# Friction, Fracture and Earthquakes at the Interface of Sliding blocks

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Friction is generally described by a single degree of freedom, a 'friction coefficient'. We experimentally study the space-time dynamics of the onset of dry and boundary lubricated frictional motion when two contacting bodies start to slide. We first show that the transition from static to dynamic sliding is governed by rupture fronts (closely analogous to earthquakes) that break the contacts along the interface separating the two bodies. The structure of these 'laboratory earthquakes' is given by singular solutions describing rapid shear cracks. This framework establishes a new (and fruitful) paradigm for quantitatively describing friction onset, earthquake' motion and arrest.

**Keywords:** tribology, friction, earthquakes, fracture, friction onset

Despite an enormous amount of effort, a fundamental understanding of friction has long eluded us. Frictional motion has for centuries been thought to be governed by "friction laws", material characteristic ratios between normal and shear forces. On the other hand, over the last 50 years theoretical descriptions of earthquakes have modeled them as ruptures propagating along natural faults; which are, themselves, spatially extended frictional interfaces separating tectonic plates. Much work has been focused on the nature of these ruptures, but experiments to characterize their structure have only been available over the past few years.

A frictional interface is composed of an ensemble of discrete contacts whose total area (the real contact area, *A*) is orders of magnitude smaller than the nominal contact one. Local motion (slip) is initiated when contacts are broken. The fracture of the contacts along a spatially extended interface does not happen simultaneously. Instead, the dynamics of contact fracture take place by means of propagating ruptures. These rupture are, essentially, identical to the earthquakes that enable locked tectonic plates to initiate their relative motion. Characterization of the dynamic fields that drive these ruptures and how they couple to the dissipative mechanisms on the interface are therefore critical to our fundamental understanding of the onset of friction..

In this talk we will describe precise measurements of both the motion of these 'laboratory earthquakes' together with simultaneous , high-speed, measurements of all of the components of the strain tensor at the tip of these propagating ruptures, over their entire range of allowed velocities. These measurements, when coupled with our real-time measurements of the real contact area reveal:

1. Ruptures responsible for the loss of stability of a frictional interface are, in general, well-described by singular fracture mechanics solutions for propagating shear cracks.
2. Surprisingly, a single value of the fracture energy of the interface is the only input needed to provide a quantitative description of "laboratory earthquakes" over the entire allowed range of rupture velocities (from 0.01-.99$C_R$, where $C_R$ is the Rayleigh wave speed of the material used).
3 All of stress components are well-described by the fracture mechanics solution for all rupture velocities,.
4. The equation of motion describing all subsonic frictional ruptures is in excellent agreement with that predicted by fracture mechanics. Moreover, this framework quantitatively describes when, where, and how a rupture (earthquake) will arrest its motion.

We will also touch on fundamental differences of frictional motion when the up-down symmetry of the two "identical" sliding bodies is lost. We will show that the rupture modes, in this case, have a qualitatively different character than those that mediate the frictional motion of identical bodies.

If time permits, we will also present new measurements that describe how the nucleation of rupture modes takes place. While the initial nucleation process is beyond the fracture mechanics description, it is of critical importance if one wishes to understand the *onset* of both frictional motion and natural earthquakes.

## Some key references

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