EPSC Abstracts
Vol. 15, EPSC2021-258, 2021, updated on 29 May 2022
https://doi.org/10.5194/epsc2021-258
Europlanet Science Congress 2021

An analysis of the seismic scattering on Mars, using the InSight seismic data

Foivos Karakostas[1,2], Nicholas Schmerr[2], Ross Maguire[2,3], Quancheng Huang[2,4], Doyeon Kim[2], Vedran Lekić[2], Ludovic Margerin[5], Ceri Nunn[6], Sabrina Menina[7], Taichi Kawamura[7], Philippe Lognonné[7], Domenico Giardini[8], and Bruce Banerdt[6]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy (foivos.karakostas@ingv.it)
[2]Department of Geology, University of Maryland, College Park, MD, USA
[3]Department of Computational Mathematics, Science and Engineering, Michigan State University, East Lansing, MI, USA
[4]Department of Physics, New Mexico State University, Las Cruces, NM, USA
[5]Institut de Recherche en Astrophysique et Planétologie, Université Toulouse III Paul Sabatier, CNRS, CNES, Toulouse, France
[6]Jet Propulsion Laboratory, CA, USA
[7]Université de Paris, Institut de Physique du Globe de Paris, France
[8]ETH Zürich, Switzerland

The scattering of seismic waves is the signature of random heterogeneities, present in the lithospheric structure of a terrestrial planet. It is the result of refraction and reflection of the seismic waves generated by a quake, when they cross materials with different shear rigidity, bulk modulus, and density and therefore different seismic wave velocities, compared to the ambient space. On Earth, the seismic waves show relatively weak scattering, identified in later arriving coda waves that follow the main arrivals of body waves and decay with time. In contrast, seismic wave scattering is much more significant on the Moon, where the high heterogeneous structure of the lunar megaregolith, produced through millions of years of impact bombardment, is a structure that creates an extreme scattering environment.

The landing of the NASA InSight mission on Mars in 2018, which carried and deployed a seismometer for the first time on the Martian ground, offered a pristine dataset for the investigation and analysis of the characteristics of the scattering attenuation of the Martian crust and uppermost mantle which is important for understanding the structure of the Martian interior. Lognonné et al. (2020) used a methodology based on the radiative transfer model (Margerin et al., 1998) to offer the first constraints for the scattering and attenuation in the Martian crust. In this study, we performed a further examination based on more and newer events of the Martian Seismic Catalog (InSight Marsquake Service, 2021).

The Marsquake Catalog contains events that are categorized according to the frequency content of the seismic signal (Clinton et al., 2021). In this study, we used 19 events of 4 different families, namely the Low Frequency, Broadband, High Frequency, and Very High Frequency events, for our investigation. We focused our investigation on the characteristics of the S-coda waveforms and for this reason, we worked on the respective energy envelopes. We manually picked the envelopes, defining the time window of the S-coda waves, as well the frequency range for each event, directly from the spectrograms of the events' signals, using an appropriately developed visual tool.

We used a modeling approach (Dainty et al., 1974) that was developed for the computation of the energy envelopes of shallow events (Lunar impacts) and a diffusive, highly scattering layer, sitting over an elastic half-space. The energy envelope depends on the thickness of the diffusive layer, the range of the seismic ray, the diffusivity and the attenuation in the top layer, and the seismic wave velocity in the underneath elastic half-space. We analyzed all the tradeoffs between the terms of the modeling equation, namely the geometrical relationship of the velocity contrast between the diffusive layer and the elastic half-space with the seismic ray range and the diffusive layer thickness, the diffusivity with the diffusive layer thickness, and between the diffusivity and the velocity contrast of the two examined layers.

The presence of the aforementioned tradeoffs made the definition of a unique model a very hard task, as the information for the azimuthal characteristics of the signal is not available for the examined events. This is a limitation that exists in seismology only while working with one station, with the InSight seismometer being the only station on a planet, and the amplitude of the seismic signal is not big enough to perform a specific polarization analysis and derive the azimuthal origin of the recorded signal. For this reason, we reviewed the fit between the modeling and the data, depending on the frequency content of the events.

The Low Frequency and the Broadband events, which have a frequency content mainly below the tick noise detected at 1 Hz, could not satisfy the modeling approach of a simple diffusive layer. The spectral envelopes of the S-coda waves of these events are decaying very rapidly, which suggests an origin in a more elastic environment. This is in agreement with previous studies (Giardini et al., 2020) that suggest that these events are generated deeper in the Martian mantle. For this reason, we applied another approach to these signals, with an energy envelope equation designed for deep moonquakes (Dainty et al.,1974), but it was not either capable to fit the examined data envelopes, suggesting the absence of a very thick megaregolith structure on Mars.

Based on the results of the High Frequency (HF) and Very High Frequency (VF) events we observed a range of possible paths and diffusivities that can satisfy the data and we investigated the tradeoffs between the parameters of a modeling equation that control the shape of the energy envelope for the events. The analysis of these tradeoffs does not permit us to make any assumptions about the depth of the diffusive region in the Martian crust and the upper mantle as their azimuthal characteristics are unknown and therefore it is not feasible to tell if the difference in the result analysis reflects vertical or lateral variations of the uppermost diffusive layer in the Martian lithosphere.

The results of this study illustrate one of the challenges in working with single-station seismic data where event location information, including distance, azimuth, and depth are crucial for understanding the lateral variation in seismic properties of a planet. The existence of a seismic network on the planetary scale will improve the ability of phase peaking and location identification of the events and therefore it will give additional constraints for a similar analysis.

References

Clinton, J. F. et al. (2021). The Marsquake catalogue from InSight, sols 0–478.Phys Earth Planet In, 310:106595.

Dainty, A. M. et al. (1974). Seismic scattering and shallow structure of the Moon in Oceanus Procellarum.The Moon,9(1-2):11–29.

Giardini, D. et al. (2020). The seismicity of Mars.Nat Geosci, 13(3):205–212.InSight Marsquake Service (2021).

Mars Seismic Catalogue, InSight Mission; V5 2021-01-04.

Lognonné, P. et al. (2020). Constraints on the shallow elastic and anelastic structure of Mars from InSight seismic data.NatGeosci, 13(3):213–220.

Margerin, L. et al. (1998). Radiative transfer and diffusion of waves in a layered medium: new insight into coda Q.GeophysJ Int, 134(2):596–612.