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Modelling of 67P cometary particles dynamic in the vicinity of the Rosetta spacecraft

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1. Introduction

The interpretation of a number of Rosetta datasets (e.g. GIADA, COSIMA, MIDAS...), relies on the description of cometary particles dynamic in the close vicinity of the spacecraft (s/c). In particular, the charged particles behaviour in the 3D s/c sheath open to the instrument entrances is complex and has not been described at such scales.
The existence of a warm electrons population (a few 10 eV energy) in the cometary plasma, as revealed during the Rosetta-comet rendez-vous phase, has been driving the s/c potential to negative values typically in the range -1 to -20V, as inferred from RPC measurements [1].
Observation of cometary particles in the 14µm to ~mm range by GIADA [2] and COSIMA [3] allowed to distinguish so called 'compact' particles, of processed materials from the solar nebula, from 'fluffy' aggregates, of more primitive origin. When detected, such particles have been observed to reach the instruments at speeds of ~m/s or less. In particular, it was inferred that fluffy aggregates are disrupted by electrostatic forces in the vicinity of the s/c due to the effects of local plasma, hence resulting in "particle showers" observed by the instruments.

Based on those observations we consider compact particle populations with typical densities of 3kg/m^3 on the one hand and fragments as produced by the disruption of fluffy aggregates in the s/c vicinity with low densities of 1 kg/m^3 on the other hand.

As illustrated in Figure 1, we use simplified numerical models of the Rosetta s/c and surrounding plasma environment to explore the parameter space (q/m, v), from which we derived conditions leading either charged particles to reach the s/c surface and instruments entrances or being repulsed.

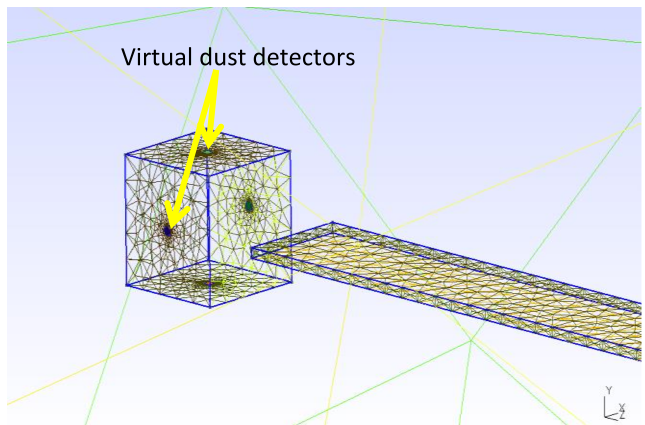

Fig1: Simplified Rosetta numerical model

We use a Particle-In-Cell code adapted to model charged dust in plasmas (the Spacecraft Plasma Interaction Software) to simulate the cometary particles behaviour in the vicinity of the s/c. The s/c potential is fixed to typical values (e.g. -10V for Figures 2, 3 and 4), and the sheath structure is described in terms of plasma densities and potential. In the example of Figure 2 the plasma density was fixed at 200cm^{-3} (T=100eV) and the secondary electrons density is seen to be larger than 500cm^{-3} in the first 10cm of the simplified s/c surface.

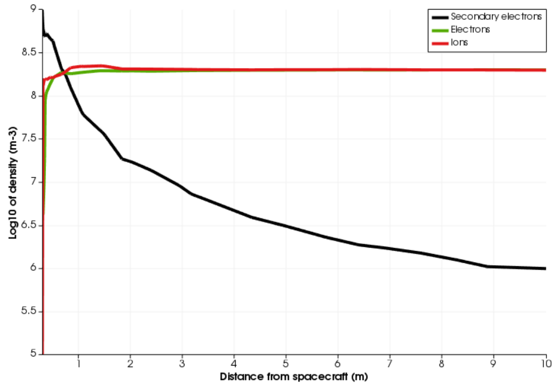

Fig.2: Plasma electrons, ions, and s/c generated secondary electrons profiles within 10m from the centre of the s/c body.

The particles are emitted from a single point or a surface from a distance to the s/c with a distribution of q/m and velocities in the range 1 to 1000m/s. As illustrated in Figure 3, depending on their initial characteristics, some reach the s/c while others are deflected by the s/c potential.

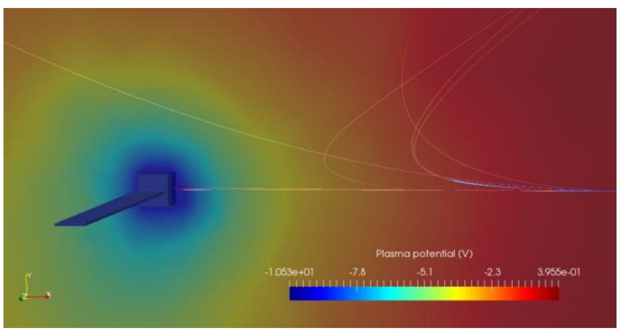

Fig.3: Plasma potential (with Rosetta surface potential fixed at -10V) together with particle trajectories originating from a point source located 8.0m away.

The particles are tracked until they are stopped by the s/c surface or exit the simulation domain boundary. The set of coordinates, velocities, potential and charge as well as plasma electric field and potential are recorded along each trajectory as illustrated in Figure 4.

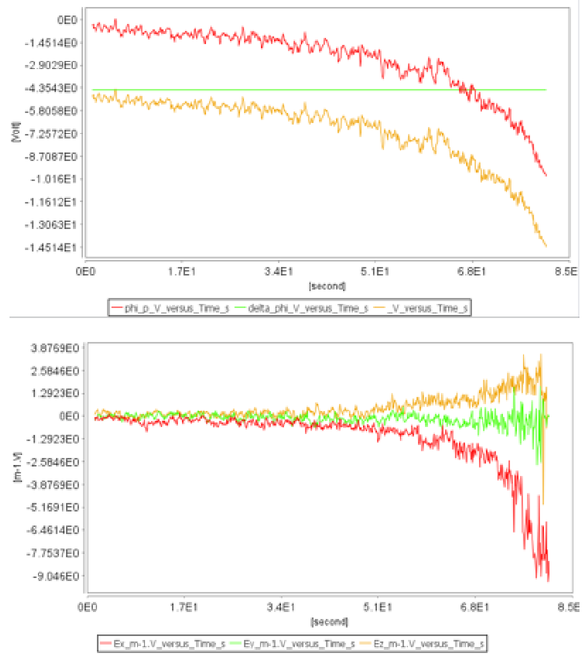

Fig.4: Upper panel: plasma and dust potential along the trajectory from outside the sheath to the s/c surface for a collected particle. Bottom panel: electric field components along the trajectory.

The s/c model is iterated in complexity such as to represent a realistic sheath and instrument entrance geometry, computing time permitting. In the end, we will elaborate on dust particles behaviour in the s/c sheath and measure the dust characteristics at impact on surfaces mimicking instruments entrances (fluxes, velocities, q/m distributions), in order to help the interpretation of Rosetta observations.

References

[1] A. Errikson et al, The Plasma Environment of Rosetta at Comet 67P, Proceedings of the 14th SCTC, Noordwijk, April 2016
[2] M. Fulle et al, ApJL, 802:L12, 2015
[3] S. Merouane et al, A&A, 596, A87, 2015