GRAVITY SCIENCE INVESTIGATION OF CERES FROM DAWN. R.S. Park[1], A.S. Konopliv[1], B. Bills[1], J. Castillo-Rogez[1], S.W. Asmar[1], N. Rambaux[2], C.A. Raymond[1], C.T. Russell[3], M.T. Zuber[4], A. Ermakov[4], S.D. King[5], M.D. Rayman[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA (e-mail Ryan.S.Park@jpl.nasa.gov); [2]IMCCE, Observatoire de Paris, Paris, France; [3]UCLA, Los Angeles, CA, USA; [4]Massachusetts Institute of Technology, Cambridge, MA, USA; [5]Department of Geoscience, Virginia Tech, Blacksburg, VA, USA

Introduction: The Dawn gravity science investigation utilizes the DSN radiometric tracking of the spacecraft and on-board framing camera images to determine the global shape and gravity field of Ceres [1,2]. The gravity science data collected up to High-Altitude Mapping Orbit phases have been processed. Currently, the latest gravity field called CERES08A is available, which is globally accurate to degree and order 5. Combining the gravity and shape data gives the bulk density of 2162.5 ± 8 kg/m^3. The inverse correlation of Bouguer gravity with topography indicates that the surface of Ceres is likely compensated, and that its interior presents a low-viscosity layer at depth. The degree 2 gravity harmonics show that the rotation of Ceres is very nearly about a principal axis. This consistent with hydrostatic equilibrium at the 1% level, and infers a mean moment of inertia of Ceres is 0.36, implying some degree of central condensation. Assuming a two-layer model of Ceres, the core size is expected to be ~280 km with corresponding average thickness of the outer shell of ~190 km.

Data: The Dawn spacecraft acquired DSN radiometric data at X-band (8.4 GHz) and on-board framing camera images (93 μrad/px) since it's approach to and orbit around Ceres. The data collected during the Approach to High-Altitude Mapping Orbit phases were processed to determine the shape and gravity field of Ceres. The reconstructed root-mean-square residual of the processed range, Doppler, and optical data were 0.5 meter, 0.02 mm/s, and 0.2 pixel, respectively.

Shape and Gravity: A global shape of Ceres was computed using a stereo-photoclinometry method [3], which provides control points that can be used as an additional constraint on Ceres-relative position of the Dawn spacecraft. Based on the collected data, we get volume $= (434.0 \pm 1.5)\times 10^6$ km^3 (with volumetric mean radius $R \approx 470$ km), $GM = (62.6285 \pm 0.0008)$ km^3/s^2, pole right ascension, $\alpha_0 = (291.421 \pm 0.007)$ deg, pole declination, and $\delta_0 = (66.758 \pm 0.002)$ deg. The accuracy of the rotation rate determined based on the data acquired up to HAMO is comparable to the value reported by Chamberlain *et al.* [4] of $\Omega = (952.1532 \pm 0.0001)$ deg/day.

Figure 1 shows the Ceres gravity RMS magnitudes (using normalized spherical harmonic coefficients).

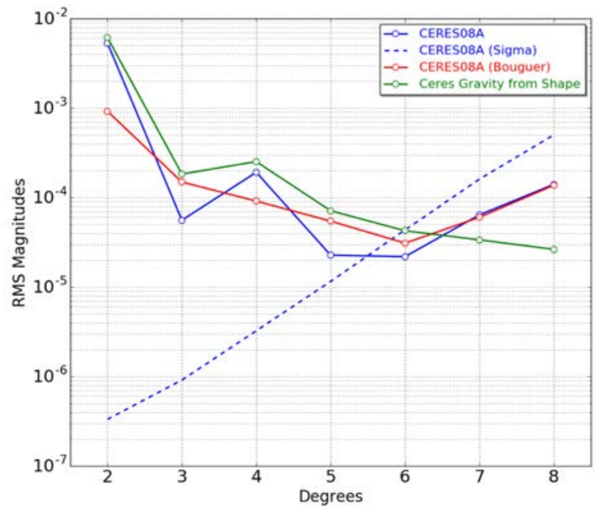

Figure 1: Gravity and error (i.e., sigma) spectra of CERES08A based on normalized spherical harmonic coefficients. The gravity spectrum shows that coefficients up to degree 5 are determined with sufficient accuracy.

Note that the power spectrum is computed using *normalized* spherical harmonic coefficients. The power spectrum shows that harmonic coefficients of CERES08A up to degree 5 are determined with sufficient accuracy. Figure 1 also shows the power spectrum of the Bouguer gravity field (i.e., difference between CERES08A and the gravity from shape).

Combining the mass and volume values gives the bulk density of 2162.5 ± 8 kg/m^3, where the uncertainty is dominated by the volume uncertainty in the shape model (<0.4 %). As shown in previous studies [5,6], the density of Ceres is much less than a silicate body, such as Moon and Vesta (~3300-3500 kg/m^3), indicating a likely mixture with lighter materials, such as ice and salts. The offset between the center-of-mass and center-of-figure is about 1 ± 0.4 km, indicating that there may be a small level of internal heterogeneity at the longest wavelength, such as variations in the crustal density/thickness or an offset in the core location. The best-fit ellipsoid yields the principal semi-axes of $\{483.1, 481.0, 445.9\}$-km with the major axis along ~47°E (or ~227°E) direction. Figure 2 (top) shows the surface topography projected onto a (482×482×446)-km ellipsoid (i.e., mean ellipsoid), which ranges from -6.5 to 7.9 km. Figure 2 also dis-

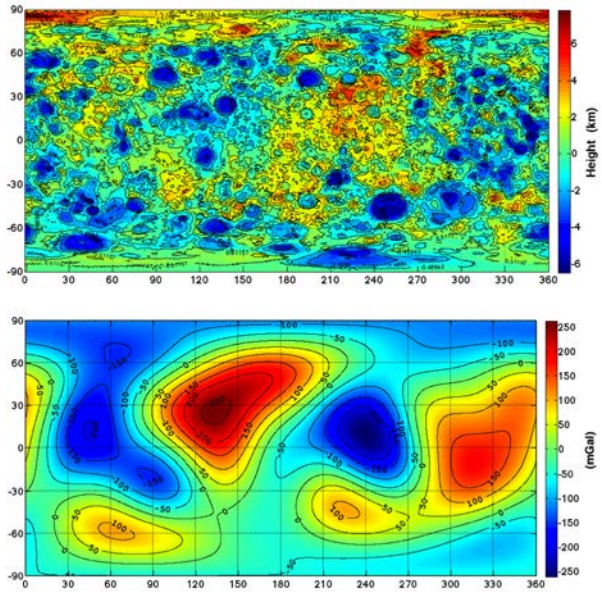

Figure 2: Ceres topography (top) and Bouguer gravity (bottom) projected on to a (482,482,446)-km ellipsoid. The topography variation ranges from -6.5 to 7.9 km. The surface and Bouguer gravity plots are based on the truncated CERES08A, through degree 5 excluding J_2. The Bouguer gravity ranges from -260 to 260 mGal.

plays the Bouguer gravity plot, which shows low values for the high topography area, or vice versa, indicating that the surface of Ceres is likely compensated and pointing to a low-viscosity layer at depth consistent with thermal evolution models [7].

Assuming a two-layer model of Ceres, the densities of the inner and the outer layers can be approximated by solving Clairaut's equations of rotational equilibrium to third order [8]. While the exact density of that material cannot be inferred in detail, we use the grain density of heavily altered CM chondrites as a reference (i.e., 2900 kg/m^3). This leads to a core size estimate of 280 km from MOI constraints, corresponding to a mean outer shell thickness of 190 km.

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