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Taking the pulse of Mars using the InSight VBB seismometer

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Mars has a pulse; the Sun and the Martian moons, Phobos and Deimos all raise tides that cause periodic variations in the planet's shape and gravity field. The amplitude and phase of this tidal response provide information about the interior structure of Mars, notably on the state and size of its core. One goal of the InSight mission is therefore to use the VBB seismometer as a gravimeter to measure Mars's response to tides raised by Phobos.

Because Phobos is so close to Mars, degree-2, -3 -4 and further tides are all present and will be sensitive to the elastic properties of different depth ranges within Mars. A measurement by InSight of the tidal acceleration allows the gravimetric factors δ_l to be derived. For Mars models with and without a liquid core, in order to distinguish between likely models, δ_l will need to be measured with an uncertainty of 1% or better. The effect on Q_l of the core state is different to that of varying the mantle temperature; a measurement of Q_3 and/or Q_4 to a precision of about 10% would allow these two effects to be disentangled.

The two most important noise sources are thermal noise (temperature-induced changes in geometric properties of the VBB) and pressure noise (deformation of the Martian surface due to the pressure). At diurnal frequencies, the expected contributions are 8x10^{-4} and 4x10^{-6} ms^{-2}, compared with the full tidal signal of 6x10^{-9} ms^{-2} and with the VBB temperature sensitivity. Using matched filtering and data stacking, end-to-end simulations show that in the worst-case scenario the error is less than 2.5% after two Martian years, and in the nominal case, the error is less than 0.1%.

To link the measured gravity variations with δ_l, knowledge of the absolute gain of SEIS is required. To do so, an absolute calibration will be done in-situ, for the first time on Mars, by altering the tilt of the SEIS assembly using leveling actuators. The modeled error on the VBB gain is 0.4% with respect to Earth reference instruments, plus errors on the ephemerides of Phobos (around 0.5%), and errors on the terrestrial VBB transfer function.

To avoid the need for an active calibration, an alternative method is to determine δ_l or Q_l at two different degrees and taking the ratio (e.g. δ_4/δ_2). Since these both depend in the same way on the VBB gain, the ratio of measurement is independent of gain uncertainty and Phobos mass and reduces errors from Phobos ephemerides.

Using *a priori* models, it is expected for the nominal duration of InSight to constrain the state of the core and its size using the Phobos tides better than $\pm$ 120 km.