Canadian Association of Physicists

Association canadienne des physiciens et physiciennes

Contribution ID: **2106** Type: **Oral (Non-Student) / Orale (non-étudiant(e))**

Power-law Viscoelastic Rheology Controls the Occurrence of Aftershocks

Wednesday 13 June 2018 12:00 (15 minutes)

Aftershocks are ubiquitous in nature. They are the manifestation of relaxation phenomena observed in various physical systems. In one prominent example, they typically occur after large earthquakes. They also occur in other natural or experimental systems, for example, in solar flares, in fracture experiments on porous materials and acoustic emissions, after stock market crashes, in internet traffic variability, to mention a few. The observed aftershock sequences usually obey several well defined non-trivial empirical laws in magnitude, temporal, and spatial domains. In many cases their characteristics follow scale-invariant distributions. The occurrence of aftershocks displays a prominent temporal behavior due to time-dependent mechanisms of stress and/or energy transfer. In this work, we consider a slider-block model to mimic the behavior of a seismogenic fault. In the model, we introduce a nonlinear viscoelastic coupling mechanism to capture the essential characteristics of crustal rheology and stress interaction between the blocks and the medium. We show that the nonlinear viscoelasticity plays a critical role in triggering of aftershocks. It explains the functional form of the empirical Omori-Utsu law, which describes the temporal decay of the aftershock rate, and gives physical interpretation of its parameters. The proposed model also suggests that the power-law rheology of the medium controls the decay rate of aftershocks. To verify this, we analyzed several prominent earthquake aftershock sequences to estimate their decay rates and correlate with the rheological properties of the underlying lower crust and mantle, which were estimated from the postseismic surface deformation. Our modelling suggests that the power-law rheology exponent n controls the decay rate of aftershocks and is related to the parameter p of the Omori-Utsu law. The obtained results indicate that for the first time we provide a clear mechanism for the aftershock generation that follow a power-law decay rate and give a physical interpretation of its functional form. The obtained results highlight the importance of nonlinear viscoelastic effects operating in various systems exhibiting relaxation phenomena and can stimulate relevant empirical observations and experiments in order to detect and quantify such effects.

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Session Classification: W2-1 Pattern Formation 2 (DCMMP) | Formation de motif 2 (DPMCM)

Track Classification: Condensed Matter and Materials Physics / Physique de la matière condensée et matériaux (DCMMP-DPMCM)