Nova Sagittarii 1943 (V1148 Sgr): A Luminous Red Nova?

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Abstract

Nova Sagittarii 1943 (V1148 Sgr) was an eighth magnitude optical transient that was unusual in having a late-type spectrum during its outburst, in striking contrast to the normal high-excitation spectra seen in classical novae. Unfortunately, only an approximate position was given in the discovery announcement, hampering follow-up attempts to observe its remnant. We have identified the nova on two photographic plates in the Harvard archive, allowing us to determine a precise astrometric position. Apart from these two plates, obtained in 1943 and 1944, none of the photographs in the Harvard collection, from 1897 to 1950, show V1148 Sgr to limits as faint as g \approx 18.3. Modern deep images show a candidate remnant at i \approx 19.2, lying only 0\degree 26 from the site of the nova. V1148 Sgr may have been a luminous red nova (LRN), only the sixth such known in the Milky Way. However, it lacks the near- and mid-infrared excesses, and millimeter-wave emission, seen in other LRNe, leaving its nature uncertain. We urge spectroscopy of the candidate remnant.

Unified Astronomy Thesaurus concepts: Novae (1127); Transient sources (1851); Stellar mergers (2157); Variable stars (1761)

1. The Unusual Optical Transient Nova Sagittarii 1943

The eighth magnitude optical transient Nova Sagittarii 1943 (V1148 Sgr) was discovered on material in the Harvard College Observatory’s Astronomical Photographic Glass Plate Collection4 by Margaret Mayall. Unfortunately, her discovery was presented only briefly in a meeting abstract several years later (Mayall 1949), and to our knowledge no further information was ever published. Nevertheless, V1148 Sgr has remained of considerable interest because of the unusual spectroscopic characteristics that she described. Mayall’s discovery was made on objective-prism plates, obtained with the 10 inch Mctalf telescope at Bloemfontein, South Africa. She described the spectrum of V1148 Sgr on the discovery photograph, taken on 1943 August 19, as resembling that of a late K-type star, with strong absorption lines at Ca I 4226 Å and Ca II H and K, and possibly absorption bands of TiO. Five days later, the Ca I and Ca II absorption continued to be strong, but the spectrum now had a “banded” appearance, with wide Balmer emission features. The final spectrum, on 1943 August 29, showed “wide bright bands.” These findings are extremely unusual for a classical nova (CN), which develops a high-excitation emission-line spectrum without prominent absorption features, soon after the outburst (e.g., Williams et al. 1991; Walter et al. 2012). In retrospect, it seems possible that the bright emission bands described by Mayall at the final epoch were actually a misinterpretation of a spectrum of a very cool object with strong molecular absorption bands, as further discussed below.5

Unfortunately, Mayall’s three objective-prism plates are no longer available in the Harvard Plate Collection, so her spectroscopic findings cannot be investigated. Moreover, Mayall provided only approximate coordinates for V1148 Sgr, which lies in an extremely crowded field in the Galactic bulge (Galactic coordinates (l, b) = (5° 2, -3° 0)). Thus, until now, its precise location has been unknown. However, Mayall reported that the nova had also been detected on three direct plates in the Harvard collection, raising the possibility that it could be recovered from that material.

2. Astrometry

Of the three direct plates mentioned by Mayall, two are available in the Harvard archive. One of them is plate SB4269, obtained on 1944 August 20 (about one year after the light-curve maximum) with the 60 inch Rockefeller Reflector at Bloemfontein, which is of excellent quality. It clearly shows the nova, albeit at a faint level. The transient is marked in ink on the glass side of the plate, presumably by Mayall herself. We digitized this plate with a UMAX Technologies scanner, as described by Mink et al. (2006). Using the resulting .fits image, we identified about a dozen nearby reference stars that are contained in the recent Gaia Early Data Release 3 (EDR3; Gaia Collaboration et al. 2016, 2021), and measured their (x, y) positions using the imexamine task in IRAF.6 We corrected their EDR3 positions from the Gaia 2000 epoch7 to the epoch of the plate, using the proper motions given in the Gaia catalog, and employed them to place a precise astrometric frame on the image. The rms scatter of the registration was 0\arcsec 027 and 0\arcsec 019 in R.A. and decl., respectively. The derived position of V1148 Sgr (J2000 equinox, 1944.6 epoch) is:

18:09:07.801, −25:59:13.41.

*Deceased 2017 October 29

4 For more information: https://library.cfa.harvard.edu/plate-stacks

5 Mayall was very familiar with the normal spectral evolution of CNe, having announced her objective-prism discoveries of five other novae in her 1949 abstract, along with many others during her long career. Thus it is significant that she did not describe any of her three plates of V1148 Sgr as exhibiting a normal nova spectrum.

6 IRAF was distributed by the National Optical Astronomy Observatories, operated by AURA, Inc., under cooperative agreement with the National Science Foundation.

7 We obtained the Gaia astrometry from the Vizier service at https://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=I/350/gaiadr3, which provides positions adjusted to the 2000 epoch using the measured proper motions.
This position differs by some 24" from the approximate one given by Mayall. We note that Duerbeck (1987) had attempted to identify the remnant of V1148 Sgr, and gave coordinates for a 14th-magnitude star; this was the brightest object close to the Mayall position. He stated that it is "very probably not the ex nova." This object is detected on the SB4249 plate (and was one of the Gaia reference stars used in our astrometric solution); it is clearly distinct from the nova.

3. Photometry

The Digital Access to a Sky Century at Harvard (DASCH) project (Grindlay et al. 2009) is a long-term effort aimed at digitizing many of the plates in the Harvard collection, and performing photometry on the images. The DASCH Lightcurve Access website provides the photometry (calibrated to the Sloan g band) and image cutouts. We searched for plates covering the location of V1148 Sgr, finding some 191 images. Of these only one plate, RB12347, obtained on 1943 August 24, shows the nova. Stellar images on this plate are elongated, but nevertheless the nova is conspicuous, at magnitude $g = 9.55 \pm 0.34$, according to the photometry provided by the DASCH website. The star's position, magnitude, and observation date are consistent with the data presented by Mayall. This bright object coincides with the transient seen a year later, but considerably fainter, on SB4269, as described in the previous section. Thus it is clearly V1148 Sgr.

The 60 inch Rockefeller plates are not being scanned at this time by the DASCH project, so the DASCH website does not provide a magnitude determination for the 1944 observation recorded on SB4269. Instead, we performed aperture photometry on the nova and about a dozen neighboring stars, using the image scan described in the previous section. We then calibrated the data using $g$ magnitudes from the Pan-STARRS1 catalog (Chambers et al. 2016) for the neighbor stars. This analysis yielded a magnitude of $g = 16.72 \pm 0.35$ for V1148 Sgr, at the date 1944 August 20.

There are 138 preeruption plates available from the DASCH website, covering the range 1897 August 4 to 1943 August 2.

We examined the image cutouts for these plates, and V1148 Sgr was not detected on any of them. After the outburst there are 51 plates, from 1944 August 23 to 1950 July 17, which likewise do not show the transient. The limiting $g$ magnitudes vary widely for these plates, but generally range from $\sim 15.5$ to $\sim 16.5$ for most of them. However, from 1930 to 1939, some 74 plates of the site were obtained with the 24 inch Bruce Doublet, and these plates reach as faint as $\sim 18.0$ to $18.2$ mag for the best ones. The last two plates taken in 1943 before the detection near maximum on August 19 were obtained on 1943 May 15 and August 2. The limiting $g$ magnitudes on these two plates are $\sim 15.9$ and $15.5$, respectively. The DASCH database contains no plates between the one on 1943 August 24 showing the nova near maximum and the SB4269 plate obtained on 1944 August 20. Two more plates were obtained in 1944, both of them on August 23. Neither one shows the nova; however, their limiting magnitudes are only $\sim 15.5$ and 16.3. The best postoutburst plate, A26840, was obtained on 1949 June 8, and does not show the nova to a limiting magnitude of $\sim 18.3$.

Figure 1 shows four image cutouts from Harvard plates. The left panel shows the nova site on plate A17599 (24 inch Bruce Doublet, 1935 June 4). The limiting magnitude on this plate is about 17.3, based on reference to the Pan-STARRS1 sequence described above. There is no object detected at the nova position. The second frame in the figure is from the plate RB12347 described above (3 inch Ross Fecker telescope, 1943 August 24). Here the nova is conspicuous, near maximum light, in spite of the shallow limiting magnitude of $\sim 14.6$ because of the trailed stellar images on this plate. The cutout in the third panel of Figure 1 shows the nova (between the two ink marks) on plate SB4269 (1944 August 20); this is the plate used for the astrometry and photometry described above. The fourth panel in the figure shows a cutout from the excellent plate A26840, obtained on 1949 June 8. As noted above, the limiting detection magnitude on this image is about 18.3, and the nova is not seen.

In summary, there are two Harvard direct plates showing V1148 Sgr, obtained on 1943 August 24 (mag 9.55) and 1944 August 20 (mag 16.72). These are in addition to the three objective-prism detections reported by Mayall (1949) on 1943 August 19, 24, and 29, at a reported brightest magnitude of $\sim 8$. The rise to maximum occurred sometime between 1943 August 2 and 19. The deepest preoutburst plates do not show a progenitor brighter than $\sim 18.0$ to $18.2$ mag. By mid 1949 the nova was fainter than $g \approx 18.3$.  

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8 Duerbeck's star is at J2000 equinox and epoch position 18:09:05.847, $-25:59:08.08$, which is 27′52″ away from the location of V1148 Sgr.
9 http://dasch.rc.fas.harvard.edu/lightcurve.php
10 Obtained using the image-access tool at https://ps1images.stsci.edu/cgi-bin/ps1cutouts. Note that the Harvard plates were obtained using unfiltered blue-sensitive emulsions, so that the $g$ bandpass is a fairly close approximation to their sensitivity function.
the northeast corner of the frames in Figure 1. This raises the question whether the nova could be a member of the cluster. Only one, or possibly two, CNe are known to have occurred in the Galactic globular-cluster system (e.g., Doyle et al. 2019 and references therein).

V1148 Sgr is located 300° from the center of NGC 6553. The tidal radius of the cluster, calculated from information in Harris (2010),12 is ~460°. Thus cluster membership is not ruled out. However, as Figure 2 shows, the nova site is immersed in a rich Galactic-bulge field population. Color–magnitude and proper-motion diagrams of stars in Gaia EDR3 lying within 90° of V1148 Sgr show a nearly pure bulge population, with very few cluster members.13

A tighter constraint on cluster membership would be provided by the proper motion of the nova. If the faint star noted above is the remnant, then by combining its Gaia position with our astrometry from the 1944 plate, we calculate a proper motion of \((\mu_\alpha, \mu_\delta) = (-4.5, -1.1) \text{ mas yr}^{-1}\). This is in poor agreement with the mean proper motion of the cluster, for which we find \((\mu_\alpha, \mu_\delta) = (+0.4, -0.5) \text{ mas yr}^{-1}\) from data in the Gaia catalog.

In summary, the sparse available information casts doubt on, but does not absolutely rule out, a physical association of V1148 Sgr with the globular cluster NGC 6553. It is possible that a future data release from Gaia may provide a parallax, and a proper motion independent of the astrometry of the nova, for the candidate remnant. This could produce a more critical membership test—but only if evidence emerges that the candidate described in Section 4 is in fact the remnant.

6. Was V1148 Sgr a Luminous Red Nova?

Luminous red novae (LRNe) are a class of dust-forming astrophysical transients that has been recognized in recent years. CNe become increasingly blue as their eruptions proceed and their ejecta become optically thin, exposing a hot central source. LRNe erupt suddenly, like CNe, but they become extremely cool and red after their outbursts, due to an expanding photosphere and dust formation in the outflow. LRNe are generally considered to be the result of binaries undergoing common-envelope interactions and stellar mergers (see, for example, recent papers by Ivanova et al. 2013, Pastorello et al. 2019, and Howitt et al. 2020, and references therein); this was definitely the case for the Galactic LRN V1309 Sco, which was shown to have been a close binary with a rapidly decreasing orbital period before its eruption (Tylenda et al. 2011).

The known LRNe that have occurred in the Milky Way are V4332 Sgr (Martini et al. 1999; Bond 2018), V838 Mon (Sparks et al. 2008; Woodward et al. 2021), OGLE-2002-BLG-360 (Tylenda et al. 2013), CK Vul (Nova Vul 1670; Kamiński et al. 2021a), and V1309 Sco. In the Local Group, three LRNe have been recorded in M31: M31 RV (Bond 2011), M31LRN 2015 (MacLeod et al. 2017), and AT 2019zhd (Pastorello et al. 2021). LRNe are often associated with old populations, including elliptical galaxies and the bulges of the Milky Way and other spiral galaxies; however, V838 Mon arose from a

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11 Due to a typographical error, Mayall designated the cluster NGC 6533.

12 Online version of 2010 December, at http://physwww.mcmaster.ca/~harris/mwgc.dat.

13 The color–magnitude diagram of the cluster, from the Gaia catalog, exhibits a clump of very red horizontal-branch stars, and the Gaia proper motions of the cluster stars are tightly concentrated. These make it easy to distinguish the members from the field.
young open star cluster (Afşar & Bond 2007), and several extragalactic LRNe appear to have originated from massive stars (e.g., Smith et al. 2016; Blagorodnova et al. 2017, 2021). (There is an extensive literature on LRNe, and we have cited only a few relevant and recent papers).

In the case of V1148 Sgr, the late-type spectrum at the discovery epoch described by Mayall (1949) may make it a candidate for another Galactic LRN, similar to prototypes like V4332 Sgr and V838 Mon—if so, only the sixth one known in the Milky Way. Indeed, several authors have made the suggestion that V1148 Sgr was a LRN, including Bond & Siegel (2006), Retter et al. (2006), and Smith et al. (2016). The apparent similarity of V1148 Sgr to V838 Mon and other red transients was noted by Kimeswenger (2007), who made an unsuccessful attempt to identify its remnant by searching the vicinity for H$_2$-emitting objects. However, our candidate, described in Section 4, is considerably fainter than the objects he considered.

The fragmentary observations discussed in Section 3 indicate that V1148 Sgr declined some ~10 mag over the first year since its outburst, at blue wavelengths. This is not dramatically different from V838 Mon’s drop of about 9 mag in B in the first year after its eruption (e.g., Figure 5 in Sparks et al. 2008).

Mayall’s description of the nova’s spectrum, at the final objective-prism observation, as having bright emission bands (see Section 1) remains a puzzle. A normal CN does rapidly develop a spectrum with broad, high-excitation emission lines (see the references cited in Section 1). However, Mayall did not characterize the spectrum as being that of a normal CN, indicating that it was unusual. It is conceivable that in fact the spectrum had, by late 1943 August, become that of an extremely cool object, as is the case for LRNe. For example, Barsukova et al. (2007, their Figure 1) and Munari et al. (2007, their Figure 2) show late-time blue-region spectra of V838 Mon that are dominated by extremely strong molecular absorption. These can give the spectrum a superficial appearance of having strong emission bands, in the form of the continuum levels between the molecular bands. Unfortunately, since Mayall’s spectrum plates are now lost, it is not possible to verify this interpretation.

An argument against V1148 Sgr being a LRN comes from the fact that all of the known recent Galactic LRNes became conspicuous near- and mid-infrared sources following their outbursts: V4332 Sgr (Banerjee et al. 2015), V838 Mon (Woodward et al. 2021), OGLE-2002-BLG-360 (Tyliceda et al. 2013), and V1309 Sco (Tylenda & Kamiński 2016). The remnant of the much older event CK Vul is not bright in the mid-infrared, but shows a far-infrared flux excess (Evans et al. 2002).

To investigate whether there is a near- or mid-infrared source at the site of V1148 Sgr, we downloaded “Super-Mosaic” images obtained with the Spitzer Space Telescope from the NASA/IPAC Infrared Science Archive. In Figure 3 we show frames with the same 55″ angular height as in Figure 2. The left-hand image is in the optical ground-based r band, from the PanSTARRS-1 website, centered on the coordinates of the nova. The remaining panels show Spitzer frames from the Infrared Array Camera at 3.6, 4.5, 5.8, and 8.0 μm, and from the Multi-Band Imaging Photometer at 24 μm. These images demonstrate that there is no bright near- or mid-infrared source at the location of V1148 Sgr. The candidate remnant discussed in Section 4 is only marginally detected in the two shortest-wavelength Spitzer frames.

In addition, CK Vul, along with V4332 Sgr, V838 Mon, and V1309 Sco, all lie at the centers of cool, compact molecular nebulae, which are prominent at millimeter wavelengths (Kamiński et al. 2018, 2021a, 2021b). Kamiński et al. (2022) attempted to detect CO emission from V1148 Sgr with the Atacama Pathfinder Experiment (APEX) 12 m submillimeter telescope, with unsuccessful results. Unfortunately, they pointed at the Duerbeck position discussed in Section 2. This would have placed the nova outside the APEX beam size, which ranged from 13′′2 to 18′′7. However, Kamiński has informed us privately that his team has also observed V1148 Sgr with the Submillimeter Array (SMA), with a beam large enough to include the revised position reported here. No detection was made in the SMA data.

7. Summary and Future Studies

We have used Harvard plate material to determine a precise astrometric position for V1148 Sgr, an optical transient that appears to have had some spectroscopic features consistent with the handful of other members of the class of LRNe. However, this interpretation remains questionable because of the absence of a near- and mid-infrared or millimeter source at its location. Thus the nature of this transient remains unclear.

We have identified a faint candidate remnant of the event for which a spectroscopic study would be useful. However, the observation would be challenging because of the source’s faintness, as well as a neighboring star ~1″ away (which itself may be another candidate counterpart).

The LRN CK Vul is surrounded by a faint “hourglass” nebula seen in narrow-band H$_2$ and [N II] images (Kamiński et al. 2021a and references therein). Thus deep optical imaging of V1148 Sgr in these bandpasses would be of interest.

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14 A Galactic-bulge microlensing event is ruled out by the changing spectrum reported by Mayall.

15 https://irsa.ipac.caltech.edu/data/SPITZER/Enhanced/SEIP/overview.html

16 https://web.cfa.harvard.edu/sma/
H.E.B. remembers with gratitude the introduction to the Harvard plate collection, nearly five decades ago, by Dr. Martha L. Hazen, who became a cherished friend.

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This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC: https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

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