Gutenberg-Richter, Omori and Cumulative Benioff strain patterns in view of Tsallis entropy and Beck-Cohen Superstatistics.

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The corner stones of Statistical seismology as that of Gutenberg-Richter (GR), Omori and Benioff laws analysed using the ideas of Tsallis entropy and its dynamical superstatistical interpretation offered by Beck-Cohen. The earthquake generation process is a complex phenomenon, manifested in the nonlinear dynamics and in the wide range of spatial and temporal scales that are incorporated in the process. Despite the complexity of the earthquake generation process and our limited knowledge on the physical processes that lead to the initiation and propagation of a seismic rupture giving rise to earthquakes, the collective properties of many earthquakes present patterns that seem universally valid. The most prominent is scale-invariance, which is manifested in the size of faults, the frequency of earthquake sizes and the spatial and temporal scales of seismicity. A variety of fault attributes, such as the distribution of fault trace-lengths or fault displacements, exhibit power-law scaling and (multi)fractal geometries. The frequency-size distribution of earthquakes generally follows the Gutenberg-Richter (GR) law that resembles power-law scaling in the distribution of dissipated seismic energies and fault rupture areas, limited in each case by the size of the seismogenic system. The aftershock production rate following a main event generally decays as a power-law with time according to the modified Omori formula. The modified Omori formula expresses a short-term clustering effect associated with the occurrence of large events and their triggered aftershock sequences.

Based on statistical physics and the entropy principle, a unified framework that produces the collective properties of earthquakes from the specification of their microscopic elements and their interactions, has recently been introduced. This framework, called nonextensive statistical mechanics (NESM) was introduced by Tsallis (1988), as a generalization of classic statistical mechanics due to Boltzmann and Gibbs (BG), to describe the macroscopic behaviour of complex systems that present strong correlations among their elements, violating some of the essential properties of BG statistical mechanics. Such complex systems typically present power-law distributions, enhanced by (multi)fractal geometries, long-range interactions and/or large fluctuations between the various possible states, properties that correspond well to the collective behaviour of earthquakes and faults. Here, we provide an overview on the fundamental properties and applications of NESS. Initially, we provide an overview of the collective properties of earthquake populations and the main empirical statistical models that have been introduced to describe them. We describe the main statistical physics models that have been introduced to describe earthquake occurrence and we summarize the classic (BG) statistical mechanics approach to the phenomenology of earthquakes. We provide an analytic description of the fundamental theory and the models that have been derived within the NESM framework to describe the collective properties of earthquakes.

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