Laboratory Scale Model of an Earthquake Fault

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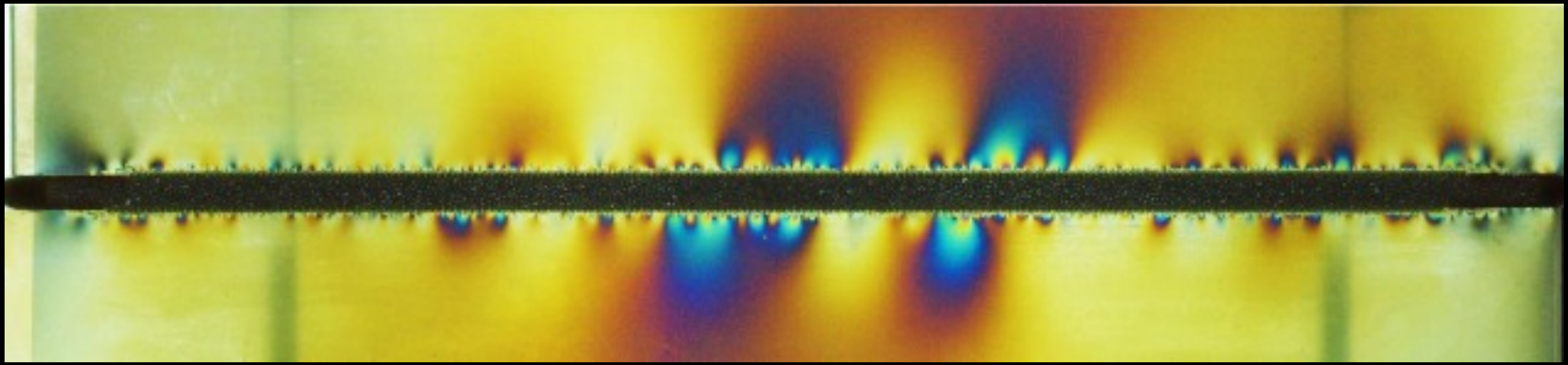
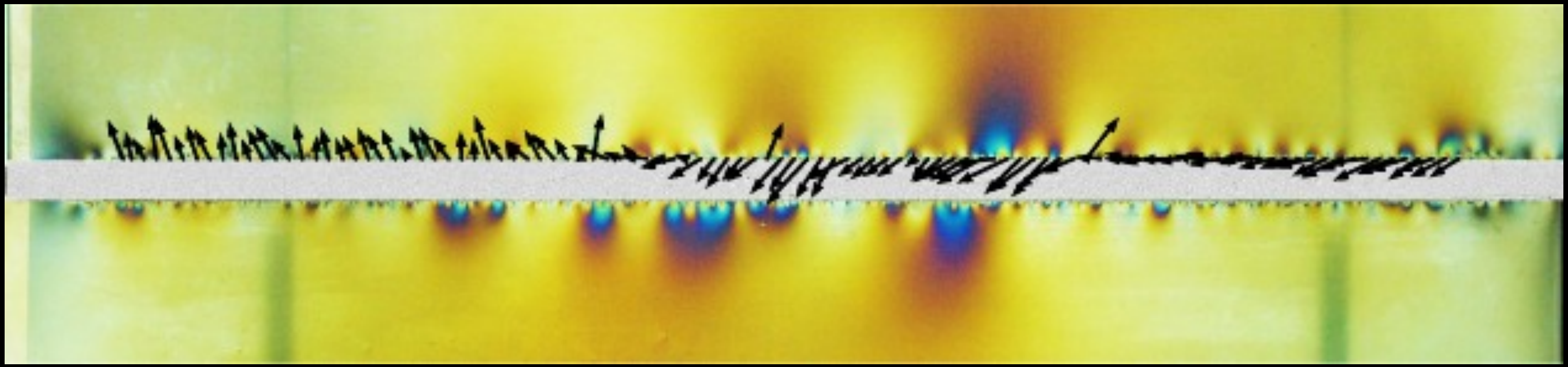
Los Alamos National Laboratory



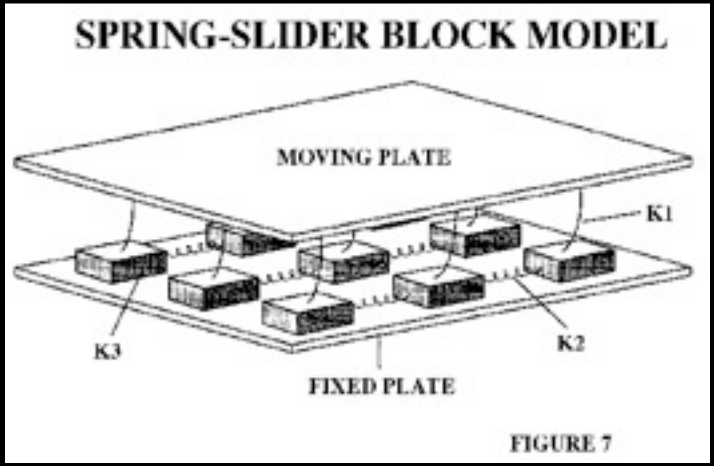


Center for Nonlinear Studies
Los Alamos

Earthquakes are complex and impactful - Generic stick-slip motion vs real earthquakes?

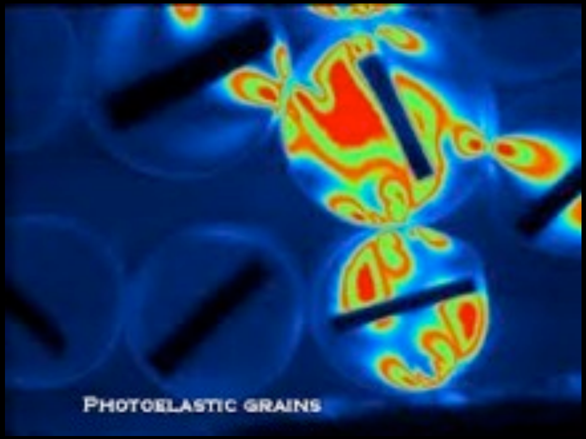



Burridge-Knopoff Model

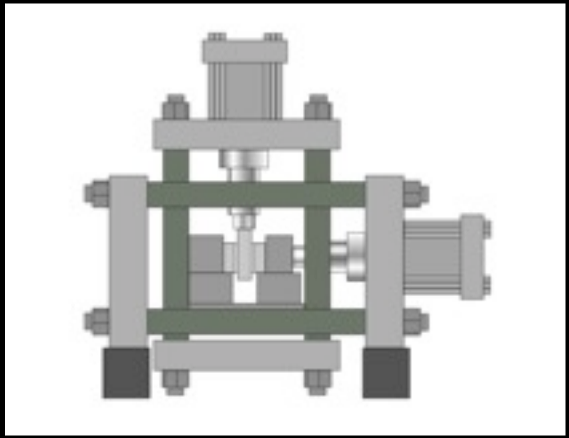


Granular Stick-Slip Motion

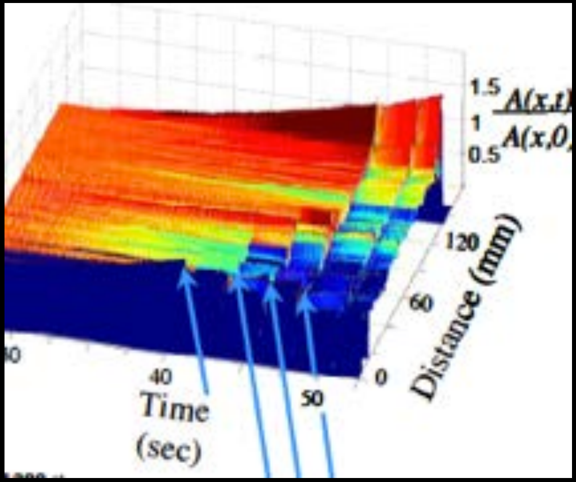
Behringer - Duke
Daniels - NC State



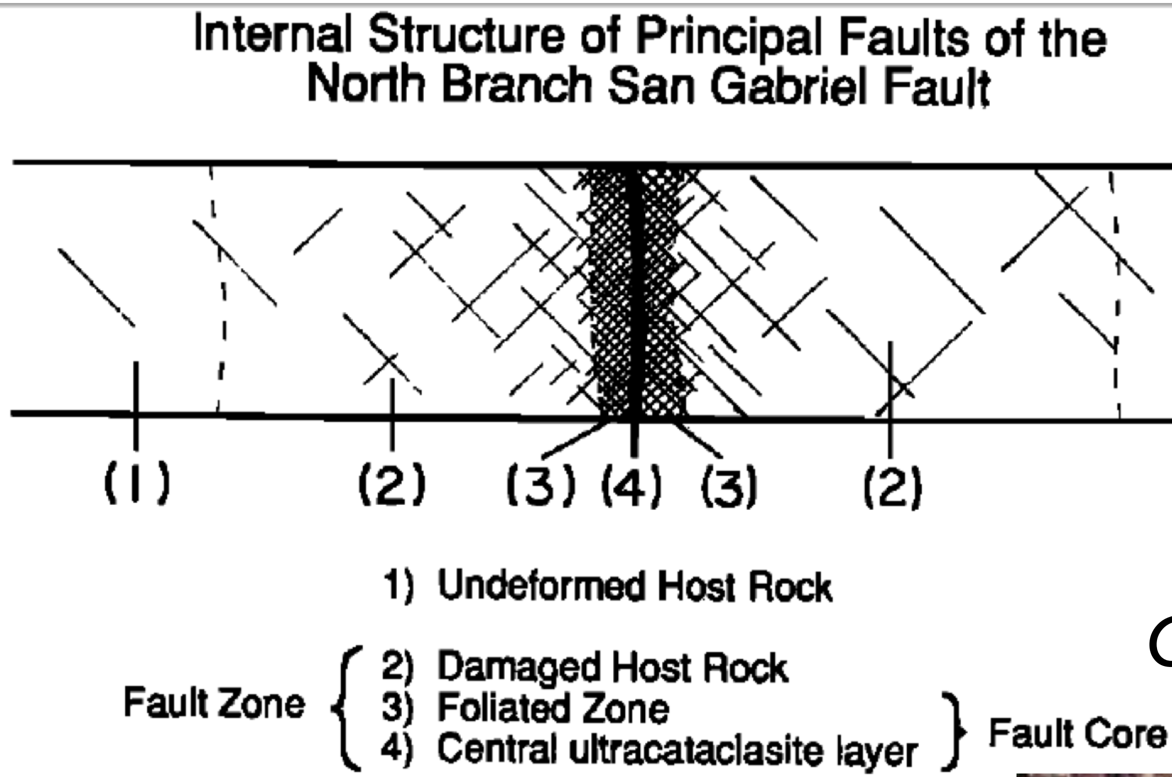
Granite Blocks w/ Glass Granular - Marone PSU



Block on Block Friction
Fineberg - Hewbrew U.



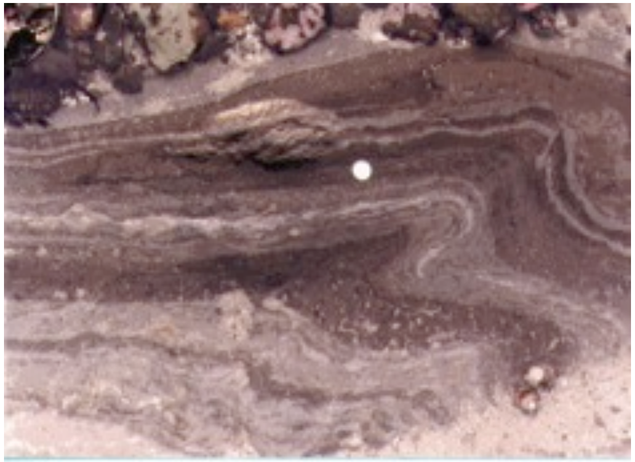
Fault zones contain gouge, a granular material



Top View

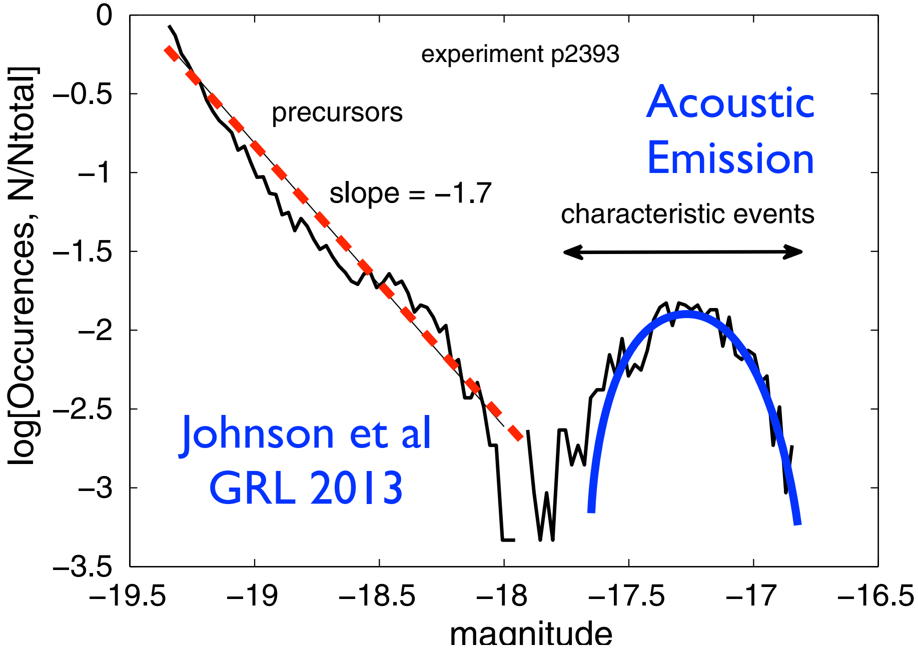
Chester et al., *J. Geophys. Res.* (1993)

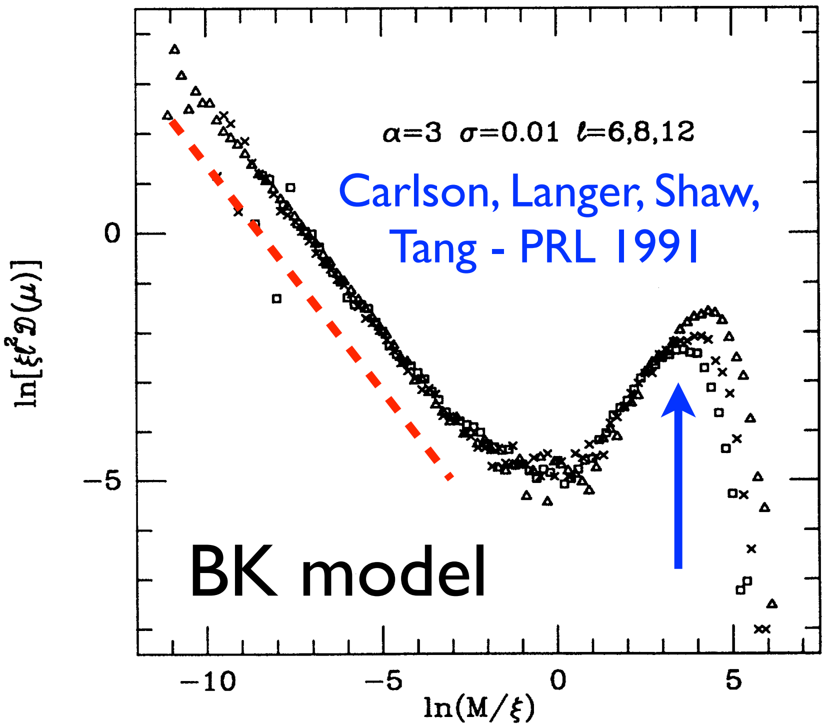
Granular Fault Gouge

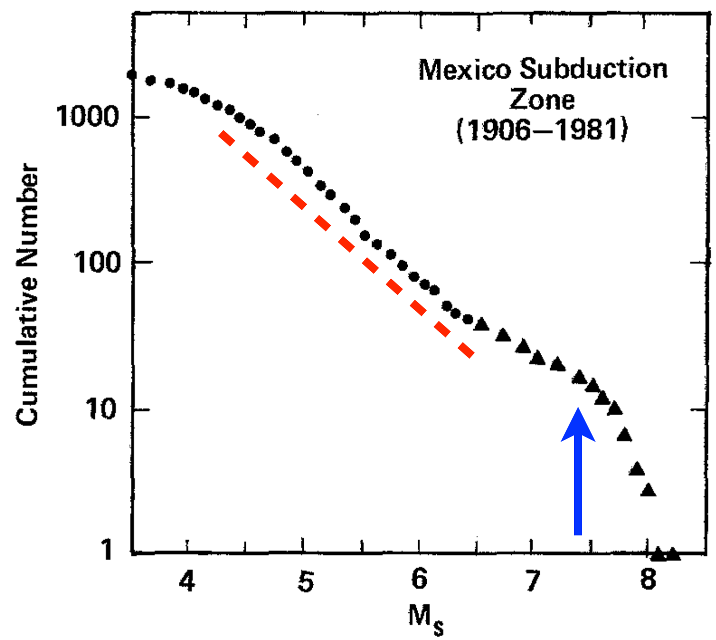


ref: http://crust.geol.vt.edu/asayed/research/Gouge.htm

Some characteristics of models, measurements, and earthquakes





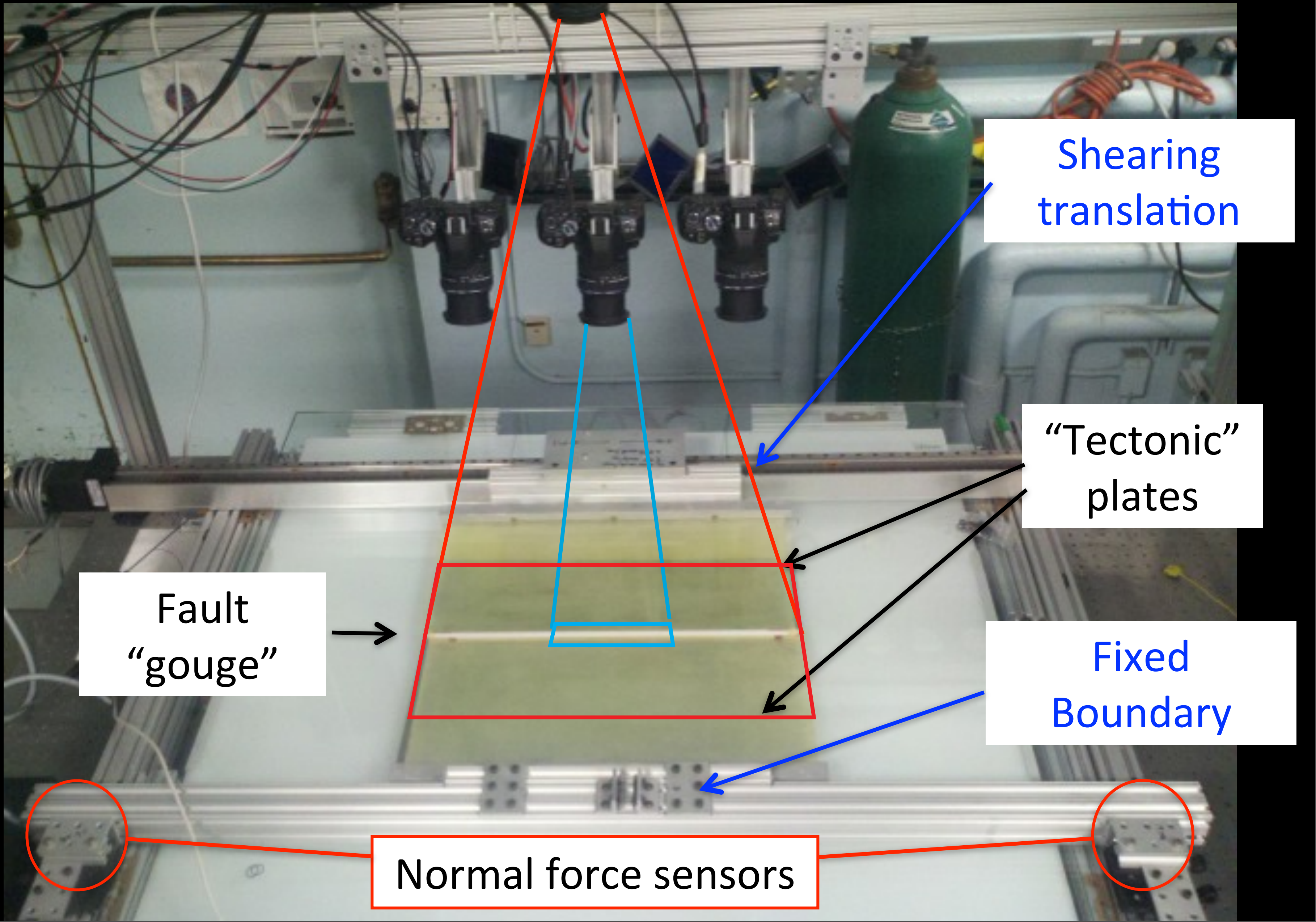


Outline

- Built an experimental “Lab Quake” apparatus with granular “fault gouge” and elastic “tectonic plates”.
- Measurements of plate strain (ball bearing motion) and stress (photoelastic response).
- Global Response: Moment Distributions and Recurrence Time
- Granular Response: Corresponding granular motion for events

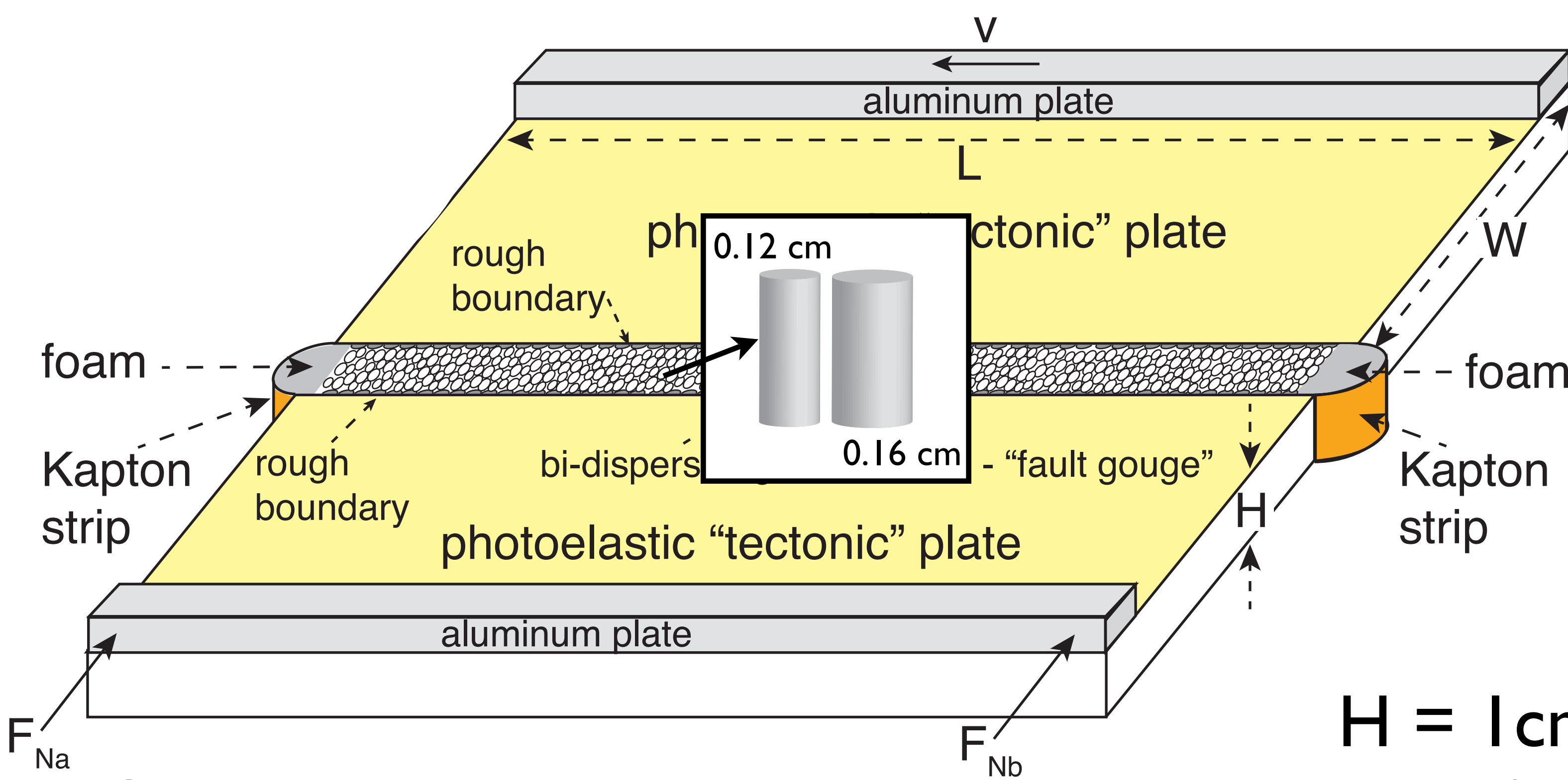
Geller, Dahmen, Backhaus, RE arXiv

Experimental Apparatus



Experimental Schematic

$v = 4\ \mu m/sec: L^{-1} dx/dt = 8x10^{-6}\ s^{-1}$

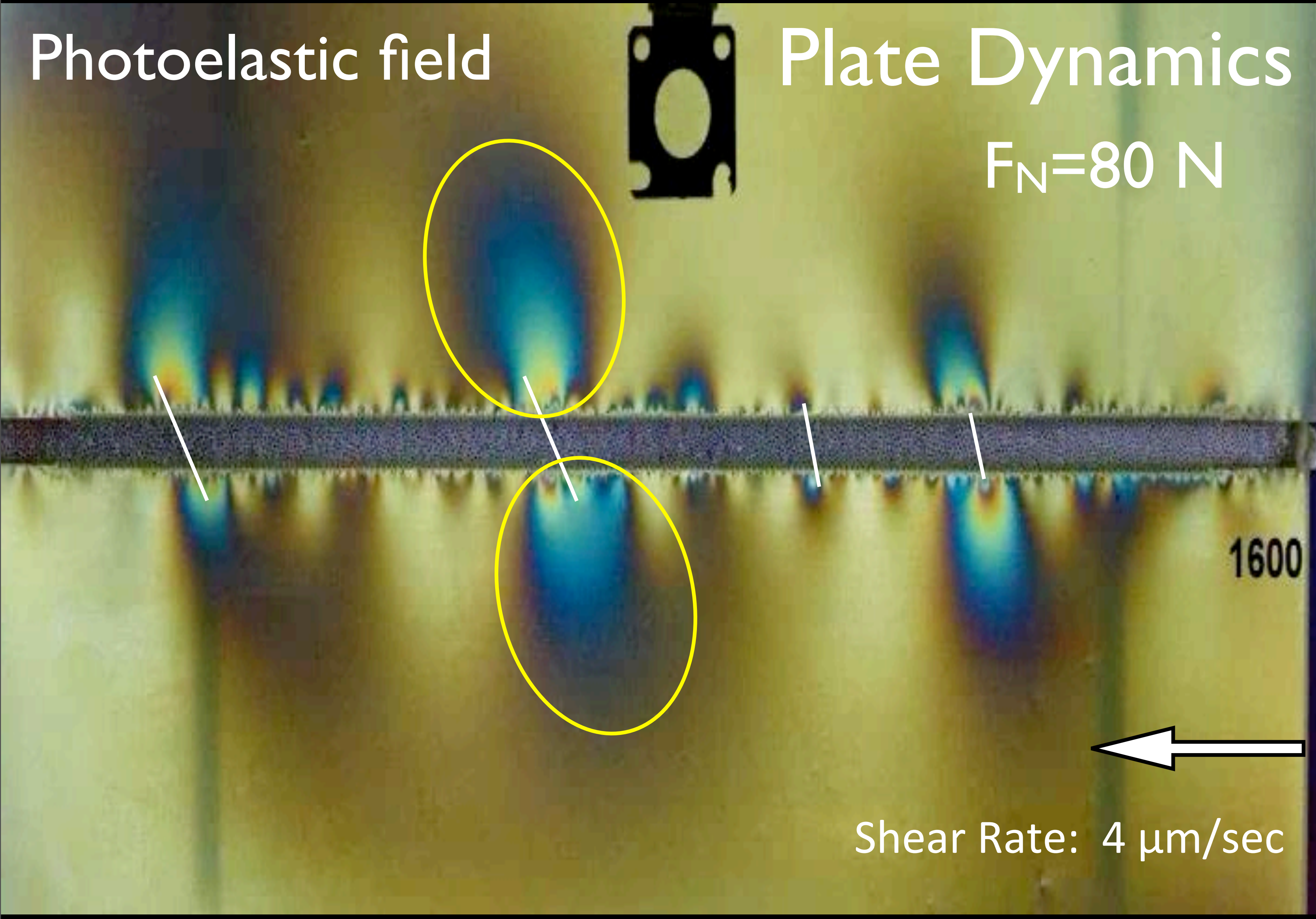


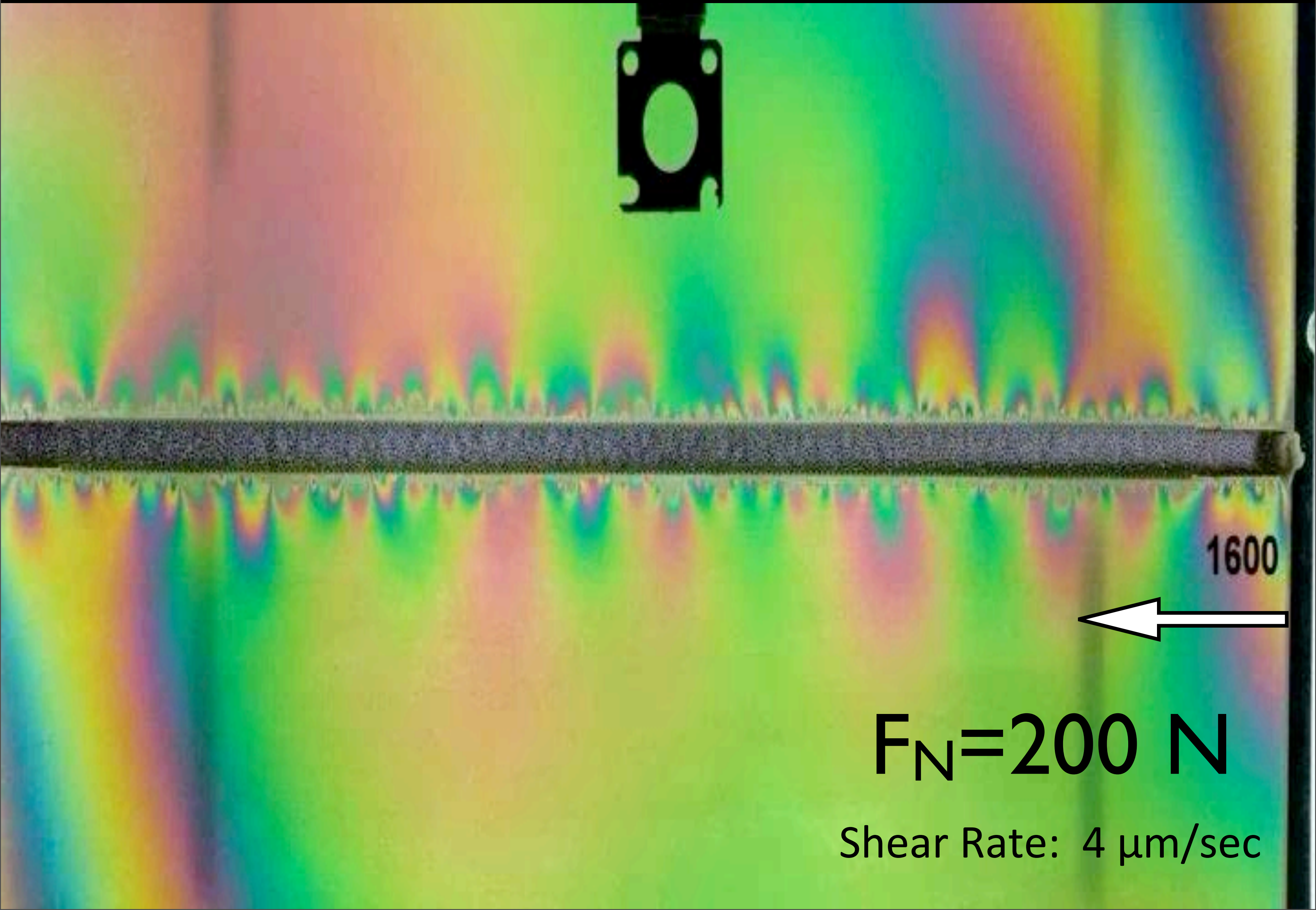
Compressive Normal Force

$F_N = F_{Na} + F_{Nb}$

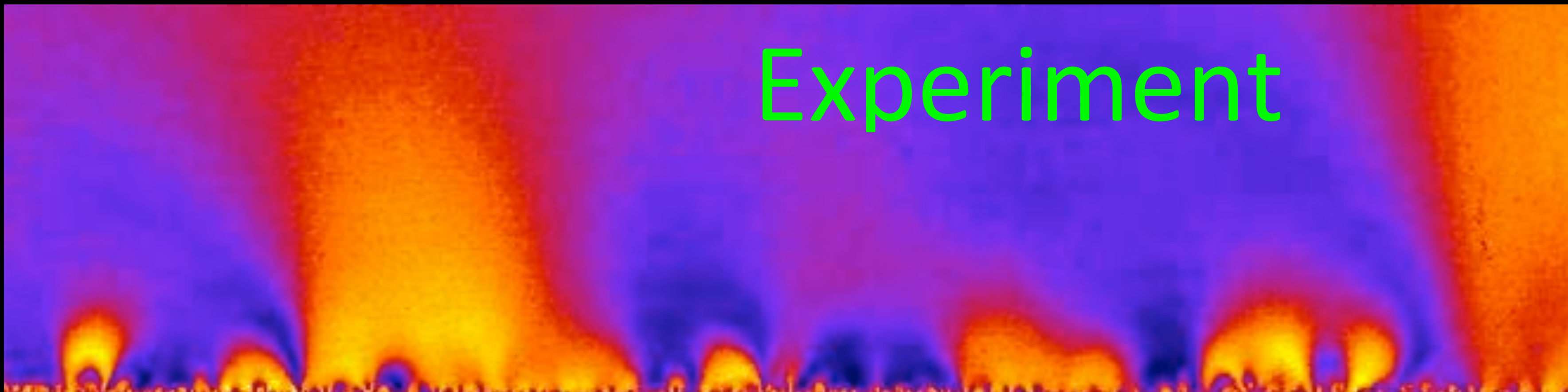
H = 1cm
L = 50 cm
W = 25 cm

$E_{plate} \sim 2.5$ MPa $E_{grain} \sim 1$ GPa (hard sphere gas)

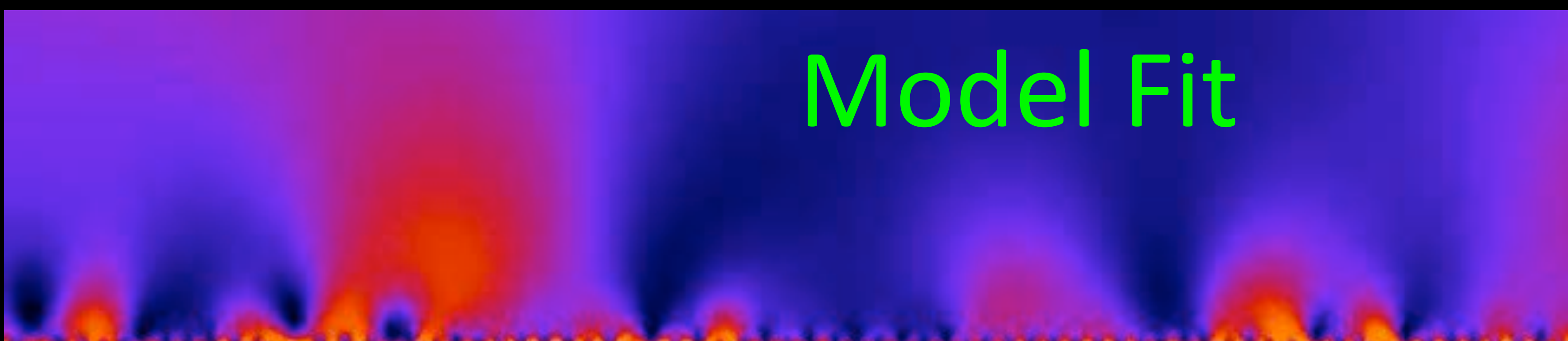

Photoelastic field
Plate Dynamics
F_N=80 N
1600
Shear Rate: 4 µm/sec


1600
F_N=200 N
Shear Rate: 4 µm/sec

Macroscopic Stress Field

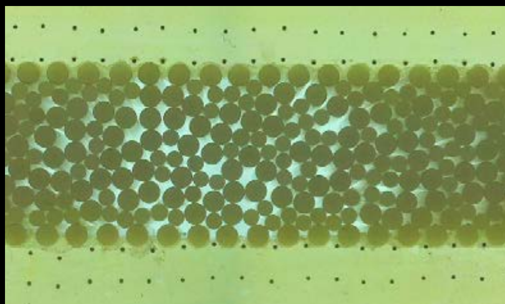


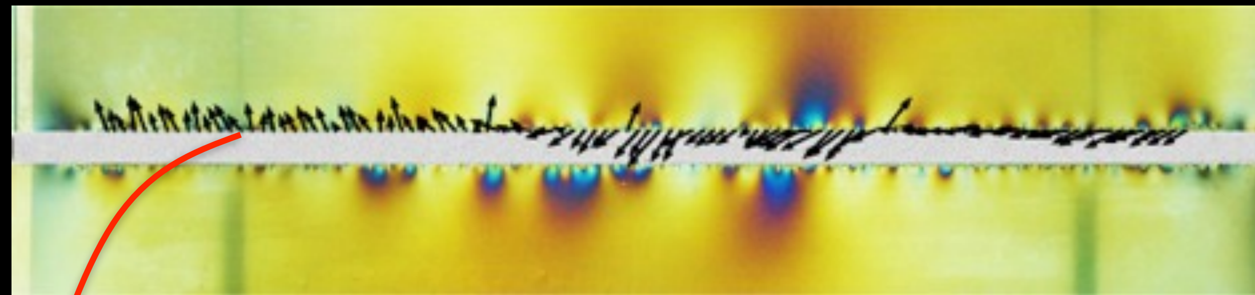
202 unknown experimental F_N and F_T



Maximize image cross correlation
over 202 synthetic F_N and F_T

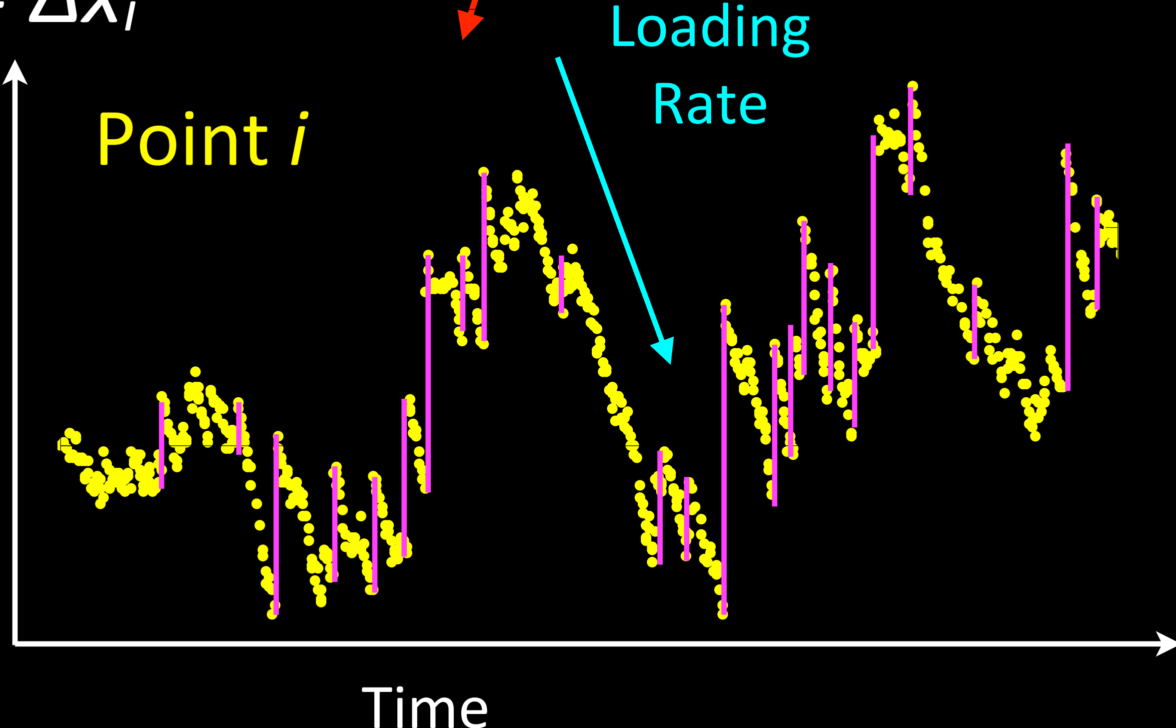
Detailed Interfacial Displacements





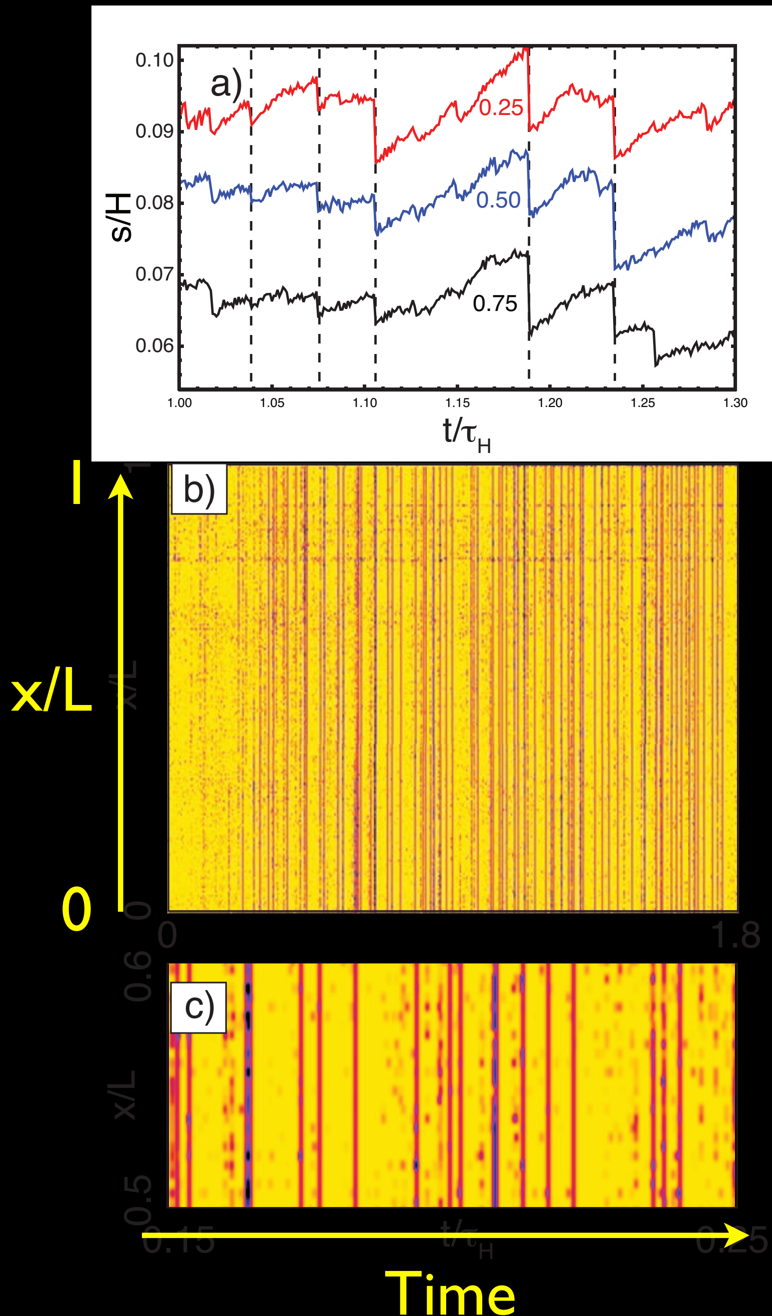
x →

$s_i = \Delta x_i$



Moment of event j

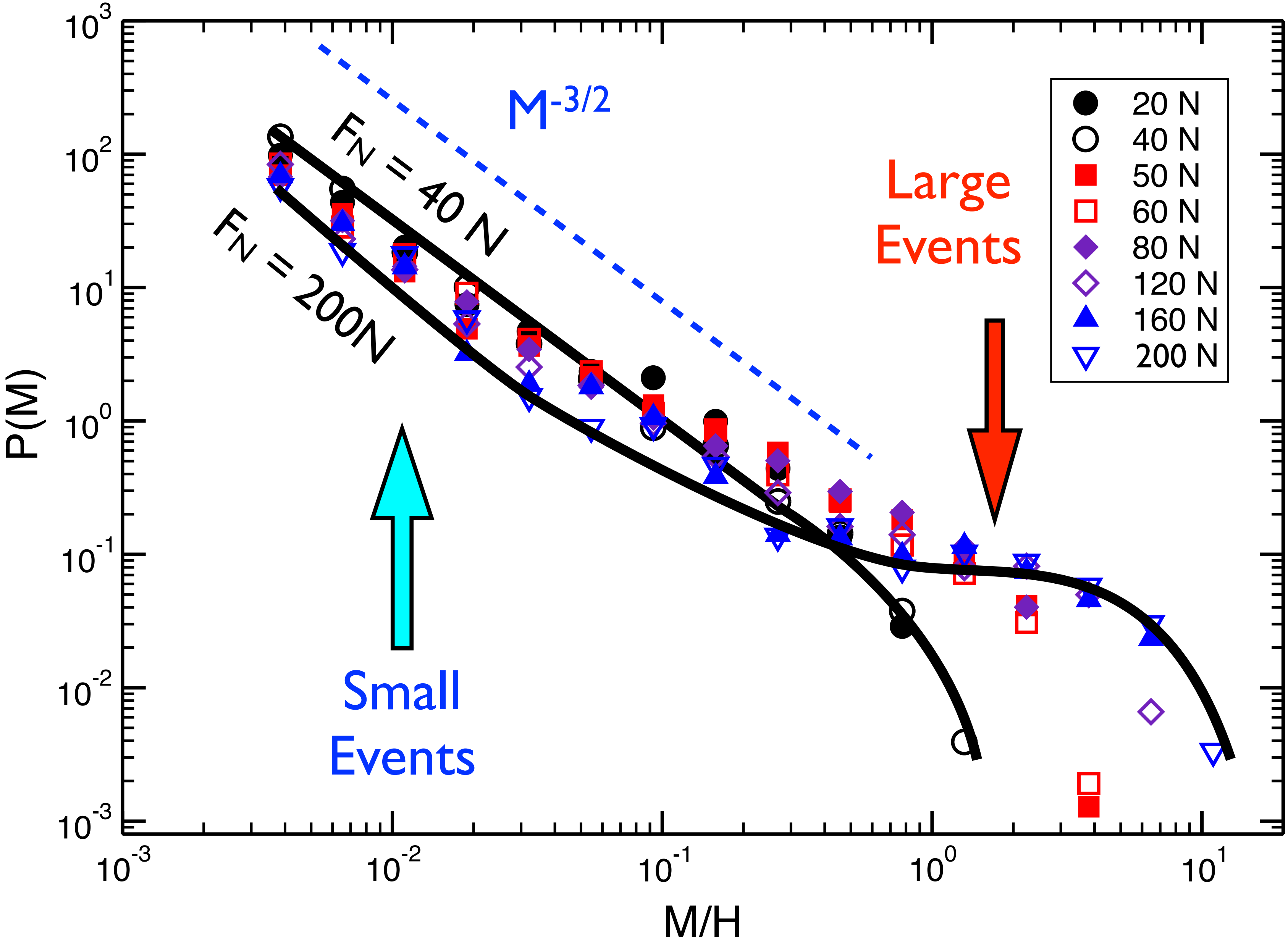
$$M_j = \sum s_i^j$$



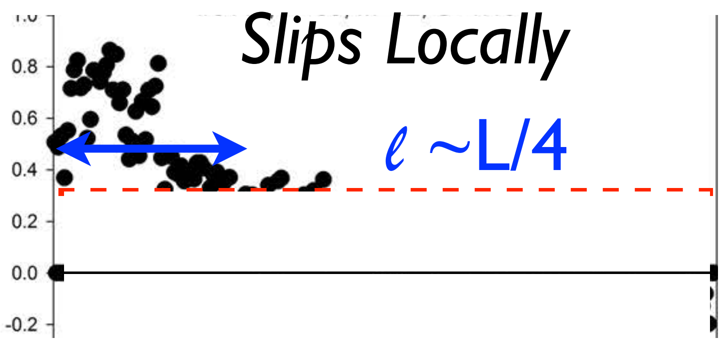
Temporal Structure - 3 locations: L/4, L/2, 3L/4

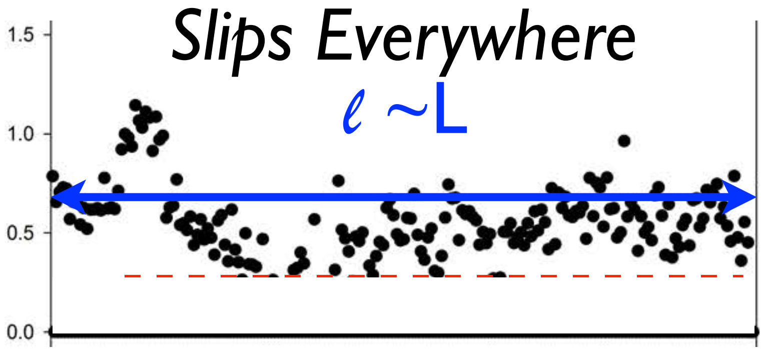
Spatio-Temporal Structure - “Large” and “small” events; small events are spatially distributed

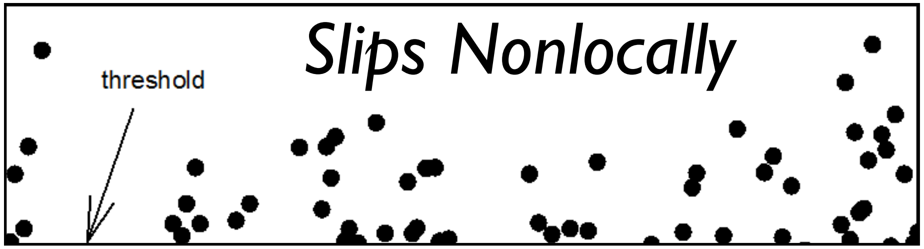
Moment Distribution



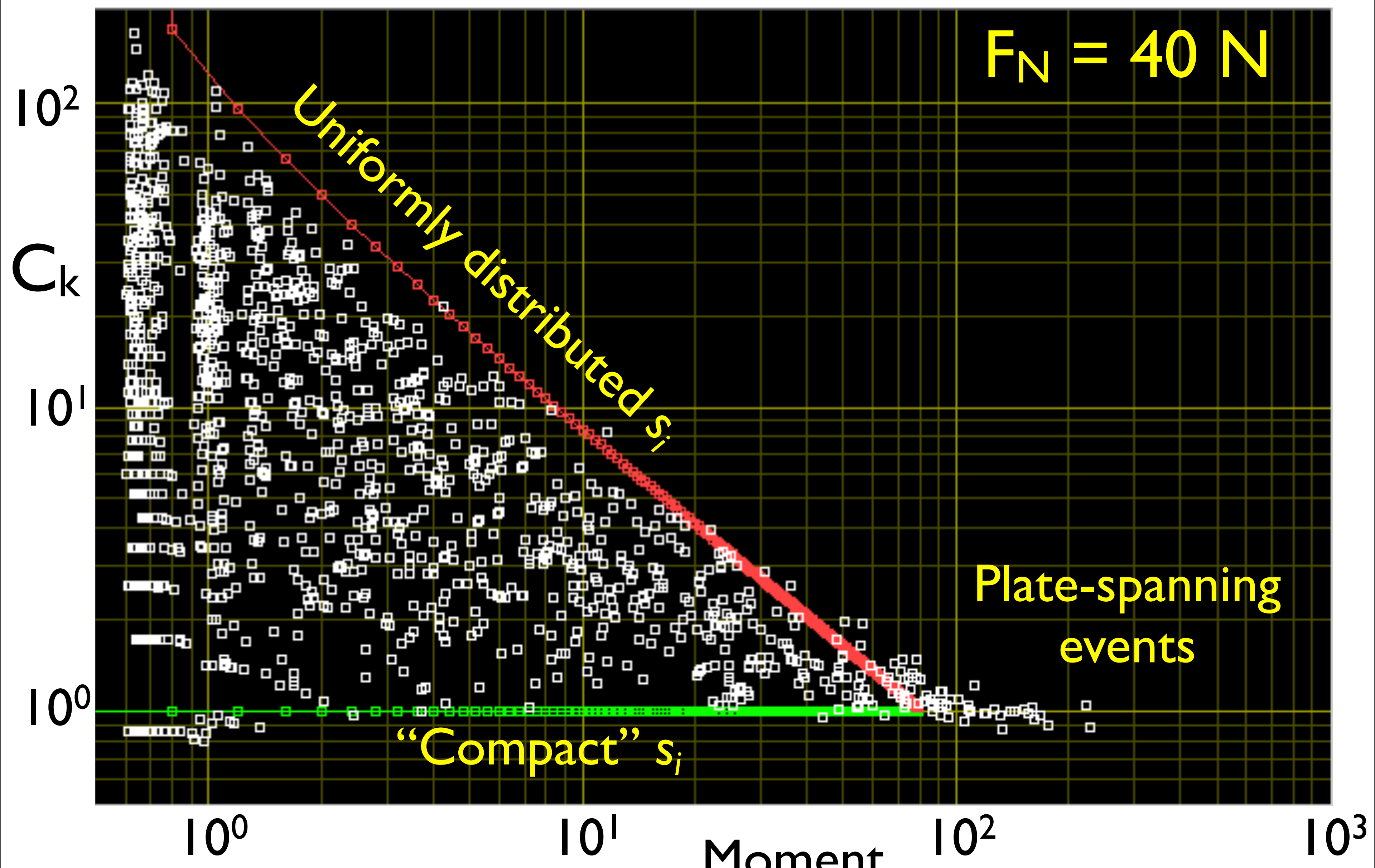
Event Spatial Distribution



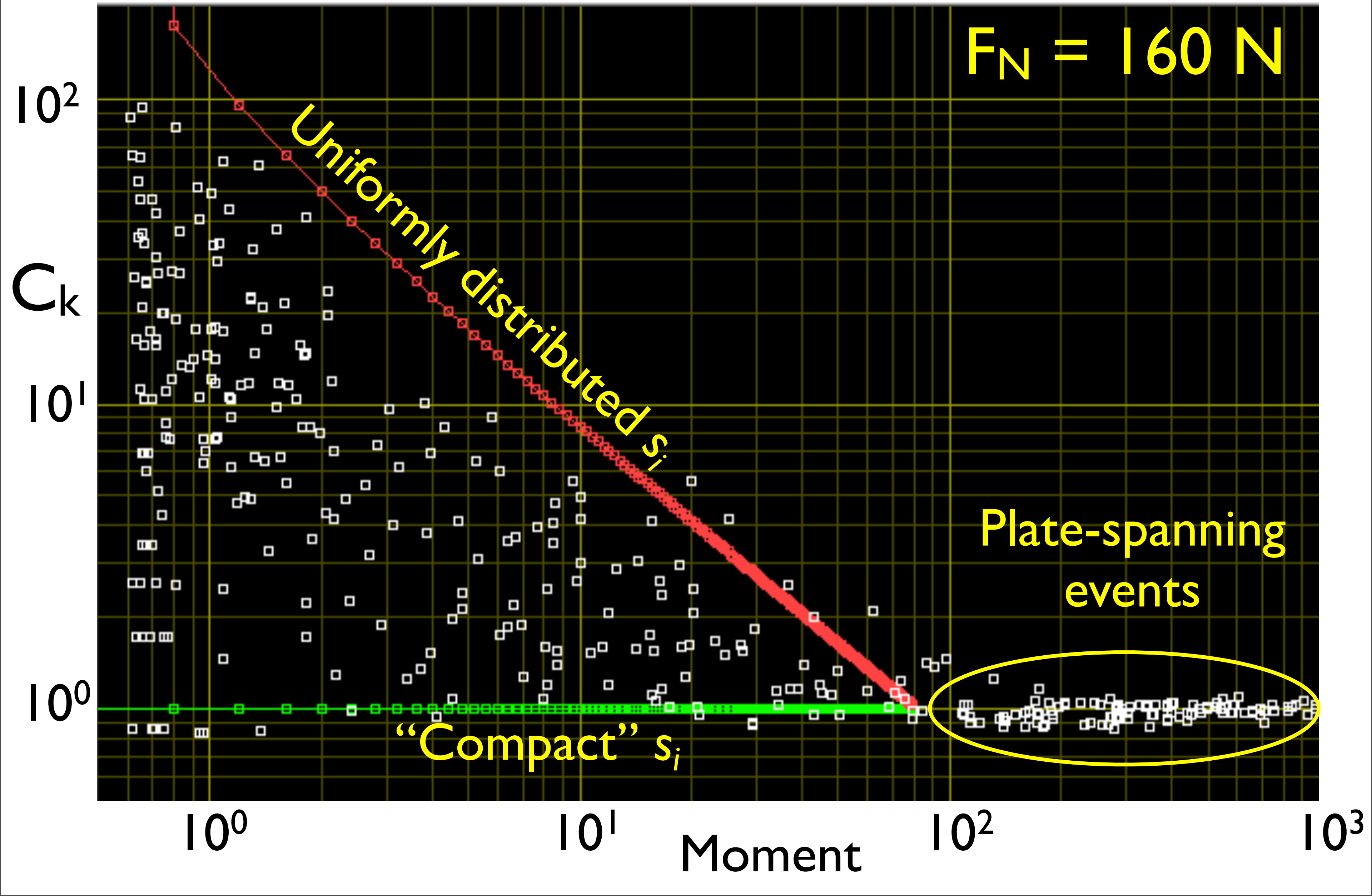




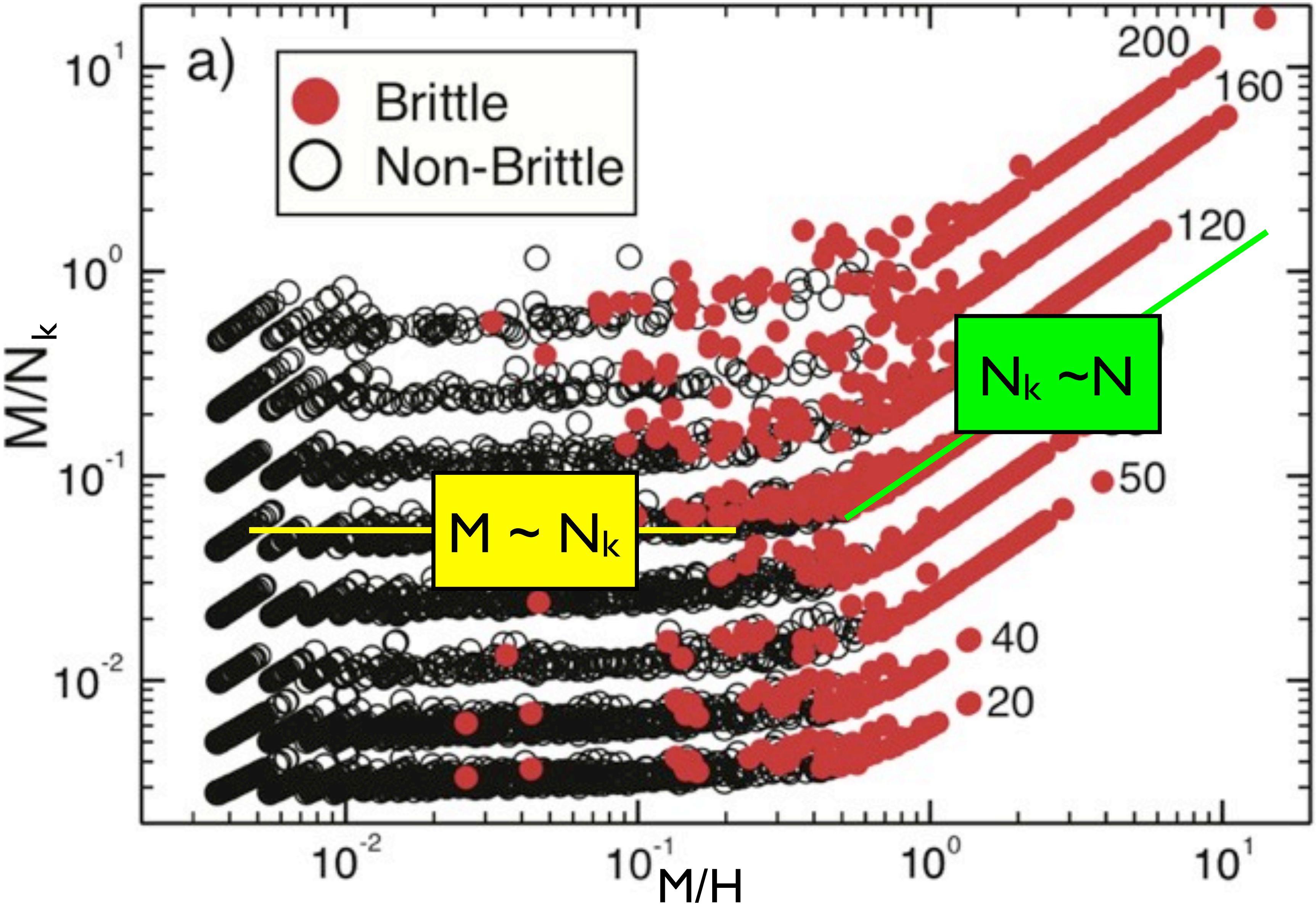
Spatial Distribution of Events



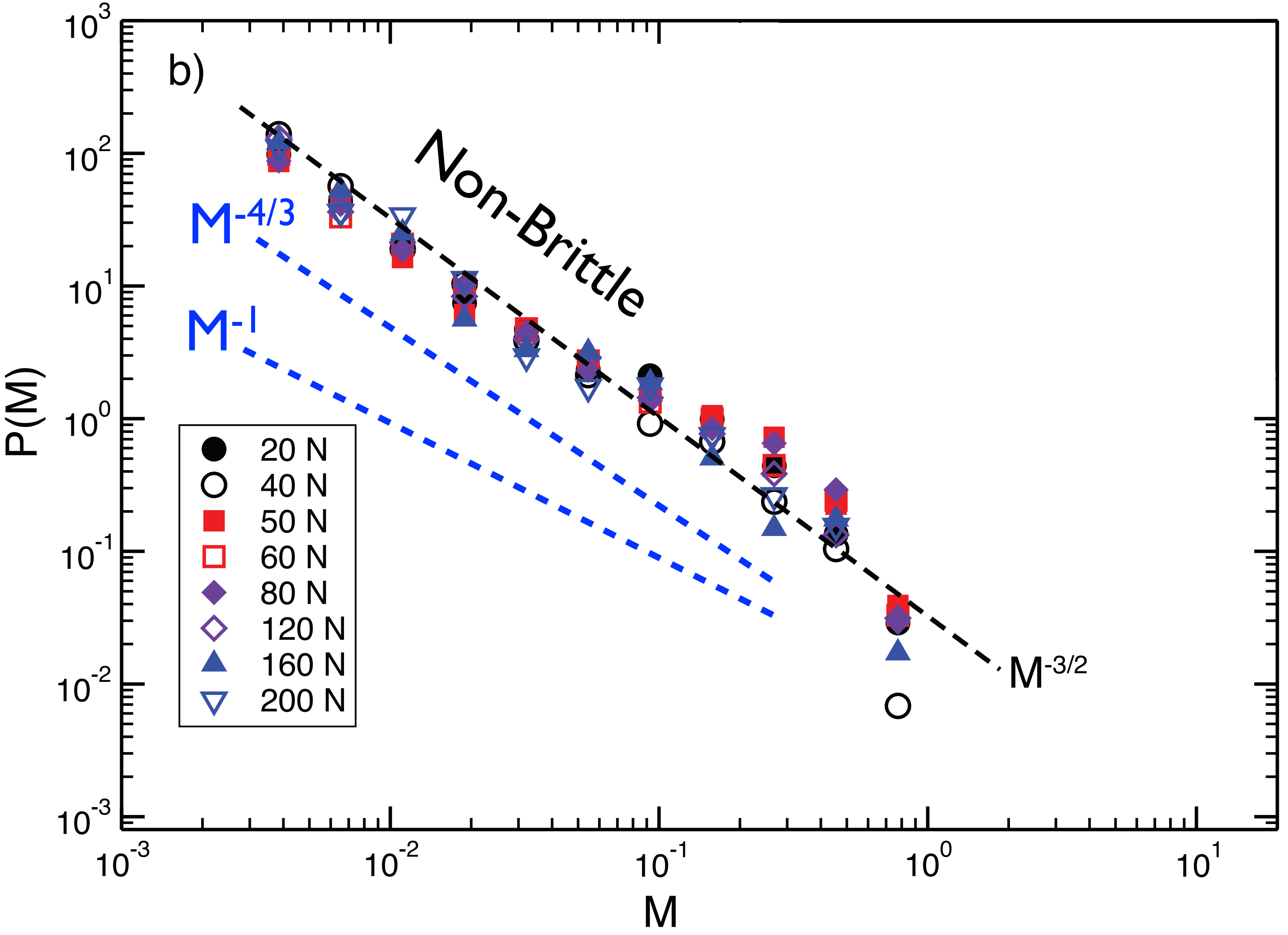
Spatial Distribution of Events



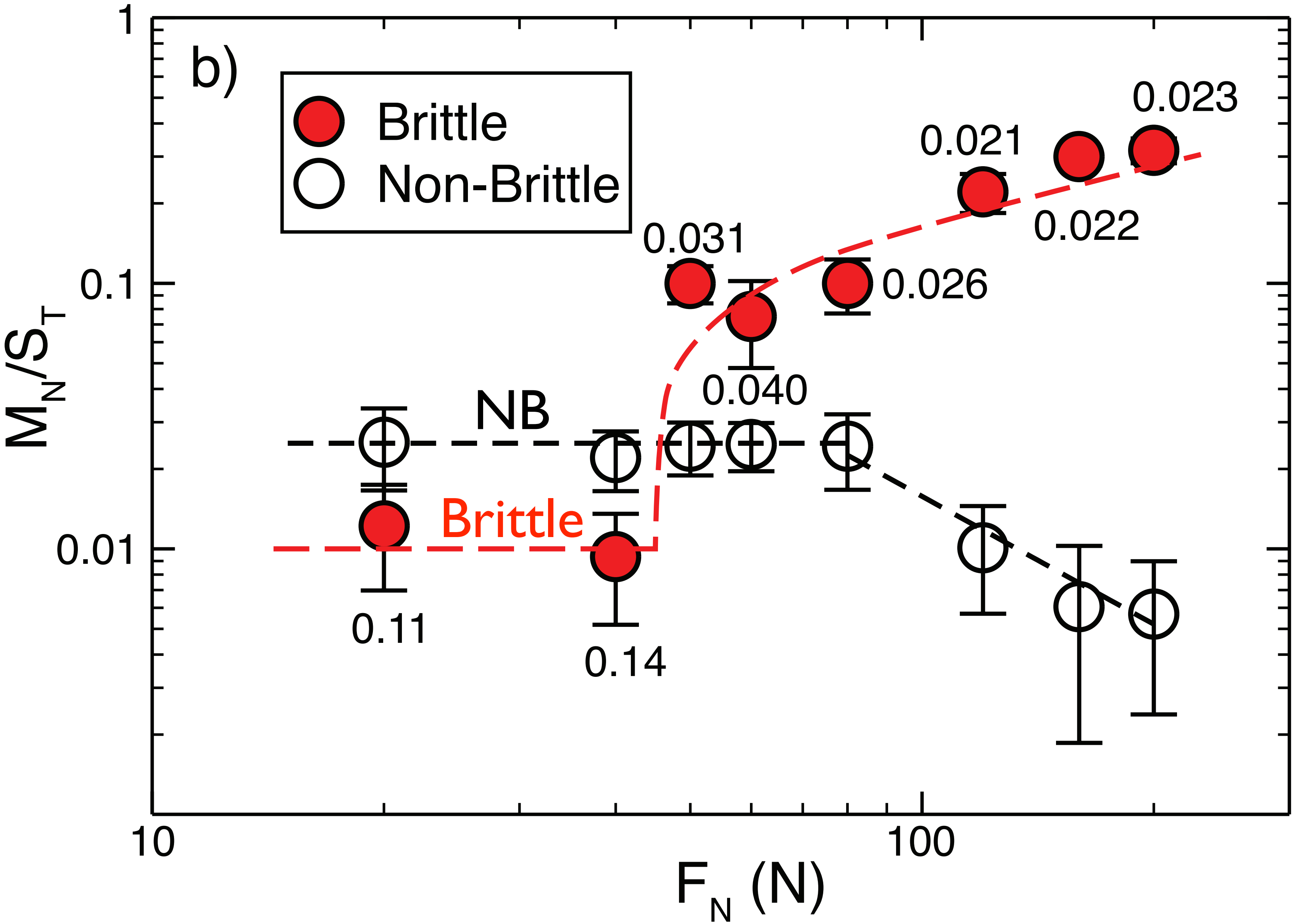
Moment per Number Moved N_k



Moment Distribution - Separated



Fractional Slip



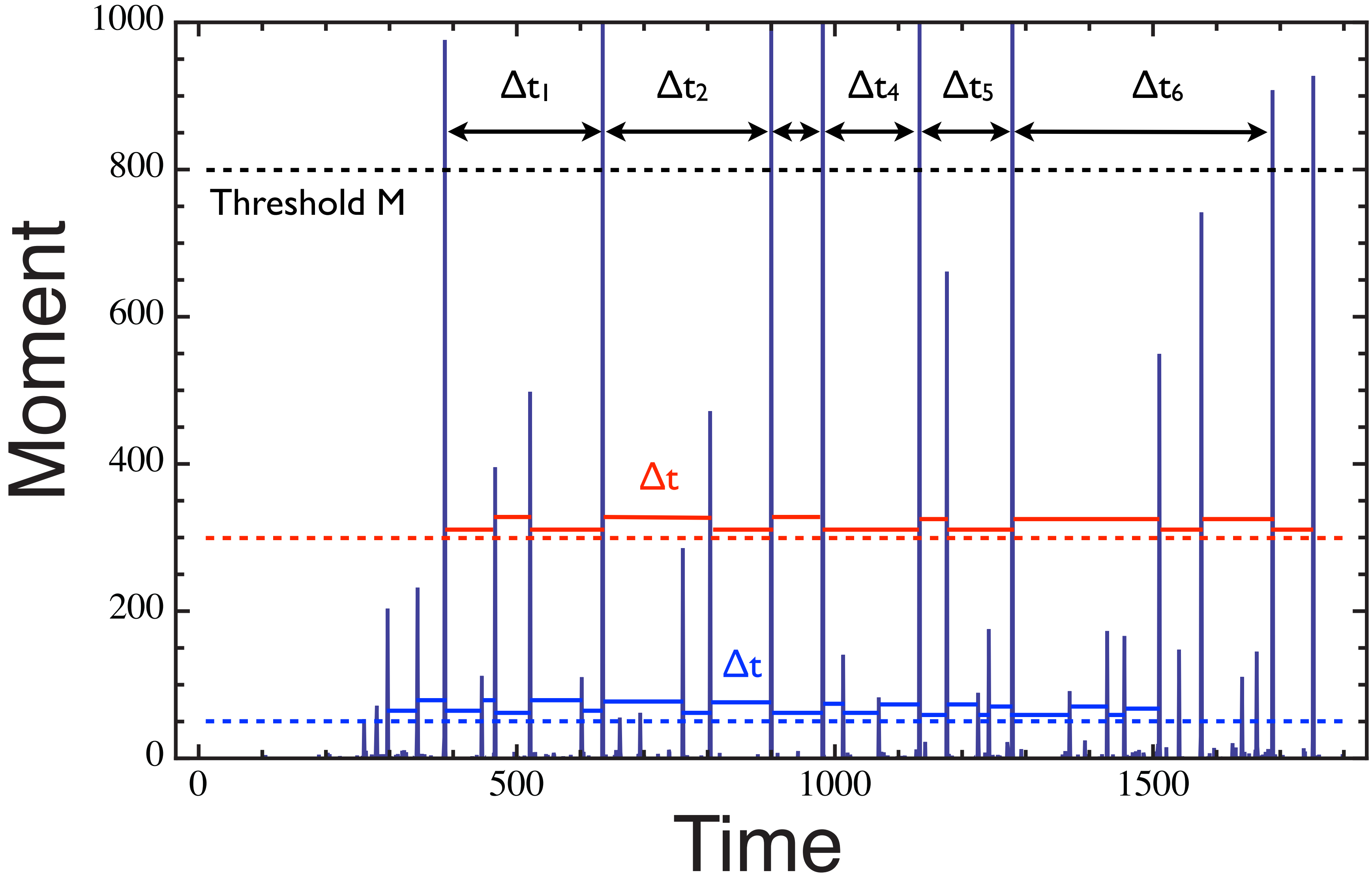
Moment Distribution

$P(M) \sim M^{-1.5}$ for small M (mean-field result).

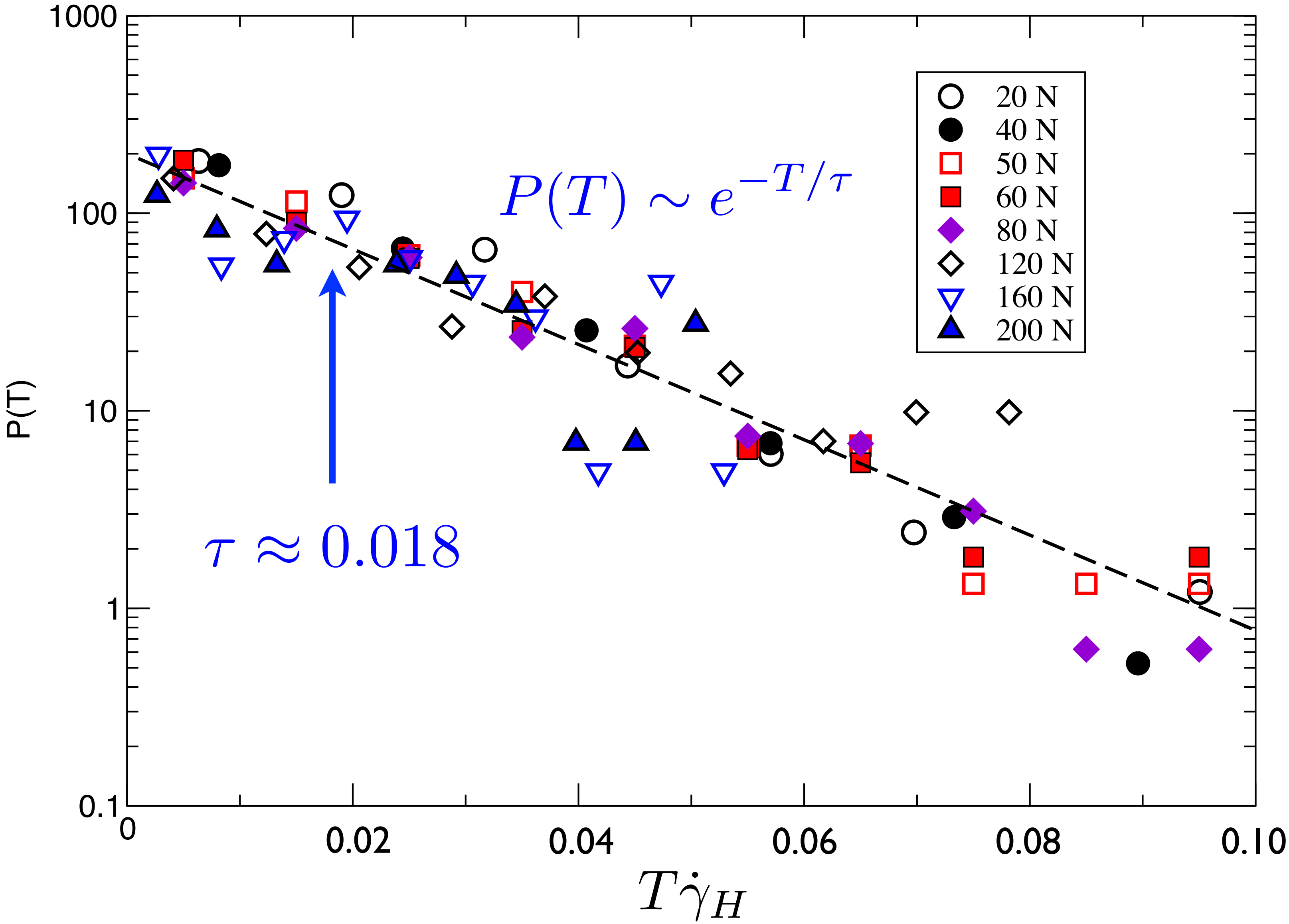
Enhanced probability for large, system-spanning events at higher F_N - Log-Normal distribution (?)

How about temporal recurrence?

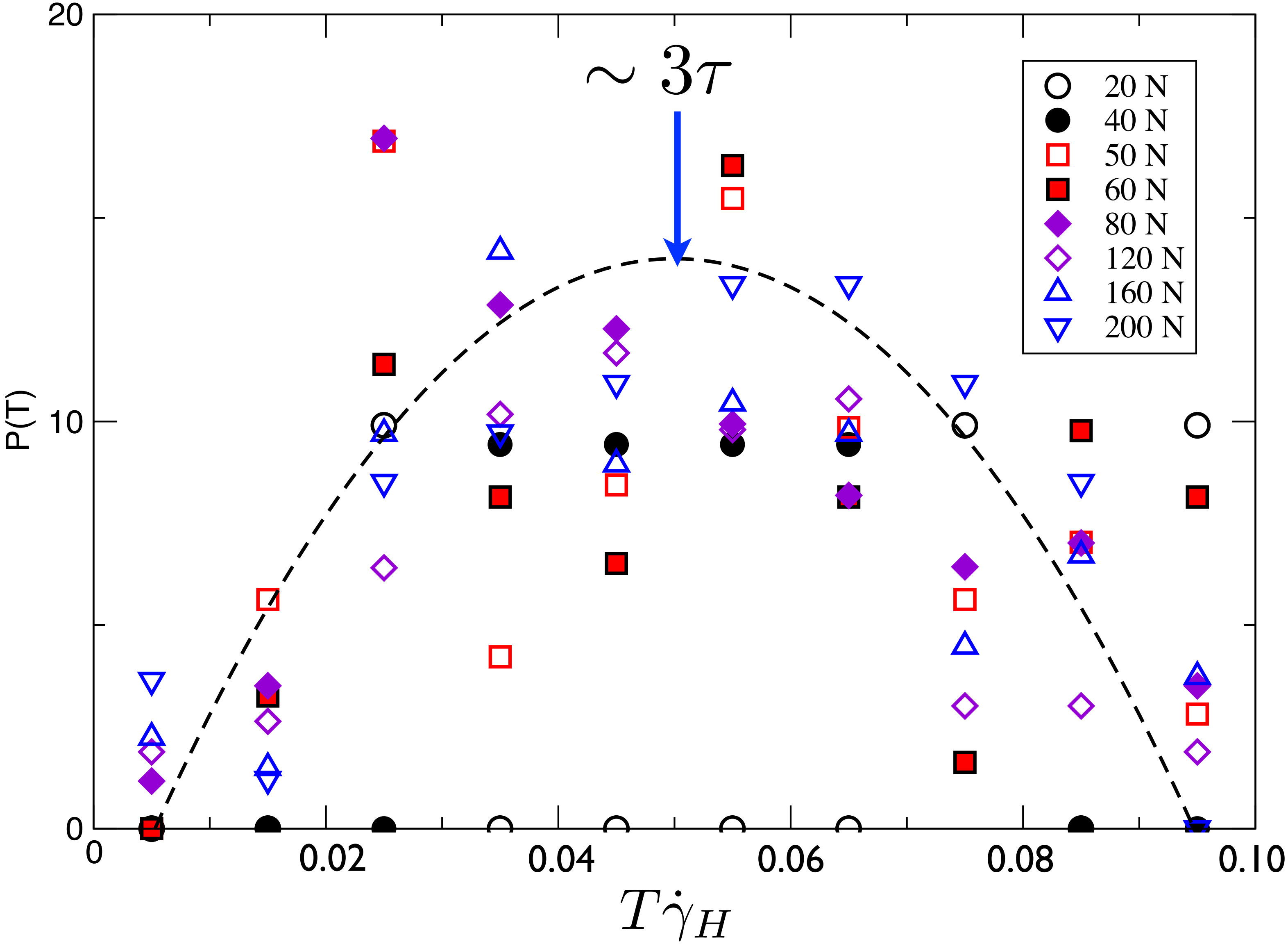
Recurrence Time Statistics



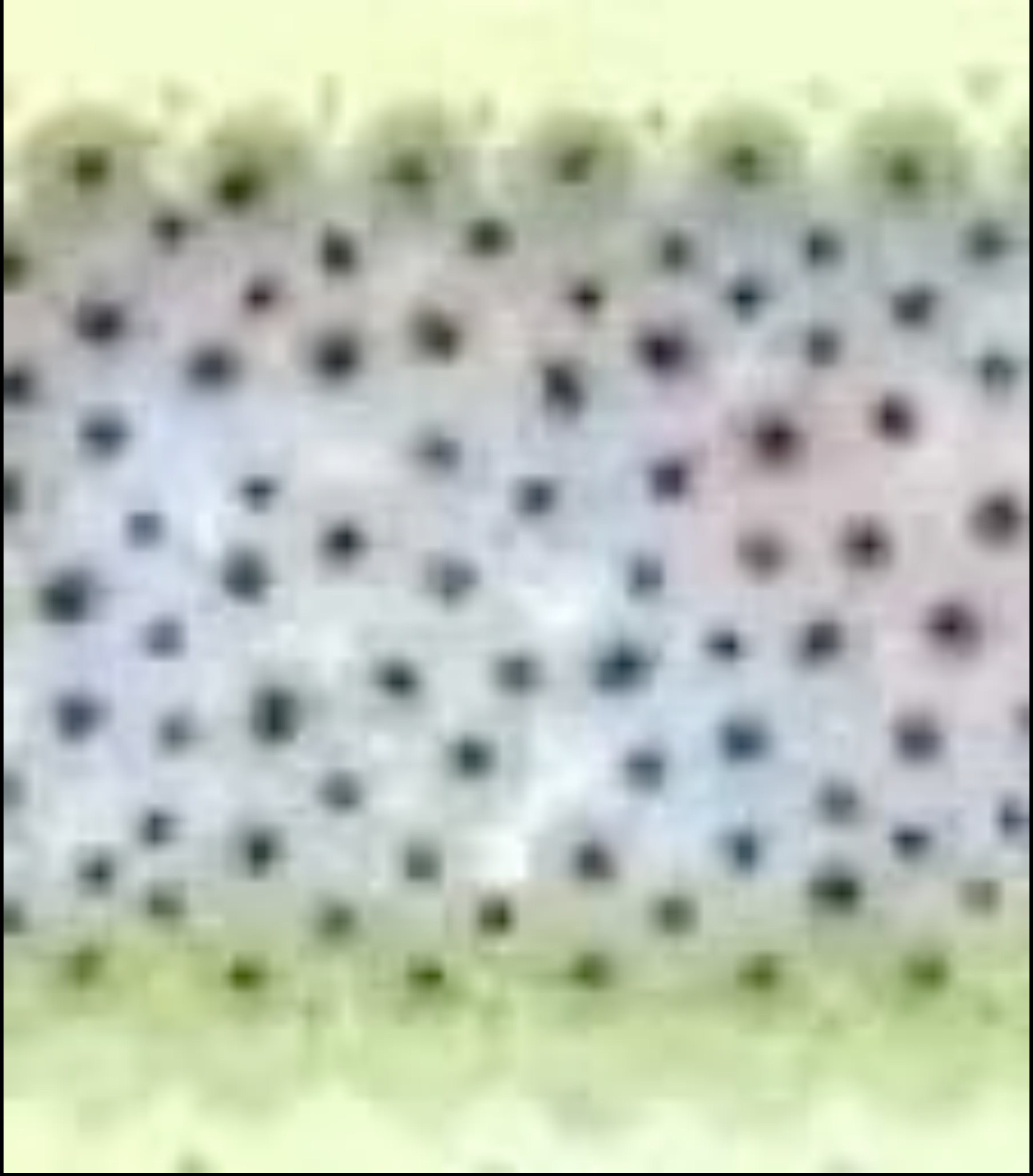
Non-Brittle: Poisson distributed



Brittle: Broad Distribution

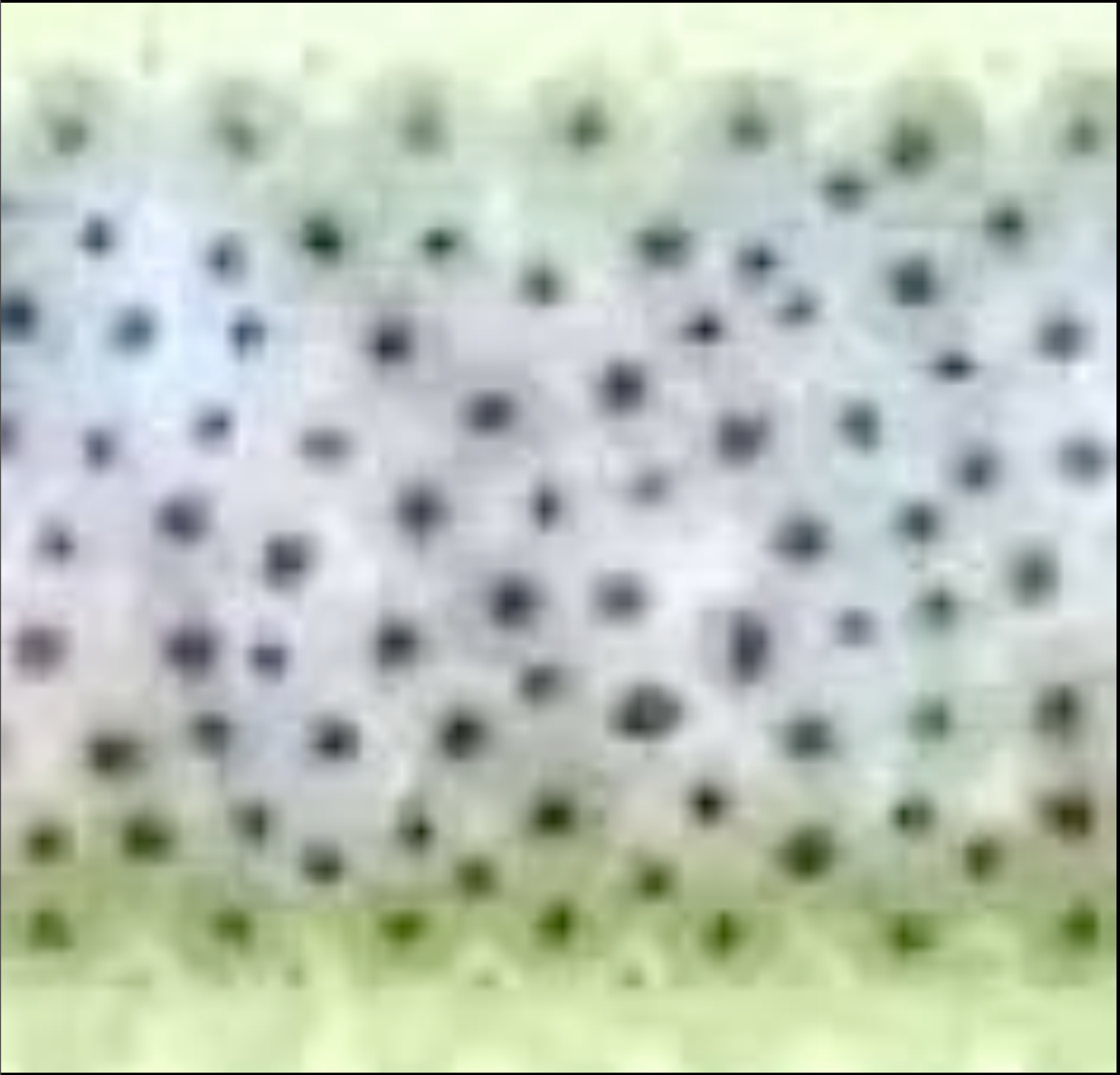


What is happening in the granular material?



F_N=40 N

x 60000

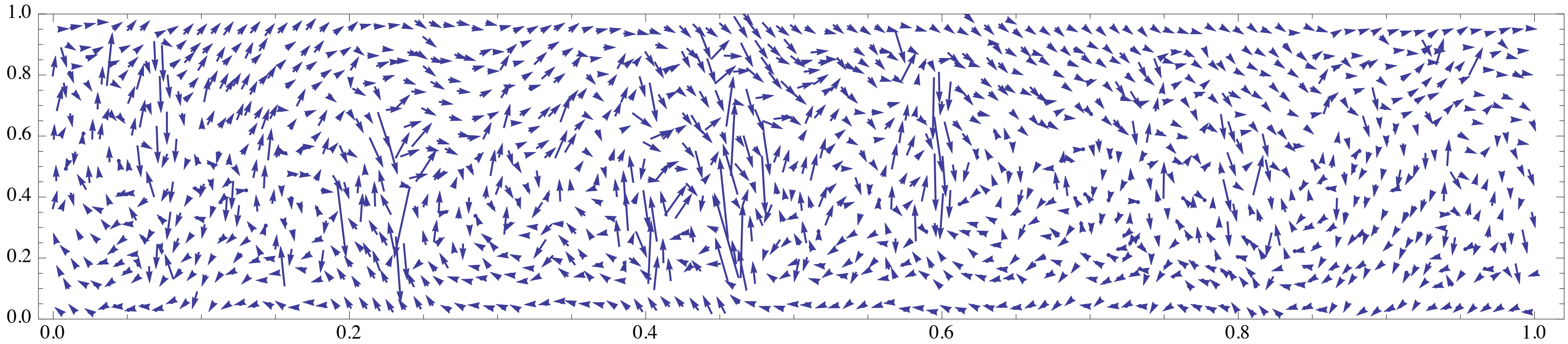


F_N=200 N

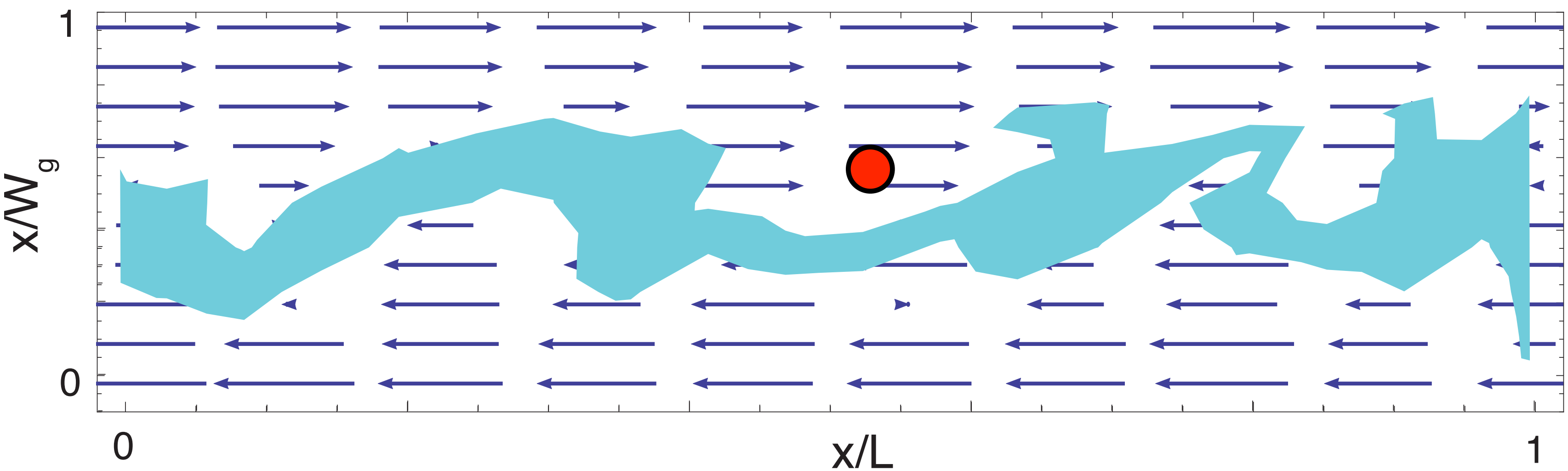
x 60000

Characteristic Brittle Event

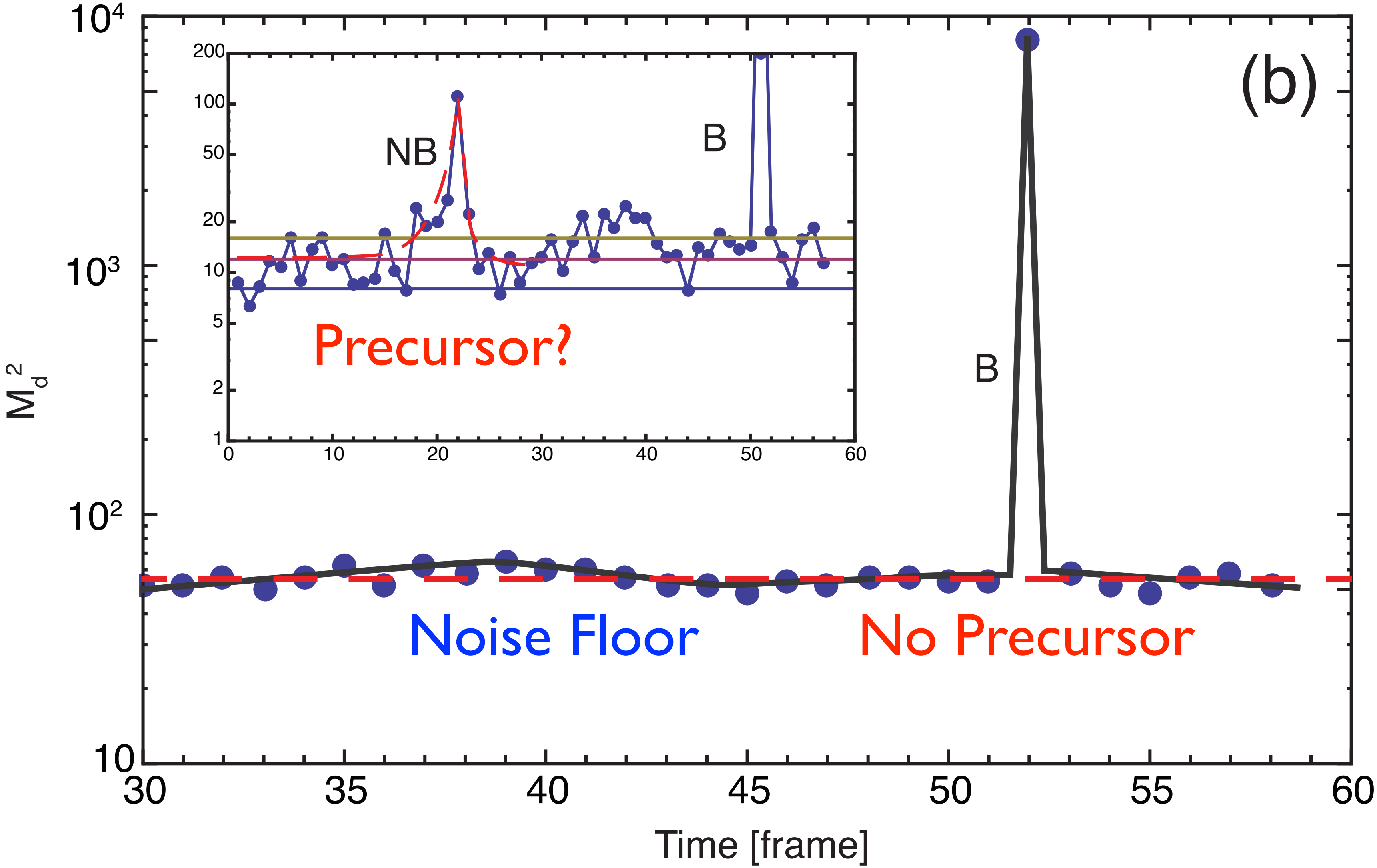
Local Grain Displacements



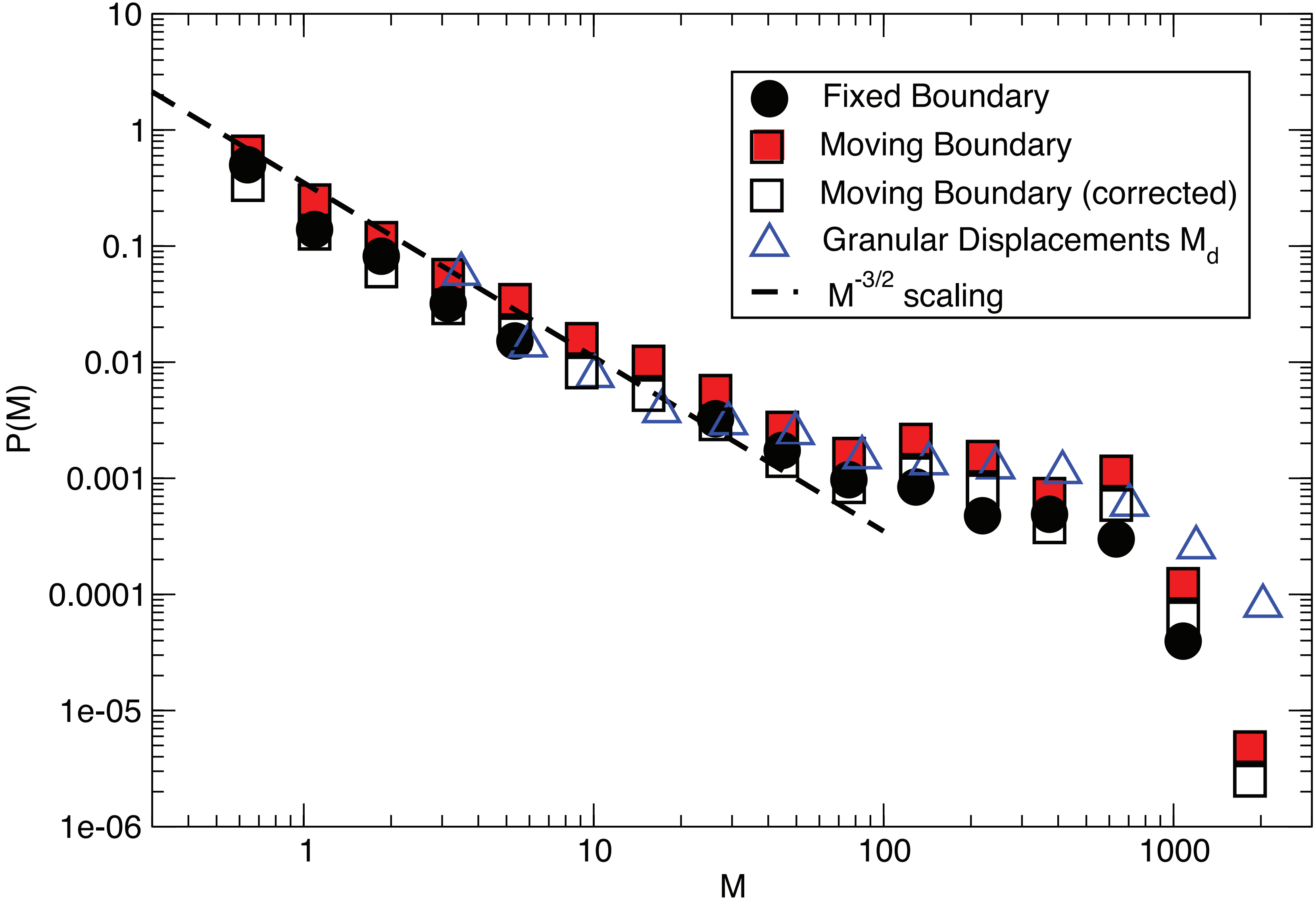
Mean Lateral Displacements



Total spatial RMS displacements



Where ever you look - it's the same



Summary

- “Lab Quake” apparatus with granular “fault gouge” and “tectonic plates”.
- $M^{-3/2}$ distribution for non-brittle events and Log-Normal distribution for brittle events.
- NB events Poisson distributed; Brittle events have a characteristic repeat period.
- Friction? - Scaling? - Size? - Fracture? - Earthquakes?