THE OLD NOVA BT MONOCEROTIS*

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Abstract. Spectroscopic observations through most of the eclipse cycle of BT Mon reveal the presence of both low and high velocity gas streams. Acceleration through a Laval-nozzle-effect at the inner Lagrangian point of the system and powering of the emission lines through kinetic energy losses of Coriolis deflected and subsequently colliding gas streams are considered as possible mechanisms at work in the system.

1. Introduction

The old nova BT Mon (Nova Monocerotis 1939) deserves and has recently received much attention. Photometric investigations have yielded one of the deepest eclipses found in any postnova so far (Robinson *et al.*, 1982). Our own spectroscopic investigations have left us puzzled.

2. The Data

BT Mon was observed on 7 nights in December, 1982, with the IDS spectrograph at the 1.52 m telescope at ESO, La Silla. The 54 spectrograms cover 82% of the eclipse cycle. The wavelength range of most observations was 3800–7300 Å with a dispersion of 172 Å mm^{-1}. Several observations are of higher dispersion and correspondingly smaller wavelength regions. The data were reduced at the ESO reduction facility in Garching and at the newly installed system in Münster.

3. The Light Curve

The calibrated spectra allow us to measure fluxes in the lines as well as in the continuum and to follow them through the eclipse cycle. Figure 1 shows the continuum variation at 5000 Å.

From several observed eclipses a mean minimum time was derived,

$$\text{JD hel. (min)} = 2\,445\,323.6875\,,$$

which fits very well into Robinson *et al.*'s ephemeris. No indication of a period change could be detected.

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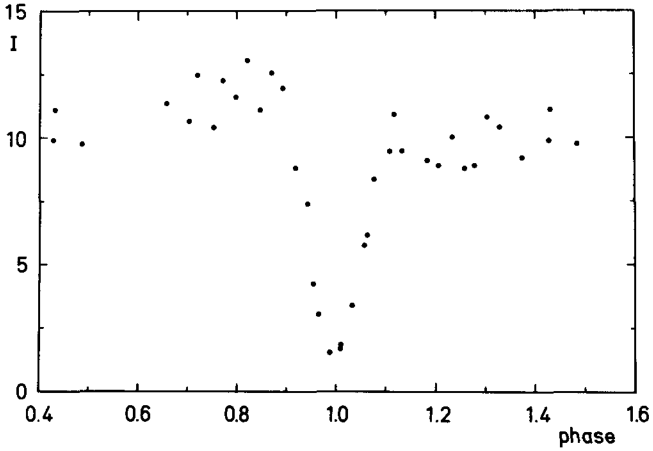

Fig. 1. Light curve of BT Mon at 5000 Å; arbitrary intensity units.

4. The Radial Velocity Curves

Radial velocity curves were obtained through various procedures. Mean RV-curves were derived from cross correlations of the spectra. Detailed RV-curves were obtained from Gaussian fits to the emission lines He II, Hα, and Hβ. Figure 2 shows a mean RV-curve. It is at once apparent that the curve has a hitherto unknown peculiarity, a high velocity spike at the time of eclipse. While it is fairly obvious that the spike must be associated with the contribution of high velocity gas dominant during eclipse, the details of the model are not simple. A more subtle but no less disturbing phenomenon becomes obvious when instead of using a mean RV-curve, individual curves for the

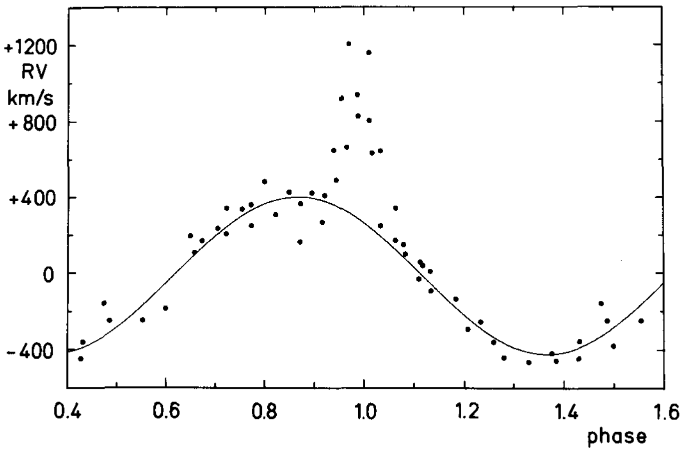

Fig. 2. Radial velocity curve of BT Mon, derived from cross-correlation of spectra.

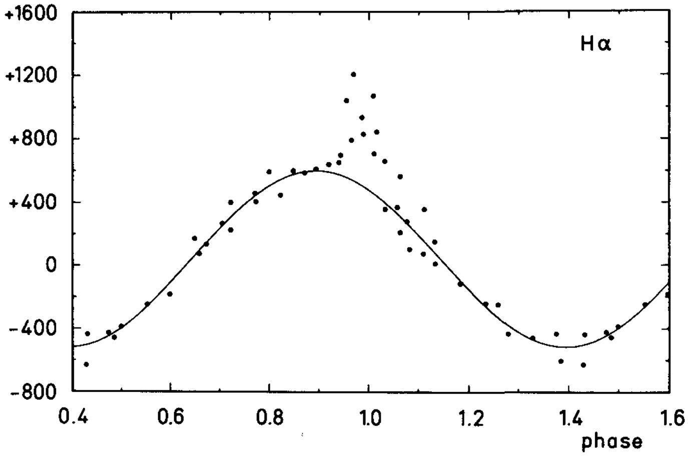

Fig. 3. Radial velocity curve of BT Mon, based on the Doppler displacements of the Hα line.

different lines are plotted (Figure 3: Hα RV-curve). The differences in amplitudes are significant (Hα: 557 km s^{-1}, Hβ: 402 km s^{-1}, He II: 303 km s^{-1}) while the peak velocities of the spikes seem to be approximately the same, if one allows for a short eclipse of the He II contribution which will be justified later on. The most important feature, however, is the noticeable phase shift from phase zero (eclipse) as a function of amplitude. The simple interpretation that the eclipse is that of the hot spot rather than the eclipse of a luminous disc can be ruled out. While the presence of a region of higher luminosity is indicated in Figure 1 at phase 0.8, it is far too weak to account for the decline through 2.7 mag. during minimum, and furthermore, it is not at the right location.

Apparently, we observe not the RV-curve due to orbital motion alone but the superposition of different velocities whose resultants are shown in Figure 3. Assuming that the observed curves result from adding different sine curves at different phase shifts for the three lines Hα, Hβ, and He II to a fixed curve representing the unknown orbital motion, it is possible to derive the true velocities. The K_1 value is 248 km s^{-1}, the added values are 105 km s^{-1} for He II, 266 km s^{-1} for Hβ and 489 km s^{-1} for Hα. It is now possible to determine the zero points of the added velocities and thus the directions of the additional motions, if the zero points for the orbital motion are assumed to occur at eclipse and at 180° from eclipse.

5. The Line Fluxes

Figures 4 and 5 show the variations of emission line fluxes of Hα and He II during the eclipse cycle. A strenghtening of the lines is observed before eclipse with a peak probably around phase 0.75. The lines appear systematically weaker after eclipse. The variations for most of the lines differ not greatly from a sinusoidal variation, which makes them likely to be due to the view of a hot region from different aspects during the cycle.

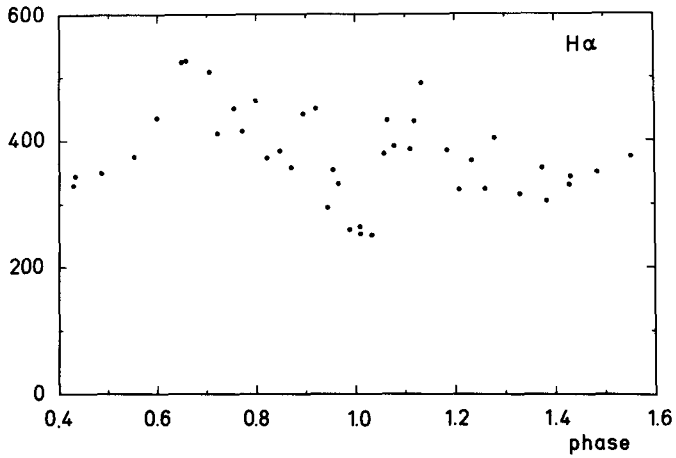

Fig. 4. Line fluxes of the Hα emission line; arbitrary intensity units. The photometric minimum is only weakly indicated.

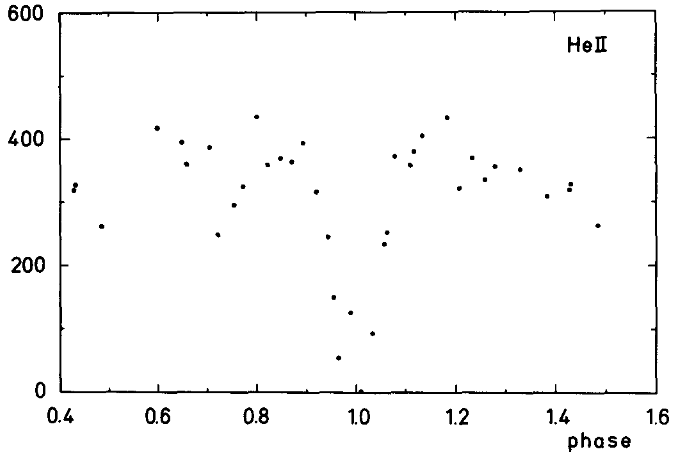

Fig. 5. Line fluxes of the He II 4648 line; arbitrary intensity units. The minimum is very pronounced.

The most surprising result, however, is the fact that the strength of Hα shows a decline by only $\frac{1}{3}$ of the maximum value during eclipse, while C III disappears completely, He II and Hβ for short intervals during the eclipse.

6. The Model

As often in astronomy, data are not sufficiently scarce to permit a simple model, but not sufficiently complete to reveal the full detail of a more complicated picture. There are, however, a few preliminary conclusions which can be drawn: Assuming that the correct RV of the orbit has been derived, taking the secondary to be of type K5–7 as seems to be indicated from 21 identified weak absorption lines and blends visible mostly during minimum, furthermore, using Robinson *et al.*'s relation between q and $\cos i$, we find no acceptable solution for the masses.

However, an orbital velocity of 190 km s^{-1} together with $i = 79°$, yields a solution $\log q = 0.17, M_1 = 0.48 M_\odot, M_2 = 0.72 M_\odot$. The dimensions of the system derived from these data allow a purely gravitational acceleration to about 500 km s^{-1}. If, however, the energy radiated in the emission lines derives from collisions of gas streams of different directions, the original velocities must be higher by at least a factor two. The presence of high velocity gas in the system is corroborated by Boroson-Greenstein diagrams, especially for Hα. Here, velocities up to 3000 km s^{-1} are observed, velocities which clearly do not result from gravitational acceleration at the location of origin of the line.

We thus propose an acceleration mechanism already at the location where the gas stream leaves the secondary. Such a mechanism could exist in the form of a Laval nozzle which increases the sound velocity of some 10 km s^{-1} at which the gas enters the region around the inner Lagrangian point to supersonic velocities. The wide spread of velocities in the system then requires either a self-regulating system supplying a range of different velocities or noticeable contributions from the velocities around the Mach disks forming at some distance from the nozzle.

If a simplified two-gas stream model is invoked, we can reproduce the observed features with a low-velocity stream showing a larger Coriolis deflection, which shows sufficient bending towards the primary to eventually collide with a high-velocity gas stream of small Coriolis deflection and a velocity which at all locations within the Roche lobe of the primary exceeds the velocity of escape, such that this stream leaves the system almost undeflected. The interaction of the two streams marks the region of highest radiative energy whereby the outer parts contribute mostly Hα radiation while regions closer to the primary produce more Hβ in accordance with a flatter Balmer decrement for hotter regions, in the innermost region He II is generated. Ionization and excitation are the results of collisions of the gas stream particles which loose considerable velocity as suggested by the increasingly lower gas velocities observed for lines of higher energy.

So far we can deduce only this rather qualitative model which has been checked for consistency only. Besides this, two rather firm conclusions can be drawn: ex-novae may well be more complicated than has hitherto been assumed, and, more observations are needed.

Reference

Robinson, E. L., Nather, R. E., and Kepler, S. O.: 1982, *Astrophys. J.* **254**, 646.