PRELIMINARY ANALYSIS OF THE BROAD He I EMISSION LINES IN R CrB

R.Surendiranath, K.E.Rangarajan and N.Kameswara Rao
Indian Institute of Astrophysics
Bangalore 560034
INDIA

ABSTRACT:

During light minimum phase, R CrB shows a broad emission line spectrum of He I including λ 10830, λ 7065, λ 7281, λ 3889, λ6678 and λ 3188. But λ5876 is very weak. The observed intensity ratios of I(λ 3889)/I(λ 5876) and I(λ 7065)/I(λ5876) were greater than 1. The anomalous intensities of these lines appear to be due to optical depth efects. Peliminary analysis is presented to derive the physical conditions of the emitting gas.

I. INTRODUCTION

During the visual light minimum, R CrB shows three types of spectra: a) an absorption line spectrum similar to that observed at maximum light, b) A sharp emission line spectrum mainly due to singly ionized metals; the spectrum is displaced to the blue by 3 to 10 kms^{-1} with reference to the absorption spectrum observed at maximum, c) A broad emission line spectrum consisting of lines of He I, H and K lines of Ca II and the D lines of Na I. The He I lines seen are: λ 10830, λ 7065, λ 7281, λ3889, λ6678 and λ3188. But λ 5876 is very weak. (see Fig.1). Typical line widths are as follows: He I λ 3889 extends from +270 kms^{-1} to -270 kms^{-1}. The Ca II H and K lines extend from +310 kms^{-1} to -310 kms^{-1} (Gaposchkin, 1963; Rao, 1981).

RY Sgr also shows such emission lines during minimum. Such anomalies in He I lines are also seen in V348 Sgr (Dahari and Osterbrock, 1984). It is likely that other R CrB type stars also exhibit similar phenomenon. These lines change their profiles as the minimum progresses.

We envisage a possible scenario as follows: A highly excited and electron collision-dominated gas is ejected at high velocities during light minimum. The emission lines probably arise from this and we attempt model calculations described in Sec. II to derive physical conditions of the gas cloud.

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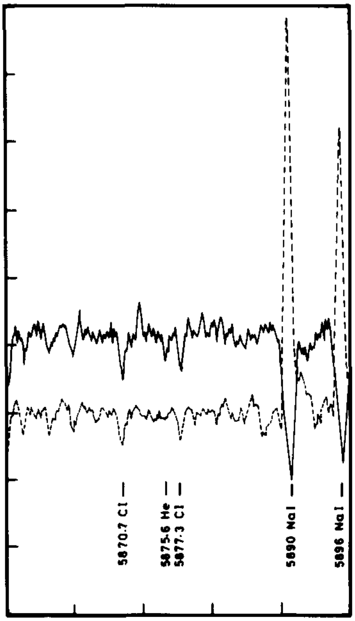

Fig. 1. Spectra of R CrB near λ 5876 region. The lower one was taken at minimum (11 July 1962) by G.H. Herbig when the star's V magnitude was 10.0; the upper one was taken at maximum (11 April 1973).

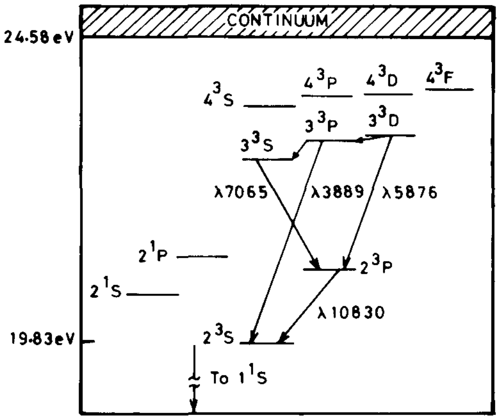

Fig. 2. Energy level diagram for the model He I atom used for the NLTE calculations. Radiative transitions solved in detail are shown by arrows. For the calculations using the photon escape probability formalism, the continuum and the level 1'S were not included.

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II. MODEL CALCULATIONS

Following Feldman and MacAlpine (1978), we first solved the equations of statistical equilibrium for an 11 level He I atom, and derived the line intensities. The effect of finite optical depth τ was introduced, by means of escape probability for the photon $\varepsilon(\tau)$, into the equilibrium equations. The coupled equations were solved for the level populations by using the Gauss-Jordan method. The intensity ratios I(λ3889)/(λ5876) and I(λ7065)/ I(λ5876) were found to be >1 for values of election temperature (Te), electron density (Ne) and optical depth $\tau_\circ$ (10830) in the range.

$$\mathrm{Te} \sim 10^4 \,^\circ\mathrm{K},\ \mathrm{Ne} : 10^{11} \text{ to } 10^{12} \mathrm{cm}^{-3} \text{ and } \tau_\circ(10830): 300\text{-}500$$

Next, using the complete linearization technique of Auer et al (1972), we did Non-LTE line transfer calculations. The model slab of gas for which the transfer calculations were done was divided into 50 layers characterized by Te, electron pressure Pe, and column mass. The upper and lower boundaries had a difference in Te of $3 \times 10^3 \,^\circ$K and the change over the 50 layers in between was uniform. Likewise, Pe values changed unformly and the boundary values differed by a factor around 5.

The composition of the gas was 98% He (by number) and the rest C, H and heavy elements. A 13 level He I model atom was used (see Fig.2). Doppler broadening was assumed. The stellar radiation field was assumed to have no effect on the gas cloud. The emission line profiles were computed for λ10830, λ3889, λ7065, λ5876, λ4.3μ and λ18.6μ. The fluxes (integrated over the line profile) for these lines were calculated.

Various model slabs with Te, Pe, and τ were tried in the range Te : 5×10^3 to 2×10^4, Ne 10^7 to 10^{15} cm^{-3} and $\tau_\circ$ (λ5876) of 40 to 100. The following values of $\tau_\circ(\lambda5876) \sim 10^2$, Ne $\sim 10^{11}$ cm^{-3} and Te $\sim 1.6 \times 10^4 \,^\circ$K, seem to give the flux ratios F(λ3889)/F(λ5876) and F(λ7065)/F(λ5876) as 3.2 and 1.1 respectively, close to the observed ratios. The above calculations do not incorporate velocity fields. The main conclusion is that large optical depths are needed to cause the inversion in the line intensity of λ5876.

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