Ionization coefficients resulting from the direct molecular simulation of meteor entry flows

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Ionization coefficients have a paramount importance in meteor astronomy. Firstly, to reduce the uncertainties in the input to the chemistry models of the upper atmosphere. Second, for the interpretation of radar and radio observations, which currently relies on phenomenological methods, derived under the assumption of free molecular flow, hence, poorly accounts for the dynamics of the vapor, detailed chemistry, and diffusion processes.

In this work, we aim at providing an accurate description of the dynamics of the ablated vapor around a meteoroid by means of the Direct Simulation Monte Carlo (DSMC) method. In particular, we compute free electron densities and the resulting ionization efficiencies for different entry velocities and altitudes of detection.

DSMC is an established method for the simulation of transitional flows, where the hydrodynamic regime does not hold and analytical solutions cannot be found. Hence, it represents an excellent technique for the study of meteor flows, not least for the simplicity with which it is possible to include physico-chemical models in the algorithm. In particular, an evaporation boundary condition suitable to model multicomponent silicate materials is introduced. Transport properties of the ablated vapor are computed from Lennard-Jones potentials and the elastic cross sections are retrieved by fitting the collision integrals over a wide range of temperatures. Finally, inelastic cross sections for direct and electron impact ionization of metals are computed according to the Drawin model and the link between DSMC steric factors and ionization efficiencies is provided.