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Determination of Enceladus' gravity field from Cassini radio science data

Marzia Parisi, Luciano Iess, and Marco Ducci
Dipartimento di Ingegneria Meccanica e Aerospaziale – Sapienza Università di Roma

In May 2012 the Cassini spacecraft completed its last gravity flyby of Saturn's moon Enceladus (identified as E19 in the sequence), following E9 in April 2010 and E12 in November 2010. The multiarc analysis of the gravity data collected during these low-altitude encounters has produced a stable solution for the gravity field of Enceladus, leading to compelling inferences and implications on the interior structure, but also raising new questions on the evolution of this small but yet fascinating icy body.
The gravitational signature of the satellite was detected by means of precise Doppler tracking of the Cassini spacecraft around closest approach ($\pm$3h) of the three flybys. Cassini tracking system exploits both X/X and X/Ka links, with accuracies that range between 0.02 – 0.09 mm/s at 60 s integration time. Range-rate measurements were processed into a multi-arc least square filter so as to attain a solution for the quadrupole field of Enceladus and its degree-3 zonal harmonic J3, the most important indication of hemispherical asymmetries. In addition to these crucial parameters, corrections to the estimated orbits of Cassini and Enceladus were applied. The inclusion in the dynamical model of the neutral particle drag exerted by Enceladus south polar plumes (1) is essential for a satisfactory orbital fit.
The results of the analysis show that Enceladus is indeed characterized by a predominant quadrupole term, with its J2/C22 ratio being that of a body not in hydrostatic equilibrium. The estimate of tesseral degree-2 coefficients (C21, S21 and C22), being statistically close to 0 (at a 3-σ level), imply that the adopted rotational model for the satellite is consistent with the observed gravity field. Furthermore, the estimated value for J3 turned out to be statistically significant (although only about 1/50 of J2) and pointing at a significant hemispherical asymmetry that is consistent with the presence of a regional sea at depth.

References
(1) C.C. Porco et al., Science 311, 1393 (2006).