Photometry, Spectroscopy, and Classification of Nova V475 Scuti

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Abstract The classification of and distance to the nova V475 Scuti (Nova 2003) are determined. This paper reports that the nova type for V475 Sct is determined to be a slow Fe II nova at a distance of 2 ± 0.6 kpc (approximately 6500 ly).

1. History of the discovery of the nova V475 Sct

V475 Sct (Nova Scuti 2003) was discovered on 28.58 August 2003 UT by Hideo Nishimura of Kakegawa, Shizuoka-ken, Japan (Green 2003). The position of the nova was reported as R.A. $18^h 49^m 38^s$ Dec. −9° 33' 45" J2000. The discovery magnitude was reported as $V = 8.5$.

The progenitor star is documented in the *USNO A2.0 Catalog* as USNO-A2.0 0750-148 33804 with magnitudes of $B = 17.2$, $R = 16.4$ (Monet *et al.* 1998). There is no documentation of variability in this progenitor star. It is widely accepted that novae are close binary stars. The interested reader is encouraged to consult Hellier for a more detailed treatment of novae (Hellier 2001).

2. Description of the equipment used for the observations

The telescope used in this study is a 0.36m Schmidt-Cassegrain that is housed in a permanent observatory. For this project, the telescope was operated at f/11. The instrumentation used for photometry and spectroscopy was placed at the Cassegrain focus of the telescope.

The camera is an SBIG ST-10XME CCD camera that uses a Kodak KAF3200ME detector. The photometric filters conform to the Johnson-Cousins spectral set and were supplied by Schuler Astro-Imaging (Schuler 2002). Photometric reduction was accomplished using AIP4Win v1.4.25 (Berry 2000). All images were processed using dark and flat field frames. The spectrometer is a Model SGS spectrometer manufactured by Santa Barbara Instrument Group. The instrument was operated in low-resolution mode yielding 10Å per pixel. The spectroscopic data were reduced using the WINDOWS based SPECTRA (v1.2) software, supplied with the spectrophotometer.

3. Spectrometric data results

3.1. Dominant spectral features

Figure 1 shows four spectra of V475 Sct taken by the author over a 38-day period. The most prominent feature of these spectra is the Hα peak located at 6563Å.

This peak is caused by the recombination of the ionized hydrogen into the nova ejecta. Notice that as time progresses the width of the Hα peak increases slightly. The importance of this observation will be addressed later in the paper.

The first spectrum was taken twelve days after maximum brightness and clearly shows the development of Fe II peaks at 4900 Å and 5250. These peaks slowly recede in intensity over the following 38 days.

3.2. Determining the nova's rate of expansion

The rate of expansion of the nova is a key indicator when determining the nova type and is measured by determining FWHM of the Hα peak. The faster the expansion rate, the wider the Hα peak becomes. The velocity, *v*, of the expanding nova can be calculated using the Doppler Law, shown in equation 1:

$$v = \Delta\lambda \, c / \lambda_0 \tag{1}$$

where $\Delta\lambda$ equals the FWHM of the Hα peak, c = the speed of light in a vacuum, and λ_0 equals the wavelength of the Hα line at rest.

Figure 2 illustrates the progressive widening of the Hα FWHM peak and the calculated rate of expansion. Four determinations were made of the expansion rate of V475 Sct. The maximum expansion rate of 1882 km/sec was observed on October 19, 2003, at 0217 UT.

4. Photometric data results

4.1. Determining t_0 and t_2

The point of maximum brightness and the point at which the nova has decreased by two *V*-band magnitudes of brightness are t_0 and t_2, respectively. Figure 3 shows the light curve in the *V*-band for the nova V475 Sct. The time frame covered is from before the t_0 point and until 65 days after the t_0 point. Table 1 shows the sources for this data. For calibration purposes, the author used a photometric sequence for V475 Sct provided by the U.S. Naval Observatory (Henden 2003).

4.2. Estimating the distance to the nova

Della Valle and Livio (1995) have calibrated a relationship for novae between the absolute magnitude at maximum (t_0) and the rate of decline in luminosity. The faster is the decline of the nova the brighter is its peak luminosity. Thus, it is possible to determine the absolute magnitude at maximum of a nova by measuring its rate of decline. Once the apparent magnitude at maximum has been measured, the difference in the absolute and apparent magnitude yields the distance to the nova. Della Valle and Livio developed a formula to determine the distance to a nova as a function of the time that it takes for the nova to decrease in brightness by two apparent magnitudes from its maximum value:

$$M_v = -7.92 - 0.81 \arctan \{(1.32 - \log(t_2)) / 0.23\}, \tag{2}$$

where M_v equals the absolute *V*-band magnitude of the nova, t_2 is the time in days for the nova to drop exactly two magnitudes in brightness in the *V*-band, and the value of the arctangent is in radians. In the case of V475 Sct, the t_2 time was 25 days. Therefore, the absolute *V* magnitude of the nova is calculated to be −7.66.

Once the absolute magnitude of the nova has been determined, the distance to the nova can be calculated by using the distance modulus formula,

$$m_v - M_v = 5\log(D) - 5 + A_v\,, \tag{3}$$

where m_v equals the apparent or observed magnitude of V475 Sct at maximum, D equals the distance to the nova in pc, and A_v is the total galactic absorption of the light path to the nova in *V*-band magnitudes. The total galactic absorption can be determined by:

$$A_v = a_v \times D, \tag{4}$$

where a_v is the galactic absorption factor of 1.9 *V* mags/kpc.

The nova reached a peak magnitude $m_v = 8.0$ on JD 2452884.4. The factor for *V*-band galactic absorption was determined from the NED Coordinate and Extinction Calculator and determined to be 1.9 *V* magnitudes kpc^{-1} (Schlegel 1998). The distance modulus equation is solved until the ratio between A_v and D is 1.9. The D value that fits the equation for V474 Sct is 2.1 kpc or ~6800 ly. The dispersion of the relationship reported above (equation 2) suggests that this distance is affected by an uncertainty on the order of 20–30 percent.

5. Nova classification

Typical novae are classified as “Fast” or “Slow.” The difference is that fast novae reach their t_2 point in less than 12 days, while slow novae show a t_2 point of greater than 12 days (Della Valle and Livio 1998). In addition, fast novae tend to have high luminosities at maximum, which correspond to M_v of −9. The progenitors of these novae tend to lie close to the galactic plane (within about 100 pc) and come from a relatively young disk star population. The stronger spectral lines tend to possess flat, jagged maxima. Williams reports that fast novae tend to have broad peaks with expansion velocities extending to 5000 km/sec in spectra taken early after t_0 (Williams 1992).

Slow novae tend to have maximum M_v of less than −7.5 and have a FeII spectroscopic classification, meaning that FeII lines are common and strong when compared to the fast novae spectra. The novae also tend to lie farther from the galactic plane (more than 1000 pc). Williams reports that slow novae tend to have narrow peaks with expansion velocities seldom above 2500 km/sec in early spectra.

6. Conclusions

The t_2 of V475 Sct has been shown to be 25 days by photometric examination. The spectrum of V475 Sct shows definite FeII lines in the early spectra as seen in Figure 1. The expansion velocity, which was derived from the Hα peak widths, showed a maximum velocity of 1882 km/sec. These peaks are sharp and narrow in appearance. The M_v for V475 Sct, at -7.6 ± 0.2 lies slightly above the maximum predicted by Della Valle for slow novae but is significantly lower than the maximum of $-9\ M_v$ predicted for fast novae. The CDS-SIMBAD database reports that the galactic latitude of V475 Sct is $-3.95°$. At a distance of 2094 pc, the distance from the nova to the galactic plane would be about 150 pc ($\sin 3.95° \times 2094$ pc $= 144$ pc). This is an anomaly in that most slow novae are reported to lay more than 1000 pc from the galactic plane. Therefore, V475 Sct would be classified as a slow, FeII type nova and would be expected to have a progenitor that is a Population II star. The white dwarf component is likely to be $<1\ M_\odot$. However, this particular nova is somewhat brighter and lies much closer to the galactic plane than the typical slow nova.

7. Acknowledgements

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References

Berry R., and Burnell, J. 2000, "Astronomical Image Processing Software," version 1.4.25, provided with *The Handbook of Astronomical Image Processing*, Willmann-Bell, Richmond, VA.
Delle Valle, M., and Livio, M. 1995, *Astrophys. J.*, **425**, 704.
Delle Valle, M., and Livio, M. 1998, *Astrophys. J.*, **506**, 818.
Green, D. W. E. 2003, *IAU Circ.*, No. 8190.
Hellier, C. 2001, *Cataclysmic Variable Stars: How and Why They Vary*, Springer-Praxis, Chichester, England, 161.
Henden, A. 2003, private communication.
Monet, D., *et al.* 1998, *USNO-A V2.0 Catalog of Astrometric Standards*, U.S. Naval Observatory, Flagstaff, AZ.
Pojmanski, G. 2002, *Acta Astron.*, **52**, 397.
Schlegel, D. J., Finkbeiner, D. P., and Davis, M. 1998, *Astrophys. J.*, **500**, 525.
Schuler, C., ed. 2002, *Technical Handbook on CCD Filters for Astronomers*, Schuler Astro-Imaging, Sudbury, MA.
Williams, R. E. 1992, *Astron. J.*, **104**, 775.

Table 1. Photometric data points.

Date	*JD*	*V mag*	*Source*	*Note*
2003 08 24.1	2452876.4	14	Pojmanski 2002	
2003 08 26.1	2452878.4	10.15	W. Liller	
2003 08 28.1	2452880.4	8.94	Pojmanski 2002	
2003 08 29.4	2452881.4	8.5	H. Nishimura	
2003 09 01.83	2452884.4	8	T. Scarmato	T_0
2003 09 04.4	2452886.9	8.6	R. Stubings	
2003 09 06.2	2452888.7	8.81	D. Starkey	
2003 09 15.4	2452898.0	9.24	K. Nakajima	
2003 09 18.4	2452901.0	9.27	K. Nakajima	
2003 09 26.1	2452908.6	10.02	D. Starkey	T_2
2003 10 05.1	2452917.6	9.57	D. Starkey	
2003 10 13.2	2452925.5	9.87	D. Starkey	
2003 10 17.2	2452930.5	10.40	D. Starkey	
2003 10 24.2	2452936.6	11.46	D. Starkey	
2003 10 26.8	2452939.1	11.90	M. Verdenet	
2003 11 03.3	2452945.9	12.40	H. Matsuyama	
2003 11 06.9	2452949.4	15.00	D. Starkey	

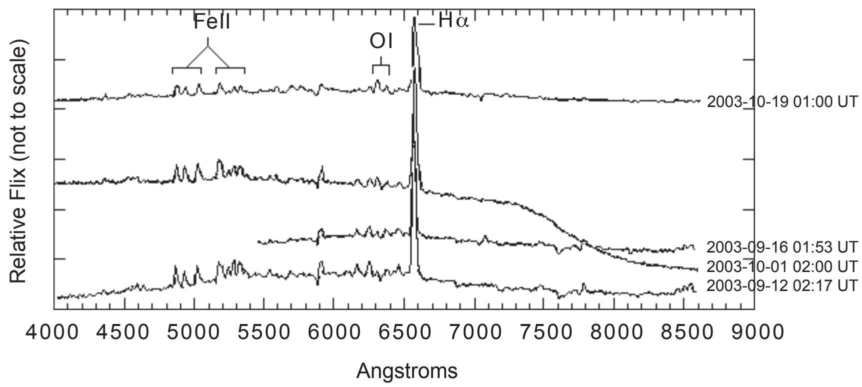

Figure 1. Four spectra of V475 Sct taken over a period of 38 days. The prominent Hα peak shows a decrease in amplitude during the time frame of the four observations. FeII peaks are prominent in three of the four spectrums.

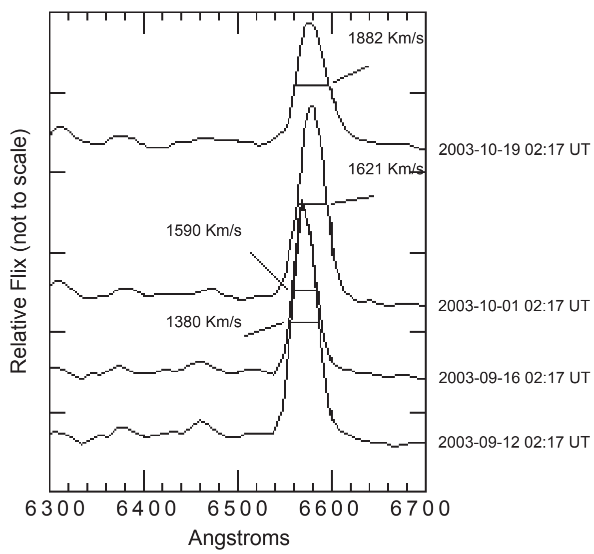

Figure 2. An enlargement of the Hα peaks from Figure 1. The FWHM values for each peak are seen to increase slightly over the period of observation but their overall low value indicates a “slow type” nova.

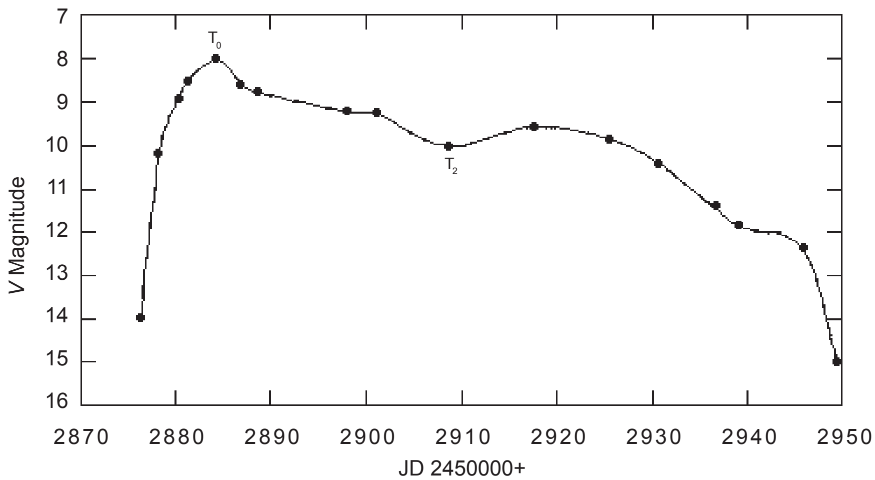

Figure 3. The *V* magnitude of V475 Sct indicated from Table 1. The span between the t_0 (brightest *V* magnitude of the nova) and the t_2 point (two magnitudes less than t_0) are used to indicate the distance to the nova via the Della Valle relationship.