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Cooling of Electrons in a Weakly Outgassing Comet

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The plasma instruments, Mutual Impedance Probe (MIP) and Langmuir Probe (LAP), part of the Rosetta Plasma Consortium (RPC), onboard the Rosetta mission to comet 67P revealed a population of cold electrons (<1eV) (Engelhardt et al., 2018; Wattieaux et al, 2020; Gilet et al., 2020). This population is primarily generated by cooling warm (~10eV) newly-born cometary electrons through collisions with the neutral coma. What is surprising is that the cold electrons were detected throughout the escort phase, even at very low outgassing rates ($Q<1e26\ s^{-1}$) at large heliocentric distances (>3 AU), when the coma was not thought to be dense enough to cool the electron population significantly.

Using a collisional test particle model, we examine the behaviour of electrons in the coma of a weakly outgassing comet and the formation of a cold population through electron-neutral collisions. The model incorporates three electron sources: the solar wind, photo-electrons produced through ionisation of the cometary neutrals by extreme ultraviolet solar radiation, and secondary electrons produced through electron-impact ionisation.

The model includes different electron-water collision processes, including elastic, excitation, and ionisation collisions.

The electron trajectories are shaped by electric and magnetic fields, which are taken from a 3D collisionless fully-kinetic Particle-in-Cell (PIC) model of the solar wind and cometary plasma (Deca 2017, 2019). We use a spherically symmetric coma of pure water, which gives a r^{-2} profile in the neutral density. Throughout their lifetime, electrons undergo stochastic collisions with neutral molecules, which can degrade the electrons in energy or scatter them.

We first validate our model with comparison to results from PIC simulations. We then demonstrate the trapping of electrons in the coma by an ambipolar electric field and the impact of this trapping on the production of cold electrons.