

Research Note

Spectroscopy and $UBVR_J$ - $JHKLM$ photometry of Nova Cassiopeiae 1995: the first 210 days

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Abstract. The results of spectroscopic and $UBVR_J$ - $JHKLM$ photoelectric monitoring of the peculiar Nova Cassiopeiae 1995 during the first 210 days of the eruption are presented and briefly discussed. We found a total amplitude of $\Delta B=11.4$ mag, a reddening $E_{B-V}=0.45$ and no evidence for significant mass loss. The nova is still around maximum brightness seven months after onset of the outburst.

Key words: stars: individual (Nova Cas 1995) – stars: novae

1. Introduction

Nova Cassiopeiae 1995 was discovered on August 24, 1995 by Yamamoto (1995) at $V=9.2$ mag. Early low resolution spectra obtained by Ohshima et al. (1995), Iijima & Rosino (1995) and Della Valle et al. (1995) show prominent H I and Fe II emission lines on top of a blue continuum. The photometric behaviour, the satellite ultraviolet spectra (Gonzalez-Riestra et al. 1996, hereafter GR96) and line profiles evolution on high resolution Echelle+CCD spectra (Munari et al. 1995, Munari 1996) all show the peculiarity of this very slow and large amplitude nova, still fluctuating around maximum more than half a year after the onset of the outburst.

In this paper we present in graphical form the results of our spectroscopic and photometric monitoring covering the first 210 days of the nova evolution. We plan to follow the nova

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evolution in coming observing seasons and publication of data in numerical form is postponed to a future paper.

2. Observations

$UBVR_J$ data have been collected with: (a) the 0.45 m reflector of the Associazione Friulana di Astronomia e Meteorologia, (b) the Sternberg Astronomical Institute (SAI) 0.60 m reflector in Crimea, (c) the SAI 0.70 m reflector in Moscow, and (d) the 1.0 m reflector at the Tien-Shan High-Altitude Observatory (Kazakhstan). Internal errors in $UBVR_J$ are generally ≤ 0.02 mag and do not exceed 0.04 mag at all sites. The same comparison stars have been used at all sites: BD+53.216 ($V=9.59$, $B-V=0.11$, $U-B=-0.24$, $V-R_J=0.15$) and BD+53.222 ($V=9.91$, $B-V=0.24$, $U-B=+0.16$, $V-R_J=0.19$).

$JHKLM$ photometry has been secured with the SAI 1.25 m telescope in Crimea. The internal errors do not exceed 0.03 mag in JHK , and tend to increase at L and M due to the nova faintness at these wavelengths. The adopted comparison star is HR 464 ($J=1.55$, $H=0.95$, $K=0.82$, $L=0.67$, $M=0.96$).

High (range 3500-8700 Å, resolution from 0.2 to 0.5 Å) and low resolution spectra (range 3200-7600 Å, resolution 17 Å) have been obtained on several dates with the Echelle+CCD and B&C+CCD spectrographs mounted on the 1.82 m telescope operated by Osservatorio Astronomico di Padova on top of Mt.Ekar (Asiago, Italy).

3. Evolution

The flare which peaked at JD=2450069 (Dec 17, 1995) divided the evolution of the nova into two distinct phases.

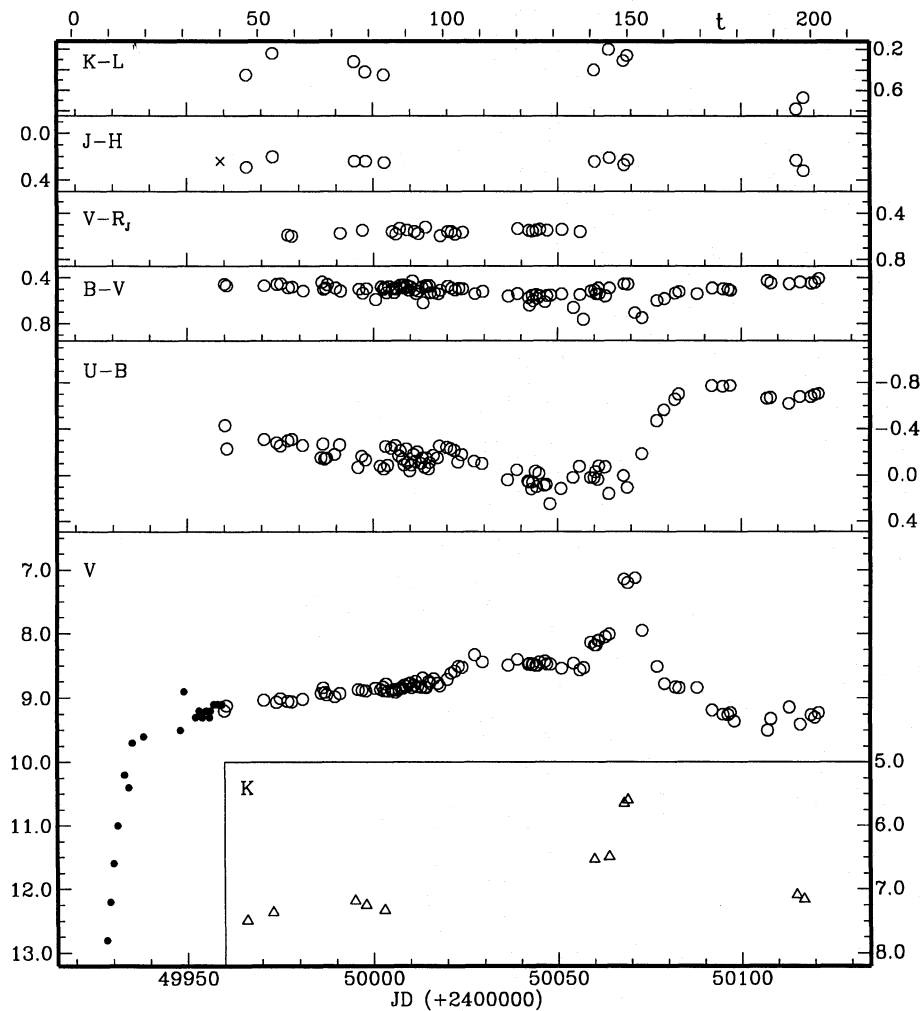


Fig. 1. *UBVR - JHKLM* lightcurves of Nova Cas 1995 during the first 210 days since onset of the outburst. The step in the ordinate scale is the same in all color panels. *V* and *K* lightcurves are plotted on a common scale. *Filled circles* = daily averages of data collected from IAU Circulars or amateur astronomers estimates circulated on World Wide Web; *open circles* and *triangles* = our photoelectric data; *cross* = from Woodward et al. (1995).

3.1. Pre-flare

On POSS prints we have measured the magnitude of the nova precursor against a faint comparison sequence that we have calibrated with the photoelectric photometer at the 1.0 m telescope in Kazakhstan. The precursor has been found to have $B=19.0$ (± 0.2) and to be on the red POSS plate ~ 2 mag fainter than a nearby star which has $V=16.89$ and $R=15.48$.

We began to observe the nova a few days after discovery and the data we have collected are plotted in Fig. 1. For sake of completeness, a few earlier *V* observations as appeared in the IAU Circulars and circulated on *World Wide Web* have been daily averaged and included in Fig. 1. The nova has shown a steady brightening amounting to 0.6 mag day^{-1} during the rise to maximum. Extrapolating this back to the quiescence brightness sets the date for the onset of the outburst to

$$t_0 = 2449919 \quad (\equiv \text{Jul. 20, 1995}) \quad (1)$$

This corresponds to day 0 at the top of Fig. 1. The nova took 15 days to enter the long lasting maximum. For $15 \leq t \leq 100$ the nova stayed on a plateau characterized by a leisurely and very smooth brightening by 0.0064 mag day^{-1} . During this phase all colors remained constant with the exception of *U - B*

which reddened from -0.33 to -0.12 . The colors match those of a mid-F supergiant with $E_{B-V} \sim 0.4$ mag. During the interval $100 \leq t \leq 138$ the nova passed through a minor flaring of 0.3 mag and subsequent 0.1 mag decrease, which had no effect on colors, except *U - B* which continued the previous reddening trend with a shift of -0.1 mag.

Our low resolution, pre-flare spectra are dominated by a mid-F supergiant continuum with weak emission lines ($H\alpha$ is in moderate emission but high Balmer lines appear in pure absorption). With passing time, the Balmer continuum from marginal emission changes to deeper and deeper absorption and the absolute intensity of the emission lines decrease, with no changes in the ionization or excitation degrees.

All line profiles are composed of a narrow ($\text{FWHM} \sim 87$ km sec^{-1} , $\text{RV}_{\odot} \sim 41$ km sec^{-1}) emission with on the blue wing a sharper absorption component ($\text{FWHM} \sim 60$ km sec^{-1} , $\text{RV}_{\odot} \sim 148$ km sec^{-1}). Ca II H&K and Na I D doublet lines present strong interstellar absorptions, having a $\text{FWHM} = 30 \pm 2$ km sec^{-1} and a heliocentric radial velocity of $\text{RV}_{\odot} = -23 \pm 2$ km sec^{-1} (GR96 found -15 km sec^{-1} on IUE spectra). The equivalent widths of the interstellar D1 and D2 sodium lines are $0.75(\pm 0.05)$ and $0.62(\pm 0.01)$ Å, respectively. Comparing

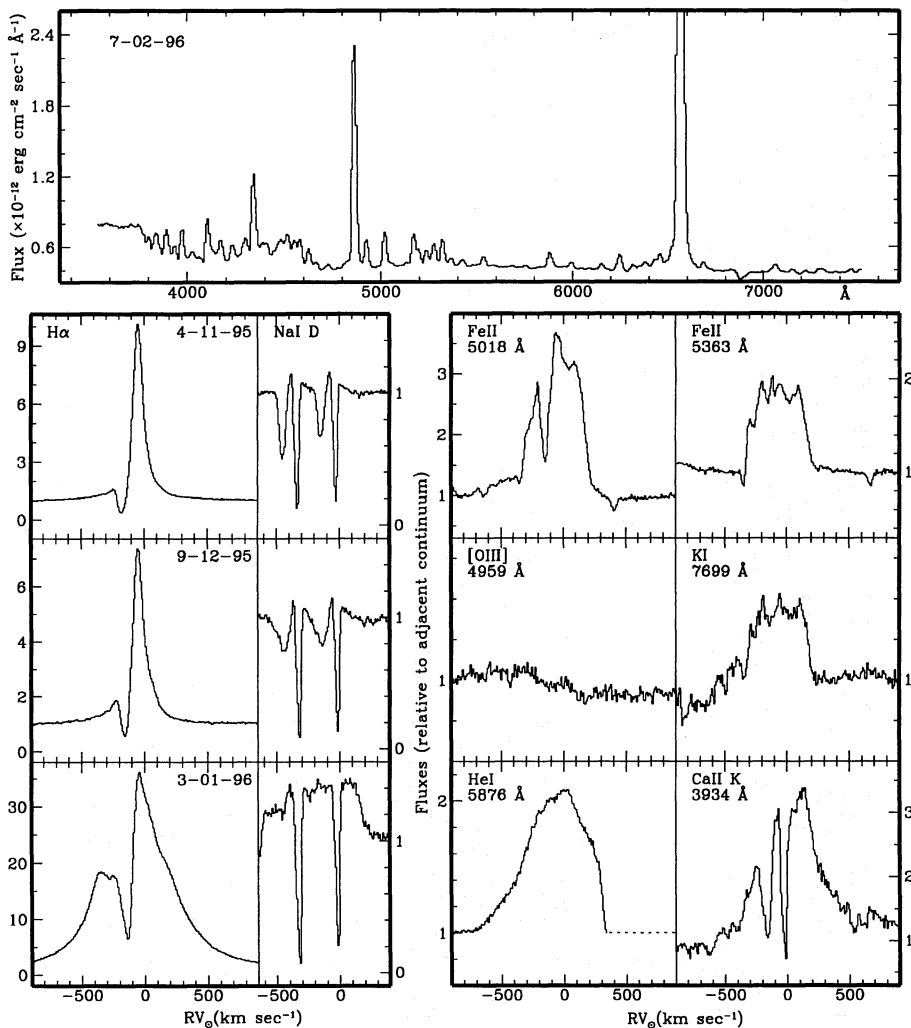


Fig. 2. Samples of spectrophotometric data. *Upper panel:* B&C+CCD low resolution spectrum secured on Feb. 7, 1996 ($t = 202$). The fluxes are in units of 10^{-12} erg cm^{-2} sec^{-1} \AA^{-1} . *Lower left panel:* evolution of the $\text{H}\alpha$ and Na I D doublet profiles from Echelle+CCD spectra secured on Nov 4, 1995 ($t = 107$), Dec 12, 1995 ($t = 142$) and Jan 3, 1996 ($t = 167$). The fluxes are normalized to the adjacent continuum and the abscissae are heliocentric radial velocities (in km sec^{-1}). *Lower right panel:* profiles of selected emission lines from Echelle+CCD observations on Jan 3, 1996 ($t = 167$). The [OIII] 4959 \AA region is presented to document the absence of the line and the portion of the spectrum longward of He I 5876 \AA is omitted being dominated by the Na I D profile. The profiles are not influenced by the instrumental width which is ~ 12 km sec^{-1} .

with the calibration by Munari & Zwitter (1996) for the same instrumental set-up and noting that K I 7699 \AA does not show the interstellar absorption, a reddening of

$$E_{B-V} \sim 0.45 \text{ mag} \quad (2)$$

may be estimated (GR96 derived $E_{B-V} = 0.6$ from IUE observation of the 2200 \AA interstellar *hump*). Given the relatively large galactic latitude ($|b| = 9^\circ$), such a reddening suggests a distance to the nova of several kpc.

3.2. Flare and subsequent evolution

During $138 \leq t \leq 160$ a major flare brought the nova from $V = 8.6$ to $V = 7.1$ (at a mean rate of 0.07 mag day^{-1}) and then back to $V = 8.8$. The colors passed the event unaffected, with the remarkable exception of $U - B$ which started to get bluer at flare maximum, rapidly decreasing from $+0.1$ to -0.8 mag. The total amplitude of the outburst (comparing quiescence with the flare) is:

$$\Delta B = 11.4 \text{ mag} \quad (3)$$

Following $t \geq 160$ evolution has been characterized by the nova resuming the long term trend of the plateau at maximum, with some fluctuation in brightness and constant colors.

The post-flare spectra show an increase of several times of the emission line intensity (cf. $\text{H}\alpha$ and Na I D lines in Fig. 2), with the Balmer continuum jumping into strong emission. The appearance at the same time of strong emissions by Ca II H&K, Na I D and He I, with continuum colors ($B - V$, $J - H$) staying constant, suggests that the photospheric temperature did not change, and visibility of He I lines is a mere result of a general increase of the emission line intensities. At time $t = 202$ nebular lines are still undetected.

Line profiles changed remarkably as well. All emission components increased their FWHM to ~ 550 km sec^{-1} , without detectable RV_\odot changes. The absorption components, on the contrary, maintained the same FWHM, RV_\odot and equivalent width compared with pre-flare conditions. Only in the case of the Na I D doublet the stellar absorption component has disappeared after the flare.

4. Conclusions

The nova is characterized by three distinct regions: (a) the *photosphere*, a real one, not the matter/radiation de-coupling boundary in an expanding envelope. The photosphere did not change the temperature throughout the protracted maximum and the JD=2450069 flare; (b) an extended atmosphere, where emission lines and Balmer continuum form. The volume emission measure of the atmosphere dramatically increased after the flare, due to some optically thin mass injection from the underlying photosphere. The blown material however did not dilute outwardly; and (c) a stable, moderate excitation, kinematically cool and external inverting layer, which seems to have passed unaffected the flare event (no significant change in the excitation/ionization conditions). This may suggest that no matter lost by the photosphere reached escape velocities and collided/mixed with the inverting layer.

Nova Cas 1995 has some resemblance with HR Del but also with symbiotic novae like PU Vul. To assess if it is a close binary with a cool dwarf like HR Del, or a wider pair harboring a cool giant, necessitate more observations during the advanced decline from maximum. The faintness in quiescence however does not seem to favor the symbiotic nova option, unless the cool component was heavily obscured by circumstellar dust.

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