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Gravity Field Characterization around Small Bodies

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A small body rendezvous mission requires accurate gravity field characterization for safe, accurate navigation purposes. However, the current techniques of gravity field modeling around small bodies are not achieved to the level of satisfaction. This thesis will address how the process of current gravity field characterization can be made more robust, both operationally and theoretically.

First we perform the covariance analysis around small bodies via multiple slow flybys. Flyby characterization requires less laborious scheduling than its orbit counterpart, simultaneously reducing the risk of impact into the asteroid's surface. It will be shown that the level of initial characterization that can occur with this approach is no less than the orbit approach. Next, we apply the same technique of gravity field characterization to estimate the spin state of 4179 Touatis, which is a near-Earth asteroid in close to 4:1 resonance with the Earth. The data accumulated from 1992-2008 are processed in a least-squares filter to predict Toutatis' orientation during the 2012 apparition. The center-of-mass offset and the moments of inertia estimated thereof can be used to constrain the internal density distribution within the body. Then, the spin state estimation is developed to a generalized method to estimate the internal density distribution within a small body. The density distribution is estimated from the orbit determination solution of the gravitational coefficients. It will be shown that the surface gravity field reconstructed from the estimated density distribution yields higher accuracy than the conventional gravity field models. Finally, we will investigate two types of relatively unknown gravity fields, namely the interior gravity field and interior spherical Bessel gravity field, in order to investigate how accurately the surface gravity field can be mapped out for proximity operations purposes. It will be shown that these formulations compute the surface gravity field with unprecedented accuracy for a well-chosen set of parametric settings, both regionally and globally.