Particle based Simulation of Stick-Slip on a Rough Fault – Details of the Slip Dynamics

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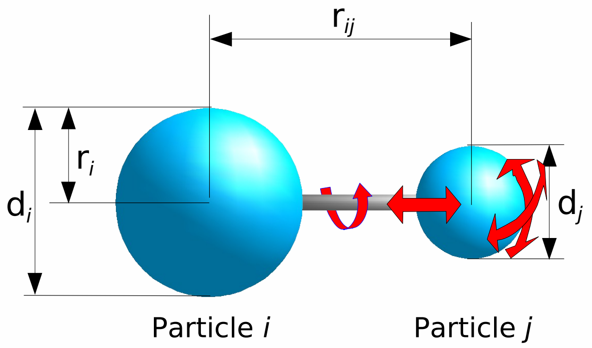
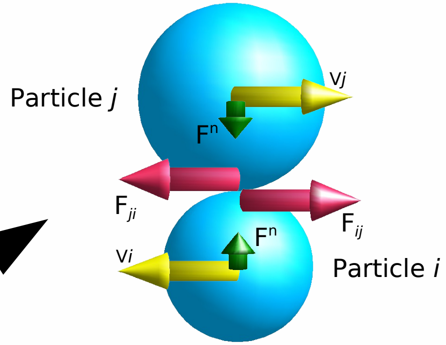
Introduction

- Particle based fault model
  - 2D
  - rough fault
- Investigation of rupture properties
  - source time function
  - final slip distribution
  - rupture parameter scaling

The LSM Approach

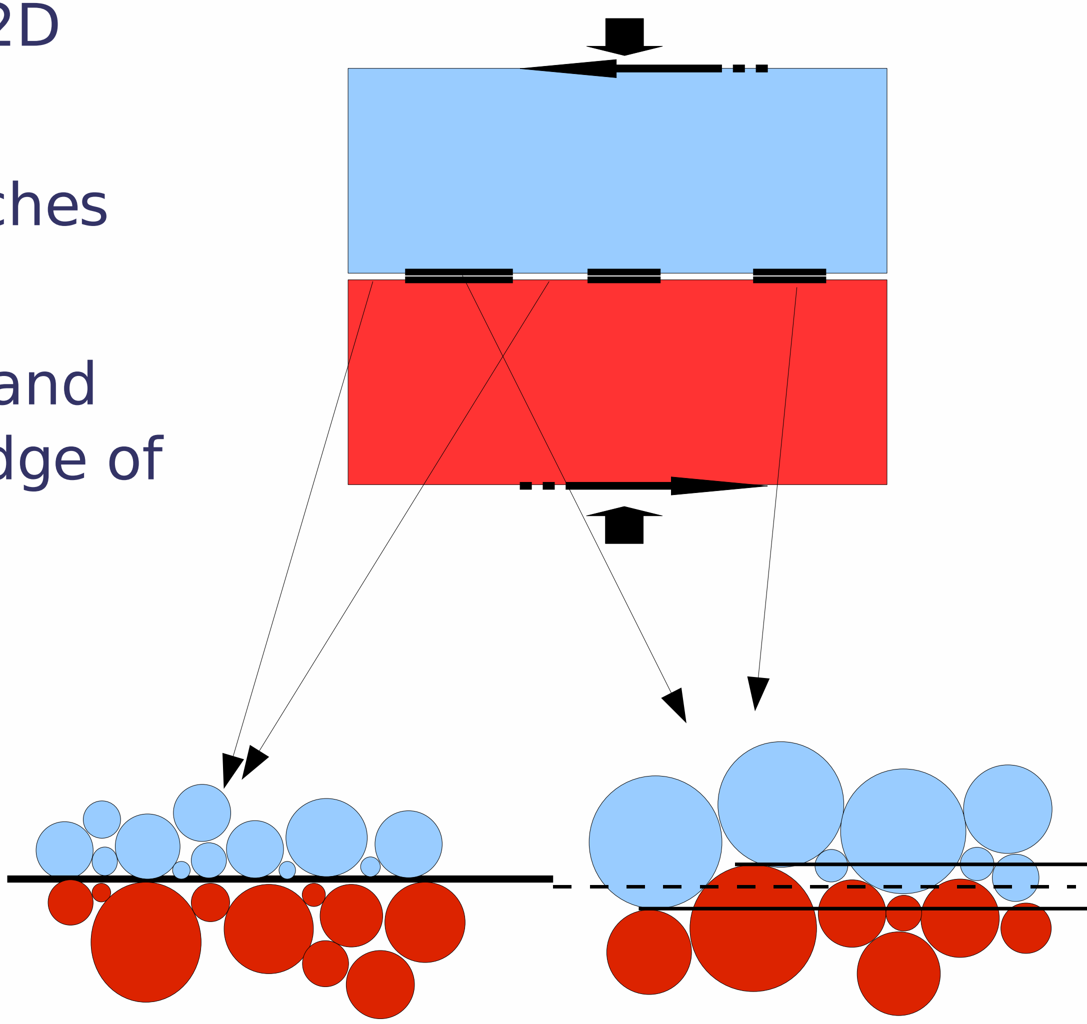
- Brittle-elastic "linked" interactions
- Spherical particles interacting with nearest neighbors
  - Normal, bending and twisting forces
  - Can break if deformed too far
- Free elastic interactions
- Frictional interactions





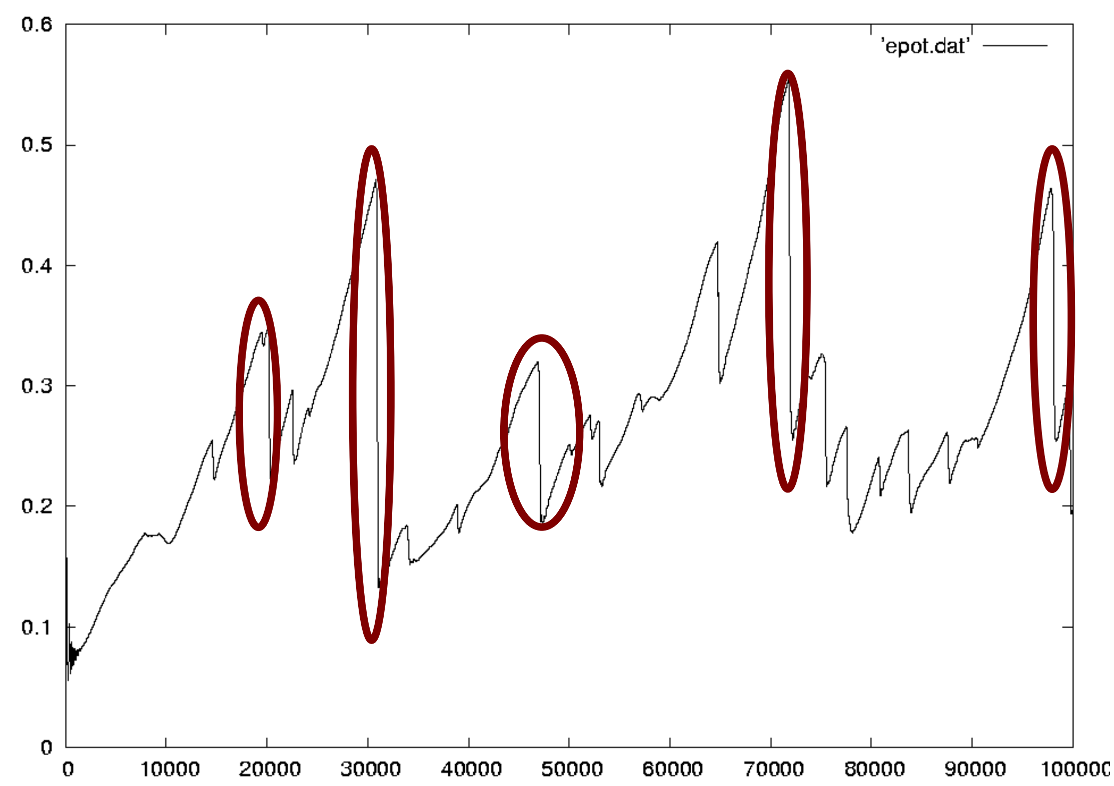
The Fault Model

- 1D fault embedded in 2D elastic block
- smooth and rough patches along the fault surface
- constant normal force and shear velocity at the edge of the elastic block



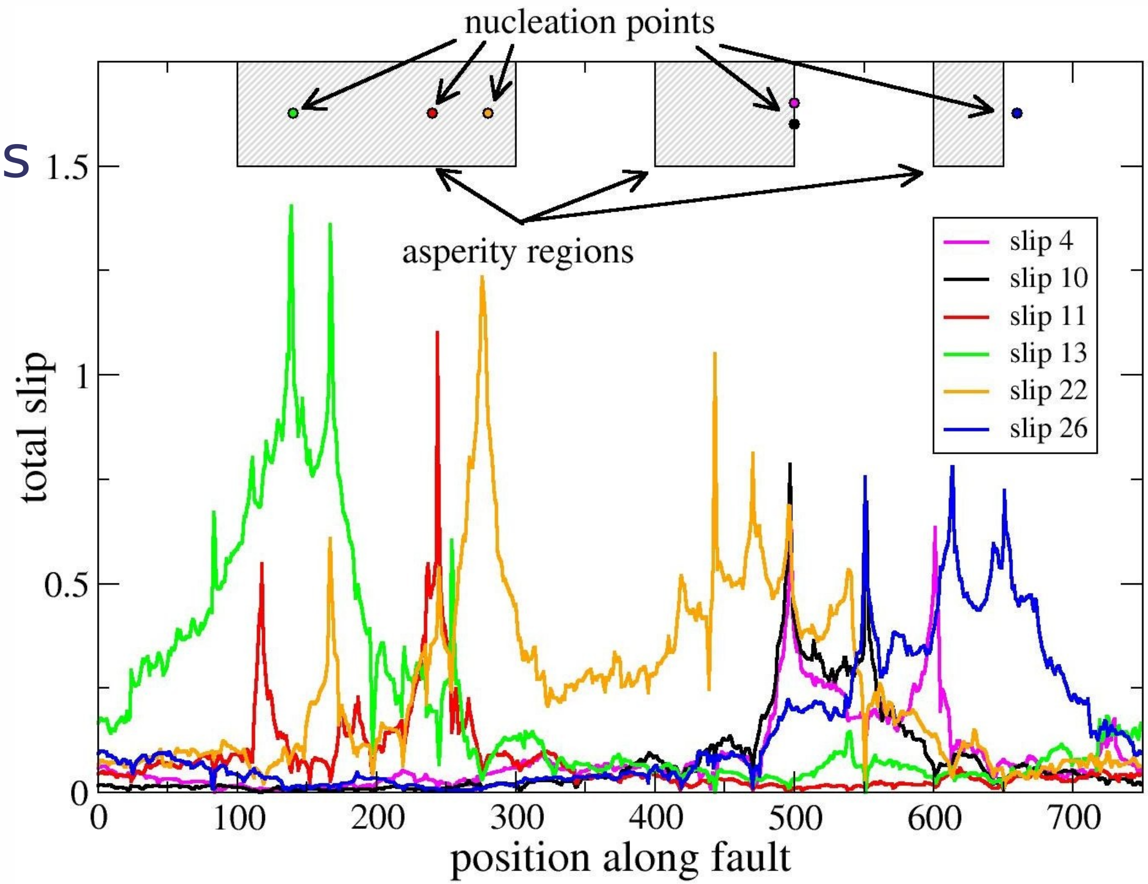
Stick-Slip Dynamics of the Fault

- Slow stress/energy buildup
- Stress drop at slip events
- Used to identify major slip events



Slip distributions and nucleation points

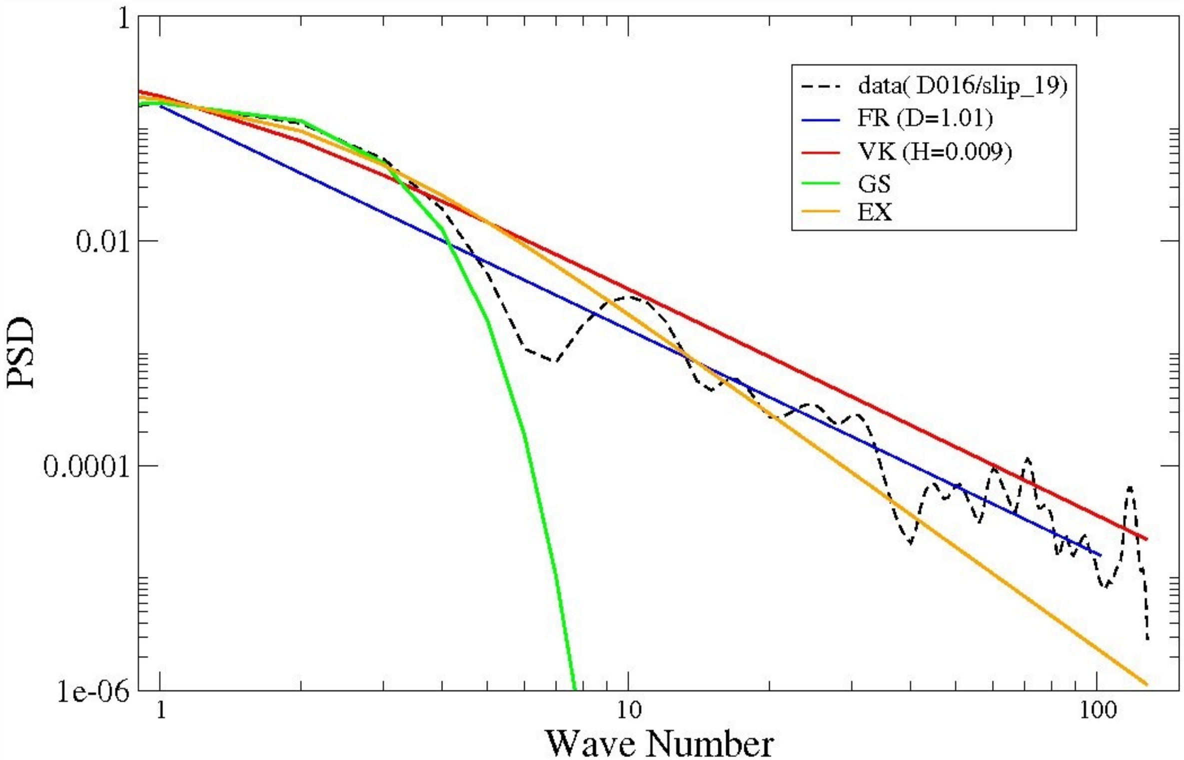
- nucleation points in or near high roughness regions
- high slip near nucleation



Slip distribution statistics

- calculate Power Spectral Density (PSD) of slip distribution
- fitted different functions to PSD (similar to Mai & Beroza, JGR 2002)
  - Gaussian
  - Exponential
  - von Karman
  - Fractal

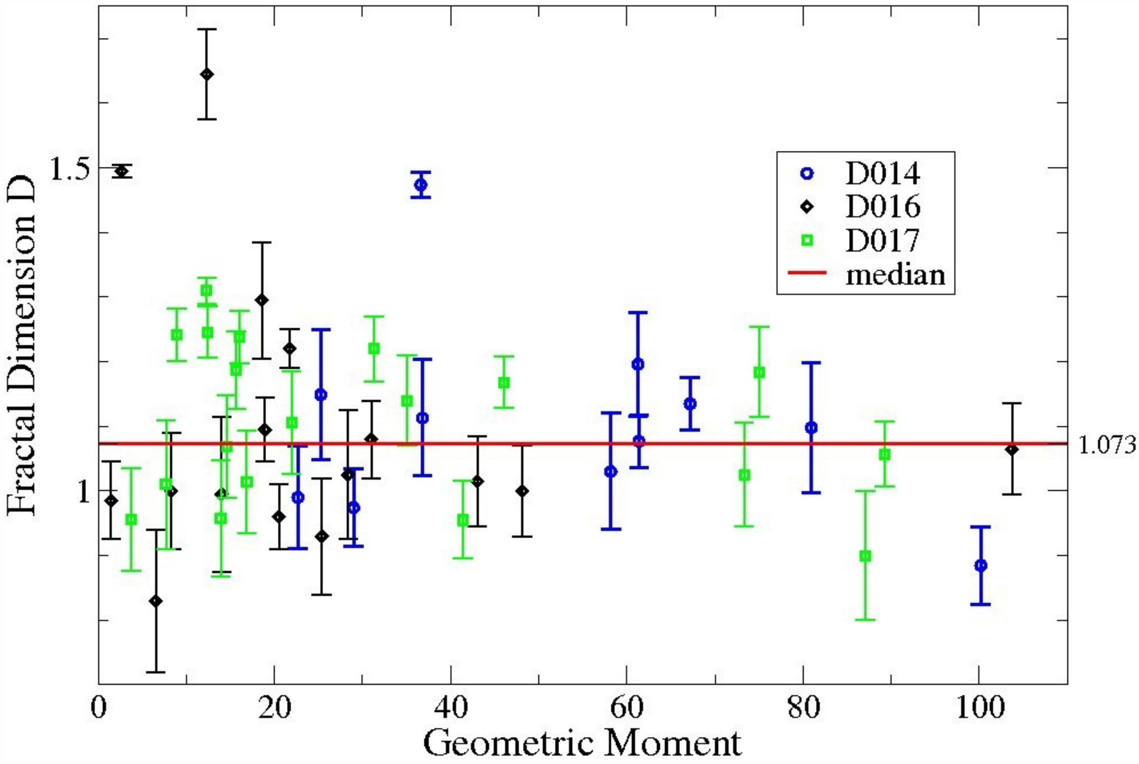
Slip distribution PSD fit



- Gaussian & Exponential don't fit
- von Karman and Fractal (D~1) do fit
- but: von Karman distribution with correlation length > fault length

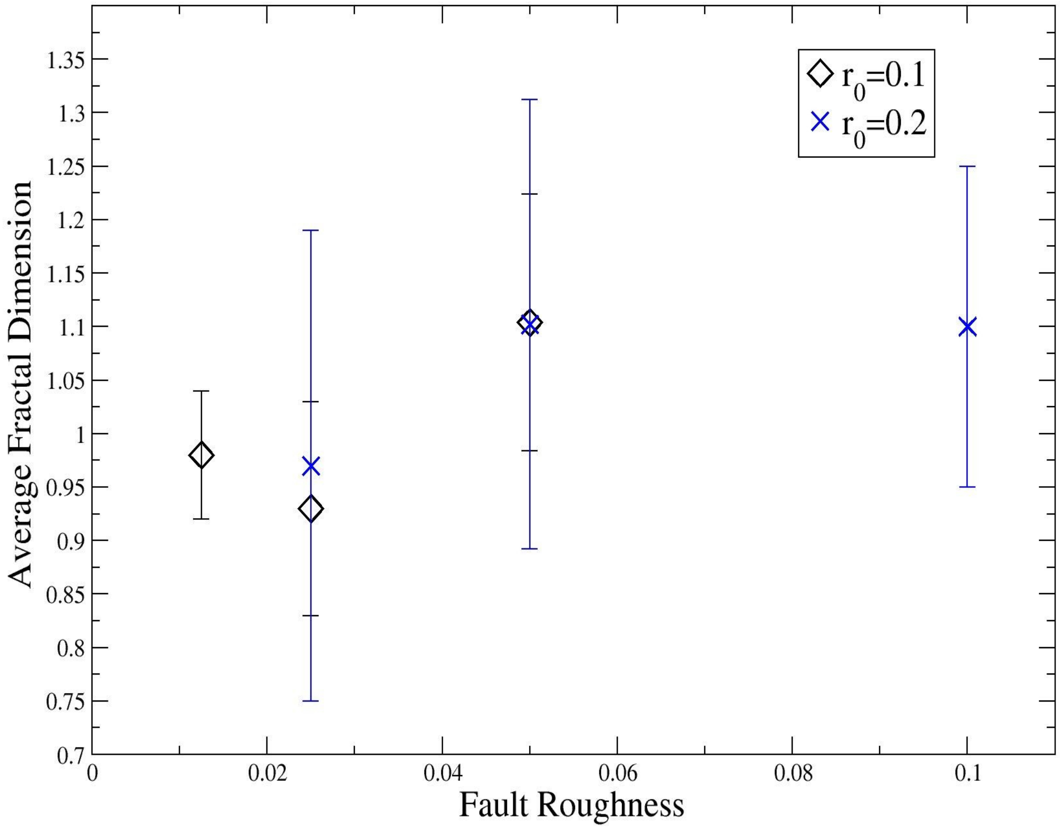
Fractal dimension (I)

- for most events, D~0.85...1.3
- some outliers D>1.5
- average D=1.1±0.16
- median D=1.07
- 1D slice though 2D distribution with D~2.1 ? (P.M. Mai)



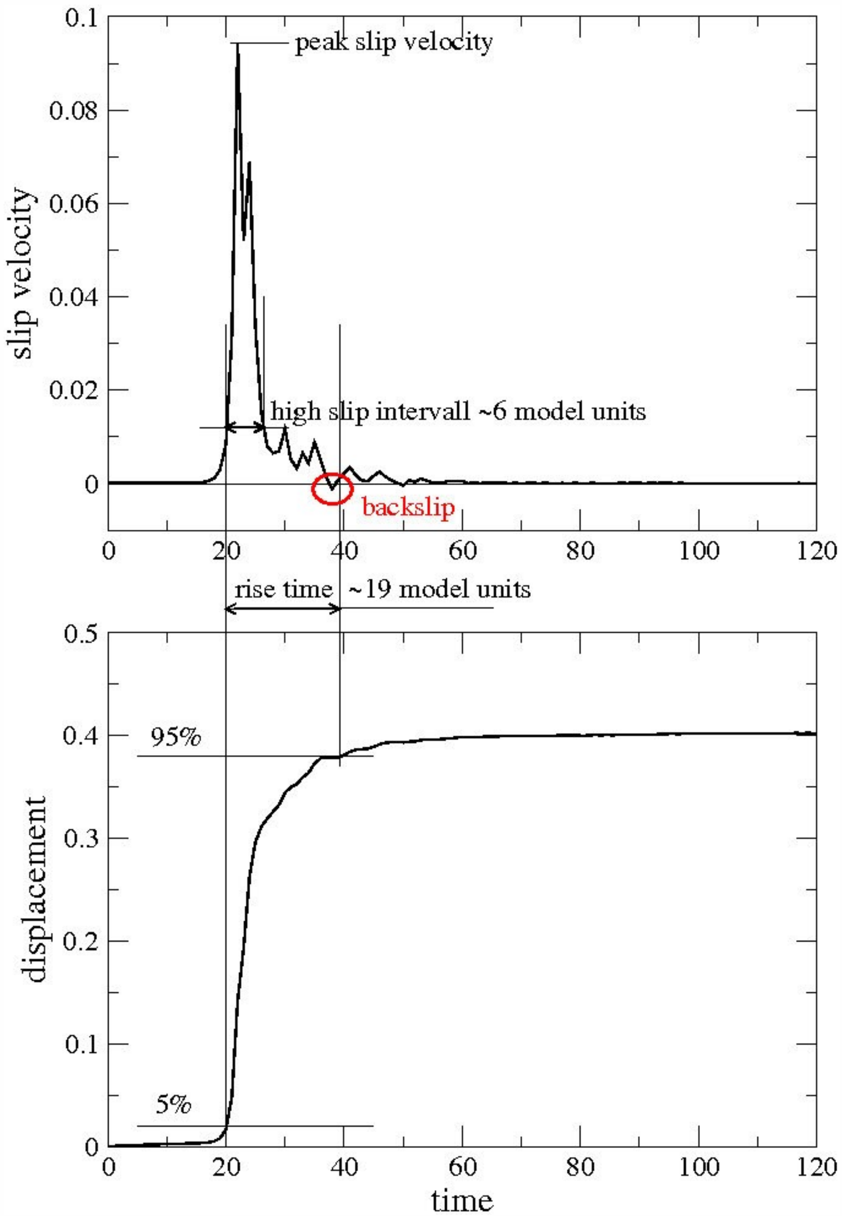
Fractal Dimension (II)

- no clear dependence on fault roughness



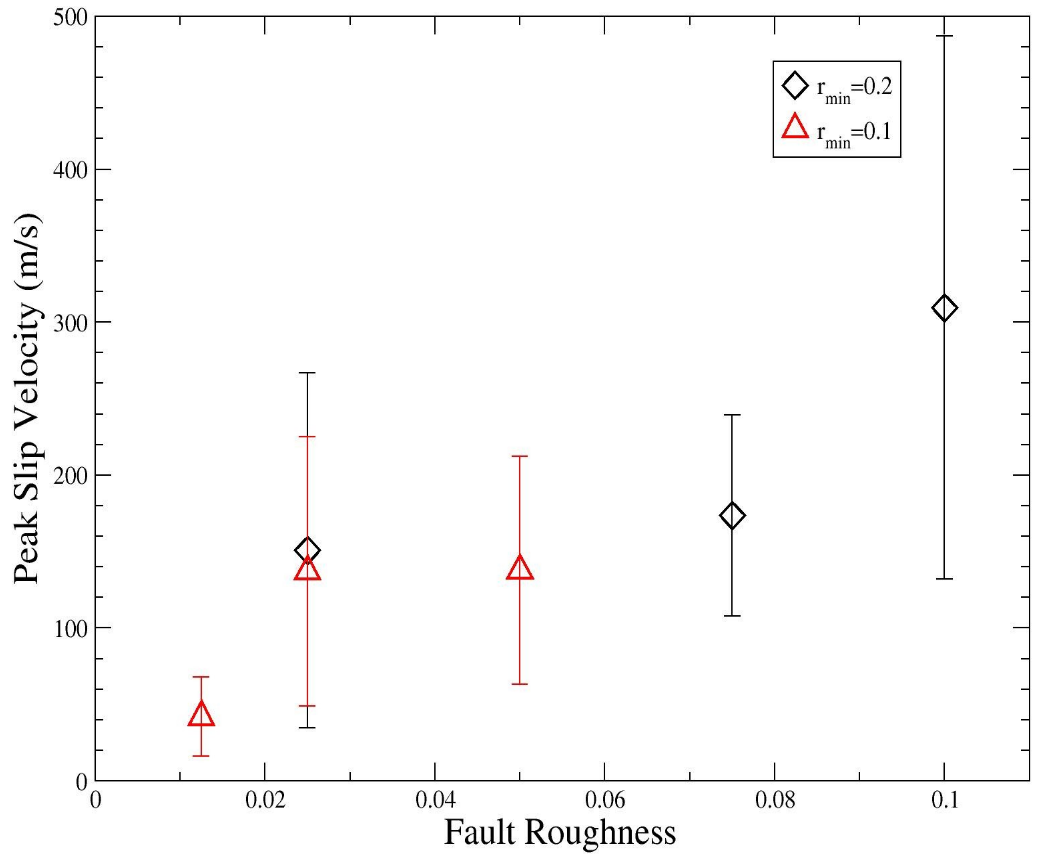
Source-Time Functions

- Pulse-like rupture
- Pulse duration ~20-30 time units, event duration 60-250 time units
- high slip rate concentrated towards beginning of the pulse
- absolute peak slip velocity significantly too high



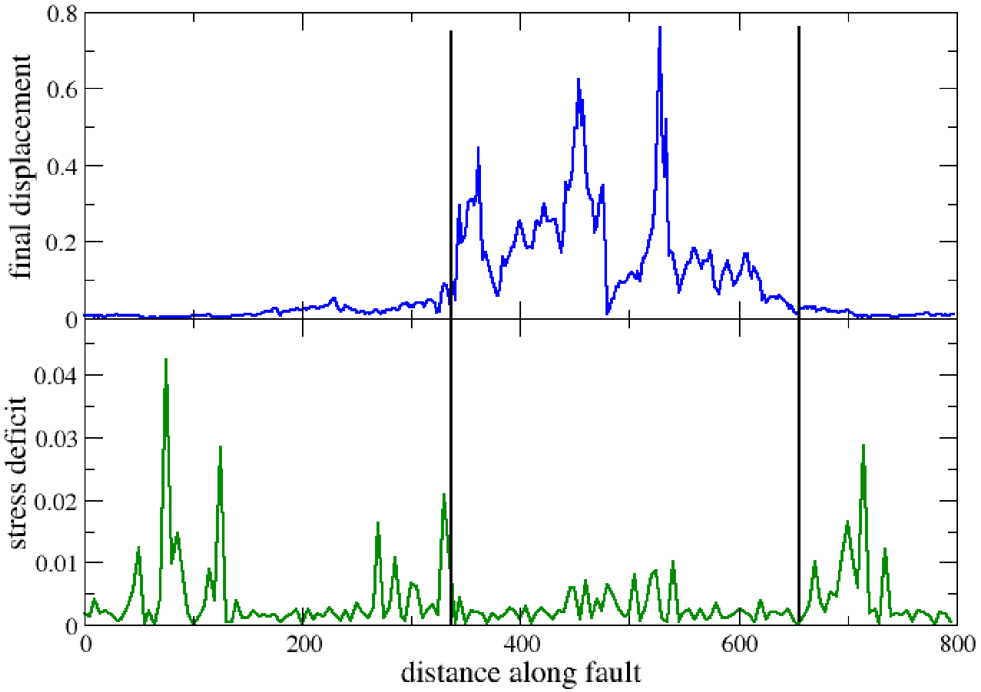
Slip Velocities

- peak slip velocity strongly dependent on fault roughness
- models with smallest roughness approach realistic slip velocities



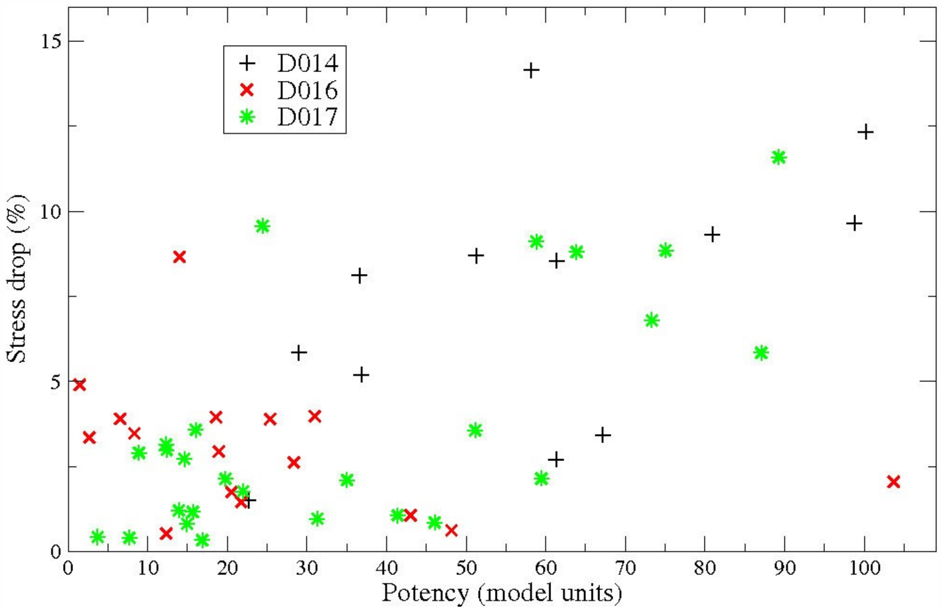
Pre-Slip Stress and Final Slip Distribution

- “stress deficit”: different between current stress and yield stress of the fault - “closeness to failure”
- high displacement in low “stress deficit” areas
- slip stopped by far from failure area



Stress Drops

- no clear correlation between stress drop and event size
- average stress drops dependent on fault roughness
- realistic stress drops: 2-8MPa (20-80 Bar)

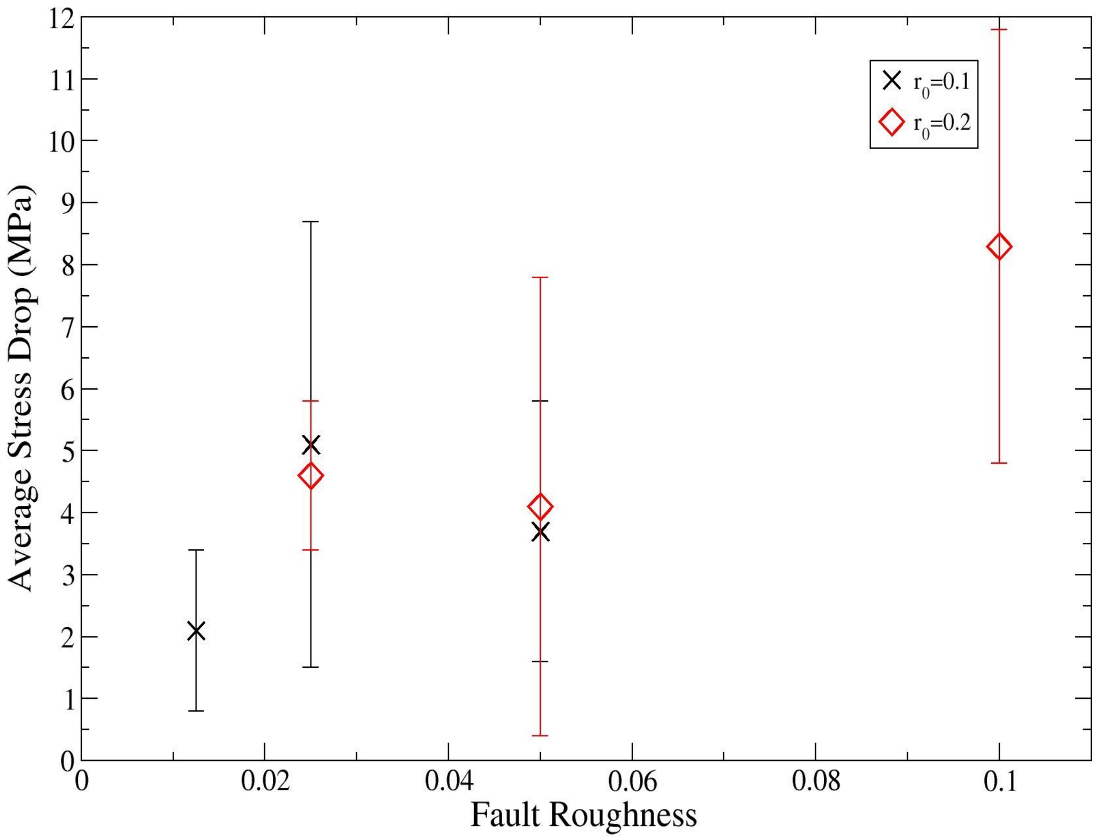


D014: roughness 0.1

D016,D017: roughness 0.05

Stress Drops (II)

- dependent on fault roughness
- rougher faults show higher stress drops

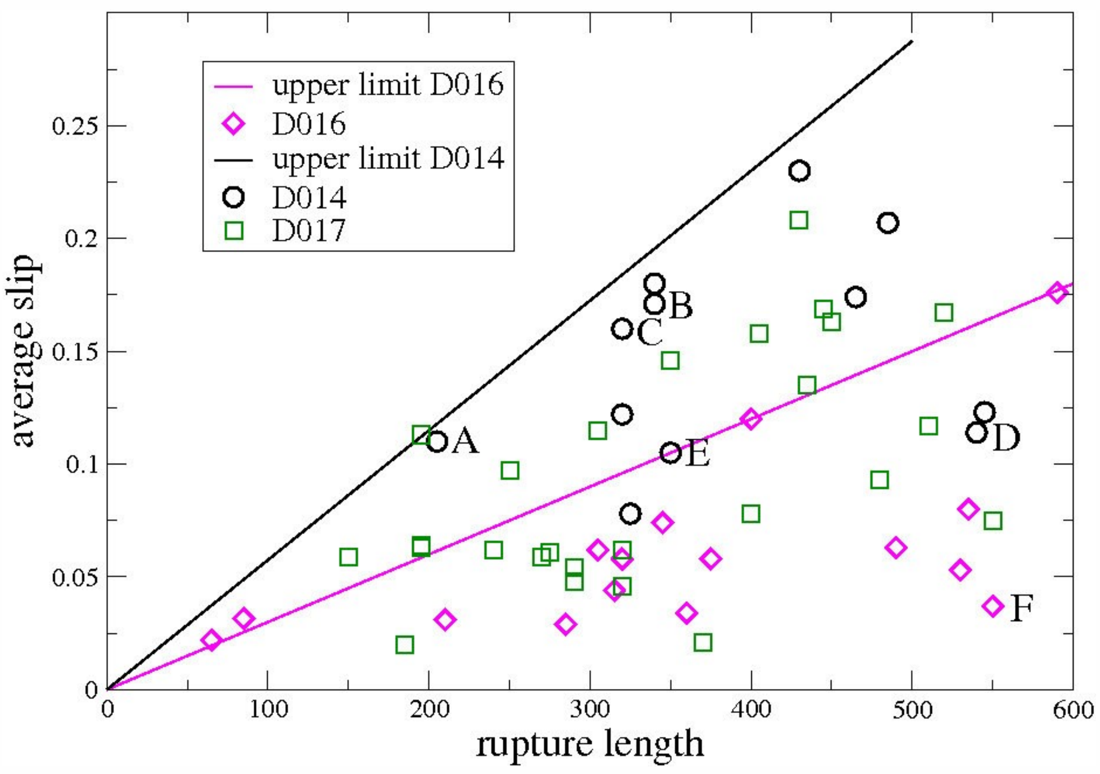


Rupture Parameter Scaling

- Assumptions:
  - constant stress / strain drop
  - similar shape of the rupture area
- Average displacement is proportional to rupture length
- In 2D -> Moment proportional to square of rupture length

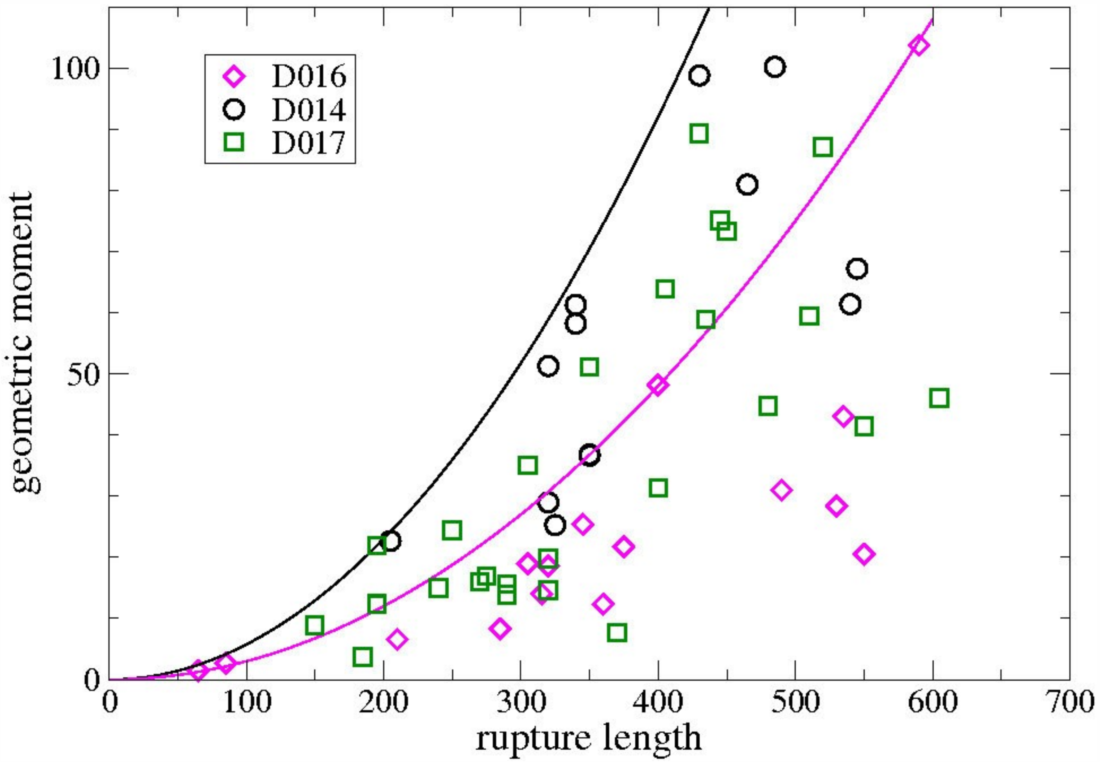
Scaling (I) – Displacement vs. Rupture Length

- large scatter
- expected linear scaling only as upper limit
- model specific



Scaling (II) – Moment vs. Rupture Length

- large scatter
- expected quadratic scaling only as upper limit
- model specific



Conclusions

- complex rupture dynamics
- some realistic behavior
  - stress drops
  - shape of source-time functions
  - slip distributions ?
- some not so realistic
  - peak slip velocities
- strong influence of roughness parametrization