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Formation of Helium Lines in Solar Prominences

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Abstract. We summarize the results on the formation of the helium spectrum in solar prominences obtained over recent years. The radiative transfer problem under non-LTE conditions is solved to compute the profiles of the lines of He I and He II. The structure of the prominence-to-corona transition region (PCTR) has a major influence on the resulting spectrum of the resonance lines since they are formed mostly in this part of the prominence. However, subordinate lines are also affected by the structure of the PCTR. We pay particular attention to the formation of the He II 304 Å resonance line which is routinely observed from space, but yet not fully understood. Future steps in the modelling will be addressed.

Keywords: Solar Prominences, Radiative Transfer
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INTRODUCTION

Accurate measurements of temperature, density, ionisation, filling factor are crucial to construct realistic models of prominences but difficult to obtain as the prominence plasma is not in local thermodynamic equilibrium because of the strong incident radiation coming from the Sun. Moreover, we witness a large span of measured values depending on the observed structure, and on the technique used. Non-LTE radiative transfer modelling of prominence plasma sheds light on the line formation mechanisms and helps us to interpret spectroscopic and imaging observations.

COMPUTATIONS

The code solves the hydrostatic equilibrium, ionisation equilibrium, and the statistical equilibrium and radiative transfer equations for hydrogen. In a second step the statistical equilibrium and radiative transfer equations are solved for the He I–He II system. We use the equivalent two-level atom method. The solution of the radiative transfer equation is achieved by the Feautrier method. The code is described in [1, 2, 3]. We use 20 energy levels for H I, 29 levels for He I, and 4 levels for He II. The first two resonances lines of each species are treated using partial redistribution in frequency.

The prominence is represented as a 1D vertical slab above the limb and irradiated by the solar disc. The prominence plasma can be chosen to be isothermal and isobaric, but it is usually best to take into account the prominence-to-corona transition region (PCTR). In the PCTR we adopt the pressure and temperature profiles given by [4].

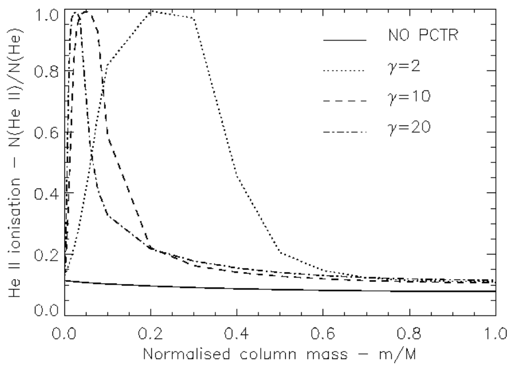

FIGURE 1. He II ionisation ratio as a function of position in the prominence. The coronal boundary is at the left ($m = 0$) and the centre of the slab is at the right ($m = M$).

RESULTS

The presence of the PCTR affects the formation mechanisms of all He lines. Results from [3, 5, 6] have shown that in solar quiescent prominences (negligible velocity fields) the scattering of the incident radiation coming from the Sun is dominant in the formation of most lines. The contribution of collisional excitation becomes important at high temperatures and pressures. The effect of velocity-dependent incident radiation to simulate moving (e.g. eruptive) prominences were investigated in [7, 8]. We found that the He resonance lines are very sensitive to Doppler dimming. In solar prominences, the He II line at 304 Å is mostly formed by the scattering of the incident radiation. The He II ion is populated either by photoionisation when there is no PCTR, either by collisional ionisation when a PCTR is present (see Fig. 1).

1D plane-parallel prominence slabs have allowed great progress to be made in the understanding of the formation of helium lines in solar prominences. More detailed results are presented in [9]. We are now investigating the formation of the helium spectrum in 2D cylindrical models [10].

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