and photometric follow-up of the peculiar nova V5852 Sgr (discovered as OGLE-2015-NOVA-01), which exhibits a combination of features from different nova classes. The photometry shows a flat-topped light curve with quasi-periodic oscillations, then a smooth decline followed by two fainter recoveries in brightness. Spectroscopy with the Southern African Large Telescope shows first a classical nova with an Fe II or Fe II b spectral type. In the latter spectrum, broad emissions from helium, nitrogen and oxygen are prominent, and the iron has faded which could be an indication to the start of the nebular phase. The line widths suggest ejection velocities around  $1000 \text{ km s}^{-1}$ . The nova is in the direction of the Galactic bulge and is heavily reddened by an uncertain amount. The V magnitude 16 days after maximum enables a distance to be estimated and this suggests that the nova may be in the extreme trailing stream of the Sagittarius dwarf spheroidal galaxy. If so it is the first nova to be detected from that, or from any dwarf spheroidal galaxy. Given the uncertainty of the method and the unusual light curve we cannot rule out the possibility that it is in the bulge or even the Galactic disk behind the bulge.

**Key words:** binaries: close – novae, cataclysmic variables – white dwarfs.

## 1 INTRODUCTION

Classical novae (CNe) form a subclass of the cataclysmic variable stars. They are ‘close binary systems consisting of a white dwarf (WD) and a Roche lobe filling companion’ (Bode & Evans 2008). Matter accreted by the WD from the secondary accumulates and is compressed on the WD surface. When the critical temperature and

density are reached, a thermonuclear runaway is triggered, causing a nova eruption (Priyalnik 1986). Typical ejecta velocities and masses are  $\sim 1000 \text{ km s}^{-1}$  and between  $10^{-5}$  and  $10^{-4} M_{\odot}$ , respectively (Gaposchkin 1957; Gallagher & Starrfield 1978).

Nova light curves are classified on the basis of their decline rate in various ways, but often in terms of time in days ( $t_2$ ) for the decline by 2 mag from maximum light (Payne-Gaposchkin 1964). More recently, Strope, Schaefer & Henden (2010) published an atlas of light curves of 93 novae based on visual estimates collected by American Association of Variable Star Observers (AAVSO),

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and they proposed a classification scheme based on the light-curve shape and rate of decline. They defined seven classes: S (smooth), P (plateau), D (dust dip), C (cusped secondary maximum), O (oscillations), F (flat-topped) and J (jitters). It is important to recognize that this classification is based on visual light curves, and given that the colours of novae typically change during their evolution, we should not expect other bands to track the visual curves with any degree of precision. Nevertheless, this nomenclature has been used by others for *I*-band light curves of novae [e.g. Mróz et al. (2015) where they classified OGLE *I*-band light curves of 39 novae in the Galactic bulge using the same scheme], and we therefore refer to it here.

In addition to the photometric classification, various approaches have been taken to classify the spectral evolution of novae (McLaughlin 1944; Gaposchkin 1957; Williams 2012). Post-outburst spectra are divided into two spectroscopic classes: the Fe II-type novae which show numerous narrow Fe II emission lines with P Cygni profiles and He/N-type novae which show broad He, N and H emission lines. A third class was also introduced, known as hybrid novae. These show a transition between the two types (Fe II and He/N) or simultaneous emission lines of both types (Williams 1992). From a study of 22 Galactic novae, Della Valle & Livio (1998) established that novae showing He/N spectroscopic features are faster, and have brighter maxima, compared to those from the Fe II class. The precise mechanism responsible for the formation of the different spectral features after the explosion is poorly understood, but it is thought that the WD mass and the circumstellar environment play a crucial role in this matter (Shafter et al. 2011).

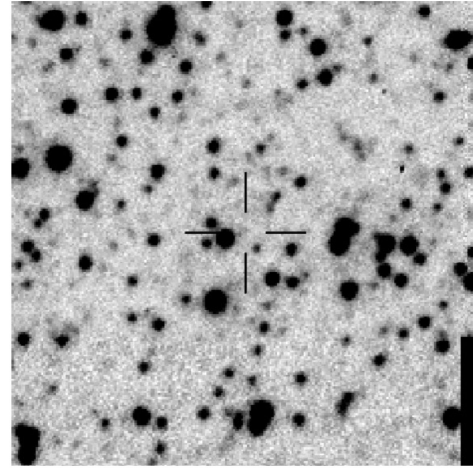
In this paper, we report the discovery of an unusual nova, V5852 Sgr, that may be a member of the trailing stream of the Sagittarius Dwarf Spheroidal Galaxy (henceforth the Sagittarius stream). At about 20 kpc, the Sagittarius dwarf is our nearest neighbour and is being tidally disrupted by its interaction with the Milky Way. It was discovered by Ibata, Gilmore & Irwin (1995) via the distinctive velocities of its stars. It has since been shown to be stretched into a stream that loops around the Milky Way, with an estimated total mass of about  $5 \times 10^8 M_{\odot}$  (Majewski et al. 2003), making it the largest dwarf spheroidal galaxy in the Local Group.

The nova shows combined features from different nova spectrophotometric classes and presents an interesting case to study. In Section 2, we present the discovery and the photometric (optical and IR) follow-up of the object. SALT (Southern African Large Telescope) spectroscopic optical data (between 4500 and 7800 Å) are detailed in Section 3. We present in Section 4 a discussion aiming to classify the nova, and establish its location and our conclusions.

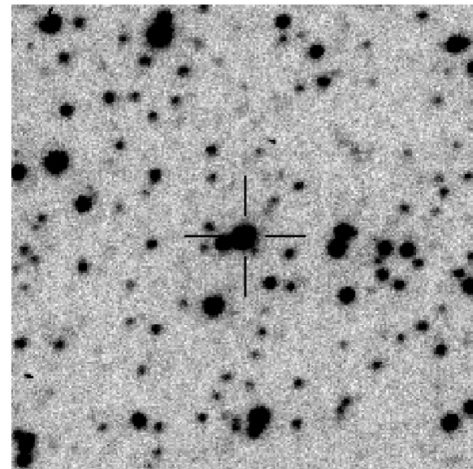
## 2 DISCOVERY AND PHOTOMETRIC DATA

### 2.1 Discovery

V5852 Sgr was announced as a CN candidate and given the name OGLE-2015-NOVA-01, on 2015 March 5 by Mróz & Udalski (2015) based on observations from the Optical Gravitational Lensing Experiment (OGLE) survey. The transient was detected by the Early Warning System, which has been designed for the detection of microlensing events. Fig. 1 presents charts of the nova before and during the eruption. From the time of the discovery, however, it was clear that the light curve (Fig. 2) does not resemble that of a microlensing event. The star is located in the direction of the Galactic bulge at equatorial coordinates of  $(\alpha, \delta)_{J2000.0} = (17^{\text{h}}48^{\text{m}}12^{\text{s}}.78, -32^{\circ}35'13''.44)$  and Galactic coordinates of  $(l, b) = (357^{\circ}.16, -2^{\circ}.36)$ .



(a) Finding chart before the eruption



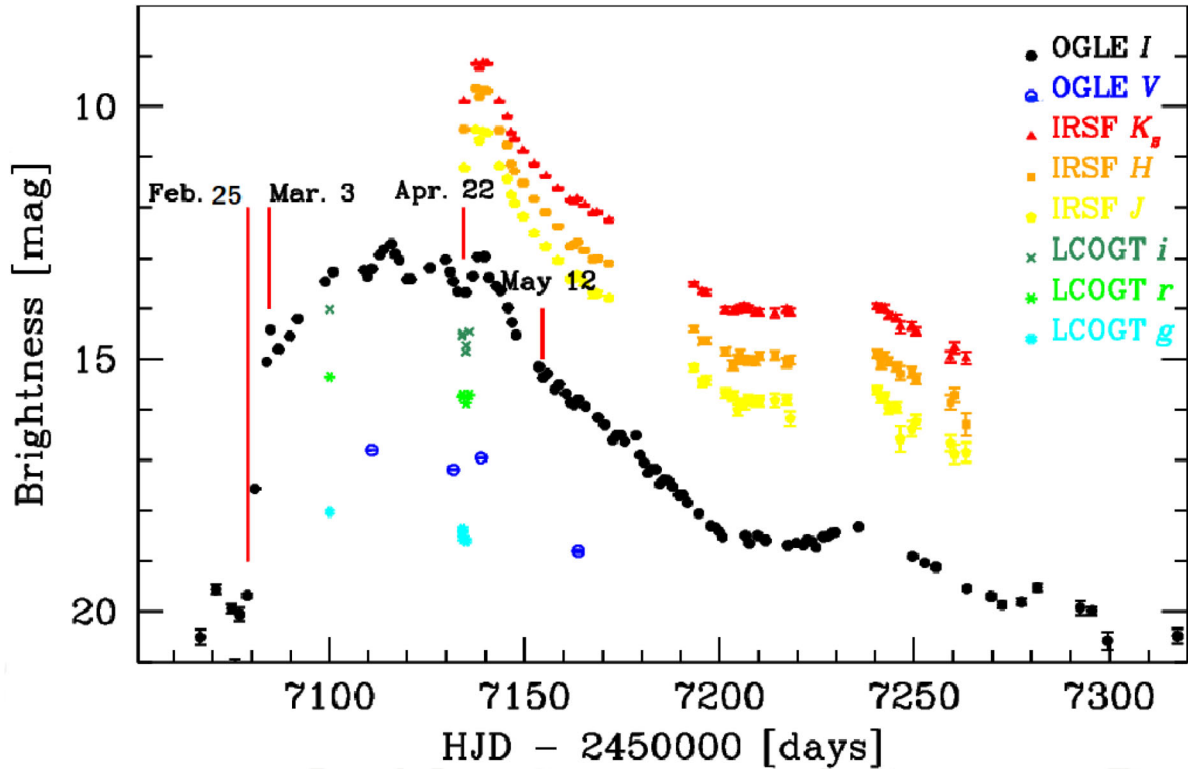
(b) Finding chart during the eruption (5<sup>th</sup> of March 2015)

**Figure 1.** Finding charts for V5852 Sgr before and during the eruption in the *I* band. (North is up and east is to the left, image size 1 arcmin  $\times$  1 arcmin). (a) Finding chart before the eruption. (b) Finding chart during the eruption (2015 March 5).

### 2.2 Observation and data reduction

The source has been observed by the OGLE variability survey since 2010 with a typical cadence of 1–2 d. This survey uses the 1.3 m Warsaw Telescope located at Las Campanas Observatory, Chile, operated by the Carnegie Institution for Science. Observations were taken through *V*- and *I*-band filters, closely resembling those of the standard Johnson–Cousins system. The photometry was carried out with the difference image analysis algorithm (Alard & Lupton 1998; Wozniak 2000). Details of reductions and calibrations can be found in Udalski, Szymański & Szymański (2015). The light curve of the 2015 eruption data is shown in Fig. 2. In Tables 1 and 2, we present OGLE *V*- and *I*-band photometry, respectively.

Multicolour *gri* photometry was obtained using the Las Cumbres Observatory Global Telescope Network (LCOGT) 1 m robotic telescope at the South African Astronomical Observatory (SAAO), Sutherland, South Africa on 2015 March 19 and April 22–23. The data are presented in Table 3 and included in Fig. 2. The photometry was carried out with DOPHOT (Schechter, Mateo & Saha 1993) and



**Figure 2.** The photometric data from OGLE, LCOGT and IRSF as a function of Heliocentric Julian Date (HJD), colour coded as indicated. The first two red bars indicate the dates when the eruption starts. The SALT spectra were obtained on April 22 and May 12.

**Table 1.** OGLE *V*-band photometry. The time series photometry is available from the OGLE Internet Archive.<sup>a</sup>

HJD	<i>V</i>	$\Delta V$
-2457000	(mag)	
110.84656	16.799	0.005
131.79511	17.184	0.006
138.84101	16.924	0.005
163.78319	18.945	0.017

<sup>a</sup><ftp://ftp.astrouw.edu.pl/ogle/ogle4/NOVAE/BLG>

calibrated with the aid of the AAVSO Photometric All-Sky Survey (APASS;<sup>1</sup> Henden et al. 2009).

The source was observed by the *Swift* satellite (Gehrels et al. 2004) on 2015 April 11, 15 and 20 with a total exposure time of 2.61 ks. No X-ray source was detected with the X-Ray Telescope (Burrows et al. 2005) at the position of the nova, which gives  $3\sigma$  upper limits of 0.022, 0.024 and 0.008 counts  $s^{-1}$ , respectively, in the 0.3–10 keV energy range. Upper limits were estimated with the SOSTA tool, which is a part of the XIMAGE package (version 4.5.1).

We also analysed images taken with the UVOT (Ultraviolet/Optical Telescope; Roming et al. 2005) on board *Swift* and estimated the brightness of the source with the UVOTSOURCE tool, which performs aperture photometry. We detected a faint counterpart in the *U* band ( $21.03 \pm 0.58$  mag), while the source was invisible in the *UVW1* filter (which peaks at 260 nm) images. The UVOT observations are summarized in Table 3.

**Table 2.** A sample of OGLE *I* photometry. The rest of the data can be found on the electronic version and are available from the OGLE Internet Archive.<sup>a</sup>

HJD	<i>I</i>	$\Delta I$
-2457000	(mag)	
66.86475	20.507	0.153
70.89930	19.559	0.092
74.85976	19.941	0.089
75.83561	21.281	0.335
76.90152	20.055	0.135
78.87609	19.678	0.043
80.89831	17.569	0.010
83.80943	15.059	0.002

<sup>a</sup><ftp://ftp.astrouw.edu.pl/ogle/ogle4/NOVAE/BLG>

We obtained infrared photometry with the SIRIUS camera (Nagayama et al. 2003) on the 1.4 m Japanese-South African InfraRed Survey Facility (IRSF) at SAAO Sutherland. This has a  $7 \text{ arcmin} \times 7 \text{ arcmin}$  field of view,  $0''.45$  pixels and provides simultaneous *JHK<sub>S</sub>* photometry. Exposures of 125 s were achieved by combining 25 dithered 5 s exposures. Photometry on the 2MASS system was performed relative to the nearby stars 2MASS17481467–3235040 and 2MASS17481308–3235223. The rms of the instrumental magnitudes of these reference stars was only  $\sigma_J = 0.010$ ,  $\sigma_H = 0.008$ ,  $\sigma_K = 0.007$  mag, demonstrating that they do not vary.

As can be seen in Fig. 1, the field is crowded; in particular the nova is only  $2''.8$  from 2MASS17481299–3235142 ( $J = 12.9$ ,  $H = 11.4$ ,  $K_S = 10.8$ ). So to do aperture photometry, the stars in the immediate vicinity of the nova, and of the two reference stars, were subtracted using DAOPHOT in IRAF before the photometry was performed. The

<sup>1</sup> <https://www.aavso.org/apass>

**Table 3.** LCOGT and *Swift* photometry of V5852 Sgr.

HJD −2457000	Filter	Exp. time (s)	Magnitude
LCOGT			
100.60483	<i>g</i>	450	18.026 ± 0.011
100.61375	<i>r</i>	180	15.366 ± 0.006
100.61103	<i>i</i>	180	13.982 ± 0.004
134.54530	<i>g</i>	200	18.552 ± 0.054
134.54815	<i>i</i>	100	14.545 ± 0.017
134.55012	<i>r</i>	100	15.751 ± 0.022
134.57024	<i>g</i>	200	18.405 ± 0.033
134.60703	<i>g</i>	200	18.468 ± 0.043
134.60988	<i>i</i>	100	14.513 ± 0.029
134.61164	<i>r</i>	100	15.749 ± 0.028
134.64962	<i>g</i>	200	18.365 ± 0.065
134.65258	<i>i</i>	100	14.499 ± 0.028
134.65433	<i>r</i>	100	15.712 ± 0.033
135.49551	<i>i</i>	100	14.858 ± 0.035
135.52847	<i>g</i>	200	18.598 ± 0.040
135.53115	<i>i</i>	100	14.739 ± 0.049
135.53302	<i>r</i>	100	15.870 ± 0.024
136.41910	<i>i</i>	100	14.462 ± 0.053
136.42073	<i>r</i>	100	15.712 ± 0.056
<i>Swift</i>			
124.36	UVW1	720	>20.07 <sup>a</sup>
127.52	UVW1	479	>19.85 <sup>a</sup>
133.41	U	1345	21.03 ± 0.58

<sup>a</sup>3 $\sigma$  limit.

2MASS magnitudes of the reference stars were then used to derive the zero-points and an average taken. Photometry was done using apertures with radii of 5, 7 and 10 pixels. For measurements of  $J$ ,  $H < 14$  and  $K_S < 13.5$ , the choice of aperture makes no significant difference to the result. For much fainter magnitudes, the results from the 5 and 10 pixel apertures can differ by up to 0.2 mag. The measurements listed in Table 4 were made with a 7 pixel aperture.

### 2.3 Light curve

The eruption started between 2015 February 25 (HJD 2457078.88) and 27 (HJD 2457080.90), when the source brightened by 2 mag from  $I = 19.7$  to 17.6; by March 3 (HJD 2457084.8) it had reached  $I = 14.4$ . This was followed by a short pre-maximum halt and then a nearly linear rise by 1.5 mag in 14 d. The source peaked on 2015 April 3 (HJD=2457115.87) at  $I = 12.7$  (although the maximum could have taken place 10 days earlier, when no observations were collected because of heavy storms over Las Campanas). Between 2015 March 20 and May 1, the source showed a long, flat peak, similar to F class light curves, with additional semi-regular oscillations on a time-scale of 12 d and amplitude of 0.8 mag, reminiscent of the early stages of D class (e.g. V992 Sco) or J class light curves (Strope et al. 2010). At this phase, the light curve also resembled the early stages of the outburst of the red nova V838 Mon (Munari et al. 2002, fig. 5) and the 2011 outburst of the recurrent nova T Pyx (Surina et al. 2014, fig. 1).

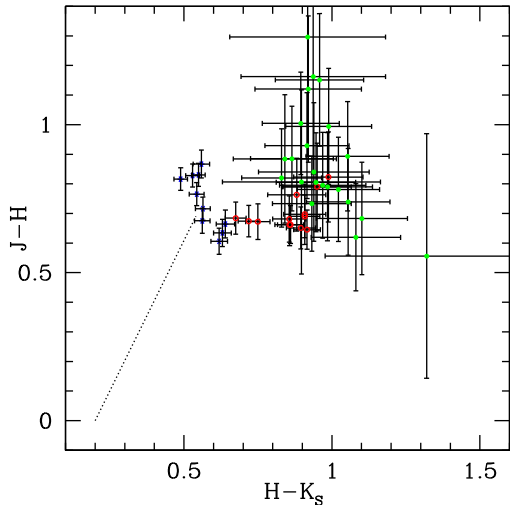
Infrared  $JHK_S$  (Table 4) measurements were only initiated when it was clear that the  $I$  light-curve development was unusual and, as can be seen in Fig. 2, the  $JHK_S$  curves more or less follow the fall of the  $I$  curve. Fig. 3 shows the development of the infrared colours. The reddening vector indicates that  $(J - H)_0$  is close to zero or slightly negative and that it is remarkably constant, while

**Table 4.** Near-infrared photometry from IRSF at  $JHK_S$  bands.

HJD −2457000	$J$	$\Delta J$	$H$	$\Delta H$	$K_S$	$\Delta K_S$
(mag)						
134.52332	11.21	0.02	10.45	0.01	9.91	0.01
137.49937	10.45	0.02	9.64	0.01	9.15	0.01
138.46439	10.67	0.03	9.81	0.02	9.25	0.01
139.55240	10.49	0.02	9.67	0.01	9.14	0.01
140.40741	10.52	0.02	9.69	0.01	9.15	0.01
143.61646	11.19	0.02	10.47	0.01	9.91	0.01
145.55649	11.43	0.03	10.76	0.01	10.20	0.01
146.50150	11.75	0.03	11.14	0.02	10.52	0.01
147.43051	11.91	0.03	11.28	0.02	10.65	0.01
149.66654	12.18	0.03	11.51	0.02	10.87	0.01
152.49157	12.51	0.03	11.82	0.02	11.15	0.01
155.45161	12.77	0.03	12.10	0.02	11.38	0.02
158.57664	13.05	0.04	12.37	0.02	11.62	0.02
161.62666	13.41	0.04	12.77	0.03	11.85	0.02
162.64767	13.40	0.04	12.74	0.03	11.88	0.02
163.60868	13.34	0.04	12.68	0.02	11.82	0.02
165.41369	13.50	0.04	12.85	0.03	11.95	0.02
167.57171	13.72	0.06	13.03	0.04	12.12	0.03
168.65172	13.70	0.04	13.01	0.03	12.10	0.02
171.65273	13.79	0.05	13.11	0.03	12.25	0.02
193.51274	15.17	0.07	14.40	0.05	13.52	0.04
195.61862	15.46	0.08	14.64	0.07	13.65	0.05
196.61061	15.43	0.08	14.64	0.07	13.69	0.05
201.53558	15.68	0.09	14.86	0.08	14.03	0.06
203.59956	15.74	0.09	15.12	0.09	14.04	0.06
204.60055	16.00	0.11	15.01	0.09	14.02	0.06
205.31855	15.89	0.10	14.89	0.07	13.99	0.06
206.37154	15.90	0.10	15.01	0.08	13.96	0.06
207.34053	15.81	0.09	15.03	0.08	14.01	0.06
209.26551	15.83	0.09	15.04	0.09	14.07	0.06
210.41849	15.82	0.10	14.94	0.08	14.07	0.06
214.23445	15.81	0.13	14.93	0.09	14.09	0.09
217.27441	15.81	0.10	15.07	0.08	14.01	0.06
218.19040	16.17	0.14	15.02	0.08	14.06	0.06
240.39200	15.62	0.08	14.89	0.08	13.96	0.06
241.47998	15.78	0.10	15.09	0.09	13.99	0.06
242.31996	15.75	0.09	14.94	0.08	13.99	0.06
243.40194	15.98	0.10	15.05	0.08	14.13	0.06
245.38289	15.95	0.10	15.16	0.08	14.18	0.07
246.43287	16.58	0.27	15.28	0.14	14.37	0.13
249.44780	16.38	0.15	15.26	0.10	14.34	0.08
250.45178	16.23	0.13	15.39	0.10	14.45	0.08
259.29456	16.66	0.16	15.86	0.15	14.96	0.12
260.31153	16.88	0.19	15.71	0.14	14.78	0.10
263.28446	16.85	0.19	16.29	0.22	14.97	0.12

$(H - K_S)_0$  gets slightly redder with time. A negative value for  $(J - H)_0$  has been seen in other novae (Whitelock et al. 1984) and is attributed to very strong emission lines in the  $J$  band (the SAAO  $J$  filter used by Whitelock et al. is more sensitive to the He I 1.083  $\mu\text{m}$  line than is the IRSF  $J$  filter and therefore their  $J - H$  is very negative when this line is strong). Given that nova spectra are dominated by emission lines, it is not possible to properly transform photometry taken through different filters, so detailed comparisons of nova colours are difficult.

It is obvious that the overall development of the light curve (Fig. 2) is quite unlike any of the standard nova classes as can be seen by comparing it with the OGLE light curves of bulge novae (Mróz et al. 2015). The decline at around HJD 2457150 and the recovery around HJD 2457230 could possibly have been the consequence of dust forming and gradually dispersing. However,



**Figure 3.** Evolution of the  $JHK_S$  colours; asterisks, open circles and filled circles represent observations before HJD 2457150, between HJD 2457150 and 2457200 and after HJD 2457200, respectively. The dotted vector shows the effect of correcting for reddening assuming  $E(J - H) = 0.69$  and  $E(H - K_S) = 0.34$  (see Section 2.4).

Fig. 3 shows no indication of the very red colours associated with significant quantities of dust. The colours of dust-forming novae are illustrated in fig. 4 of Whitelock et al. (1984) for several other novae.

We measured decline times in the  $I$  band over 2 and 3 mag of  $t_2 = 34 \pm 2$  and  $t_3 = 45 \pm 2$  d, respectively. So this nova was moderately fast to average according to the criteria in Bode & Evans (2008), although given the unusual characteristics of the light curve and the fact that we only have decay rates at  $I$ , and not  $V$ , it is not entirely clear how this should be interpreted.

In the pre-eruption images, we detected a possible very faint progenitor  $I_{\text{pre}} = 20.77$ , which is invisible in the  $V$ -frames (as expected given the reddening discussed in Section 2.4). We did not find any significant periodic variability before the eruption.

In summary, our photometric data show a moderately fast outburst, followed by a flat-topped light curve with oscillations and a smooth decline followed by two faint recoveries in the brightness (between HJD 2457220 and 2457270 and between 2457280 and 2457300). A comparison with the light-curve classes presented by Stroepe et al. (2010) shows that the flat-topped light curve of V5852 Sgr is similar to the F class light curves. In addition, the quasi-periodic oscillations during the peak in the intensity are similar to both J class and O class light curves. This combination of features indicates the unusual light-curve development of V5852 Sgr. Note that a flat-topped light curve with oscillations is also seen for the 2011 light curve of the recurrent nova T Pyx. A detailed spectrophotometric study by Surina et al. (2014) of the T Pyx 2011 outburst shows a pre-maximum halt followed by a slow flat-topped outburst with quasi-periodic oscillations of a period  $\sim 2$  d.

The remarkable features in the light curve justified our request for SALT spectra to establish if the spectral development was also unusual.

## 2.4 Reddening and distance

Given its position towards the bulge, we expect the nova to be heavily reddened; determining exact values poses a challenge. At  $l = -2:8$  and  $b = -2:4$ , it is very close, but just outside the

region around the Galactic Centre ( $|l| < 3^\circ$ ,  $|b| < 1^\circ$ ) for which Nishiyama et al. (2009) determined an interstellar extinction law that is significantly different from that generally assumed (Cardelli, Clayton & Mathis 1989). Recently, Nataf et al. (2015) have shown that large variations in the extinction ratios are common around the Galactic Centre.

The VVV extinction calculator, which is based on Gonzalez et al. (2012), indicates  $E(J - K_S) = 1.03$  corresponding to  $A_K = 0.71 \pm 0.12$  and  $A_V = 6.44$  mag on the Cardelli law or  $A_K = 0.54 \pm 0.12$  and  $A_V = 8.88$  mag on the Nishiyama law. As an alternative approach, we measured the centroid of the red giant clump ( $V - I$ ) $_{\text{clump}} = 3.99 \pm 0.03$  on the colour-magnitude diagram, using the OGLE data for stars in an area of 2 arcmin  $\times$  2 arcmin around the nova. The intrinsic colour of the Galactic bulge red clump stars is 1.06 (e.g. Nataf et al. 2013), so the colour excess is  $E(V - I) = 2.93 \pm 0.03$  in this direction. Using the extinction relations for the Galactic bulge from Nataf et al. (2013), we find  $A_I = 3.60 \pm 0.17$  mag and  $A_V = 6.53 \pm 0.18$  mag. Although this method estimates the extinction foreground of the bulge red clump stars, we can reasonably assume that most of the extinction is in the foreground disc and therefore included. This method should provide the best possible measure for the line of sight to the nova and therefore in the following analysis we assume  $A_V = 6.53$  and  $A_I = 3.60$ . It is important to recognize that many of the conclusions of this paper are critically dependent on this assumption.

The distances to novae are often estimated from their decline rates, noting that fast novae are more luminous than slow ones. However, the individual measurements have considerable uncertainties, and the validity of the so-called ‘maximum magnitude versus rate of decline’ relations was recently questioned by Kasliwal et al. (2011), Cao et al. (2012) and Shara et al. (2016). Furthermore, these relations have not been defined in the  $I$  band and no empirical relation between the rate of decline in  $I$  and  $V$  has been derived (Munari, private communication).

A relationship sometimes used to derive distances is based on the understanding that all novae have a similar  $V$  mag 15 d after maximum:  $M_V = -6 \pm 0.44$  (Downes & Duerbeck 2000). Coincidentally, V5852 Sgr was measured at  $V$  about 16 d after maximum (Table 1) with  $V = 17.18$  (making the reasonable assumption that maximum at  $V$  and  $I$  are close together in time), corresponding to  $V_0 = 10.65$  and a distance ( $(m - M)_0 = 16.65$  mag) in the range 17–27 kpc. Because of the unusual light curve (Section 2.3) and the extension in the peak of brightness with quasi-periodic oscillations, this distance must be regarded as very uncertain.

There are several possible explanations of the large distance estimate. Most obviously, it suggests the nova is behind the bulge, rather than in it. At about 22 kpc, it would be about the right distance to be associated with the Sagittarius stream (Ibata et al. 1995). Although it is a few degrees away from where the Sagittarius stream crosses the Galactic plane, it is within the area where the OGLE group found RR Lyr variables that are members of the Sagittarius stream (see fig. 3 in Soszyński et al. 2014). The nova is not coincident with the main density of OGLE variables (with distances from Pietrukowicz et al. 2015), but it is plausibly within the volume occupied by the trailing stream from the Sagittarius dwarf which can be seen from Torrealba et al. (2015) when their fig. 16 is interpolated through the Galactic plane. Furthermore, the radial velocity (see Section 3.3) although uncertain is consistent with membership of the Sagittarius stream.

We need to consider other possible explanations as alternatives to membership of the Sagittarius stream. First, it could be in the Galactic disc behind the bulge; at 22 kpc it is less than 1 kpc above

the plane. This is discussed further in Section 3.3 in the context of the nova's radial velocity. Secondly, given its peculiar light curve, this nova may not follow the usual decay rate–luminosity relations and therefore could be in the bulge. Thirdly, because of the peculiarity of the reddening law discussed above, it is possible that the interstellar extinction at  $V$  is higher than the  $A_V = 6.53$  used here and therefore that the nova is in the bulge and not subluminal. Although values as high as the  $A_V = 8.88$  mag derived from the Nishiyama law can be ruled out, because in that case the red clump stars would not have been observable.

Some combination of greater reddening and slightly subluminal nova could also explain the observations. It has been suggested that novae in the bulge, which originate from low-mass WDs, are somewhat fainter than those in the disc [e.g. Della Valle & Livio (1998) and Della Valle (2002)]. There is also some evidence that relatively slow novae are more common in the bulge and fast novae in the disc (Shafter et al. 2011).

### 3 SPECTROSCOPIC DATA

#### 3.1 Observation and data reduction

The nova was observed on 2015 April 22 and May 12, using the Robert Stobie Spectrograph (RSS; Burgh et al. 2003; Kobulnicky et al. 2003), mounted on the SALT situated at the SAAO, Sutherland, South Africa. The observation on 2015 April 22 consists of two spectral ranges: [4500–5850 Å] and [5800–7000 Å]. The RSS long-slit mode was used with a 0.6 arcsec slit at a resolution of  $R \sim 5000$  for both spectral ranges with exposure times of ( $4 \times 100$  s) and ( $2 \times 150$  s), respectively. The poor weather conditions and seeing resulted in a limited S/N.

The May 12 observation was carried out, under good seeing ( $\sim 1.0$  arcsec). The data cover three spectral ranges, [4500–5450 Å], [5400–6750 Å] and [6700–7850 Å]. The RSS long-slit mode was used with the same narrow slit as above resulting in a resolution of  $R \sim 7000$  for the first spectral range while a different grating was used for the second and third spectral ranges at a resolution of  $R$

$\sim 5000$ , with exposure times of ( $5 \times 200$  s), ( $4 \times 100$  s) and ( $4 \times 100$  s), respectively. The spectra are reduced and calibrated using the PYSALT pipeline (Crawford et al. 2010). The images are combined, the background is subtracted and the spectra are extracted using the IRAF (Image Reduction and Analysis Facility) software (Tody 1986).

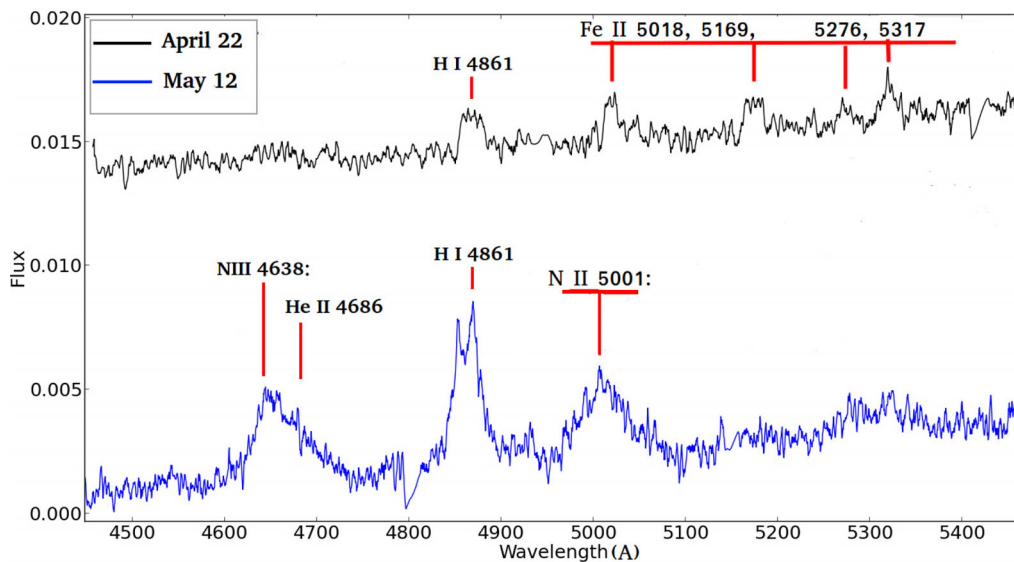
#### 3.2 Spectral changes

In Figs 4–8, we show the smoothed spectra, where the top spectrum represents the April 22 observation and the bottom spectrum represents the May 12 observation. The spectral lines were identified mostly using the list from Williams (2012). The only clear absorption features in either spectrum are telluric. The April 22 spectra show several broad flat-topped Fe II, H I and N II emission lines. However, in the May 12 spectra, the Fe II lines become weaker and almost disappear, in contrast to the He and N lines that become stronger. H $\beta$  (Fig. 4) and to some extent H $\alpha$  (Fig. 7) show a double peak. These could be the consequence of bipolar ejection or an optically thin shell of gas [see e.g. models of Nova Eri 2009 by Ribeiro et al. (2013)]. Further in the red, between 6750 and 7850 Å, the May 12 spectrum shows strong He, O and possibly C emission lines.

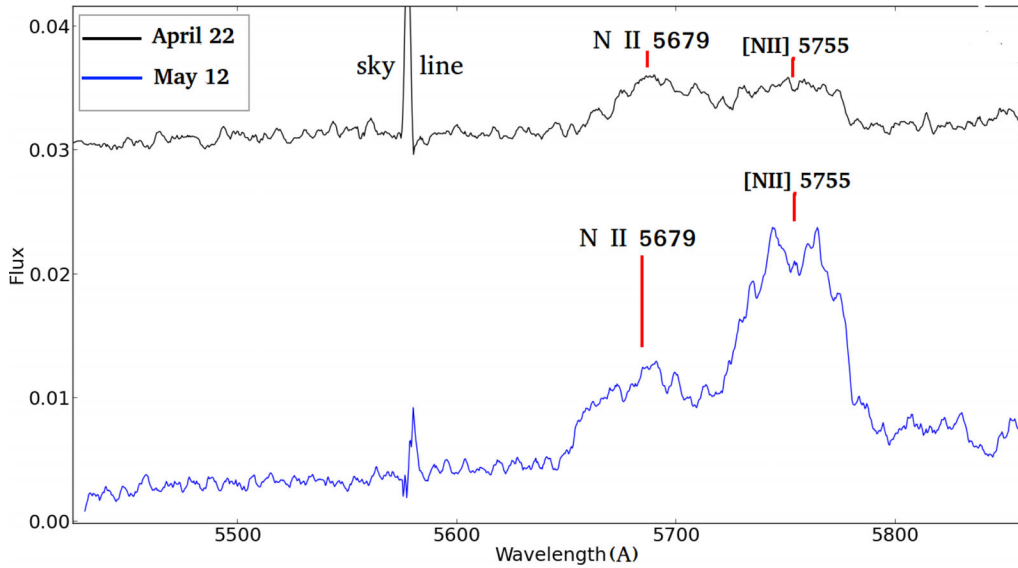
#### 3.3 Radial and expansion velocities

The Balmer lines have asymmetric profiles, similar to other novae in the transition stage. In the May spectrum, H $\alpha$  and H $\beta$  have double peaks with the red peak stronger than the blue one; [N II] 5755 Å, O I 7773 Å and possibly C II 7236 Å are also double peaked. We derived, using a Lorentzian fitting, the full width at half-maximum (FWHM) of H $\alpha$ , H $\beta$  and [N II] 5755 Å lines. We found that for H $\alpha$  the FWHM  $\sim 2300 \pm 200$  km s $^{-1}$ , for H $\beta$  the FWHM  $\sim 2400 \pm 200$  km s $^{-1}$  and for [N II] 5755 Å the FWHM  $\sim 2700 \pm 200$  km s $^{-1}$ .

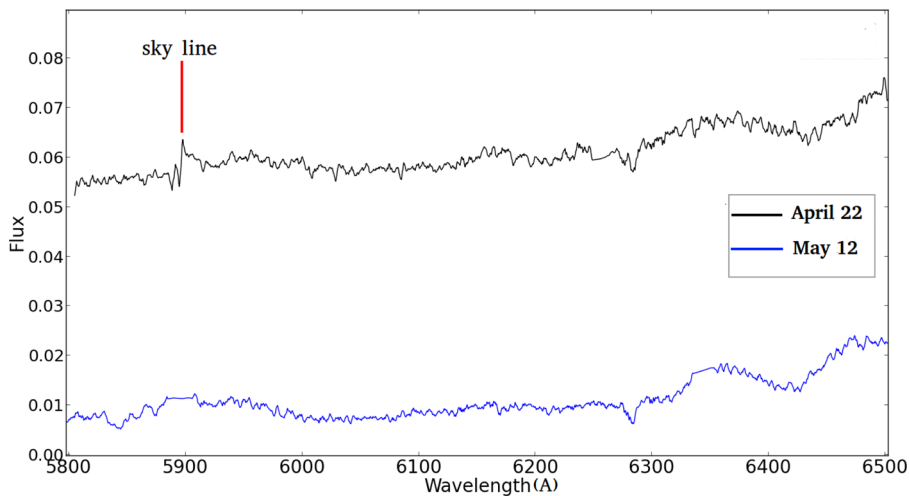
In order to derive the radial velocity of the nova, we measured the H $\alpha$ , H $\beta$ , Fe II 5018, 5317 Å, N II 5679 Å and [N II] 5755 Å



**Figure 4.** The flux plotted to arbitrary units between 4440 and 5450 Å. The April 22 spectrum (upper) shows several broad Fe II emission lines and H $\beta$  line. However, in the May 12 spectrum (lower), the Fe II lines become weaker and almost disappear in contrast to the He and N that start to appear. The H $\beta$  line shows a double peak. For clarity, the April 22 spectrum is vertically shifted. In the April 22 spectrum, chip gaps are between 4927.2 and 4953.4 Å and between 5409.0 and 5433.9 Å. In the May 12 spectrum, the chip gaps are between 4790.9 and 4810.0 Å and between 5140.5 and 5158.4 Å.



**Figure 5.** As in Fig. 4, but between 5400 and 5850 Å. The April 22 spectrum (upper) shows broad and relatively weak N II 5679 Å line and [N II] 5755 Å line. In the May 12 spectrum (lower), the [N II] line becomes stronger compared to the N II line. For clarity, the April 22 spectrum is vertically shifted.



**Figure 6.** As in Fig. 4, but between 5850 and 6500 Å. No strong emission lines are present in this spectral range. For clarity, the April 22 spectrum is vertically shifted. In the April 22 spectrum, the chip gap is between 6242.8 and 6267.1 Å. In the May 12 spectrum, the chip gaps are between 5877.9 and 5902.7 Å and between 6332.6 and 6355.9 Å.

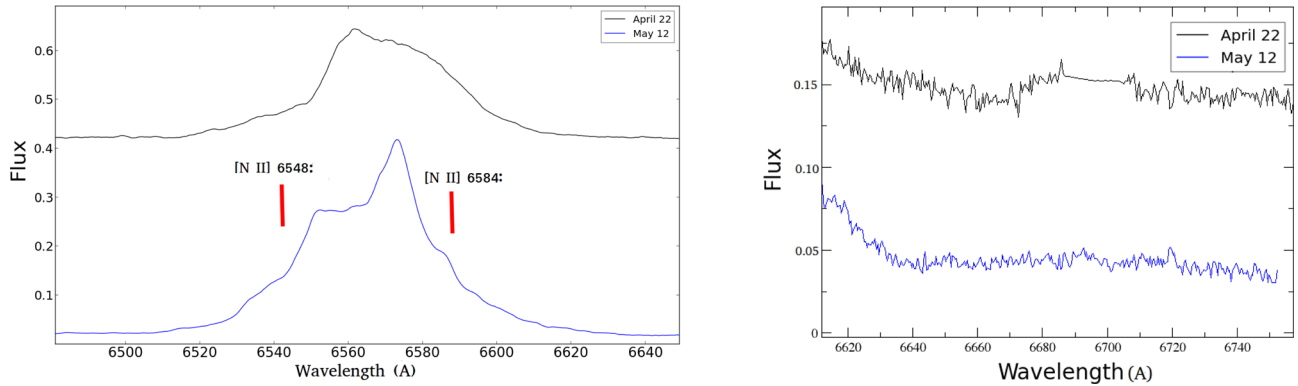
emission lines for the April 22 observation. We also measured the  $H\alpha$ ,  $H\beta$ , N II 5679 Å, [N II] 5755 Å, C II 7326 Å and O I 7773 Å emission lines from the second spectrum (May 12). For the radial velocity calculations, the rest wavelengths of the emission lines are derived from the multiplet table of astrophysical interest (Moore 1945) and the results listed in Table 5. In view of the change in the mean velocities of the lines, we checked the wavelengths of the overlapping night sky lines with care. We used the European Southern Observatory UVES sky emission spectrum (Hanuschik 2003) for this purpose. The lines at 4861.5, 5577.5, 5890, 5896, 6300, 6562, 6864, 7276.3, 7316.1, 7341 Å,... all agree well with the UVES sky emission lines.

Measurements of permitted lines are potentially shifted to the red by optical depth effects and must be regarded as unreliable. The most reliable measures of a nova radial velocity come from the CNO recombination lines and forbidden lines, which are almost always

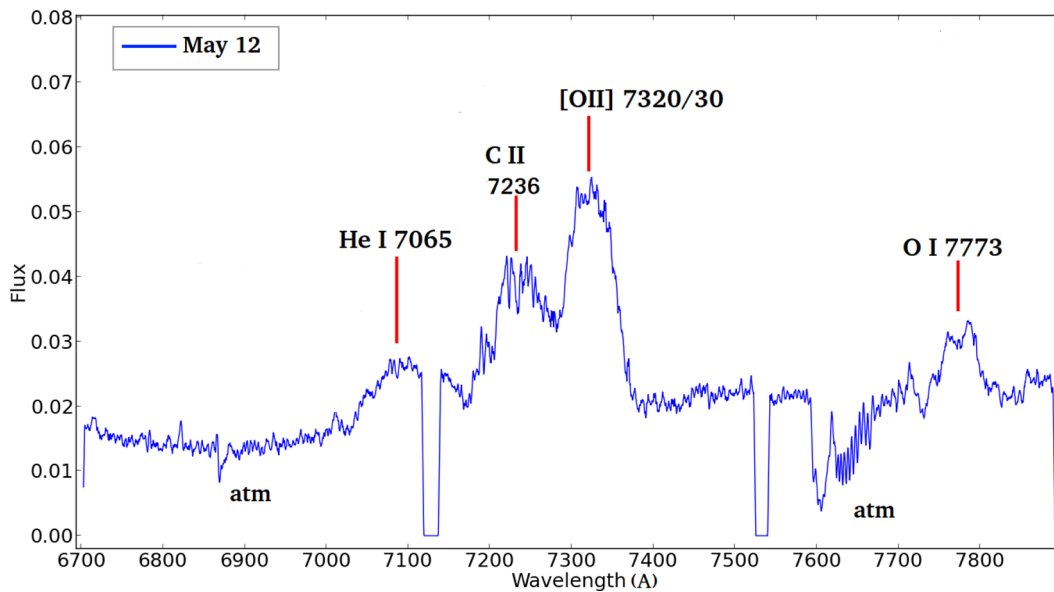
optically thin. The [O II] 7319, 7330 Å is a blend, so we use only N II 5679 Å, [N II] 5755 Å and C II 7236 Å from the May spectrum to derive the radial velocity. These lines give a mean heliocentric radial velocity of  $\sim 110 \pm 50 \text{ km s}^{-1}$ .

The determination of nova radial velocities is not straightforward since many factors can affect it, including the WD orbital motion, optical depth effects and most importantly the asymmetry of the ejecta (Williams 1994). In both observations, the lines are shifted towards the red which would not be expected from optically thick ejecta.

It is not entirely clear why the radial velocity changes between the two epochs. Although both spectra appear to lack P Cygni absorptions, it is possible that the first one was not optically thin and that absorption influences the blue side of the lines shifting them to the red, although the size of the shift makes this unlikely. It is also possible to speculate that the eruption was very asymmetric



**Figure 7.** As in Fig. 4, but between (a) 6480 and 6640 Å, (b) 6620 and 6750 Å. The April 22 spectrum (upper) shows broad H $\alpha$  emission line (FWHM  $\sim 2300 \text{ km s}^{-1} \pm 200 \text{ km s}^{-1}$ ). In the May 12 spectrum (lower), the H $\alpha$  line shows a double peak similar to the one of H $\beta$ . Both [N II] 6548, 6584 Å are expected to be present but merged with the broad H $\alpha$ . For clarity, the April 22 spectrum is vertically shifted. In the April 22 spectrum, the chip gap is between 6685.5 and 6708.1 Å.



**Figure 8.** As in Fig. 4, but between 6750 and 7850 Å. The May 12 spectrum shows strong C, He and O emission lines. In the May 12 spectrum, the chip gaps are between 7111.8 and 7134.4 Å and between 7521.4 and 7542.1 Å.

and that what we see in the first spectrum is a redshifted clump of material, that later slows, although such an explanation seems contrived.

The velocity of the Sagittarius stream has not been measured in the direction of the nova, but the central part of the Sagittarius Dwarf Spheroidal Galaxy has a mean velocity of  $140 \text{ km s}^{-1}$  with a velocity dispersion of only  $10 \text{ km s}^{-1}$  (Ibata et al. 1995). The mean measurement from the more reliable lines in the second spectrum is consistent with this value. On the other hand, the Galactic bulge has a high velocity dispersion and it is certainly not possible to use the velocity to rule out membership of the bulge.

Williams (1994) discusses the radial velocities of Galactic novae that are mostly within the solar circle and in the direction of the bulge. These have systematically large negative velocities and, as Williams points out, this indicates that either high internal absorption skews their emission lines to bluer velocities or most of the novae are moving out from the Galactic Centre. It is much more difficult to skew the lines of a nova to the red, so if our nova is in the plane, behind the bulge, it would be moving away from the

Galactic Centre. That possibility cannot be ruled out, but it seems more likely that it is in the bulge, or the Sagittarius stream.

### 3.4 Spectroscopic classification

The spectra of V5852 Sgr leave no doubt that this is a CN. CNe are divided into two spectroscopic classes (Fe II and He/N). The two nova spectral classes have distinctly different properties. He/N novae exhibit broad, high-ionization lines, rectangular profiles, few absorption features if any and a rapidly decreasing visible luminosity. The line broadening is due to high expansion velocities. The spectra are dominated by He, N and H emission lines. The prominent He and N transitions, the line widths and the rectangular line profiles are all attributed to emission from high-velocity gas (WD ejecta; Williams 2012).

Fe II novae have spectra characterized by low-excitation narrow Fe II, Na I lines and CNO lines in the far red. They also show prominent P Cygni absorption features characteristic of an optically thick expanding gas. The class of Fe II can be divided into two subclasses



**Table 5.** Heliocentric radial velocities of the emission lines for the April 22 and May 12 observations. The uncertainty for all the values is  $\pm 50 \text{ km s}^{-1}$ .

Line	$V_{\text{rad}}$ (April 22)	$V_{\text{rad}}$ (May 12)
	(km s $^{-1}$ )	
H $\alpha$	300	155
H $\beta$	320	140
Fe II 5018 Å	260	–
Fe II 5317 Å	180	–
N II 5679 Å	380	140
[N II] 5755 Å	150	45
C II 7236 Å	–	140
O I 7773 Å	–	160

Fe II n (narrow) and Fe II b (broad) where respectively narrow or broad emission lines are present in the spectrum. Although no P Cygni absorption features are seen in either spectra, the April 22 spectrum presents features and lines that characterize the Fe II spectroscopic class. A moderate FWHM of  $\sim 2500 \text{ km s}^{-1}$  and the flat-topped broad lines favour the possibility of an Fe II b (broad) spectroscopic class. The May 12 spectrum shows several N lines which might indicate a transition into He/N class. However, the absence of some helium lines (He I 5876 and 6678 Å) that are expected to be present for the He/N class suggests that at this stage the nova was actually in transition to the nebular phase.

#### 4 DISCUSSION AND CONCLUSIONS

V5852 Sgr was reported as a possible CN by the OGLE sky survey on 2015 March 5. Putting together the nova distance, luminosity and radial velocity with their uncertainties leaves the membership of the nova open to three possibilities. The first puts the nova in the Sagittarius stream and the second puts it in the plane behind the bulge moving away from the Galactic Centre and the third puts it in the Galactic bulge (see Section 3.3). It is worth noting that the mass of the Sagittarius dwarf is  $10^8$ – $10^9 M_{\odot}$  so the expected nova rate in that galaxy will only be one per 10 to 100 years. The nova rate in the bulge is  $\sim 2$  orders of magnitude higher, so the bulge is a more probable site (Mróz et al. 2015). So the location will have to remain open, at least until we gain a better understanding of the characteristics of novae with this type of light curve. The membership to the Sagittarius dwarf galaxy would make it the first nova to be discovered in a dwarf spheroidal galaxy.

The photometric follow-up (OGLE, IRSF, LCOGT) revealed a peculiar nova light curve. The spectroscopic and photometric data revealed combined features rarely observed in CNe. The nature of V5852 Sgr is best described as an unusual one. Based on our spectra and the classification criteria of Williams (1992), V5852 Sgr shows an Fe II or Fe II b spectroscopic class in a transition to the nebular phase. Tracking the spectroscopic and photometric evolution of the object is essential for a definitive classification. If the object is a classical, moderately fast nova, the same spectroscopic features should remain until the nebular phase develops. A detailed study of the elemental abundances is also essential. Hence, further observations are needed to definitively identify the object and understand the physical mechanism responsible for this explosion.

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## SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

**Table 2.** A sample of OGLE *I* photometry.

(<http://www.mnras.oxfordjournals.org/lookup/suppl/doi:10.1093/mnras/stw1396/-/DC1>).

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