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To creep or to snap? How induced heat governs the brittleness of matter

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The growth of fractures within mechanically loaded materials often shows two different behaviors. When loaded below a particular threshold in energy release rate, cracks tend indeed to creep at very slow velocities, while the rupture becomes catastrophic beyond this threshold, with propagation velocities approaching that of the material mechanical waves. Understanding according to which of these two behaviors a material is prone to break is of paramount importance, notably in engineering, where the brittle rupture of structures can lead to unpredicted disasters. It is also fundamental in Earth science, as damaging earthquakes are rather generated by abrupt ruptures in the crustal rocks than by their slow deformations. To explain both behaviors, we focus here on the thermal effects which are auto-induced by the growth of cracks. During their propagation, some of the system's energy is indeed partly dissipated by Joule heating, which is arising from the friction in a damaged zone around the fracture fronts. The heat hence generated can in return have a significant impact on the physics of the propagation. For instance, the stability of faults is believed to be affected by the thermo-pressurization of their in situ fluids. Independently of this effect, we show, how statistical physics, as understood by an Arrhenius law that includes the dissipation and diffusion of heat around the fracture tip, can explain the full dynamics of cracks, from the slow creep to the fast rupture.

We indeed show that such a model can successfully describe most of the experimentally reported fracture rheology, quantified in terms of velocity / energy release rate relations, in two different types of polymers, acrylic glasses and pressure sensitive adhesives, over eight decades of crack velocities. In these two cases, it is sufficient to assume that these polymers are homogeneous to model their failure. Yet, we in addition illustrate how the thermal disorder, from both the ambient temperature and the propagation induced heat, should interact with the matter typical quenched disorder in fracture energy. Numerical simulations of planar cracks in heterogeneous media indeed show that such quenched disorder helps to trigger hot avalanches in the propagation of

cracks, making the overall toughness of a material highly dependent on both its heterogeneities, as it is often reported in the literature, and its thermal properties.