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Computed vs. Observed Line Profiles of Metallic Atoms in Prominences

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Abstract. By solving simultaneously the radiative transfer and statistical equilibrium equations we compute lines profiles for the Ca II H and K lines, Mg II h and k lines and He I at 584,3 Å for several prominence models given by the hydrogen atom. The computed profiles are compared with the observations in order to constrain the physical plasma parameters of solar prominences.

1. Introduction

To be able to extract information from solar prominences it is necessary to construct theoretical models which allow us to predict their physical parameters, like temperature, electronic density, etc. Spectral lines, as well, provide information about the medium where they develop as their profiles and intensities are influenced by these parameters. The calculation of populations and line profiles of many elements, within the prominence is of great importance to establish the the range where the parameters vary, and this is possible when we compare the calculated profiles with the observed ones. In this work, we present a study of the behaviour of the line profiles of the Mg II *h* and *k* lines, Ca II *H* and *K* lines, and He I 584 Å obtained with different atmosphere models (i.e., for different values of temperature, pressure, microturbulence velocity, etc.).

2. Atmosphere Model

Fontenla & Rovira (1985) computed several prominence models for different values of the free parameters assuming several hypotheses in their theoretical model, such as: ambipolar diffusion, radiative losses effects (Cox & Tucker, 1969), filamentary structure, where each thread is represented by a slab with a cold core, standing vertically above the solar surface (no interaction between them), steady state and hydrostatic equilibrium. We have computed several atmosphere models using the F-R code for the following ranges of the atmospheric parameters: central core temperature [4000 to 10.000 K], plasma pressure [0.01 to 1 dyn/cm^2], microturbulence velocity [6 to 20 km/s], length of the central core [60 km to 480 km] and number of threads [1 to 1500].

3. Populations

To compute the line profiles we used a numerical code that reduces the statistical equilibrium and radiative transfer equations to a single system of non-linear operator equations, by incorporating the integral form of the radiative transfer equation into the statistical equilibrium equations (Auer et al, 1972). The input data to this code are the atmosphere models. Briefly, the populations of the different energy levels of any metallic specie can be computed, with the only requirement of having the necessary atomic parameter for that specie. Since the calculations are made for only one thread, the emergent intensity is computed by adding several threads (n) according to

$$I_\nu^+(\tau_\nu,\mu) = \sum_{i=0}^{j=n-1} e^{-\frac{T}{\mu}} \int_0^T S_\nu(t_\nu) e^{-\frac{(t_\nu-\tau_\nu)}{\mu}} \frac{dt_\nu}{\mu} \qquad \textit{with } \mu > 0$$

4. Results

Several models, obtained with different parameters, were employed. For every model, we computed the populations of the different energy levels and emergent intensities in order to compute their line profiles and to investigate the dependence on the free atmospheric parameters. The atomic models we considered, consist for both Ca II and He I of five bounded levels plus a continuum. In the case of Mg II, six bounded levels and a continuum were used.

4.1. Line profiles

As an example, Figure 1 shows the computed line profiles for one of the prominence models, and their comparison with the observed profiles for the Ca II and Mg II lines. The observations were obtained with the OSO 8 LPSP instrument (Vial 1982). The model we used has a temperature at the center of the core of 8000 K, a microturbulence velocity of 18 km/s, a gas pressure of 0.01 dyn/cm^2, and a length of the core of 120 km.

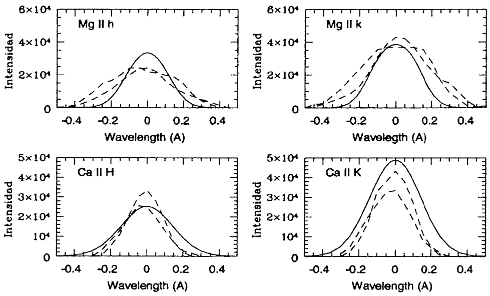

Figure 1. *Line Profiles (solid lines) obtained with an atmosphere model (T=8000 K, v=18 km/s, p=0.01 dyn/cm^2 and L=120 km.), the slashed line correspond to the observations.*

4.2. Dependance on the free parameters

To illustrate how atmospheric parameters such as temperature, pressure etc, modify the shape of each line profile, we have plotted in Figure 2 the intensity at the center of the line as function of these physical parameters.

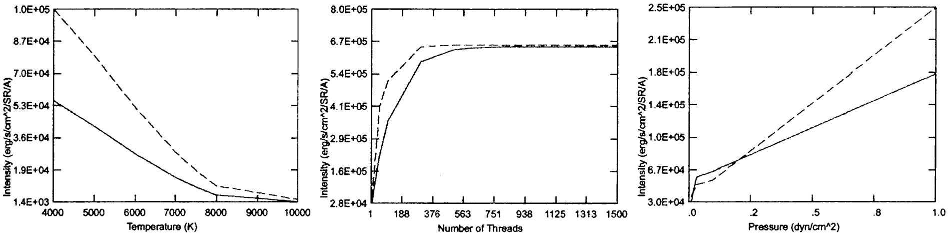

Figure 2. *Intensity vs. temperature (left) and intensity vs. number of threads (center) for Ca II H (slashed) and K (solid) lines. Intensity vs. pressure (right) for Mg II h(slashed) and k (solid lines).*

5. Conclusions

In this section we present some of the results obtained by studying the line profile dependance on the free parameters that model a solar prominence. We observe that Ca II and Mg II ionize with 8000 K approximately. From this temperature the populations of Ca III and Mg III become important and this explains why the intensities for these species decrease when the central temperature grows. For He I 584,3 line we found that the intensity grows with temperature. When we studied the effect of adding threads to the model, we found that the He I do not depend on the number of threads, meanwhile, as lines for Mg II and Ca II are optically thin there's a strong dependance, specially for Ca II ones. The same behaviour is found studying their intensities as function of the width of the central core, for Ca II and Mg II the wider the central region is, the stronger the intensity becomes. For He I we found a constant function, meanwhile the optical depths for the five lines studied, decrease with an increasing temperature. To finish this brief analysis we can add that, both, intensity and optical depth are increasing functions of the gas pressure for He I and Mg II lines. On the other hand, for Ca II lines we have found decreasing functions.

References

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