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Earthquake clusters expected from bare statistics: How bursts and swarms emerge from exogenous and epidemic aftershock processes.

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Earthquake catalogs exhibit strong spatio-temporal correlations. As such, earthquakes are often classified into clusters of correlated activity. Clusters themselves are traditionally classified in two different kinds: (i) bursts, with a clear hierarchical structure between a single strong mainshock, preceded by a few foreshocks and followed by a power-law decaying aftershock sequence, and (ii) swarms, exhibiting a non-trivial activity rate that cannot be reduced to such a simple hierarchy between events.

The Epidemic Aftershock Sequence (ETAS) model is a linear Hawkes point process able to reproduce earthquake clusters from empirical statistical laws [Ogata, 1998]. Although not always explicit, the ETAS model is often interpreted as the outcome of a background activity driven by external forces and a Galton-Watson branching process with one-to-one causal links between events [Saichev et al., 2005]. Declustering techniques based on field observations [Baiesi & Paczuski, 2004] can be used to infer the most likely causal links between events in a cluster. Following this method, Zaliapin and Ben‐Zion (2013) determined the statistical properties of earthquake clusters characterizing bursts and swarms, finding a relationship between the predominant cluster-class and the heat flow in seismic regions.

Here, I show how the statistical properties of clusters are related to the fundamental statistics of the underlying seismogenic process, modeled in two point-process paradigms [Baró, 2020].

The classification of clusters into bursts and swarms appears naturally in the standard ETAS model with homogeneous rates and are determined by the average branching ratio (nb) and the ratio between exponents α and b characterizing the production of aftershocks and the distribution of magnitudes, respectively. The scale-free ETAS model, equivalent to the BASS model [Turcotte, et al., 2007], and usual in cold active tectonic regions, is imposed by α=b and reproduces bursts. In contrast, by imposing α<0.5b, we recover the properties of swarms, characteristic of regions with high heat flow.

Alternatively, the same declustering methodology applied to a non-homogeneous Poisson process with a non-factorizable intensity, i.e. in absence of causal links, recovers swarms with α=0, i.e. a Poisson Galton-Watson process, with similar statistical properties to the ETAS model in the regime α<0.5b.

Therefore, while bursts are likely to represent actual causal links between events, swarms can either denote causal links with low α/b ratio or variations of the background rate caused by exogenous processes introducing local and transient stress changes. Furthermore, the redundancy in the statistical laws can be used to test the hypotheses posed by the ETAS model as a memory‐less branching process.

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