MMM Profiles of HeI Lines: Ion Dynamics Effect

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Stark profiles of the HeI 4471 and 4922 Å overlapping lines are calculated by the Model Microfield Method. Even at high densities ($3 \cdot 10^{16}$ cm^{-3}) an ion dynamics effect is exhibited by varying the reduced mass of the radiator-perturber system or the ionic temperature.

Recent experimental work [1, 2] has pointed out an ion dynamics effect on the profile of the 4471 Å overlapping HeI line. Such an effect on Helium line profiles was predicted by the Model Microfield Method (MMM) as early as 1971 [3]; the ion dynamics effect on the H_α and H_β lines, the linear $\mu^{-1/2}$-dependence of any quantity constructed from the profile (μ being the reduced mass of the radiator-perturber system) are reported in [4] (see also [5]). A previous work on the 4471 Å HeI line [6] has already shown a smearing of the dip by the inclusion of the ion dynamics which is in qualitative agreement with the results of [1, 2]. The aim of this note is to present new data on the 4471 and 4922 Å lines varying the reduced mass of the radiator-perturber system or the ionic temperature in order to allow a direct comparison with recent experiments.

The general framework of the calculations can be found in [3] and [6]. The most prominent features are the following: i) after projection upon the relevant levels the Schrödinger equation is solved in the presence of a compound model field $\boldsymbol{E}_e + \boldsymbol{E}_i$: the convolution of the separately calculated electronic and ionic profiles which has been shown in [6] to be inadequate for overlapping lines is thus avoided. ii) The time dependence of the electronic as well as of the ionic part of the plasma microfield is fully taken into account through the time covariance $\Gamma(t) = \langle \boldsymbol{E}(t) \cdot \boldsymbol{E}(0) \rangle$ from which the jumping frequencies of the model fields are calculated. The covariance derived from a plasma

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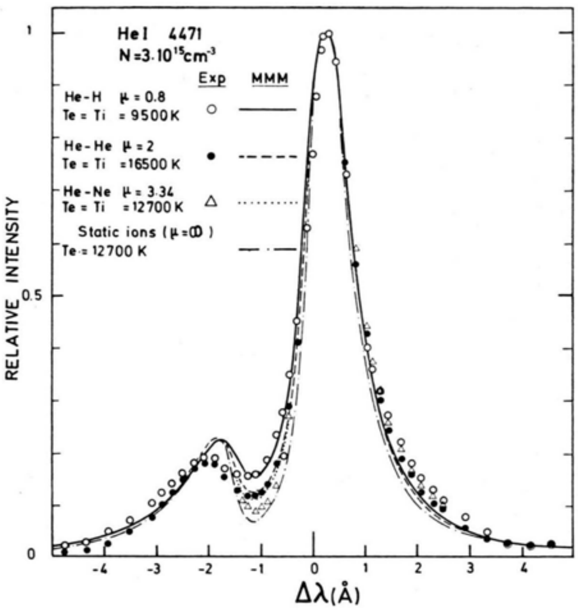

Fig. 1. Experimental (Ref. [1]) and MMM theoretical profiles of the 4471 Å HeI line at an electron density $N = 3 \cdot 10^{15}$ cm^{-3}. Temperature and reduced mass of the radiator-perturber system are indicated for each plasma. The Doppler profile is taken into account in the calculations.

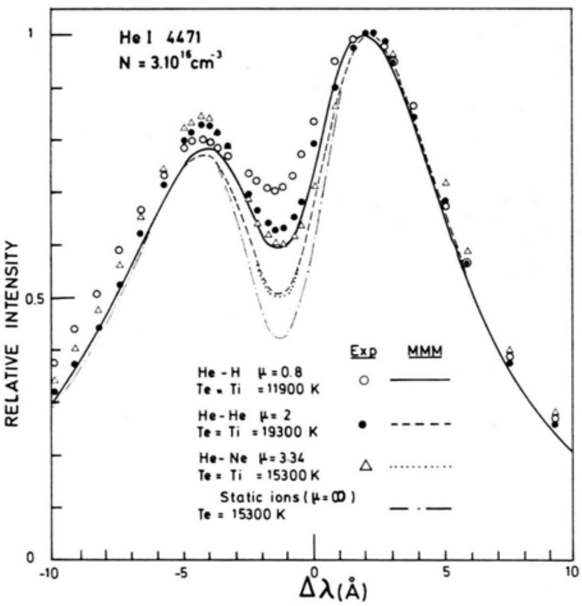

Fig. 2. Experimental (Ref. [1]) and MMM theoretical profiles of the 4471 Å HeI line at an electron density $N = 3 \cdot 10^{16}$ cm^{-3}. Temperature and reduced mass of the radiator-perturber system are indicated for each plasma. The Doppler profile is taken into account in the calculations.

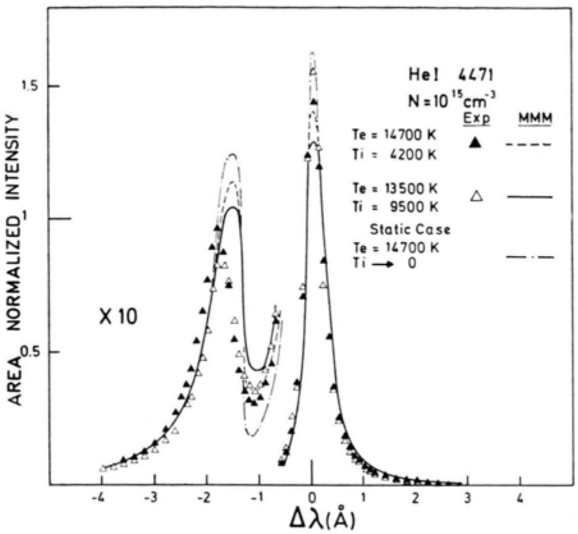

Fig. 3. Experimental (Ref. [2]) and MMM theoretical profiles of the 4471 Å HeI line at an electron density $N = 10^{15}$ cm^{-3}. Electronic and ionic temperatures are indicated for each plasma. The Doppler profile is taken into account in the calculations.

model of independent particles with Debye fields is given in [7].

Figures 1 and 2 give the 4471 Å results for three different values of the reduced mass of the radiator-perturber system corresponding, as in [1], to hydrogen, helium and neon perturbing ions. In the calculations we put equal values for the electronic and the ionic temperatures despite the fact that the latter is found 3000–6000 K lower than the electronic one for the He-He and He-Ne plasmas. The reason for this choice is that no definite value of the ionic temperature is given in [1] and that calculations with an ionic temperature 4000 K lower than the electronic one show only a few percent variation of the relative dip intensity. As shown on Figs. 1 and 2 the agreement with the experiments particularly good at $N = 3 \cdot 10^{15}$ cm^{-3} is partially broken at the highest density $N = 3 \cdot 10^{16}$ cm^{-3}, the effect of the ion dynamics being always present. At high densities ($N \gtrsim 10^{16}$ cm^{-3}) the profile is in fact dominated by the "collective field" i.e. fields smaller than a few E_0 (E_0 being the typical field) whose time duration is not known. The jumping frequencies of the model field can be related to the time duration of strong fields (see [7]), but not to that of weak fields: the jumping frequency in this case may not describe accurately enough the actual time duration of the fields of interest. If we assign with some arbitrariness the time duration of the weak fields to be of the order of the inverse of the plasma frequency the profile values in the dip are rather different and in much better agreement with the experiments at densities $N \geqq 10^{16}$ cm^{-3}.

Figure 3 allows the comparison of the 4471 Å MMM calculations with the experimental results of [2]. The perturbing ions are helium ions, the temperature of which is varied from 4200 to 9500 K at a fixed electron density and at an approximately

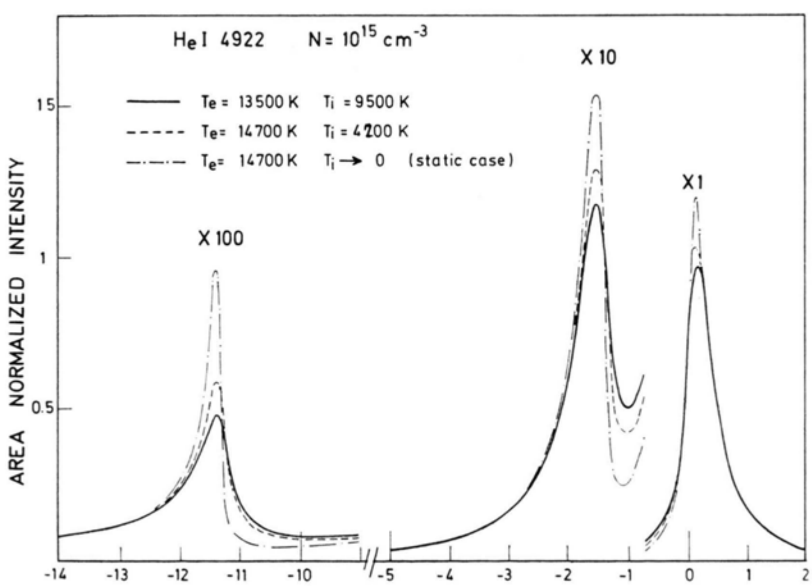

Fig. 4. MMM theoretical profiles of the 4922 Å HeI line at an electron density $N = 10^{15}$ cm^{-3}. Electronic and ionic temperatures are indicated for each profile. The Doppler profile is taken into account in the calculations.

constant electron temperature. The area normalised representation of the profiles reveals that the ion dynamics effect is present in the whole line shape and not only in the dip between the two components. With regard to the qualitative effects (smearing of the dip, lowering of the intensity of both components by the inclusion of ion dynamics) the agreement with the experiment is very good. Nevertheless experimental profiles (particularly the position and the intensity of the forbidden component) are not entirely recovered by the theory.

In this comparison with the experimental results of [1] and [2] we have checked by calculations at constant electronic temperature that the observed features are really imputable to a reduced mass or ionic temperature effect, i.e. are not induced only by the variation of the electronic temperature from one experiment to the other.

Finally, Fig. 4 gives the theoretical profiles of the 4922 Å line for the physical conditions of [2]. The effect of ion dynamics is exhibited by the three components with the same qualitative features as in the case of the 4471 Å line. These examples show conclusively the existence of a non negligible ion dynamics effect in HeI lines and the intrinsic ability of the Model Microfield Method to take it into account.

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