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PROPERTIES OF REGIONS FORMING THE FeII EMISSION LINES IN BE STARS

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Abstract. We study FeII and Balmer hydrogen emission lines observed simultaneously of 18 southern Be stars. We use the self-absorption-curve method (SAC) to determine the optical depth regime of FeII emission lines and to derive first insights on the physical properties of their forming regions.

1 Introduction

While emission in the first Balmer terms appears for all B sub-spectral types, in Fe II lines is apparent mainly for types earlier than B5 with rare exceptions in latter B sub-types. Many authors carried out more or less systematic studies on the strongest Fe II lines in Be stars. However, it has not been yet stated the optical depth regime that these lines obey in the circumstellar envelope (CE) nor the actual location of their formation region. To this purpose, several members of different multiplets of Fe II lines in the optical range are to be analyzed with empirical methods that avoid, as much as possible, model-dependent diagnostics.

2 Observations and some correlations

The observations of 18 stars were obtained at the Complejo Astronómico El Leoncito (CASLEO), San Juan, Argentina, on March and September 1996 and March 2002 using the 2.15 m telescope and a REOSC echelle Cassegrain spectrograph with mean resolution $R = 11500$.

An interesting result found is that the equivalent width of the central depression of the profiles of $H\beta$, $H\gamma$ and $H\delta$ correlates with $V\sin i$. This can be consistent with the material producing the emission and self absorption in these lines being in flattened enough region of the extended envelope interior to the region where $H\gamma$ and $H\delta$ are formed.

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3 The SAC curves and Results

The SAC method developed by Friedjung & Muratorio (1987) and Muratorio & Friedjung (1988) makes explicit the opacity effect of the emitting layers on the emission lines. It then may carry information on the line opacity. Horizontal displacements of SAC segments of multiplets with a common lower level, as well as vertical displacements of segments relative to multiplets with common upper levels, can lead to the estimate of relative level populations and to derive their excitation temperature. The comparison of the empirically re-composed SAC with the SAC function $Q = (1 - e^{-\tau})/\tau$, where τ is the opacity of a reference multiplet, may then lead to an estimate of the optical depth of lines and to the radius of the line emitting region. The relative displacements of individual SAC segments of multiplets with common upper or lower levels can be expressed as: $|\Delta(X, Y)| = (\chi_1 - \chi_2)(5040/T_{\text{ex}})$, where χ_1 and χ_2 are the excitation potentials of two given levels. They can be used to obtain the excitation temperature T_{ex} . However, when T_{ex} is high the displacements are too small to be measured, as it is the case for our program stars. To obtain an estimate of the excitation temperature, we used then an alternative iteration process.

SAC curves showed that $\partial Q/\partial \tau < 0$ which implies that FeII are optically thick. The excitation temperatures we obtained range from 4300 to 13300 K. The radii of the FeII emitting regions range from 4.3 to $1.1R_*$. The obtained radii are systematically smaller than those obtained using Huang's (1972) expression, $\Delta_p = 2V \sin i (R/R_*)^{-j}$, suited for optically thin lines. However, as shown by our results, Fe II lines are optically thick and the separation of the peaks is further a function of the velocity field and the optical thickness (Cidale & Ringuélet 1989).

4 Conclusions

We conclude that all Fe II lines observed in the optical range are optically thick and are formed very close to the central star at distances that range from 1 to 4.25 stellar radii, where the excitation temperature range from 4300K to 13300K according to the star. In our case, the SAC method could not be used in its whole potentiality and thus, it was not possible to derive the populations of the levels involved in the different transitions. We consider that it is necessary to represent in some detail the physical characteristics of the Be CE based on the first order properties derived here. In particular, it is suited to include the source function of the lines in the SAC and to study the influence of the optical depth on the shape of the emission line profiles.

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