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Measurement of Mercury's Rotational Parameters with Image and Laser Altimetry Data from MESSENGER

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Abstract

Knowledge of the rotational parameters of a celestial body is of paramount importance for tying observations to a body-fixed reference. Moreover, the rotational state of Mercury can provide clues to the interior structure of the planet. We present initial results of the measurement of Mercury's rotational parameters from stereo images and laser altimeter profiles obtained by the MESSENGER spacecraft, which is now in orbit around Mercury. Our technique combines the benefits and the complementarity of laser altimetry and stereo imaging. This combination allows us to obtain estimates for the orientation of the rotational axis, the mean rotation rate, and its small oscillations, i.e., the physical libration in longitude.

1. Introduction

Mercury displays several distinctive dynamical characteristics. The rotation and orbit of the planet are tidally coupled so that Mercury rotates three times for every two revolutions around the Sun. In addition to its mean rotation, longitudinal librations are expected because of Mercury's eccentric orbit and the asymmetric distribution of mass within the planet. Measurements of rotational parameters are of considerable interest, as the libration amplitude and obliquity of the spin axis are related to internal structural parameters [1]. This link offers an opportunity to derive information about the nature of this planet's interior (e.g., core size) not available for other planets of the Solar System family.

Mercury's libration and obliquity have been estimated from Earth-based radar observations [2,3]. From the large libration amplitude obtained (38.5 arc sec, or approximately 450 m at the equator), it was concluded that Mercury's core is at least partially molten. With the MESSENGER spacecraft now in orbit about Mercury, independent measurements for confirmation or refinement of the rotational parameters are now possible. As of February 2014, MESSENGER's Mercury Dual Imaging System (MDIS) had obtained more than 200,000 images of Mercury. Sets of images form stereo pairs and enable the construction of a large-area digital terrain model of the planetary surface [4,5]. Further, MESSENGER's Mercury Laser Altimeter (MLA) has performed over 30,000,000 high-accuracy range measurements to Mercury's northern hemisphere.

2. Method

With the large data sets collected by MESSENGER we have performed a co-registration of a time-dependent network of laser altimeter measurements with the static topography data obtained from stereo images. The co-registration is implemented as a non-linear least-squares adjustment, which minimizes the height differences between the data sets. In this iterative process, the rotational parameters and static offsets between the data sets are obtained [5,6]. Appropriate weighting of the observables is performed to account for varying observation conditions (e.g., off-nadir pointing).

In order to verify our approach, a comprehensive simulation of MESSENGER observations under assumed rotational parameters was performed. The simulation considered uncertainties in position and attitude of the spacecraft, as well as errors arising from different absolute referencing and spatial resolutions of the data sets. With the use of a random-number generator for the errors, several simulation runs were performed. From the scatter of the results of the simulations, we substantiated our

error estimation process and verified the lack of bias in our method. We found that we can measure the rotational parameters at least to the same accuracy as estimates derived from Earth-based radar observations [2].

The next step is to apply the method to estimate rotational parameters from actual observations made from orbit about Mercury.

References

[1] Peale, S.J., Does Mercury have a molten core?, *Nature 262*, 765–766, 1976

[2] Margot, J.-L., Peale, S.J., Jurgens, R.F., Slade, M.A., Holin, I.V., Large longitude libration of Mercury reveals a molten core, *Science 316*, 710–714, 2007

[3] Margot, J.-L., Peale, S.J., Solomon, S.C., Hauck, S.A., Ghigo, F.D., Jurgens, R.F., Yseboodt, M., Giorgini, J.D., Padovan, S., Campbell, D.B., Mercury's moment of inertia from spin and gravity data, *J. Geophys. Res. Planets 117*, E00L09, doi:10.1029/JE004161, 2012

[4] Preusker, F., Oberst, J., Head, J.W., Watters, T.R., Robinson, M.S., Zuber, M.T., Solomon, S.C., Stereo topographic models of Mercury after three MESSENGER flybys. *Planet. Space Sci. 59*, 1910–1917, 2011

[5] Preusker, F., Stark, A., Oberst, J., Becker, K., Perry, M., Solomon, S.C., Topography of Mercury: A global model from MESSENGER orbital stereo mapping, *European Planetary Science Congress 2014 (this meeting),* 2014

[6] Stark, A., Oberst, J., Preusker, F., Gwinner, K., Peale, S.J, Margot, J.-L., Zuber, M.T., Solomon, S.C., A technique for measurements of physical librations from orbiting spacecraft: Application to Mercury, *EPSC Abstracts 7*, paper EPSC2012-254, 2012