EPSC Abstracts
Vol. 12, EPSC2018-1242, 2018
European Planetary Science Congress 2018

Planetary seismology reborn: Prospects for exploring interiors on Mars, icy ocean worlds and beyond

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Abstract

Seismic data are promising for determining interior structure of planetary bodies. The InSight mission is expected to land in 2018, and the data will be used to model the interior of Mars. In advance of proposed missions to Europa and Titan, modeling of signal amplitude and characteristics are vital. Future missions may take advantage of low cost and complexity deployment to obtain seismic data without a dedicated seismic mission.

1. Introduction

In order to obtain detailed information on planetary interiors, seismological measurements are of critical importance [4]. Much of our knowledge of the internal structure of the planetary bodies in our solar system is achieved through observations such as gravity field, rotation, and tides, but those observations provide an integrated view of interiors which is non-unique. For the Earth, on the other hand, we have a detailed picture of the interior primarily obtained through the study of seismic data.

In the coming decades, many landed missions will explore terrestrial and icy ocean worlds. Seismic instruments will likely be a common component of many such landed mission concepts, such as the proposed Europa Lander and Dragonfly missions [3,10]. The InSight mission, launched this year, will be the first since Viking to use seismometers to learn about the interior of Mars. Prospects are now bright for a new era of planetary seismology, but it is important to model likely signal and noise [5,7] to design future missions and instruments.

2. Expectations for InSight mission

On May 5, 2018, InSight successfully launched and is expected to arrive on Mars on November 26, 2018. Along with a heat flow probe and meteorological and magnetic instruments, InSight will deliver two 3-component seismometers which will be placed on the surface of Mars [1]. InSight has 2 major science goals: 1. Understand formation and evolution of Mars. 2. Determine the level of tectonic activity on Mars. To achieve these goals, the InSight team will be routinely locating all observed seismic activity with state of the art single station location techniques [2]. After events are detected and located, Bayesian inversion techniques will be applied to a variety of seismic observables ranging from body wave and surface wave measurements to analysis of converted waves beneath the station and ambient noise techniques [6]. Such techniques have been tested with Earth data and simulated Mars data, but undoubtedly real Mars data will be surprising.

3. Icy ocean worlds

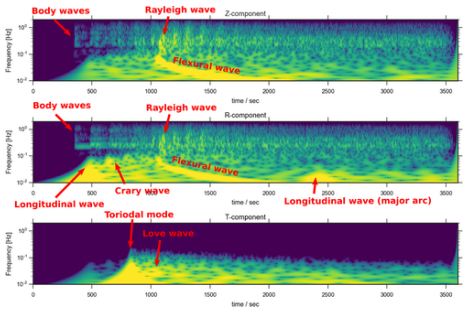

Figure 1: 3 component spectrograms illustrating seismic signals observed on icy ocean worlds.

With the prospect of landed instruments on Europa and Titan, we need to simulate likely seismic signals on icy ocean worlds [9], using realistic thermodynamic models of the interiors [11]. Unique seismic phases differing from those observed in terrestrial worlds can be used to determine ice shell thickness and ocean depth (figure 1). Statistical modeling of icequake recurrence rates can be used to estimate signal and noise amplitude [7].

4. Future mission possibilities

While a dedicated geophysical mission such as InSight allows for unprecedented instrument sensitivity, there is also excellent science potential for seismic data from low cost/complexity deck deployments. An experiment deploying seismometers on and below the engineering model of the "Curiosity" rover [8] shows the potential of simple deck-mounted instruments (figure 2). Experience with InSight will also allow testing of on-board preprocessing, likely necessary in future missions as a secondary scientific payload.

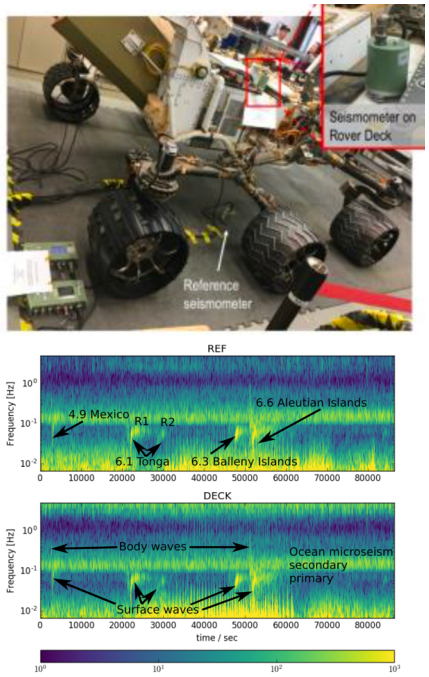

Figure 2: Deployment of seismometer on the deck of the MSL engineering model and the ground below (top), and records showing clear seismic arrivals on both instruments (bottom).

5. Summary and Conclusions

With the upcoming landing of InSight, and multiple potential sources of new planetary seismic data in the upcoming decades, planetary seismology is poised for rapid expansion. Seismology is a powerful enough tool for exploring the interior and activity of other planetary bodies that it should become as standard a tool for inclusion in landed missions as cameras.

Acknowledgements

This research was supported through Research and Technology Development funds from Jet Propulsion Laboratory, California Institute of Technology, under a contract with the NASA. Some work has also been supported by Project 16-HW16_2-0065 of the NASA Habitable Worlds program. © 2018, California Institute of Technology.

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