CONSTRAINTS ON THE MARTIAN UPPER MANTLE STRUCTURE FROM INSIGHT SEISMIC DATA.

A. Khan[1], S. Ceylan[1], M. van Driel[1], D. Giardini[1], P. Lognonne[2], H. Samuel[2], N. Schmerr[3], S. Stähler[1], A. C. Duran[1], Q. Huang[3], Doyeon Kim[3], C. Charalambous[4], J. F. Clinton[1], P. M. Davis[5], M. Drilleau[6], F. Karakostas[3], V. Lekic[3], R. R. Maguire[3], C. Michaut[7], M. P. Panning[8], W. T. Pike[4], B. Pinot[2], M. Plasman[2], J.-R. Scholz[9], R. Widmer-Schnydrig[10], T. Spohn[11], S. E. Smrekar[8], W. B. Banerdt[8]; [1]ETH Zürich, [2]Université de Paris, Institut de Physique du Globe de Paris, CNRS, [3]University of Maryland, [4]Imperial College, [5]UCLA, [6]ISAE SUPAERO, [7]Université de Lyon, [8]Jet Propulsion Laboratory, California Institute of Technology, [9]Max Planck Institute for Solar System Research, [10]Black Forest Observatory, University of Stuttgart, [11]Institute of Planetary Research, German Aerospace Center (DLR).

Introduction: The seismicity of a terrestrial planet depends on the state of strain within that planet. The amount of strain that has accumulated is itself dependent upon the thermal evolution of the planet which is governed by how heat is dissipated. At some point the accumulated strain causes material failure that produces a disturbance which travels from the point of origin through the planet as seismic waves. The disturbances propagate directly to the recording station as P- and S-waves and as reflected and refracted phases that have interacted with internal boundaries or the surface (e.g., PP, PPP, SS, and SSS). Our current knowledge of the internal structure of Mars derives from a combination of observations made in-situ, from orbit, and through experimental and geophysical studies [1-4]; yet details remain perfunctory. With the deployment of a seismometer on the surface of Mars as part of NASA's InSight mission [5], the Seismic Experiment for Interior Structure (SEIS) [6] has been collecting continuous data since early 2019. The primary goal of InSight is to improve our understanding of the internal structure and dynamics of Mars, in particular that of the mantle [7].
Here we describe preliminary constraints on the structure of the mantle of Mars based on inversion of seismic body wave arrivals from a number of marsquakes [8]. Mission overviews are presented in [9,10].

Methodology: We consider 8 of the largest (moment magnitude is estimated to be between 3 and 4) low-frequency events with dominant energy >1 Hz [11] for which P- and S-waves are identifiable (Figure 1), enabling epicentral distance estimation [12]. The 8 events occur in the distance range 25-75 degrees. Body wave arrivals (main P- and S-waves and surface reflections PP, PPP, SS, SSS) are picked using complimentary methods: visually inspection of narrow-band filtered time-domain envelopes, polarisation filtering and vespagrams, and waveform matching. The resultant set of differential travel times (PP-P, PPP-P, SS-S,…) are subsequently inverted for radial profiles of seismic P- and S-wave velocity and epicentral location of the events. To determine interior structure, we rely on two independent methods: a "traditional" seismic parameterization, wherein the model is delineated by a set of layers of constant P- and S-wave velocitiy, and a geophysical parameterization that combines phase equilibria, seismic properties, and thermo-chemical parameters [4]. Complimentary approaches are presented in [13].

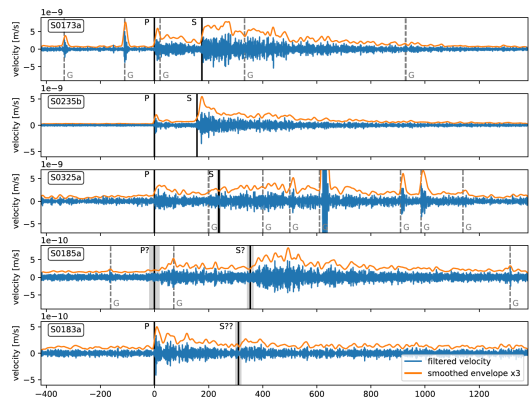

Figure 1: Vertical component seismograms, including envelopes for five events with visible P- and S-wave arrivals ``G" denotes glitches, i.e., impulsive signals originating from the instrument assembly itself due to large daily temperature variations [14].

Results: We present a preliminary radial velocity model for the upper mantle of Mars, with implications for the thermo-chemical evolution of the planet that match a cooling, differentiated body, and a thick lithosphere. Based on the location of the events, we are able to constrain structure well into the upper mantle (>300 km). Our estimate of the average crustal thickness as seen by all events is compatible with the local crustal thickness at the InSight landing determined from observations of converted phases [15, 16]. Finally, we also consider implications for thermal evolution and present-day surface heat flow [17,18].

Acknowledgments: We acknowledge NASA, CNES, partner agencies and institutions (UKSA, SSO,

DLR, JPL, IPGP-CNRS, ETHZ, IC, MPS-MPG) and the operators of JPL, SISMOC, MSDS, IRIS-DMC and PDS for providing SEED SEIS data. InSight data is archived in the PDS, and a full list of archives in the Geosciences, Atmospheres, and Imaging nodes is at https://pds-geosciences.wustl.edu/missions/insight/.

References: [1] Yoder C. F. et al. (2003) Science doi:10.1126/science.1079645. [2] Zharkov V. N. and Gudkova T. (2005) Solar System Res. doi:10.1007/s11208-005-0049-7 [3] Rivoldini T. et al. (2011) Icarus doi:10.1016/j.icarus.2011.03.024 [4] Khan A. et al. (2018) JGR doi:10.1002/2017JE005371 [5] Banerdt, W.B. et al. (2020) *Nature Geo.*, 13, 183. [6] Lognonné et al. (2019) Space Sci. Rev., 215, 12 [7] Smrekar S. E. et al. (2019) *Space Sci Rev*, *215,* 3. [8] InSight Mars SEIS Data Service (2019) https://doi.org/10.18715/SEIS. INSIGHT.XB_2016. [9] Panning M. P. et al. (2021) LPSC 52. [10] Lognonne P. et al. (2021) LPSC 52. [11] Clinton J. (2020) PEPI doi:10.1016/j.pepi.2020.106595. [12] Giardini D. (2020) Nature Geosci. doi: 10.1038/s41561-020-0539-8. [13] Drilleau M. et al. (2021) LPSC 52. [14] Scholz J.-R. et al. (2020) Earth Space Sci. doi:10.1029/2020EA001317. [15] Lognonne P. et al., (2020) Nature Geosci. doi: 10.1038/s41561-020-0536-y. [16] Panning M. P. et al. (2021) LPSC 52. [17] Michaut, C. et al. (2021) LPSC 52. [18] Samuel H. et al. (2019) Nature doi:10.1038/s41586-019-1202-7.