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Inversion of Mars' structure using geodynamic constraints

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With the recent successful landing and the ongoing deployment of its instruments, the InSight mission will soon provide the first series of Martian seismic recordings. Such data will allow the present-day deep structure of the planet to be revealed. While inverse methods are powerful tools to achieve this goal, they are prone to two main limitations: the large size of the parameter space to be explored, and the non-uniqueness of the solution. This is particularly true for spatially uneven and relatively small amounts of seismic recordings, as in the case of InSight, which consists of a single station, and a precious, but limited amount of expected Marsquakes.
To better constrain the interior of Mars using the upcoming InSight recordings, we have developed a Monte-Carlo Markov-Chain inversion of seismic data, where the modeling of Mars' thermochemical history is part of the forward problem. Such a modeling accounts for the main Martian envelopes: an essentially metallic core surrounded by a convective silicate envelope, overlaid by a stagnant lithospheric lid. The latter includes a crust enriched in time-decaying, heat-producing radioactive elements. This thermo-chemical frame is integrated via a parametrized approach, allowing the long-term planetary evolution to be accurately modeled at a reasonable computational cost.

Consequently, instead of varying independently seismological parameters along the inversion process (crustal thickness, core size, seismic velocities, etc.), our built-in geodynamic frame significantly reduces the parameter space, by self-consistently accounting for the interdependencies between various quantities: temperature, composition, rheology, and their influences on crustal thickness.
Further constraints on these different physical parameters will come from recent measurements directly performed under Mars' interior P-T conditions. The resulting output parameters from the thermo-chemical modeling yield the seismic structure required for the inversion process.
Our approach can also constrain the value of physical quantities inaccessible to direct measurements, such as the rheology of the Martian mantle. Finally, our method naturally yields the entire thermo-chemical history of Mars associated with each model.
Our implementation has been benchmarked against analytical and numerical solutions in spherical geometry, and we successfully tested our inversion approach against synthetic data.

We will present the details of our inversion method, together with its performances using synthetic data. Finally, we will apply our approach to the data that InSight instruments are expected to collect, in order to constrain the current state of Mars' interior, and to infer its long-term evolution.