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Double harmonic-series gravitational field model for bilobed small bodies: example for 67P/Churyumov-Gerasimenko

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An increasing number of small extraterrestrial objects in the Solar System are found to have bilobed shapes, which could have resulted from the merger of two independently formed bodies. It is both natural and justified to treat the lobes separately to account for, or discern, any potential difference between them (Andert, et al., 2015). Gravity provides a crucial constraint on the interior mass distribution of the body and is among the key scientific objectives in most space missions. Most often, the gravitational field is modeled as a spherical harmonic (SH) series, whose coefficients are then used along with other constraints to interpret the interior structure.

In this study, a double harmonic-series approach for the bilobed bodies is presented. Namely, a harmonic series is established for each lobe to facilitate the investigation of their interior structures separately. The focus of the analysis is on comet 67P/Churyumov-Gerasimenko, the rendezvous target of the Rosetta mission with an exemplary bilobed shape and variable gravity field (Sierks et al. 2015; Pätzold et al. 2016, 2019). We employ the ellipsoidal harmonic (EH) series, whose coefficients are fully analogous to those of the SH and whose reference surfaces fit more closely the triaxial shapes of the individual lobes (Hu 2016).

We develop the double EH model for 67P via simulations and assess the model performance around the body. Additionally, we discuss the equivalence of the double EH model to the SH model as well as the conditions for direct model transformation from the latter. We revisit the physical meaning of the EH coefficients and demonstrate how their known relationship to the body's mass density moments can be leveraged to interpret different mass distributions of the comet. Importantly, there should be no restriction on the applicability of the method to other bilobed objects.

Reference

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