Effect of variable scatterer length-scales and frequency dependent attenuation on the decay of lunar seismic coda. Jean-Francois Blanchette-Guertin[1], Catherine L. Johnson[1,2], Jesse F. Lawrence[3]. [1]University of British Columbia (2020-2207 Main Mall, Vancouver, BC V6T1Z4, CANADA; jguertin@eos.ubc.ca), [2]Planetary Science Institute (1700 Fort Lowell, Suite 106, Tucson, AZ 85719), [3]Stanford University (397 Panama Mall, Mitchell Building, Room 360, Stanford, CA 94306).

Overview: We present coda decay times from synthetic lunar seismic events made using various scattering models of the lunar interior. The synthetics' coda decay times are compared to those of seismic events from the Apollo Passive Seismic Experiment dataset [1]. The main objectives of this project are to identify a suite of lunar interior models that reproduce the APSE data characteristics, as well as to investigate the effects of various scattering and attenuation structures on the propagation of seismic energy in the Moon.

The Modified Phonon Method: The phonon method [2] tracks a large number of seismic packets as they travel within the Moon. At each of the model velocity interfaces (e.g. core-mantle boundary), the probability that a phonon is reflected or transmitted, with or without phase conversion, depends on the reflection and transmission coefficients. If the phonon is within a region where the scattering probability (p_{sc}) is set to be greater than 0, the phonon encounters a randomly oriented scatterer every δ_{sc} m, where δ_{sc} is randomly sampled from a power-law distribution (Fig. 1A). The phonon will be scattered, or not, based on the scattering probability and the velocity and density perturbations associated with the scatterer. These perturbations are given by $dv = rv_{per}$ and $d\rho = r\rho_{per}$, where r is a random number between 0 and 1 drawn from a uniform distribution, and v_{per} and ρ_{per} are arbitrary values between 0 and 100% of the velocities and density of the layer is which the phonon is travelling. The model has been improved from [3] by implementing isotropic scattering, power-law distributions of scatterer length-scales, frequency dependent intrinsic attenuation, as well as background scattering (low levels within the entire Moon).

We calculate seismograms for four different scattering models of the Moon and two different source depths (20 and 1100 km), all using a modified version of the velocity and density profiles from [4] (with solid core and without the surface low-velocity layer). We calculate synthetics at two sampling frequencies (7 and 40 Hz), corresponding to the long-period (LP) and short-period (SP) APSE data. We also simulate the APSE instrument effect (signal degradation caused by limited analog-to-digital resolution with noise (~1-3 digital units).

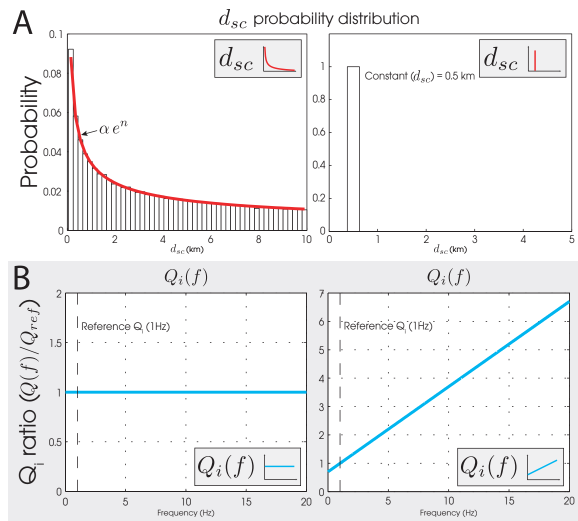

Figure 1: The scattering models use one of the scatterer length-scale probability distributions in A, and one of $Q_i(f)$ in B.

Synthetic and APSE data analysis steps: Each of the synthetic and APSE seismograms was processed as follows [1]:

1. Deconvolve the APSE instrument response
2. Bandpass filter the signals into three LP bands and four SP bands: 0.25-0.75 Hz, 0.75-1.25 Hz, 1.25-1.75 Hz, 2-4 Hz, 4-6 Hz, 6-8 Hz and 8-10 Hz.
3. Generate the signal envelope.
4. Average the envelopes for the horizontal channels (assumes horizontal isotropy). Smooth the envelope function using a 5 minute (LP) or 35 second (SP) running window, keeping the 75th percentile (empirically determined).
5. Determine visually where the amplitude starts decaying exponentially (the beginning of the fit).
6. Determine the time at which the amplitude is twice the background noise. This determines the end of the fit.
7. Least-squares fit an exponential decay curve of the form e^{-t/τ_d} to the decaying section of the smoothed envelope. τ_d is the characteristic decay time.
8. Convert τ_d to the frequency-specific decay factor $Q_c = \pi f_c \tau_d$, where f_c is the central frequency of the frequency band analyzed.

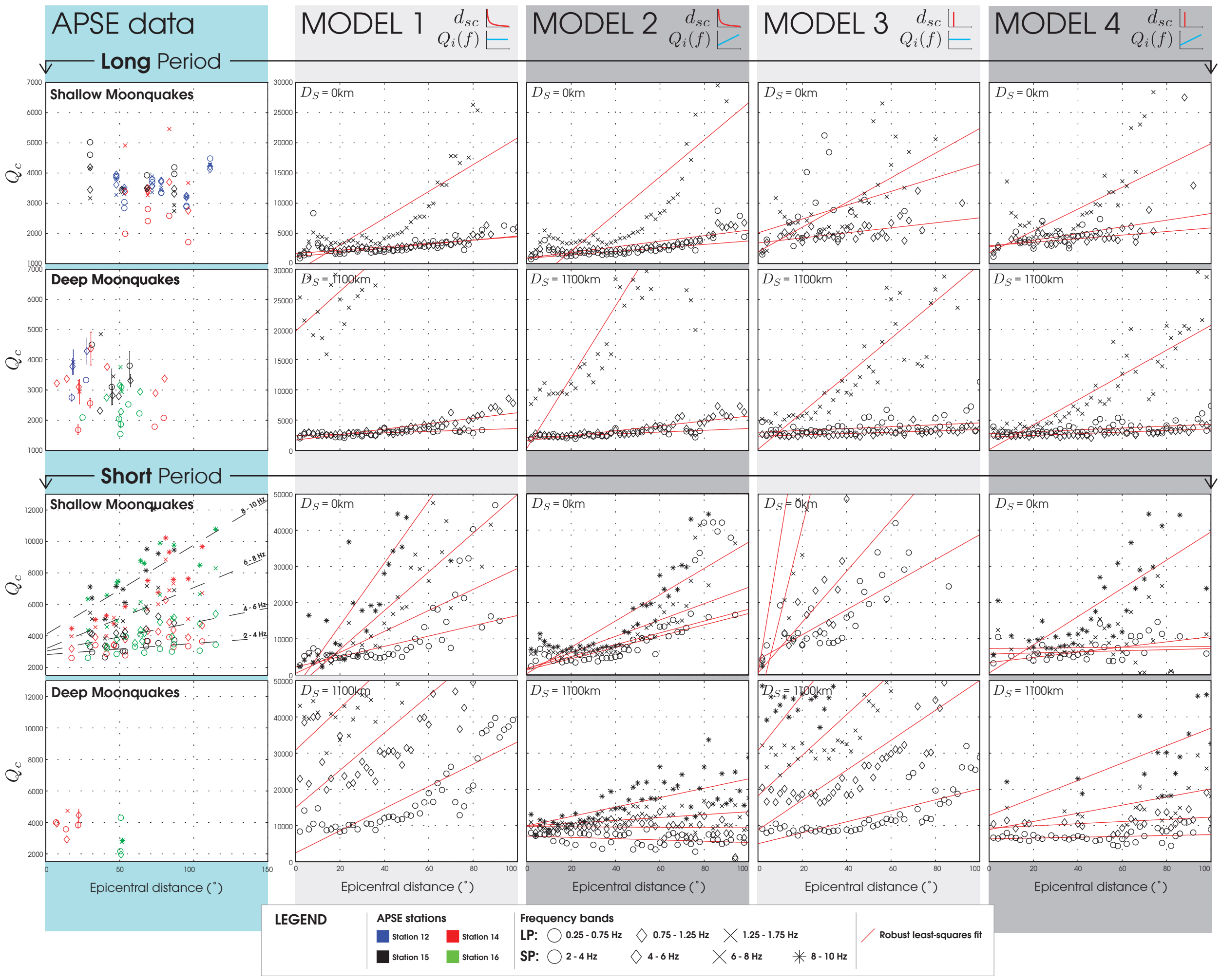

Figure 2: APSE results (left) for shallow and deep moonquakes, and synthetic results from 4 models with either a power-law derived or constant d_{sc}, and a constant or frequency-dependent Q_i.

Results from Synthetics:

• Q_c is nearly constant over the range of epicentral distances covered by the APSE data (0-100°) in the long-period frequency bands (seen in the APSE data). A weak increase of Qc with distance, as observed in the synthetics, might not be observable in the APSE data due to noise.

• There is no dependence of Q_c on frequency in the 0.25-1.25 Hz band (seen in APSE data). Q_c values are larger for the 1.25-1.75 Hz band for Models 1 & 2 (not seen in the APSE data) suggesting that the frequency-size distribution of scatterer length-scales in our models needs adjusting to have relatively fewer scatterers with scale lengths corresponding to the 1.25-1.75Hz band.

• Q_c is dependent on epicentral distance in the short-period frequency bands (seen in APSE data).

• For short periods, all models show a clear increase of Q_c with distance. Models with a constant $Q_i(f)$ show that Q_c also markedly increases with frequency as for the APSE data.

• At higher frequencies, the deep event Q_c values are overall larger than the shallow event Q_c values (not seen in the available APSE data).

• Q_c values from our synthetics overall are larger than seen in the APSE data, possibly reflecting too much scattering in the models.

• Internal reflections in a thin low velocity layer at the surface (not shown here) may reduce the amount of scattering required to reach APSE values. The generation of coda waves in this low velocity layer, combined with the effects of scattering, will be part of future investigations.

References: [1] Blanchette-Guertin, J.-F. et al. (2012), *JGR*, doi: 10.1029/2011JE004042. [2] Shearer, P. and P. Earle (2004) *Geophys. J. Int.*, 158, 1103-1117.
[3] Blanchette-Guertin, J.-F. et al. (2012), *LPSC 43*, #1473.
[4] Garcia, R.F. et al. (2011), *PEPI*, doi: 10.1016/j.pepi.2011.06.015