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Modelling of Spherical Extended Atmospheres: Some New Results

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Abstract. Assuming an extended spherical atmospheric model we analyze the continuum and line behaviors considering 3 different temperature laws and different density distributions. We show that - for the continuum intensity distribution - at some physical conditions, a limb brightening profile appears.

1. Introduction

In this investigation we explore the main characteristics of a simple spherical symmetric model and we analyze qualitatively common features between the model and Be-star phenomena. Our aim is to discuss how the different hypothesis introduced in modelling Be stars modifies the output.

2. The model

The expanding atmospheric model we adopt assumes a non-rotating, steady-state and spherically symmetric medium. We describe the deepest atmospheric layers by the classical atmospheric models, where hydrostatic equilibrium (HE), radiative equilibrium (RE) and local thermodynamic equilibrium (LTE) is assumed. For the outer layers we assume that the matter is expanding (as the observational data suggest us) and we conserve the LTE condition throughout the entire atmosphere. In computing the models we consider solar chemical composition, a stellar effective temperature ($T_{\rm eff}$) of 15000 K, log$g$=3.5 and a stellar radius of 7 solar radii.

We establish the density distribution by means of the continuity equation. This implies that we need to define a velocity law and a mass-loss rate. We compute different density distributions by keeping the same velocity law (V) and by changing the mass-loss rate $(\dot{M})$ as a free parameter.

The radiation field interacts with a medium consisting of hydrogen (H) in LTE. The main continuum absorption sources taken into account are: H transitions: bound-free and free-free, H^- transitions: bound-free and free-free, Rayleigh scattering by HI atoms and Thomson scattering by free electrons.

We propose an ad-hoc expansion law for the atmospheric material like the one we show in Figure 1. In the inner atmospheric region (the photosphere) we calculate the temperature consistently with the RE condition. In the outer

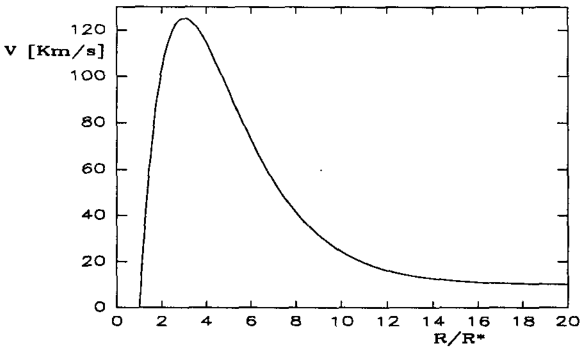

Figure 1. Velocity Law.

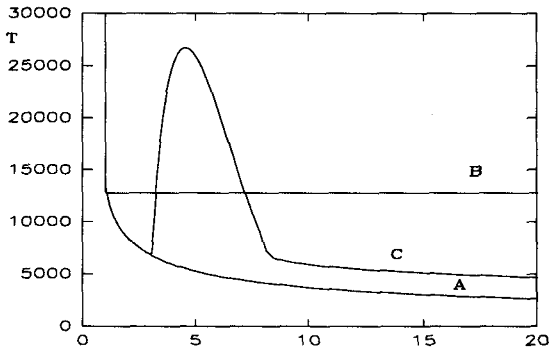

Figure 2. Temperature law

layers we distinguish three kinds of temperature laws: A) T in agreement with the RE condition, B) T constant and C) T when the RE condition is not satisfied. In this case a dissipative term of the form $V^2.dV/dR$ is introduced in the energy equation. We solve the transfer equation for both a plane-parallel and a spherically symmetric atmosphere, by means of a powerful numerical method: the Implicit Integral Method (IIM), (Crivellari et al. 1994, Gross et al. 1997). This method is very stable, fast and accurate. In this first approximation we assume that the is material at rest in order to solve the transfer equation.

Assuming LTE and a static atmosphere we calculate the first members of the Balmer series in order to compare how different effects, such as sphericity and temperature law, modify the line profile.

3. Results

We compute several models adopting the three temperature laws described above and for different values of the mass-loss rate . The continuum flux was calculated from the UV spectral region up to the IR region.

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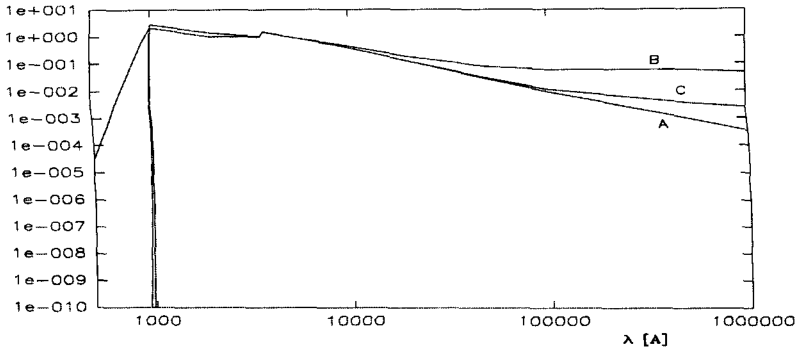

Figure 3. Continuum flux. PP: plane parallel model. A) B) and C) Spherical model flux with temperature laws as described in the model.

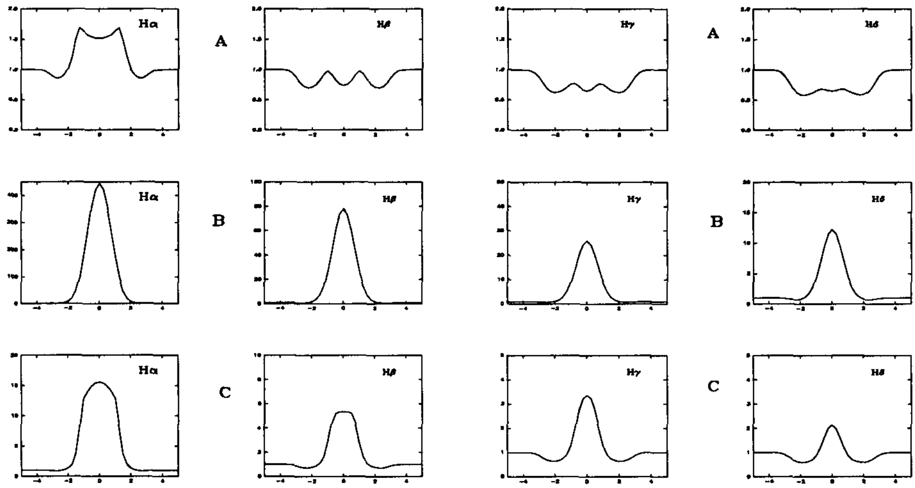

Figure 4. Balmer Series

We analyze how the temperature distribution affects the continuum spectra and the flux distribution inside the frequency of the first members of the Balmer series.

We plotted the emergent continuum flux. In order to compare the fluxes we normalized the monochromatic flux to the flux calculated at 5000 Å . We measure the emission by comparing it with the solution of a classical plane-parallel model.

All models – plane parallel and spherical with the three different temperature laws – coincide within 1% in the visible region. We can see that model B has the largest IR emission and the chromospheric model C is placed always between models B and A.

Consistent results are found when we plot the Balmer line profiles. When the temperature law is constant Hα and Hβ are single peaked emissions. This

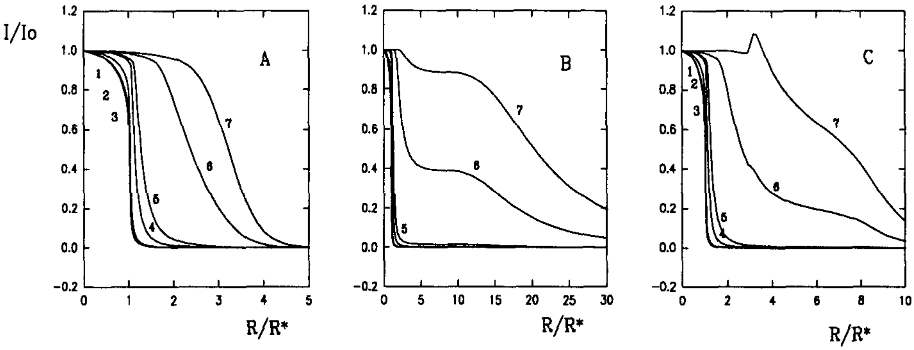

Figure 5. Intensity distribution. 1) 360 nm, 2) 500 nm, 3) 1000 nm, 4) 5 μm, 5) 10 μm, 6) 50 μm, 7) 100 μm.

is a sphericity effect. When a temperature gradient is present an absorption profile is superimposed depending on the density distribution.

Finally, we plot the monochromatic emergent intensity distribution over the stellar disk and the envelope model. The figure below shows that for the UV and visible wavelengths the intensity decays close to the photosphere. For the IR wavelengths the intensity drops down in the envelope at a distance depending on temperature and density.

4. Conclusions

With a very simple spherical model we can reproduce qualitatively the two main features of the Be star phenomenon:

- the IR excess.
- the emission profile in the Balmer series.

Both features have their origin in the sphericity effect. A third feature to be verified is the variation of the stellar disk diameter with wavelength; introducing a chromosphere produces limb brightening.

We suppose that the Be phenomena involves a lot of complex mechanisms which could be included in models of higher order. This present study is only the first step in evaluating the significance of the sphericity effect in Be phenomena.

References

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Crivellari, L., Simonneau, E. 1994, ApJ 429, 1