EFFECT OF TWO TYPES OF NON-MAXWELLIAN ELECTRON DISTRIBUTIONS ON TEMPERATURE SPECTROSCOPIC DIAGNOSTICS

C. Möller and M. Lamoureux
Laboratoire de Spectroscopie Atomique et Ionique,
Université Paris-Sud, 91405, Orsay, France

Continuum emission due to bremsstrahlung and direct radiative recombination is studied in two types of fusion-plasmas with non-Maxwellian electron distributions. The calculated emissivity coefficients $J_\omega(\hbar\omega)$ are shown to depart from the Maxwellian ones. The main consequence of the modification of the spectrum is to invalidate the usual electron temperature diagnostic which consits in equating $d\ln J_\omega(\hbar\omega)/\ d(\hbar\omega)$ to $1/kT_e$.

Case I corresponds to the critical density region of a laser-produced plasma (Langdon 1980, Mora and Yahi 1982). The distribution function is $c_m \exp(-v/v_{\circ,m})^m$ with m=5 for all values of the incident electron velocity $v_{\circ,m}$. Case II corresponds to very steep temperature gradients for which the spacial scale of the transport region is larger than the gradient scale itself (Albritton 1983, Luciani et al. 1984, Campbell 1984). On the higher temperature side of the heat front, the tail of the distribution is depleted with respect to the Maxwellian one . At a particular distance from it, this tail can be roughly described by the above analytical function but with m=3.

Universal emissivity curves (Lamoureux et al. 1984) were given in case I, for completely stripped ions, for bremsstrahlung and recombination separately, provided Kramers' atomic data are suitable. Another set of curves can be similarly established in case II as well. Results can be extended to less strongly ionized plasmas by employing an efficient degree of ionization (Kim and Pratt,1983), ($Z+Z_i$)/2, for the captures into each ion A^2i^+. Results concerning bremsstrahlung are given in Fig. 1 ; the departure of the two non-Maxwellian curves from the Maxwellian straight line reflects the non-Maxwellian character of the distribution, and the variability of their slope points out the failure of the usual diagnostic in most regions of the spectrum.

We then evaluate as an example the total emissivity coefficient $J_\omega(\hbar\omega)$ produced at the kinetic temperature of 1 keV and the density of 10^{21} e/cc in an Aluminium plasma consisting of 25 % Al^{13+}, 50 % of Al^{12+} and 25 % of Al^{11+}.(See Fig. 2). In case II, non-Maxwellian effects are felt only at high photon energies. In case I, the non-Maxwellian character is more pronounced ; it is found over the entire spectrum, and especially right above the Al^{13+} 1s threshold, as was observed experimentally (Matthews et al. 1983). The usual temperature diagnostic is then very mileading as is illustrated by the dotted curve of Fig. 2.
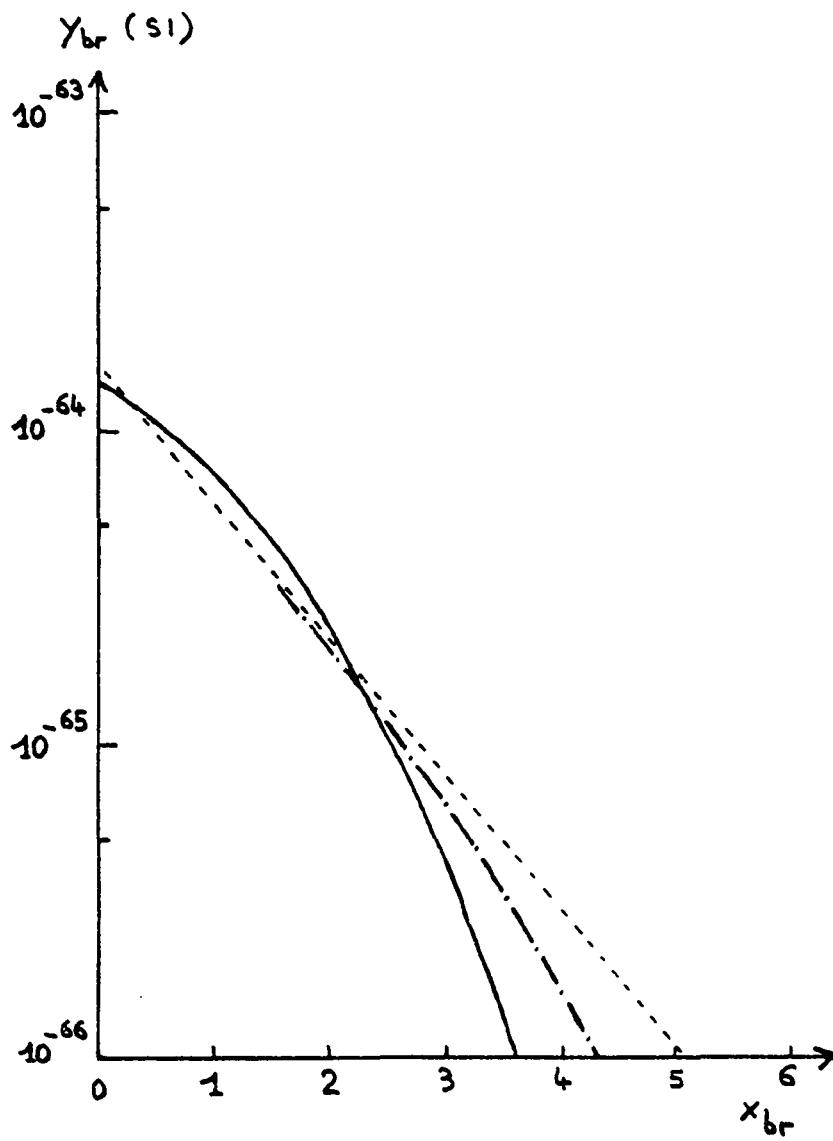
Fig. 1 : Reduced emissivity for bremsstrahlung y_{br} versus photon energy $x_{br} = \hbar\omega/kT_e$. y_{br} is related to the emissivity coefficient j_{br} by $y_{br}(\hbar\omega) = j_{br}(\hbar\omega)(kT_e)^{1/2} / (N_e N_i Z_i^2)$.
(- - -) : Maxwellian distribution, (——) : non-Maxwellian, case I;
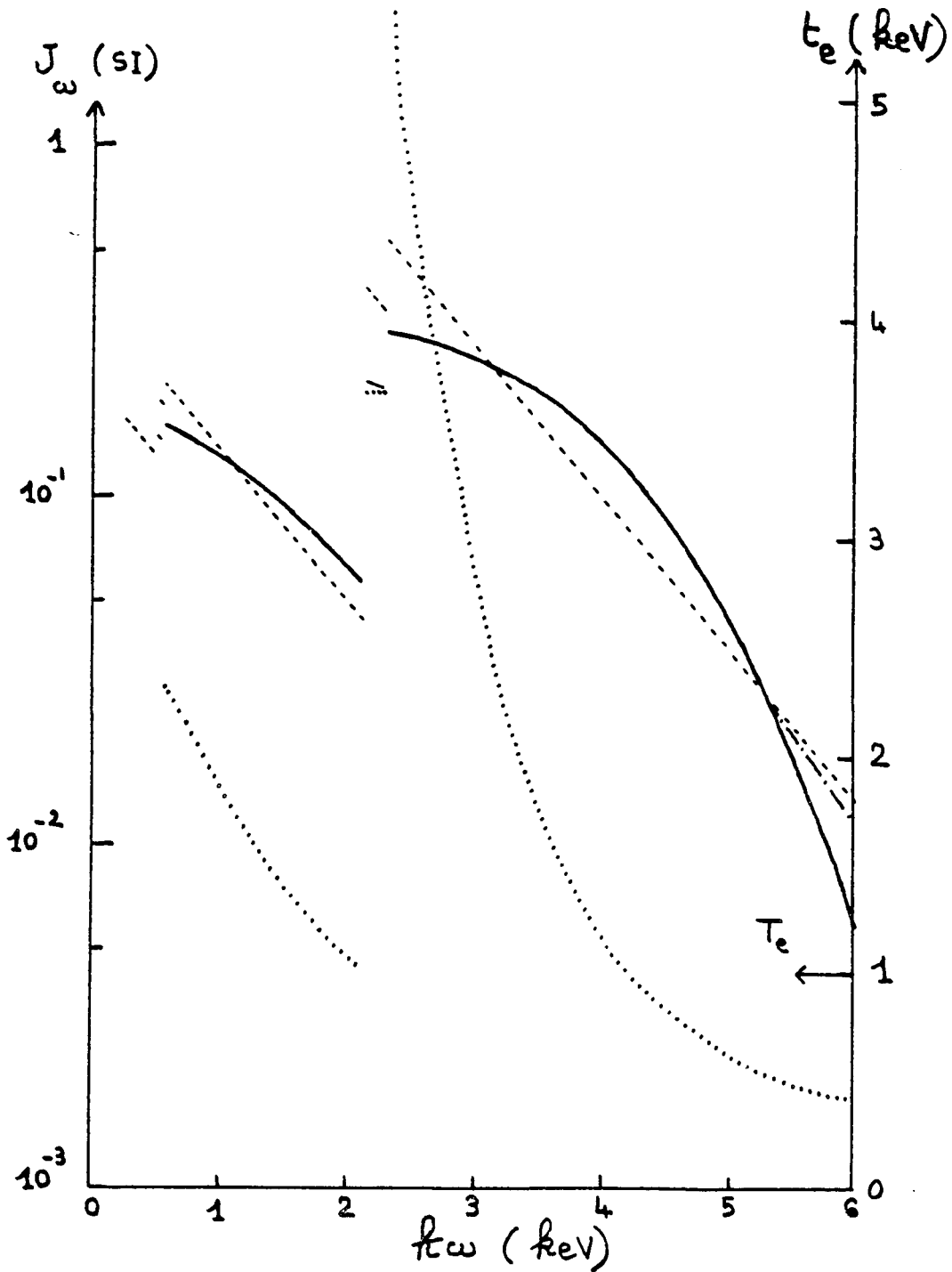(— . —) : non-Maxwellian, case II .

101

Fig. 2 : Total emissivity coefficient J_ω versus photon energy $\hbar\omega$ for an Al plasma, at $T_e =1$ keV and $d = 10^{21}$ e/cc, consisting of 25 % Al^{13+}, 50 % Al^{12+} and 25 % Al^{11+}. (- - -) : Maxwellian distribution, (—) : non-Maxwellian, case I , (— . —) :non-Maxwellian,case II.

Misleading temperature t_e obtained from the diagnostic whereas the kinetic temperature is T_e, (....) : non-Maxwellian distribution, case I. (Dotted curves should be read on the right ordinate).

REFERENCES

Albritton, J.R. 1983, Phys. Rev. Lett., 50, 2078.

Campbell, P.M. 1984, Phys. Rev. A, 30, 365.

Young Soon Kim, and Pratt, R.H. 1983, Phys. Rev. A, 27, 2913.

Lamoureux, M., Möller, C., and Jaeglé, P. 1984, Phys. Rev. A, 30, 429.

Langdon, A.B. 1980, Phys. Rev. Lett., 44, 575.

Luciani,J., Mora, P., and Pellat, P., to be published, and private communication.

Mora, P., and Yahi, H. 1982, Phys. Rev. A, 26, 2259.

Matthews, D. L., Kauffmann, R.L., Kilkenny, J.D., and Lee, R.W. 1983, *Rutherford Appleton Laboratory Report* No. RL83-043.