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Measurements of Martian rotational variations by space geodetic techniques

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Variation of planetary rotation provides us information concerning both the interior structure and the surface mass redistribution. Such information is valuable for elucidating not only present condition but also evolution of a planet as a system. Precession and nutation of Mars reflect the present status of the core-mantle sub-system, besides length-of-day variation and polar motion of Mars are induced by variation of the atmosphere-cryosphere sub-system.

Two-way tracking of orbiters on Mars were executed to elucidate the physics of Mars. Precession and length-of-day variation have been measured by means of tracking data of Viking 1 and 2, and Mars Pathfinder. The results of the Love number k{sub}2{/sub} obtained by two Martian explorers, namely, Mars Global Surveyor (MGS) and Mars Odyssey, predict existence of a liquid core inside Mars. Seasonal variations of the polar caps on Mars were estimated mainly based on the laser altimeter data on MGS in conjunction with gravity data. Although Mars rotation observations by two-way tracking have produced scientific results as shown above, these measurements had limitations in terms of accuracy within the framework of traditional technologies concerning space geodesy and astrometry. Thus, the new configurations of orbiter-to-lander tracking had been proposed for two Martian explorers. To achieve the accuracies in the order of 1 mas (mill-arc second) to detect Martian rotation variation, orbiter-to-lander tracking were proposed for NetLander and ExoMars. Unfortunately these ideas have still not been approved as real missions for Mars.

A Japanese research group has recently started to plan a new Martian explorer; MELOS (Mars Exploration with Lander-Orbiter Synergy). As one of the missions of MELOS, we are proposing areodetic observations using space geodetic techniques such as four-way Doppler measurements and inverse VLBI [1]. By measuring the Mars rotation with higher accuracy, we will be able to determine the state of the core (liquid or solid) more clearly, estimate its radius if it is liquid, and figure out the quantities of seasonal surface mass redistribution. Four-way Doppler measurements (FWD) are ranging rate measurements of target spacecraft via relay spacecraft. Utilizing the heritage of FWD by SELENE, we plan to track the multi-landers of MELOS relayed by the MELOS Orbiter. The expected accuracies for these observations are almost in the same order as that in the case of orbiter-to-lander tracking. We also introduce a new technology called inverse VLBI. One ground radio telescope, not a VLBI network, observes both the orbiter and the landers with same-beam or switching of the antenna. The signals from the landers are coherently locked with those of the orbiter, and phase differences between the two spacecraft are also measured at the orbiter. The functions of the orbiter and the landers may be exchanged depending on the limits of resources including mass and electric power of each spacecraft, although, the precisions of the measurements are independent of such configuration changes. One of the remarkable characteristics of inverse VLBI is that the theoretical accuracy of positioning depends only on the observation frequency and does not depend on the distance between the radio sources and the ground stations. Therefore, X-band observation of inverse VLBI will achieve the accuracy of 0.3 mm which is much better than that of FWD, RARR, and differential VLBI. Including the systematic phase noise, the accuracy for the rotation is estimated to be better than 3 mas. The inverse VLBI system, however, needs higher carrier to noise ratio than conventional tracking, and therefore it is necessary to develop more efficient antenna and receiver system. It is also important to calibrate the phases through links with higher accuracies.

Reference: [1] Kawano et al. (1999) J. Geod. Soc. Japan, 45, 181-203.

Keywords: Mars, rotation, space geodesy, inverse VLBI