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ComMoDE: A software for assessing dust environment during comet fly-by

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Future missions to comets such as the Comet Interceptor mission, developed by ESA and JAXA, require the prediction of the dust environment encountered by the spacecraft when approaching the comet. For this objective the dust production in terms of quantity, particle sizes, and velocity, has to be considered, since the dust hazard assessment is crucial for cometary fly-by missions. For supporting the Comet Interceptor project, ESA has fostered a research and technology activity in this direction. In this framework, available datasets related to the dust environment of comets, gathered during missions such as Giotto, and Rosetta, have been reviewed. The first objective of the data analysis is to select the most relevant datasets to be used for comparisons with computational predictions performed using COmMoDE (Cometary Model of Dust Environment), in order to validate the predictions and estimate the potential inconsistencies. The second is to perform a general assessment in order to define a set of trade-offs for the tool and model to be developed. In parallel, existing models for coma comet have been assessed and a model based on the fountain one has been derived.

Finally, this model has been integrated in a dedicated software ComMoDE (Cometary Model of Dust Environment). This tool is based on a time-efficient and highly flexible dust model to support the planning and operation of future cometary missions. ComMoDE is specifically designed to allow for a large range of different parameters. To account for the solar-radiation pressure, dependence of the dust outflow velocity and dust production rate on the emission angle and variation in the dust production rate in relation to the rotation of the nucleus, we use test particles for each emission angle and scale the dust number density accordingly. Since the acceleration region of the dust is not considered in the model, the trajectory of each test particle can be solved analytically. The architecture of the software is resumed in Figure 1: the model is incorporated in functions, embedded in an interface written in Python.

Figure 1: Software infrastructure scheme

The different possible trade-offs to be defined to input a fly-by trajectory are highlighted in Figure 2, showing a sketch of the ComMoDE interface. The software can output the dust number densities for a chosen number of particle size bins and in addition calculate the flux, fluence and total impact mass along a chosen fly-by trajectory. Once the trajectories post-processing produced valid results, the user can access the visualization environment, in which multiple trajectories can be processed.

To validate ComMoDE, it has been compared with DSMC predictions performed using DRAG3D. Since these lasts are computationally expensive, it is only possible to model the coma up to a few tens of the nucleus radius. ComMoDE results for the total impact mass were also compared to measurement data of Giotto at comet 1P/Halley. The best estimate of the impact mass on the Giotto spacecraft is 0.32 g. At comet 1P/Halley a knee in the power-law distribution was observed which could not be modelled with ComMoDE. The average cumulative power-law index of the mass distribution is 0.85 as described in the literature. When converting the cumulative power-law index of the mass distribution in the coma to a differential power-law index of the size distribution at the surface one gets 4.05. ComMoDE predicts a total impact mass of 1.06 g. Varying the power-law index, gives results from 0.08 g to 6.2 g. Hence, ComMoDE is able to reproduce the measurement data of Giotto to within one order of magnitude, which is a good agreement considering the large uncertainties of the problem.

Figure 2: Sketch of ComMoDE interface

Finally, there are no major differences between the DSMC and ComMoDE outside of the acceleration region ($R > 10R_N$). Further, ComMoDE is able to reproduce the total impact mass measured by Giotto at comet 1P/Halley. Hence, it can be concluded that ComMoDE is able to provide accurate and reliable results for the total impact mass measured by Giotto at comet 1P/Halley.