Broad-Band Time-Reversal Seismology

Supervisors: Lapo Boschi (Università di Padova),
Irene Molinari (INGV Bologna), Piero Poli (Università di Grenoble, Francia)

Efforts to image seismic rupture in space and time could provide a fundamental contribution to research in earthquake physics, but are hindered by the difficulty of determining a unique image from available data. Recent research shows that least-squares inversions of seismic and/or geodetic data lead to very non-unique, and thus unreliable solutions (Mai et al., 2016). The main alternative to least-squares inversion is currently the back-projection method, which however involves some fundamental simplifications that limit its effectiveness (e.g., Fukahata et al.2014). With this PhD thesis, we shall implement and validate an innovative method to map slip on a seismic fault, based on the concept of acoustic/seismic time reversal (e.g., Boschi et al., 2018), which does not suffer from the above limitations.

The proposed method is designed to specifically take advantage of broadband (period from ~10 to 200s) surface-wave data. Surface waves have not been adequately exploited in rupture-imaging efforts so far. The wealth of currently under-utilised data that we will thus be able to employ is such that a breakthrough in the accuracy and resolution of seismic-source imaging can reasonably be expected. Both Love and Rayleigh waveform information will be used to constrain kinematic parameters describing the rupture. This will complement existing slip inversion methods, the majority of which are based on high frequency (~1Hz) seismic observations (body waves) or almost zero-frequency geodetic observations (GPS, Insar) but cannot benefit from the great wealth of information carried by surface-wave frequencies. Applications of our method will be aimed at large and very-large earthquakes, with faults significantly larger than typical Love and Rayleigh wavelengths.

A feasibility test of the proposed method has already been successfully carried out by members of our team (Boschi et al., 2018). The selected PhD candidate will build on this preliminary work. Initially (months 1-12), existing software will be expanded, to generalise to three dimensions the two-dimensional maps of slip obtained by the algorithm of Boschi et al. (2018). This effort will result in a first, international peer-reviewed publication. Next (months 13-20), the problem of translating the time-reversed displacement field to actual slip on a fault will be addressed via kinematic and dynamic inversions. Finally (months 21-32), our method will be applied to the study of seismic events that are usually not classified as earthquakes, i.e. so-called “slow-slip phenomena”. In particular, our surface-wave (and thus low-frequency) method should be particularly well suited to identify "very-low-frequency earthquakes" (e.g., Beroza and Ide, 2012), and the controversial slow-slip precursors first proposed by Ihmlé and Jordan (1994). In all these endeavours, data from the AlpArray project, of which the INGV is a contributor, will be employed together with publicly available global databases. Months 33-36 will be devoted to the redaction of the candidate's doctoral dissertation.

- Beroza, G. C., and S. Ide (2011). Slow earthquakes and nonvolcanic tremor. http://dx.doi.org/10.1146/annurev-earth-040809-152531.
- Boschi, L., I. Molinari, and M. Reinwald (2018). A simple method for earthquake location by surface-wave time-reversal. Geophys. J. Int., 215, 1--21, doi:10.1093/gji/ggy261.

- Fukahata, Y., et al. (2014). Theoretical relationship between back-projection imaging and classical linear inverse solutions, Geophys. J. Int., 196, 552—559.
- Ihmlé, P. F., and T. H. Jordan (1994). Search for Slow Precursors to Large Earthquakes, Science, 266, 1547—1551.
- Mai, M., et al. (2016). The Earthquake-Source Inversion Validation (SIV) Project, Seism. Res. Lett., 87, 690—708.