SEVERE VIOLATIONS OF GLOBAL PLASMA MODELS

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Global plasmas models (GPM) are of great value for the characterisation of plasmas. They provide quasi-analytical expressions for internal plasma properties, such as electron density $n_e$ and electron temperature $T_e$ as functions of the external plasma control parameters (the knobs) such as pressure, filling-composition and plasma-size. Several success-stories can be found in literature [1]. GPMs were among others employed for capacitively coupled low-pressure plasmas used for IC technology, atmospheric inductively coupled plasmas for elemental analysis, the plasma in the Philips QL lamp and to support the interpretation of time-resolved Thomson scattering measurement performed on a capacitively coupled helium RF discharge (cf. [2] and the reference given therein).

The first step in most GPMs is to compute the electron temperature $T_e$ using the electron balance. The underlying idea is that the ambipolar efflux of electron-ion pairs (e-i) dictates the rate of volume ionisation in the active plasma region. This gives $T_e$-values that in general fit well with the values found with experimental methods. Note that inherent to the GPM-method these $T_e$-values only depend on the size of the plasma and the diffusion coefficient (thus the pressure and some species dependent features). Thus they do not depend on the energy coupling-mode of the plasma. To state it differently; direct current or inductively coupled plasmas have the same $T_e$-value as microwave induced plasmas (MIP) of the same size, pressure and plasma gas.

In this contribution we will present two examples for which severe differences were found between the $T_e$ as found with the GPM and the $T_e$ found by Thomson scattering (TS).

The first example is that of the microwave induced plasma (MIP) known as TIA (Torche à Injection Axiale). This TIA mostly generates atmospheric argon plasmas of filamentary structures. We found with TS a $T_e$-value that is about a factor 2 larger than what the GPM predicts (1.7 eV in stead of 0.9 eV)! The explanation that can be given is that, as the filaments created by the TIA sweep around in air, nitrogen is entrained. Due to charge transfer collisions between Ar$^+$ and N$_2$ giving N$_2^+$ and the subsequent dissociative recombination of N$_2^+$ a huge local volume recombination sink is created. This removes electron ion pairs at a frequency that is about 10$^2$ times larger than what ambipolar efflux can realise. Therefore a larger $T_e$-value is demanded than the value needed to support the losses of e-i pairs due to the ambipolar efflux.

The second example is that of a MIP created by a surfatron in argon of about 10 mbar. The GPM normally gives $T_e$-values that agree within 5% with results of TS. However by mistuning the power-coupling of the same MIP, we could create conditions in which the $T_e$-values (found with TS) are about a factor 2 smaller than the normal (GPM-supported) $T_e$-values. This means that in contrast to the statement given above the $T_e$-value depends on energy coupling-mode. The basic reason behind this interesting phenomenon is still under study.