Using the Mars background SEIS seismic noise for inverting landing site, crust and upper mantle seismic structure.

The InSight mission landed on Mars on November, 26th, 2018 and deployed successfully the SEIS experiment, a 6 axis seismometer composed with a three axis Very Broad Band sensor and a three axis Short Period instrument. SEIS (Lognonné et al., 2019) is managed by CNES and is scientifically lead by IPGP, which is also responsible for the SEIS data distribution and archiving, in addition to the inversion of the Mars Internal structure. Its core instrument is an ultra-sensitive 3 axis Very Band Seismometer.

As observed in the early times of seismology by Bertelli (Bertelli, 1872), the Earth's surface is permanently oscillating due to microseismic, non-coherent Rayleigh surface waves between 3 and 10sec which were first explained by Longuet-Higgins (1950). One century after Bertelli, the Apollo seismometer did not recorded any natural microseism on the Moon, as the later, possibly related to continuous micro-impacts, might be several order of magnitude below the Apollo resolution (Lognonné et al., 1998). 50 years after Apollo, InSight is monitoring seismically the third terrestrial planetary body of the history of seismology, and is getting continous record of a background seismic noise, which is depending on both the local time, wind strength and has climatic variations.

More than 300 of seismic events have been sofar detected by SEIS and are extensively analyzed by the SEIS team. Most are high frequencies events, likely propagating in the upper crust. No large quakes enabling surface waves detection has been to date performed. But after more than one year, we will also get more and more continuous data, enabling to stack the continuous signals in order to detect in this noise small amplitude but coherent seismic waves stochastically excited by the atmosphere. This could include surface waves.

In contrary to Earth, where most of the microseisms are related to the non-linear interaction of oceanic waves with the sea floor and with coast lines, the micro-seismic noise of Mars in only related to the coupling of the atmosphere with the Martian surface. The noise detected by the VBBs is however not so easy to understand and is likely a mixture of noise. One part is local noise, associated to the interaction of the lander with the wind, leading the lander to generate forces on the ground detected by SEIS. A second, but weaker part is micro-seismic noise, a likely superimposition of Rayleigh waves and acoustic waves. In both cases, the sources are likely acoustic emissions related to the local and remote turbulences (e.g. Posmentier, 1976 and Cuxart et al., 2016 for Earth observation) which are then converted into Rayleigh waves and are guided in the low velocity subsurface layers.

The first goal of the PhD will be to separate, by using both the SEIS and APSS data, the lander noise from the planet background seismic noise. This will request to process the complete collection of continuous data, as functions of wind direction and local time, in order to separate noise related to local origin from noise related to global or regional origin. Such analysis has already been able to show coherencies between VBB axis as well as a possible transfer function, but need to be improved with the wind direction and amplitudes. This process will not be key for searching for micro-seismic noise, but also for improving the signal to noise ratio of all detected events, which will allow significant contribution to ongoing structural analysis made with the recorded quakes. The second goal of this project will be to couple observations, analysis and modeling of the SEIS data together with observation, analysis and modeling of the APSS (Banfield et al., 2019) data in order to constrain and model the source of the Rayleigh and acoustic waves. Although associated to the shear wind in the atmosphere, the altitude of the sources and their local or remote location with respect to the InSight station is obviously still unknown after only a few weeks of observation. The expected nominal mission duration will furthermore allow a systematic monitoring of these microseism, in order to quantify their daily evolution with respect to local mean solar time and their yearly evolution with season. We expect to provide unique constrain on the activity of the Planetary Boundary layer through the seismic monitoring of the Martian microseism, in way similar to what has been done recently on Earth for the tracking of cyclones (e.g. Davy et al., 2014, 2015) and with an approach complementing the analysis to be made with the more classical pressure, temperature and wind sensors of InSight (Spiga et al., 2018). From these temporal models of high frequency pressure and Reynold stresses fields we will then will model both the generated micro-seismic noise, the acoustic infra-sound noise and will compare it to observation in order to quantify the source and the amplitude of shear stresses associated to the acoustic emission.

The last goal of the PhD will be to constrain, with these seismic waves generated by the atmosphere, the subsurface and possibly the crustal and lithospheric structure of the planet, independently of quakes and impacts. Our early predictions already suggested that a variety of signals from the atmosphere expected to be detected by the InSight seismometer, were potential source for internal sounding, from the static loading of pressure variations associated to dust devils (Kenda et al. 2017) to Planetary boundary layer turbulence (Murdoch et al. 2017) and global hum (Niskikawa et al. 2019). The microseism, through autocorrelation of the seismic signals, will provide additional constraints on the landing site upper crustal structure (e.g. Knapmeyer et al., 2019). At longer period, we will search, from a longer period stack, signature of global hum (Niskikawa et al. 2019), which might provide key constrains on the lithospheric structures.

These upper crust and lithosphere imaging will complete the deeper structure imaging, expected to be performed from quakes and impacts, as detailed by Panning et al. (2017) and Daubard et al. (2018) respectively and will provide the first seismic imaging of the landing site of a Mars mission. Deeper, they will complete the tidal analysis.

Candidate shall have a Master of Earth or Planetary Science or Master of Physics. Expertise in seismology and data processing will be very much welcome. The PhD, to be supervised by Pr. Philippe Lognonné, SEIS Instrument Principal Investigator (lognonne@ipgp.fr), will be made in the Planetary and Space Science team of IPGP, in close collaboration with the Seismological Laboratory of IPGP (Pr. E.Stutzmann). Collaboration with other InSight related teams is very likely. The Thesis will be a joint Thesis between CNES and ED STEP'UP, Université de Paris and will require application to both CNES (prior March 30th) and STEP'UP