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The final decline of Nova (V1974) Cygni 1992 and discovery of an associated extended emission nebulosity

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Abstract. New spectroscopic observations of Nova Cygni 1992 (V1974 Cyg) carried out in 1994–95 have shown a progressive decrease of the ionization level, made evident by the fading or disappearance of the emission lines of [Ne V], [Ne III], [Fe VII], [Fe VI] and [O III], which were outstanding in the 1992–93 spectra. An echelle spectrum obtained at Asiago in October 1995 clearly shows the complexity of the velocity field of the nova.

By scanning three spectra in 1994–95 perpendicular to the direction of the dispersion along Hα, it has been found all around the nova an extended emission nebulosity, having an upper diameter of about 3 arcmin in July 1994 and nearly 4 arcmin in May and October 1995. By assuming that the excitation of this nebulosity was due to the ultraviolet radiation emitted by the nova in the 1992 outburst, we found the distance to the nova about 1.9 ± 0.1 kpc.

Key words: stars: individual: Nova Cyg 1992 – stars: Novae

1. Introduction

To complement the spectroscopic study in the optical region of Nova (V1974) Cyg 1992, carried out at Asiago from February 1992 to December 1993 (Rafanelli et al., 1995; hereafter Paper I), we present some additional observations made in 1994 and continued, as far as possible, in 1995.

As reported in Paper I, the nova reached its visual maximum V_0=4.4 at the epoch T_0 = 1992 February 22.5 (JD 2448675). The light curve was typical of a fast nova, with velocity of decline t_2 = 16 days. From the color excess E_{B-V}=0.17 (A_V=0.5) and the relation MMRD (Capaccioli et al., 1989) the absolute visual magnitude of the nova at maximum M_V=–8.3 and its distance d=2.8 kpc were derived.

The nova entered in the nebular stage at the end of April 1992. Its spectral evolution in the subsequent months and in 1993 was characterized by the progressive strengthening of the forbidden lines of [Ne V], [Ne IV], [Ne III], [O III], [Fe VII] and [Fe VI]. The highest degree of ionization was attained in July 1993, five hundred days after maximum, when even the coronal lines of [Fe X], [Fe XI] and [A X] were observed; the effective temperature of the central source was higher than 650 000 K. Some months later began the fall of the ionization level.

A preliminary determination of the element abundance confirmed that the nova had an overabundance of neon and, therefore, could be included in the class of the neon-novae (Paper I). Overabundant were also oxygen, nitrogen and helium.

The study of this nova was so interesting that we thought worthwhile to follow-up with the Asiago telescopes its further spectroscopic evolution. New CCD spectra were, therefore, taken at Asiago with the same instruments and reduced with the same procedure as reported in Paper I, including also some spectra obtained by one of us (M.R.) with the 2.2 m telescope of the Calar Alto Observatory (DSAZ). The available material is listed in Table 1, where the head-lines give: date and JD; number of days from T_0; visual magnitude; type of spectrograph and grating; spectral range and resolution. The V magnitudes of the nova during the final decline were derived by extrapolation of the light curve over V=13, assuming a mean rate of decline of +0.006 mag/day.

In addition to the CCD spectra listed in Table 1 we have examined some objective prism spectra obtained at Asiago with the Schmidt telescope of 67/92 cm in the years 1993–1995. These spectra, extend to the near ultraviolet, have a dispersion of 650 Å/mm at Hγ and about 300 Å/mm at 3500Å. They were used for qualitative determinations of the relative intensities of the [Ne V] and [Ne III] lines.

2. The final decline

Table 2 gives wavelengths, identification and intensities relative to Hβ of the most significant emission lines still present in 1994–95. We have included in the table, to make easier the comparison with the data of Paper I, also the intensities observed in October and November 1993.

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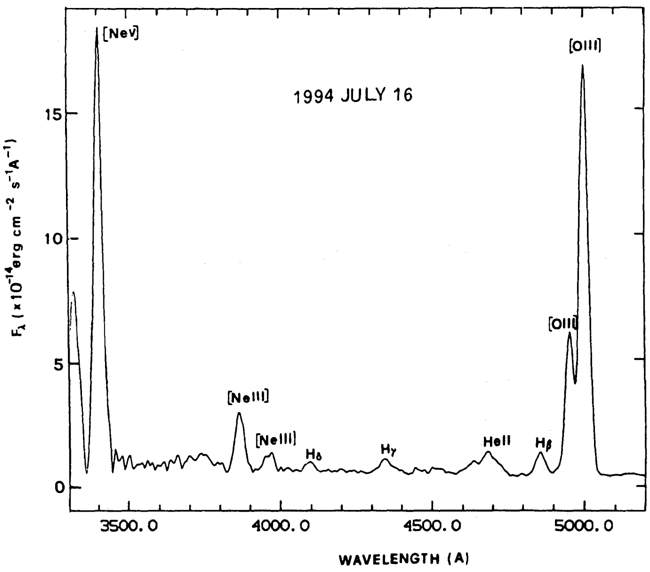

Fig. 1. The spectrum of Nova Cygni 1992 at 875 days after maximum. The [Ne V] line at 3426Å, which in July 1993 (Paper I, Fig. 5) was by far the strongest feature in the spectrum, faded steeply from 62.9 to 19.7 (relative to Hβ) in the course of one year. This line has now an intensity just a little higher than that of [O III] 5007Å

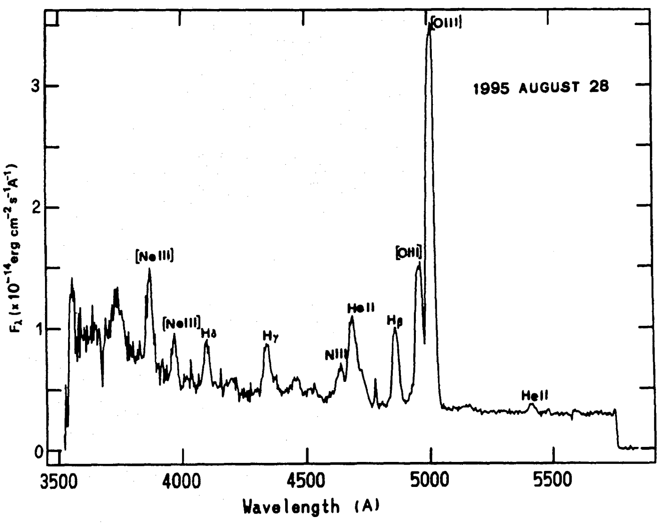

Fig. 2. The spectrum at 1283 days after maximum, is characterized by the fall of the general degree of ionization. With a few exceptions, most of the lines have become weaker than Hβ and are barely perceptible. The [O III] line at 5007Å, with intensity 5.67 relative to Hβ, appears now, on objective prism spectra, the strongest feature after Hα

Table 1. Boller and Chivens and Echelle spectroscopic observations

Date		JD (–2440000)	days	V	Sp–Gr	Spectral Range (Å)	R (Å)
1994							
Jun	30	9534.6	860	14.2	BC-600	3950 – 5100	6
Jul	16	9550.4	876	14.5	BC-150	3400 – 7500	24
Dec	11	9698.4	1024	15.5	BC-600	4000 – 5000	6
1995							
May	5	9842.7	1168	16.1	BC-400	3800 – 7600	9
Jul	22	9920.5	1246	16.3	BC-300	3700 – 5800	12
Aug	28	9958.4	1284	16.5	BC-300	3700 – 7250	12
Oct	12	10003.5	1329	16.8	E - 300	4800 – 6650	0.6
Oct	28	10019.4	1345	16.9	BC-600	5750 – 6750	6

days: number of days from the visual maximum
R: spectral resolution

Although some of the data reported in Table 2 may be somewhat uncertain due to blends or weakness of the lines, it is apparent that the general degree of ionization has been steadily decreasing in the last two years. At first disappeared the forbidden lines of [Fe X], [Fe VII] and [Fe VI], which were not particularly strong even in 1992–93. Then occurred the dramatic fall, by nearly a factor twenty in the time span of one year, of the [Ne V] doublet 3346–3426Å. These lines were by far the strongest in the objective-prism (OP) spectra of November 1993 and still outstanding in July 1994 (Fig. 1), while no longer recorded in the OP spectra of August 1995.

The doublet of [Ne III] 3869–3968Å underwent also a steep decline from November 1993 to August 1995, while the nebular doublet of [O III] 4959–5007Å weakened more gradually. At the end of August 1995 this doublet was still prominent compared to the other emission lines (Fig. 2).

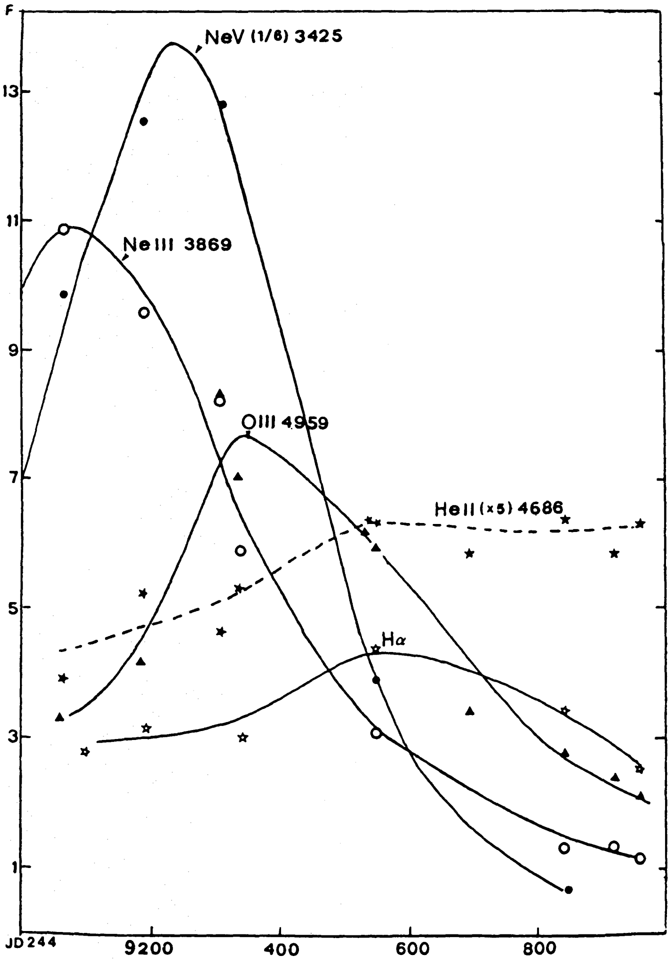

Fig. 3. Temporal development of the emission lines of the nova from November 1993 to August 1995

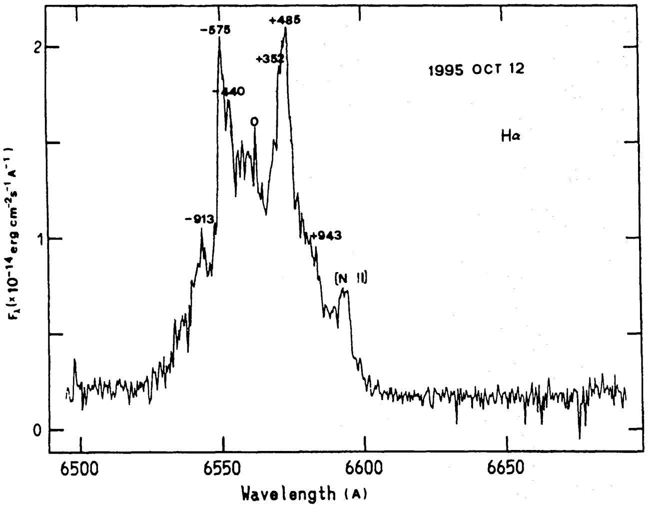

Fig. 4. Echelle spectrum of the nova (1995 October 12). Hα displays a saddle-shaped profile, with two symmetric peaks of very high strength having radial velocity about $\pm$ 530 km s^{-1}. The forbidden line of [N II] 6584Å is weakly present at the red side of Hα

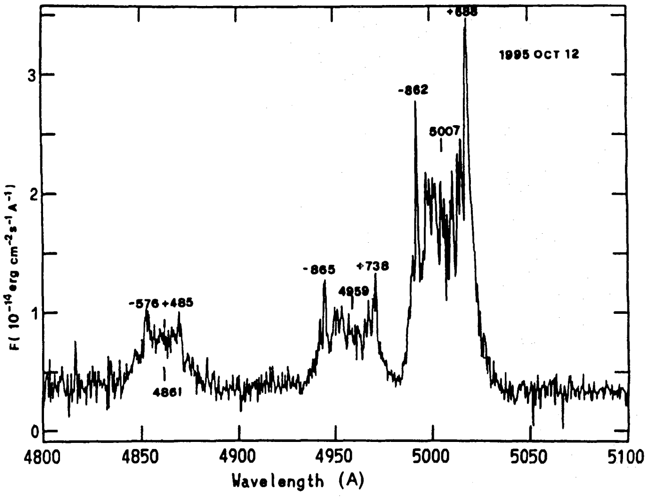

Fig. 5. The forbidden lines of [O III] at 4958 and 5007Å show strong symmetric peaks with radial velocity of about 700 – 800 km s^{-1}. Hβ displays the same double peaked profile as Hα in Fig. 4

As shown in Table 2, the Balmer decrement remained more or less constant, while the intensity of Hβ steadily faded from 60 to 20 $\times$ 10^{-14} erg cm^{-2} s^{-1}. The temporal development of the intensities (relative to Hβ) of the most significant lines, corrected for the interstellar extinction (E_{B-V}=0.17), is represented in Fig. 3. The increasing strength of Hα from July 1993 to May 1994 was partly due to blend with the [N II] lines 6548-6584, which, however, became negligible from October 1995 (Fig. 4). A slight strengthening of the He II lines, in particular of He II 4686, was noticed in the last two years against the general tendency of decreasing of the ionization level. This fact was probably due to the slow re-establishment of the accretion disk around the white dwarf (Martin 1989).

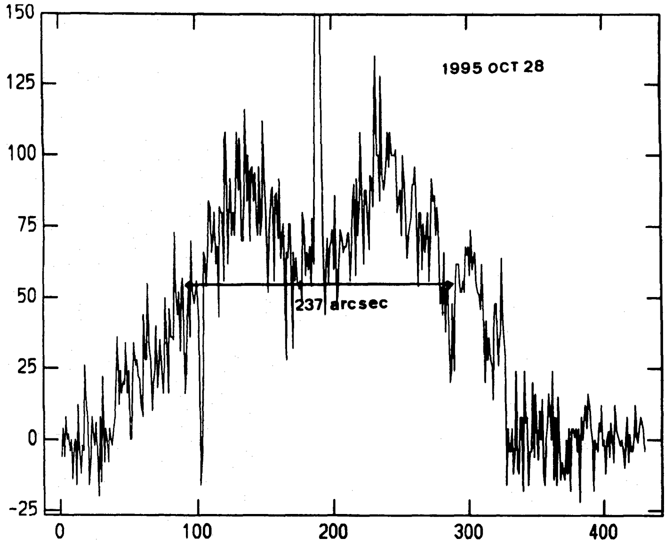

Fig. 6. Evidence of an extensive emission nebulosity around the nova found by scanning perpendicularly to the dispersion an Hα spectrum of the nova taken on 1995 October 28

The analysis of the echelle spectrum of the nova taken at the 1.82 m telescope on 1995 October 12 is particularly interesting. The tracings (Figs. 4,5) of the strongest emission features are characterized by a pair of very bright peaks, symmetric about the rest wavelength, with radial velocities from $\pm$ 500 km s^{-1} of Hα to $\pm$ 700 – 900 km s^{-1} of [O III], and wide wings at each side, vanishing at higher velocity. The central region between the two symmetric peaks displays an irregular profile. The mean radial velocity of the center of symmetry of [O III] lines is $-82\pm$ 3 km s^{-1}.

3. An extensive emission nebulosity around the Nova

By scanning the field of three Boller & Chivens spectra along a line perpendicular to the dispersion (east–west on the sky), one of us (T.I.) found around the nova a roughly symmetric extended Hα emission nebulosity. The diameter of the upper boundary of the emission region was about 3.0 $\pm$ 0.2 arcmin in July 1994, 3.5 $\pm$ 0.1 in May and 3.95 $\pm$ 0.1 in October 1995 (Fig. 6). Since the ejecta of the nova with an expansion rate less than 0.4 mas/day cannot have travelled such a large distance during a few years, an obvious alternative is that the interstellar medium may have been excited by the ultraviolet radiation emitted by the nova during its outburst in February 1992. With this assumption we obtained the distance of the nova 1.7, 1.96 and 1.98 kpc from the three spectra. The slight discrepancy very likely depends on some uncertainty about the position of the upper boundary of the faint nebulosity. The data concerning this Hα nebulosity and the interpretation of its luminescence need to be confirmed by further observations. Anyway, we adopted for the distance of the nova d=1.9 $\pm$ 0.1 kpc. It may be interesting to remark that this distance, derived without any assumption on the luminosity of the nova, nor on the interstellar absorption or expansion velocity of the ejecta, is in good agreement with the values given by

Table 2. Identification and emission line fluxes (relative to Hβ) from November 1993 to October 1995

λ (Å)	Ion	mult.	1993 Nov 19	Dec 18	1994 Jun 30	Jul 16	Dec 11	1995 May 5	Jul 22	Aug 28	Oct 28
3426	[Ne V]	1F	64.30			19.65		0.75		...	
3869	[Ne III]	1F	7.30	5.30		2.80		1.21	1.22	1.08	
3968	[Ne III]	1F	2.34	1.75		0.90		0.52	0.45	0.47	
4102	Hδ	1	0.48	0.35	0.45	0.45	0.59	0.48	0.53	0.48	
4200	He II	3	0.08	0.06	...	...	...	...	...	0.19	
4340	Hγ	1	0.54	0.50	0.50	0.52	0.52	0.66	0.55	0.63	
4363	[O III]	2F	1.50	1.60	...	...	0.26	0.27	0.30	0.12	
4640	N III	2	0.48	0.40	0.53	0.49	0.52	0.55	0.48	0.48	
4686	He II	1	0.90	1.05	1.25	1.24	1.14	1.55	1.49	1.47	
4725	[Ne IV]	1F	1.05	1.05	0.60	0.60	0.38	0.50	0.25	0.33	
4861	Hβ	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4959	[O III]	1F	8.40	7.10	6.30	6.00	3.50	2.82	2.40	2.10	
5007	[O III]	1F	25.20	21.60	18.50	18.10	10.30	7.85	7.20	5.64	
5159	[Fe VII]	2F	0.22	0.25		0.20		0.02		...	
5412	He II	2	0.15	0.15		0.22		0.17		0.12	
5677	[Fe VI]	1F	0.15			0.12		0.09		...	
5876	He I	11	0.05			0.09		0.13		0.13	
6087	[Fe VII]	1F	0.45			0.24		0.07		...	
6563	Hα	1	3.54			5.20		4.08		3.82	3.05
6678	He I	46	0.03			0.09		0.04		...	
7065	He I	10	0.03			0.12		0.10		0.11	
7320-30	[O II]	1F	0.35			0.28		0.31		0.10	
4861	Hβ	*a*	0.06	0.045	0.030	0.031	0.028	0.015	0.016	0.018	0.0105
	FWHM	*b*	1650	1560	1565	...	1535	1750	1770	1745	1445

a: absolute intensity of Hβ in 10^{-11} erg^{-2} s^{-1}
b: mean FWHM in km s^{-1}

Hjellming (1994), Chochol et al. (1994) and by Paresce et al. (1995) with different methods.

Paresce et al. (1995) discovered an expanding ring around the nova with the HST observations. The expansion rate, 0.297 mas/day in the major axis and 0.218 mas/day in the minor axis (Paresce et al. 1995), corresponds respectively to velocities of 950 km s^{-1} and 700 km s^{-1} at the distance of 1.9 kpc. These velocities are nearly the same as the radial velocities of the main peaks of [O III] emission lines (Fig. 5). The profiles of the emission lines suggest that the ring may be largely inclined, because if this is not the case, the peaks near the center of the lines should have highest intensities.

4. Concluding remarks

The new data on Nova Cyg 1992 collected at Asiago in the last two years (1994–95) improve but do not change substantially the conclusions reached in Paper I. The contraction of the central source, which is now going towards its pre-outburst stage, and the contemporary dissipation of the expanding shells around the nova, may explain the drop of the ionization level, observed in 1995.

The observations confirm that the average expansion rate of the gas ejected during the outburst, measured by the FWHM of the strongest emission lines, underwent a decrease in 1994–95 as compared with the results in 1992–93 (Paper I), although with some fluctuations (Table 2). It must be remarked, however, that the determination of the FWHM in low dispersion spectra is somewhat uncertain and gives only an overall value of the dynamical situation around the nova. The echelle frames obtained with a much higher resolving power have shown how complex are the profiles and how the velocity fields for the different elements differ.

The Hα emission nebulosity around the nova at relatively large distance, likely excited by the ultraviolet radiation emitted by the nova in its outburst, has offered the occasion to advance some suggestions about the effects of the nova explosion on the circum-stellar matter. We are perfectly aware that there are still some dubious points. They will be cleared-up by further observations in the next years.

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