Investigation of Mars Seismic Attenuation Using InSight SEIS Data. T. Kawamura[1], L. Margerin[2], M. Drilleau[1], S. Menina[1], P. Lognonné[1], S. Stähler[3], N. C. Schmerr[4], M. van Driel[3], and B. Banerdt[3], [1] Université de Paris, Institut de Physique du Globe de Paris,(35 rue Hélène Brion 75205 Paris CEDEX 13; kawamura@ipgp.fr), [2]Institut de Recherches en Astrophysique et Planétologie, [3]ETH Zurich, [4]University of Maryland, [5]Jet Propulsion Laboratory

Introduction: NASA InSight (the Interior Exploration using Geodesy and Heat Transport) has placed the first broadband seismometer (SEIS) on the Martian surface and now continuously monitoring Martian seismic activity [1,2]. Since the first detection of a marsquake in March 2019, SEIS detected more than 200 marsquakes and Mars has been revealed to be a seismically active planet [3]. The dataset can now be used to perform the seismic investigation of the Mars interior and interpret this in a comparative manner by referring to the examples from the Earth and the Moon.

In this study, we investigate the seismic attenuation on Mars and compare this with the Earth and the Moon. Attenuation can be described as a combination of inelastic absorption and elastic diffusion of energy. Such properties will give important constraints on the composition of the Mars interior and also its thermal state. Another interesting aspect will be to discuss the water content with respect to the attenuation. Given the large variety of water content for the Earth, the Moon and Mars, the attenuation feature will be likely to differ significantly between these planets and satellite. Here we use the seismic dataset obtained by InSight SEIS and construct a 1D structure of seismic attenuation on Mars. Then we refer to the values obtained for the Earth and the Moon to discuss the possible implication on their differences and similarities.

Method: We used spectral analyses to estimate the seismic attenuation on Mars (Figure 1). Attenuation will be expressed using a quality factor *Q*. We used a simple model where we express seismic spectra as follows(e.g. [4]).

$$A(\omega) = \frac{\Omega_0}{\left(1+\left(\omega/\omega_c\right)^2\right)^{1/2}} exp\left(-\frac{\omega t}{2Q}\right)$$

The first component of the model represents the contribution from the seismic source. Ω_0 is the DC level of the spectra which is proportional with the seismic moment. ω_c is the corner frequency. The second component represent the attenuation which included the quality factor *Q* and propagation time of the studied seismic phase *t*. Note that here, *Q* represent the combined effect from absorption and diffusion and we should regard this as an effective or apparent *Q*. It is widely known that Q will vary with frequency. Thus, we used a model where Q is constant up to a certain frequency (typically, we used 1 Hz) and then varies with frequency as $Q \propto f^{\alpha}$. With the model, we take the seismic catalog [3, 5-6] and for each event, we fitted the model described to search for a 1D Q structure that best describes the observed events. This will require *a priori* velocity model and source locations and we referred to a list of prelaunch Martian models [7] for the velocity model and the catalog provided by Marsquake Service (MQS) for the location. We use Markov Chain Monte-Carlo method to invert for the model. ω_c and Ω_0 for each event and a 1D *Q* model simultaneously to search for the best sets of parameters.

Results: The data set we have enables us to probe Mars down to about 1000-1200 km depth depending on the velocity model we choose. For the preliminary investigation, we chose a small dataset described in Giardini et al. [3]. Inversions were performed in different configurations; (a) Only with 4 best S/N ratio events. Q_P and Q_S independent, (b) Only with 4 best S/N ratio events. Q_P / Q_S fixed to 9/4, (c) 8 events. Q_P and Q_S independent, (d) 8 events. Q_P / Q_S fixed to 9/4, which is the value obtained Poisson elastic material with $V_P/V_S = \sqrt{3}$. In all cases, the best constraints were obtained at about 100-200km depth which correspond to lower crust to upper mantle. In this region, we obtain ~300 and ~1000 for Q_P and Q_S respectively, when they are inverted independently, Interestingly, we found Q_S lower than Q_P which not expected for typical elastic materials. Fixing the Q_P / Q_S gives Q_P ~1350 and Q_S~600. When we focus on the depth distribution of the quality factor, the cases (a) and (b) only constrained *Q* down to about 150 km depth, while (c) and (d) proved down to about 1200 km. On the other hand, results were consistent after we added more events will lower S/N ratio. Q_P shows a slight variation with depth where its first decrease with depth until 100-200 km and then increase again reaching 500 at 400 km depth. However, this might be due to the loss of resolution due to the small dataset and thus needs to be confirmed with future more complete investigation. Unlike Q_P, Q_S is almost constant with depth and always falls around 1000. When Q_P / Q_S is fixed, we found less variation with depth also for Q_P and both Q_P and Q_S stays almost constant.

Implication and Future Work: While our results are preliminary with a relatively small number of events, they have some important implication with respect to what we learned on the Moon. The values we found are significantly smaller compared to *Q* values found on the Moon [7]. The Moon is known to be in very high *Q* (3000-8000), thus low attenuation, condition which was attributed to the dry condition with lack of fluid. All the

Q values we found are significantly lower than this and imply stronger attenuation on Mars than on the Moon. We speculate that Mars, which has strong evidence for the past existence of water at the surface, shows lower seismic *Q*, even at 100-200 km depth. On the other hand, this interpretation may be premature until the variation of attenuation with depth needs is further investigated with more seismic events. Given the discussion in the previous investigations [2,3], it is possible that we find higher *Q* values for different depths.

Our first attempt to constrain the attenuation characteristics already showed interesting difference from what was learned from the Moon. To fully quantify the attenuation of Mars we will require a more expansive catalog of seismic events. So far InSight has detected more than 200 seismic events and continues to grow [3,6]. Notably we need to add smaller and local events that should give us further constraints on the shallower region to study more the depth variation of the quality factor.

References: [1] Banerdt et al., Nat. Geosci., under review [2]. Lognonné et al., Nat. Geosci., under review. [3] Giardini et al., Nat. Geosci., under review. [4] Aki and Richards (2002), Quantitative seismology (2 ed.). University Science Books. [5] InSight SEIS Data. https://doi.org/10.18715/SEIS.INSIGHT.XB_2016 [6] Marsquake Event Catalog. http://doi.org/10.12686/a6. [7] Nakamura and Koyama (1972), J. Geophy. Res., 87, B6, 4855-4861.

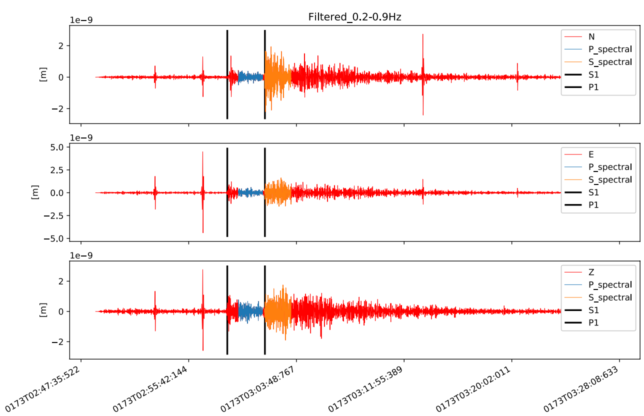

Figure 1. Example of seismic events used in the study of martian attenuation. The 3 components data from Very Broradband seismometer (VBB) of InSight is presented. The event is one of the best quality events we observed so far (2019/05/23 02:22:48; S0173a).