COMPARATIVE STUDY OF ELECTRON BREMSSTRAHLUNG IN VARIOUS HIGH ρ - T POTENTIALS

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In order to calculate bremsstrahlung cross sections in plasmas, an atomic potential which includes the effects of the surrounding plasma is required. For the high ρ - T conditions we are considering ($n_e = 10^{25}$ cm^{-3}, T = 500 eV), plasma correlative effects are important. In these strongly coupled plasmas, the Debye-Hückel potential is irrelevant and not considered here. The statistical Thomas-Fermi (TF) potential (Feynmann, Metropolis, and Teller, 1949) is known to be correct at very high densities but does not contain correlation information. A semiclassical treatment of correlations that accurately reproduces results of numerical simulations of strongly coupled plasmas is the hypernetted chain (HNC) approximation to the hierarchy of equations describing density distributions (Hansen and McDonald, 1981). The method generates many-body distributions using an analytic two-body interaction that successfully approximates quantum effects at short distances. These distributions are used in the Poisson equation to find the effective potential (Cauble, Blaha, and Davis, 1984). An alternative method (Gupta and Rajagopal, 1982) of including correlations is to treat them in a quantum mechanical manner, taking into account ion correlations as well as electron exchange and correlation; this is done in density functional theory (DFT), where electron wavefunctions and the effective potential which is used here are obtained self-consistently (Dharma-wardana and Perrot, 1982; Perrot and Dharma-wardana, 1984). Comparison of these methods can be found elsewhere (Cauble, Gupta, and

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Davis, 1984). These potentials for aluminum at 10^{25} cm^{-3} and 500 eV are displayed in Fig. 1.

Electron bremsstrahlung Gaunt factors are obtained from the three types of potentials described above by three different atomic physics methods (Pratt, 1983). The most sophisticated method is the multipole relativistic partial wave expansion model, which has been used for plasmas only recently (Feng, et al). The other two methods are much simpler (and consequently require much less computer time). The Born-Elwert form factor approximation, which is known to be best suited for high energies, overestimates the Gaunt factors at low energies. On the contrary, the classical mechanics approach (Lamoureux and Pratt, 1983), which is not valid at high energies, is more appropriate in the low energy range (see Fig. 2). As expected, the more screened the ion, the smaller the Gaunt factor; thus the TF potential leads to smaller Gaunt factors than the other two potentials. To further explain the influence of the choice of the potential, it is useful to recall that the range of radius probed by the bremsstrahlung process is estimated by the inverse of the momentum transferred. This accounts for the (somewhat accidental) similarity of the Gaunt factors obtained from the TF and DFT potentials in the example illustrated in Fig. 2 (The radius of interest here is about 1.2 a.u.).

In the high ρ - T case considered here, the relative discrepancies between the Gaunt factors obtained from the various atomic methods, all of them taking screening into account, can be as large as 50%. The type of average atom potential used to describe the plasma appears to be less influential (< 10%) than the choice of atomic method.

REFERENCES

Cauble, R., M. Blaha, and J. Davis 1984, Phys. Rev. A 29, 3280.

Cauble, R., U. Gupta, and J. Davis 1984, Proceedings of IAU Colloquium No. 86, Washington, D.C., this volume.

Dharma-wardana, M.W.C. and F. Perrot 1982, Phys. Rev. A 26, 2096.

Feng, I.J., M. Lamoureux, R.H. Pratt, and H.K. Tseng 1983, Phys. Rev. A 27, 3209.

Feynmann, R.F., N. Metropolis, and E. Teller 1949, Phys. Rev. 75, 1501.

Gupta, U. and A.K. Rajagopal 1982, Phys. Rep. 87, 259.

Hansen, J.P. and I.R. McDonald 1981, Phys. Rev. A 23, 2041.

Lamoureux, M. and R.H. Pratt 1983, Proceedings of the 2nd Int'l. Conference on the Radiative Properties of Hot Dense Matter, Sarasota (to be published in J. Quant. Spectros. Rad. Trans.).

Perrot, F. and M.W.C. Dharma-wardana 1984, Phys. Rev. A 29, 1378.

Pratt, R.H. 1983, Fundamental Processes in Energetic Atomic Collisions, ed. by H.O. Lutz, J.S. Briggs, and H. Kleinpoppen (Plenum Press, New York).

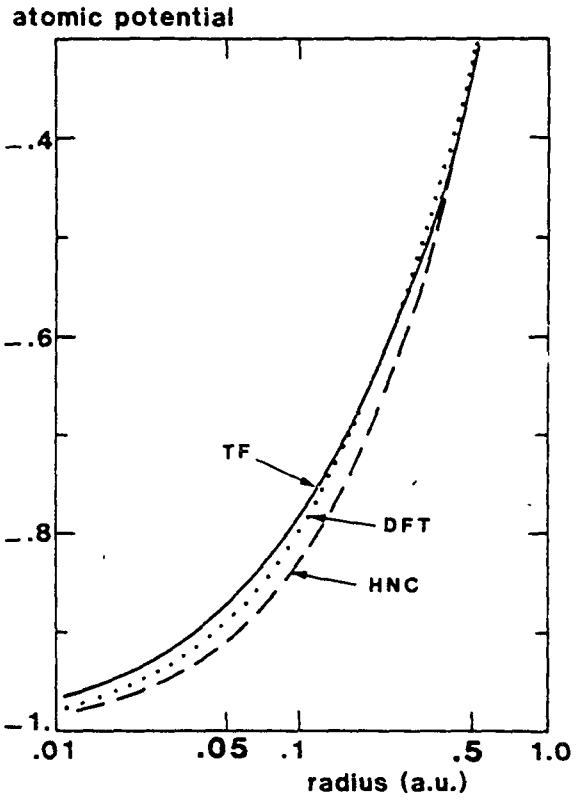

Fig. 1: Average atom potential (rV(r)/Z) for an Aℓ plasma at the temperature of 1 keV and the electron density of 10^{25} e/cc in models of increasing complexity. (-): TF; (---): HNC-Poisson; (···): DFT.

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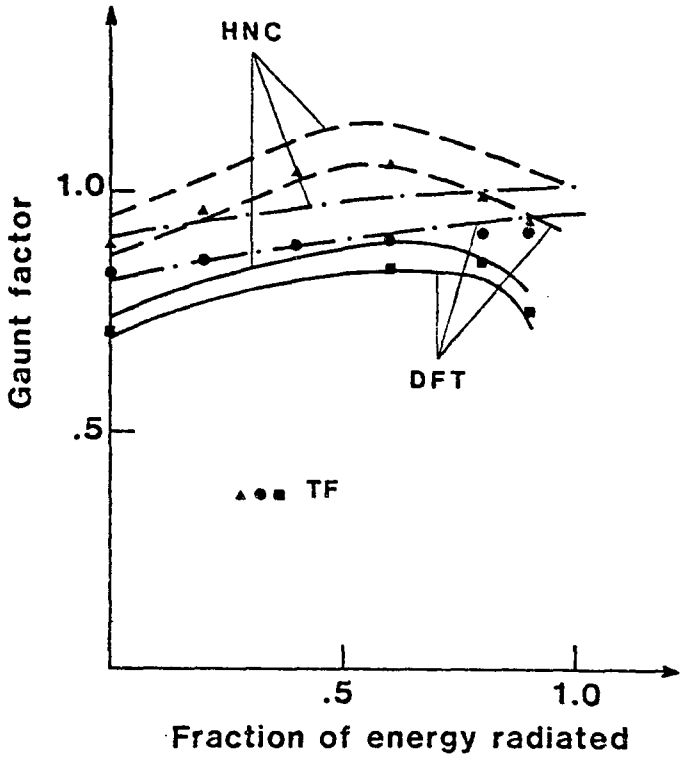

Fig. 2: Electron bremsstrahlung Gaunt factors obtained from the potentials of Fig. 1, for incident electrons of 1 keV, and using three atomic methods of increasing complexity. (-·- ●): classical mechanics approach; (---▲): Elwert Born form factor; (——■): Multiple relativistic partial wave expansion model.

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