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Constraining Seismic Anisotropy on Mars: New Challenges and First Detection

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Seismic anisotropy is now commonly studied on Earth and has been detected at various depths, from the crust to the top of the lower mantle, in the lowermost mantle, and in the inner core. In the mantle, observations of seismic anisotropy are often taken as an indication of past or present deformation resulting in the preferential orientation of anisotropic minerals. In the crust, it can come from stress-induced oriented cracks, compositional layering, or crystallographic preferred orientation of minerals.

While many questions remain regarding the presence and interpretation of seismic anisotropy on Earth, scientists are now faced with new, exciting challenges in trying to constrain the structure of other planetary bodies. One of the goals of NASA's InSight mission, which landed on Mars in November 2018 and includes a very broadband seismometer, is to constrain Mars interior structure. Compared to seismic studies of Earth, which benefit from the availability of a wealth of high quality data recorded on many seismic stations, difficulties with InSight stem from having only one seismic instrument and only a few high quality events.

In this study, we analyzed the horizontally polarized (SH)-wave reflections generated from the shallowest crustal layer (layer 1) detected at 8 ± 2 km beneath the InSight lander site by a previous receiver function (RF) study. From Sol 105, when the first low-frequency marsquake was recorded, to Sol 1094, a total of 83 broadband and low-frequency events were detected, but only nine are rated as quality-A with constraints on both their epicentral distance and back azimuth. Of those nine events, we selected four that did not show any interference with mantle triplications generated by the olivine to the wadsleyite phase transition and that had a clear signal after the direct SH phase. A model space search approach enabled us to obtain a range of acceptable SH-wave velocities and layer thicknesses, which we then compared with the RF models of Knapmeyer-Endrun et al. (2021). We found that the acceptable SH-wave speeds are systematically lower than those from the RF study. Since this RF analysis is sensitive to vertically polarized (SV)-waves, we interpret this difference as the signature of radial anisotropy with an anisotropy coefficient

[illegible]=([illegible]/[illegible])^2 between 0.7 and 0.9. Modeling of preferred alignment of inclusions shows that dry or fluid-filled cracks/fractures, and igneous inclusions can reproduce the observed radial anisotropy amplitude with $V_{SV}>V_{SH}$.