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Variable circumstellar lines of hypergiant Rho Cas

ABSTRACT

The circumstellar lines of ϱ Cas are presented for two dates of observations. The analysis, based on non-LTE radiative transfer in spherical symmetry, results in conclusion that the observed variability can correspond to the change by an order of magnitude of the mass loss rate and by a factor of two of the extension of the envelope.

1. INTRODUCTION

The variable hypergiant ϱ Cas is known as having dense, expanding circumstellar envelope (de Jager, 1980). Recent discussion of activity of this star is presented by Gesicki (1991). The proposed structure of envelope of ϱ Cas is based on non-LTE analysis of five BaII circumstellar absorption lines, observed in spectra obtained in DAO in year 1970. The fitting of calculated to observed profiles indicates that the layer of BaII formation should be thin (not more than 5% of stellar radius) and should be accelerated and become cooler while expanding. The maximum temperature of the envelope was estimated for 12000K and the mass loss rate for about $10^{-3} M_{\odot} yr^{-1}$. The variability of circumstellar profiles, recorded in 1970, can result either from a change of the density (and simultaneously the mass loss rate) at constant extension of the envelope, or from a change of the extent of BaII layer at a constant mass loss rate. The factor of changes in both cases is about 3.

The above conclusions are based on a small sample of line profiles. Therefore any additional observations of BaII lines are very much welcomed for improving the investigations of the unstable envelope of this hypergiant. For this reason we have analyzed the archive spectral observations of ϱ Cas and the first and most interesting results are presented in this paper.

2. THE OBSERVATIONS

Fig.1 presents fragments of the spectra of ϱ Cas, obtained in DAO on Sept.17, 1979 and Oct.9, 1981, in dispersion of 10Å/mm. From five strong optical BaII lines we can measure only three, unfortunately not the resonance lines. The variability of circumstellar component, which is shifted at about 40km/s relatively to the photosphere, is clearly visible and is much stronger than in 1970 spectra (Gesicki, 1991). In 1981 the line shapes are similar to those recorded in 1970 but in 1979 they have the circumstellar absorption much deeper and more extended in short wavelength direction. This second fact is an evidence of a higher outflow velocity.

3. DISCUSSION

In the paper of Gesicki (1991) there is described the computer code for solution of radiative transfer equation in spherically symmetric, expanding layer, for five levels BaII ion in non-LTE. The procedure of fitting of theoretical circumstellar profiles to observations has been applied to the presented spectra. It has been assumed that the Doppler broadening is constant across the envelope with value of 10km/s (close to the expected velocity of sound). The remaining parameters of the envelope (i.e. the outer radius and the gradients of velocity and temperature fields) are assumed similar to those estimated in the above cited paper. For different assumed envelope structure there have been performed series of calculations of line profiles to reproduce the observed BaII profiles as good as possible. The result is that in 1981 the circumstellar envelope was very similar to its state in 1970, with radius of 5% of stellar radius, terminal velocity of 40km/s, mass loss rate of $10^{-3} M_{\odot} yr^{-1}$, although with lower temperature (about 9000K). In 1979, however, it was two times more extended, with maximum temperature lower (8000K) and with mass loss rate ten times higher. The terminal outflow velocity was 50km/s. The summary of the parameters is in Table 1. The right part of Fig.1 shows profiles of BaII lines calculated with the above mentioned parameters and for the two dates of observations. There are presented only the three observed lines although all five were calculated. It is seen that the fit for spectra from 1981 is reasonably good. For the fit to the spectra from 1979 there are visible the differences in short wavelength wing of circumstellar component. This fact can indicate that the velocity field in the actual shell is more complicated than that assumed in the model. The analysis could be improved if in the spectra there would be present the resonance lines of BaII 4934Å and 4554Å, which are more sensitive on temperature structure of the envelope.

Sargent (1961) reported a change (in year 1959) of the density of the envelope and of the mass loss rate by a factor of 10. His estimation of mass loss rate was

Table 1. The parameters of the envelope, estimated from the fit shown in Fig.1.

	Sept.17,1979	Oct.9,1981
radius	$0.10R_*$	$0.05R_*$
terminal velocity	$50km/s$	$40km/s$
max. temperature	8000K	9000K
mass loss rate	$10^{-2}M_\odot yr^{-1}$	$10^{-3}M_\odot yr^{-1}$

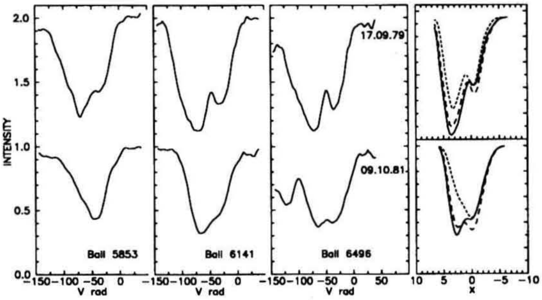

Fig.1 The three spectral lines of BaII. The observed profiles are those presented in radial velocity scale (in km/s). The dates of observations for the upper and lower sequences are indicated in figures. The far right part presents the theoretical profiles calculated for respective observations. The x axis is in Doppler velocity units, the limits are chosen to cover the same range as in observations. The three spectral lines are in this case superposed, with the following presentation: short dashed line - 5853Å, long dashed line - 6496Å, continuous line - 6141Å.

two orders of magnitude smaller than ours, but this can be questioned (Lambert et al., 1981). Nevertheless his conclusions concerning the mass loss variability scale remain valid. For February 1979 Lambert et al. (1981) obtained the mass loss rate as greater than $10^{-3}M_\odot yr^{-1}$. This is in agreement with our estimations. This discussion indicates that ϱ Cas is very active and therefore it is still worth of observations and analysis.

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