Working models for the gravitational field of Phobos

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Phobos is the larger and closer of the two natural satellites of Mars. Despite decades of Martian exploration, we still know very little about Phobos. Many fundamental properties of this small potato-shaped body stay vague, for example, its gravitational field. SHI Xian and coauthors from Shanghai Astronomical Observatory and Technical University Berlin recently updated working models for the gravitational field of Phobos. Their work, entitled "Working models for the gravitational field of Phobos", was published in *SCIENCE CHINA Physics, Mechanics & Astronomy*, 2012, Vol 55(2).

Mars has two natural satellites, Phobos and Deimos. Unlike the Earth's Moon, the Martian moons are relatively small in size and irregularly shaped. Different scenarios have been suggested for the origin of these two bodies, such as captured asteroids or reaccreted ejectas from an impact event on Mars. However, none of the origin theories has yet been confirmed. To unveil the mysteries of the Martian moons, scientists need more detailed understandings of their physical properties, among which the gravitational field is of great importance. Existing gravitational field models of Phobos are all based on early shape models with relatively low resolution and precision. Since 2003, ESA's Mars Express (MEX) probe has been orbiting Mars in an elliptical polar orbit. This special orbit allows it to perform regular flybys of Phobos, during which plenty of high-quality imaging data are accumulated. These data have helped establish a new, high-resolution shape model of Phobos. This provides a good opportunity to improve the gravitational field model.

The authors introduced three different methods to develop shaped-based gravitational field models, namely, the harmonic expansion approach (HEA), mass elements approach (MEA), and polyhedron approximation approach (PAA). These methods are commonly used in gravitational field modeling for small solar system bodies. The HEA analytically transforms the spherical harmonic expansion coefficients of the shape model to the coefficients of the gravitational field model. While treating the body as an accretion of cubes or a polyhedron, the MEA and PAA numerically calculate values of gravitational potential or force on a certain spatial grid. All three methods have their own advantages, especially when considering different purposes. Therefore, the authors adopted them all in the modeling. Comparisons of the results show good consistency, which further confirms the reliability of the acquired model as well as the feasibility of the methods.

A set of spherical harmonic coefficients for Phobos' gravitational field was obtained by applying the HEA. These coefficients complete a model up to degree and order 17, which is the most detailed one so far. Analyses of the lower-degree coefficients reflect characters of Phobos as an irregularly-shaped small body. The modeled value of is 20% less than the estimate reported by the MEX Radio Science team. However, since the estimate has an uncertainty of around 50%, this deviation indicates little about the internal structure of Phobos. These model coefficients are ready to be used as coarse or initial values in orbital analysis for spacecrafts. The HEA also yields a precise estimate of Phobos' volume as .

As deep space exploration goes on, more and more missions aim to land on small bodies like Phobos. Therefore, it has become necessary to model the surface gravity of these bodies. Due to the weak gravitation and relatively fast rotation, materials on the surface of these small bodies usually experiences a strange dynamical environment that is not always correlated to the topography. Using the MEA, the authors have produced a surface gravity map for Phobos. The gravity anomaly shows a large dynamic range of approximately . Prominent surface features such as crater Stickney can be identified easily.

The working models introduced in this article serve as a benchmark for further studies of Phobos' internal structure as well as surface environment. The authors are working on an in-depth comparative analysis between the dynamical environment and surface features, in search of hints about the surface evolutionary history of Phobos. Also, scientists can gain better insight into the internal mass distribution of Phobos when a more precise measurement is done for the gravitational field.

More information: Shi X, Willner K, Oberst J, et al. Working models for the gravitational field of Phobos. Sci China-Phys Mech Astron, 2012, 55: 358-364, doi:10.1007/s11433-011-4606-4

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