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Electron transport and streamer propagation in the atmosphere of Titan and other N_2:CH_4 or N_2:O_2 mixtures

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Here we approach the study of extraterrestrial lightning by studying the formation and propagation of streamer discharges on Titan with an atmospheric composition of N_2:CH_4=98.4%:1.6%. Therefore, we simulate the motion of electrons from initial electron-ion patches in N_2:CH_4 and for comparison also in N_2:O_2 mixtures with a percentage of nitrogen ranging from 20% to 98.4%. First, we solve the Boltzmann Equation and obtain the rate coefficients for ionization and attachment of electrons in different N_2:CH_4 and N_2:O_2 gas mixtures and hence the critical electric fields E_k. Subsequently, we use a 2.5D particle-in-cell Monte Carlo code to calculate the motion of electrons in different ambient electric fields and in different gas ratios. We study which conditions are necessary for an avalanche-tostreamer transition and present spatial distributions of the electron density and of the electric field as well as the electron energy distribution and the temporal evolution of streamer velocities. Finally we compare our results with those for Earth, i.e. in a gas composition of N_2:O_2=0.8:0.2, and conclude that avalanche-to-streamer transitions in N_2:CH_4 are likely for low percentages of nitrogen or for high normalized ambient fields (E/E_k). This work will lay the foundation for the studying streamer discharges in other atmospheres (e.g. of exoplanets) as well as for the search of high-energy events associated to the atmospheric electricity of other planets.