IMPROVED MODELLING FOR SPATIALLY RESOLVED SPECTROSCOPY OF A P CYG ENVELOPE

M.BOURGUINE[1,2] AND A. CHALABAEV[1]
[1] *CNRS, Observatoire de Grenoble, UJF-B.P.53X,38041 Grenoble CEDEX France*
[2] *FIAN Astro-space Center, Moscow, Russia*

1. General remarks

Our study, of which we give here a progress report, addresses two problems. The first is to develop methods and software permitting to compare a wide range of theoretical models of stars with envelopes with observational data produced or expected to be produced by high angular resolution optical interferometry combined with spectroscopy. The second problem is to find out the modes of interferometric observations (base length, spectral resolution etc) that are most informative for determining the physical parameters of stellar envelopes.

We started with the relatively simple case of a spherically symmetric stellar envelope of the Bep star P Cyg. Because of the diversity of theoretical models, the number of parameter sets to be considered in comparing observational data with theoretical predictions is rather large even in the case of spherical symmetry. In order to be able to interpret the observational data using a small- or medium-scale computer, it is practical, at least at the first stage, to employ a simplified model permitting a rapid performance of the calculations for many parameter sets. The more refined and time consuming codes like those used by Pauldrach and Puls (1990), and de Koter et al. (1993) may be employed at the final stage for the analysis of a limited number of models.

Furthermore, in non-spherically symmetric cases (e.g. Be stars) both the number of parameters to be determined and the complexity of theoretical models are even larger, and computational efficiency becomes one of the critical points.

For time being, we use a code that computes the emergent monochromatic intensity distributions for any reasonable stationary spherically symmetric model defined by radial velocity $V(R)$ and envelope temperature $T(R)$ as functions of radial distance R, and mass-loss rate dM/dt.

Calculations of the line source function are performed for a 3-level + continuum model of the H atom and are limited to the Hα line. Following Drew (1985), the envelope is taken to be completely opaque in the Lyman continuum, so that direct recombinations to and photoionizations from the ground level cancel out.

In calculating statistical equilibrium, the line radiation transfer was treated in the Sobolev approximation. Computation of the emergent intensity is

L. A. Balona et al. (eds.), Pulsation, Rotation and Mass Loss in Early-Type Stars, 502–504.

https://doi.org/10.1017/S0074180900215751 Published online by Cambridge University Press

based on the code developed by Bertout (1984).

The simplicity of the 3-level atomic model used so far allows to solve the statistical equilibrium equations very rapidly, although with poor accuracy. It should be improved at the next stage, when we are planning to take into account the influence of higher levels. Preliminary analysis shows that except for the innermost part of the envelope, the influence of levels $n > 3$ can be accounted for accurately enough without noticeable decrease in efficiency.

2. Interferometry vs. spectroscopy

At which extent can the interferometric spectro-imaging provide interesting physical information that cannot be obtained with much more simple spatially unresolved spectroscopy? In order to answer this question, it is necessary to compute a grid of multiparametric models of the object under study that covers sufficiently well the parametric space domain of interest, and to search for pairs of models, which yield similar spectral line profiles, while differing significantly in monochromatic intensity distributions.

This was done for the case of P Cyg. We considered a grid of 100 3-parameter models of the envelope. The varied parameters were mass-loss rate dM/dt ($5\,10^{-6}$ – $5\,10^{-5} M_{\odot}/\mathrm{y}$), parameter α (3.0 - 4.5) of the velocity law $V(R) = V_{\mathrm{inf}}(1 - R_*/R)^{\alpha}$, and envelope temperature T (10000 K - 14000 K). The terminal velocity was taken to be 300 km/s.

For each model we calculated the Hα profile I(λ) and the effective radius $R_{\mathrm{eff}}(\lambda)$. The usefulness of $R_{\mathrm{eff}}(\lambda)$ for a condensed representation of the results of interferometric observations is discussed in Burgin and Chalabaev (1992). The preliminary result is that on the considered grid the interferometric observations are not much more informative than conventional spectroscopy. This conclusion disagrees with our earlier result (Burgin and Chalabaev 1992). The reason is that in that paper the calculation for envelopes with a different temperature structure were based on a single model taken from Drew (1985), and the dependence of excited levels population on the temperature was estimated very approximately. It was supposed that the Menzel departure coefficients are nearly constant, and that the dependence on temperature may be sufficiently well represented by the dependence of Boltzmann factors, which is not the case for photoionization-recombination controlled levels.

A qualitative assessment of the comparative merits of interferometric spectro-imaging and classical spectroscopy for differentiating between various theoretical model would require an analysis of the influence of observational errors and depends on the instrumentation considered. Application to realistic situations would also require the extension of the analysis to the case of observations in several lines. Both these problems will be addressed in further work.

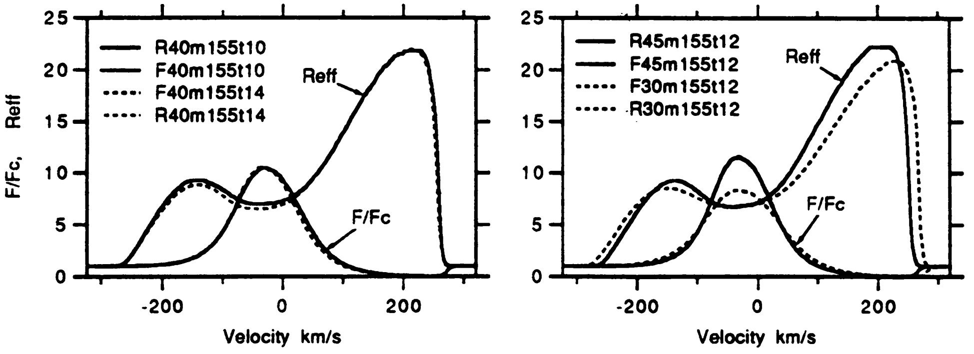

Fig. 1. Left: comparison of the results for models with the same velocity law (α=4.0) and various envelope temperatures (T=10000 K and T=14000 K). Right: the same for fixed T=12000 K and various velocity laws (α=3.0 and α=4.5). In both cases $dM/dt = 1.5\,10^{-5} M_{\odot}/y$. Effective radius $R_{\rm eff}$ is measured in units of stellar radius, positive velocities correspond to blue-shifted emission.

References

Bertout C.: 1984, *Astrophysical Journal* **285**, 269

Burgin M.S, and Chalabaev A.A.: 1992, *Proceedings of the ESA Colloquium on Targets for Space-based Interferometry, Beaulieu, France, 13-16 October 1992* **ESA SP-354**,

Drew J.E.: 1979, *Monthly Notices of the RAS* **217**, 867

de Koter A., Schmutz W., & Lamers H.J.G.L.M.: 1993, *Astron. Astroph.* **277**, 561

Pauldrach A.W.A. & Puls J.: 1990, *Astronomy and Astrophysics* **237**, 409

https://doi.org/10.1017/S0074180900215751 Published online by Cambridge University Press