

Early post-maximum spectral evolution of the fast novae V4742 Sagittarii and V4743 Sagittarii

G. E. Morgan,¹ F. A. Ringwald^{1,2*} and J. W. Prigge²

¹Central Valley Astronomers, PO Box 3063, Pinedale, CA 93650, USA

²California State University Fresno, Department of Physics, 2345 E. San Ramon Ave., M/S MH37, Fresno, CA 93740-8031, USA

Accepted 2003 May 22. Received 2003 May 19; in original form 2003 March 26

ABSTRACT

The novae V4742 and V4743 Sagittarii (Sgr) erupted less than a week apart in 2002 September. This paper collects together early IAU Circular observations, plots light curves, and presents our own spectra of these novae. The spectra were collected with equipment commercially available to amateur astronomers. We identify the major spectral emission lines, measuring full widths at half-maximum, velocity widths and equivalent widths. Both novae displayed fast Duerbeck type A light curves. The eruption of V4743 Sgr fits into the spectral classification scheme for novae proposed by Williams et al. with a principal Fe II spectrum giving way to an auroral spectrum. We observed only the principal Fe II phase in V4742 Sgr, during which its He I 706.5-nm emission line appeared early then faded along with the Fe II complex. This was unlike the spectral evolution of V4743 Sgr, in which the He I 706.5-nm line emerged after the Fe II complex diminished.

Key words: line: identification – instrumentation: miscellaneous – methods: observational – stars: fundamental parameters – novae, cataclysmic variables.

1 INTRODUCTION

The spectra of novae during their eruptions have been under study for over a century (Payne-Gaposchkin 1957). A nova eruption occurs when a white dwarf's gaseous envelope accretes enough mass from a binary companion to result in a thermonuclear runaway, with subsequent expansion and ejection of hot gas. The interaction of the inherent nuclear reactions, the physical attributes of the underlying star system, and the motion of the expanding gas all determine the nature and evolution of the nova spectra (Warner 1989; Hellier 2001).

V4742 Sagittarii (V4742 Sgr) was discovered on 2002 September 15.1 UT by William Liller, at approximately $V = 8.5$ (Liller et al. 2002). It was confirmed as a nova on September 16.8 by Christian Buil with a $0.038 \text{ nm pixel}^{-1}$ spectrum taken with a 20-cm telescope (Buil 2002). He reported the H α line to have a velocity width of 1100 km s^{-1} and a very deep P-Cygni profile, which are typical for a young nova. Precise astrometry by H. Yamaoka using an image taken by B. Monard on September 16.7 UT (Samus et al. 2002) yielded a position of $\alpha = 18^{\text{h}}02^{\text{m}}21^{\text{s}}.864$, $\delta = -25^{\circ}20'32''.22$ (J2000.0).

V4743 Sgr was discovered on 2002 September 20.4 by Katsumi Haseda, at approximately $V = 5.0$ (Kato et al. 2002b). It was confirmed as a nova on September 21.4 by Mitsugu Fujii (Kato, Fujii & Ayani 2002a). He reported the H α line to have a velocity width

of 2400 km s^{-1} and strong Balmer and Fe II emission lines. Precise astrometry using an image by D. West (Haseda et al. 2002) yielded a position of $\alpha = 19^{\text{h}}01^{\text{m}}09^{\text{s}}.38$, $\delta = -22^{\circ}00'05''.9$ (J2000.0).

2 OBSERVATIONS

We collected spectra of both novae with a 25.4-cm Meade LX200 telescope, a Santa Barbara Instruments Group (SBIG) ST-10XME charge-coupled device (CCD) camera, and an SBIG Self-Guiding Spectrograph. The spectrograph used a $100\text{-}\mu\text{m}$ slit and a grating of 150 line mm^{-1} . This optical combination yielded a dispersion of $0.325 \text{ nm pixel}^{-1}$. Five spectroscopic data sets were collected for each nova within a six-week period after maximum. Each of the five V4742 Sgr and V4743 Sgr images had integration times of 10 and 2.5 min, respectively. Following the target frames, dark frames were collected. Image reductions used dark-frame subtractions only; no flat fields were used. Night-sky emission lines were present in all images. Wavelength calibration was accomplished with contemporaneous images of target novae and a mercury lamp. Sky background subtractions were performed in a way that optimally minimized the ever-present night-sky mercury 546.1-nm line. In all the data runs, wavelength errors were $\pm 0.4 \text{ nm}$.

3 RESULTS

Figs 1 and 2 show the changing spectra for each nova. The spectra near the bottom of each plot were taken earlier than the ones above:

*E-mail: ringwald@csufresno.edu

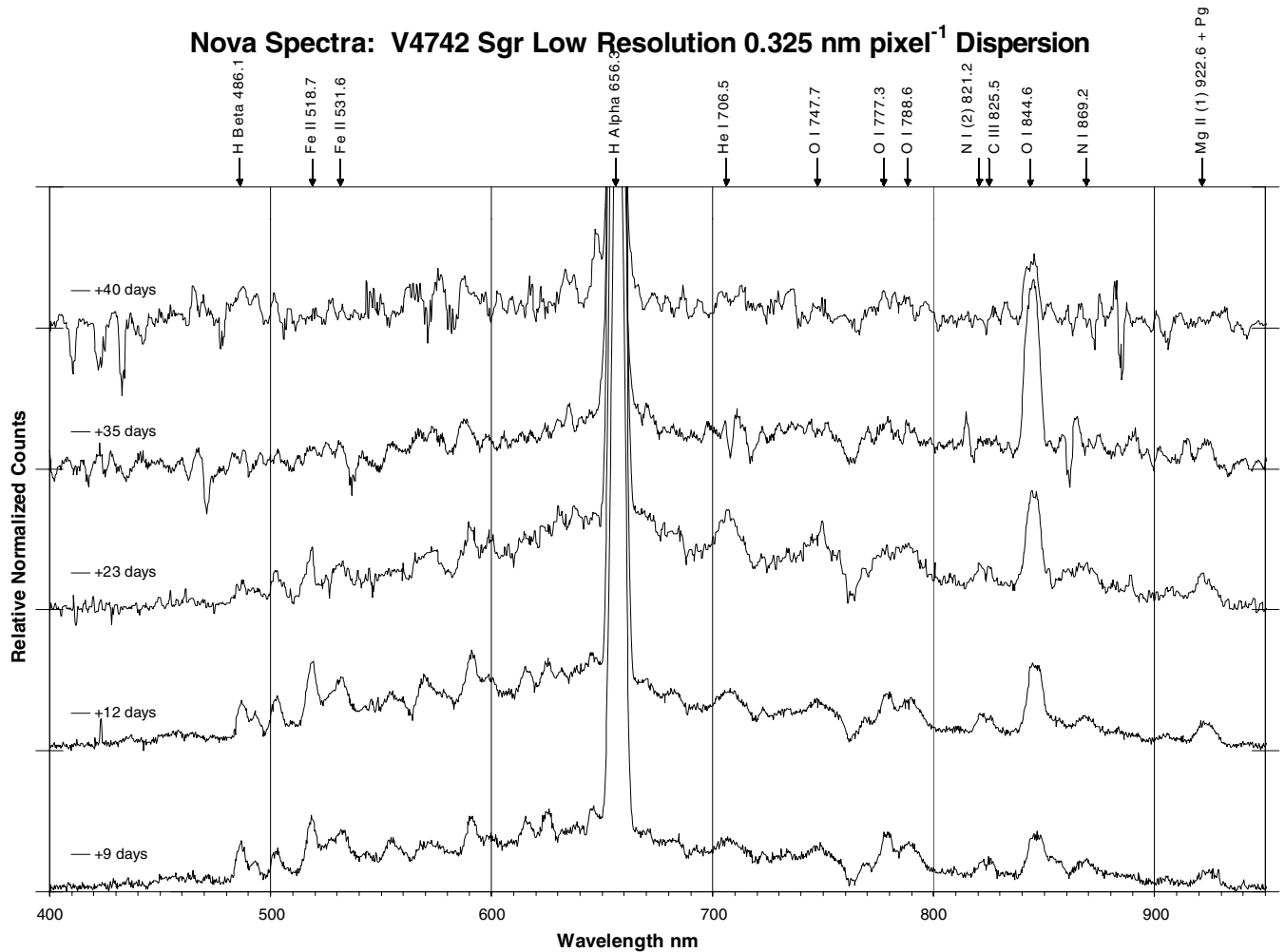


Figure 1. Time-staggered spectra, $T_{\max} = 2002$ September 15.5. The zero flux levels are marked with tick marks on each vertical axis. Instrumental spectral resolution ~ 3 nm.

a constant was added to the relative normalized count values to stagger the spectra vertically and show their changes better. As the novae evolve, different emission lines disappear and others emerge. As the brightness of each nova diminishes with time, the signal-to-noise ratio decreases proportionately and the noise level in each vertical plot is seen to increase.

The nova thermonuclear runaway ejects hot nuclear processed material out into the interstellar medium. The time required for a decline of two magnitudes (t_2) or three magnitudes (t_3) from maximum brightness provides a clue to the nature of the expanding shell. Fast novae have t_2 values of the order of tens of days. Slow novae have t_2 values of the order of over 80 d (Warner 1989). We have measured $t_2 = 12$ d and $t_3 = 23$ d for V4742 Sgr, and $t_2 = 9$ d and $t_3 = 16$ d for V4743 Sgr (see Fig. 3). V4742 Sgr was therefore a fast nova, and V4743 Sgr was a very fast nova, using the classification of Warner (1989).

The light curves of both novae shown in Fig. 3 were compiled from IAU Circulars and from VSNET observations (Nogami et al. 2002). V4742 Sgr reached a maximum of $V = 7.9$ on 2002 September 15.5. It began as a smooth exponential decline with a type A light curve in the classification scheme of Duerbeck (1981)

with a smooth and fast decline without major disturbances, like those of CP Pup and V1500 Cyg. V4743 Sgr reached a maximum of $V = 5.0$ on 2002 September 18.3. It also displayed a smooth type A light curve.

The velocity of the expansion was measured spectroscopically. Table 1 includes the major emission lines for both novae as well as values for full widths at half-maximum (FWHM) and equivalent widths (EW) in nanometres. The velocity widths (VW) measured for V4742 Sgr range between 2700 and 3000 km s⁻¹. Velocity widths for V4743 Sgr range between 2200 and 2700 km s⁻¹. Both the photometric and the spectroscopic data show that the nova ejections are taking place at high velocities.

Williams et al. (1991, 1994) found that the optical spectra of novae fall into two basic classifications. Identification of the strongest non-Balmer emission lines in the visible region determine the initial classification of the principal spectrum. Novae with strong Fe II lines comprise one group, and novae with strong He and N lines make up the other group. The dominant non-Balmer emission lines present early after maximum, in both novae, are those of Fe II. The following two sections describe the spectroscopic changes of each nova.

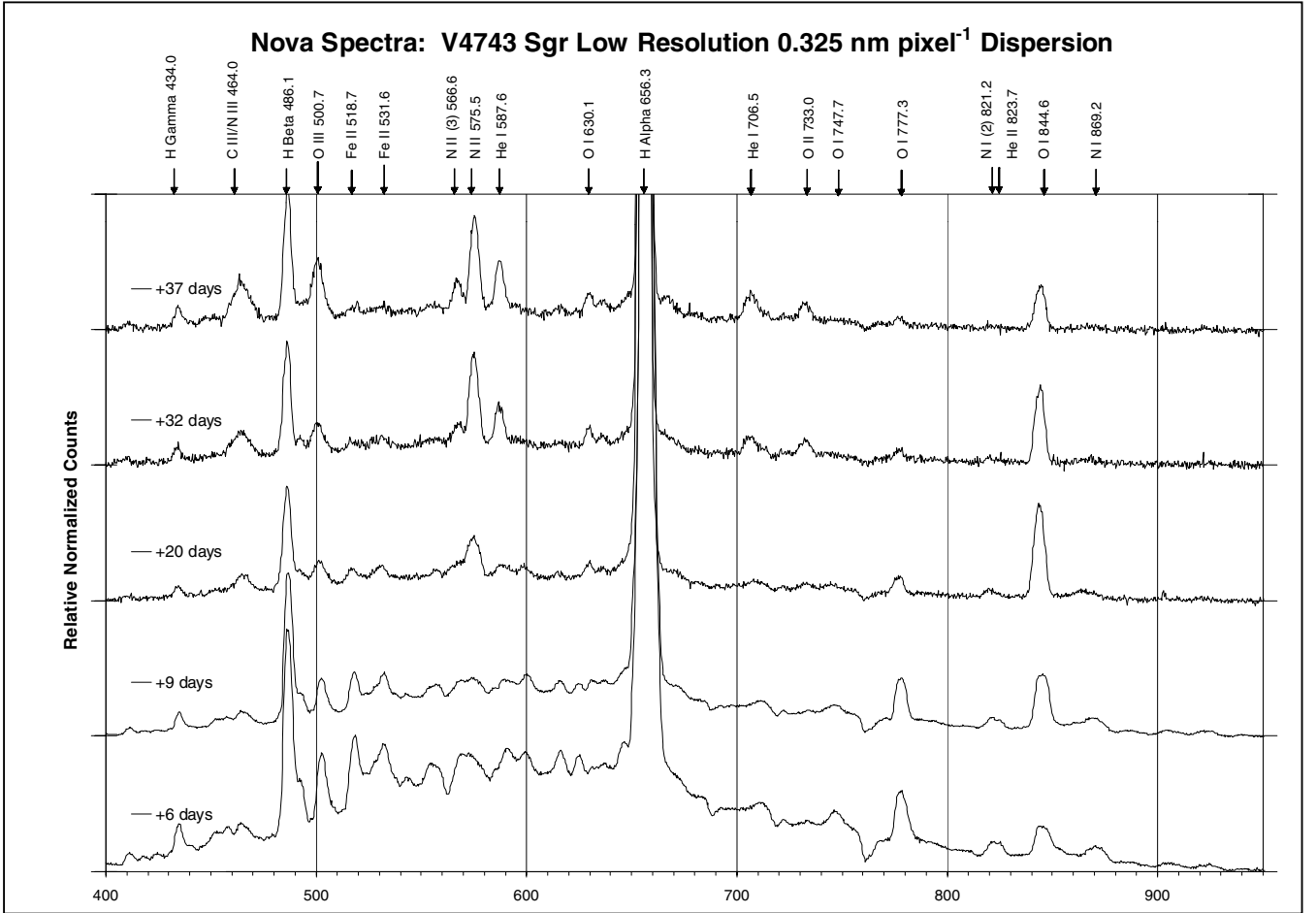


Figure 2. Time-staggered spectra, $T_{\max} = 2002$ September 18.3. The zero flux levels are marked with tick marks on each vertical axis. Instrumental spectral resolution ~ 3 nm.

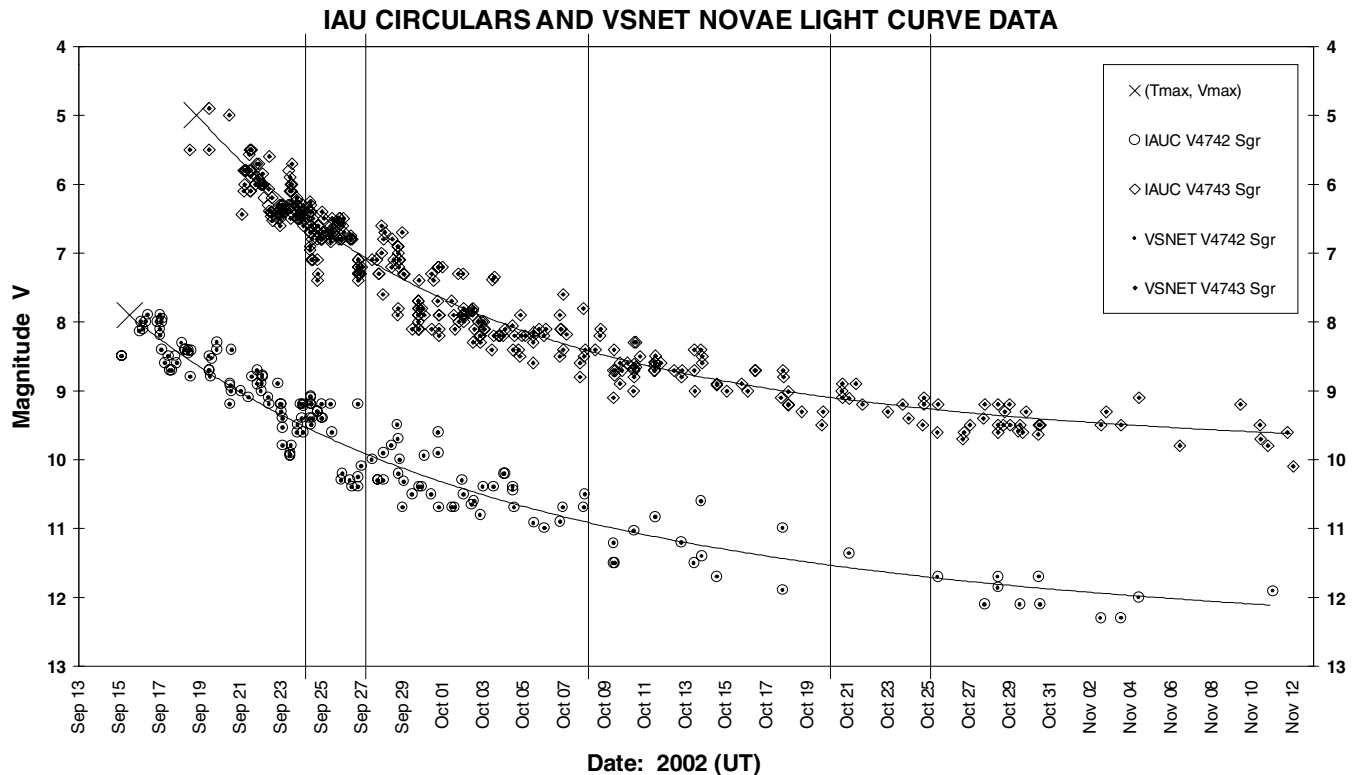
3.1 V4742 Sgr spectral evolution

Fig. 1 shows that Fe II multiplets dominate the early post-outburst spectrum. Balmer-series emission lines are present, but are not dominant, other than $H\alpha$, during the first 23 d after outburst. As spectral evolution takes place, many prominent Fe II multiplets, 42, 48, 49 and 74, between 492 and 647 nm decline towards zero by day 35. $H\gamma$ is missing, to 40 d. $H\beta$ is present early and is only <50 per cent that of the Fe II peaks, then fades by day 35. $H\alpha$ is the dominant feature of the spectrum. He I 706.5 nm is present early and diminishes by 35 d. It does not fade as fast as the Fe II complex. O I 747.7 nm is present early and diminishes by day 35. It also does not fade as fast as the Fe II complex. O I 777.3 nm is present early and fades by day 35. O I 788.6 nm is present early and fades after 35 d. N I (2) 821.2 nm is present early, then diminishes by day 35. C III 825.5 nm is present early, declining towards zero after 35 d. The O I 844.6-nm line remains relatively constant throughout the study, with one notable exception. It appears that, around 35 d after maximum, there was a temporary increase in the intensity of the O I 844.6-nm line. N I 869.2 nm is present early, declining towards zero by 35 d. A blend of Mg II (1) 922.6 nm and Paschen γ is present early, declining towards zero by 40 d. It appears that, around 40 d after outburst, all of the initial lines to the short-wavelength side of the dominant $H\alpha$ peak have faded significantly. Only one other

line, O I 844.6 nm, is still detectable with this particular instrument setup.

3.2 V4743 Sgr spectral evolution

Fig. 2 shows that Fe II multiplets dominate the early post-outburst spectrum. Balmer emission lines are prominent, and remain through 37 d. As spectral evolution takes place, the Fe II emission lines begin to disappear, while He I, He II, N II, [O II] and [O III] lines emerge. $H\gamma$ remains at ≤ 20 per cent of the $H\beta$ intensity through 37 d. C III/N III 464.0 nm is present early, and continues to increase in intensity through day 37. $H\beta$ at 486.1 nm remains the second most dominant peak after 37 d. [O III] 500.7 nm begins to emerge at about 20 d, continues to increase in intensity and becomes the fourth largest peak by 37 d. Many prominent Fe II multiplets, 42, 48, 49 and 74, between 492 and 647 nm decline towards zero by 32 d. N II (3) 566.6 nm begins to emerge at about 20 d and continues to increase. [N II] 575.5 nm emerges prior to 20 d, and is the third most dominant peak after 37 d. He I 587.6 nm begins to emerge at about 20 d and continues to increase. [O I] 630.1 nm begins to emerge prior to 20 d and continues to increase. $H\alpha$ is the dominating feature of the spectrum. He I 706.5 nm is not present early. It begins to emerge at about 20 d and continues to increase. C II 711.7 nm is present early and diminishes by 20 d. [O II] 733.0 nm begins to emerge at about



V4742 Data $t_2 = 12$ days $t_3 = 23$ days					
Run #	Spectral Data Date (UT)	V	Days since Tmax	Delta mag since Vmax	Airmass
Tmax	2002 Sep 15.5	Vmax 7.9	-	-	-
1	2002 Sep 24.181	9.6	9	1.7	3.08
2	2002 Sep 27.153	9.9	12	2.0	2.68
3	2002 Oct 08.174	10.9	23	3.0	2.55
4	2002 Oct 20.119	11.5	35	3.6	2.25
5	2002 Oct 25.111	11.7	40	3.8	2.31

V474 Data $t_2 = 9$ days $t_3 = 16$ days					
Run #	Spectral Data Date (UT)	V	Days since Tmax	Delta mag since Vmax	Airmass
Tmax	2002 Sep 18.3	Vmax 5.0	-	-	-
1	2002 Sep 24.186	6.5	6	1.5	2.21
2	2002 Sep 27.167	7.1	9	2.1	2.12
3	2002 Oct 08.197	8.4	20	3.4	3.07
4	2002 Oct 20.126	9.1	32	4.1	2.33
5	2002 Oct 25.087	9.2	37	4.2	2.09

Figure 3. Each nova has a smooth type A light curve (Duerbeck 1981) that has a fast decline without major disturbances. The vertical lines indicate the dates spectra were collected for each nova (Brown & Pearce 2002; Duerbeck, Sterken & Fu 2002; Garcia, Shida & Pearce 2002; Ivison 2002; Ivison & Lowe 2002; Kato et al. 2002; Samus 2002; Tanaka et al. 2002; West 2002; Yamaoka et al. 2002).

20 d and continues to increase. O I 747.7 nm is present early and diminishes by 20 d. O I 777.3 nm is present at 6 d through 37 d, and has a very slow rate of decline, slower than any other observed peak. N I (2) 821.2 nm is present early, declining towards zero by 32 d. He II 823.7 nm is present early and declines towards zero after 20 d. O I 844.6 nm remains relatively constant throughout the study, with one notable exception. It appears that, around 20 d after maximum, there was a temporary increase in the intensity of the O I 844.6-nm line. N I 869.2 nm is present early, declining towards zero by 20 d.

4 SUMMARY

In the classification scheme of nova spectral evolution proposed by Williams et al. (1991, 1994), the Fe II nova will most likely make a transition from principal phase to auroral phase. The auroral transition shows forbidden lines along with low-ionization lines such as [N II] 575.5 nm and [O I] 630.1 nm. As the nova shell expands, the ejected material density decreases. The lower-density gas allows for these forbidden lines with their higher transition probabilities.

Higher-density gases are, of course, still present, but in localized regions within the shell. Our spectroscopic observations are consistent with each nova eruption showing features of a fireball expanding into a thin shell of gas, containing hot, dense knots, as in fireworks.

With equipment available to amateur astronomers, we have observed two novae in the early stages of their eruptions. The two novae were similar in that both (1) were fast novae (V4743 was very fast), (2) had high ejection velocities, (3) had principal spectra of the more common Fe II type, (4) had type A light curves, and (5) had atomic line patterns with only slight differences. They differed in that (1) V4743 Sgr was much brighter than V4742 Sgr, (2) V4742 Sgr had its He I 706.5-nm line present early, in contrast to V4743 Sgr, and (3) V4742 Sgr showed mostly a decline of existing lines, with the exception of H α and O I 844.6 nm, without the emergence of additional peaks at our last observation. This was due either to the lack of an observable spectral transition within this time-frame or to our inability to resolve peaks as the nova brightness diminished. By contrast, V4743 Sgr clearly developed into a common strong auroral spectral phase, consistent

Table 1. The major peaks of each nova have been identified. An atomic identification has been assigned to each of the major peaks. The full widths at half-maximum (here just FW) values are in nm with errors of ± 0.4 nm. The velocity widths (VW) are $\times 10^3$ km s $^{-1}$ with errors of $\pm 0.2 \times 10^3$ km s $^{-1}$. The equivalent widths (EW) are in nm and do not have instrument resolution corrections. Finally, d are days after maximum.

(a) Spectroscopic data set for V4742 Sagittarii

λ (nm)	Atomic ID	+6 d			+9 d			+20 d			+32 d			+37 d		
		FW	VW	EW	FW	VW	EW	FW	VW	EW	FW	VW	EW	FW	VW	EW
486.1	H β	4.9	3.0	101	5.2	3.2	66									
518.7	Fe II	5.5	3.2	44	5.9	3.4	28	2.3	1.3	369						
531.7	Fe II	5.5	3.1	12	7.5	4.2	9									
656.3	H α	6.2	2.8	102	6.5	3.0	134	6.5	3.0	147	5.9	2.7	117	5.9	2.7	170
706.5	He I	4.8	2.0	4	7.1	3.0	2	4.6	1.9	8						
747.7	O I	4.9	2.0	8	4.6	1.8	6	3.3	1.3	11						
777.3	O I	5.2	2.0	26	5.9	2.3	14									
788.6	O I	8.1	3.1	21	7.8	3.0	8									
821.2	N I (2)															
825.5	C III															
844.6	O I	7.2	2.5	43	7.8	2.8	50	6.8	2.4	142	7.5	2.7	391	7.5	2.7	732
869.2	N I	7.5	2.6	21	7.8	2.7	11									
922.6	Mg II (1) +Pg	7.1	2.3	24	8.2	2.7	91									

(b) Spectroscopic data set for V4743 Sagittarii

λ (nm)	Atomic ID	+9 d			+12 d			+23 d			+35 d			+40 d		
		FW	VW	EW	FW	VW	EW	FW	VW	EW	FW	VW	EW	FW	VW	EW
434.0	H γ	4.5	3.1	19	4.2	2.9	23	5.8	4.0	173	3.3	2.2	172	3.2	2.7	131
464.0	C III/N III	6.2	4.0	5	5.8	3.8	7	6.8	4.4	18	6.8	4.4	28	6.8	4.4	160
486.1	H β	4.9	3.0	40	4.5	2.8	59	4.5	2.8	75	4.2	2.6	63	3.9	2.4	74
500.7	[O III]							5.5	3.3	13	7.1	4.3	20	5.5	3.3	44
518.7	Fe II	5.8	3.4	12	5.5	3.2	12	6.8	3.9	9						
531.7	Fe II	6.5	3.7	4	4.9	2.7	5	5.8	3.3	4						
566.6	N III (3)													4.9	2.6	13
575.5	[N II]							7.1	3.7	13	5.2	2.7	26	5.2	2.7	31
587.6	He I										4.6	2.3	11	5.2	2.7	17
630.1	[O I]							3.6	1.7	6	3.6	1.7	11	4.0	1.9	3
656.3	H α	5.8	2.7	66	6.2	2.8	122	5.2	2.4	223	4.9	2.2	215	4.9	2.2	264
706.5	He I										8.1	3.4	19	5.8	2.5	41
733.0	[O II]										7.1	2.9	17	6.2	2.5	28
777.3	O I	6.5	2.5	14	5.8	2.3	17	6.2	2.4	33	3.9	1.5	70	5.6	2.1	179
821.2	N I (2)															
823.7	He II															
844.6	O I	7.8	2.8	16	7.8	2.8	47	6.2	2.2	385	5.5	2.0	807	6.2	2.2	480
869.2	N I	9.1	3.1	18	10.1	3.5	8									

with the spectral evolutionary classification of Williams et al. (1991, 1994).

ACKNOWLEDGMENTS

We wish to thank Dr Harold Downing, and Dr Tom and Cynthia Downing, for donating the Downing Planetarium, on the grounds of which our new Campus Observatory stands, as well as the College of Science and Mathematics, for the spectrograph.

REFERENCES

Brown N., Pearce A., 2002, IAUC 7982
 Buil C., 2002, <http://www.astrosurf.com/buil/us/nsgr2/nsgr2.htm>
 Duerbeck H. W., 1981, PASP, 93, 165
 Duerbeck H. W., Sterken C., Fu J. N., 2002, IAUC 7974

Garcia J., Shida R. Y., Pearce A., 2002, IAUC 8000
 Haseda K., West D., Yamaoka H., Masi G., 2002, IAUC 7975
 Hellier C., 2001, Cataclysmic Variable Stars: How and Why They Vary. Springer-Praxis, Chichester, chapter 11
 Ivison R. J., 2002, IAUC 7988
 Ivison R. J., Lowe T. B., 2002, IAUC 8035
 Kato T., Fujii M., Ayani K., 2002a, IAUC 7975
 Kato T., Haseda K., West J. D., Kammerer A., Bedient J., Pearce A., 2002b, IAUC 7973
 Kato T. et al., 2002, IAUC 7976
 Liller W., Kato T., Waagen E., King B., Puig C., Bedient J., Linnolt M., 2002, IAUC 7971
 Nogami D. et al., 2002, VSNET online database, at <http://vsnet.kusastro.kyoto-u.ac.jp/vsnet/index.html>
 Payne-Gaposchkin C., 1957, The Galactic Novae. North-Holland, Amsterdam
 Samus N. N., 2002, IAUC 7976

Samus N. N., Buil C., Yamaoka H., Monard B., 2002, IAUC 7972
Tanaka T., Nishimura H., Garcia J., Linnolt M., Bedient J., O'Meara S. J.,
West D., Kato T., 2002, IAUC 7975
Warner B., 1989, in Bode M. F., Evans A., eds, *Classical Novae*. Wiley,
Chichester, p. 1
West J. D., 2002, IAUC 7978
Williams R. E., Hamuy M., Phillips M. M., Heathcote S. R., Wells L.,
Navarrete M., 1991, *ApJ*, 376, 721 (Paper 1)

Williams R. E., Phillips M. M., Hamuy M., 1994, *ApJS*, 90, 297
Yamaoka H., Monard B., Buil C., Kato T., Schmeer P., Shida R. Y., Pearce
A., 2002, IAUC 7972

This paper has been typeset from a $\text{\TeX}/\text{\LaTeX}$ file prepared by the author.