Towards a general collisional radiative model

TOWARDS A GENERAL COLLISIONAL RADIATIVE MODEL

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1. INTRODUCTION

Collisional Radiative Models (CRMs) are a widely used tool in the modelling of plasmas. The results of such models appear as source terms in the particle and energy balances of plasma transport models. Usually such models calculate a partial Quasi Steady State Solution (QSSS). This means that the spatial and temporal relaxation of most excited state densities is neglected, which is valid for a broad variety of plasmas.
Recently a new CRM has been developed which combines two interesting properties:

- validity for a broad range of electron densities, as stepwise processes are taken into account;
- the number of non-QSSS levels can be chosen arbitrarily, generalising the concept of the so-called *coefficients of net ionisation and recombination*.

As a result of these properties it is possible to fully describe radiative transfer, while simultaneously the model is valid for higher electron densities, as step processes can be taken into account. An application of this model is discussed in a second contribution to this conference [1]. Other research groups are kindly invited to participate in this research.

2. THE MODEL

In case the change of internal energy of the heavy particles is due to electron collisions and radiative processes the Atomic State Distribution Function (ASDF) can be calculated from plasma parameters, such as the electron density and temperature by solving a set of continuity equations. If the electron density is low only a few excited levels have to be taken into account. This holds for e.g. the conventional fluorescent lamps where, due to an electron density of around 5×10^{17} m^{-3}, a model with only four to six excited atomic mercury levels gives an accurate description of the discharge [2]. If the electron density rises more levels must be taken into account because of the onset of the stepwise excitation and ionisation processes [3].

In the model both numerical and analytical techniques have been combined. The lowest excited states, which are in Corona Balance (CB) have to be calculated numerically. The highest states are in Partial Local Saha Equilibrium (pLSE). In the case of an ionising plasma, the intermediate levels are in a so-called Excitation Saturation Balance (ESB). It was shown both numerically by Fujimoto [4] and analytically and experimentally by Van der Mullen [3,6] that the deviation from Saha equilibrium of the levels in ESB depends on their effective principal quantum number in a known way. Also these levels can therefore be treated analytically and the number of levels for which the continuity equation has to be solved can be further reduced. This truncation technique minimises the numerical effort which is needed and works in the case of recombining plasmas as well [5].

3. NUMERICAL IMPLEMENTATION

The program is written in C++ and has been ported to Windows and UNIX-based systems. For MS-Windows a graphical interface has been developed (see figure 1 for a sample).
The input parameters for the model are the cross sections for the collisional processes, the effective radiative decay frequencies, the electron and heavy-particle temperatures. Further the electron

density and the densities of the non-QSSS states must be specified. The program calculates the rate coefficients of the collisional processes from the cross sections by integrating over the velocity distribution. At this moment the Maxwellian equilibrium distribution is assumed, but the implementation of other velocity distributions is possible. From these data, the program calculates the ASDF, the radiation production and the ionisation and recombination coefficients.

Further the program provides default values for the cross sections of the collisional processes involving the higher excited states. These values are calculated from a hydrogen approximation. This approximation is of course not valid for the lower states, for which the cross sections can be entered by specifying parameters of a chosen fitting function. *See [1] for a specific application.*

4. ACKNOWLEDGEMENTS

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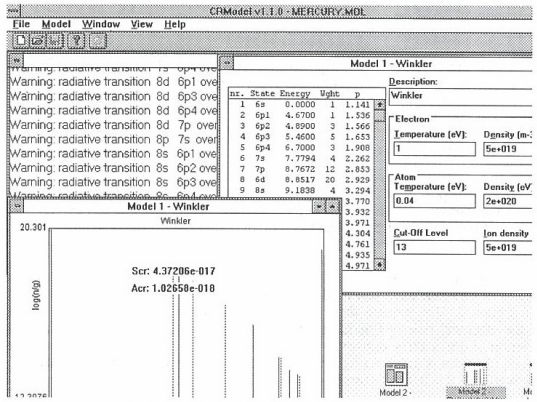

Fig. 1: User interface of the CRM program.