Elementary physical processes, transport and scattering, of electrons in planetary atmospheric discharges

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Lightning is one of the most spectacular natural phenomena and definitely one of the most dramatic. In the chain of processes leading to lightning, the electron scattering from the gas molecules, transport and thermalization of the electrons, are fundamental processes, followed by large-scale charge separation which results in the build-up of a strong electric field. Lightning is not just associated with our planet. It has been observed on the various planets of the solar system. While the appearance of lightning on Venus and eventually in dust storms on Mars are still open issues, we have clear evidences of lightning on Jupiter, Saturn, Uranus and Neptune [1].

It is well-documented, that lightning discharges produce electromagnetic pulses (EMP), due to the rapid current pulse, as well as a quasi-electrostatic (QE) field due to the removal of charge from the thundercloud. When the QE field exceeds the breakdown threshold in the mesosphere of our planet, the sprite discharges can be initiated, while the EMP field similarly leads to heating, ionization and optical emissions often referred to as elves [2].

In this work, we study the properties of electron transport in gaseous mixtures that mirror planetary atmospheres. Calculations have been performed over a range of the applied electric fields using a numerical solution of the Boltzmann equation [3]. The following influences of specific physical processes on electron kinetics are identified: (i) for Earth's atmosphere the effects of 3-body attachment are studied, (ii) for Venusian atmosphere the effects of the gas temperature are examined, and (iii) for gas giants, the influence of planetary magnetic field is investigated. Calculations of electron transport properties have also been performed in radio-frequency electric and magnetic fields. The calculated transport coefficients are then used as input in fluid models of various orders for streamer discharges [4]. Values of streamer velocity, ionization level behind the front and average electronic energies are calculated for various gas mixtures relevant to planetary atmospheres.

References

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