HIGH TIME RESOLUTION SPECTROSCOPIC OBSERVATIONS OF STELLAR SHOCK WAVES

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ABSTRACT. An absorption line-splitting phenomenon, first reported by Cottrell and Lambert (1982a), has been shown to occur at about maximum light in the semi-regular pulsations of the R Coronae Borealis (RCB) star, RY Sgr (Lawson 1986). This has been interpreted as a shock wave propagating through the photospheric layers (Lawson and Cottrell 1986). We present spectroscopic observations of this star, taken to coincide with this line-splitting event. A sequence obtained during 1986 October revealed that this event extended over about 6 days (out of a period of about 40 days) and began at about the bluest B-V. This colour maximum, which corresponds to maximum photospheric temperatures and minimum radius, leads the V maximum by about 6 days.

1. INTRODUCTION

Shock wave phenomena have been observed in a number of different types of relatively normal composition stars (e.g., W Vir stars : Sanford 1952; RR Lyrae stars : Oke 1966; RV Tauri stars : Abt 1955; Mira stars : Hinkle et al 1984; β Cephei stars : Crowe and Gillet 1988). The shocks are most graphically seen by the discontinuity in the radial velocity curve. However, with their appearance in one RCB star, which as a group have hydrogen deficient carbon rich atmospheres, one can study the propagation of these waves under substantially different atmospheric opacity conditions. This paper presents some preliminary observations. Also we indicate the importance of simultaneous photometric observations and the usefulness of a small University operated observatory, where we can obtain key sequences of data in these semi-regular pulsators.

2. OBSERVATIONS

All the observations were obtained using telescopes at Mount John University Observatory.

The spectra were acquired using an échelle spectrograph and image

G. Cayrel de Strobel and M. Spite (eds.), The Impact of Very High S/N Spectroscopy on Stellar Physics, 205–208.

tube attached to a 0.6m Boller and Chivens telescope. The observations presented here were recorded on Kodak IIaD plates and traced using a Joyce-Loebl microdensitometer at the University of Canterbury. These plates were only obtained at phases which were known from previous cycles to be the most likely to show splitting of the spectral lines. Later this year, the image tube and photographic plate combination will be replaced by an 1872 element Reticon linear diode array detector, designed and built by one of our graduate students, Phillip MacQueen.

The UBV photometry was undertaken on a 0.6m Optical Craftsmen telescope using a single channel photometer, as part of a larger program to determine the amplitude and period of southern RCB stars.

3. DETAILS OF THE LINE-SPLITTING EVENT IN RY SGR

In Figure 1 we show the B-V, V and radial velocity determinations for the interval, 1986 August - October, while Figure 2 is a sample sequence of spectra which illustrate the development of the line splitting phenomenon. In particular, the latter figure shows the growth of another line (presumably produced by the shock wave) in the blue wing of the stronger lines in the spectrum. This is illustrated here by the two SiII lines and one FeII line. It should be noted that although the two silicon lines are of the same multiplet and excitation potential, they

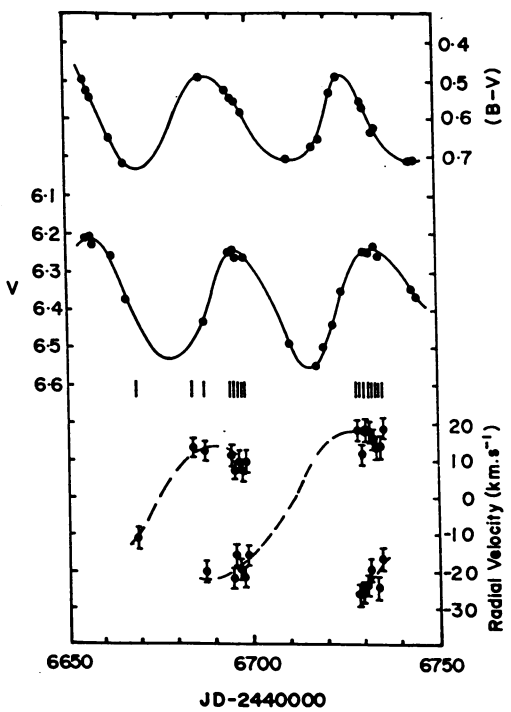

Figure 1. B-V, V and radial velocity curves for the RCB star, RY Sgr. The vertical lines between the V and velocity curves indicate the dates on which spectroscopic observations were obtained. The curves drawn on this figure are 'eye-ball' best fits to the data.

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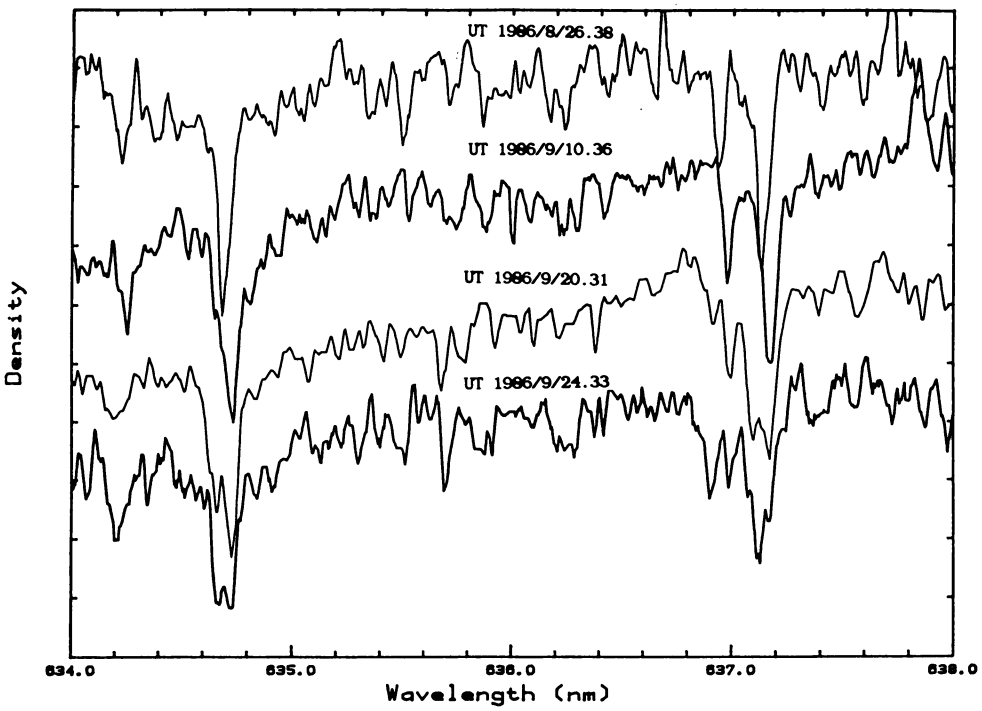

Figure 2. Sample spectra of RY Sgr acquired at the times shown immediately above each plot. The shift of the lines towards longer wavelength is clearly seen between the first and second spectra. The gradual strengthening of the blue (shock) component of the lines is shown in the second to fourth spectra.

show different development during the cycle. The continuous spectral coverage in 1986 October show similar effects in the shock induced features, but any detailed variation from cycle to cycle is yet to be investigated. We expect to do this with the Reticon system, which will enable much **higher signal to noise** and **higher time resolution** data to investigate the propagation of the shock wave and to look for depth dependence effects in the spectral lines. Already we have seen (see Ti II line in Figure 1 of Cottrell and Lambert 1982b) some lines which show emission above the continuum as a consequence of the shock.

The onset of the splitting phase commences near the maximum on the colour curve (minimum B-V, highest surface temperature and minimum radius) as the shock reaches the deepest photospheric layers. This **colour maximum leads** the **visual maximum** by between 4 and 8 days.

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4. THE FUTURE

We hope that our continued spectroscopic and photometric coverage of RY Sgr will lead to a better understanding of the propagation of shock waves in stellar material. Our observational program also involves the investigation of many other southern RCB stars, the first phase of which is to obtain good photometric ephemerides of the pulsation of these stars with a view to determining appropriate phases for detailed spectroscopic work.

On the theoretical side, we have recently begun work with Peter Wood (Mount Stromlo and Siding Spring Observatories) to model the pulsations and determine the conditions under which shock waves will be produced, and also whether realistic pulsational amplitudes can be obtained, in these hydrogen deficient, carbon rich stellar envelopes.

One of us (PLC) would like to thank both the IAU and the Council of the University of Canterbury for generous travel support which enabled participation in this symposium. We would also like to thank Pam Kilmartin for obtaining many of the photometric observations and Alan Gilmore for acquiring some of the spectra when teaching commitments kept us away from the mountain.

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DISCUSSION

CROWE At what luminosity phase does the line splitting occur?

COTTRELL The line splitting begins at minimum B-V (maximum temperature) which can lead the V maximum by between 4 and 8 days. This then gives a phase ϕ = 0.8 to 0.9 for the line splitting.

CROWE Yes, it seems that the velocity discontinuity usuallly occurs at phase ϕ = 0.9, with respect to visual light maximum, for the Population II pulsating variables as well as for BW Vulpeculae (and for Miras).

COTTRELL Precise phasing has not been done because of the semi-regular nature of the star and incomplete spectral coverage.