Subject offered for a contract starting October 2016

SUBJECT TITTLE: Reconstruction of the earthquake rupture process through coherent teleseismic imaging and statistical modeling

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Financing: Doctoral contract without teaching assignment

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In the last two decades, the steady densification of seismological networks has dramatically improved our capability of investigating the details of the earthquake rupture, integrating classical modeling of seismic slip with new "antenna" approaches that track high-frequency radiation (above 1 Hz) emitted by the seismic rupture and coherently recorded at teleseismic distance.

The study of many large earthquakes in recent years (e.g., Satriano et al. 2014; Grandin et al., 2015; Vallée and Satriano, 2014 –see the figure) has demonstrated that, when looking at the rupture process from its high-frequency (HF) radiation, higher complexity emerges. In particular, HF radiation is not directly associated with large fault slip but rather occurs at the border of the large slip areas, possibly within zones of abrupt changes of rupture velocity or slip rate. These discontinuities can be, in turn, associated with fault segmentation and spatial heterogeneities of frictional properties, fracture energy or stress drop, as expected from theoretical studies (e.g., Spudich and Frazer, 1984; Gabriel et al., 2013).

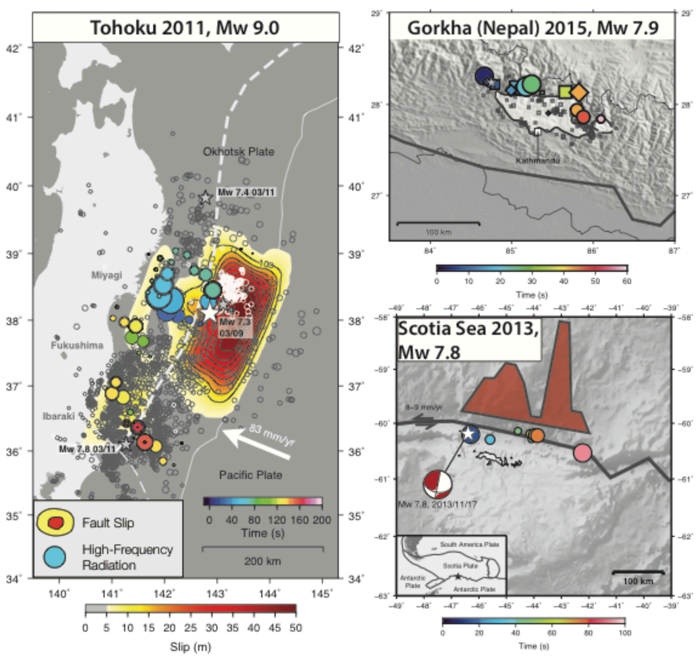

Figure: Fault slip vs. high-frequency radiation for three recent earthquakes. HF sources are indicated by circles. Fault slip area is in color (Tohoku) or in gray (Gorkha). For Scotia Sea, a fault slip profile is shown in red.

An important issue is however whether the current imaging methods are able to accurately reconstruct the rupture process on the fault or whether they are rather sensitive to specific areas, depending on the resolution and on the relative position of the receiver array with respect to the source. It is today crucial to

assess the actual resolving power of coherent imaging methods and the hypothesis behind those approaches.
A second issue is to understand what the coherent images of the earthquake rupture can tell us on the rupture mechanism. Can we discriminate between rupture velocity and slip-rate variations? Can we interpret radiative sources in terms of localized frozen heterogeneities (e.g., friction, geometry) or dynamic heterogeneities (e.g., coseismic stress changes, fault segment interaction) on the fault?

The **objective** of this project is to address the above questions through the methodological development of the coherent imaging approaches and the construction of synthetic source models to assess their imaging power and to test the underlying physical hypotheses.

Coherent imaging techniques exploit the wave field coherence across a recording array of seismic stations at teleseismic distance. The entire network can be seen as an antenna able to track in space and time the strongest sources of seismic energy during the rupture propagation. These methods are inherently high-frequency (resolution degrades at lower frequencies) and make little or no assumption on the properties of the wave field (e.g., propagation effects) and on fault geometry and rupture kinematics. This, on one hand, makes the approaches very fast and easy to implement, but, on the other hand, makes it difficult to interpret the results in terms of actual kinematic or dynamic properties of the earthquake rupture.

In a **first part** of the project, the student will use simplified synthetic source models to carefully assess the different hypotheses, like, e.g., the importance of taking care of propagation effects or of the focal mechanism. The student will then investigate how to reconcile the different images of the same rupture process obtained by different seismic antennas. The final aim is to develop a new, more robust and consistent statistical framework for imaging the broadband earthquake source process.

A **second part** of the project will be focused on the development of more complex source models (e.g., stochastic kinematic source models, like the k^{-2} model of Ruiz et al., 2011), in order to assess the possibility of discriminating and correctly imaging several kinematic or geometric aspects of the rupture (e.g., rupture velocity, slip-rate, fault geometry) and characterizing, from a statistical point of view, the size and distribution of the slip heterogeneities and the scale dependence of their radiating behavior. We will also consider the possibility of using dynamic or hybrid models in order to investigate the effect of local or non-local interactions between rupture fronts and with the radiated wave field.

At the end of the project, we expect to accomplish the following **achievements**:

1. To develop a new, more robust and more consistent approach for imaging the spatio-temporal complexity of the earthquake rupture;
2. To build a new framework for interpreting the coherent source images in terms of the statistical variability of mechanical properties on the fault and fault geometry;
3. To explore the link between high-frequency emission and rupture dynamics.

This thesis subject will be developed in collaboration with Prof. Gaetano Festa (University of Naples, Italy).