Rupture speed of supershear slip instabilities

David Kammer¹, Ilya Svetlizky², and Jay Fineberg³

¹ETH Zurich, Switzerland (dkammer@ethz.ch)
²Harvard University, Cambridge, MA, USA
³The Hebrew University of Jerusalem, Israel

Shear ruptures propagating along natural faults or simulated faults in analog laboratory experiments present a wide range of rupture velocities. Most ruptures propagate at velocities below the Rayleigh wave speed and Linear Elastic Fracture Mechanics (LEFM) theory has been shown to predict quantitatively well the observed propagation speed. However, early theoretical and numerical work suggested that ruptures may surpass the shear wave speed and propagate at velocities that can reach the longitudinal wave speed. This was later confirmed in laboratory experiments and observed as supershear earthquakes in nature. While the transition from sub-Rayleigh to supershear propagation has been studied extensively, current knowledge of propagation speed in the supershear regime is limited to a couple of idealistic set-ups. Here, we analyse the propagation speed of supershear ruptures along various nonuniform interfaces using simulations and experiments. We show that an approximate fracture mechanics theory describes well supershear rupture speeds as observed in our experiments and simulations. Furthermore, the theory uncovers a critical rupture length below which supershear propagation is impossible. Beyond this critical length, a rupture can sustain supershear propagation for arbitrarily low prestress levels if local non-uniformities cause transition. The presented theory provides a tool to better understand the potential for supershear ruptures in more realistic heterogeneous systems.