

## PLANETARY GRAVITY FIELDS AND THEIR IMPACT ON A SPACECRAFT TRAJECTORY.

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**Introduction:** The present work touches an interdisciplinary aspect of space exploration: the improvement of spacecraft navigation by means of enhanced planetary interior model derivation. The better the bodies in our solar system are known and modelled, the more accurately (and safely) a spacecraft can be navigated. In addition, the information about the internal structure of a planet, moon or any other planetary body can be used in arguments for different theories of solar system evolution.

The focus of the work lies in a new approach for modelling the gravity field of small planetary bodies: the implementation of complex ellipsoidal coordinates (figure 1, [4]) for irregularly shaped bodies that cannot be represented well by a straightforward spheroidal approach. In order to carry out the required calculations the computer programme GRASP (**G**ravity Field of a Planetary Body and its Influence on a **S**pacecraft Trajectory) has been developed [5]. The programme furthermore allows deriving the impact of the body's gravity field on a spacecraft trajectory and thus permits predictions for future space mission flybys.

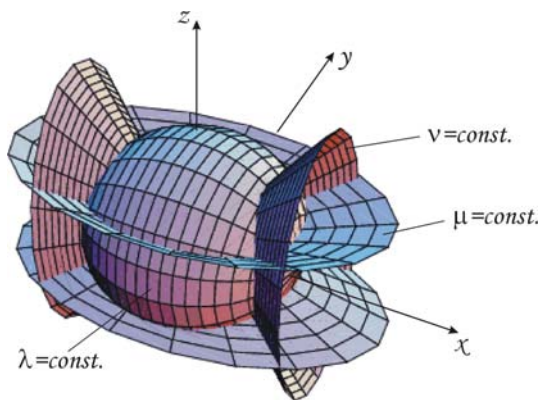


Figure 1: ellipsoidal coordinates.

**Gravity Field:** Founded on homogeneous and reasonable heterogeneous interior models of small planetary bodies higher order gravity fields can be determined within GRASP and are described by the moments of gravitation (mass coefficients up to an optional degree and order). Latter are derived by the application of Neumann's second method [2] and the numerical integration of infinitesimal volume elements, calculated by the scale factors of a three-axial ellipsoid (elliptic coordinates) due to the bodies

non-spherical shapes. Actual shape data of the planetary bodies (e.g.  $5^\circ \times 5^\circ$  grid of the body's radius) can be implemented within the approach but because of long computation times provide no useful input.

**Trajectory:** Further to the derivation of a planetary body's gravity field, GRASP offers the option to calculate the trajectory of a spacecraft influenced by a nearby body, provided that a starting point (e.g. closest approach) and a starting velocity of the spacecraft are given. The spacecraft trajectory is calculated through the numerical integration method of Runge-Kutta and allows predictions for future flyby scenarios in order to derive more information about the body's interior structure.

**Amalthea:** In order to state an example for the approach, Jupiter's small inner moon Amalthea served as the study object. Data from ground observations, the Voyager flybys and GALILEO [3] (dedicated to explore the Jovian system in great detail in the years 1995 to 2003) has been implemented into GRASP and the first higher order gravity field (mass coefficients up to degree and order 6) of Amalthea has been derived. It has already been incorporated into a database of gravity models for solar system bodies at NASA's Goddard Space Flight Center and is furthermore available for future applications and analysis.

GALILEO made its final experiment of its successful mission on November 5, 2002: a close Amalthea flyby. The spacecraft's state vector (radius, velocity) at closest approach and the gravity models of Amalthea have been integrated and various spacecraft trajectories around closest approach have been calculated. Because of the moon's low density of about  $860 \text{ kg/m}^3$  [1] no information about the quadrupole or higher degree moments of gravitation could be derived. Thus no analysis of Amalthea's interior could be made from this specific flyby. Predictions for future flyby scenarios show that not even a closer flyby would generate a much higher gravity signal, which implies that other means like in-situ geological measurements are needed to get information about the moon's interior structure.

Nevertheless, the generated gravity field models reflect the most likely interior structure of the moon and can be a basis for further exploration of the Jovian system.

**References:** [1] Anderson, J.D. (2005) Amalthea's Density is Less Than the Density of Water, in preparation. [2] Heiskanen, W.A., Moritz, H. (1967) Physical Geodesy. W.H. Freeman and Company, San Francisco. [3] Thomas, P.C., et al. (1998) The Small Inner Satellites of Jupiter. *Icarus* 135, p. 360-371. [4] Webster, Arthur G. (1925) The Dynamics of Particles and of Rigid, Elastic, and Fluid Bodies. Lectures on Mathematical Physics, 3<sup>rd</sup> Edition. B.G.Teubner, Leipzig. [5] Weinwurm G. (2004) Amalthea's Gravity Field and its Impact on a Spacecraft Trajectory. Vienna University of Technology Series: Geowissenschaftliche Mitteilungen, Volume 70.

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