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The Interior of the Moon from the Gravity Recovery and Interior Laboratory (GRAIL) Mission

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The Gravity Recovery and Interior Laboratory (GRAIL) mapped the Moon from March through December 2012 at average altitudes from 55 km down to 11 km. The current global gravity field resolves spatial blocks of <5 km, and gravity at greater length scales has been improved in quality by as much as a factor of 106 over previous lunar gravity models. GRAIL gravity, combined with topography from the Lunar Orbiter Laser Altimeter (LOLA) and observations from Lunar Laser Ranging (LLR) are being used to improve substantially our understanding of the interior structure of the Moon.
The bulk density of the lunar highlands crust is 2550 kg m^{-3}, much lower than previously thought, and implies an average porosity $\sim$12% in the top several km of crust. The low bulk crustal density enables production of a global crustal thickness model that for the first time satisfies Apollo seismic constraints, and is characterized by an average crustal thickness of 34 - 43 km. An admittance approach can be used to estimate variations of density with depth. Density in the lunar maria decreases with depth indicating less fractured basaltic flows over more fractured crust, while the farside highlands show an increase in density with depth likely related to decreasing fracturing and porosity. The interior of the South Pole-Aitken impact basin displays a distinctive structure with a near-surface, low-density layer 2–3 times thinner than the rest of the farside.
The product of the gravitational constant and lunar mass, GM, is now sufficiently well determined that the Moon's mass and mean density are limited by the accuracy of G. The tidal Love number k2 has an average value of 0.02416$\pm$0.00022 at a 1-month period; independent k2 solutions from the Jet Propulsion Laboratory and NASA/GSFC differ by 1%. The normalized mean moment of inertia of the solid Moon, Is/MR^2=0.392728$\pm$0.000012, is improved by an order of magnitude over previous estimates. A combination of the density, moment of inertia and Love number allows construction of models of the Moon's deep interior that have a fluid outer core with radius 200–380 km, a solid inner core with radius 0–280 km, and a deep mantle zone of low seismic shear velocity. The mass fraction of the combined inner and outer core is $\leq$1.5%.