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Electron cooling at a weakly outgassing comet

Peter Stephenson[1], Marina Galand[1], Jan Deca[2], Pierre Henri[3,4], and Gianluca Carnielli[1]
[1]Imperial College London, Physics, London, United Kingdom of Great Britain – England, Scotland, Wales (p.stephenson18@imperial.ac.uk)
[2]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, Colorado, USA
[3]Lagrange, OCA, CNRS, UCA, Nice, France
[4]LPC2E, CNRS, Orleans, France

The Rosetta spacecraft arrived at comet 67P in August 2014 and then escorted it for 2 years along its orbit. Throughout this escort phase, two plasma instruments (Mutual Impedance Probe, MIP; and Langmuir Probe, LAP) measured a population of cold electrons (< 1 eV) within the coma of 67P (Engelhardt et al., 2018; Wattieaux et al, 2020; Gilet et al., 2020). These cold electrons are understood to be formed by cooling warm electrons through collisions with the neutral gas. The warm electrons are primarily newly-born and produced at roughly 10eV within the coma through ionisation. While it was no surprise that cold electrons would form near perihelion given the high density of the neutral coma, the persistence of the cold electrons up to a heliocentric distance of 3.8 au was highly unexpected. With the low outgassing rates observed at such large heliocentric distances ($Q < 10^{26}$ s^{-1}), there should not be enough neutral molecules to cool the warm electrons efficiently before they ballistically escape the coma.

We use a collisional test particle model to examine the formation of the cold electron population at a weakly outgassing comet. The electrons are subject to stochastic collisions with the neutral coma which can either scatter or cool the electrons. Multiple electron neutral collision processes are included such that the electrons can undergo elastic scattering as well as collisions inducing excitation and ionisation of the neutral species. The inputted electric and magnetic fields, which act on the test particles, are taken from a 3D fully-kinetic, collisionless Particle-in-Cell (PiC) model of the solar wind and cometary ionosphere (Deca et al., 2017; 2019), with the same neutral coma as used in our model. We use a pure water coma with spherical symmetry and a $1/r^2$ dependence in the neutral number density to drive the production of cometary electrons and the electron-neutral collisions.

We first demonstrate the trapping of electrons in a potential well around the comet nucleus, formed by an ambipolar field. We show how this electron-trapping process can lead to more efficient cooling of electrons and the subsequent formation of a cold electron population, even at low outgassing rates.