On the origin of earthquakes: combining seismic observations and analog experiments

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Context

Since the first earthquake recording in 1884, the development and improvement of seismic networks provide 50 years of instrumental recordings of Earth's seismicity to seismologists. This is a gold mine that is currently investigated to understand earthquake processes and their origin. Many information and models have already been extracted, such as the so-called Gutenberg-Richter law which states that the probability of an earthquake, $P(M>M_0)$, of a given energy, M, follows an exponential law such that $\log(P(M>M_0))=-bM+a$. The slope of this law, called "b-value", is investigated to produce seismic hazard maps which are used for building construction. As a result, a wrong estimation of this parameter can have catastrophic human and economic consequences. The way it is currently estimated relies on strong *a priori* choices and neglects time variations even though we know they exist[1]. In that context we have developed a Bayesian approach able to detect spatial and time variations of the "b-value" avoiding these strong *a priori* assumptions and which properly estimates the uncertainties on the inferred parameters.

In addition, physicists also study earthquake processes through experimental apparatus and physical approach, trying to link earthquake origin to physical parameters in a well constrained environment. The group of E. Bayart (LPENSL) focuses on ruptures propagation along a highly confined gouge layer[2] thanks to a setup that they developed and which enables the detection of smaller ruptures preceding and succeeding a main event. In parallel, the group of O. Ramos (ILM) developed an experimental system able to reproduce in details and with millions of events, the main statistical relations describing seismicity[3].

Due to the scale difference, the comparison of the rupture processes observed on natural faults and in laboratory experiments is not straight forward. Only a statistical approach can fill this gap. Therefore, the goal of this project is to link experiments and observations through a novel Bayesian approach to get a physical understanding of the b-value variations.

Objectives & Working plan

The aim of this project is thus to better understand the origin of earthquakes by applying a new statistical Bayesian methodology to both seismic data (LGL-TPE) and experimental data (LPENSL & ILM) and ultimately to link observations to physical parameters. First, the aim is to investigate spatial and time variations of the "b-value" applying a novel Bayesian approach, from global to regional scale, using 50 years of seismicity, which has never been done before. The Bayesian approach is already successful on synthetic cases (see Figure 1).

Second, the aim is to link these variations to physical processes by analysing experimental data with the same methodology. The experimental setup of E. Bayart and O. Ramos enable to investigate different processes of the earthquake origin and to gather experimental data for different geometries and loading configurations. While the study of E. Bayart (LPENSL) focuses on the transition from static to sliding friction, the apparatus of O. Ramos (ILM) allows to investigate steady frictional motion.

Both E. Bayart (LPENSL) and O. Ramos (ILM) have already resources and man power to perform experimental work. Therefore, the post-doctorate scholar will focus on processing datasets, coming from both seismology and physic experiments.

The postdoctoral scholar will be supervised by S. Durand (LGL-TPE), B. Gardonio (LGL-TPE), E. Bayart (LPENSL) and O. Ramos (ILM). S. Durand and B. Gardonio are seismologists with a strong expertise in seismic data analysis. E. Bayart and O. Ramos are experimental physicists. E. Bayart has an expertise in solid friction and dynamic fracture and O. Ramos is a specialist in granular matter, and crackling dynamics.

References

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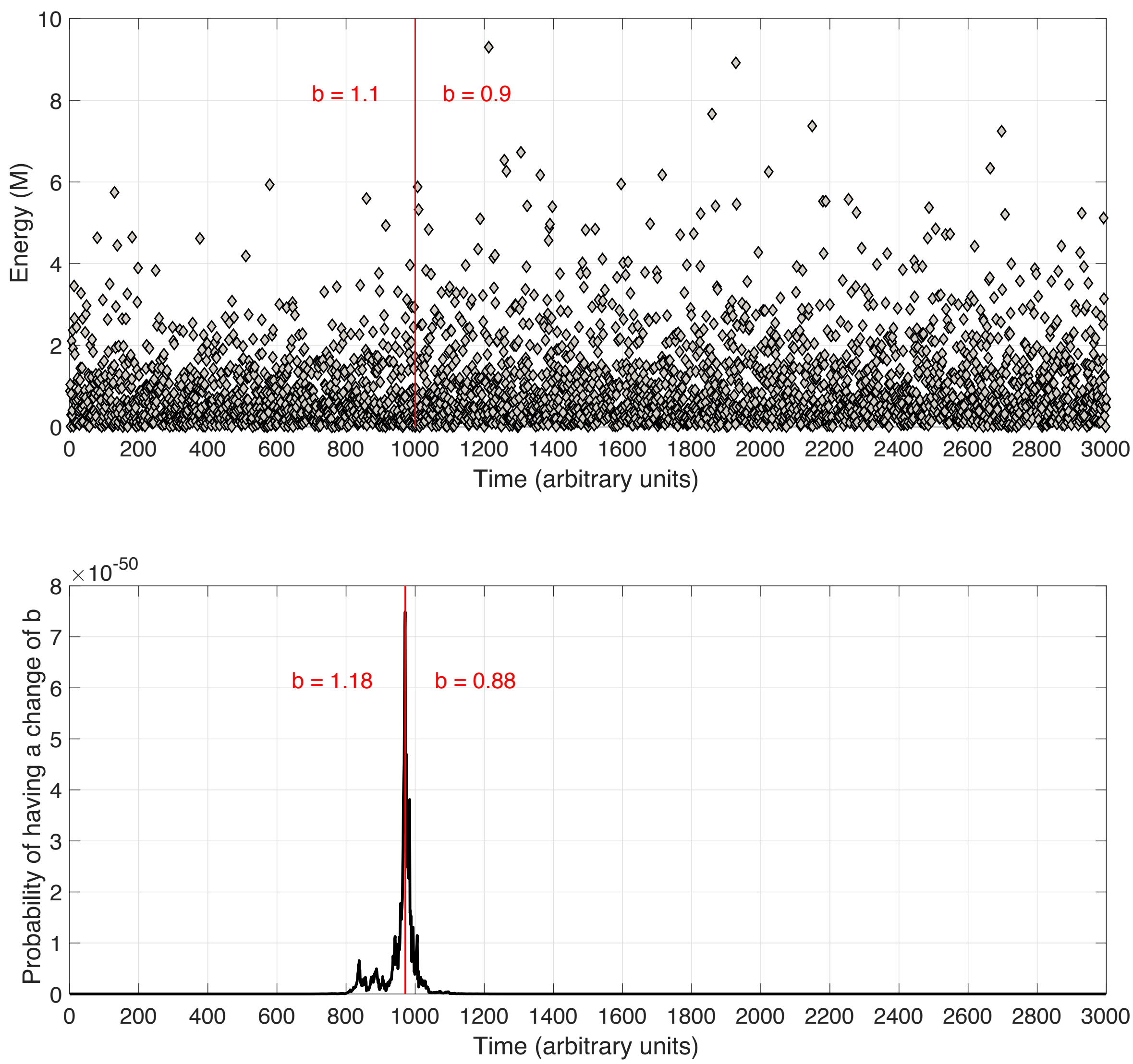

Figure 1: Proof of concept of our Bayesian approach on a synthetic case. We generated two exponential distributions (one with b=1.1 and one with b=0.9) with the change occurring at t=1000 (top). We are able to compute the probability of having a change at any time in the b-value and we recover quite well a distribution centered on t=1000 with reasonable b values (bottom). The standard deviation of this distribution also gives an estimation of the uncertainty.