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Cometary ion dynamics under weakly outgassing conditions

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Plasma density observations from the Rosetta Plasma Consortium reveal two distinct physical regimes for the ion dynamics in the coma of comet 67P/Churyumov-Gerasimenko. At lower rates of outgassing when the Rosetta spacecraft was close to the cometary nucleus, ions moved with the neutral gas background; at higher rates of outgassing, a diamagnetic cavity formed, and the observed plasma density attested to ion acceleration with respect to the background neutral gas. The diamagnetic cavity was detected around perihelion from April 2014 to February 2016. The end of this period corresponds to the transition between the two regimes, as the comet moved away from the Sun, outgassing decreased and Rosetta got closer to the cometary nucleus.

Current global 3D plasma models of the cometary ionosphere underestimate observed ion number densities during the low outgassing regime. A simple radial model lacking acceleration better explains Rosetta plasma observations. In order to identify the cause of the underestimation by the current global plasma model, we assess the sensitivity of the cometary ion dynamics to several parameters during the transition. For that purpose, we use our in-house 3D ion test particle model driven by the fields generated by a hybrid model. First, we assess the sensitivity of the ion dynamics to collisions between the ions and the neutral background. This process is not sufficient to explain the discrepancy. Next, we evaluate the sensitivity of the ion dynamics with electron temperature through the ambipolar electric field. Current models assume adiabatic electron behavior; however, electrons trapped close to the cometary nucleus by the ambipolar field are collisional, not adiabatic, and the resultant cooling feeds back to weaken the ambipolar electric field. We show that the resulting simulated plasma density is affected by the use of a more realistic electron temperature profile derived from electron test particle modelling, bringing it closer to the Rosetta plasma density.