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Modelling the trajectories of cm to meter sized chunks in the vicinity of comet 67P/Churyumov-Gerasimenko

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Abstract

In order to support Rosetta mission analysis studies, the trajectory propagation and visualization system ROVIZ is being developed. Observations of Comet 103P/Hartley 2 showed an ensemble of cm to meter sized particles. We "abuse" ROVIZ to model the trajectories of such chunks in the vicinity of the Rosetta target comet 67P/Churyumov-Gerasimenko.

1. Rosetta trajectory propagation and visualization system (ROVIZ)

The Rosetta mission [4] will reach its target comet 67P/Churyumov-Gerasimenko in 2014. To support mission analysis studies, ROVIZ provides several capabilities:

- spacecraft trajectory propagation,
- modelling of spacecraft attitude and also the attitude of movable components,
- simulation of instrument fields of view,
- ground track and coverage analysis,
- visualization,
- creation of SPICE kernels [1] for spacecraft position and attitude.

For the trajectory propagation, the following forces are taken into account:

- Comet gravitational attraction:
  - the comet shape is approximated by some hundred thousand point masses,
  - the deviation of forces from those of a single center point mass are precomputed on a polar grid with exponential radius coordinate.
- Third body gravitational attraction:
  - the Sun position is taken from respective SPICE kernels [1].
- Solar radiation pressure:
  - the spacecraft bus is assumed to be spherical, solar panels are assumed to be planes facing the Sun, the High Gain Antenna is neglected,
  - a completely diffuse reflection is assumed (the partly specular reflection of the solar panels is approximately compensated by the irradiance transformed into electricity).
- Outgassing force:
  - the momentum flux is taken form the results of 2D model runs with the Inner Coma Environment Simulator (ICES) [5].

An example trajectory illustrating the complex concert of forces is shown in Fig. 1.

2. Large chunks observed at 103P/Hartley 2

While the forces on small dust particles in cometary comae are dominated by outgassing and solar radiation pressure, the trajectory of larger particles would be more influenced by gravity. Ground based radar observations indicated an ensemble of particles larger than a few cm at 103P/Hartley 2 [3]. The EPOXI mission could indeed observe such chunks with sizes in the cm to meter range [2].

3. Modelling chunk trajectories with ROVIZ

The Rosetta spacecraft has a mass of about 1400 kg (when it reaches the target comet). The cross section area exposed to forces by solar radiation pressure

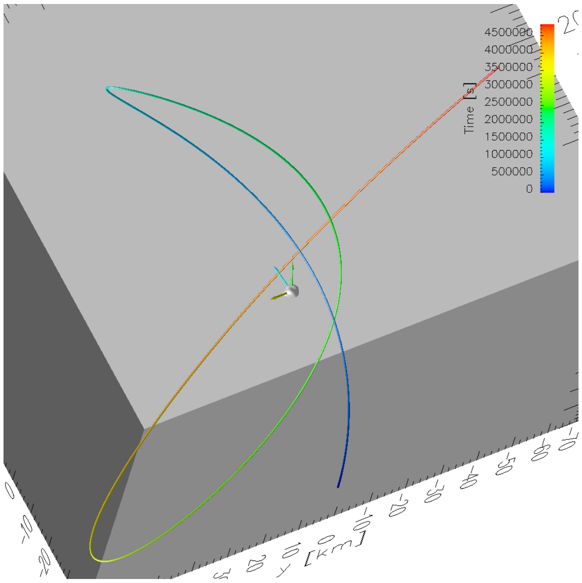

Figure 1: Example of a spacecraft trajectory computed with ROVIZ. The yellow arrow points to the Sun, the green arrow is normal to the comet's orbit plane, and the cyan arrow is the rotation axis of the comet. The color of the trajectory encodes the time. The gray background box is aligned with the J2000 reference frame.

and comet outgassing is dominated by the large solar panels, which amount to an area of about $70\,\mathrm{m}^2$. If we assume that the chunks have a density comparable to the mean density of 67P/Churyumov-Gerasimenko — which is currently believed to be about $300\,\mathrm{kg/m}^3$ — and spherical shape, we can easily estimate their mass and respective cross section area (just bare area, neglecting for the moment any particular reflection characteristics), cf. Tab. 1. Thus, the ratio between

Table 1: Comparison of mass and cross section area of the Rosetta spacecraft and chunks of different size.

		Chunks	
	Rosetta	∅ 1 cm	∅ 1 m
Mass [kg]	1400	$1.6 \cdot 10^{-4}$	$1.6 \cdot 10^{2}$
Area [m^2]	70	$7.9 \cdot 10^{-5}$	$7.9 \cdot 10^{-1}$
Ratio [kg/m^2]	20	2	200

gravitational forces and pressure forces (solar radiation and comet outgassing) for such chunks is of the same order of magnitude as for the Rosetta spacecraft. Like for Rosetta, gravitational and pressure forces are similarly important in determining the trajectory. We use ROVIZ to model trajectories for chunks of different sizes and dynamical states in order to assess the possibility to encounter an ensemble as found at 103P/Hartley 2 also at 67P/Churyumov-Gerasimenko.

Acknowledgements

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