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An extensive optical study of V2491 Cyg (Nova Cyg 2008 N.2), from maximum brightness to return to quiescence

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ABSTRACT

The photometric and spectroscopic evolution of the He/N and very fast Nova Cyg 2008 N.2 (V2491 Cyg) is studied in detail. A primary maximum was reached at $V = 7.45 \pm 0.05$ on April 11.37 (±0.1) 2008 UT, followed by a smooth decline characterized by $t_2^V = 4.8$ days, and then a second maximum was attained at $V = 9.49 \pm 0.03$, 14.5 days after the primary one. This is the only third nova to have displayed a secondary maximum, after V2362 Cyg and V1493 Aql. The development and energetics of the secondary maximum is studied in detail. The smooth decline that followed was accurately monitored until day +144 when the nova was 8.6 mag fainter than maximum brightness, well into its nebular phase, with its line and continuum emissivity declining as t^{-3}. The reddening affecting the nova was $E_{B-V} = 0.23 \pm 0.01$, and the distance of 14 kpc places the nova at a height above the galactic plane of 1.1 kpc, larger than typical for He/N novae. The expansion velocity of the bulk of ejecta was 2000 km/s, with complex emission profiles and weak P-Cyg absorptions during the optically thick phase, and saddle-like profiles during the nebular phase. Photo-ionization analysis of the emission line spectrum indicates that the mass ejected by the outburst was 5.3×10^{-6} $M_\odot$ and the mass fractions to be $X = 0.573$, $Y = 0.287$, $Z = 0.140$, with those of individual elements being N = 0.074, O = 0.049, Ne = 0.015. The metallicity of the accreted material was [Fe/H] = −0.25, in line with ambient value at the nova galacto-centric distance. Additional spectroscopic and photometric observations at days +477 and +831 show the nova returned to the brightness level of the progenitor and to have resumed the accretion onto the white dwarf.

1. Introduction

Nova Cyg 2008 N.2 (=V2491 Cyg, hereafter NCyg08-2) was discovered by K. Nishiyama and F. Kabashima at ~7.7 mag on CCD images exposed on April 10.73 UT (see Nakano, 2008), and confirmed spectroscopically by Ayani and Matsumoto (2008). Immediately following the discovery, it was found that prior to the outburst NCyg08-2 was an X-ray source (Ibarra and Kuulkers, 2008; Ibarra et al., 2008, 2009), detected from the ROSAT survey era (1990/91) to three months before the outburst (a Swift observation for Jan. 2, 2008). The only other nova to have been detected in the X-rays before the outburst was Nova Oph 1998 (=V2487 Oph, Hernanz and Sala, 2002). This contributed to trigger a tight X-ray monitoring of the outburst evolution, which results are described by Page et al. (2008, 2010); Osborne et al. (2008); Ness et al. (2008a,b); Kuulkers et al. (2008); Takei et al. (2009); Takei and Ness (2010). NOph08-2 displayed initially a hard X-ray spectrum originating from shocked gas, while a much brighter and softer X-ray spectrum emerged later. This super-soft X-ray emission, that originates from the protracted H-burning during the constant-luminosity phase (Krautter, 2008), ended about 45 days past optical maximum (Hachisu and Kato, 2009; Page et al., 2010).

IR spectroscopic observations of NCyg08-2 have been briefly described by Lynch et al. (2008), Rudy et al. (2008), Ashok et al. (2008) and to a larger extent by Naik et al. (2009). They found a modest reddening, large expansion velocities remaining stable over time, slow spectral evolution and a classification as 'He/N' nova following Williams (1992).

So far only preliminary descriptions of photometric and spectroscopic behavior in the optical have been published, and only in the form of telegrams/circulars. Tomov et al. (2008a,b) reported about the presence, on their low resolution prismatic spectra, of absorption components in Hβ and Hγ at large radial velocities, ranging from −3500 to −6400 km/s depending on the observing date and line.

In this paper we present a detailed study of NCyg08-2 at optical wavelengths, including a photo-ionization analysis of the ejecta and their chemical composition, based on our tight photometric and spectroscopic monitoring of the outburst, that extended from nova discovery well into its return to quiescence.

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2. Observations

$BV\,R_CI_C$ photometry of NCyg08-2 has been obtained with several robotic, remotely controlled or manually operated telescopes of the ANS Collaboration. Technical details of this network of telescopes and their operational procedures are presented by Munari et al. (submitted for publication). The network has been used already for detailed studies of some other recent novae (e.g. Munari et al., 2008a,b, 2010b).

All photometric measurements were carefully tied to the local $BV\,R_CI_C$ sequence calibrated by Henden and Munari (2008) against Landolt's equatorial standards. The photometry is listed in Table 1 and the resulting light-curve is presented in Fig. 1. In all, we obtained 66 independent $BV\,R_CI_C$ runs distributed over 53 different nights and spanning an interval of 830 days. The median value of the Poisson errors of the photometric points in Fig. 1 is 0.005 mag in V, 0.008 in $B-V$, 0.006 in $V-R_C$, 0.004 in R_C-I_C and 0.006 in $V-I_C$. The mean r.m.s. of standard stars from the linear fit to color equations is 0.019 mag in V, 0.029 in $B-V$, 0.027 in $V-R_C$, 0.017 in R_C-I_C and 0.039 in $V-I_C$.

Spectroscopic observations of NCyg08-2 have been obtained with several telescopes: (i) the 3.5 m TNG in La Palma (Canary Islands, Spain) and the high resolution spectrograph SARG, operated at a resolving power of 75,000, (ii) the 1.82 m in Asiago equipped with the spectrograph/imager AFOSC with a 300 ln/mm grism and a 1720 ln/mm volume phase holographic grism, and (iii) the 0.6 m telescope of the Schiaparelli observatory in Varese equipped with a multi mode spectrograph and various reflection gratings. A detailed journal of the spectroscopic observations is provided in Table 2. The spectroscopic data have been reduced and calibrated in IRAF using standard techniques involving correction for bias, dark and flat fields, and absolute fluxing using spectrophotometric standard stars observed along with the nova. The high accuracy of the absolute fluxes has been checked on all spectra by integrating the fluxes over the V and R_C bands (whose wavelength ranges are completely covered by our spectra) and comparing them with photometric data in Table 1. The differences never exceeded 0.1 mag for both photometric bands.

3. Photometric evolution

3.1. Rise, maximum brightness and early decline

The early photometric evolution (first 5 days) of NCyg08-2 is shown in greater detail in Fig. 2. To draw it, we have used in addition to our photometry also literature data as indicated. Some of the literature data refer to unfiltered CCD observations calibrated against the red USNO-B magnitudes (rhomb symbols). They have been transformed into V magnitudes by applying a rigid shift of +0.68 mag as indicated by the comparison with nearly simultaneous true V band data in Fig. 2. This is nicely confirmed by the photometry of Henden and Munari (2008) for 2005 field stars around NCyg08-2 that gives for them an average $V-R_C = +0.61$.

The interpolating line in the V panel of Fig. 2 has been drawn by hand to guide the eye, while the lines in the other panels correspond to the following expressions:

$$B-V = +0.46 - 0.095 \times \Delta t + 0.009 \times (\Delta t)^2 \quad (1)$$

$$V-R_C = +0.54 + 0.310 \times \Delta t - 0.058 \times (\Delta t)^2 + 0.003 \times (\Delta t)^3 \quad (2)$$

$$V-I_C = +1.22 + 0.055 \times \Delta t - 0.011 \times (\Delta t)^2 + 0.0001 \times (\Delta t)^3 \quad (3)$$

where Δt is the time since maximum in the V band. These behaviors are normal for novae, for ex. similar to those displayed by the moderately slow FeII nova V2615 Oph (N Oph 2007, Munari et al., 2008a).

Table 1
Our $BV\,R_CI_C$ photometry of Nova Cyg 2008-2.

HJD	V	$B-V$	$V-R$	$V-I$	$R-I$	Obs	HJD	V	$B-V$	$V-R$	$V-I$	$R-I$	Obs
4568.475	8.090					R040	4618.410	14.001	0.135	0.647	0.500	−0.074	R030
4569.478	8.521	0.383	0.963	1.287	0.404	R030	4627.447	14.262	0.154	0.407	0.197	−0.107	R010
4572.479	9.397			1.242		R030	4628.454	14.346	0.147	0.399	0.246	−0.077	R010
4572.643	9.438	0.185	1.036	1.239	0.270	R040	4636.426	14.510	0.298	0.162	0.070	−0.055	R010
4576.472	9.849	0.030	0.953	1.043	0.180	R030	4637.416	14.523	0.281	0.242	0.157	−0.053	R010
4576.580	9.816	0.061	0.971	1.051	0.198	R060	4637.454	14.602	0.272	0.267	0.052	−0.100	R030
4576.614	9.856	0.080	0.967	1.056	0.185	R040	4638.447	14.557	0.271	0.163	0.135	−0.034	R010
4576.681	9.735	0.065		1.075		R010	4639.418	14.574	0.294	0.126	0.046	−0.085	R010
4579.508	9.807	−0.002	0.821	0.909	0.168	R030	4645.416	14.762	0.353	0.134	0.126	0.015	R030
4579.545	9.743	0.017	0.783	0.888	0.161	R040	4649.440	14.762	0.359				R010
4580.508	9.639	−0.022	0.754	0.847	0.166	R030	4652.432	14.941	0.434	−0.068	0.120	0.092	R030
4580.639	9.753	−0.052	0.781	0.912	0.166	R010	4653.156	14.713	0.498				R010
4581.475	9.612	−0.013	0.744	0.857	0.178	R030	4655.440	14.814	0.452				R010
4581.522	9.646	−0.020	0.726	0.830	0.172	R060	4657.446	14.838	0.359				R010
4581.598	9.648	−0.017	0.732	0.845	0.187	R010	4658.396	14.824	0.448				R010
4582.475	9.492	0.006	0.689	0.806	0.184	R030	4660.420	14.918	0.470				R010
4583.486	9.796	−0.055	0.767	0.872	0.179	R030	4667.371	14.931	0.563				R010
4584.466	10.585	−0.051	0.962	0.946	0.099	R030	4672.417	15.013	0.665				R010
4588.480	11.424	−0.168	1.251	1.024	−0.047	R030	4683.463	15.447	0.635	−0.189	−0.042	0.107	R030
4589.512	11.734	−0.221	1.377	1.093	−0.077	R030	4690.432	15.330	0.737				R010
4589.577	11.769	−0.230	1.277	1.056	−0.072	R010	4697.357	15.533	0.766				R010
4592.497	12.029	−0.186	1.339	1.045	−0.088	R030	4698.364	15.514	0.610				R010
4593.521	12.280	−0.253	1.386	1.072	−0.106	R030	4699.355	15.473	0.635				R010
4594.526	12.437	−0.207	1.364	1.052	−0.136	R010	4700.409	15.474	0.744				R010
4595.516	12.528	−0.279	1.332	1.009	−0.116	R010	4701.399	15.768	0.750				R010
4595.517	12.474	−0.248	1.348	1.023	−0.133	R030	4703.411	15.504	0.604				R010
4598.444	12.657	−0.225	1.279	0.991	−0.105	R030	4705.411	15.791	0.564				R010
4598.518	12.685	−0.222	1.245	0.971	−0.128	R010	4706.402	15.534	0.663				R010
4599.542	12.738	−0.239	1.199	0.915	−0.125	R010	4708.386	15.598	0.655				R010
4601.462	12.955	−0.216	1.234	0.931	−0.127	R030	4709.386	15.734	0.446				R010
4601.519	12.871	−0.221	1.227	0.896	−0.148	R010	4712.400	16.022	0.446				R010
4613.428	13.820	0.001	0.805	0.524	−0.125	R030	5044.382	17.442		0.380	0.705	0.325	R140
4614.474	13.739	−0.035	0.723			R010	5398.504	17.876		0.390	0.625	0.242	R140

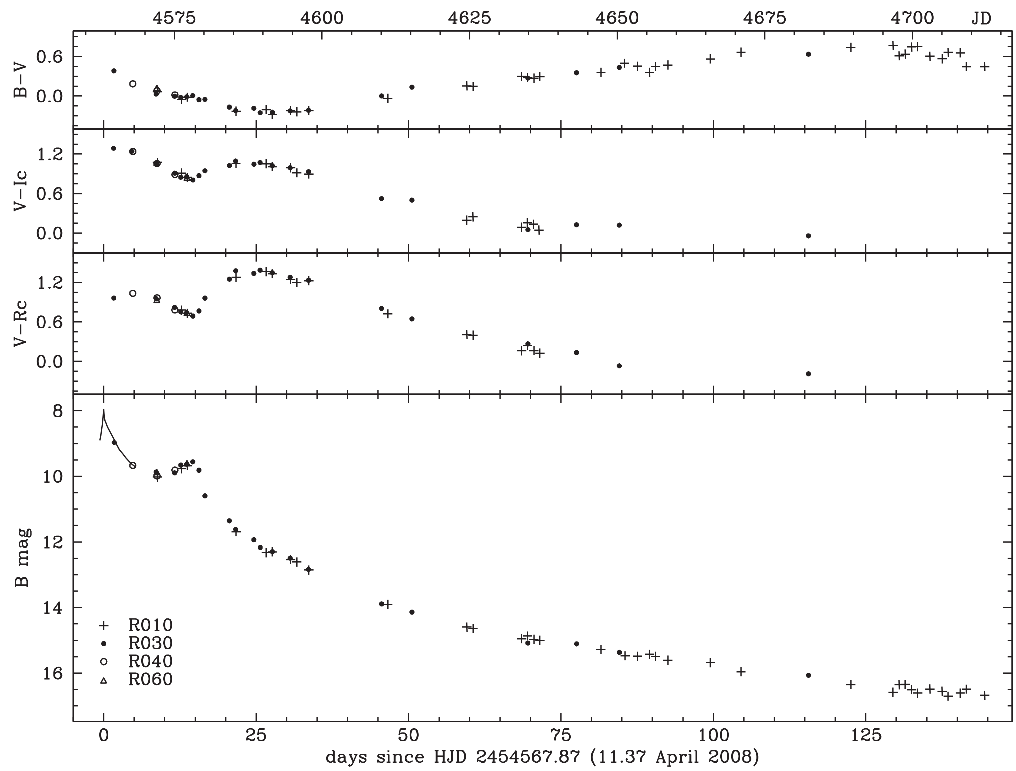

Fig. 1. Light and color evolution of Nova Cyg 2008 N.2 from our CCD observations. The line around maximum brightness in the *B* band panel is taken from Fig. 2. Photometry from Table 1, at epochs later than day +150, is not included.

Table 2
Journal of the spectroscopic observations.

Date	UT	Δt (day)	Expt. (s)	Disp (Å/pixel)	λ range	Tel. (m)
2008 04 13	01:41	+1.70	900	1.75	3830–7300	0.6
2008 04 13	02:32	+1.74	900	0.30	6200–6760	0.6
2008 04 15	23:45	+4.62	1800	1.75	3820–7550	0.6
2008 04 16	00:57	+4.67	3600	0.36	5465–6240	0.6
2008 04 16	02:32	+4.74	900	1.68	6220–8900	0.6
2008 04 22	23:14	+11.6	1800	1.75	3880–7550	0.6
2008 04 26	05:40	+14.9	300	(*75,000*)	4620–7920	3.5
2008 05 02	22:29	+21.6	1800	1.75	3850–7550	0.6
2008 05 02	23:40	+21.6	900	1.68	6300–8700	0.6
2008 05 14	00:32	+32.7	1800	0.60	6175–6835	0.6
2008 05 14	01:24	+32.7	2700	3.50	3880–7750	0.6
2008 07 27	21:47	+108	2700	4.24	3750–7790	1.8
2008 07 27	22:57	+108	900	0.64	6400–7050	1.8
2009 07 31	22:56	+477	7200	4.24	3700–7770	1.8
2010 08 21	00:13	+862	1800	2.38	3700–8140	1.8

The heliocentric time t_0 of maximum in the *V* band is well constrained in Fig. 2 to be April 11.37, 2008 UT, with an uncertainty of 0.1 days. It will be used in this paper to count the elapsed time. The nova reached a maximum brightness of $V \sim 7.45$ and the decline time was $t_2^V = 4.8$ days, which corresponds to a classification as *very fast* nova according to Warner (1995).

The rise to maximum has been very fast too, with the last one magnitude jump completed in 0.6 days (cf Fig. 2). The negative observation by Beize (2008), who found nothing down to a limiting magnitude of 14 at the position of the nova on April 8.83, implies that the last 6.5 mag of the rise to maximum have been covered in less than 2.5 days.

3.2. Reddening

Our high resolution spectrum obtained with the 3.5 m TNG telescope on day +14.9 provides a clean view of the absorption lines of interstellar NaI toward NCyg08-2. The profile of the NaI line at 5889.953 is presented in Fig. 3. It shows several components associated to individual absorption clouds and/or spiral arms crossed by the line of sight to NCyg08-2. We have fitted them with sharp Gaussians, as common practice in high resolution spectroscopic studies of complex interstellar lines (e.g. Savage and Sembach, 1996; Welsh et al., 2010). The resulting individual Gaussians and the overall fit are overplotted to the observed spectrum in Fig. 3, and their parameters are listed in Table 3. Five components are clearly present, with heliocentric velocities ranging from +4.1 to +49.4 km/s. Their equivalent widths have been transformed into the corresponding amounts of reddening using the calibration by Munari and Zwitter (1997). The total reddening affecting NCyg08-2 sums up to $E_{B-V} = 0.24$.

van den Bergh and Younger (1987) derived a mean intrinsic color $(B-V)_0 = +0.23 \pm 0.06$ for novae at maximum, and $(B-V)_0 = -0.02 \pm 0.04$ for novae at t_2. For NCyg08-2, from Table 1 and

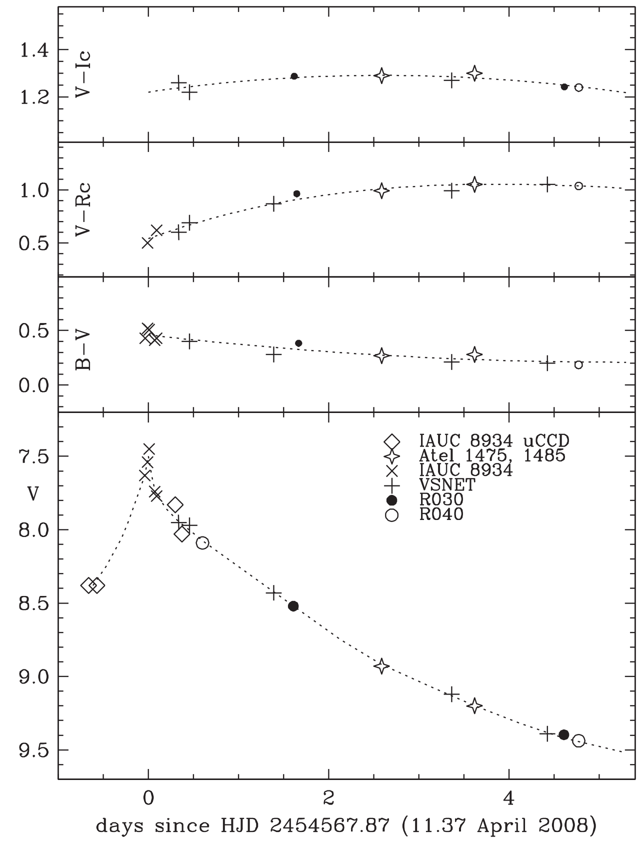

Fig. 2. Zooming onto the earliest photometric evolution of Nova Cyg 2008 N.2 combining our and other data as indicated.

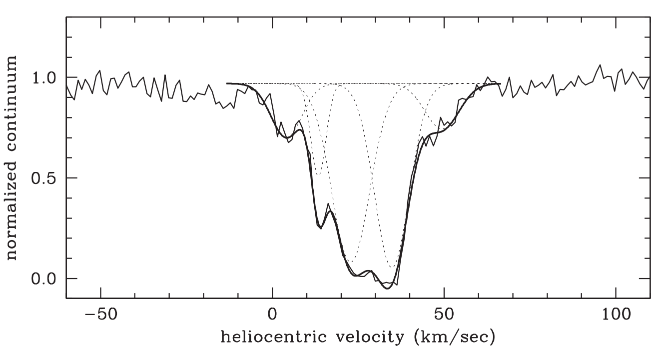

Fig. 3. Portion of the SARG spectrum centered on interstellar NaI 5889.953 Å line and corrected for telluric absorptions. The parameters of plotted Gaussians (dotted lines) are given in Table 3. The thick line is the overall multi-Gaussian fit.

Table 3
Heliocentric velocity, full width at half maximum, equivalent width and corresponding E_{B-V} for the individual components of the interstellar NaI 5889.953 Å line shown in Fig. 3.

$RV_{\odot}$ (km/s)	FWHM (km/s)	e.w. (Å)	E_{B-V}
+49.4	10	0.069	0.018
+34.8	10	0.252	0.089
+22.8	11	0.268	0.097
+ 13.4	5	0.055	0.015
+4.1	9	0.072	0.019
Total			0.238

Fig. 2, it is $B-V$ = +0.46 at maximum and $B-V$ = +0.20 at t_2, which correspond, respectively to E_{B-V} = 0.23 and E_{B-V} = 0.22.

The three estimates, corresponding to observing dates Δt = 0, +4.8 and +14.9 days, are in perfect agreement, and in the rest of this paper we will adopt E_{B-V} = 0.23 ± 0.01 as the reddening affecting NCyg08-2.

3.3. Distance

The rate of decline from maximum and the observed magnitude 15 days past maximum are calibrated tools to estimate distances to novae.

Published relations between absolute magnitude and rate of decline generally take the form $M_{\max} = \alpha_n \log t_n + \beta_n$. Cohen (1988) M_V—t_2^V relation provides $M_V = -9.06$ for NCyg08-2. For E_{B-V} = 0.23 and a standard R_V = 3.1 extinction law, this corresponds to a distance of 14 kpc to NCyg08-2, and to a height above the galactic plane of z = 1.1 kpc. The shorter distance of 10.5 kpc preliminary derived by Helton et al. (2008), rests on the large E_{B-V} = 0.43 they adopted from Rudy et al. (2008). Using instead our more accurate value of E_{B-V} = 0.23 would bring Helton et al. (2008) distance in close agreement with the 14 kpc we derived.

The M_B–t_2^B relations of Capaccioli et al. (1989) and Th. Schmidt-Kaler (cf Duerbeck, 1981) cannot be used with NCyg08-2 because the re-brightening toward 2nd maximum set in before the nova had declined by two whole magnitudes in the B band. For the same reasons, all relations involving t_3 are not applicable to NCyg08-2.

Buscombe and de Vaucouleurs (1955) suggested that all normal novae have the same absolute magnitude 15 days after maximum light. However, 15 days after maximum light corresponds to the time of 2nd maximum for NCyg08-2, and Buscombe and de Vaucouleurs's relation is therefore not applicable.

The interstellar material causing most of the extinction is concentrated within 150 − 200 pc of the galactic plane. The line of sight to NCyg08-2 (at galactic coordinates l = 67.2, b = +4.4 deg) emerges from it at about 2 kpc from the Sun, and it is approximately aligned with the Orion-Cygnus spiral arm. According to the Brand and Blitz (1993) maps, the mean heliocentric radial velocity of the interstellar material along the line of sight to NCyg08-2 increases up to ~30 km/s at 2 kpc distance. This is the range of velocities observed for the stronger individual components of the interstellar NaID profile (Table 3).

The galacto-centric distance of NCyg08-2 is R = 13 kpc ($R^2 = R_0^2 + d^2 - 2R_0 d \cos l$, where d = 14 kpc is the distance Sun-nova and R_0 = 8.5 kpc the galacto-centric distance of the Sun). NCyg08-2 is therefore located in the external part of the Galaxy, at a significant height above the equatorial plane and in a low metallicity ambient.

3.4. Second maximum and advanced decline

A relevant feature of the light-curve of NCyg08-2 is the re-brightening it displayed during early decline, two weeks past the principal maximum. To characterize some properties of this 2nd maximum, we have treated it as the emergence and then the disappearance of an *additional source* (hereafter AS) superimposed onto a normal and smooth underlying decline. Consequently, we have fitted (with a low degree polynomial) the light-curve of Fig. 1 outside the re-brightening phase and then subtracted it to the light-curve itself. The resulting light-curve for AS (i.e. the photometric development of the 2nd maximum isolated from the rest) is presented in Fig. 4.

The AS development appears symmetric in the rise and decline branches and of a shape not much dissimilar from a Gaussian profile. It started on day +5.5, well before the nova could have decline by 3 mag from maximum. The peak brightness of AS occurred on day +14.5 (April 25.9), and AS ended by day +24 when the nova set back onto the normal exponential decline from maximum. At

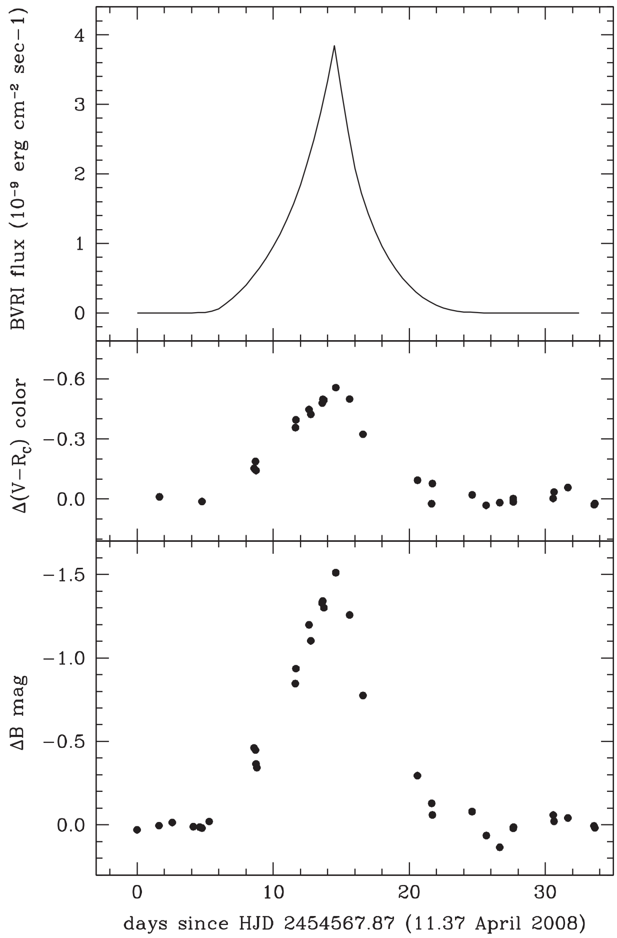

Fig. 4. Light-curve, color evolution and flux evolution of the 2nd maximum. They are obtained as difference between the observed values and the underlying unperturbed decline, extrapolated from the photometric behavior before and after the phase of the 2nd maximum. The flux in the top panel is reddening corrected and integrated over the $BV\,R_CI_C$ bands.

the time of peak AS brightness, NCyg08-2 became, with respect to the underlying unperturbed decline, brighter by $\Delta B = -1.5$ mag and bluer by $\Delta(B-V) = -0.02$, $\Delta(V-R_C) = -0.58$ and $\Delta(V-I_C) = -0.42$. At its peak brightness on day +14.5, the AS isolated from the rest would have shone at $V = 9.64$, $(B-V) = -0.02$, $(V-R_C) = -0.09$, $(V-I_C) = +0.18$, thus at an absolute magnitude $M_V = -6.83$. These colors, when corrected for the $E_{B-V} = 0.23$ reddening, are broadly consistent with those of a mid B-type star. Assuming that the bolometric correction for AS is the same of a B5-type super-giant photosphere (*B.C.* = −1.0 mag, Livingston, 2000), the peak luminosity reached by AS was 1×10^5 $L_\odot$, or about 1/3 of the 3.5×10^5 $L_\odot$ of primary maximum. Integration over time of the luminosity radiated by AS provides a total of 2.5×10^{44} erg, an amount equivalent to the hydrogen burning of 2.7×10^{-8} $M_\odot$ of material of solar composition.

A second maximum has been rarely seen in novae, other two well known cases are V2362 Nova Cyg 2006 and V1493 Nova Aql 1999a, discussed in detail by Munari et al. (2008b). The time interval between principal and secondary maxima for these two novae have been 240 and 45 days, respectively. That seen in NCyg08-2 is therefore occurring much earlier (14.5 days) than in the other two known cases.

A generally accepted explanation for the secondary maxima is still missing. Pejcha (2009) suggested episodic fuel burnings, and Hachisu and Kato (2009) the release of additional energy associated with rotating magnetic fields. However, the lack of a periodic signal in their X-ray observations of NCyg08-2 argues, for Page et al. (2010), against the presence of a magnetic white dwarf in the system.

4. Spectral evolution

The spectral evolution of NCyg08-2 is presented in Fig. 5. It covers the period from maximum optical brightness to advanced decline when the nova was well into the nebular stage (later evolutionary stages are covered in Fig. 10). We also collected high resolution observations of the Hα emission line profile at four distinct epochs, and they are presented in Fig. 6. These high resolution Hα will not be discussed in detail in this paper because they are merged into a larger dataset by Ribeiro et al. (submitted for publication) that present a 3D morpho-kinematical model of NCyg08-2 ejecta.

NCyg08-2 displayed strong He and N lines since maximum brightness, with negligible contribution by FeII lines. Following Williams (1992), it thus belong to the "He/N" class of novae. These novae tend to be associated with a younger stellar population, evolve faster, eject less material and harbor more massive white dwarfs than the novae of the "FeII" type. The He/N novae lay closer to the galactic disk than the FeII variant which display an older and more spheroidal spatial distribution, resembling that of the Bulge (e.g. della Valle and Livio, 1998; Shafter, 2008 and references therein). As a He/N nova, NCyg08-2 is unusually high above the galactic plane, it laying at $z = 1.1$ kpc, much larger than the scale height of ⩽100 pc estimated by della Valle and Livio (1998) for He/N novae. Other He/N novae high above the Galactic plane were V477 Sct (=Nova Sct 2005 N2), located at $z = 0.6$ kpc (Munari et al., 2006), or V2672 Oph (=Nova Oph 2009) at $z = 0.8$ kpc (Munari et al., in press).

As typical for very fast novae, NCyg08-2 displayed very broad emission lines and weak P-Cyg absorption components. P-Cyg profiles were last detected on day +11.6 on our spectra, and Table 4 summarizes their properties. From Table 4, the average FWHM of emission components was 4420 km/s and the average velocity shift of the absorption components was −4540 km/s, with however a significant dispersion among different lines. This velocity is far larger than predicted by McLaughlin (1960) relationships for mean velocities of both *principal* and *diffuse enhanced* absorption spectra, which predicts −1650 and −2750 km/s, respectively. Tomov et al. (2008a,b) reported about a possible P-Cyg absorption component in Hβ at −6400 km/s on their low resolution, prismatic spectra for day +2.58, and one at −5350 km/s in Hγ for day +3.71. Our larger resolution, very high S/N spectra for days +1.7 and +4.7 do not show these high velocity absorptions, which could have been either spurious or very short lived. The spectroscopic evolution of NCyg08-2 has been directed toward increasing excitation conditions along the decline from maximum, as normal for novae. On our spectra, HeII 5412 and 4686 Å become visible for the first time on day +21.6, when the nova was $\Delta B = 3.6$ mag down from maximum.

The large optical thickness of Hα during the early outburst phases and the 2nd maximum is illustrated by the great intensity of OI 8446 Å in the spectra of Fig. 5. Its intensity under normal recombination, optically thin conditions should be 0.6 of the OI 7774 line, which is instead far weaker on day +4.62 spectrum and absent on day +21.6 spectrum. The inversion in intensity between the two OI lines is usually associated with fluorescence pumped by absorption of hydrogen Lyman-β photons, as first pointed out by Bowen (1947). For the Lyman-β fluorescence to be effective, the optical depth in Hα should be large, presumably owing to the population of the $n = 2$ level by trapped Lyman-α photons. The $F_{8446}/F_{H\alpha}$ flux ration under optically thin, low ionization

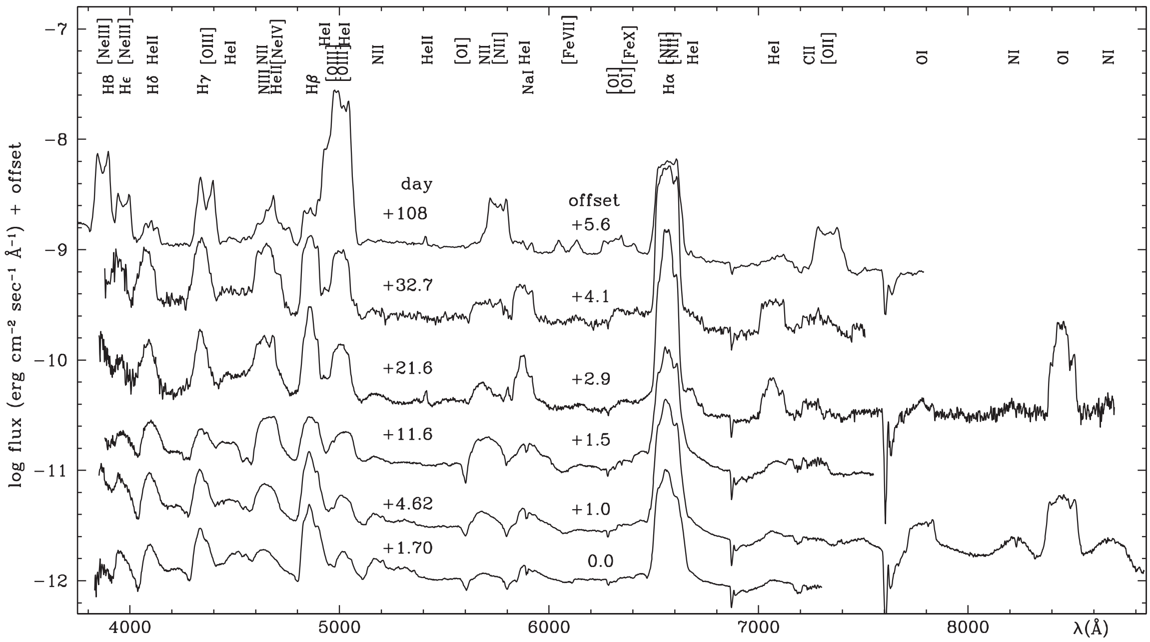

Fig. 5. Spectroscopic evolution of Nova Cyg 2008-2. The spectra are offset for clarity by the indicated quantity. The ordinate scale is logarithmic to emphasize the visibility of weaker features. Fig. 10 presents the spectral appearance of Nova Cyg 2008-2 at later epochs.

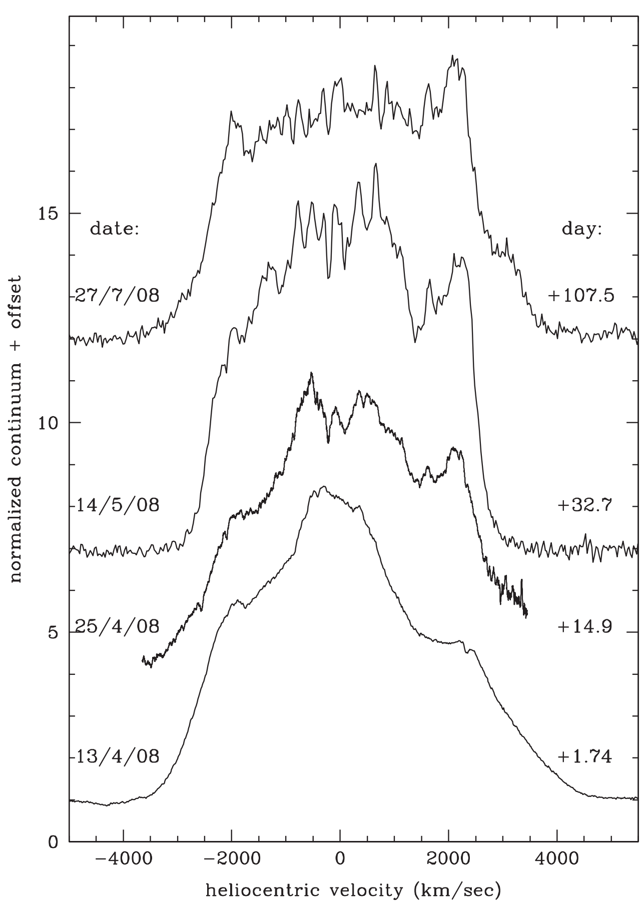

Fig. 6. The evolution of the Hα of Nova Cyg 2008-2 on our high resolution observations (see Table 2).

conditions and typical nova chemical abundances is quite low, $\sim 10^{-3}$ (Strittmatter et al., 1977). On days +4.62 and +21.6, the ratio $F_{8446}/F_{H\alpha}$ was 0.12 and 0.13, respectively.

On day +108 the nova was well into its nebular stage, and all lines of the spectrum in Fig. 5 for that date were displaying a double peaked, saddle-like profile typical of an expanding shell or bi-polar flow. Such a profile for the un-blended [OIII] 4363 Å and [NeIII] 3869 Å lines is presented in Fig. 7, where the velocity separation of the two peaks is 4000 km/s. It is worth to note that this velocity separation for the two peaks of the nebular emission line profiles is the same velocity separation of the shoulders in the Hα emission line profile observed close to optical maximum brightness (cf spectrum for day +1.74 in Fig. 6).

As in most novae, also in NCyg08-2 Hβ evolved un-blended with other major lines during the whole pre-nebular phase. Fig. 8 illustrates the time dependence of its integrated flux, and how it settled onto the dilution t^{-3} time scale as soon as the photometric re-brightening, connected to the 2nd maximum, was over. The same dilution t^{-3} time scale was reached, past 2nd maximum, also by the flux through the *V*-band as illustrated by the lower panel of Fig. 8. Only at later times, the decline of the flux through the *V*-band started to deviate from the t^{-3} slope, because of the increasing contribution from the resumed accretion around the central star (see Section 7) while the ejecta continued to fade away. Fig. 8 also illustrates the evolution of the width of Hβ, plotted as the width at half of peak intensity (somewhat different from the FWHM of the Gaussian fitting to the actual profile). The evolution of the width has been characterized by two distinct slopes (plotted as dashed lines in the top panel of Fig. 8), with the transition between the two occurring at the time of 2nd maximum. During the rise and decline from 2nd maximum, the width of Hβ (and the other lines as well) displayed a single expansion/contraction cycle (the solid line in the top panel of Fig. 8), superimposed on the underlying trend.

The highest ionization line in the nebular spectrum of NCyg08-2 on day +108 was [FeX] 6375 Å. Its intensity is however too low to qualify that spectrum as a “coronal” one. Nevertheless the line is clearly present with a saddle-like profile. Its expansion velocity is ∼1300 km/s, lower than that of the other lines, suggesting an origin in the inner part of the expanding ejecta.

Table 4
Parameters for the absorption lines and the corresponding P-Cyg emission components during early evolution of NCyg08-2.

			Day	+1.7	+4.7	+11.6
Hα	6562.817	abs	$RV_\odot$ (km/s)	−4400	−4590	−4300
			E.W. (Å)	1.6	1.6	1.8
		em	$RV_\odot$ (km/s)	+40	+93	+200
			E.W. (Å)	825	1100	1250
			FWHM (km/s)	4445	4090	4235
Hβ	4861.332	abs	$RV_\odot$ (km/s)	−3980		
			E.W. (Å)	3		
		em	$RV_\odot$ (km/s)	+ 100	+83	+200
			E.W. (Å)	200	188	126
			FWHM (km/s)	4380	4390	5040
Hγ	4340.468	abs	$RV_\odot$ (km/s)	−4040	−4275	−4845
			E.W. (Å)	4	4	5
		em	$RV_\odot$ (km/s)	+85	−75	+ 178
			E.W. (Å)	73	68	66
			FWHM (km/s)	4305	4070	4840
NaI	5892.938	abs	$RV_\odot$ (km/s)	−4620	−4855	
			E.W. (Å)	4	4	
HeI	5875.651	abs	$RV_\odot$ (km/s)	−4820	−4865	
			E.W. (Å)	0.2	0.2	
NII	5684.947	abs	$RV_\odot$ (km/s)	−4290	−4560	−4565
			E.W. (Å)	5	5	8

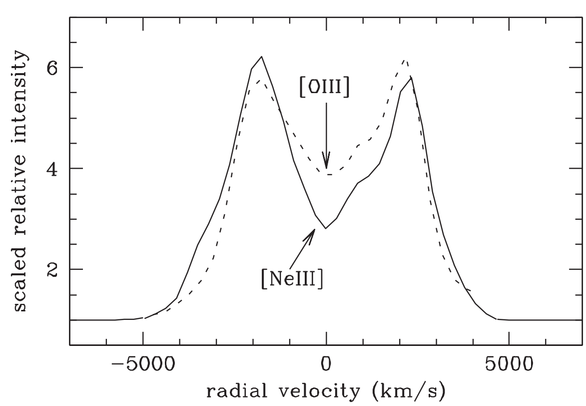

Fig. 7. Profiles of [OIII] 4363 and [NeIII] 3869 emission lines on the July 27, 2008 (day +108) nebular spectrum of Nova Cyg 2008-2.

5. Photo-ionization analysis

A photo-ionization analysis of NCyg08-2 nebular spectrum for day +108 has been performed with the CLOUDY code, version c90 (Ferland et al., 1998), with the emission line fluxes given in Table 5. The geometry modeled by CLOUDY is that of a spherically symmetric shell, with radially variable density and filling factor. Given the emerging complexities of nova ejecta, in particular of the fast novae, with bi-polar structures, equatorial belts, polar cups and jets, diffuse prolate structures etc. (see Ribeiro et al., 2009 for RS Oph; Woudt et al., 2009 for V445 Puppis; Munari et al., in press for V2672 Nova Oph 2009; Ribeiro et al., submitted for publication for V2491 Cyg) the spherical shell geometry adopted by CLOUDY may appear as an over-simplification. The parameters derived by CLOUDY should therefore regarded as first order approximations, useful to frame the overall picture in terms of energetics of the central star, nebula dimension, chemical composition, mass of the ejecta. This is the sense of the photo-ionization analysis carried out in this section.

We assumed a black-body emission for the central star and modeled all lines in Table 5. The density profile of a shell, expanding as $r = vt$, is $\rho(r) \propto r^{-3}$ and we adopted it. This is supported by

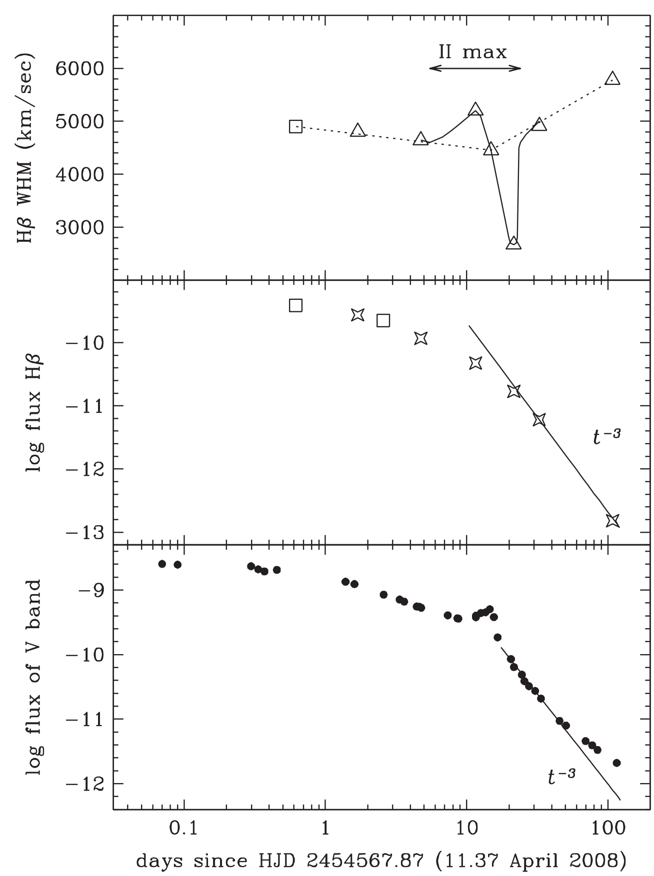

Fig. 8. Evolution of the width at half intensity of the Hβ emission line (top panel), its integrated flux (log of erg cm^{-2} s^{-1} units; middle panel) and integrated flux through the *V*-band (erg cm^{-2} s^{-1} units; lower panel).

the results in Fig. 8. We did not fix inner and outer radii for the ionized shell (r_{in} and r_{out}), and treated them as free parameters along with the covering factor $\omega = \Omega/4\pi$ (which is the fraction of the 4π sr that is covered by gas, as viewed from the location of the central star). Only the abundances of chemical elements with observed

Table 5
Reddening corrected fluxes of the emission lines in the July 27, 2008 (day +108) spectrum of Nova Cyg 2008-2. The last two columns express the fluxes relative to Hβ as observed and as resulting from CLOUDY photo-ionization modeling (see Section 5).

λ_o (Å)	Ion	F_λ^{dered} (erg cm^{-2} s^{-1})	$\frac{F_\lambda^{dered}}{F_{H\beta}^{dered}}$	$\frac{F_\lambda^{cloudy}}{F_{H\beta}^{cloudy}}$
7324	[OII]	4.113E−13	1.22	0.66
6584	[NII]	1.219E−12	3.63	2.57
6563	Hα	9.256E−13	2.76	2.91
6548	[NII]	3.856E−13	1.15	0.87
6374	[FeX]	3.165E−14	0.09	0.20
6364	[OI]	3.728E−14	0.11	0.01
6300	[OI]	1.126E−13	0.34	0.03
6087	[FeVII]	9.495E−14	0.28	0.11
5876	HeI	1.674E−14	0.05	0.02
5755	[NII]	8.053E−13	2.40	0.67
5412	HeII	1.003E−14	0.03	0.05
5007	[OIII]	9.740E−12	29.90	34.97
4959	[OIII]	2.972E−12	9.12	12.11
4861	Hβ	3.359E−13	1.00	1.00
4720	[NeIV]	6.940E−14	0.20	0.33
4686	HeII	3.000E−13	0.89	0.66
4363	[OIII] + Hγ	1.331E−12	3.96	2.76
4101	Hδ	2.268E−13	0.68	0.27
3968	[NeIII] + Hϵ	7.398E−13	2.20	1.93
3869	[NeIII]	2.545E−12	7.58	5.81

lines were allowed to change, and all others were kept fixed to their solar value. The fluxes of the emission lines as resulting from the CLOUDY modeling are listed in Table 5 together with their observed values. The overall χ^2 of the model is 43.7, or 18.0 if [OIII] 5007 is ignored. Table 6 summarizes the modeling results and Table 7 provides the chemical mass fractions.

The shell of ionized gas at day +108 appears to extend from r_{in} = 85 to r_{out} = 180 AU. Both the inner and outer radii are density boundaries (no neutral matter external to the shell). These radii correspond to expansion velocities of ~1350 and 2900 km s^{-1}, respectively. The velocity at the inner radius nicely fits that observed for [FeX] (1300 km s^{-1}), at the outer border the velocity observed for [NII] (2750 km s^{-1}), and the mean value matches the ~2000 km s^{-1} observed for [OIII] and [NeIII] lines (cf Fig. 7).

The central ionizing source is found to have a radius R = 0.006 R$_\odot$, a temperature $T_{\rm eff}$ = 370,000 K, and therefore a luminosity 650 L$_\odot$, corresponding to $M_{\rm bol}$ = −2.3. Both the radius and the luminosity are smaller than expected during the constant-luminosity phase of fast novae (Starrfield, 1989; Krautter, 2008), indicating that by day +108 the stable H-burning at the surface of white dwarf was concluded. This is in agreement with evidences from X-ray observations that place the end of the stable H-burning phase of NCyg08-2 around day +42, according to Page et al. (2010), or day +50 following Hachisu and Kato (2009).

Table 6
Parameters of the CLOUDY model best fitting the de-reddened emission line ratio of Table 5. From top to bottom: temperature, radius and luminosity of the central black-body source; inner and outer radii of the emitting shell; hydrogen density; electronic density and temperature at the inner and outer radii; covering factor; and element.

$\log T_{BB}^{eff}$ (K)	5.57	ω	0.22
$\log R_{BB}$ (cm)	8.63	H/H$_\odot$	0.60
$\log L_{BB}$ (erg/s)	36.40	He/He$_\odot$	0.75
$\log r_{\rm in}$ (cm)	15.11	N/N$_\odot$	59
$\log r_{\rm out}$ (cm)	15.43	O/O$_\odot$	4.3
$\log \rho_{\rm H}^{in}$ (cm^{-3})	6.28	Ne/Ne$_\odot$	6.5
$\log N_{\rm e}^{in}$ (cm^{-3})	6.36	Fe/Fe$_\odot$	0.6
$\log T_{\rm e}^{in}$ (K)	4.28		
$\log \rho_{\rm H}^{out}$ cm^{-3})	5.32		
$\log N_{\rm e}^{out}$ (cm^{-3})	5.31		
$\log T_{\rm e}^{out}$ (K)	4.07		

Table 7
Mass-fraction abundances of measured elements in Nova Cyg 2008 N.2 and, for reference, in the Sun.

	NCyg	Sun		NCyg	Sun
X	0.573	0.704	N	0.074	0.001
Y	0.287	0.279	0	0.049	0.008
Z	0.140	0.017	Ne	0.0147	0.0017
			Fe	0.0010	0.0013

5.1. Mass in the shell

The hydrogen mass fraction in the ionized shell is X = 0.543, and the covering factor is ω = 0.22. Therefore, the total gas mass within the ionized shell is

$$M_{shell} = \frac{\omega}{X}\int_{r_{in}}^{r_{out}} 4\pi r^2 \rho_{\rm H}(r)\,dr = 5.3\times10^{-6}\ {\rm M}_\odot \quad (4)$$

This is very close to the range of ejected mass (from 2.0 to 1.5 × 10^{-5} M$_\odot$) predicted by various authors (Politano et al., 1995; Starrfield et al., 1998, 2008) for a WD mass of 1.25 M$_\odot$. Hachisu and Kato (2009) estimated a mass of 1.3 M$_\odot$ from fitting their models to the light-curve of NCyg08-2. This is in agreement with all physical models of nova explosion that predict the a mass of the white dwarf closer to the Chandrasekhar limit with decreasing speed classes t_2 and t_3 (Starrfield, 1989).

The kinetic energy of the ejected shell is

$$E_{kin} = \frac{\omega}{X}\int_{r_{in}}^{r_{out}} 2\pi r^2 \rho_H(r)\left(\frac{r}{t}\right)^2 dr = 5.6\times10^{44}\ {\rm ergs} \quad (5)$$

where the velocity of the ejecta is taken to be $v(r) = r/t$ which is consistent with an ejection over a short period of time around t = 0.

The outburst had also to provide the energy to unbound the ejected material from the WD gravitational field. For a white dwarf of 1.3 M$_\odot$ and $M_{\rm shell}$ = 1.6 × 10^{-5} M$_\odot$ ejecta, the binding energy is

$$E_{bin} = G\frac{M_{\rm WD}M_{ej}}{R_{\rm WD}} = 6.0\times10^{45}\ {\rm ergs} \quad (6)$$

The mechanical energy released by the outburst ($E_{\rm bin} + E_{\rm kin}$) corresponds to the hydrogen burning of 7.0 × 10^{-7} M$_\odot$ of accreted matter of solar composition, which is about 13% of the mass in the ejected shell.

5.2. Chemical abundances

The chemical mass fractions of NCyg08-2 given in Table 7 reflect the non-equilibrium CNO-cycle burning of hydrogen (see Gehrz et al., 1998; Hernanz, 2005), with over-abundance of nitrogen and oxygen (no abundance for carbon was derived because the spectrum at day +108 does not display measurable lines of carbon ions, and none was expected to be visible given the prevailing excitation conditions). The abundance derived for iron, which is not produced by the TNR, corresponds to a metallicity for the accreted material of [Fe/H] = −0.25. The sub-solar value agrees with expected mean ambient metallicity for the Galactic disk (−0.5 ⩽ [Fe/H] ⩽ −0.3, Maciel and Costa, 2009) at the galacto-centric distance (13 kpc) of NCyg08-2, and well within the local dispersion around the mean value.

There is a clear over-abundance of neon in the ejecta of NCyg08-2. This element is not produced during the nuclear runaway, but comes from mixing into the accreted envelope of material from the underlying massive white dwarf. In massive progenitors of white dwarfs, non-degenerate carbon ignition leads to the formation of a degenerate core mainly made of oxygen and neon. The minimum mass on the zero age main sequence leading to extensive carbon-burning is $M \sim 9.3\ M_{\odot}$ and the resulting white dwarf will have a mass of $M_{WD} \geqslant 1.1\ M_{\odot}$ (e.g. Gil-Pons et al., 2003). The observed over-abundance of neon thus confirms the evidences for a massive white dwarf in NCyg08-2 as inferred by the He/N classification, the rapid decline and small amount of ejected mass.

Hachisu and Kato (2009) fitted the light-curve of NCyg08-2 with one of their wind models characterized by the mass fractions $X = 0.20$, $Y = 0.48$, $Z = 0.32$, X (CNO) = 0.20, X (Ne) = 0.10 and X (others) = 0.02 for the sum of all remaining metals. These mass fractions are not reconciliable with our results in Table 7. We tried to fit the observed spectra by adopting the mass fractions suggested by Hachisu and Kato (2009), but we were not able to achieve a satisfactory matching with observations.

6. The progenitor and the remnant

We have re-observed NCyg08-2 on 31 July 2009 and 21 July 2010 with the AFOSC spectrograph + imager mounted on the Asiago 1.82 m telescope. These late visits at days t = +477 and +831 aimed to verify the identification of the progenitor and the remnant, if the nova had returned to quiescent brightness, and if accretion had resumed.

The identification and brightness of the progenitor of NCyg08-2 has been matter of discussion. IAUC 8934 listed various sources of measurement of the nova astrometric position, which differ by several arcsec, and reported conflicting identification with different USNO-B1.0 catalogue stars. Jurdana-Sepic and Munari (2008) soon after the discovery of the nova examined historical plates from the Asiago Schmidt telescopes plate archive. Their measured the only star visible at the position of the nova and compatible with the available astrometric positions. They found this star stable over the period 1970–1986 around mean values $\langle V \rangle = 17.06$ and $B - V = +0.82$.

A serendipitous monitoring of the field of NCyg08-2 was carried out by Balman et al. (2008) from July to November 2007. They reported that the monitoring failed to reveal any source at the nova position brighter than the $R_C = 18.2$ mag limiting magnitude of their observations. Balman et al. do not specify what is the astrometric position they assumed for the nova. They linked their unfiltered CCD observations to the magnitude scale to USNO-B1 R_C of surrounding stars. By comparing with the Henden and Munari (2008) photometric sequence, no systematic offset larger than 0.1 mag is likely to affect USNO-B1 R_C values for the region of sky surrounding NCyg08-2.

Fig. 9 compares our AFOSC I_C-band image from 31 July 2007 with the corresponding Palomar SDSS-II observation (obtained on 25 May 1989). The nova progenitor is barely perceptible on the SDSS-II image. On the AFOSC I_C-band image the nova and three nearby stars are identified, for which we have derived the following values: a star $V = 15.40$, $B - V = +1.55$, $V - R_C = +0.84$, $V - I_C = +1.50$; b star $V = 17.03$, $B - V = +0.83$, $V - R_C = +0.58$, $V - I_C = +1.15$, and c star $V = 19.03$, $V - R_C = +0.74$ and $V - I_C = +1.44$.

The values for star b are identical to those found by Jurdana-Sepic and Munari (2008). This indicates that the star they assumed could be the progenitor is indeed the field star b in Fig. 9. The true progenitor was too faint to be recorded by the Asiago Schmidt plates (limiting B magnitude typically between 18.0 and 18.5). The progenitor is catalogued as USNO-B1.0 1223-0482965 and it has no 2MASS counterpart. The USNO-B1.0 magnitudes appear unreliable for the stars in the immediate vicinity and for the progenitor itself, most probably an effect of the crowding in the field. For ex., contrary to evidence from direct inspection of the SDSS plates and results of CCD observations, the USNO-B1.0 catalogue gives the same $B \sim 16.2$ mag for both a and b stars, instead of respectively, $B = 16.95$ and $B = 17.86$. We have then estimated directly on Palomar SDSS-II images the brightness of the nova progenitor and found: $B \sim 18.3$, $R_C \sim 17.4$, $I_C \sim 16.9$ (uncertainties $\pm$ 0.2 mag). On AFOSC images for 31 July 2009 the nova shined at $V = 17.44$, $R_C = 17.06$ and $I_C = 16.73$, and $V = 17.88$, $R_C = 17.49$ and $I_C = 17.14$ on 21 July 2010 (uncertainties $\pm$ 0.03 mag). Thus, at the time of the photometric and spectroscopic observations on days +477 and +831 the nova had returned to a brightness close to that of quiescence. Finally, it has to be noted that Balman et al. (2008) report that the progenitor was fainter than 18.2 in R_C band in 2007 is equivalent to say that it was fainter than star c in Fig. 10. This was not the case at the time of the Palomar SDSS-II R_C image in Fig. 9.

7. Resuming the accretion

The spectrum of NCyg08-2 on day +477, at a time when the nova had already returned close to quiescence brightness, is presented in Fig. 10. It is characterized by a hot continuum and high excitation emission lines, with the intensity of HeII 4686 Å slightly larger than that of Hβ.

Two sets of lines are simultaneously present on the day +477 spectrum: (1) nebular lines from highly diluted, distant and expanding material, and (2) permitted lines from resumed accretion.

The first type of lines is exemplified by the saddle-like profiles of [OIII] 4959, 5007 Å lines. The inset of Fig. 10 illustrates the de-convolution of the [OIII] 4959, 5007 blend with two individual saddle-like profiles characterized by a velocity separation of

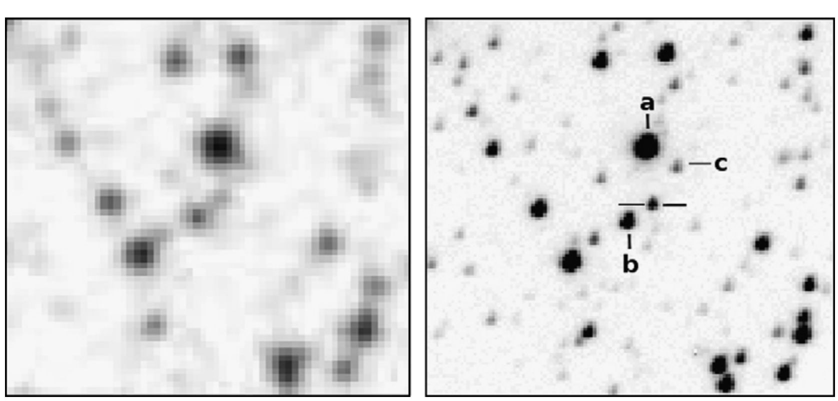

Fig. 9. Comparison between the appearance in I band of the nova progenitor on SDSS-II (plate exposed on May 25, 1989; left panel), and on our CCD observations for 31 July 2009 (day +477), at the time of the spectrum in Fig. 10, when the nova had returned to a brightness equivalent to quiescence.

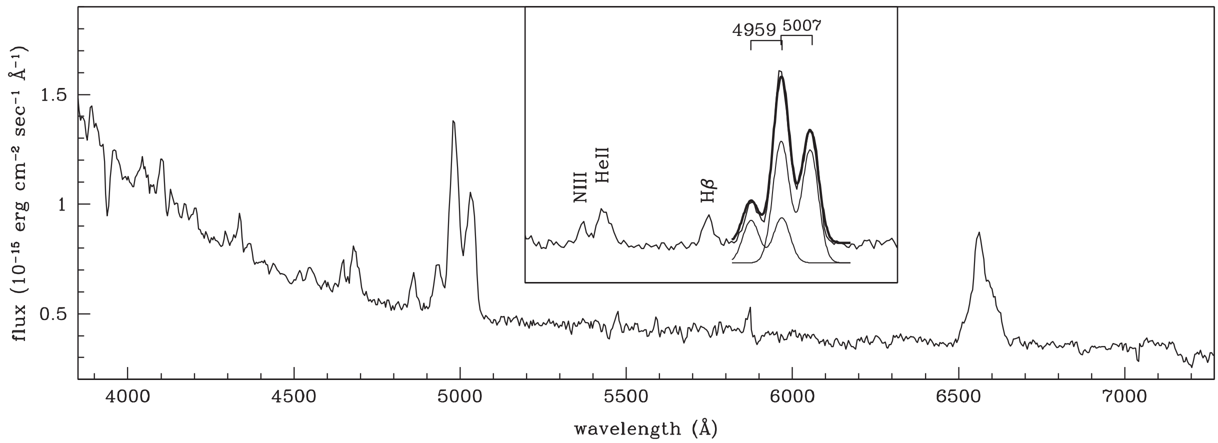

Fig. 10. The spectrum of Nova Cyg 2008-2 on 2009 Jul 31 (day +477), at the time of the photometric observations of Fig. 9. The inset shows the decomposition of the [OIII] 4959, 5007 Å saddle-like profile (see text).

3050 km/s of the two peaks. A similar de-convolution with a similar velocity separation works well for the [NII] 6548, 6584 Å blend, with in addition a single-peaked Hα component superimposed. At the time of the nebular spectrum for day +108 in Fig. 5, the velocity separation of the two peaks of the saddle-like profile of [OIII] lines was 4000 km/s. Thus, in the intervening year, (i) the expansion of the ejecta has been either slowed down or (ii) the emission from [OIII], [NII] lines at day +477 came from more internal and therefore slower layers than [OIII], [NeIII] at day +108 in Fig. 7. The first possibility requires a large deceleration of the ejecta and is not plausible. Supposing that (a) this occurred at a uniform rate in the time interval between day +108 and +477, and that (b) it involved the whole ejected shell, then the energy radiated by the associated shock front would have been $\sim 1.7 \times 10^{44}$ erg for a mean luminosity of 5.5×10^{36} erg/s $\equiv$ 1400 $L_{\odot}$. Considering that the temperatures associated to shock fronts bring the peak of the emitted energy into the most energetic part of the electromagnetic spectrum, NCyg08-2 should have been a very bright and a very hard X-ray source during the time interval between day +108 and +477, contrary to evidence from the Swift observations by Page et al. (2010) that extend to day +236. The second possibility is instead in line with the fact that the emissivity of lines depend from electron density, which declines as r^{-3}, thus faster in the outer ejecta that expand at higher velocities. A noisy spectrum obtained one year later, on day +862, shows that the [OIII] lines – so prominent on the day +477 spectrum of Fig. 10 – have disappeared, and those of [NII] appreciably reduced, as expected from dissolving ejecta and cooling central source.

The second type of lines visible on the day +477 spectrum of Fig. 10, which are characterized by a single-peaked and sharp profile, is composed by hydrogen Balmer series, HeI, HeII and NIII. These lines and the hot underlying continuum closely resemble those of cataclysmic variables, close matches being for example the spectra of BO Cet (Zwitter and Munari, 1995) or that of the old novae RR Pic (Williams and Ferguson, 1983) and HR Del (Munari et al., 1997). This close similarity with CV spectra supports the idea that accretion had already resumed at day +477 on NCyg08-2. The short time scale flickering of X-ray emission detected by Page et al. (2010) in NCyg08-2 at advanced evolutionary phase, when the hydrogen burning and super-soft phase was already over, is also supporting the fact that NCyg08-2 had resumed accretion at the time of our day +477 spectroscopic observation.

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References

Ashok, N.M., Banerjee, D.P.K., Joshi, V., et al., 2008. CBET 1354.
Ayani, K., Matsumoto, K., 2008. CBET 1334.
Balman, S., Pekon, Y., Kiziloglu, U., 2008. ATel 1504.
Beize, J., 2008. IAUC 8934.
Bowen, I., 1947. PASP 59, 196.
Brand, J., Blitz, L., 1993. A&A 275, 67.
Buscombe, W., de Vaucouleurs, G., 1955. Obs 75, 170.
Capaccioli, M., della Valle, M., d'Onofrio, M., Rosino, L., 1989. AJ 97, 1622.
Cohen, J.G., 1988. ASF Conf. Ser. 4, 114.
della Valle, M., Livio, M., 1998. ApJ 506, 818.
Duerbeck, H.W., 1981. PASP 93, 165.
Ferland, G.J., Korista, K.T., Verner, D.A., et al., 1998. PASP 110, 761.
Gehrz, R.D., Truran, J.W., Williams, R.E., Starrfield, S., 1998. PASP 110, 3.
Gil-Pons, P. et al., 2003. A&A 407, 1021.
Hachisu, I., Kato, M., 2009. ApJ 694, L103.
Helton, L.A., Woodward, C.E., Vanlandingham, K., et al., 2008. CBET 1379.
Henden, A., Munari, U., 2008. IBVS 5834.
Hernanz, M., 2005. ASPC 330, 265.
Hernanz, M., Sala, G., 2002. Science 298, 393.
Ibarra, A., Kuulkers, E., 2008. ATel 1473.
Ibarra, A., Kuulkers, E., Beardmore, A., et al., 2008. ATel 1478.
Ibarra, A., Kuulkers, E., Osborne, J.P., et al., 2009. A&A 497, L5.
Jurdana-Sepic, R., Munari, U., 2008. IBVS 5839.
Krautter, J., 2008. In: Bode, M.F., Evans, A. (Eds.), Classical Novae. Cambridge Univ. Press, p. 232.
Kuulkers, E., Ibarra, A., Page, K.L., et al., 2008. ATel 1480.
Livingston, W.C., 2000. In: Cox, A.N. (Ed.), Allen's Astrophysical Quantities, fourth ed. Springer, p. 339.
Lynch, D.K., Russell, R.W., Rudy, R.J., et al., 2008. IAUC 8935.
Maciel, W.J., Costa, R.D.D., 2009. In: Cunha, K. et al. (Eds.), Chemical Abundances in the Universe, IAU Symp., vol. 265, p. 317.
McLaughlin, D.B., 1960. In: Greenstein, J.L. (Ed.), Stellar Atmospheres. Univ. Chicago Press, p. 585.
Munari, U., Zwitter, T., 1997. A&A 318, 269.
Munari, U., Zwitter, T., Bragaglia, A., 1997. A&AS 122, 495.
Munari, U., Siviero, A., Navasardyan, H., Dallaporta, S., 2006. A&A 452, 567.
Munari, U., Henden, A., Valentini, M., et al., 2008a. MNRAS 387, 344.
Munari, U., Siviero, A., Henden, A., et al., 2008b. A&A 492, 145.
Munari, U., Frigo, A., Siviero, A., submitted for publication. PASP.
Munari, U., Henden, A., Valisa, P., Dallaporta, S., Righetti, G.L., 2010b. PASP 122, 898.
Munari, U., Ribeiro, V.A.R.M., Bode, M., Saguner, T., 2010. MNRAS, in press. <arXiv:1009.0334M>.
Naik, S., Banerjee, D.P.K., Ashok, N.M., 2009. MNRAS 394, 1551.
Nakano, S., 2008. IAUC 8934.
Ness, J.-U., Starrfield, S., Gonzalez, R., et al., 2008a. ATel 1561.
Ness, J.-U., Starrfield, S., Gonzalez, R., et al., 2008b. ATel 1573.
Osborne, J.P., Page, K.L., Evans, P.A., et al., 2008. ATel 1542.
Page, K.L., Osborne, J.P., Evans, P.A., et al., 2008. ATel 1523.
Page, K.L., Osborne, J.P., Evans, P.A., Wynn, G.A., Beardmore, A.P., Starling, R.L.C., Bode, M.F., Ibarra, A., Kuulkers, E., Ness, J.-U., Schwarz, G.J., 2010. MNRAS 401, 121.
Pejcha, O., 2009. ApJ 701, L119.
Politano, M., Starrfield, S., Truran, J.W., et al., 1995. ApJ 448, 807.
Ribeiro, V.A.R.M. et al., 2009. ApJ 703, 1955.
Ribeiro, V.A.R.M., Bode, M., Munari, U., et al., submitted for publicaiton. A&A.

Rudy, R.J., Lynch, D.K., Russell, R.W., et al., 2008. IAUC 8938.
Savage, B.D., Sembach, K.R., 1996. ARA&A 34, 279.
Shafter, A.W., 2008. In: Bode, M.F., Evans, A. (Eds.), Classical Novae. Cambridge Univ. Press, p. 335.
Starrfield, S., 1989. In: Bode, M.F., Evans, A. (Eds.), Classical Novae. Wiley, p. 39.
Starrfield, S., Truran, J.W., Wiescher, M.C., Sparks, W.M., 1998. MNRAS 296, 502.
Starrfield, S., Iliadis, C., Hix, W.R., 2008. In: Bode, M.F., Evans, A. (Eds.), Classical Novae. Cambridge Univ. Press, p. 77.
Strittmatter, P.A. et al., 1977. ApJ 216, 23.
Takei, D., Tsujimoto, M., Kitamoto, S., et al., 2009. ApJ 697, L54.
Takei, D., Ness, J.-U., 2010. AN 331, 183.
Tomov, T., Mikolajewski, M., Ragan, E., et al., 2008a. ATel 1475.
Tomov, T., Mikolajewski, M., Brozek, T., et al., 2008b. ATel 1485.
van den Bergh, S., Younger, P.F., 1987. A&AS 70, 125.
Warner, B., 1995. Cataclysmic Variable Stars. Cambridge University Press.
Welsh, B.Y., Lallement, R., Vergely, J.-L., Raimond, S., 2010. A&A 510, A54.
Williams, R.E., Ferguson, D.H., 1983. In: Livio, M., Shaviv, G. (Eds.), IAU Coll. 72, Cataclysmic Variables and Related Objects, p. 97.
Williams, R.E., 1992. AJ 104, 725.
Woudt, P.A., Steeghs, D., Karovska, M., Warner, B., Groot, P.J., Nelemans, G., Roelofs, G.H.A., Marsh, T.R., Nagayama, T., Smits, D.P., O'Brien, T., 2009. ApJ 706, 738.
Zwitter, T., Munari, U., 1995. A&AS 114, 575.