THE GEODESY OF THE MAIN SATURNIAN SATELLITES FROM RANGE RATE MEASUREMENTS OF THE CASSINI SPACECRAFT. M. Ducci[1], L. Iess[1], J. W. Armstrong[2], S. W. Asmar[2], R. A. Jacobson[2], J. I. Lunine[3], P. Racioppa[1], N. J. Rappaport[2], D. J. Stevenson[4], P. Tortora[5], [1]DIMA, Univ. La Sapienza, Via Eudossiana 18, 00184 Roma, Italy, marco.ducci@uniroma1.it, [2]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, USA, [3]Department of Astronomy, Cornell University, Ithaca NY 14850 USA, [4]California Institute of Technology, 150-21 Pasadena, CA 91125, USA, [5] DIEM-II Facolta' di Ingegneria, Universita' di Bologna, I-47100 Forli, Italy.

Introduction: Since the arrival of Cassini in the Saturnian system on July 1st, 2004, radiometric data have been used to determine the gravity field of Saturn's main satellites. During its 8 years tour in the Saturn system Cassini spacecraft had more than 80 flybys of Titan, 16 of Enceladus and some of Rhea, Dione, Hyperion and Iapetus. However, the lack of a scan platform for optical remote sensing instruments prevents simultaneous gravity and remote sensing observations. So far, Titan's geodesy has been inferred from six flybys, providing a determination of the quadrupole field as well as a 3x3 geoid. Moreover, thanks to the favorable flyby distribution along Titan's orbit, eccentricity tides have been also detected, with a relatively good accuracy in the estimate of the Love number k2. Enceladus was the only other satellite that Cassini flew by more than once for gravity observations. Doppler data provided an estimate of the quadrupole field and J3. The quadrupole field has been determined for Rhea and, after the December 2011 flyby, will be probably accessible also for Dione. The flybys of Hyperion and Iapetus provided only the mass. Here we present our latest results and an overview of our analysis methods.

Data: During gravity flybys spacecraft tracking is performed from the antennas of the Deep Space Network using two-way coherent radio links at X and Ka band frequencies (8.4 and 32.5 GHz). Thanks to the use of state-of-the-art instrumentation and hydrogen masers at the ground stations, spacecraft range rate is measured with accuracies up to 10-50 micron/s at 60 s integration times. Advanced Media Calibration (AMC) systems, available at two antennas in Goldstone and Madrid, were used to improve data quality through accurate measurements of the path delays due to dry troposphere and water vapor.

Main results:

Titan. Using data from the first 4 gravity flybys Iess et al. [1] determined Titan's quadrupole filed and Moment of Inertia factor C/MR2. A 3-by-3 geoid was also produced. In this analysis, however, tidal variations of the gravity field were neglected. Using two additional flybys (on May 20, 2010 and Feb. 17, 2011) we were able to estimate also the variable component of the gravity field. Our results are compatible with the presence of a global liquid water layer and a high viscosity interior. However, even less likely, we cannot exclude a model in which important fractions of the interior are deformable over the orbital time scale.

Enceladus. Enceladus' close flybys of April 28, 2010 and November 30, 2010 have revealed a gravity field with significant departures from a pure quadrupole. Although non-spherical gravity is dominated by large quadrupole terms as expected for a tidally-locked body degree 3 harmonics are needed to fit all available data in a single global solution. The values of J2 and C22 are not consistent with the hypothesis of hydrostatic equilibrium, although the deviations from hydrostaticity are not large. Thus, the moment of inertia factor C/MR2 can still be roughly inferred from Radau-Darwin equation. The value of C/MR2 derived both from C22 and J2 shows that Enceladus is a differentiated body. All gravity solutions require a negative J3, consistently with a negative gravity anomaly at the south pole. "Negative", in this context, can mean a subsurface concentration of liquid water without compensation but it can also mean an ocean with negative surface topography. The comparison between gravity and topography is of great importance for deciding this issue. We are working on a fit of our data driven by spherical harmonics expansion of topography to assess the degree of compensation in particular in the south polar region. Data from the next Enceladus flyby in May 2012 are expected to significantly reduce the current uncertainties and confirm our previous results.

References:

[1] L. Iess et al. Science 327, 1367 (2010).