MEASURING THE SCATTERING AND ATTENUATION OF SEISMIC WAVES IN MARS WITH THE INSIGHT SEISMOMETERS. N. C. Schmerr[1] and T. Kawamura[2], L. Margerin[3], M. van Driel[4], R. Garcia[5], F. Karakostas[2], B. Tauzin[6,7], P. Lognonné[2], [1]University of Maryland, College Park, MD (nschmerr@umd.edu); [2]Instutut de Physique du Globe de Paris 35 rue Hélène Brion, 75205 Paris CEDEX 13 (kawamura@ipgp.fr); [3]A CNRS / Université de Toulouse 14, Avenue Edouard Belin 31400 Toulouse, France (Ludovic.Margerin@irap.omp.eu); [4]Institute of Geophysics, ETH Zürich, Sonneggstrasse 5, 8092 Zürich, Switzerland (vandriel@erdw.ethz.ch); [5]ISAE-SUPAERO, 10 Ave E. Belin, 31400 Toulouse, France (raphael.garcia@isae.fr); [6]Université de Lyon, UCBL, ENS Lyon, CNRS, Laboratoire de Géologie de Lyon, Terre, Planètes, Environnement, 2 rue Raphaël Dubois, Bâtiment GEODE, Villeurbanne, 69622, France. [7]Research School of Earth Sciences, Australian National University, Australian Capital Territory 0200, Canberra, Australia (benoit.tauzin@univ-lyon1.fr).

Introduction: The amplitudes of seismic waves decrease over distance due frequency dependent energy loss via scattering and attenuation. Scattering, or extrinsic attenuation, is dependent upon the size, strength, and abundance of elastic heterogeneities within the medium [1-7]. Intrinsic attenuation results from dissipation due to anelastic processes and internal friction between molecules and defects within crystal lattices [8-13]. Both forms of attenuation are described using the seismic quality factor, Q. Scattering can arise from compositional heterogeneities, mechanical boundaries (such as fractures, cracks, veins, cavities), and other major non-radial changes in material properties of an object. Intrinsic attenuation is tied to grain boundary processes, crystal defects, fluid-filled cracks, and other dissipative viscoelastic processes. Attenuation is vital for understanding the detectability, travel times, and propagation properties of seismic waves, as well as the properties of the interior of a world.

The Interior Exploration using Seismic Investigations Geodesy and Heat Transport (InSight) Seismic Experiment for Interior Structure (SEIS) has placed a very broadband (VBB) and short period (SP) seismometers on Mars that allows us to investigate the fundamental geophysical process of seismic attenuation at Mars, which is expected to have properties falling between the Earth and the Moon. In the Earth, attenuation by seismic scattering is found to be relatively weak, and is typically confined to small-scale compositional heterogeneities in the crust, lithosphere, and mantle [7]. Intrinsic attenuation varies throughout the Earth, and is especially high where fluids [10], elevated temperatures, and changes in grain size [9] are present. On the Moon, seismic scattering is pervasive in the highly fractured and dry crust and uppermost mantle [14-16], and intrinsic attenuation is large in the deep interior [17]. At present, the total Q, layering in Q, and relative proportion of seismic scattering to intrinsic attenuation within Mars remains unconstrained.

Blind Test Results: As part of a blind test by the Mars Structure Service and Mars Quake Service in preparation for the InSight mission [18], a data base of synthetic seismograms simulating martian seismicity and internal structure models was created to test and benchmark methods for recovering internal structure [19, 20]. We have used these data to develop techniques for determination of the attenuation structure of Mars. Ultimately these approaches will be used on InSight data and provide information on the relative contribution of intrinsic and extrinsic attenuation of the martian crust, mantle, and core.

Body Wave Attenuation: Our first approach for measuring total attenuation uses body waves that traverse the martian interior. By examining the relative spectral frequency content and energy fall off rate of body wave amplitudes, or t* [21], we can estimate the total Q of the martian interior. From the blind test events we obtain t* results for P, SV, SH, pP, PP, SSH, and ScS reverberations (Q=111-291). The amplitude decay of ScS and ScS reverberations also provide an overall estimate of Q [22]; ScS and ScSn multiples were observed in one blind test event, and indicate an overall Q of 117. The use of t* and other body wave methods are uncertain as they require knowledge of the source mechanism and radiation patterns to properly recover Q, although by examining relative S and SSH, as well as P, and PP measurements these uncertainties can be reduced.

Surface Wave Multipathing: Lateral variations in crustal thickness and seismic wave speeds in the crust cause surface waves to travel not necessarily along the great circle path and depending on the strength of the variations, even multiple paths between source and receiver may be possible (so called multi-pathing). The difference of apparent back azimuths estimated from body and surface waves as well as the (non-)existence of multi-pathing may provide constraints on the strength and length scales of lateral variations in the martian crust even for very few events.

Scattering: Scattering approaches to estimating extrinsic Q examine the decay and rise times of codas of energy following body waves such as P and S. Examination of the partitioning of energy between the horizontal and vertical components (H/V ratio) also informs on the strength of scattering. From the H/V ratios of the surface waves observed in our blind test event, we estimate Q=75 for Rayleigh wave energy partitioning. The blind test synthetic data are valid down to ~5 seconds dominant period, and did not contain deep 3-D structure, so scattering effects are unlikely to be present within the deeper sampling body waves of the dataset. However, such effects are likely to be observed at Mars and are investigated with local simulations that include martian topography and randomly generated perturbations to the crust and underlying mantle.

Expected SEIS Results: As the InSight seismometers record seismicity at Mars and the detection of marsquake locations become available, the techniques described above will be used to measure the attenuation and scattering properties of Mars. These parameters can then be used to infer the relative temperature, grain size, fluid content and abundance of fractures in the martian crust, mantle, and core.

References: [1] Aki, K. (1969) *Journal of Geophysical Research* 74, 615 10.1029/JB074i002p00615. [2] Dainty, A. M. *et al.* (1987) *Bulletin of the Seismological Society of America* 77, 1728. [3] Doornbos, D. J. *et al.* (1973) *Nature-Physical Science* 243, 58 10.1038/physci243058a0. [4] Korn, M. (1993) *Geophysical Journal International* 113, 54 10.1111/j.1365-246X.1993.tb02528.x. [5] Margerin, L. in *Book* (2005) Levander, A. *et al.*, Eds. vol. 157 pp. 229-252. [6] Wu, R. *et al.* (1985) *Geophysics* 50, 582 10.1190/1.1441934. [7] Shearer, P. M. (2009). Schubert, G. *et al.* Eds. pp. 695-729. [8] Anderson, D. L. *et al.* (1965) *Journal of Geophysical Research* 70, 1441 10.1029/JZ070i006p01441. [9] Faul, U. H. *et al.* (2005) *Earth and Planetary Science Letters* 234, 119 10.1016/j.epsl.2005.02.008. [10] Karato, S. *et al.* (1998) *Earth and Planetary Science Letters* 157, 193 10.1016/s0012-821x(98)00034-x. [11] Kuster, G. T. *et al.* (1974) *Geophysics* 39, 587 10.1190/1.1440450. [12] Muller, T. M. *et al.* (2010) *Geophysics* 75, A147 10.1190/1.3463417. [13] Winkler, K. W. *et al.* (1982) *Geophysics* 47, 1 10.1190/1.1441276. [14] Blanchette-Guertin, J. F. *et al.* (2012) *Journal of Geophysical Research-Planets* 117, 10.1029/2011je004042. [15] Dainty, A. M. *et al.* (1981) *Physics of the Earth and Planetary Interiors* 26, 250 10.1016/0031-9201(81)90029-7. [16] Gillet, K. *et al.* (2017) *Physics of the Earth and Planetary Interiors* 262, 28 10.1016/j.pepi.2016.11.001. [17] Nakamura, Y. (2005) *Journal of Geophysical Research-Planets* 110, 10.1029/2004je002332. [18] Clinton, J. F. *et al.* (2017) *Seismological Research Letters* 88, 1290 10.1785/0220170094. [19] Ceylan, S. *et al.* (2017) *Space Science Reviews* 211, 595 10.1007/s11214-017-0380-6. [20] Afanasiev, M. *et al.* (2019) *Geophysical Journal International* 216, 1675 10.1093/gji/ggy469. [21] Romanowicz, B. *et al.* (2009). Schubert, G. *et al.* Eds. pp. 731-774. [22] Revenaugh, J. *et al.* (1991) *Journal of Geophysical Research-Solid Earth* 96, 19763 10.1029/91jb01486.