Applying petroleum geophysics to astrophysics:
Quantitative 4D seismic study of the solar interior

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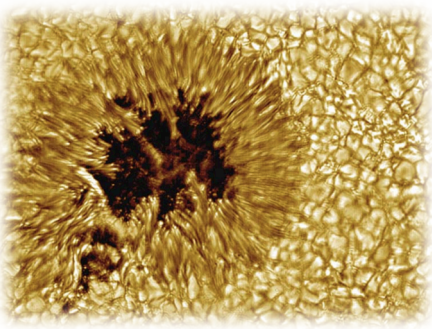
Although modern seismic methods for studying the subsurface have been around for several decades, we have witnessed some exciting breakthroughs in seismic imaging in the past few years. Data from ground-based telescopes and satellite solar observatory have provided us with unprecedented information about the flow structures beneath the visible solar surface. These results have drastically improved our understanding of the inner workings and evolution of our star, making it possible to assess and revise previous theoretical models of the Sun through empirical results.

Local helioseismology, a branch of seismology applied to studying the Sun, is to a significant extent based on tomographic methods developed in geophysics. The proposed project builds on this interdisciplinary approach and will involve the application of another new branch of seismology recently developed in petroleum reservoir monitoring. Quantitative time-lapse seismic (QTLS), as this branch of applied seismology is commonly known in the petroleum industry, differs from earlier approaches adopted in 4D seismology. The main difference lies in the fact that quantitative information is extracted and calculated from the models in QTLS, rather than simply relying on visual comparisons of seismic snapshots taken at different times.

The student working on this research project will apply and develop new methods based on QTLS for linking the structural and dynamic parameters of the plasma to the evolution of the solar interior. The project will then involve analyzing helioseismic data collected by NASA's Solar Dynamics Observatory. The expected research outcome of the project will therefore comprise new quantitative time-lapse tomographic methods applied to helioseismology as well as new models of the solar interior.



Left: Close-up picture of a sunspot (credits: Vacuum Tower Telescope, NSO, NOAO)
Right: Terrestrial seismology has provided the foundation for the study of the solar interior. Quantitative time-lapse seismic methods developed in petroleum geophysics offer the next-generation interdisciplinary approach for monitoring the solar interior.

The student embarking on this highly interdisciplinary project will have a background in geophysics or physics. Previous experience in computer-based projects or programming is useful but not essential. The student will spend time working on the research project in Italy. The interdisciplinary research training will be directly relevant to an academic career in Earth Sciences and/or Astronomy as well as a career in the petroleum industry.

References

Tong, C. H., Imaging sunspots using seismic methods, *Philosophical Transactions of the Royal Society: Mathematical, Physical and Engineering Sciences* (2005), 363, 2761-2775.

Cobden, L. J., C. H. Tong and M. R. Warner, Inversion of full acoustic wavefield in local helioseismology: A study with synthetic data, *Astrophysical Journal* (2011), 727, 68-72.