ROTATION AND INTERNAL DYNAMICS OF MARS FROM FUTURE GEODESY EXPERIMENTS

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ABSTRACT. The LaRa (Lander Radioscience) experiment on the lander platform of the ExoMars mission (the Humboldt Payload) on the surface of Mars is designed to obtain coherent two-way Doppler measurements from the radio link between the ExoMars lander and the Earth over at least one third of a Martian year. We have set up a design for LaRa and realized a breadboard.

Complementary to LaRa, in the future network-science Mars-NEXT mission, there will be radio links between other landers at the surface of Mars and the orbiter and a radio link between the orbiter and the Earth. The Mars-NEXT mission to Mars addresses different fields of investigation, of which an important part is related to planetary rotation and interior structure as for LaRa.

With the objectives to determine interior properties of Mars as well as angular momentum changes induced by CO2 sublimation/condensation process, we have simulated these Doppler measurements and developed a strategy for reaching these goals.

1. INTRODUCTION

In the last decades, several missions and observations have brought new insight on the inner structure of the terrestrial planets. This information is a big challenge for the planet interior models; these data are also our best chance to improve our knowledge of the interior. Data obtained through new space missions are the basis of the future progress in this field. Classically, as done for the Earth, the interior models are constrained through seismic data provided from an extended network of seismometers. However, for planets, in the absence of such a network, gravitation and rotation studies are the most efficient ways to learn about the interior of the planets. Practically, our study is based on the analysis of the precise orbits of spacecrafts around the planets and on the positions of landers. Our experiments will allow us to answer some of the most debated questions of the moment: the atmospheric dynamics and the state and dimension of the core.

2. EXPERIMENTS

The paper presents the concept, the objectives, the approach used, and the expected performances and accuracies of radioscience experiments based on radio links between the Earth and the surface of Mars, between the Earth and an orbiter around Mars and between this orbiter and the landers on the surface of Mars. These experiments involve radioscience equipment installed on a lander at the surface of Mars and on a spacecraft orbiting around Mars, as well as dedicated ground stations on Earth. The

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experiments are not fictive as there are at least two possibilities in the future. The first, with the generic name LaRa (Lander Radioscience), consists of an X-band transponder that has been designed to obtain, over at least 180 days (minimum guaranteed mission) and more probably over one Martian year, two-way Doppler measurements from the radio link between the ExoMars lander and the Earth (ExoMars is an ESA mission to Mars within the Aurora Exploration Programme and due to launch in 2016).

The second possibility is MarsNEXT also called MarsNet consisting in several landers at the surface of Mars and an orbiter around Mars. This mission is studied in the frame of the Next Exploration Science and Technology (NEXT) mission opportunity, as part of ESA's Aurora Exploration Programme. Following the Mars-Express Orbiter and the ExoMars rover-lander, MarsNEXT offers a unique opportunity to produce a global picture of the geophysics of Mars. The Network Mission concept addresses key science goals on a given terrestrial planet (in this case, Mars) that can only be achieved by simultaneous (or quasi-simultaneous) measurements from a number of landers, which are spaced across the surface of the planet. The primary objectives of such a mission concern a planet's internal geophysics and its meteorology. A Mars Network Mission also allows for a significant improvement to our understanding of the rotational parameters of the planet. This can be achieved by means of radio transmission between the various landers and the Earth and between these landers and a single orbiter. Studies into the rotational parameters of Mars are an important complement to internal geophysical studies. Thus important science objectives at Mars cannot be achieved by any means other than Network Science and by a Mars Network Science mission.

As mentioned above, radioscience measurements are Doppler measurements that are used to obtain Mars' orientation in space and rotation (precession and nutations, and length-of-day variations). More specifically, the relative position of a lander on the surface of Mars with respect to the Earth ground stations or of a lander with respect to an orbiter and of the orbiter with respect to Earth allows reconstructing Mars' time varying orientation and rotation in space.

3. FUTURE RESULTS

Radioscience using landers-Orbiter-Earth links will provide important constraints on the rotation of Mars and on its deformations. Analytical and numerical simulations confirm the feasibility of LaRa and emphasize the potential of future radioscience experiments.

- From Length-of-day variations it will be possible to obtain information on the mass transfer in the sublimation/condensation process of CO2;
- From precession and nutation, it will be possible to obtain the moments of inertia of the whole planet, of its core and its mantle, as well as Mars' core state and dimension;
- From tidal effects on the orbiter, it will be possible to better constrain de tidal Love number k2 and therewith further constrain the models of Mars' interior;
- Precession, nutation, moments of inertia of the core and the mantle, dimension of the core, and tidal Love number are constraints for interior modeling, which will allow a better understand of Mars evolution and habitability.

In particular, LaRa radioscience on ExoMars will improve our knowledge on the core and the rotation of Mars; LaRa feasibility has been demonstrated on a poster (Le Maistre et al.) presented yesterday. MarsNet/MarsNEXT will further improve this knowledge and will provide the possibility to further precisely determine the physical properties and dimension of the core (and possible inner core). This will allow us to obtain global properties of Mars. It will be perfectly complementary with seismic measurements, heat flow measurements, and magnetic measurements; these data will be jointly used for obtaining the best knowledge of Mars interior.

The ultimate objectives of the proposed experiments are to obtain information on Mars' interior and on the sublimation/condensation of CO2 in Mars' atmosphere. Improved knowledge of the interior will help us better understand the formation and evolution of Mars.

Improved knowledge of the CO2 sublimation/condensation cycle will enable better understanding of the circulation and dynamics of Mars' atmosphere. For further detail, see the paper on LaRa (Dehant et al., 2008, Planet. Space Sci., doi: 10.1016/j.pss.2008.08.009) and on MarsNEXT (Chicarro et al., Science Definition Document, ESA publication).