Dipartimento di Scienze della Terra
Sapienza Università di Roma

Dottorato di Ricerca in Scienze della Terra

Davide Zaccagnino
PhD student, Earth Sciences, XXXVII cycle (11/2021-)
Curriculum: Geoscience;
Tutor & Advisor: Prof. Carlo Doglioni

In integrated approach to mid-term seismic prediction

1. Research activity

The brittle crust is an extremely complicated system because of the huge number of variables to consider, wild nonlinearity and strong correlations acting therein. Slight local changes in composition of the rock can have significant influences on where the stress builds up because of the non-self-averaging property of mechanical strength, causing earthquakes. Moreover, after each seismic event, a part of the "memory" of the system gets reshuffled, so the next one may be completely different even though the local stress distribution is the same. This is the reason why often there are foreshocks, which could happen hours, days, weeks or months before it and sometimes a large earthquake happens without any warning at all: no unique mechanism exists for nucleation because of the strongly chaotical and nonlocal behaviour of such a turbulent system. Thus, no universal precursors exist; moreover, nonlocality also implies that the full past of the system (wish we be able to know it!) is not sufficient to determine its future development. Therefore, only minimal hope exists for the prediction of single seismic events in usual tectonic settings. Non-stationarity, non-typicality and clustering also cause lurking pitfalls for current seismic forecasting models.

Nonetheless, theory does not prevent seismic prediction in general, but, of course, several conditions must be fulfilled. Modelling long-term destabilization processes driving seismic dynamics is an obliged way, if one is interested in predicting, with some tolerance, large-scale seismic processes.

Several attempts of prediction and forecasting have been realized using different approaches, e.g., PSHA, VAN, hydro-geochemical analysis.

However, without a deep understanding of the physical mechanisms of seismicity, results of both probabilistic seismic and precursor analysis, "rather than providing information useful for a reliable estimate, can themselves even represent an additional risk source" (Mulargia, F., Stark, P. B., & Geller, R. J. (2017). Why is probabilistic seismic hazard analysis (PSHA) still used? Physics of the Earth and Planetary Interiors, 264, 63-75).

In the last years a flurry of theoretical, observational and computational results has been achieved; moreover, the characterization of several geophysical features (e.g., rock mechanical properties) has made impressive advances. Nevertheless, they have not been included in a seismic hazard assessment yet.

The main goal of my research activity consists in the integration of theoretical modelling, data analysis and computational simulations to evaluate the time-dependent spectrum of probability for the occurrence of earthquakes in fault systems within a given time window.

The study of seismic phenomena requires a multidisciplinary approach able to keep together the most advanced results in different fields of science. My objectives can be achieved through the simultaneous application of complementary techniques:

1) Disordered and critical systems modelling (works by Havlin, Parisi, Stanley et al.), which is expected to improve our knowledge of dynamic transitions in the brittle crust, informational and fractal analysis will provide quantitative characterization of instability.
2) GNSS, PS-InSAR, gravimetric seismic and silent slip time series analysis.
3) Analysis of complexity, memory and correlations in time and space.
4) Stochastic simulations.
5) Integration of tectonic and geophysical features in physical modelling.

Understanding the physics of large-scale seismic processes is fundamental to achieve reliable forecasting and prediction.
My project is significant because it aims at introducing new theoretical results and technical procedures for the assessment of the probability of generalized instability within the crust with potential impact on seismic hazard; in addition, I believe that my work might provide new insights not only for the comprehension of spatial and temporal organization of seismicity, but also for the occurrence of other self-excited long-memory processes (e.g., volcanic eruptions, creep fractures in facilities, epileptic seizures, market transactions …).

2. Research products

a) Publications (ISI journals)

1) **Zaccagnino, D.**, Vespe, F., & Doglioni, C. (2020). Tidal modulation of plate motions. Earth-Science Reviews, 205, 103179.
2) **Zaccagnino, D.**, Telesca, L., & Doglioni, C. (2021). Different fault response to stress during the seismic cycle. Applied Sciences, 11(20), 9596.

b) Publications (NON ISI journals)

1) **Zaccagnino, D.** (2021). L'Italia del Rischio Geologico. Scienza e politica alla sfida della Grande Transizione. SdP Journal, November 2021.

c) Manuscripts (submitted, in press)

1) **Zaccagnino, D.**, Telesca, L., Doglioni, C. (forthcoming). From simple cracks to complex sequences: how tectonics shapes seismicity. Under review.

2) **Zaccagnino, D.**, Telesca, L., Doglioni, C. (forthcoming). Correlation of seismic activity and tidal stress perturbations highlights growing instability within the brittle crust. Under review.

3) **Zaccagnino, D.**, Telesca, L., Doglioni, C. (forthcoming). The role of stress transfer in the spatial and temporal evolution of crustal dynamics from silent slip to megaquakes. Under review.

d) Abstracts

1) Lunisolar body tides speed up plates? F. Vespe, **D. Zaccagnino**, C. Doglioni, Conference: 7th International Colloquium on Scientific and Fundamental Aspects of GNSS, 05/09/2019, Zurich, Switzerland.

Rome, 18/01/2022 Davide Zaccagnino