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Accurate ephemeris reconstruction for comet 67P/Churyumov-Gerasimenko from Rosetta data analysis

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Following its arrival at 67P/Churyumov-Gerasimenko in August 2014, the Rosetta spacecraft successfully navigated in proximity of the comet for two years, using a combination of radiometric measurements and optical images collected by the onboard navigation cameras.

The reconstructed spacecraft and comet trajectories were obtained combining several long-arc and short-arc orbit determination solutions generated by ESOC Flight Dynamics during the Rosetta operations. Several discontinuities are present within these trajectories, due to the lack of a dynamical model for the representation of the comet Non-Gravitational Accelerations (NGA).

The work presented in this study represents an effort to produce an accurate and continuous ephemeris reconstruction for comet 67P/Churyumov-Gerasimenko for the period between July 2014 and October 2016, through a complete reanalysis of the Range and ΔDOR measurements collected by Rosetta during its proximity phase with the comet.

Using as input the reconstructed relative orbit of Rosetta, the radiometric observables were mapped to the comet nucleus and used to estimate the comet state and some key physical and observational parameters within a Square Root Information batch filter implemented in MONTE, most notably the NGA acting on the comet nucleus due to surface outgassing.

Several orbit determination solutions were generated by varying the model used to represent the NGA. More specifically, empirical and stochastic models were compared by evaluating the reduced χ^2 statistics of the measurement residuals to identify the most suitable trajectory estimations for each of the proposed models. From this narrow list of solutions, a preliminary selection for the final ephemeris reconstruction is proposed, based on its adherence to the original ESOC trajectory and on the consistency of the formal state uncertainties with the estimated solutions.

It will be shown that the selected ephemeris solution, using a piecewise linear stochastic NGA

model with intervals between 3 and 4 weeks, produces a continuous ephemeris reconstruction for 67P/Churyumov-Gerasimenko with maximum formal uncertainties around perihelion of σ_{pos} [20 km, 30 km, 200 km] in the Radial-Tangential-Normal reference frame. The advantage of using simple stochastic models, with limited a-priori assumptions on the involved physical processes, is that they allow to produce an unbiased estimation of the NGA variations around perihelion, which represent a valuable input for further investigations involving detailed physical models of the cometary activity.