THE SPECTRUM OF NOVA VULPECULAE 1984 N°2 AT NEBULAR PHASE

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ABSTRACT. Nova Vul 1984 n°2 has been again observed at Observatoire de Haute-Provence in the autumn of 1985, i.e. 270-295 days after maximum. It was then in the nebular phase. The spectra cover the blue-violet and the near infrared regions. Over 50 lines and blends have been identified and are given in Table 2. No clear pattern is observed in the emission bands of a width of about 1450 km/sec. The most conspicuous features observed are the forbidden NeIII and NeV lines. The infrared region is dominated by a very strong He I 1083nm emission.

1. We have already reported on the main spectral features observable in the spectrum of Nova Vulpeculae 1984 n°2 near maximum of light (Andrillat and Houziaux, 1985). At that time, its spectrum exhibited abnormally strong MgII and Mg I lines. New observations have been carried out at the Observatoire de Haute-Provence in September and October 1985, with the help of the 120-cm, 152-cm and 193-cm telescopes. The instruments were equipped with various spectrographs, as stated in Table 1, describing the observations. The visual magnitude of the Nova was about 10.4 (Schweitzer, 1986).

Table 1. Journal of Observations

Date 1985	Day After Max	Serial N°	Telescope + Receiver	Spectral Range (nm)	Dispersion nm/mm
Sept. 24	273	-	193-cm+CCD	785-1130	23
Oct. 10+13	289	QA 1296	120-cm+IIa-0Baked	329-506	8
Oct. 14	293	QA 1297	120-cm+IIa-0Baked	329-506	8
Oct. 16	295	GE 3053	152-cm+Lallemand	436-543	6,2
		GE 3054	Camera	"	"
Oct. 17	296	GE 3055,56	"	377-487	"

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The wavelength coverage, in the 330 to 1130 nm range, was only partial, and the region 540 to 790 nm could not be observed. Furthermore, the weather was in general very poor and several exposures had to be carried out through heavy atmospheric absorption, so that quantitative measurements on the line intensities and profiles would have been somewhat hazardous.

2. This nova is especially remarkable by its high luminosity in the 12.8 micron [NeII] line discovered at about 140 days after maximum by Gehrz, Grasdalen and Hackwell (1985), which represents by itself around 80 solar luminosities. Located at a distance of 3 kpc, its bolometric magnitude at maximum is estimated to be -7.6 by the same authors. Starrfield et al. (1986) obtained IUE spectra showing strong forbidden emissions from NeIII and NeIV ions, indicating a strong overabundance of this element. Starrfield et al. conclude that the outburst of Nova Vul 1984 n°2 occurred on a O-Ne-Mg white dwarf. This type of objects arise from single stars with an original mass in the 8 to 12 solar masses range. Three other recent novae showed up similar Neon overabundance : Nova V1500 Cygni 1975, Nova Cor. Austr. 1981 and Nova Aql 1982 (Gehrz, Grasdalen and Hackwell, 1985).

3. The spectrum is typically that of a nova at nebular phase, with a very weak continuum. Many strong lines cover the whole observed spectral range. In Table 2, we report the lines measured on day n° 293 on the spectra QA 1296 and 1297. The four spectra obtained a few days later with the Lallemand Camera, although at a slightly better resolution only show the stronger lines; they confirm however the absence of structure in the emission bands, which present a smooth gaussian-like profile with a width of 1450 km/sec. The near-infrared spectrum has been obtained twenty days earlier.
The main features appearing on the spectra are the following :
Hydrogen : strong Balmer lines are observed from Hβ to H10. The decrement is fairly steep, so that higher lines, if at all present, are weak contributors to blends with a line at 376 nm ([FeVII]?) and [OII] (372.7 nm). Paschen lines are recorded from P6 to P15 and are also quite strong.
Helium : the strongest line in the near-infrared is by far He I 1083 nm, which is fully saturated despite the low response of the CCD receiver at this wavelength. The other observable line in the series $n^3P°-2s^3S$ is 388.8 nm; it blends width H8 and [NeIII] 386.9 nm. Comparing the intensities of 447.1 nm and 402.6 nm, it appears that the $n^3D-2^3P°$ series has also a steep decrement, since none of the higher lines is observed. We also observe transitions of the $n^1D-2^1P°$ multiplet (492.1, 438.7 (blend with Hγ and [OIII]), and 414.3 nm). In the singlet series $n^1S-2p^1P°$, 504.8 and 443.7 nm are seen. Let us remark that for all the lines except 414.3 nm the principal quantum number n of the upper level is always smaller than 6.

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Table 2 (s=strong line, b= blend)

(nm)	Identification	(nm)	Identification
334.6bs	NeV 1F	438.7	He I 4
	O III 3	441.3	Fe II 7F?
338.5	O III 27	443.7b	He I 50
342.6s	Ne V 1F	447.1bs	He I 14
344	O III 13	451	N III 3
356.8	Ne II 9?	457.3s	Si III 2
363	Fe VI 5F?	460.7	N II 5
366.4	Fe VI 4F?	464s	N III 2
372.8	O II 1F	468.6s	He II 1
376	O III 2	471.3bs	He I 12
	Fe VII 3F?		Ne IV 1F
379.1	H 10	486.1s	Hβ
383.9	H 9	492.2	He I 48
386.9bs	Ne III 1F	495.9s	O III 1F
388.9bs	He I 2	500.7ss	O III 1F
	H 8	504.8	He I 47
396.7bs	Ne III 1F		
397 s	Hε	822.1	O I 34
402.6	He II 3	823.6	He II 6
	He I 18	844.6s	O I 3
406.8b	S II 1F	846.7	P 15
407.6	S II 1F	859.8	P 14
409.7s	N III 1	866.5	P 13
410.1s	H δ	875	P 12
414.4	He I 53	886.3	P 11
419.5	N III 6	906.9	S III 1F
420	N III 6	901.5	P 10
424.1	Fe II 21F?	922.9s	P 9
428.2	Fe II 7F?	953.2s	S III 1F
429.4	?	945.5s	P 8
431.2	Fe II 7F?	1004.9s	P 7
434bs	Hγ	1012.3s	He II 2
436.3bs	O III 2F	1083s	He I 1
		1093.8	P 6

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The 468.6 nm HeII line has about the same strength as 447.1 nm HeI but is notably weaker than the HeI 471.3 nm line. However, the 1012.3 nm line peaks at about 7 tenths of the strength of P7 (1005 nm). At 823.6 nm, there may be a contribution of the HeII 9-5 transition. The 8-5 transition, although in the observed range, would be difficult to see owing to the atmospheric bands.
Nitrogen is seen as NIII. The 409.7 nm line blends with Hδ, while 419.5-420nm are weak. 464 nm is quite a strong emission. A line at 406.7 nm may be identified as NII ($3p^3P-3s^3P°$).
Oxygen : neutral oxygen is represented by a very strong emission at 844.6 nm and also possibly contribute to a blend around 823 nm. A line at 372.7 nm is attributed to [OII]. The O++ nebular lines at 500.7 and 495.9 nm are very strong, and 436.3 overtops Hγ. We also notice a few moderately bright lines due to OIII, namely the lines at 376 nm ($2p3p^3D-2p3s^3P°$),at 334nm ($2p3p^3S-2p3s^3P°$) and a 344.4 nm ($2p3d^3P°-2p3p^3P$) indicating the presence of strong HeII radiation at 30.38 nm exciting the $2p3d^3P°$ level.
Neon : among the strongest lines seen in the violet, we note [NeIII] at 396.7 nm (blend with H7), and at 386.9 nm (blend with H8). Also, despite a poor efficiency of the spectrograph in the ultraviolet the lines of [NeV] at 334.6 and 342.6 nm are quite conspicuous. The [NeIV] $2p^3\ ^2D°-^2P°$ multiplet is the main contributer to the blend at 471.3nm. This confirms the overabundance of Neon in the nova ejecta. A weak emission at 356.8 nm is tentatively attributed to NeII.
Sulfur is represented by [SII] lines (406.8 and 407.6 nm) and [SIII] lines at 953.2 and 906.9 nm which blend with P8 and P10 respectively.
Iron : there is no clear evidence for the presence of iron lines. The best candidates are lines at 424.1, 441.3, 428.2, and 431.2 which might be due to [FeII]; there is also possible [FeVI] lines at 363 and 366.4 nm, while [FeVII] 375.99 nm may contribute to the blend seen at 376 nm. A weak feature at 429.4 remains unidentified.

In conclusion, our observations confirm a high abundance of oxygen (present at least in the form of O°,O+, and O++), and of Neon (Ne++,Ne+++, Ne++++). Hydrogen and Helium are also abundant in the ejecta, as well as Nitrogen and Sulphur. Because many sensitive lines are outside our observed spectral range, and since quantitative information is lacking on the observed lines, no conclusion can be drawn on the physical conditions in the nova shell. However, both the low value of the ratio I(500.7+495.9)/I(436.3) (less then 10), and the steep Balmer and Helium decrements indicate a fairly high temperature.

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