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Simple models for plastic deformation and slip avalanches: From crystals to bulk metallic glasses to granular materials

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Many slowly sheared solid materials are known to deform in an intermittent way, with the discrete events in the data detected as, for example, acoustic emission and serrations in the stress-strain curves. In many materials, power laws govern the statistics of the distributions in the discrete event sizes. A basic micromechanical model with a single tuning parameter (weakening ε), which describes the distributions of the stochastic deformation signature, is introduced. The model is capable of reproducing the observed stress-strain curves, acoustic emissions, related power spectra, and power-law statistics of slip avalanches, including the dependence of the cutoff on the tuning parameter and geometrical properties of slip, with a continuous phase transition from brittle to ductile behavior. Exact universal predictions for the power-law exponents and scaling functions are extracted using the mean-field theory and renormalization group tools. The results agree with recent experimental observations and simulations of dislocation dynamics in nano- and micro-crystals, sheared bulk metallic glasses, and granular materials.

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