Microfield distribution in a TCP at a neutral point*

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The observed line shapes of radiating atoms or ions immersed in a plasma are closely related to the electric microfield distribution (MFD) at the position of the radiator [1]. To determine the MFD various theoretical approaches have been proposed. Most of them are treating one-component plasmas, in particular in framework of the very successful APEX scheme [2].

We generalized and modified the APEX scheme to a classical two-component plasma (TCP) with attractive ion-electron interaction, initially for the MFD at charged point [3] and recently also at a neutral point [4]. These descriptions start with expressing the normalized MFD, $P(E)$, in a TCP in equilibrium by

$$P\left(E\right)=\frac{2E}{\pi}\int_{0}^{\infty}\mathcal{T}(k)\;\sin\left(kE\right)kdk\,,$$

where the function $\mathcal{T}(k)$ is related to the effective fields $\mathcal{E}_\alpha(r)$ around the plasma particles, i.e. electrons and ions, with charges q_α and their densities n_α. For a neutral radiator it reads:

$$\mathcal{T}\left(k\right)=\exp\left\{\sum_{\alpha}\frac{q_\alpha n_\alpha}{\varepsilon_0}\int_{0}^{\infty}\frac{dr}{\mathcal{E}_\alpha(r)}\left[\frac{\sin\left(k\mathcal{E}_\alpha\right)}{k\mathcal{E}_\alpha}-1\right]\right\}.$$

At a neutral point these effective fields $\mathcal{E}_\alpha$ are defined through the pair correlation functions $g_{\alpha\beta}$ between particles with charges q_α, q_β [3]

$$\mathcal{E}_\alpha(r)=\frac{q_\alpha}{4\pi\varepsilon_0 r^2}\;+\;\sum_{\beta}\frac{q_\beta n_\beta}{\varepsilon_0 r^2}\int_0^r\left[g_{\alpha\beta}\left(\rho\right)-1\right]\rho^2 d\rho\,.$$

The required $g_{\alpha\beta}$ are calculated from the hyper-netted chain (HNC) equations, see e.g. [5], where the attractive ion-electron interaction has been regularized at small distances taking $V_{ei}\propto[1-\exp(-r/\delta)]/r$. This theoretical approach has been checked by comparing with results of molecular-dynamics (MD) simulations, where we found very good agreement in a wide range of parameters, both for the MFD at a neutral point as well as at a charged point, see Refs. [3, 4].

As an example we plotted in Fig. 1 the MFDs, $P(E)$, resulting from the outlined theory and from MD-simulations at a neutral radiator (e.g. a H-atom) in a strongly coupled H^+-e^- plasma. At high electric fields (lower part) the agreement is perfect, while at low fields (upper part) some small discrepancies show up. There the MFD of the strongly coupled plasma also clearly deviates from the Holtsmark distribution (dash-dotted curves) for an uncorrelated TCP (i.e. $\Gamma_{ee}\to 0$), but it merges with the Holtsmark MFD at high fields. In contrast to the MFD at a neutral point, the MFD at a charged point, i.e. at a proton (open circles), decreases at high fields much faster. Intermediate field strengths ($E\sim 8E_H$) are here much more likely due to the proton-electron interaction which attracts electrons to the protons.

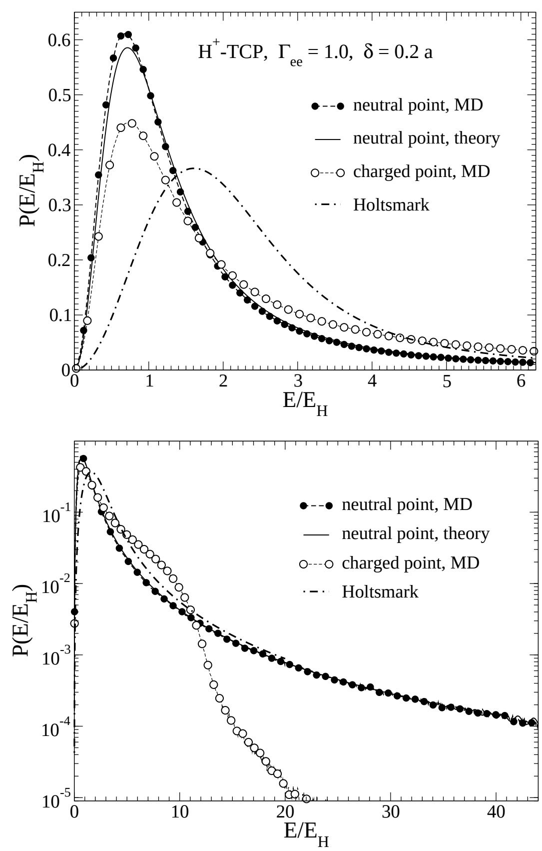

Figure 1: MFD of the outlined theoretical treatment (solid curves) and of MD-simulations (filled circles) for a neutral point in a H^+-e^- plasma with Γ_{ee}=1.0. For comparison also the MFD at a charged point (from MD) and the Holtsmark MFD are shown. The electric field is scaled in units of $E_H=e(8\pi/25)^{1/3}/4\pi\varepsilon_0 a^2$ with $a=(4\pi(n_i+n_e)/3)^{-1/3}$.

References

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