QUANTITATIVE ANALYSIS OF THE V838 MONOCEROTIS SPECTRUM

B. Kaminsky, Ya. V. Pavlenko

Main Astronomical Observatory, NAS of Ukraine
27 Akademika Zabolotnoho Str., 03680 Kyiv, Ukraine
e-mail: bogdan@mao.kiev.ua

We present the determination of the effective temperature, iron abundance, and microturbulent velocities for the pseudophotosphere of V838 Mon observed on February 25, March 2 and 26, 2002. Physical parameters of the line forming region were obtained in the framework of a self-consistent approach using fits of synthetic spectra to observed spectra in the wavelength range 5500–6700 Å. We obtained the values of $T_{\rm eff}$ 5330 ± 150 K, 5540 ± 150 K, and 4960 ± 150 K for February 25, March 2, and March 26, 2002, respectively. The iron abundance $\log N(\mathrm{Fe}) = -4.7$ does not appear to change in the atmosphere of V838 Mon from February 25 to March 26, 2002.

INTRODUCTION

The peculiar variable star V838 Mon was discovered during an outburst of the beginning of January 2002 [1]. Two further outbursts were then observed in February 2002 [2, 8]; in general, the visual magnitude of the star increased by 9 mag. The spectral evolution was dramatic — from an A-type star with many emission P Cyg lines at the time of the first outburst to a G–K giant in February–March 2002 [5] and, finally, to a L-supergiant in October 2002 [3].

The outburst mechanism as well the nature of progenitor of V838 Mon remain a mystery.

OBSERVATIONS

We used three echelle spectra — a first one (from February 25) was observed during the period between the second and third outbursts, and the two (from March 2 and 26) — after the third outburst. This spectra was kindly provided for us by Drs. Ulisse Munary (February 25 and March 26; $R = 18\,000$; freely available from [http://ulisse.pd.astro.it/V838Mon/]) and Lisa Crause (March 2; $R = 36\,000$) — see more details in [2] and [8].

PROCEDURE

Our synthetic spectra were computed in the framework of the classical approach: LTE, plane-parallel media, no sinks and sources of energy inside the atmosphere. Strictly speaking, none of these assumption is 100% valid in atmosphere of V838 Mon.

We computed a sample of LTE synthetic spectra for a grid of the Kurucz model atmospheres [7] with $T_{\rm eff} = 4000 \div 6000$ K using the WITA612 program [9]. Synthetic spectra were computed with a wavelength step of 0.02 Å, microturbulent velocities of $2 \div 18$ km s^{-1} with a step 1 km s^{-1}, iron abundances $\log N(\mathrm{Fe}) = -5.6 \rightarrow -3.6$ dex[1] with a step of 0.1 dex. Then, due to the high luminosity of the star, we formally adopt $\log g = 0$. Synthetic spectra were computed for the VALD line list [6]. The computed synthetic spectra were convolved with different profiles, and then fitted to the observed spectra following the numerical scheme described in [4, 10].

RESULTS

The example of obtained best fits of the synthetic spectra to the observed spectrum of V838 Mon for February 25 is shown in Fig. 1. The plot shows the fits for: (a) "the best" $T_{\rm eff}$, and (b) an effective temperature, which has been reduced by 1000 K. This last value corresponds better with the $T_{\rm eff}$ obtained from photometric measurements (*cf.* [8]).

Results of the determination of atmospheric parameters of V838 Mon in February and March 2002 are given in Table 1. In Table 1 $V_{\rm t}$ is a microturbulent velocity, $V_{\rm g}$ is a parameter of macroturbulence and $V_{\rm r}$ is a radial velocity.

© B. Kaminsky, Ya. V. Pavlenko, 2004

[1] In the paper we use the abundance scale $\sum N_i = 1$.

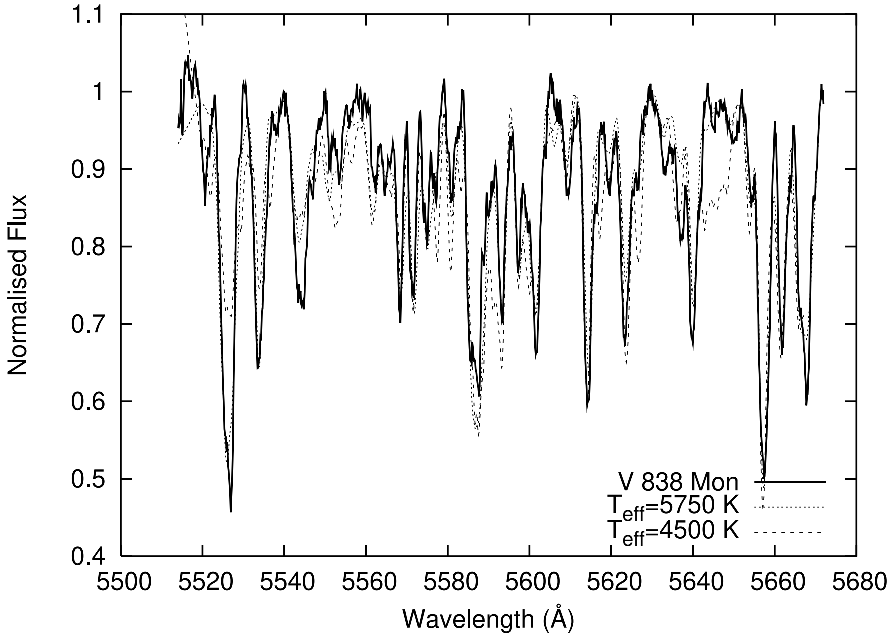

Figure 1. The best fits of synthetic spectra to the observed spectrum of V838 Mon on February 25, 2002, obtained by the minimization procedure

CONCLUSIONS

- The effective temperature for the most last date (March 26) is somewhat lower than for the previous dates. This is an expected result, taking into account an gradual cooling of the envelope.
- For March 2 we obtained a slightly higher value of the temperature than for February 25. A possible explanation is the heating of the pseudophotosphere as result of the third outburst which occurred before March 2.
- Our deduced "effective temperatures" as well as $T_{\rm eff}$ derived in [5] for all dates do not correspond with values obtained from the photometry ($T_{\rm eff}$ ~ 4200–4500 K). Most probably, the line-forming region is heated by supersonic motions — the formally determined microturbulent velocity $V_{\rm t} = 13$ km s^{-1} exceeds the sound velocity in the atmosphere (4–5 km s^{-1}).
- We obtained a moderate deficit of iron logN(Fe) ~ -4.7 in the atmosphere of V838 Mon, and we do not see any significant change in the iron abundance from February 25 to March 26. In [5] was derived $\log N(\mathrm{Fe}) \sim -4.9$ for March 18.
- The microturbulent velocities ($V_{\rm t} \sim 13$ km s^{-1}) are very similar and extremely high for all three dates. This value also agree with a value $V_{\rm t} = 12$ km s^{-1} obtained in [5].
- Analysis shows a lower value of $V_{\rm g}$ for the later dates: the effects of expansion and macroturbulence were weakened at the later stages of the evolution of the pseudophotosphere of V838 Mon.

Table 1. Atmospheric parameters for V838 Mon

Date	$T_{\rm eff}$	$V_{\rm t}$ (km s^{-1})	$\log N(\mathrm{Fe})$	$V_{\rm g}$ (km s^{-1})	$V_{\rm r}$ (km s^{-1})
February 25	5330	13.2	−4.73	54.7	−76.5
March 2	5540	13.3	−4.75	47.8	−77.6
March 26	4960	12.5	−4.68	42.5	−65.2

We stress once again that the used static LTE model is very sketchy for this star and, therefore, most of our results are rather qualitative, and they should be confirmed and/or refined in the future.

Acknowledgements. We thank Drs. Ulisse Munari, Lisa Crause for providing spectra and for discussions of our results. This research was partially supported by a PPARC visitors grants from PPARC and the Royal Society. Y. P.'s studies are partially supported by a Small Research Grant from the American Astronomical Society.

[1] *Brown N. J., Waagen E. O., Scovil C., et al.* Peculiar variable in Monoceros // IAU Circ.–2002.–N 7785.

[2] *Crause L. A., Lawson W. A., Kilkenny D., et al.* The post-outburst photometric behaviour of V838 Mon // Mon. Notic. Roy. Astron. Soc.–2003.–**341**.–P. 785–791.

[3] *Evans A., Geballe T. R., Rushton M. T., et al.* V838 Mon: an L supergiant? // Mon. Notic. Roy. Astron. Soc.–2003.–**343**.–P. 1054–1056.

[4] *Jones H. R. A., Pavlenko Ya., Viti S., Tennyson J.* Spectral analysis of water vapour in cool stars // Mon. Notic. Roy. Astron. Soc.–2002.–**330**.–P. 675–684.

[5] *Kipper T., Klochkova V. G., Annuk K., et al.* The peculiar variable V838 Monocerotis // Astron. and Astrophys.–2004.–**416**.–P. 1107–1115.

[6] *Kupka F., Piskunov N., Ryabchikova T. A., et al.* VALD-2: Progress of the Vienna Atomic Line Data Base // Astron. and Astrophys. Supl. Ser.–1999.–**138**.–P. 119–133.

[7] *Kurucz R. L.* CDROM 23, Harvard–Smithsonian Observatory, 1993.

[8] *Munari U., Henden A., Kiyota S., et al.* The mysterious eruption of V838 Mon // Astron. and Astrophys.–2002.–**389**.–P. L51–L56.

[9] *Pavlenko Y. V.* A "lithium test" and modeling of lithium lines in late-type M dwarfs: Teide1 // Astron. Rep.–1997.–**41**.–P. 537–542.

[10] *Pavlenko Ya. V., Jones H. R. A.* Carbon monoxide bands in M dwarfs // Astron. and Astrophys.–2002.–**397**.–P. 967–975.