Contrib. Astron. Obs. Skalnaté Pleso **35**, 107 – 129, (2005)

Photometric and spectroscopic variability of the slow nova V475 Sct (Nova Scuti 2003)

D. Chochol[1], N.A. Katysheva[2], T. Pribulla[1], L. Schmidtobreick[3], S.Yu. Shugarov[2], P. Škoda[4], M. Šlechta[4], A.A. Vittone[5] and I.M. Volkov[2]

[1] *Astronomical Institute of the Slovak Academy of Sciences 059 60 Tatranská Lomnica, The Slovak Republic*

[2] *Sternberg State Astronomical Institute Universitetskij Prosp. 13, Moscow 119992, Russia*

[3] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

[4] *Astronomical Institute of the Academy of Sciences, 251 65 Ondřejov, The Czech Republic*

[5] *Osservatorio Astronomico Capodimonte, Via Moiariello 16, 80131, Napoli, Italy*

Received: January 18, 2005; Accepted: April 6, 2005

Abstract. We present the $UBVRI$ photometry and 460-900 nm spectroscopy of a classical nova V475 Sct obtained after its outburst in August 2003. The object can be classified as a slow Fe II nova with the standstill at maximum and dust formation at later stages. The brightness declines $t_{2,V}$ = 48 d, $t_{2,B}$ = 50 d, $t_{3,V}$ = 53 d, $t_{3,B}$ = 58 d were found from our B,V light curves and corresponding absolute magnitudes of the nova at maximum MV_{max} = –7.16±0.15 and MB_{max} = -6.96±0.39 were calculated. The latter value yields a mass of 0.73±0.07 $M_\odot$ for the white dwarf component. We determined the colour excess $E(B-V)$ = 0.69±0.05 and the distance to the nova d = 4.8±0.9 kpc. During the standstill and on decline the 13.4-day periodicity of flares was found, the best detected in the $V-I$ index. The rapid fade of the brightness, which started 57 days after the maximum, could be related to a dust formation in the ejecta of the nova. The early optical spectra display the forest of low ionization emission lines, primarily Fe II and H, accompanied by two P Cygni absorptions, arising in the inner and outer envelope of the expanding nova shell ejected at brightness maximum and accelerated by continuous stellar wind. The spectrum taken in the nebular stage of the nova, which started in March 2004, shows very strong emission [O III] 495.9 nm and 500.7 nm lines, responsible for discrepancy of the B and V magnitudes determined from observations taken by different instruments. The nebular emission line profiles suggest a nonspherical ejection of the shell.

Key words: novae – photometry, spectroscopy – line profiles, line identifications

1. Introduction

Classical novae are semidetached binaries consisting of a red dwarf filling up its Roche-lobe and a white dwarf with the orbital periods of a few hours. According to the photometric and spectroscopic appearance, they can be divided in fast and slow novae. The classification is usually based on the time interval in which nova fades 2 or 3 magnitudes (t_2, t_3) from its maximum brightness. The fast super-Eddington novae ($t_2 < 13$, $t_3 < 30$ days) have smooth light curves with well defined maxima. They may be He/N or "hybrid" Fe II novae. The slow Eddington novae ($t_2 > 13$, $t_3 > 30$ days) have structured light curves and many of them have standstills at maximum and dust formation at later stages. They belong to the Fe II spectroscopic type (Downes & Duerbeck, 2000).

Classical nova V475 Sct (Nova Scuti 2003) was discovered by Nishimura (see Nakano & Sato (2003)) on August 28.58, 2003, at mag 8.5 at the coordinates $\alpha_{2000} = 18^h49^m37\overset{s}{.}6$, $\delta_{2000} = -9°33'50\overset{''}{.}85$ (Yamaoka, 2003). It reached the brightness maximum $V_{max} = 8.41$ and $B_{max} = 9.32$ on September 1, 2003, (this paper). We did not identify the nova precursor on the POSS prints. This sets the outburst amplitude > 12 mag.

Optical spectra of V475 Sct taken by Boeche & Munari (2003) on August 31.97 UT showed a well-developed absorption spectrum of a normal F2 supergiant with weak emission of the Balmer series down to H_ε. The Balmer-line profiles exhibited a weak absorption component blue-shifted by 500 km s^{-1} and a second emission peak red-shifted by 650 km s^{-1} with respect to the main emission line. The spectra obtained by Siviero et al. (2003) on September 6.83 displayed a well developed emission-line spectrum dominated by Fe II lines. Most lines displayed complex P Cygni profiles. The Na I D lines had an emission width of 900 km s^{-1} and a terminal velocity 1150 km s^{-1} for absorption, with superimposed interstellar components.

2. Observations and data reduction

2.1. Photometry

Our UBV photoelectric observations of V475 Sct were obtained at the Crimean station of the Sternberg Astronomical Institute at Nauchnyj (CN) and at the Simeiz station of the Crimean Astrophysical Observatory (CS) using the 0.6 m and 1 m reflector, respectively. They were carried out in the Cassegrain focus of the reflectors using the same portable single-channel photoelectric photometer with the standard UBV filters and a photomultiplier EMI 9789 B. HD 175058 and HD 174866 were used as a comparison and check star, respectively. The UBV magnitudes of the check star and the standard stars S1, S2, S3 for the CCD observations were determined by us using the primary standard star HD 175058 (Table 1). The $WBVR$ magnitudes of HD 175058 were taken from the catalogue of Kornilov et al. (1991). We found that $W \approx U$ for this star. The R

magnitude of HD 174866 was taken from the catalogue of Kornilov et al. (1991), the I magnitude was determined from our CCD photometry. The comparison and check stars were found to be stable within 0.02 in U and 0.01 mag in B and V passbands. All photoelectric UBV observations were reduced, corrected for atmospheric extinction and transformed to the international Johnson UBV system using the standard procedure.

Table 1. Comparison stars

Star	U	B	V	R	I	Note
PS	7.952	7.435	7.038	6.670		1
C1	14.22	12.93	11.46	10.09	8.97	2
SS	6.680	6.535	6.312	6.169		3
S1	11.426	11.041	10.613	10.34	10.42	4,5
S2	10.453	10.276	9.601			4
S3	11.927	12.011	11.781	11.52	11.31	4,5
S4		14.60	12.91	11.46	9.71	6
1	16.452	15.039	13.772	12.743*	11.922**	5
2		15.68	14.30	13.12	12.10	6
3		16.552	15.119	13.99	12.97	5
4		18.03	16.23	15.05	14.10	6
5		16.132	15.196	14.39	13.68	5

* $R_C = 13.057$, ** $I_C = 12.339$;
1: HD175058 primary standard for photoelectric observations (Kornilov et al., 1991); 2: primary standard for transformation to the international Johnson RI system (Shakovskoi & Sazonov, 1996); 3: HD174866 secondary standard for photoelectric observations; 4: secondary standard for photoelectric observations; 5: primary standard for CCD observations; 6: check star for CCD observations. Identifications of standards: C1 - GSC 0471.1564, S1 - GSC 5697.0442, S2 - GSC 5697.1786, S3 - GSC 5697.2677, S4 - GSC 5697.2206

The most of our $UBV(RI)_C$ CCD observations (with R and I filters in the Cousins system) were taken with the SBIG ST10-XME camera mounted in the 2.5 m Newton focus of the new 0.5 m reflector at the Stará Lesná Observatory. Further CCD $UBVRI$ observations were taken with portable SBIG ST7, Apogee Ap7p, Pictor-416, VersArray-1300 CCD cameras mounted in the Cassegrain focus of the 1.25 m, 0.6 m, 0.5 m and 0.38 m reflectors at the CN and by Ap47p and Ap7 (with R_C) CCD cameras mounted in the Cassegrain focus of the 0.7 m reflector in Moscow (M). A few observations at maximum brightness were taken at the CN using the 40/130 mm telephoto lens and portable Ap7p CCD camera.

The standard MIDAS package and own software were used for the determination of the CCD magnitudes. The CCD $BVRI$ magnitudes of the faint comparison stars 1-5 (for their position see Fig. 1) in Table 1 were determined and transformed to the international Johnson $BVRI$ system using the primary standard S3 and check star S1 for BV bands and C1 for RI bands. The star C1 was originally used as a comparison star for photometry of SS433 Shakhovskoi & Sazonov (1996). The coefficients for transformation of photoelectric and CCD observations to the international Johnson system were found using the stars in open cluster M67 (Mendoza, 1967).

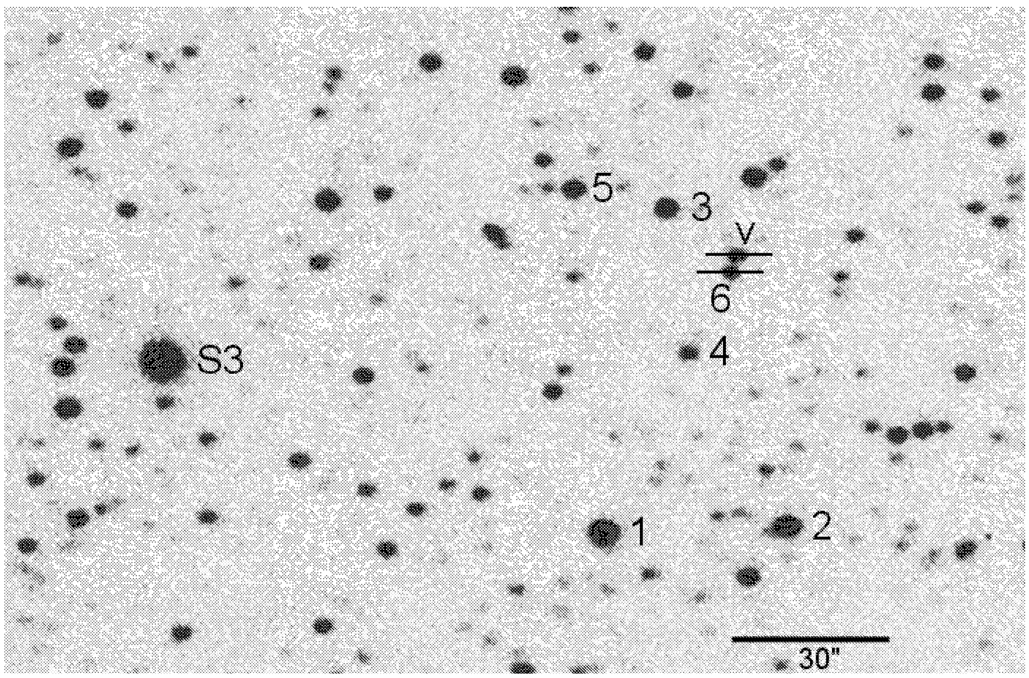

Figure 1. The CCD image of the field around V475 Sct. The north is to the top, the west is to the right.

Our V CCD image taken on November 17, 2003, using the 0.6m telescope in Crimea revealed that V475 Sct is a member of an optical pair (see Fig. 1). We determined the brightness of its southern component 6 located in an angular distance of 3.″3 from V475 Sct from our CCD observations as: U = 17.80(20), B = 17.35(8), V = 16.334(30), R = 15.444(10), I = 14.856(10), R_C = 15.718, I_C = 15.187. In cases when the nearby component 6 and V475 Sct was not resolved (all photoelectric observations and most of the CCD observations), we corrected our data for the light of this component.

The coordinates of component 6, listed in the GSC 2.2 catalogue as the object with R_1 = 15.71 mag are: $\alpha_{2000} = 18^h49^m37\overset{s}{.}663$, $\delta_{2000} = -9°33'53\overset{''}{.}74$. The nova is located inside the triangle formed by this star and another 2 nearby fainter stars (R_2 = 17.9 mag, R_3 = 17.77 mag) with the GSC 2.2 coordinates:

$\alpha_{2000} = 18^h49^m37\overset{s}{.}642$, $\delta_{2000} = -9°33'46\overset{''}{.}46$; $\alpha_{2000} = 18^h49^m37\overset{s}{.}286$, $\delta_{2000} = -9°33'47\overset{''}{.}69$.

Due to the different spectral sensitivity of the CCD cameras and different sets of filters used, our observations of V475 Sct were transformed and corrected to the international Johnson *UBVRI* system using our *UBV* photoelectric photometry and *RI* CCD photometry with the Ap7p CCD camera of the 0.6m telescope in CN (reference data). The observations from other instruments were suitably shifted for a constant value to be compatible with the reference data. The shifts, which we applied for different instruments, are given in Table 2.

Table 2. The shifts to the reference data for different instruments

Before JD 2453050					After JD 2453050				
U	*B*	*V*	*R*	*I*	*B*	*V*	*R*	*I*	Instr.
-0.27	-0.02	-0.11	0.25*	- 0.45**	-0.6	-0.7	0	0.2	1
–	0	-0.13	0	0.1	–	0	0.2	0.2	2
-0.22	-0.03	-0.03	0	0	0	-0.6	0	0	3
–	0.2	-0.05	0.05	0	0	-0.6	0	0	4
–	-0.15	-0.13	-0.10	–	–	–	–	–	5
–	0.5	-0.05	0.05	0	0	0.2	0	0.1	6
–	–	-0.04	–	–	–	0.3	–	–	7
–	-0.05	-0.02	0	0	0	0	0	0.2	8
0	0	0	–	–	–	–	–	–	9
0	0	0	–	–	–	–	–	–	10
–	–	–	–	–	0	0	0	0.2	11
–	–	–	–	–	0	-0.4	0.1	0	12

In the interval JD 2452947-2453050: * 0.0, ** -0.7.
The shift for observations in *U* filter after JD 2453252 is 0.
Instruments: 1 - SBIG ST10-XME + 500/2500 (SL), filters $(RI)_C$; 2 - SBIG ST7 + 380/5500 (CN); 3 - Ap7p + Zeiss 600/7500 (CN); 4 - Ap7p + ZTE 1250/20000 (CN); 5 - Ap7p + 40/130 mm telephoto lens (CN); 6 - VersArray-1300 + Zeiss 600/7500 (CN); 7 - Pictor-416 + AZT-5 Maksutov 500/2000 (CN); 8 - Ap47p + AZT-2 700/10500 (M); 9 - *UBV* photoelectric photometry, Zeiss 1000/14000 (CS); 10 - *UBV* photoelectric photometry, Zeiss 600/7500 (CN); 11 - Ap47p + Zeiss 600/7500 (CN); 12 - Ap7p + AZT-2 700/10500 (M), filter R_C.

The shifts during the nebular stage of the nova (after JD 2453050) differ from those during the earlier evolutionary stages. The shift for a constant value was applied also for transformation of $(RI)_C$ observations to reference data. This procedure is justified, because in transformation formulae published by Chochol et al. (2004) the $v - r$ and $r - i$ indices were almost constant around the maximum of brightness (before JD 2452947) and in the nebular stage (after

JD 2453050). During the large reddening caused by the dust formation (JD 2452947-2453050) we applied a different shift (see Table 2).

The photometric observations taken in 127 nights between August 30, 2003, and November 11, 2004, are presented in Table 3. The mean value of U, B, V, R, I magnitude taken by particular instrument in given night as well as a number of individual observations n included into the mean value are also given. The $UBVRI$ magnitudes and corresponding colour indices are displayed in Fig. 2.

2.2. Spectroscopy

Altogether 11 CCD spectra of V475 Sct were obtained at the Ondřejov observatory between September 15 and 25, 2003, using the 2 m reflector equipped with Coudé spectrograph with the dispersions 0.85 nm/mm (region 475.4-500.6 nm) and 1.7 nm/mm (regions: 547-598.3 nm, 625.7-677 nm, 750.3-801.3 nm and 814.8-865.7 nm). The CCD camera with the chip SITe 2000x800 pixels of the size of 15 micrometers was used. Initial reduction of spectra (bias subtraction, flat-fielding by an incandescent lamp, optimal aperture extraction, wavelength calibration based on ThAr hollow-cathode arcs and a heliocentric RV correction) were carried out by P.Š and M.Š in IRAF with standard tasks `ccdred` and `doslit`. Subsequent reductions and velocity measurements were carried out using the SPEFO software developed by the late J. Horn - see Horn et al. (1992) and Škoda (1996).

On August 27, 2004, the 480-670 nm spectroscopy of V475 Sct was performed at the 3.6 m telescope at La Silla, Chile, using EFOSC2 with grating 18 and a 0.″7 slit. Total observation time was 1h, splitted in three exposures of 1200s. The basic data reduction was done by LS with IRAF. The BIAS has been subtracted and the data have been divided by a flat field, which was normalized by fitting Chebyshev functions of a high order. The spectra have been optimally extracted (Horne, 1986). The wavelength calibration yielded a final resolution of 0.39nm/FWHM (full width half maximum).

The 460-900 nm spectroscopy of V475 Sct was obtained between September 2 and October 10, 2003, by the amateur astronomer Christian Buil at Castanet Tolosan (France) using the Takahashi FS-128 5-inch refractor equipped with MERIS spectrograph (sampling of 0.287 nm/pixel) + Audine KAF-0401E CCD camera. The spectra were corrected for the instrumental spectral response. Free data are available at the address http://www.astrosurf.com/buil/us/nscuti.

The list of the spectra used in the present work is given in Table 4.

3. Results and discussion

3.1. Basic parameters and classification of the nova

The basic parameters of the nova V475 Sct were determined using our photometry, presented in Table 3 and Fig. 2. The maximum of the first flare was

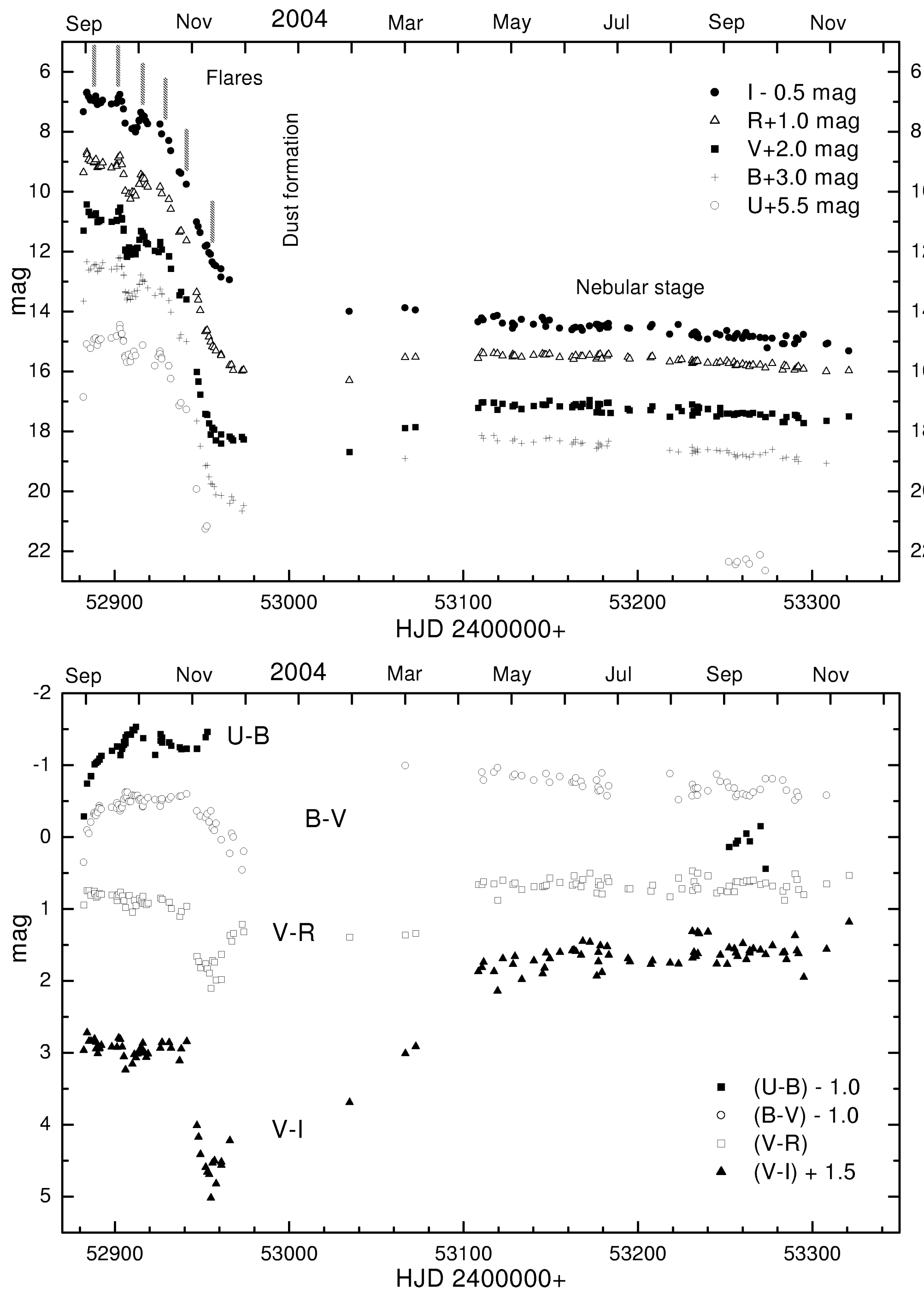

Figure 2. $UBVRI$ magnitudes (top) and $U-B$, $B-V$, $V-R$, $V-I$ indices (bottom) of V475 Sct.

Table 3. The photoelectric and CCD U, B, V, R, I magnitudes (night averages of the number of observations n) of V475 Sct obtained at the Stará Lesná, Crimea and Moscow observatories. JD = JD* + 2 400 000

JD*	U	n	B	n	V	n	R	n	I	n	Instr.
52882.27	11.359	6	10.648	6	9.297	7	8.351	7	7.834	6	1
52884.25	9.592	9	9.334	8	8.429	11	7.684	9	7.208	8	1
52884.30							7.755	3	7.189	2	8
52885.29			9.620	2	8.669	2	7.925	3	7.331	3	8
52886.30	9.735	31	9.580	34	8.785	31	7.980	35	7.448	34	1
52888.27			9.467	6	8.783	7	8.029	8	7.460	7	8
52888.36	9.425	6	9.437	36	8.776	57	7.993	34	7.467	36	1
52889.31			9.426	7	8.755	4	7.922	20	7.314	5	8
52889.31	9.391	31	9.423	31	8.720	29			7.371	24	1
52890.27			9.647	14	9.004	12	8.187	38	7.495	14	8
52890.32	9.623	20	9.674	36	9.011	36			7.595	36	1
52891.27			9.550	14	8.984	13			7.558	11	8
52891.30	9.454	9	9.544	10	8.950	10	8.161	10	7.510	10	1
52891.31	9.472	6	9.549	5	8.950	6					9
52892.29			9.549	17	8.935	19	8.139	17	7.538	18	8
52892.30	9.429	2	9.559	3	8.942	95					9
52893.31			9.370	1			8.032	1	7.450	1	8
52898.27	9.387	10	9.589	10	9.000	10	8.198	10	7.582	10	1
52901.28			9.491	2	8.963	90	8.081	5	7.540	4	3
52901.28	9.322	12	9.581	12	8.977	12	8.154	12	7.554	12	1
52901.33					8.937	51					7
52902.21			9.215	2	8.659	2	7.858	2	7.368	2	3
52902.23					8.663	72					7
52903.24					8.539	102					7
52903.26	8.948	4	9.205	13	8.568	13	7.805	13	7.256	13	1
52903.29	9.080	39	9.220	39	8.611	54					10
52904.21					8.926	7					5
52904.21	9.257	4	9.485	4	8.902	4					10
52904.24					8.885	91					7
52904.26	9.250	8	9.502	15	8.911	15	8.093	15	7.493	15	1
52905.21	9.474	2	9.798	2	9.273	2					10
52905.23					9.275	74					7
52905.24					9.242	7					5
52905.26	9.488	8	9.774	11	9.300	11	8.417	11	7.749	11	1
52906.21					9.942	54					7
52906.22	9.987	2	10.375	2	9.929	2					10
52906.22			10.345	22	9.968	7					5
52906.25	10.038	12	10.344	12	9.961	12	8.981	12	8.225	12	1

Table 3. (continued)

JD*	U	n	B	n	V	n	R	n	I	n	Instr.
52907.23	10.192	2	10.616	2	10.170	2					10
52907.25					10.169	90					7
52907.30			10.551	7	10.173	8					5
52908.23	9.937	4	10.364	4	9.858	4					10
52908.25					9.892	150					7
52908.30			10.405	13	9.895	3	9.080	3			5
52909.20			10.583	2			9.240	2			5
52909.25	10.177	3	10.600	3	10.090	3					10
52910.22	9.990	1	10.481	3	10.059	28	9.014	2	8.402	2	3
52911.19	9.839	2	10.325	1	9.899	11	9.020	3	8.376	1	3
52912.18	9.974	2	10.509	2	10.080	4	9.128	3	8.514	2	3
52913.20			10.296	5	9.872	39			8.358	7	3
52914.18			10.082	7	9.612	64	8.740	5	8.150	8	3
52914.23			10.095	10	9.605	10	8.747	10	8.119	10	1
52915.20			9.785	3	9.312	38	8.428	11	7.856	4	3
52916.18			9.934	3	9.414	19	8.492	6	7.949	3	3
52916.20			9.959	3	9.377	42	8.554	4	8.013	4	2
52916.26	9.631	4	10.005	4	9.431	4					9
52917.19			9.994	4	9.495	87	8.572	4	7.992	3	3
52918.21					9.708	43	8.767	31	8.148	11	3
52919.20			10.209	1	9.754	59	8.838	1	8.240	1	3
52923.25	10.316	1	10.459	3	9.977	1					9
52925.22	10.001	2			10.007	2					9
52926.20	9.827	2	10.257	2	9.774	3					9
52926.24	9.919	8	10.257	8	9.684	8	8.837	8	8.252	7	1
52927.22	10.040	2	10.427	2	9.932	1					9
52927.22	10.081	10	10.399	10	9.929	10	9.061	10	8.575	10	1
52931.22	10.316	10	10.633	10	10.159	10	9.252	10	8.801	10	1
52932.30	10.749	17	11.018	11	10.573	13	9.578	12	9.139	12	1
52937.21	11.645	15	11.891	14	11.455	15	10.350	14	9.844	14	1
52938.19	11.552	16	11.773	14	11.341	17	10.310	14	9.894	17	1
52941.29	11.773	5	12.000	7	11.599	7	10.635	6	10.257	5	1
52947.19	14.43	9	14.66	10	14.02	10	12.36	9	11.51	10	1
52948.17					14.34	2	12.61	2	11.67	1	1
52949.18			15.49	15	14.78	14	12.96	14	11.87	14	1
52952.18	15.76	6	16.15	13	15.42	13	13.66	13	12.33	13	1
52953.18	15.67	6	16.13	7	15.45	8	13.62	8	12.29	8	1
52954.19			16.52	9	15.73	10	13.84	9	12.54	9	1
52955.17			16.75	5	16.11	7	14.01	7	12.59	7	1
52956.17			16.76	10	15.88	10	14.16	10	12.85	10	1

Table 3. (continued)

JD*	U	n	B	n	V	n	R	n	I	n	Instr.
52957.17			16.85	8	15.94	7	14.20	7	12.94	7	1
52958.18			17.11	5	16.30	7	14.31	9	12.98	8	1
52961.14					16.41	1	14.43	1	13.35	1	2
52961.16			17.14	3	16.10	4	14.47	3	13.08	2	6
52966.14			17.40	2	16.17	54	14.80	2	13.45	1	4
52967.15			17.18	3	16.23	25	14.78	9			6
52968.14			17.30	1	16.30	31	14.96	1			6
52973.13			17.65	1	16.19	2	14.98	27			6
52974.13			17.47	2	16.27	2	14.95	3			6
53034.71					16.69	2	15.30	3	14.50	4	1
53066.63			15.90	4	15.89	4	14.53	5	14.38	2	3
53072.63					15.86	3	14.52	3	14.45	1	3
53108.56					15.22	8	14.56	8	14.85	6	8
53110.60			15.13	7	15.03	10	14.37	9	14.72	9	1
53111.58			15.23	10	15.02	16	14.40	17	14.78	15	1
53117.56			15.14	18	15.04	19	14.39	20	14.67	19	1
53119.55			15.32	14	15.28	16	14.40	18	14.64	15	1
53122.53					15.08	9	14.48	7	14.89	6	1
53128.45							14.43	3	15.07	3	1
53128.50			15.32	8	15.16	5	14.50	8	14.89	35	8
53129.52			15.25	4	15.12	4	14.48	5	14.96	30	8
53133.50			15.40	3	15.25	4	14.52	7	14.77	11	8
53140.47			15.36	5	15.15	4	14.46	4	14.93	20	8
53145.49					15.10	2	14.41	1	14.70	2	8
53146.53					15.12	25	14.44	24	14.80	24	1
53147.46			15.23	4	15.11	5	14.44	5	15.00	40	8
53149.54			15.22	10	14.98	11	14.41	11	14.79	11	1
53155.42			15.32	4	15.16	4	14.53	6	15.06	161	8
53162.41			15.43	4	15.19	3	14.52	7	15.11	85	8
53163.41			15.36	2	15.13	3	14.59	6	15.06	80	8
53164.43			15.36	3	15.12	3	14.47	3	15.03	52	8
53164.56			15.27	4	15.09	6					1
53167.45			15.41	1	15.18	1	14.49	3	15.04	38	8
53168.40			15.38	2	15.08	2	14.49	2	15.13	94	8
53172.44					15.15	60					7
53172.47					14.95	69	14.45	1	14.99	1	2
53176.52			15.57	4	15.36	4	14.58	2	14.93	169	4
53177.45			15.53	2	15.17	1	14.51	1	14.94	194	4
53177.47			15.39	1	15.08	1	14.46	1	14.98	1	11
53178.46			15.44	1	15.09	1	14.42	2	15.08	1	11

Table 3. (continued)

JD*	U	n	B	n	V	n	R	n	I	n	Instr.
53179.51			15.48	1	15.37	1	14.58	1	14.99	149	4
53181.44									14.98	64	4
53182.40			15.48	1	15.05	1	14.48	1	15.03	1	11
53182.44									14.94	259	4
53183.33			15.33	1	15.04	26	14.42	1	14.90	1	11
53183.41									15.03	221	4
53184.45					15.38	31					7
53194.44					15.24	9	14.52	10	15.05	9	1
53195.47					15.30	38	14.58	39	15.07	38	1
53207.49					15.29	5	14.54	5	15.02	4	1
53208.44					15.16	3	14.49	3	14.94	2	1
53218.43			15.63	22	15.51	26	14.68	25	15.26	25	1
53223.31			15.68	2	15.20	3	14.63	2	14.94	2	12
53225.30					15.32	3	14.60	2			12
53231.29			15.53	2	15.10	2	14.63	2	15.29	2	11
53231.41			15.73	13	15.46	14	14.72	13	15.28	14	1
53232.26			15.65	2	15.32	2	14.70	1	15.22	2	11
53233.37			15.67	27	15.35	26	14.66	26	15.19	26	1
53234.26			15.59	2	15.17	1	14.67	1	15.35	2	11
53234.35			15.69	24	15.37	24	14.65	21	15.25	24	1
53235.27					15.22	2			15.38	4	11
53240.30			15.61	2	15.25	2	14.71	3	15.43	59	11
53245.30			15.63	8	15.50	8	14.72	9	15.24	9	1
53247.30			15.66	7	15.43	8	14.69	8	15.29	8	1
53247.31					15.22	98					7
53251.32			15.65	7	15.41	8	14.65	8	15.14	8	1
53252.30	16.86	2	15.72	2	15.41	2	14.73	2	15.37	75	6
53255.28			15.77	12	15.45	12	14.69	12	15.40	12	1
53256.24	16.95	1	15.86	1	15.42	1	14.80	1	15.31	52	6
53257.27	16.86	2	15.81	2	15.40	2	14.78	2	15.24	91	6
53260.28			15.78	12	15.38	12	14.75	12	15.40	12	1
53261.35									15.31	57	6
53262.29	16.78	2	15.83	2	15.41	2	14.80	2	15.21	6	6
53264.21					15.42	2	14.80	2	15.34	3	12
53264.25	16.93	1	15.87	1	15.44	2	14.83	1	15.33	225	6
53266.28			15.76	10	15.38	10	14.78	10	15.33	10	1
53270.31	16.63	1	15.78	1	15.44	1	14.78	1	15.37	26	6
53273.27	17.15	1	15.71	1	15.52	1	14.88	1	15.39	73	6
53274.34									15.72	24	6
53277.25			15.60	1	15.41	2	14.73	1	15.40	9	6

Table 3. (continued)

JD*	U	n	B	n	V	n	R	n	I	n	Instr.
53283.26			15.90	8	15.69	8	14.94	8	15.58	8	1
53284.24					15.68	10	14.80	9	15.58	9	1
53285.27			15.87	8	15.52	8	14.83	8	15.32	8	1
53290.22			15.94	5	15.45	7	14.94	7	15.58	7	1
53291.21			15.85	5	15.47	7	14.88	7	15.39	7	1
53292.22			16.00	10	15.56	10	14.83	10	15.44	7	1
53295.17					15.72	2	14.92	2	15.27	33	11
53308.19			16.07	1	15.65	2	15.00	1	15.59	45	6
53309.21									15.56	50	6
53321.14					15.50	1	14.97	1	15.82	46	4

Table 4. Journal of spectroscopic observations

Date	$JD_{hel}^{MidExp.}$ 2400000+	Exp. [s]	Range [Å]	Obs.
2.9.2003	52885.4203	1440	4650-6700	CT
3.9.2003	52886.3411	1920	4650-8680	CT
7.9.2003	52890.3596	1320	4650-6700	CT
13.9.2003	52896.3309	2400	4650-9000	CT
15.9.2003	52898.3109	2000	6257-6770	O
16.9.2003	52899.2825	600	6257-6770	O
16.9.2003	52899.3163	1000	5470-5983	O
16.9.2003	52899.3461	3600	4754-5006	O
16.9.2003	52899.3798	820	7503-8013	O
16.9.2003	52899.3974	1200	8148-8657	O
18.9.2003	52901.2649	800	6257-6770	O
18.9.2003	52901.2883	1500	5470-5983	O
25.9.2003	52908.2910	1805	6257-6770	O
25.9.2003	52908.3177	1800	5470-5983	O
25.9.2003	52908.3576	3600	4754-5006	O
25.9.2003	52908.3554	1800	4650-6700	CT
10.10.2003	52923.3097	2880	4650-6700	CT
27.8.2004	53244.6701	3600	4742-6785	LS

Observatories: CT - Castanet Tolosan, O - Ondřejov, LS - La Silla identified as the principal maximum of the nova and according to our photometric observations it was reached at JD 2452884.27 (V = 8.43 mag, B = 9.33 mag). The F2 supergiant spectrum taken one day before the maximum suggests that in the principal maximum the expanding atmosphere of the outbursted white dwarf was ejected. The V and B light curves were used to find the rates of decline $t_{2,V}$ = 48 days, $t_{3,V}$ = 53 days, $t_{2,B}$ = 50 days, $t_{3,B}$ = 58 days and to estimate the absolute magnitudes of the nova at maximum MV_{max}, MB_{max} using the MMRD (Magnitude at Maximum – Rate of Decline) relations:

a) absolutely calibrated MV_{max} - t_2 relation (Della Valle & Livio, 1995)

$$MV_{max} = -7.92 - 0.81 \arctan \frac{1.32 - \log t_2}{0.23}, \tag{1}$$

b) MV_{max} - t_2 relation of Downes & Duerbeck (2000)

$$MV_{max} = (-11.32 \pm 0.44) + (2.55 \pm 0.32) \log t_2, \tag{2}$$

c) MV_{max} - t_3 relations of Schmidt (1957) and Downes & Duerbeck (2000)

$$MV_{max} = -11.75 + 2.5 \log t_3, \tag{3}$$

$$MV_{max} = (-11.99 \pm 0.56) + (2.54 \pm 0.35) \log t_3, \tag{4}$$

d) MV_{15} empirical relation of Downes & Duerbeck (2000). They found that novae 15 days after maximum have the similar absolute magnitude

$$MV_{15} = -6.05 \pm 0.44. \tag{5}$$

e) MB_{max} - t_3 relations (Pfau, 1976; Livio, 1992)

$$MB_{max} = -10.67 \pm 0.30 + (1.80 \pm 0.20) \log t_3 \tag{6}$$

$$\begin{aligned} t_{3,B} = 51.3 \times 10^{\frac{\mathrm{MB}_{max}+9.76}{10}} \times \\ \times (10^{\frac{2(\mathrm{MB}_{max}+9.76)}{30}} - 10^{\frac{-2(\mathrm{MB}_{max}+9.76)}{30}})^{\frac{3}{2}} days. \end{aligned} \tag{7}$$

f) MB_{15} empirical relation of Pfau (1976)

$$MB_{15} = -5.74 \pm 0.60. \tag{8}$$

We have calculated the following values of MV_{max} using these relations: MV^1_{max} = –7.11, MV^2_{max} = –7.03, MV^3_{max} = –7.44 MV^4_{max} = –7.61, MV^5_{max} = –6.62, MB^6_{max} = –7.50, MB^7_{max} = –7.37, MB^8_{max} = –6.00, with the unweighted means: MV_{max} = -7.16 ±0.15, MB_{max} = -6.96 ±0.39.

The calculated intrinsic colour index at maximum $(B-V)^{in}_{max} = 0.20$ is close to that derived by Downes & Duerbeck (2000) for the intrinsic colours of novae at maximum $(B-V)^{in}_{max} = 0.25 \pm 0.05$.

Using the derived MB_{max} = –6.96±0.39 and the formula given by Livio (1992)

$$MB_{max} = -8.3 - 10.0\log(M_{wd}/M_{\odot}), \quad (9)$$

we can estimate the mass of the white dwarf in V475 Sct as M_{wd} = 0.73±0.07 $M_{\odot}$.

The interstellar extinction can be derived:

1) from the comparison of the observed colour index at maximum $(B-V)_{max}$ = 0.91, affected by extinction, with the calculated intrinsic colour index at maximum $(B-V)^{in}_{max} = 0.2$. We thus find the colour excess $E(B-V) = 0.71$.

2) from the relation of van den Bergh & Younger (1987) who found that novae two magnitudes below maximum have an unreddened colour index of

$$B - V = -0.02 \pm 0.04. \quad (10)$$

The observed colour of V475 Sct two magnitudes below maximum is $B-V$ = 0.45, which thus yields $E(B-V) = 0.47$.

3) from the relation of Miroshnichenko (1988) who developed the photometric method to determine the interstellar extinction towards novae. He found that during "stability stage", which occurs not very long after maximum when both $U-B$ and $B-V$ indices do not change systematically, the colour excess is given by

$$E(B-V) = (B-V)_{SS} + 0.11(\pm 0.02), \quad (11)$$

where $(B-V)_{SS}$ is the mean colour index during the stability stage. In V475 Sct the stability stage lasted from September 15 to September 21, 2003. For $(B-V)_{SS} = 0.61$ we find a corresponding $E(B-V) = 0.72$.

4) from the comparison of the intrinsic colour index $B-V$ = 0.23 of F2 supergiant (Cox, 2000), as found spectroscopically on August 31.97, with our observed index for the nova of $B-V = 1.08$. This results in $E(B-V) = 0.85$.

5) from the interstellar K I (769.8979 nm) line. Munari & Zwitter (1997) derived a useful relation to estimate extinction from the equivalent width of the interstellar K I line. Our measurement of the EW of the single sharp interstellar component of this line from the Ondřejov spectrum of V475 Sct taken on September 16, provides the value of 0.179, which corresponds to the value of $E(B-V) = 0.70$.

The mean value of the reddening found from the data mentioned above is $E(B-V)$ = 0.69±0.05. Corresponding absorptions in V and B are A_V = 2.15±0.15 and A_B = 2.88±0.21. The resulting distance moduli of the nova are $V_{max} - MV_{max}$ = 15.57±0.15 and $B_{max} - MB_{max}$ = 16.28±0.39, which yields a corresponding distance to the nova of 4.8±0.9 kpc.

Using the classification scheme of nova light curves (Downes & Duerbeck, 2000), we can classify V475 Sct as a slow Eddington nova of Ca type with standstills at maximum and dust formation at later stages.

Postoutburst evolution of V475 Sct can be studied in a colour-colour diagram. The dereddened evolutionary path of the nova is shown in Fig. 3. Near the maximum and a few days afterwards, the nova moved between the supergiant I and the blackbody sequences. Later on, the colours became more blue and in the latter decline a shift to the red was detected.

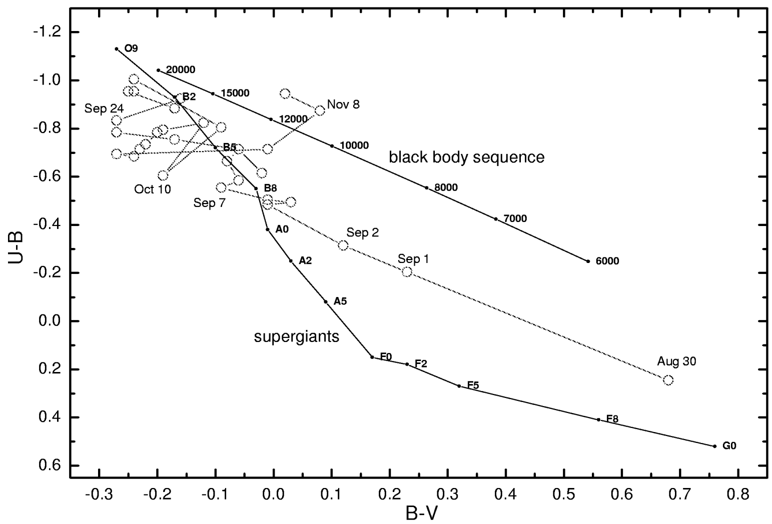

Figure 3. The evolutionary path (dereddened) of V475 Sct in the colour-colour diagram. The supergiant sequence was taken from Cox (2000).

3.2. Brightness maxima - flares

The periodic maxima of activity (flares) are present on the light curve during the standstill and on the decline (see Fig. 4). Their existence is independently confirmed by the visual AAVSO light curve (see www.aavso.org). We cannot present this light-curve here, because the AAVSO authorities ignored our request for validated data. In our light curves, the brightness maxima were detected at JD 2452000+ (888.3; 902.2; 916.2; 929.2; 941.3; 956.2), clearly indicated in the $V-I$ index. The following ephemeris, found by linear regression, is valid for the brightness maxima:

$$JD_{max} = 2\,452\,875.3\ (\pm 0.7) + 13.4\ (\pm 0.2) \times E. \qquad (12)$$

The detected maxima of activity can be caused either by pulsation of the nova envelope as discussed by Schenker (1999) or by mass transfer bursts from the red to the white dwarf caused by the periastron passage of a third body in the system, which could also have triggered the outburst of the nova around JD 2452875. The behaviour of V475 Sct is similar to the nova V723 Cas, where the flares repeated with a 180-day period (Chochol & Pribulla, 1998). Chochol et

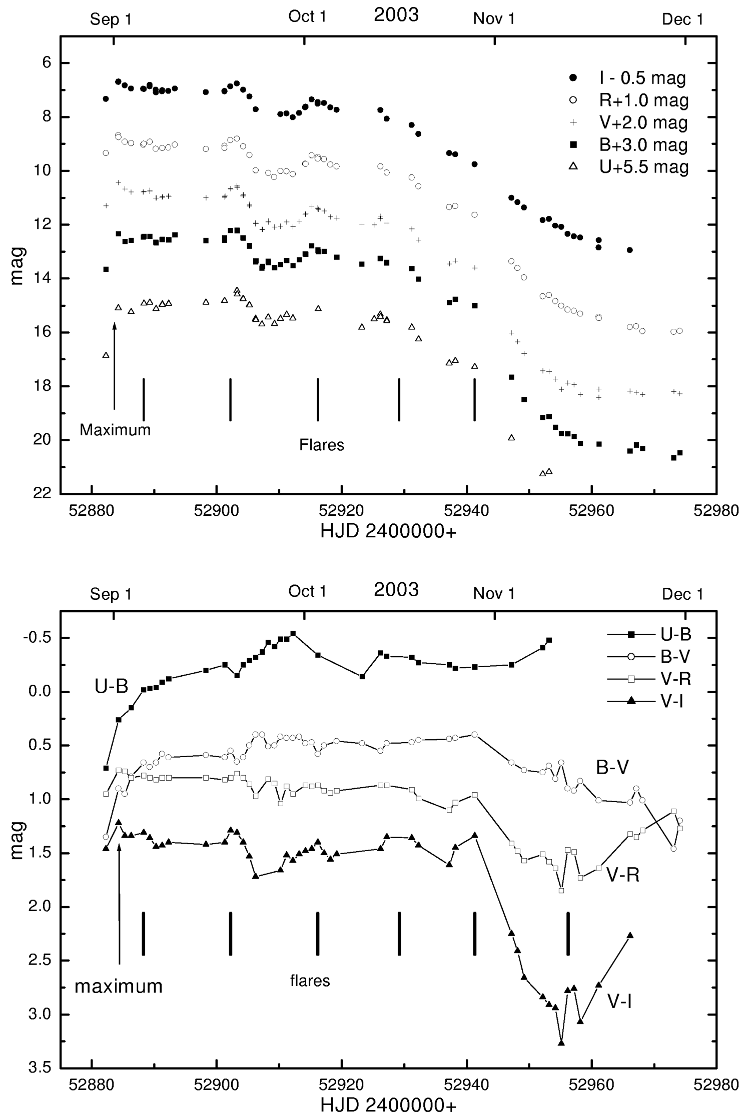

Figure 4. *UBVRI* magnitudes (top) and colour indices (bottom) of V475 Sct during the standstill and on the decline.

al. (2000) explained the flares by non-degenerate flashes on the hot white dwarf induced by mass transfer bursts from the red to the white dwarf due to the periastron passage of the third body on its 180-day orbit.

3.3. Dust formation stage and photometry during nebular stage

The light curve of V475 Sct can be characterized by the rapid fade of the optical flux which started 57 days after the principal maximum. The rapid decline of optical brightness and simultaneous increase of the $V-R$ and $V-I$ indices could be related to a dust formation in the ejecta of the nova. Infrared $JHKLM$ photometry is required to confirm the development of an IR excess due to the dust formation. The maximum of the indices was reached 71 days after the principal maximum. Their subsequent sudden change lasting ∼3 days was caused by the flare. Further observations during this interesting stage were prevented by the position of V475 Sct on the sky.

Our V and B observations obtained since April 2004 by different instruments started to differ by up to 0.7 mag (see Table 2). Such a phenomenon is associated with the nebular stage of the nova and differences in the width of the V and B filter. According to Stringfellow & Walter (2004), at the beginning of March 2004, very strong [O III] 495.89 nm and 500.69 nm emission lines, which characterize the nebular stage of the nova, had developed. These lines, located on the edge of the transmission curves of the B and V filters, are responsible for the observed difference. Chochol et al. (1993) found the same phenomenon in nova V1974 Cyg. In our spectrum of V475 Sct, taken on August 27, 2004 (see Fig. 7), we have found that fluxes of the 495.89 nm and 500.69 nm lines were 8.4 and 25.7 times larger than the flux of Hβ line.

3.4. Spectrum of the nova and outflow velocities

As it is possible to see from Fig. 5, the nova can be classified as an Fe II class object (Williams, 1992) with an emission spectrum including also O I, Na I, Ca II, Mg II and Balmer H lines accompanied by P Cygni absorptions. The spectrum was formed in an expanding shell ejected during the maximum on September 1, 2003. The first forbidden line [O I] developed between September 13 and 25, 2003. As seen in Fig. 6, two sets of absorptions were present in the P Cygni H$_\alpha$ line profile. Their radial velocities were measured with respect to the laboratory wavelength of H$_\alpha$ centered at 0 km s^{-1}. Between September 15 and 25, 2003, they increased their RVs from –480 to –640 km s^{-1} and from –1140 to –1370 km s^{-1}, suggesting the acceleration of the inner and outer envelope of the nova shell, where the absorptions arise, by continuous wind. The radial velocities of absorptions in the Na I doublet 589.0 nm and 589.59 nm were –530 km s^{-1} and –940 km s^{-1} on September 16 and –560 km s^{-1} and – 1120 km s^{-1} on September 25. Moreover, the spectrum from September 16 shows also the presence of a very broad absorption formed in the continuous wind with the RV centered at –1900 km s^{-1} and terminal velocity of the wind 2250 km s^{-1}. The radial velocities of the interstellar Na I D absorptions found from 3 available spectra are 4.7±0.5 km s^{-1} and 1.3±0.6 km s^{-1}.

The medium-dispersion spectrum obtained at La Silla (see Fig. 7) during the nebular stage of the nova shows the presence of prominent emission lines of H, He I, [O I], [N II], [O III] and [Fe VII]. Their shapes in the radial velocity scale, as presented in Fig. 8, suggest a non-spherical ejection of the main envelope of the nova. The [O I] 630 nm profile is almost symmetric with a few peaks indi-

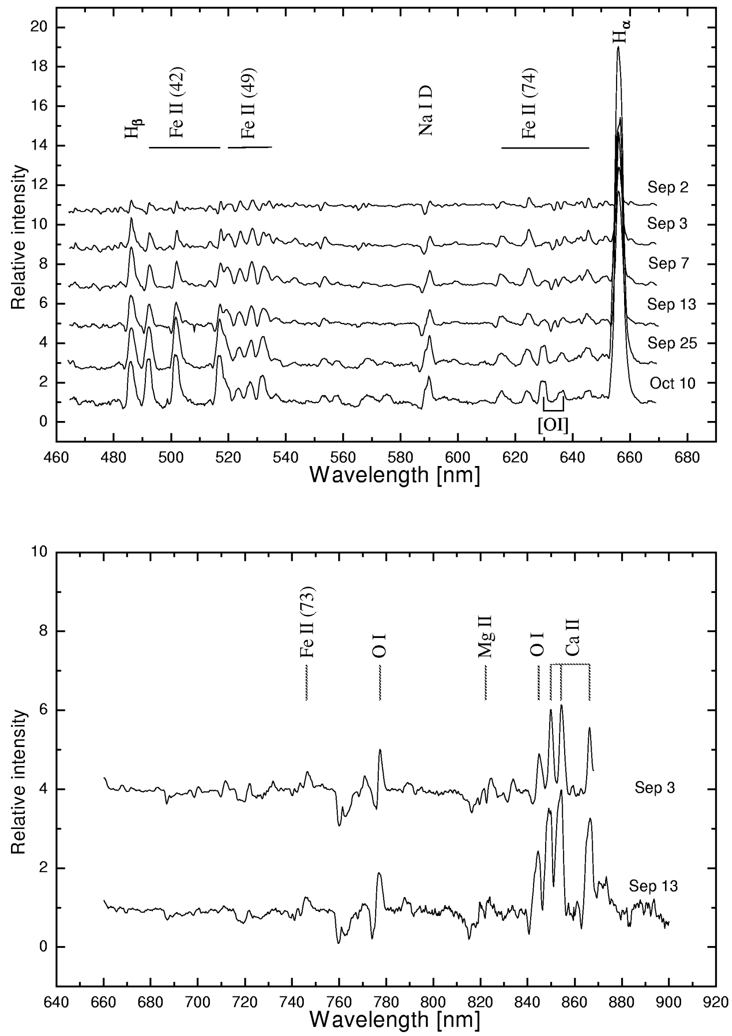

Figure 5. The low-dispersion spectra of V475 Sct.

cating the presence of an equatorial ring and polar blobs in the expanding main envelope of the nova. High-resolution spectra are necessary to study detailed structures. Another symmetric profile belongs to [Fe VII] formed in the vicinity of the hot object (its FWHM is smaller than in other lines). The radial velocity of the peak of [Fe VII] emission line is 240 km s^{-1}. This velocity probably reflects the gamma velocity of the system.

The expansion velocity of the main inner envelope of V475 Sct as calculated from the empirical relation

$$\log v = 3.22 - 0.22 \log t_3 \tag{13}$$

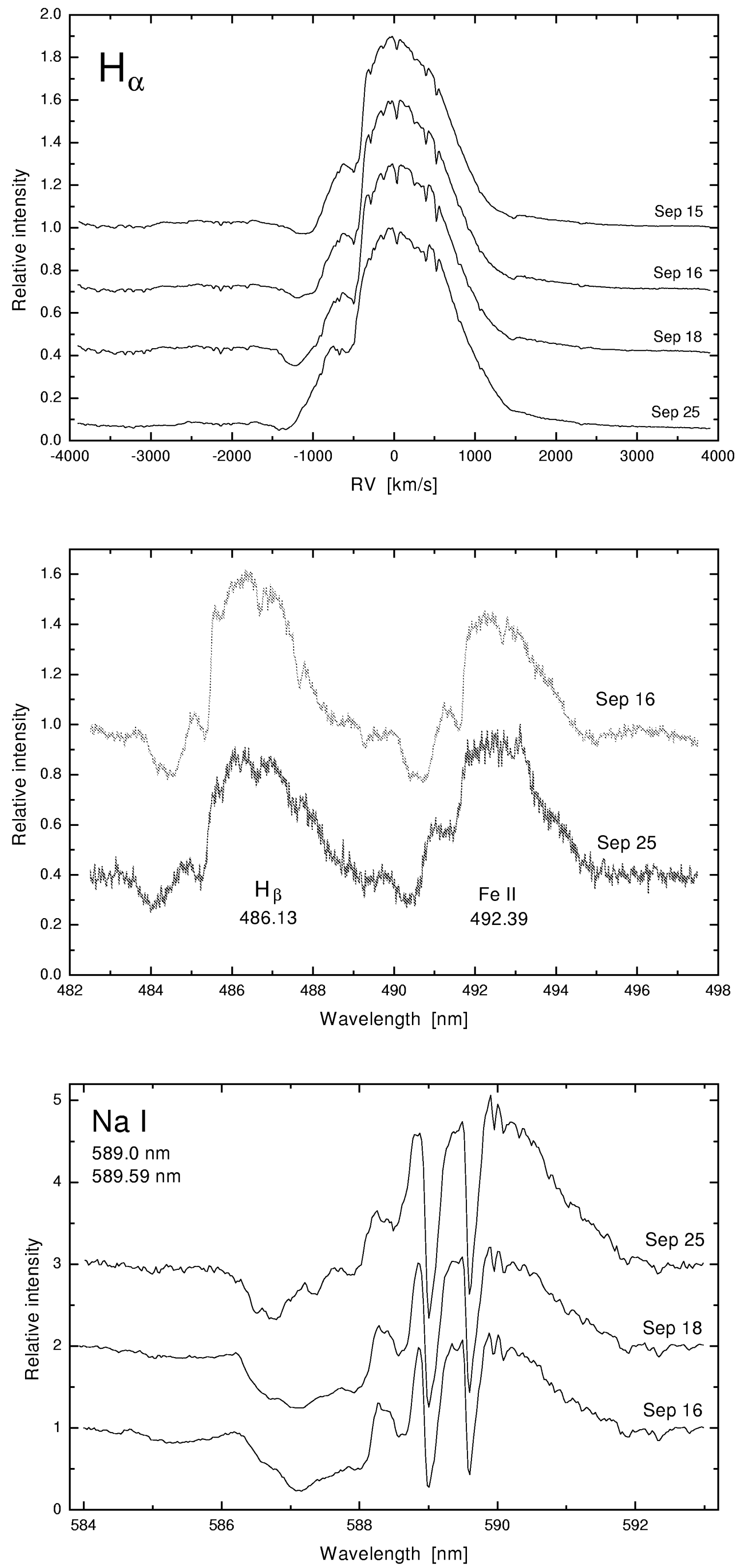

Figure 6. The evolution of the H_α (top), H_β and Fe II (middle) and Na I doublet (bottom) profiles at Ondřejov spectra.

found by Chochol et al. (1997) from nebular spectra of 13 novae, is v = 693 km s^{-1}. This value is in agreement with the expansion velocity of V475 Sct found from our spectroscopic observations taken on August 27, 2004. We have measured the full width at half maximum of the prominent emission lines presented in Fig. 8, which is a suitable measure of twice the expansion velocity of the shell (Cohen & Rosenthal, 1983). We obtained the expansion velocities in the range 550-780 km s^{-1} and the mean value of the expansion of the main envelope 655±25 km s^{-1}. We did not included into the mean the expansion velocity 490 km s^{-1} of the [Fe VII] line, because it is not formed in the main expanding envelope of the nova.

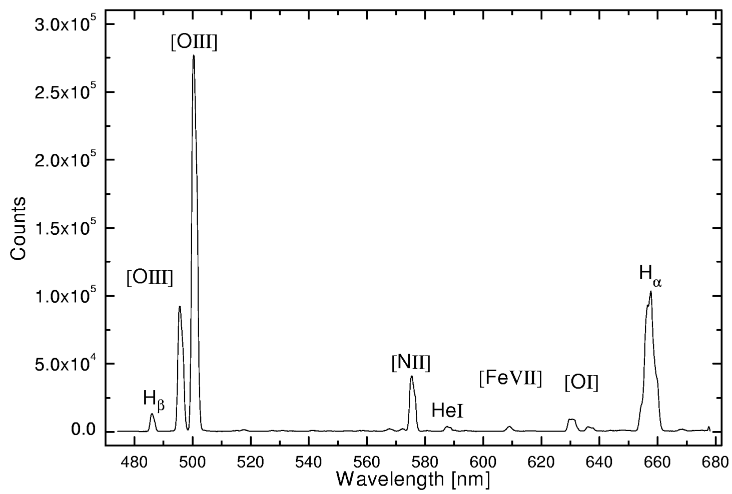

Figure 7. Nebular spectrum of V475 Sct taken at ESO on August 27, 2004.

3.5. Is V475 Sct a twin of V705 Cas?

V475 Sct resembles the dust nova V705 Cas. This nova also is of Fe II spectroscopic type. The radial velocities of V705 Cas absorptions are –550 and –1330 km s^{-1} (Elkin, 1995) close to the radial velocities of V475 Sct. For nova V705 Cas, Chochol et al. (1995) found almost the same absolute magnitude MB_{max} = –6.95 as in the case of V475 Sct, which yields a mass of the white dwarf of 0.73 $M_{\odot}$ for both novae. The dust formation stages are also similar for both novae. In V705 Cas, according to Mason et al. (1998), the carbon dust formation stage started ∼70 days after the outburst, when the observed visible magnitude steeply declined. Maximum dust shell development occurred about 105 days after the outburst with an optical depth τ_V ∼6. Unfortunately, we cannot compare the most important parameter - the orbital period. Retter & Leibowitz (1996) found the orbital photometric variations in the dust nova V705 Cas with the

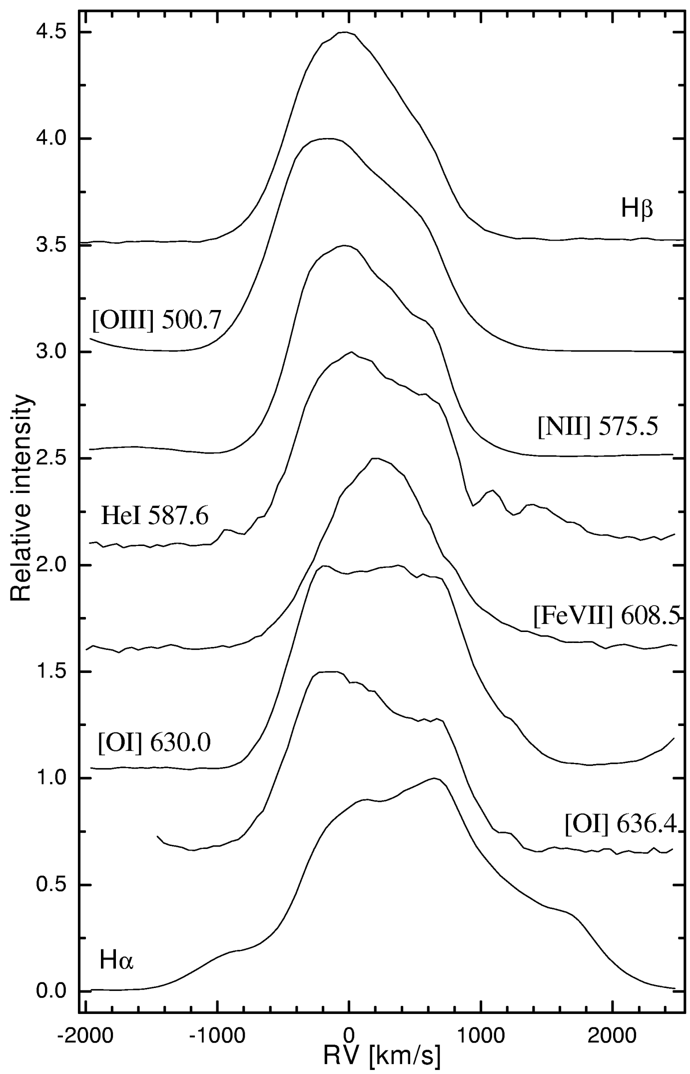

Figure 8. Emission line profiles of selected lines on August 27, 2004.

period 0.228 days. Although our longer photometric runs of V475 Sct suggest variability, we did not find any strict periodicity which can be related to the orbital motion. Further observations are needed to find the orbital period of V475 Sct.

4. Conclusion

Multicolour photometry and spectroscopy of the classical nova V475 Sct following its outburst in August 2003 allow to classify the object as a slow Eddington

Fe II nova with the structured light curve, the standstill at maximum and dust formation at later stages. The basic parameters of the nova were calculated from the B and V light curve. During the standstill and on decline the 13.4-day periodicity of flares was found, best detected in the $V - I$ index. The rapid fade in the optical flux and simultaneous increase of the $V - R$ and $V - I$ indices, which started 57 days after the maximum, could be related to a dust formation in the ejecta of the nova. The structure of the ejected shell was proposed from spectroscopy. Similarly as in nova V1974 Cyg (Chochol et al., 1997), it consists of a main massive inner envelope and an outer low-mass envelope detected after outburst as P Cyg absorptions in the emission line profiles (mainly H and Fe II). Both envelopes are accelerated by a continuous stellar wind detected as absorption in Na I D lines. In the nebular stage, the components of the main envelope are identified as peaks of structured emission line profiles. The photometric and spectroscopic evolution of the nova V475 Sct is similar to the nova V705 Cas.

Acknowledgements. This work was supported by Science and Technology Assistance Agency under the contract No. APVT-20-014402, VEGA grant 4014, projects K2043105 and Z1003909 of Academy of Sciences of the Czech Republic, the grant of VVGS/014/2003/F, partially by grants 02-02-16235 and 02-02-17524 of Russian Foundation of Basic Researches and Russian President Grant NS-388.2003.2. The authors are grateful to Dr. N.N. Samus for the help with identifications of the faint stars in the vicinity of the nova V475 Scuti, S.Yu. Shugarov and I.M. Volkov appreciate the hospitality of the Astronomical Institute of the Slovak Academy of Sciences, Tatranská Lomnica.

References

Boeche, C., Munari, U.: 2003, *IAU Circ.* , No. 8191

Chochol, D., Pribulla, T.: 1998, *Contrib. Astron. Obs. Skalnaté Pleso* **28**, 121

Chochol, D., O'Brien, T.J., Bode M.F.: 2000, *New Astronomy Reviews* **44**, Part 2, P61

Chochol, D., Hric, L., Komžík, R., Urban, Z.: 1995, in *Cataclysmic Variables*, eds.: A. Bianchini, M. Della Valle and M. Orio, Kluwer Acad. Publisher, Dordrecht, 154

Chochol, D., Grygar, J., Pribulla, T., Komžík, R., Hric, L., Elkin, V.: 1997, *Astron. Astrophys.* **318**, 908

Chochol, D., Hric, L., Urban, Z., Komžík, R., Grygar, J., Papoušek J.: 1993, *Astron. Astrophys.* **277**, 103

Chochol, D., Parimucha, Š., Pribulla, T., Shugarov, S.Y., Vaňko, M., Kroll, P.: 2004, *Contrib. Astron. Obs. Skalnaté Pleso* **34**, 5

Cox, A. ed.: 2000, *Allen's Astrophysical Quantities*, Springer-Verlag, New York

Cohen, J.G., Rosenthal, A.J.: 1983, *Astrophys. J.* **268**, 689

Della Valle, M., Livio, M.: 1995, *Astrophys. J.* **425**, 704

Downes, R.A., Duerbeck, H.W.: 2000, *Astron. J.* **120**, 2007

Elkin, V.: 1995, *Pisma Astron. Zh.* **21**, 750

Horn, J., Hubert, A.M., Hubert, H., Koubský, P., Bailloux, N.: 1992, *Astron. Astrophys.* **259**, L5

Horne, K.: 1986, *Publ. Astron. Soc. Pac.* **98**, 609

Kornilov, V.G., Volkov, I.M., Zakharov, A.I., Kozyreva, V.S. Kornilova, L.N., Krutjakov, A.N., Krylov, A.V., Kusakin, A.V., Leontiev, S.E., Mironov, A.V., Moskhaliov, V.G., Pogrosheva, T.M., Sementsov, V.N., Khaliulin, K.F.: 1991, *Trudy GAIŠ*, **63**, MGU Moscow, 235, in Russian

Livio, M.: 1992, *Astrophys. J.* **393**, 516

Mason, C.G., Gehrz, R.D., Woodward, C.E., Smilowitz, J.B., Hayward, T.L., Houck J.R.: 1998, *Astrophys. J.* **494**, 783

Mendoza, E.E.: 1967, *Tonantzintla Tacubaya* **4**, 149

Miroshnichenko, A.C.: 1988, *Astron. Zh.* **65**, 582

Munari, U., Zwitter, T.: 1997, *Astron. Astrophys.* **318**, 269

Nakano, S., Sato, H.: 2003, *IAU Circ.* , No. 8190

Pfau, W.: 1976, *Astron. Astrophys.* **50**, 113

Retter, A., Leibowitz, E.M.: 1995, *IAU Circ.* , No. 6234

Schenker, K.: 1999, *PhD thesis*, University Basel

Schmidt, T.: 1957, *Z. Astrophys.* **41**, 182

Shakhovskoi, N.M., Sazonov, A.N.: 1996, *Pisma Astron. Zh.* **22**, 580

Siviero, S., Marrese, P.M., Munari, U.: 2003, *IAU Circ.* , No. 8199

Stringfellow, G.S., Walter, F.M.: 2004, *Bull. Am. Astron. Soc.* **36**, 776

Škoda, P.: 1996, in *Astronomical Data Analysis Software and Systems V.*, eds.: G.H. Jacoby and J. Barnet, ASP Conf. Ser. **101**, San Franciso, 187

van den Bergh, S., Younger, P.F.: 1987, *Astron. Astrophys.* **70**, 125

Williams, R.E.: 1992, *Astron. J.* **104**, 725

Yamaoka, H.: 2003, *IAU Circ.* , No. 8199