THEORETICAL EMISSION-LINE PROFILES COMPUTED AT ONDŘEJOV

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(Paper read by P. Harmanec)

Abstract. A rotationally symmetrical disk-shaped envelope was considered and the steady-state equations for level populations solved using the escape probability approximation. The line profiles were then calculated and compared with observations.

The recent theoretical work by Marlborough (1969, 1970) represents a considerable progress in the quantitative interpretation of emission lines of Be stars. We feel that such an approach is necessary if one wants to know the real physical conditions in gaseous envelopes, their origin, etc. Therefore we decided to construct a similar program for computations of theoretical profiles of emission lines from envelopes of Be stars.

We started with a very simplified model. Our original program assumed the envelope to be a flat hydrogen disk, axially symmetrical about the axis of rotation of the star. The conditions in the disk are assumed to be independent of the distance from the equatorial plane, i.e. all the properties of the matter are functions of the distance from the axis of rotation only. Also it is assumed that the support of the envelope is centrifugal and thus the velocity of an arbitrary point is the Keplerian velocity of circular motion. Finally, the continuum radiation of the central star is assumed to be Planckian.

The input data of the program are as follows: the mass, radius and effective temperature of the central star, the profiles of the absorption lines formed in the atmosphere of the central star, the density of atoms, the electron temperature, and the thickness of the disk as functions of distance from the axis of rotation.

First, the steady-state equation for level populations is solved for a given grid of points in the envelope. The departure coefficients from LTE populations, b_n, are calculated for the levels of principal quantum number $n \leq 20$. The levels of $n > 20$ are assumed to have the populations appropriate to thermodynamic equilibrium with free electrons. The radiative bound-bound transitions are treated by a modified Sobolev's escape probability method (see Kříž, 1973), assuming the absorption, emission and induced emission profiles to be identical and having the Gaussian thermally broadened shape. Only the diluted radiation of the central star is considered in calculating the bound-free radiative transitions. The rate coefficients for collisional processes are calculated by Johnson's (1972) formulae.

The intensity of the line radiation emitted at each point of the disk toward the observer is calculated (for the required lines and required wavelengths) by means of the precomputed level populations, assuming the angle of inclination $i = 90°$. Finally, the flux of energy emitted by the entire envelope is integrated. For these calculations we used the simplified solution of the equation of line-radiation transfer in media

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with large velocity gradients given by Kříž (1973) – see Equation (45) of that paper. Consequently we cannot compute the central parts of emission lines because of the small corresponding velocity gradient.

As a result we have obtained a series of theoretical line profiles for different models of gaseous disks. We have tried to match these profiles to the observed profiles of Be stars. It is very easy to find a model which gives excellent agreement with observations of one line (we have used Hα). Unfortunately, we are able to construct a large number of models giving the same profile of Hα. Therefore a comparison of the profile of one line has no meaning and we must compare as many lines as possible.

It is very difficult to construct a model which matches more observed lines. Figures 1 and 2 show observed profiles of Hα and Hβ in EW Lac (Gray and Marlborough, 1974), and the corresponding theoretical profiles. The differences are clearly larger than the observational errors.

We therefore arrived at the conclusion that our models are oversimplified. We are now working on a new, more sophisticated program. It will enable us to construct models of elliptical rings (see Huang, 1973), use arbitrary angles of inclination, compute centres of the lines, etc.

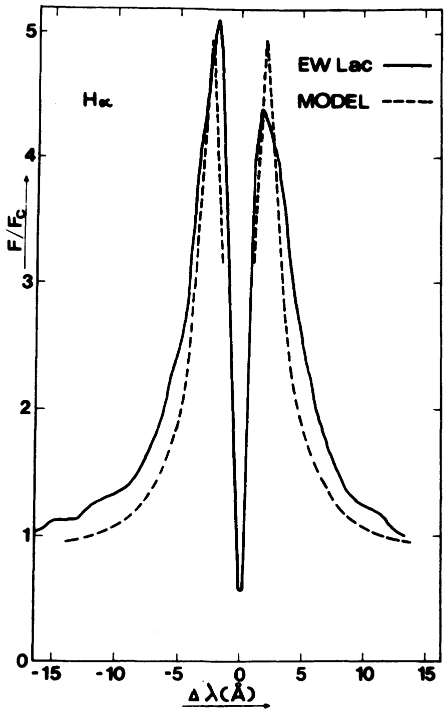

Fig. 1. The profile of Hα in EW Lac observed by Gray and Marlborough (1974) compared with a theoretical model characterized by the following parameters: mass, radius and effective temperature of the central star are 10 $M_{\odot}$, 4.66 $R_{\odot}$, 20 000 K, respectively; the disk has radius 172.4 $R_{\odot}$, thickness 13.6 $R_{\odot}$; number of hydrogen atoms per cm^3 is 10^{11}; and the electron temperature equals 20 000 K (everywhere in the disk).

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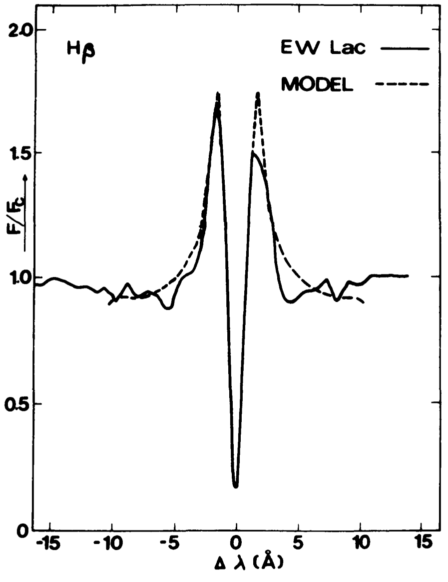

Fig. 2. Comparison of observed profile of Hβ with theoretical model. For details, see caption for Figure 1.

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