Beyond InSight - Seismological Exploration of Ocean Worlds

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Since the *Viking* mission, no successful planetary lander mission has been equipped with a seismometer. This is unfortunate, given that most of the knowledge about Earth's deep interior was derived from seismological observations. Spring 2018 will see the launch of the *InSight* mission, which will install broadband seismometers on Mars. Analyses of these exciting new data will be able to harness the enormous progress that has taken place in the last 40 years in seismological signal processing.

Plans for a proposed NASA *Europa Lander* include a seismometer, which could operate for more than 20 days on the surface. Together with gravity and magnetometry studies from the *JUICE* and NASA's *Europa Mission*, the seismometer would allow measurements of the radial depths of compositional interfaces in the ice, the ocean and the deeper interior. We present estimations of Europa's seismic wavefield using state-of-the-art finite-element simulations, taking into account seismic sources from tidal ice cracking as well as ocean circulation, building on prior studies (Kovach and Chyba 2001, Lee et al. 2003, Cammarano et al. 2006, Panning et al. 2006, Leighton et al. 2008) .

The results show that determination of the ice thickness, the ocean depth and the thickness of a sediment layer on the ocean bottom would be possible with performances comparable to those of an evolution of the *InSight SP* instrument, as proposed in the recent report of the NASA Science Definition Team.

We will also describe preliminary analyses of other ocean worlds, Enceladus, Titan, Ganymede, and Callisto, where seismic investigations may address unique science questions about their structure, composition, and possible habitability through time. Seismology may provide information about fluid motions within or beneath ice, and can record the dynamics of ice layers, which would reveal mechanisms and spatiotemporal occurrence of crack formation and propagation. Investigating these structures and processes in the future calls for detailed modeling of seismic sources and signatures, building on observations in terrestrial cryoseismology (Zhan et al. 2014, Podolskiy & Walter 2016) in order to develop the most suitable instrumentation.

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