The double outburst of the unique object V838 Mon

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Abstract. We present spectroscopic and photometric observations of the recent peculiar outburst of V838 Mon, carried out at Rozh en and Toruń observatories. Our data cover a period of three months beginning just before the second eruption. The evolution of the outburst is divided into four phases. The changes of particular spectral features for each of these phases are shortly discussed.

V838 Mon is one of the most enigmatic stellar phenomena observed during the last several years. The outburst in the beginning of 2002 January (Brown 2002) with an amplitude in V of at least 5\text{m} pointed to a possible classification of this object as a nova. Its relatively cool K giant type spectrum almost unchanged during the next three weeks (Zwitter & Munari 2002) suggested that it could be an extremely slow nova. Simultaneously, many metal lines showed P Cyg profiles with an outflow velocity of about 200–300 km s\text{−1}, whereas the hydrogen Balmer lines presented emission peaks without P Cyg absorption components. Iijima (2002) suggested that we observed the flare-up phase of a post-AGB star. All these speculations were broken about February 1, when an unexpected second outburst (V amplitude \sim 4\text{m}) similar to the first one, occurred. Few days later, on about February 4–5, V838 Mon reached the maximum with almost 6\text{m}5 in V band.

V838 Mon phenomenon has excited numerous observers, amateurs and professional astronomers, which reflected in nearly 30 IAU Circular publications dedicated to this object. Additionally, almost 400 messages has been posted in the amateur VSNET network. Recently, the first scientific paper concerning V838 Mon has been published (Munari et al. 2002). However, there is no idea about the physical mechanism of V838 Mon activity, yet.

We observed V838 Mon photometrically in UBVRI\textsc{c} system using the 60cm Cassegrain telescope at Toruń Observatory with one-channel diaphragm photometer equipped with a cooled C31034A photomultiplier. The high-resolution (0.2 Å/pix) spectra were collected with the coude spectrograph fed by the 2m telescope at Rozhen Observatory. Low-resolution spectroscopic observations (2 Å/pix) were carried out at Toruń Observatory using the Canadian Copernicus Spectrograph attached at the Cassegrain focus of the 90cm telescope. All our CCD spectra were processed using the available tasks in the IRAF software package. Part of the Toruń spectra, obtained in the best weather conditions,
Figure 1. Compiled V/vis light curve of V838 Mon during the 2002 outburst. The dates when the spectra shown in Figs. 2 and 3 were obtained are denoted with solid (Rozhen) and dashed (Toruń) arrows.

Figure 2. Normalized to the local continuum profiles of Hα (left) and NaI (right) lines. For two spectra in the left panel the local continuum is shown with a dashed line to underline the remarkable variations in the Hα broad emission wings.

were transformed to the absolute energetic scale (erg cm\(^{-2}\) s\(^{-1}\) Å\(^{-1}\)) by means of several spectrophotometric standards observed during the same night.
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The entire outburst of V838 Mon in 2002 lasted four months, from the beginning of January until the end of April. The brightness evolution of the object can be divided into four distinct periods (Fig. 1):

- January – first plateau between the first and second eruptions;
- February 2–10 – maximum of the brightness, most noticeable in U light;
- February 11–April 15 – second plateau;
- after April 15 – rapid decrease in the optical range.

The most interesting episodes during these periods are illustrated by our spectra in Figs. 2 and 3.

During the period of the first plateau several relatively strong P Cyg profiles of low excitation and resonance lines of CaII, NaI, BaII, and others were superimposed on a gK type (pseudo)photosphere spectrum. As an example we show the profiles of Na I doublet 5890 Å, 5896 Å (Fig. 2). The emission component of these lines indicates probably the stellar velocity of about 50–70 km s\(^{-1}\). The absorptions show outflow velocity about 200–300 km s\(^{-1}\) with a terminal one reaching \(-500\) km s\(^{-1}\). At the same time H\(\alpha\) shows relatively weak emission almost centrally cut by a self-absorption component. The velocities measured for both of them are about 50–70 km s\(^{-1}\), i.e. close to the stellar velocity as well. A possible source of this complex H\(\alpha\) profiles could be a stationary or rotating zone near the photosphere.

During the second outburst and its maximum suggested that the lines with low excitation potential practically did not change, indicating that the region producing these features is sufficiently far from the central object. At the same time the flux in H\(\alpha\) emission increased at least three times faster than the flux in continuum (Fig. 2). Simultaneously, we observed a rapid development of the P Cyg absorption component. The most striking effect was the appearance of strong and very broad H\(\alpha\) emission wings extended to about \(\pm 1600\) km s\(^{-1}\). They have completely vanished very quickly after the second outburst. We did not observe similar wings in any other lines in the spectrum of V838 Mon, and what’s more – in other hydrogen lines. This argues for a non Doppler origin of the wings. We suggest Raman scattering of Ly\(\beta\) photons by neutral hydrogen as a possible explanation. In the spectral region covered by our observations the best additional indication for the presence of Ly\(\beta\) photons (except H\(\alpha\) wings!) could be OI 8446 Å line excited by Bowen fluorescence (Bowen 1947). Unfortunately, we have obtained a spectrum in this region on February 21, when also the H\(\alpha\) wings were at least one week (i.e. since February 13, Fig. 2) completely invisible. Nevertheless, a very spectacular light-echo (e.g. Munari et al. 2002) observed around V838 Mon reveals the high abundance of matter, dust and – first of all – neutral hydrogen which must be a quantum trap for Ly\(\beta\) photons. Moreover, the Doppler structure of the Ly\(\beta\) should be exactly the same as the main emission component of H\(\alpha\), which shows the existence of an outflow with escape velocity 200–300 km s\(^{-1}\). Raman scattering should multiply this velocity by a factor \(\sim 6.4\) around H\(\alpha\) wavelength, what corresponds exactly to the width of the broad wings.

During the second plateau (pseudo)photosphere reaches again a gK type, possibly luminosity class II (Fig. 3). H\(\alpha\) showed pure P Cyg profiles with emis-
sion component decreasing in intensity. The absorption component indicates a terminal velocity of nearly 300 km s\(^{-1}\) (Fig. 2). Also, the emission component of the low excitation lines slowly weakened. Remarkable decrease of the terminal velocity is seen in the absorption component. The P Cyg absorption component in NaI at the end of February was almost the same as in H\(\alpha\).

The rapid changes in the H\(\alpha\) profile, observed during maximum and the second plateau, suggest the formation of an outflowing shell of matter, expanding with velocity of about 250–300 km s\(^{-1}\).

Finally, in the last rapid decrease phase, surprisingly a pure M giant spectrum appeared. In case the F0 subdwarf identified by Munari et al. (2002) is the true progenitor and taking into account the lack of stellar wind the only way V838 Mon to return to the progenitor state seems to be a contraction of the present pseudophotosphere.

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