

Comparative planetary seismology across the telluric planets

Supervisor: Dr Jessica Irving (School of Earth Sciences)

Project Enquiries: jessica.irving@bristol.ac.uk

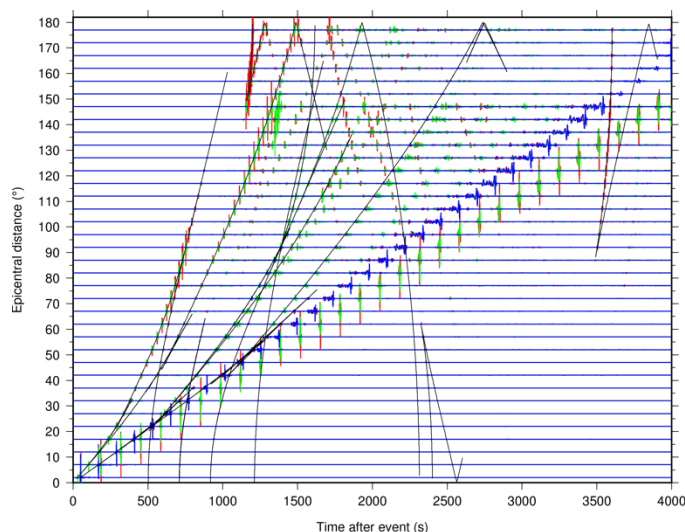


Fig 1: Waveforms simulated for a hypothetical venusquake. Venus is assumed to be compositionally like the Earth but hotter (Unterborn *et al*, 2018). Three colours correspond to different components of motion, body wave arrivals are indicated by black lines.

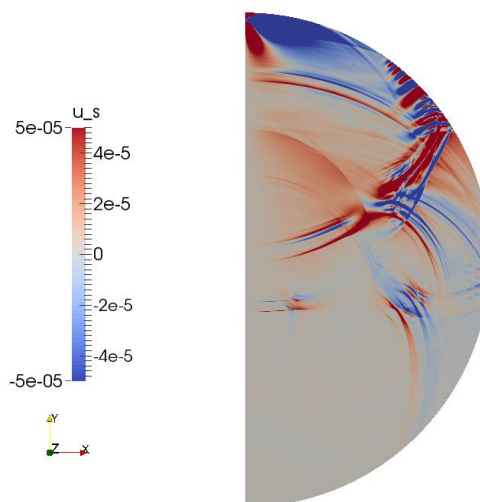


Fig 2: Wave propagation through a model of Mars' interior. Both the Venus and Mars simulations were carried out in AxiSEM (Nissen-Meyer *et al*, 2014).

Project Background

With the successful completion of the InSight geophysical mission on Mars (e.g., Banerdt *et al* 2020) and plans to put new geophysical equipment on the Moon, we have entered a new era of planetary seismology. We have models informed by seismic data describing the layered structures of Earth, the Moon, and Mars (e.g., for Mars' core, see Irving *et al*, 2023). Nonetheless, there is a great deal of uncertainty regarding both the internal structures of the telluric, or rocky, planets in our solar system and the seismic probes which might best illuminate these bodies. Good models exist for some planetary interiors, but other planets and moons remain poorly modelled. However, a wealth of new tools are now available to understand both instrumented and un-explored planetary interiors. This project will apply Earth-tested seismological modelling to existing models of planetary interiors to understand what information we can glean from existing data and deployments, as well as making predictions on what might be possible elsewhere in our solar system.

Project Aims and Methods

There is a strong interest in planetary interiors at the University of Bristol. This seismological project will focus on investigating seismic data from Mars, the Moon, and Earth, and simulating data on a range of different planets. The target planets will depend on the interests of the student; they are likely to include Venus and Mercury as well as those planets from which we have seismological data. Questions the project could seek to answer include:

- How would Mercury/Venus look to a seismologist?
- Could floating seismometers with sensitivity like those deployed in Earth's oceans help us understand the deep interior of Venus? (These floating seismometers are called MERMAIDs, see Hello *et al*, 2011 and Simon *et al*, 2021 for details.)

- Which seismic phases are particularly sensitive to the properties of non-terrestrial planetary cores?
- What are the similarities and differences between seismic observables for different viable models of telluric planets? Are there some observations which are always useful?

To answer these, and similar, questions a range of different tools will be used. Beyond ray-theoretical predictions of seismic waves travelling through planets, it is now possible to simulate the full wavefield generated by a seismic event, whether through a spherically symmetric model, or a more complex planet. Mineral physics has provided new data and Equations of State which can be incorporated into the modelling of planetary interiors using appropriate software (e.g., Cottaar *et al* 2014); this approach has been successfully used for Mars.

The project will involve assessing seismic waveform data. Available data includes seismograms from the Apollo missions, signals detected by the InSight mission's broadband seismic sensor, and seismic data from the Earth which can be used for benchmarking where needed. Modelling planetary interiors based on reasonable putative planetary compositions may be important depending on the direction this project takes.

Candidate

The successful applicant should have a background in Earth Sciences, Physics, or a related physical science, preferably to MSc/MSci level. A strong interest in Earth or planetary sciences is essential, as is some experience of computational work or coding in any language. We welcome and encourage student applications from under-represented groups. We value a diverse research environment.

Training

The project will be based around working with existing seismic data and simulating seismic waveforms. Modelling planetary interiors is likely to also be part of this project, depending on the interests of the student. Training in all the software and techniques needed to conduct this research will be provided to the student. The student will be encouraged to attend local and international workshops where appropriate to gain additional skills. The student will be expected to present results at national and international conferences and to publish findings in international journals. This will require strong communication and written skills.

References / Reading List

Please contact Dr Irving if you need access to a copy of any paper listed below.

- Banerdt et al., 2020. Initial results from the InSight mission on Mars. *Nature Geosci.*, 13:183–189
- Cottaar et al, 2014. BurnMan: A lower mantle mineral physics toolkit. *Geochem. Geophys. Geosyst.*, 15:1164–1179
- Dapr , & Irving, 2024. Global seismology in the interior of Enceladus. *Icarus*, 408, 115806.
- Leng et al., 2019. AxiSEM3D: broad-band seismic wavefields in 3-D global Earth models with undulating discontinuities. *Geophys. J. Int.*, 217:2125-2146
- Nissen-Meyer et al, 2014. AxiSEM: broadband 3-D seismic wavefields in axisymmetric media. *Solid Earth*, 5:425–445
- Hello et al., 2011. Modern MERMAIDs: New floats image the deep Earth. *Eos*, 92, 337-338
- Simon, Simons & Irving, 2021. A MERMAID miscellany: Seismoacoustic signals beyond the P wave. *Seismol. Res. Lett.*, 92(6):3657-3667
- Irving et al., 2023. First observations of core-transiting seismic phases on Mars. *Proc. Natl. Acad. Sci.*, 120(18), e2217090120
- Unterborn, Schmerr & Irving. The Devil in the Dark: A Fully Self-Consistent Internal Seismic Model for Venus. *Lunar Planet. Sci. XLIX*, 1768, 2018

Eligibility: It is possible to award non-UK residents with an STFC PhD training grant, but special conditions apply and a fee waiver by the University is required which is by no means not guaranteed.

Application deadline: 14.00 GMT, 12th February 2025

Apply to the University of Bristol: <http://www.bristol.ac.uk/study/postgraduate/apply/>.

Please select PhD in Geology as the programme in the online application system.