SPECTROSCOPIC EVOLUTION OF NOVA VUL 1984 No. 1 (PW Vul) AND No. 2

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ABSTRACT. Spectroscopic observations of two novae (Nova Vul 1984 No. 1 and No. 2) have been carried out at the Asiago Observatory from the moment of their discovery up to now. A short preliminary description of the spectral characteristics and evolution of these two novae is reported together with a brief comparison of their properties.

1. Introduction

Nova Vul 1984 No. 1 (PW Vul) and Nova Vul 1984 No. 2 were included in the programme of spectroscopic observations of novae carried out at the Asiago Observatory since the moment of their discovery. Their spectra were mostly obtained with the following instruments : a) 122 cm telescope equipped with prismatic spectrograph and Carnegie-RCA image-tube. Spectral range λλ3850 - 7700 A; dispersion 60 A/mm at Hγ. b) 182 cm telescope with Boller & Chivens grating spectrograph and Varo image-tube. Two gratings are available giving dispersions of 60 and 120 A/mm, within the region λλ3800 - 9300 A. Some spectrophotometric observations were made by one of the Authors (T.I.) and Dr. R. Falomo with the Reticon system mounted on the Boller & Chivens spectrograph.

The purpose of this paper is that of giving a preliminary description of the characteristics and spectral evolution of the two novae. Detailed data on the available material and final results will be presented in successive papers.

2. Nova Vul 1984 No. 1 (PW Vul)

2.1. Light curve

This nova was discovered by Wakuda (1984) on July 28, 1984 of visual magnitude 9.2, still rising. The maximum ($m_V = 6.3$) was attained on August 4, 1984 (JD 2445917). The decline from the maximum, at first very steep (rate of decline over the first two magnitudes drop: d = 0.5 mag/day), was followed by semiperiodic brightness oscillations (P ≅ 15 days) of

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relatively high amplitude ($1\sim2$ magns.) which persisted for more than 100 days after the maximum. The visual light curve based on the AAVSO observations hitherto published in the IAU Circulars is represented in Fig. 1.

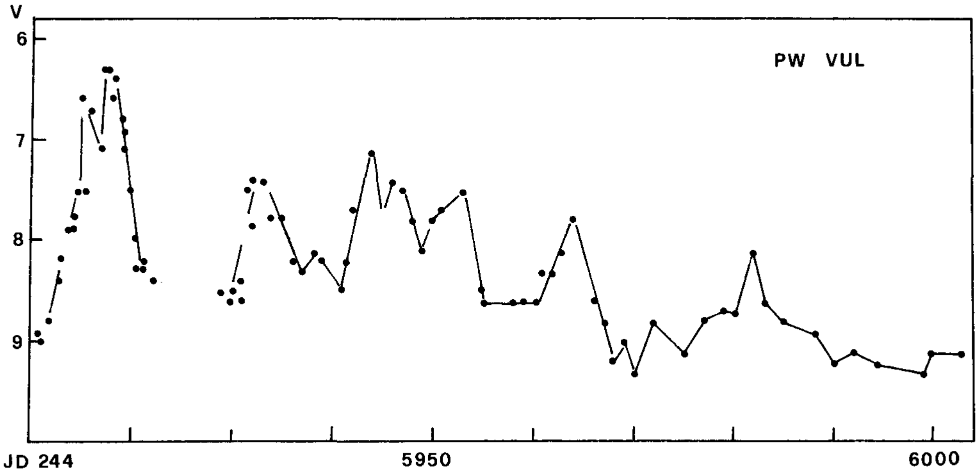

Fig. 1. Visual light curve of N Vul-1 (PW Vul)

2.2. Spectral evolution from July to December 1984

The spectra obtained at the end of July when the nova was still brightening were characterized by wide emission lines, mostly of hydrogen (from Hα to H16), Fe II (mult. 27, 28, 37, 38, 42, 48, 49, 73), O I, N I, N II, Mg II, Ca II, Ti II and Na I 5890-96. These lines were flanked by broad P Cygni absorptions (system I) with central radial velocity of about -530 km/sec which steadily increased to -610 km/sec in the following days. On August 4 - 5, with the nova near maximum, was observed the weakening of the emission lines, many of which faded to invisibility; at the same time all absorption features enhanced. The absorption spectrum was somewhat alike to an F 2 I type. In the course of the oscillations an inverse correlation was noticed between the intensities of the emission lines and the brightness.

Since August 11 most of the emission lines showed a saddle-shaped profile, more or less pronounced, with intensity peaks separated by about 580 km/sec. The red component was slightly stronger than the blue one. In this period emerged a second absorption system (system II: diffuse-enhanced) stronger than system I. The mean radial velocities of the two systems in August were -770 ± 25 km/sec (system I) and -1350 ± 40 km/sec (system II). By October the velocity of system I increased to -790 km/sec and that of system II to -1640 km/sec. Mean halfwidth of the emission lines : 760 km/sec.

From mid-August to November the degree of excitation slowly increased. Most of the low I.P. lines including the Fe II emissions (except those of mult. 42) weakened or disappeared, while were emerging and strengthening the He I lines, the blend of N III at λ4640, and the forbidden lines of O I 6300, 6364 and N II 5755. In the spectra taken in November, when the nova had already declined to $m_V \cong 9.4$, the prominent emission lines were Hα (100), Hβ (10), [N II] 5755 (6.7), Fe II 5018 (5.2: possibly blended with He I 5016), [O I] 6300 (4.8), N III 4640 (4.5), [O I] + N II 6365 (4.0), N II 5942 (3.9), He I 5876 (3.5) and Hγ (3.5). The numbers in the parentheses give the intensities of the emission lines relative to Hβ, derived from an IDS tracing obtained at La Silla by Dr. Falomo. All of the permitted lines were still flanked by the two systems of P Cygni absorption. The spectrum did somewhat change in December (Fig. 2): the lines of Fe II mult. 42 were fading, while appeared or strengthened those of N II, N III and He II 4686. The two absorption systems were blurred forming a unique system of diffuse absorption (central velicity ∿ − 1850 km/sec). At the end of December the nova ($m_V \cong 9.5$) had reached the transition phase to the nebular stage.

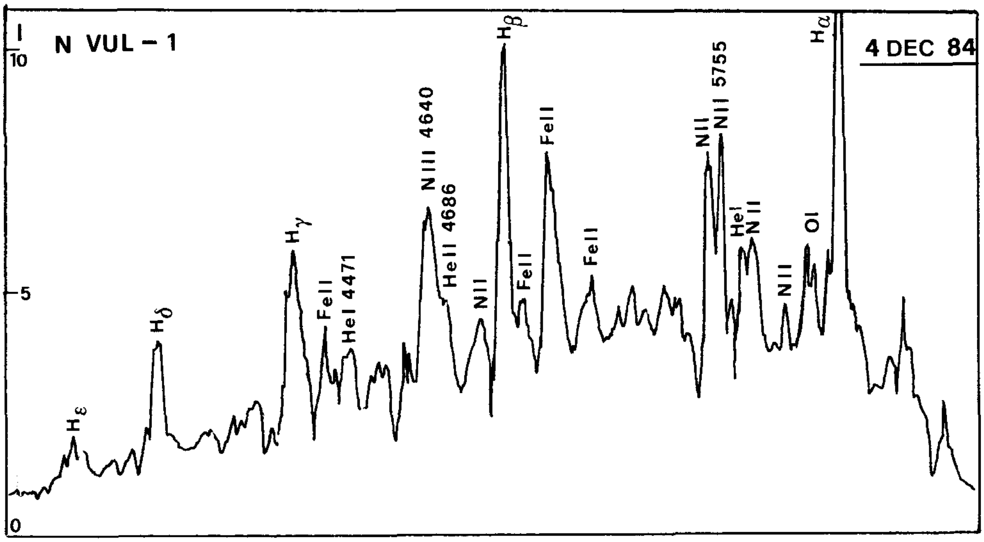

Fig. 2. Microphotometer tracing of the spectrum of N Vul-1 obtained on Dec. 4, 1984 with the 122 cm telescope. The ordinates give relative intensities.

2.3. The infrared spectrum

The spectral evolution of the nova in the photographic infrared region (λλ6600 − 9300 A) followed the same pattern as in the visual region. On August 17 the infrared spectrum was characterized by broad emission lines flanked by the double system of P Cygni absorptions. The prominent emissions were O I 8446 which was the strongest line in the infrared, O I 7773 and Ca II 8498, 8542, 8662. Several blends of N I, O I and weak lines of Fe II, C II and Mg II were also recorded. From August to November was observed the gradual fading to invisibility of the Ca II triplet. At the same time emerged and strengthened the Paschen lines from P 14 to P 9

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and that of C II 7233 which soon became the third strongest line after O I 8446 and O I 7773 (Fig. 3). The doublet of [O II] 7320, 7330 was emerging in Novemver. A remarkable change in the spectrum occurred in December: all of the low excitation lines disappeared except O I 8446 which was still strong. The forbidden lines of A III at λ7135 and λ7751 were recorded and [O II] 7320 + 7330 became nearly as strong as O I 8446. The following lines were also strengthening: C II 7117 (mult. 20), 7234 (mult. 3), He II 8237 and He I 6678, 7065.

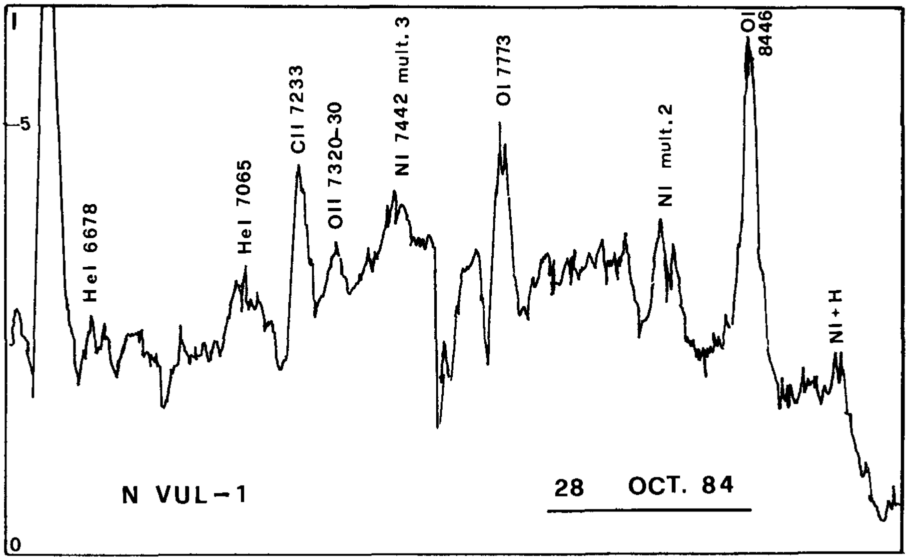

Fig. 3. Microphotometer tracing of the infrared spectrum of N Vul-1 obtained on Oct. 28, 1984 with the B & C spectrograph.

2.4. The nebular phase

Very likely the nova entered in the nebular phase at mid-January 1985, having faded to $m_V \cong 9.8$. On Jan. 7 the spectrum was still alike to that of Dec. 31, but at the end of the month were already visible [O III] at λ5007, λ4959 and λ4363 which are typical of the nebular stage. All absorption features had disappeared. On April 9, 1985 the prominent lines in the spectum were (Fig. 4) Hα + [N II] 6548, 6584; [O III] 5007, 4959; [N II] 5755; Hβ; [O III] 4363 + Hγ; N III 4640; He II 4686 and He I 5876. The degree of excitation was very high. The following forbidden lines were also recorded: [Fe VII] 6087, 5721, 5276, 5159; [Fe VI] 5678, 5176 and possibly rather weak [Fe X] 6374 and [A X] 5534. The presence of [Fe XIV] 5303 is suspected. In the infrared region the strongest lines were those of [O II], followed by He I 7065, O I 8446 (still visible but weakened), C II 7234, [A III] 7135, 7751 and the Paschen lines.

The further evolution of the spectrum was rather slow. No important changes were observed in the course of the following months except an increasing strength of the [O III] lines and of those of [Fe VI] and

[Fe VII] relative to Hβ. In July emerged the forbidden lines [Ne III] 3869 and 3968 which remained, however, always weak.

The spectrophotometric observation made on August 23, 1985 with the Reticon system gives the following intensities of the emission lines relative to Hβ : Hα (40), [N II] 6584 (12.8), [N II] 6548 (32), [O I] 6300 (2), [Fe VII] 6087 (2.7), He I 5876 (2), [N II] 5755 (16), [O III] 5007 (115), [O III] 4959 (40), Hβ (10), He II 4686 (3.5), N III 4640 (5), [O III] 4363 (16) and Hγ (5).

After Dec. 1985 began the fading of most of the lines. The last spectrum of the nova taken on May 12, 1986 shows only a few lines : [O III] 5007, 4959, Hα, Hβ and [N II] 5755, the latter two are just at the limit of visibility.

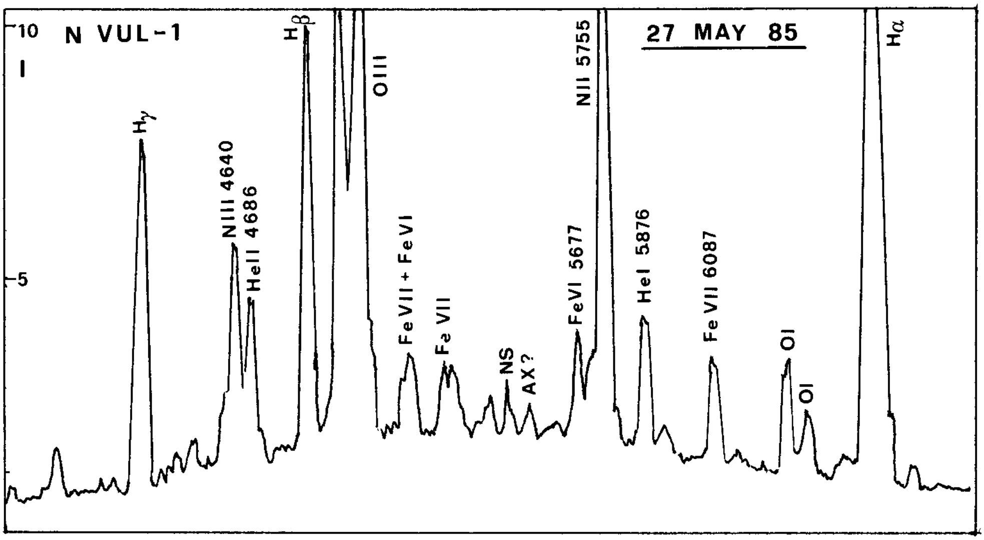

Fig. 4. Intensity tracing of the spectrum of N Vul-1 taken of May 27, 1985 with the B & C spectrograph at the 182 cm telescope.

3. Nova Vul 1984 No. 2

3.1. Light curve

This nova was discovered at visual magnitude 6.8 by Collins (1984) on Dec. 22, 1984. Its visual light curve (Fig. 5) is based on the AAVSO observations hitherto published (dots) and on the photoelectric V mag. (circles) kindly communicated in advance of publication to the Authors by D'Ambrosio and Di Paolantonio of the Teramo Observatory. The maximum was attained on Dec. 27, 1984 (JD 2446062) with $m_V \cong 5.5$. The decline was smooth. The nova lost 2 magns. in 20 days and 3 magns. in 31 days. The rate of decline over the first two magns. drop was therefore d = 0.1 mag/day.

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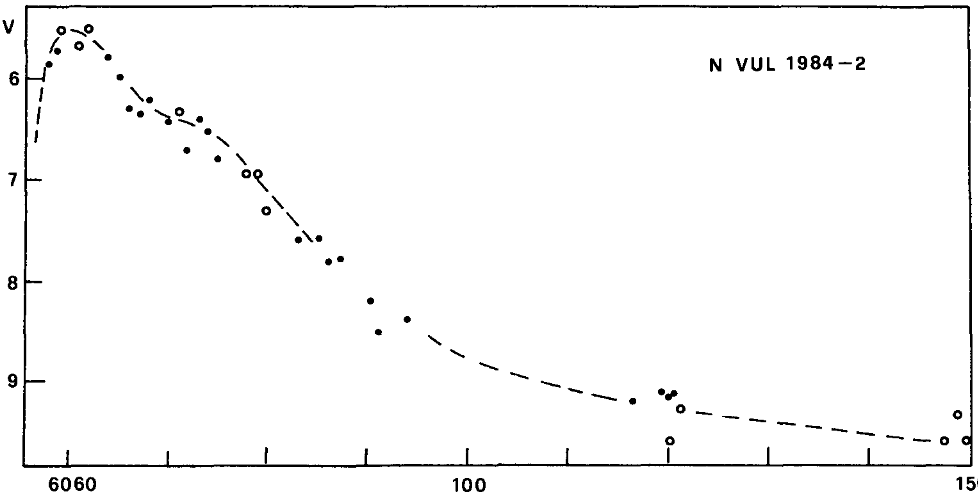

Fig. 5. Visual light curve of N Vul-2. Dots represent AAVSO observations; circles are photoelectric V mag. derived by D'Ambrosio and Di Paolantonio.

3.2. Spectral evolution from Dec. '84 to March '85

The spectra obtained at Asiago from Dec. 28 to Jan. 3, a few days after the maximum, were characterized by wide emission bands (halfwidth 585 ± 15 km/sec) of the Balmer lines from Hα to H8; Fe II (mult. 37, 38, 42, 46, 48, 49, 73, 74); He I 6678, 7065 (very weak); Na I 5890-96; Ca II 3968, 3934. Some weak lines of N II and Si II were also recorded. The strong emission lines were flanked by two systems of P Cygni absorption, having the mean central radial velocities: - 660 km/sec (system I) and -1390 km/sec (system II).

At the end of February, the nova having declined to $m_V \cong 9.4$, the system II disappeared. The Balmer lines were flanked by a unique system of P Cygni absorption with radial velocity of - 840 km/sec at its centre. Some N II and He I lines had strengthened and the forbidden lines of O I 6300, 6364; N II 5755 and O III 4363 had appeared and were growing. In March 29, the spectrum was nearly the same, but the Fe II were slowly fading.

3.3. The nebular phase

The nebular phase was reached in April 1985 ($m_V \cong 9.7$) when weak forbidden lines of O III and Ne III emerged gradually strengthening during the month. The excitation level was increasing. At the end of April He I 5876 was stronger than the blend of Na I 5890-96 which was still relatively intense. In the near infrared the outstanding line was that of O I 8446 which was somewhat weaker than Hα. Lines of [O II] 7320 - 30; O I 7773, 7254 and He I 7065, 6678 were also recorded with moderate intensities. The expansion velocity derived from the halfwidth of the emission features was 790 ± 40 km/sec.

At the end of June (Fig. 6) the prominent lines were (in order of decreasing strength): Hα, [O III] 5007, He I 5876, Hβ, [O III] 4959, [O I] 6300, [N II] 5755, Hγ, [O III] 4363, Mg I (?) 4571, [Ne III] 3869 and [Ne III] 3968. The N III blend at λ4640 was strengthening. All absorption features and most of the low I.P. emission lines had disappeared, including Na I doublet. The Fe II were fading.

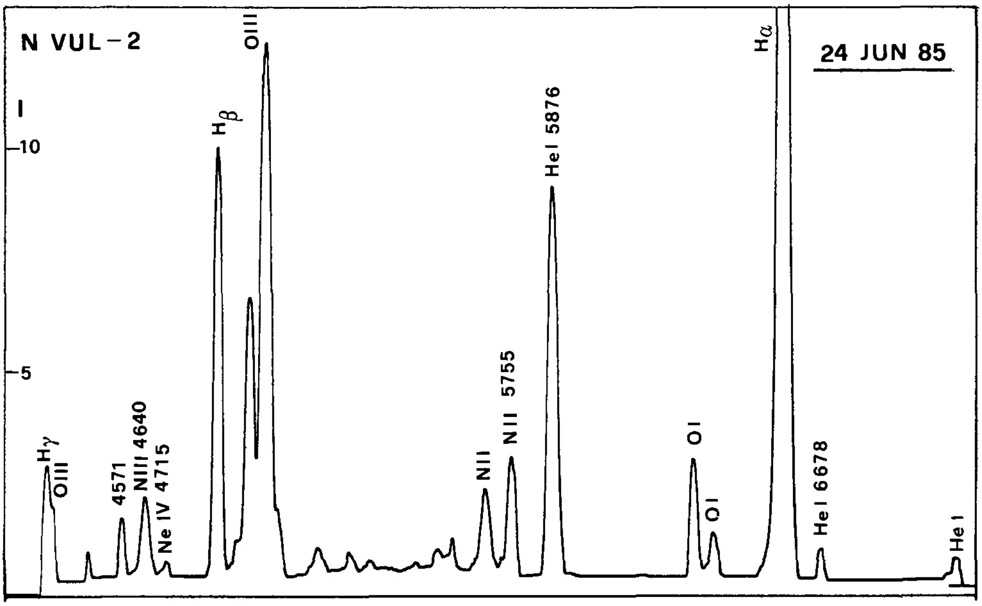

Fig. 6. Intensity tracing of the spectrum of N Vul-2 taken on June 24, 1985 with the B & C spectrograph.

Two weeks later, in July, was observed the enhancement of the He I lines and the He II 4686 emerged and strengthened. The nova had reached the full nebular stage, while the [O III] and [Ne III] lines were further growing. The blend of [Ne IV] at λ4715 emerged becoming soon as strong as N III 4640. The three lines of N III, He II and [Ne IV] displayed a peculiar shape, hazy and nebulous, different from other emission features. From July to November the spectrum did not show significant changes.

In the infrared was remarkable the fading of O I 8446 which was just perceptible in November. The strongest lines were He I 7065, [O II] 7320 - 30 and He I 6678.

The last spectra (Fig. 7) of the nova were obtained at Asiago in May and July, 1986. The degree of excitation is still high: the prominent lines were (in order of decreasing strength): [O III] 5007, Hα , [O III] 4959, [Ne III] 3869, [Ne IV] 4715, [Ne III] 3968, Hβ, [O III] 4363, He I 5876, He II 4686, N III 4640, [N II] 5755, Hγ and [Fe VII] 6087.

The spectroscopic observation of this nova, which is slowly declining, is still continuing at Asiago.

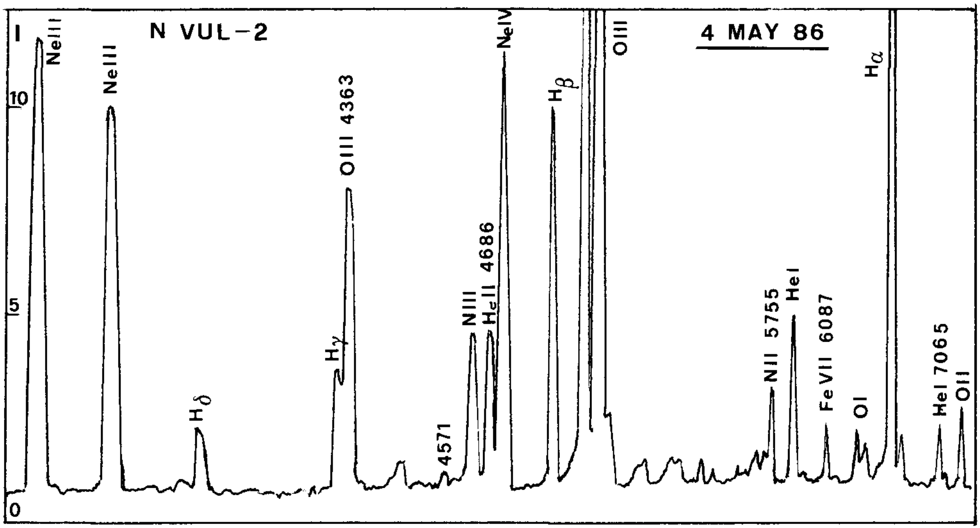

Fig. 7. Intensity tracing of a spectrum of N Vul-2 obtained with the B & C spectrograph on May 4, 1986, when the nova was in an advanced nebular phase. Note the high intensity of the Ne III and Ne IV lines.

4. Conclusions

The differences between the two novae examined in this paper and some of their peculiarities can be summarized in the following points:

a) N Vul-1 had, immediately after the maximum, a rapid decline ($d = 0.5$ mag/day) followed however by strong semiperiodic brightness fluctuations lasting for several months. Its light curve and also the spectral characteristics are similar to those of Nova V 400 Per 1974 (Rosino, 1978). The light curve of N Vul-2, on the contrary, has been smooth, with a regular decline ($d = 0.1$ mag/day). It looks somewhat alike, among many others, to the light curve of Nova V 1229 Aql 1970 (Ciatti and Rosino, 1974).

If the statistical relation between velocity of decline and absolute magnitude at maximum of the novae (Payne-Gaposchkin, 1957) can be applied, we obtain $M_{pg} = -8.5$ for N Vul-1, which may be rather uncertain because of the irregularity of its light curve, and $M_{pg} = -7.4$ for N Vul-2.

b) The spectral evolution during the nebular phase was faster and the degree of excitation was higher in N Vul-1 than in N Vul-2. In the former the fading of the lines with high I.P. began in Dec. 1985, that is eleven months after the nova had entered in the nebular stage. In N Vul-2 after more than 15 months the spectrum still shows lines with high I.P.

c) The most important difference of the two novae is found in the nebular stages. While both had extremely strong [O III] lines, in N Vul-1 the emission lines of [Ne III] appeared lately and were always weak, in N Vul-2, on the contrary, these lines appeared soon and reached an intensity comparable to that of [O III]. In N Vul-2 the blend of [Ne IV] was also prominent. Our results are consistent with the extremely high intensity of [Ne II] 12.8 μm of this nova (Gehrz et al., 1985) and suggest an overabundance of Neon in the gas ejected by N Vul-2. The overabundance of Neon has been also observed in Nova CrA 1981 (Williams et al., 1985) and in Nova Aql 1982 (Rosino et al., 1983; Snijders et al., 1984).

Starrfield et al. (1986) suggested that the explosion of novae with ejecta rich in O, Ne and Mg should be more violent than that of other novae. Our results, however, seem to indicate that the explosion of N Vul-1 was stronger than that of N Vul-2.

d) Finally we would like to remark the presence in the spectrum of N Vul-2 of a fairly strong line at λ4571 with saddle-shaped profile, which persisted from February to the end of 1985. This line was observed also in the spectra of some other novae (RR Tel and Eta Carinae, Thackeray, 1977; Nova Aql 1982, Rosino et al., 1983), but is not present in the spectrum of N Vul-1. It seems that the 4571 line is associated with a high abundance of Neon. Its attribution to Mg I seems to be doubtful, the right identification is not yet found.

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