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Modeling the Interior Structure of Vesta: Exploring Solutions Using Simulated Dawn Data

P. Tricarico (1), A. S. Konopliv (2), S. W. Asmar (2), C. A. Raymond (2), C. T. Russell (3), D. E. Smith (4), M. T. Zuber (5)

(1) Planetary Science Institute, Tucson, AZ, USA (tricaric@psi.edu) (2) Jet Propulsion Laboratory, Pasadena, CA, USA (3) Earth and Space Science, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA, USA (4) Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD, USA (5) Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA

Abstract

The Dawn mission will determine the topography, gravity, and rotational state of Vesta, allowing the indirect study of its interior structure. We explore the extent to which we will be able to determine the characteristics of the interior features, using a Monte Carlo approach. The shape and density of core, mantle, and crust are parametrized and independently sampled, in order to generate a gravity solution that can be compared directly with the data. This method is particularly suited to explore the full extent of physical solutions that are compatible with the data. Several scenarios for the interior structure of Vesta (strongly differentiated, weakly differentiated, almost uniform density) will be assumed and tested, in order to assess to which level of detail each one can be reconstructed.

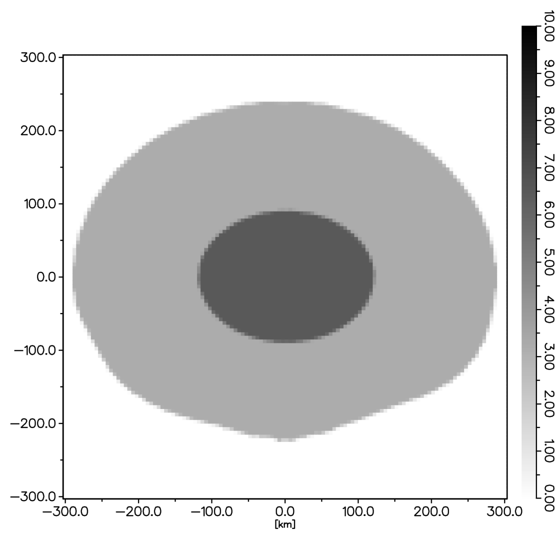

Figure 1: Section of Vesta displaying its interior structure and density distribution. This model, used for the test study presented here, has only two components: core and mantle. Models with three components (core, mantle, crust) will be presented at the meeting. The shape of Vesta is from [5].

Introduction

Vesta is most likely a differentiated body. Mineralogical and isotopic data suggests that heating, melting, formation of a metal core, a mantle, and a basaltic crust took place in the first few million years of solar system history [1]. Thermal modeling by [2] suggests that heating by ^{26}Al would keep the mantle of Vesta hot for $\sim$ 100 My. It is possible that the mantle experienced a substantial if not complete melting that resulted in the formation of a metal core [1]. Results by [3] on the excess ^{182}W measured on eucrites samples suggests that accretion, differentiation, and core formation on Vesta took place in the first 5–15 My. [4] estimated the radius of the core using mass balance from the density of Vesta and a variable fraction of silicates, with their best estimate of a core radius smaller than 130 km, an olivine-rich mantle with thickness $\sim$ 65–220 km, and a crust with thickness $\sim$ 40–85 km. By studying the interior structure of Vesta, we will provide constraints to accretion and differentiation models of Vesta, and look into the effects of the large impact in the southern hemisphere.

Method

A mass density is assigned to every point interior to Vesta's shape, using a smooth function that models the shape and density of core, mantle, and crust, and the transition between layers. The gravity field generated

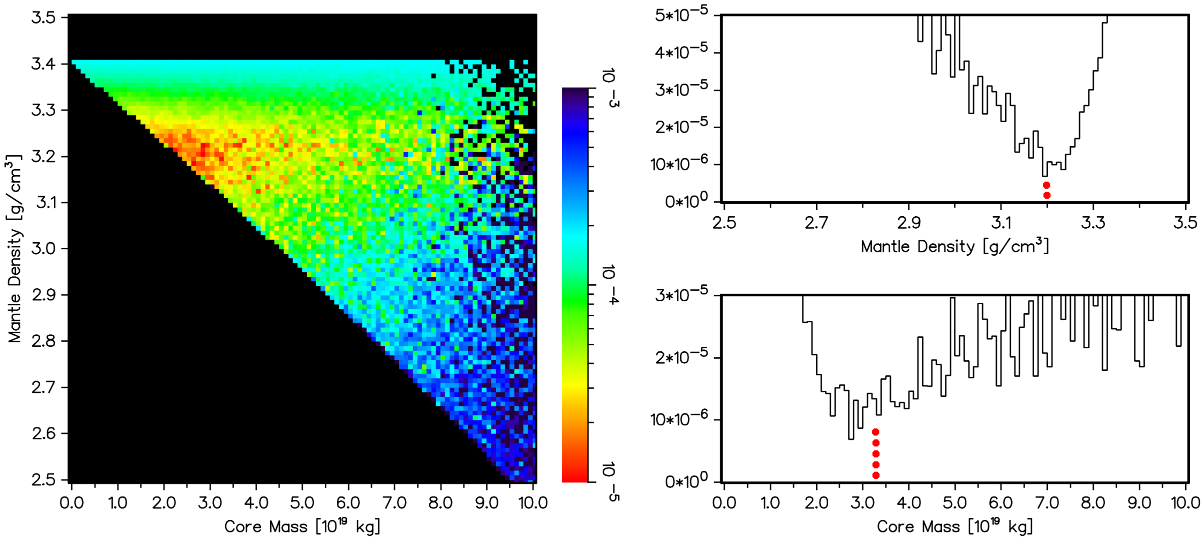

Figure 2: Left: diagram showing the matching between the gravity field resulting from the Monte Carlo sampling, and the nominal gravity field. Data is displayed in the mantle density vs. core mass variables, and the color scale, in arbitrary units, represents the discrepancy between sampled and nominal gravity. The lower left triangular region is forbidden due to total mass conservation. Right: identical data, projected in each of the two variables separately. The red dots mark the nominal value of the parameters.

by any given choice of parameters is then computed using Monte Carlo sampling, and the result is compared to a nominal gravity field chosen as reference, a proxy of Dawn's data. The measure of the discrepancy between the two gravity fields is based on the covariance matrix of the reference gravity field.

Preliminary Results

In Figure 1 we show the mass density distribution of a test, using only two components, chosen as reference. Figure 2 shows the result of the Monte Carlo approach, trying to reconstruct Vesta's interior. The minimum in each variable is the best fit value, but more importantly, a range of solutions nearby the minimum can also be considered in good agreement with the data, depending on the error model used and the confidence level chosen for the study. In the case displayed, an error model for the High Altitude Mapping Orbit (HAMO) was used. We plan to present simulations with an error model for the Low Altitude Mapping Orbit (LAMO) phase at the meeting, with much improved sensitivity and better uncertainties in the coefficients of the gravity field. Several nominal configurations for the interior structure of Vesta will be also tested, varying the characteristics of core, mantle, and crust, in order to assess to which level of detail each one can be reconstructed.

Acknowledgments

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References

[1] Keil, K. 2002. Geological History of Asteroid 4 Vesta: The "Smallest Terrestrial Planet". Asteroids III 573-584.

[2] Ghosh, A., McSween, H. Y. 1998. A Thermal Model for the Differentiation of Asteroid 4 Vesta, Based on Radiogenic Heating. Icarus 134, 187-206.

[3] Lee, D.-C., Halliday, A. N. 1997. Core formation on Mars and differentiated asteroids. Nature 388, 854-857.

[4] Ruzicka, A., Snyder, G. A., Taylor, L. A. 1997. Vesta as the HED Parent Body: Implications for the Size of a Core and for Large-Scale Differentiation. Meteoritics and Planetary Science 32, 825-840.

[5] Thomas, P. C., Binzel, R. P., Gaffey, M. J., Zellner, B. H., Storrs, A. D., Wells, E. 1997a. Vesta: Spin Pole, Size, and Shape from HST Images. Icarus 128, 88-94.