THE GRAVITY FIELD OF VESTA AND IMPLICATIONS FOR INTERIOR STRUCTURE.

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Introduction: With the Dawn mission to Vesta [1] well into the Low Altitude Mapping Orbit phase [1] (average radius of 475 km), having completed Survey (average radius of 3000 km) and High Altitude Mapping Orbit (average radius of 950 km) phases, the gravity investigation has produced a global coverage solution. When correlated with a shape model derived from the framing camera data, these data can constrain the interior structure from the core to the crust [2]. The investigation [3] utilizes the precision 8 GHz Doppler tracking of the spacecraft and landmark tracking from framing camera images to measure the gravity fields of Vesta to a half-wavelength surface resolution better than 90-km by the end of the mission. The solution also yields the spin pole location and rotation. The second-degree harmonics together with assumptions on obliquity or hydrostatic equilibrium determine the moments of inertia and constrain the core size and density. To date, the determination of GM is highly accurate for a gravity field of degree 8 with 140-km resolution. J_2 is not consistent with a homogeneous density body, and neglecting the effects of non-hydrostaticity, indicates a core size of close to half the mean radius.

Gravitational Field of Vesta: Figure 1 shows an 8th degree and order map of the gravitational field from HAMO (an 18th D&O field from LAMO will be available shortly); the spectrum is shown in Figure 2. For the solution to date (named VESTA10D), with uncertainties 3 times the formal errors, the normalized gravity coefficients are: GM (km3/s2)= 17.28867 ± 0.00003 (0.0002%), J_2 = 0.0317799 ± 0.0000002 (0.0005%), C_{22} = 0.0043513 ± 0.0000003 (0.007%), S_{22} = 0.0003641 ± 0.0000005 (0.1%), C_{21} = 0.00000000 ± 0.00000003, S_{21} = 0.00000001 ± 0.00000003.

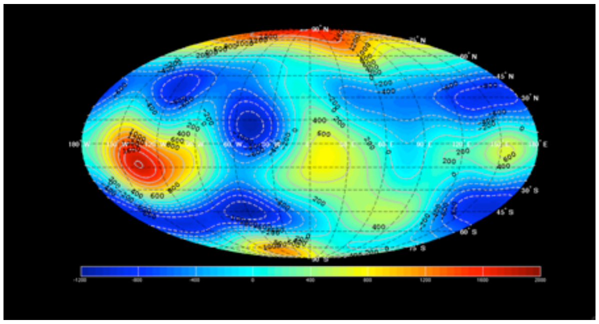

Figure 1: Radial Acceleration (mGal) on a 290x265 ellipsoid that can be used for spherical harmonic expansion without diverging at the poles.

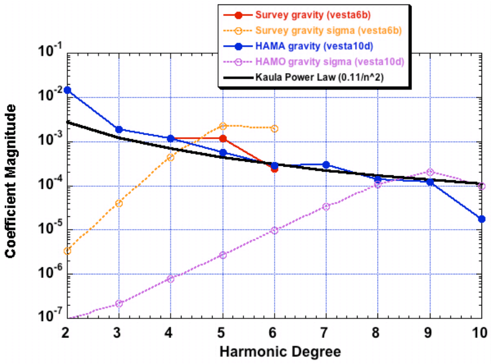

Figure 2: Spectrum of the gravity field harmonic expansion where degree 8=104 km half-wavelength.

Three-Layer Model: In order to explore the implications of the gravity and shape for the interior structure of Vesta, three-layer mass-balance models were calculated and compared to the measured gravitational moment J_2. Two mantle densities were selected (3.17 and 3.3 g/cc) covering a range of accepted values, and for each case, three crustal densities were modeled (2.50, 2.70, 2.90 g/cc). Core density was fixed at an average value for iorn meteorites. For each pair of crustal and mantle densities, the core flattening was varied between 0.0 and 0.30. An expected value from hydrostatic equilibrium for the a core flattening is 0.1; however, Vesta is not hydrostatically equilibrated at present as discussed below. As shown in Figure 3, For an assumed core flattening of 0.1, and a mean crustal thickness of 22.5 km (Fig 4, 5), a mantle density of 3.17 g/cc corresponds to a crustal density of

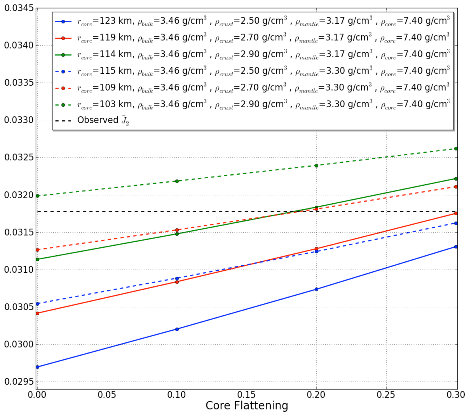

Figure 3: Comparison of modeled J_2 from 3-layer models to the observed J_2 from gravity.

2.99 g/cc, while 3.30 g/cc corresponds to crustal density of 2.78 g/cc. An average core size of ~105-120 km is needed to match the observed J_2, for these ranges of assumed densities.

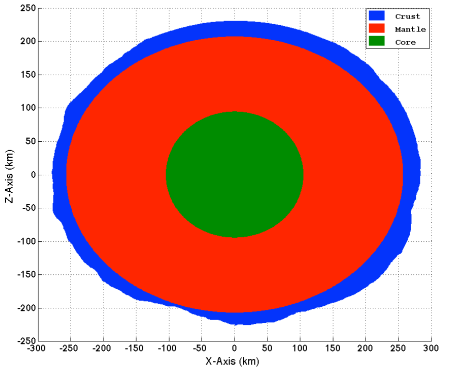

Figure 4: Dimensions of the three-layer model.

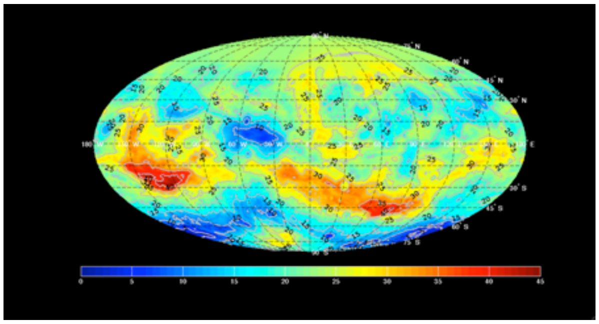

Figure 5: Assumed crustal thickness for the 3-layer models, taken to be the difference between the surface and a mantle modeled by an ellipsoid of 257x207 km.

Bouguer Maps: Figure 6 shows a representative Bouguer map: observed gravity minus gravity from a 3-layer model. Contours show the surface acceleration difference in mGal and background plot represents the topography. The shape volume is 7.497e+07 km^3, crust volume = 1.771e+07 km^3, crust density = 2.99 g/cc, mantle volume = 5.216e+07 km^3, mantle density = 3.17 g/cc, core volume = 5.094e+06 km^3, core density = 7.40 g/cc, core size = 115.6, 104.0 km, core average size = 111.6 km, and core flattening = 0.1.

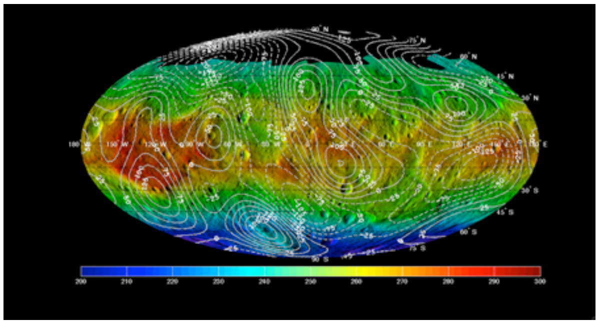

Figure 6: Representative Bouguer map.

Hydrostatic Equilibrium: It was already known prior to Dawn that the shape of Vesta is reasonably well approximated by a triaxial ellipsoid, which departed from an oblate spheroid in that the two equatorial axes differ by 8 km. For slowly rotating fluid bodies, the expected shape is that of a MacLaurin spheroid, with a short axis aligned with the spin axis, and two equatorial axes equal to each other and longer than the polar axis. The angular momentum of Vesta, assuming a homogeneous density distribution, is only 44% of that at the bifurcation into two stable fluid configurations. As a result, if Vesta were hydrostatic, it would have an axisymmetric shape. Our gravity analysis has confirmed that Vesta is not currently in hydrostatic equilibrium. There are three separate components to this confirmation. First, for a hydrostatic body, far removed from tidal influences, rotation is the only source of non-spherical perturbations. We have measured higher degree gravity coefficients which have a variance spectrum similar to that expected for solid bodies. Second, the non-zero values of C_{22} and S_{22} attest to non-hydrostatic structure, even at harmonic degree 2. Finally, the degree two zonal coefficient J_2 is too large to be hydrostatic. If we compare the observed J_2 value to that imposed by the rotational potential, the apparent fluid Love number is k_2= 1.85, whereas the largest possible value is 1.5. This suggests that the gravitational field of Vesta is at present dominantly that of a solid body rather far from hydrostatic equilibrium.

Vesta Physical Parameters: In addition to the gravity field estimate, other determined parameters include the Vesta pole position and rotation rate and body-fixed locations of the landmarks from the optical data. The landmark locations are given in a coordinate system with the center-of-mass as the origin and thus can be used to find the offset between the shape model and gravity field [4]. Current estimates show the frame tie offset of the Gaskell shape model is constrained to be less than several hundred meters.

The solution of the pole location from the Vesta10d solution is RA=309.031 ± 0.003 and Dec = 42.2264 ± 0.0002. More recent Doppler data have sufficient quality to solve for Vesta's rotation rate. **The** Moment of Inertia from obliquity is also under investigation for the dataset to date.

References: [1] Russell, C. T. and Raymond, C. A (2011) *Space Sci Rev* 10.1007/s11214-011-9836-2. [2] Zuber , M. T., et al. (2011) *Space Sci Rev* 10.1007/ s11214-011-9806-8. [3] Konopliv, A. S., et al. (2011) *Space Sci Rev* 10.1007/s11214-011-9794-8. [4] Konopliv, A. S., et al, (2002) *Icarus* 160, 289-299.