

Funding:



# Acoustics of Failure

Geohazard Forecasting

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Collaborators:



SQUISHLAB



DANIELS LAB



# Earthquakes and Landslides



Earthquake fault [Alec,28]

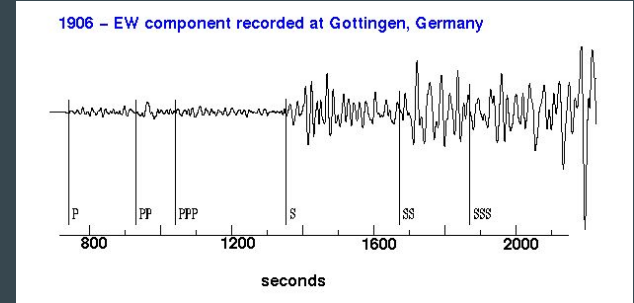
# Earthquakes and Landslides



Zhang Heng's vase  
(132 CE) [24]



The first “artificial  
earthquakes” [21]

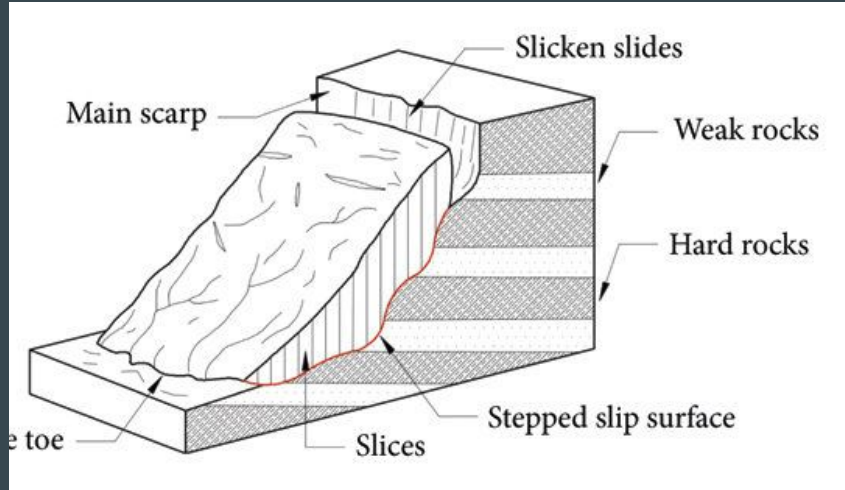


Göttingen- the first  
Seismograph (1903) [20]

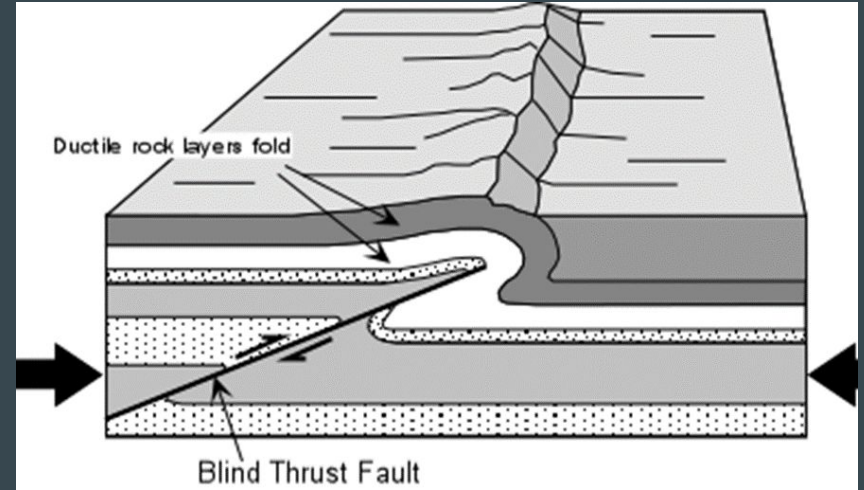
Wiechert and Mintrop



# Earthquakes and Landslides



The matter of a landslide  
(granular) [22]



The gouge of an earthquake  
(Filled with granular matter)  
[23]

# Granular Materials- Solid, Liquid or Gas?

“Solid”  
Sandcastle  
[19]



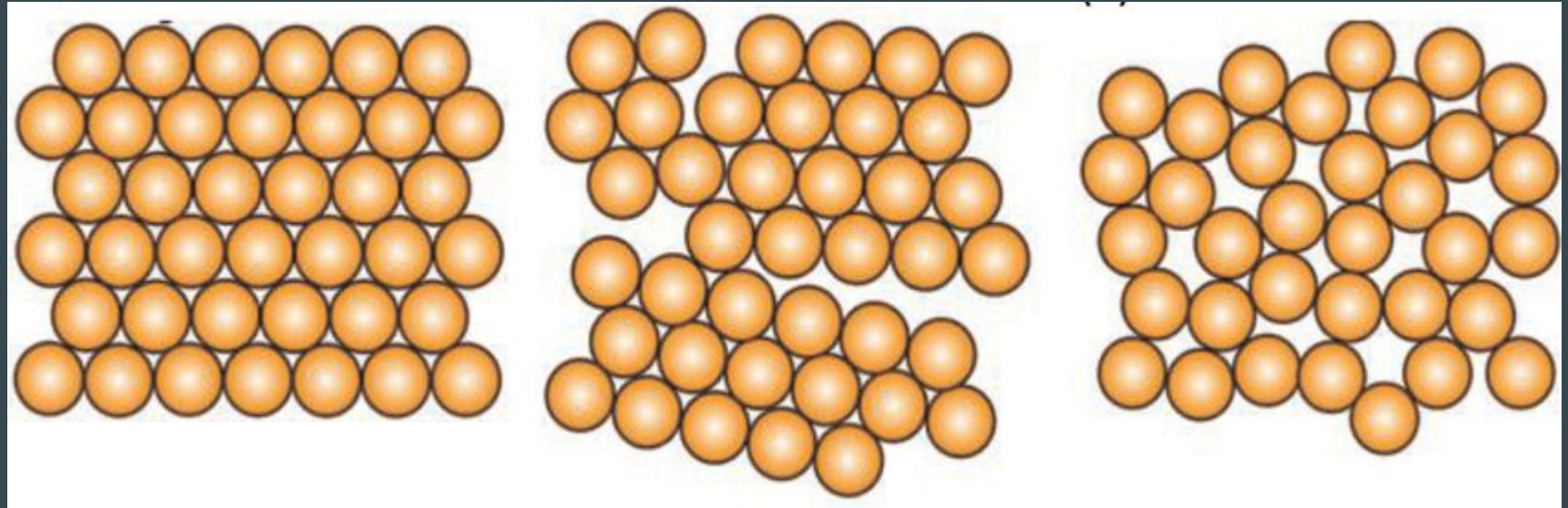
Flowing  
“Liquid”  
Hourglass  
Sand [26]



“Gaseous”  
Sand in a  
Sandstorm  
[25]



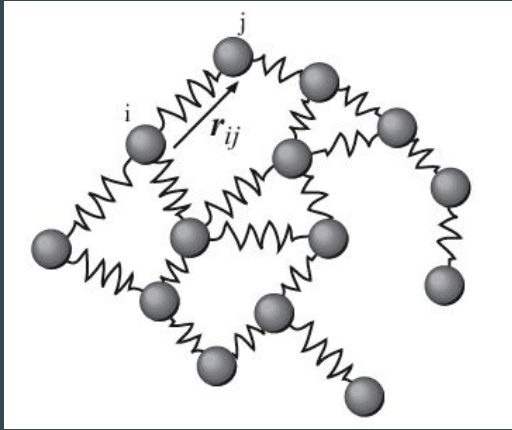
# Order vs Disorder [22]



Crystalline

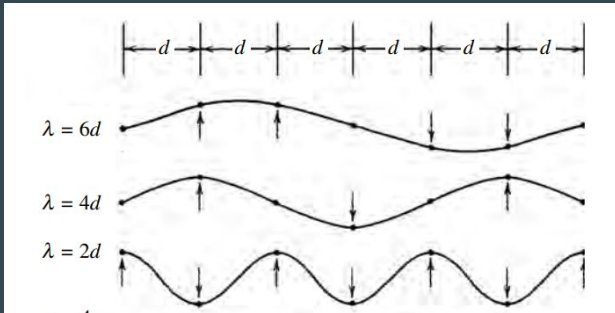
Amorphous

# Debye Scaling and Phonons

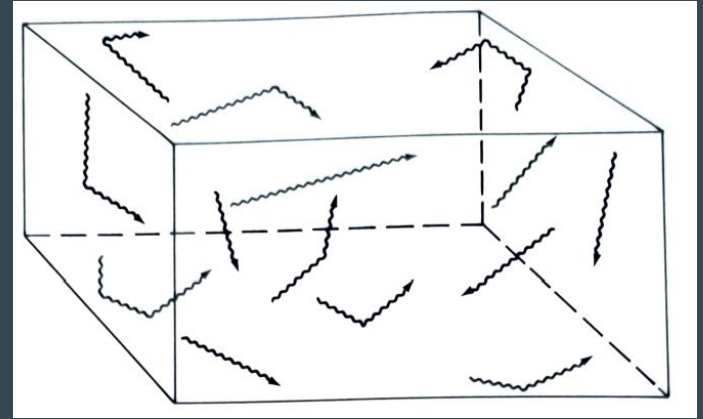


Spring Lattices [27]

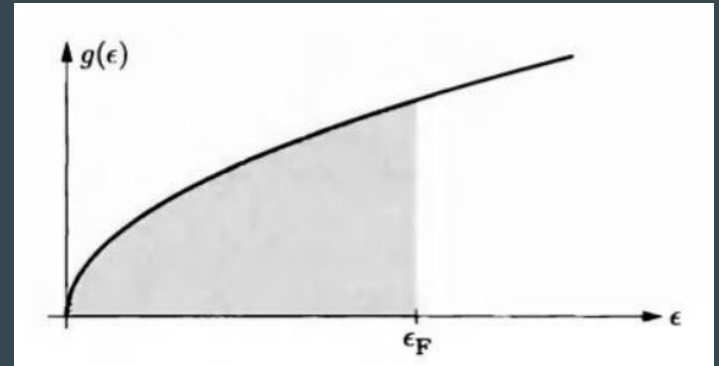
$$D(\omega) \propto \omega^{d-1}$$



Phonons waves [5]



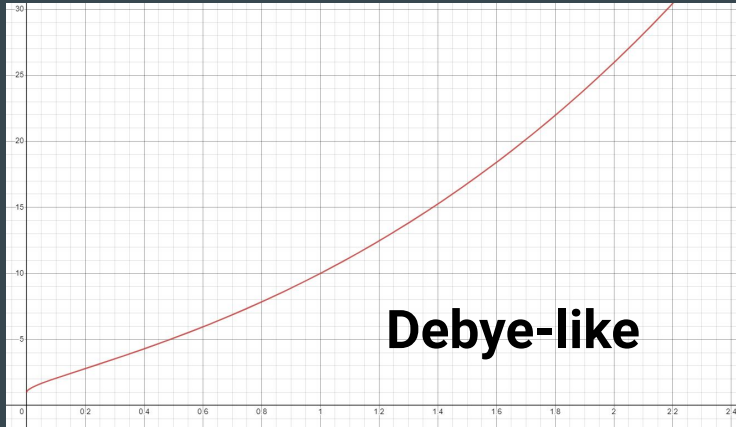
Phonons in a solid [5]



Debye Scaling in 3D [6]

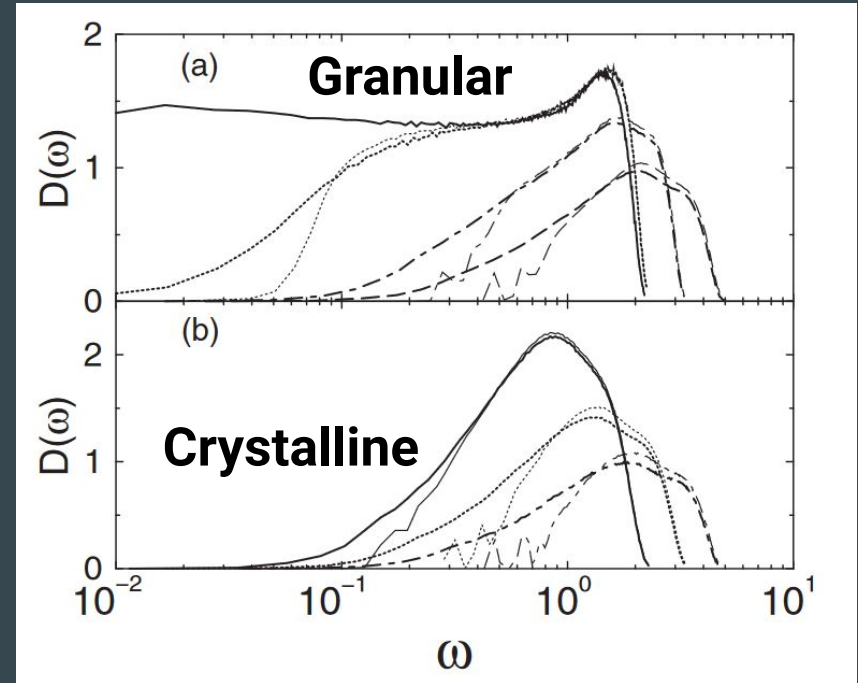
# Density of Modes in Granular Materials

Debye[6] :



$$D(\omega) \propto \omega^2$$

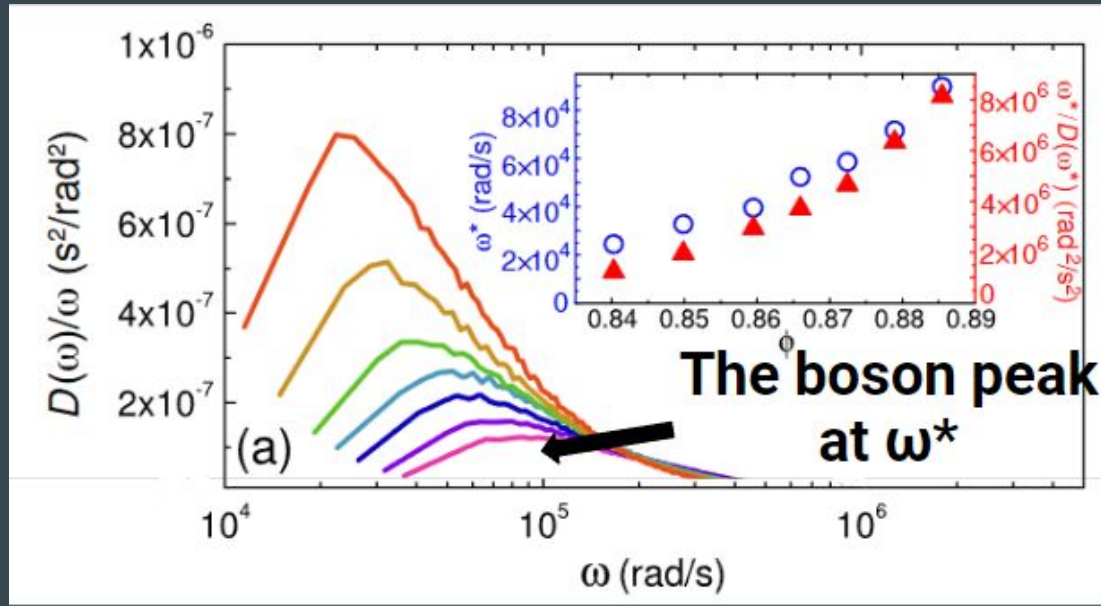
Experiments[7] :





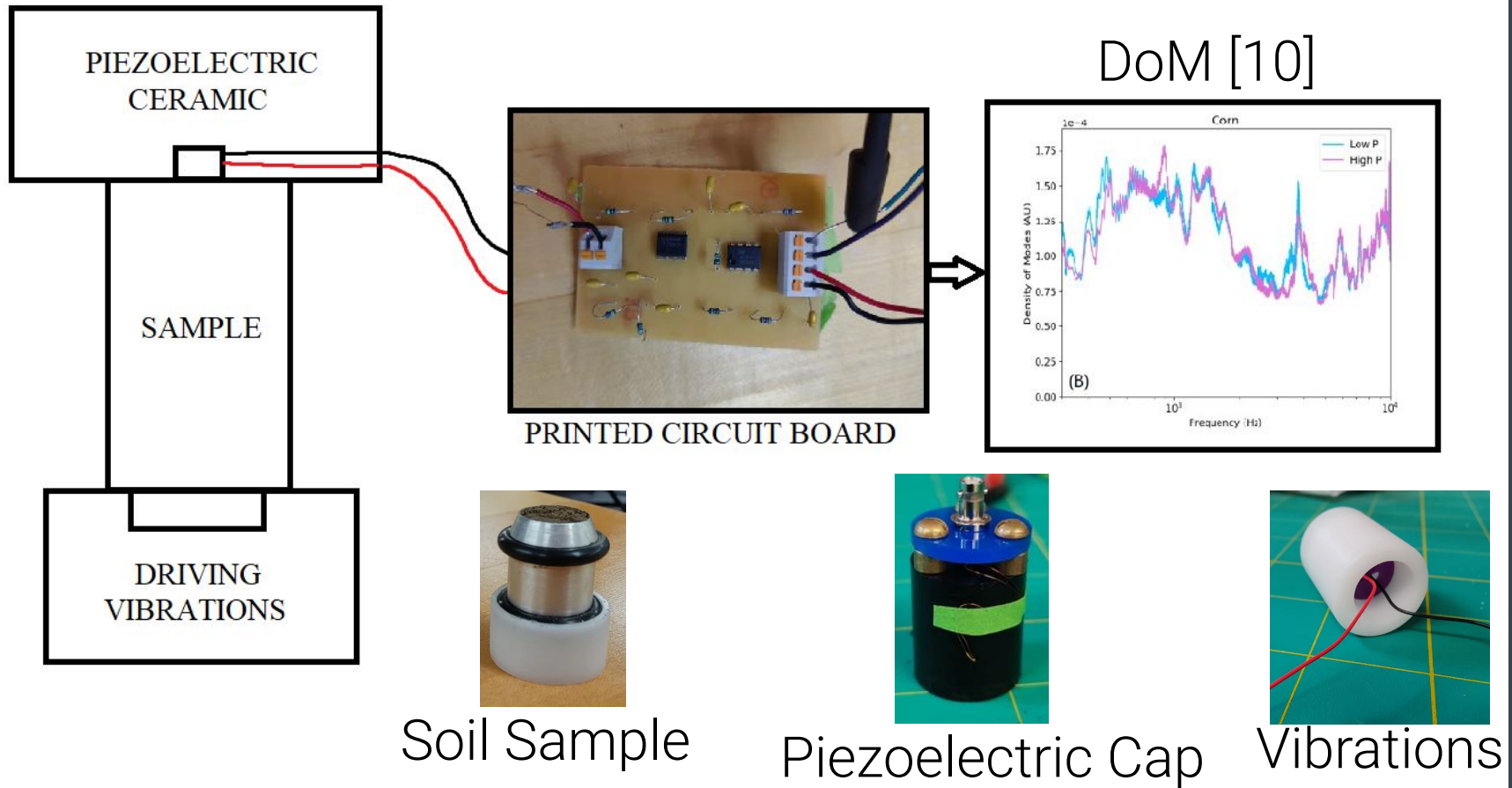
# The Boson Peak- change in $\omega^*$

Normalizing  
for  $\omega^*$ [4]

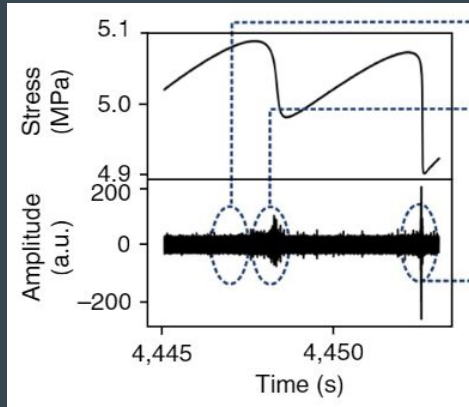


The change  
in  $\omega^*$  with  
pressure[4]

# Measuring the DoM



# Thermal Techniques- calculating the DoM



Measuring Voltage  
and Velocity using  
Piezos[17]

$$C_v(t) \equiv \frac{\sum_i \langle v_i(\tau + t) \cdot v_i(\tau) \rangle_\tau}{\sum_i \langle v_i(\tau) \cdot v_i(\tau) \rangle_\tau}$$

Velocity  
Autocorrelation [12]  
[8]

$$D(f) \equiv \int_0^\infty C_v(t) \cos(2\pi ft) dt.$$

Density of Modes  
[13][8]

## Acoustics of Failure

Does the change in boson peak frequency ( $\omega^*$ )  
inform us about granular loss of rigidity?

# References (1/2)

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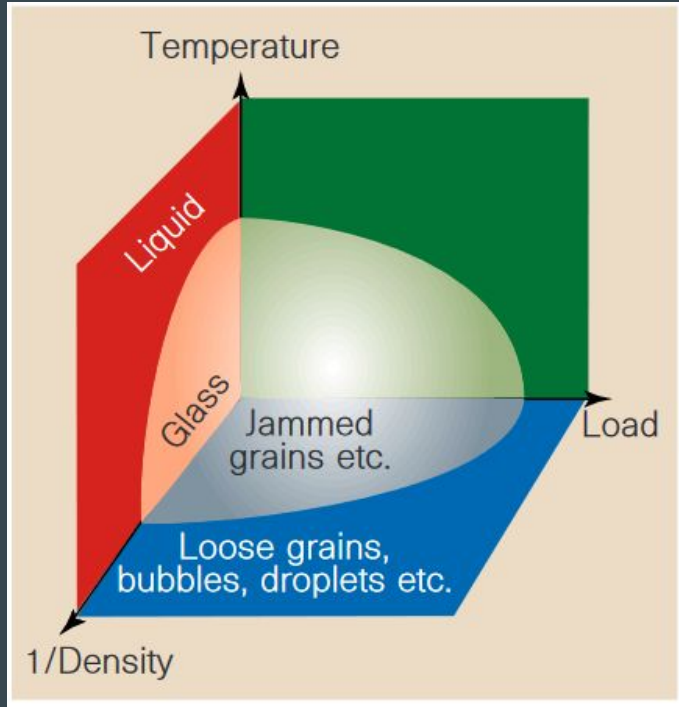
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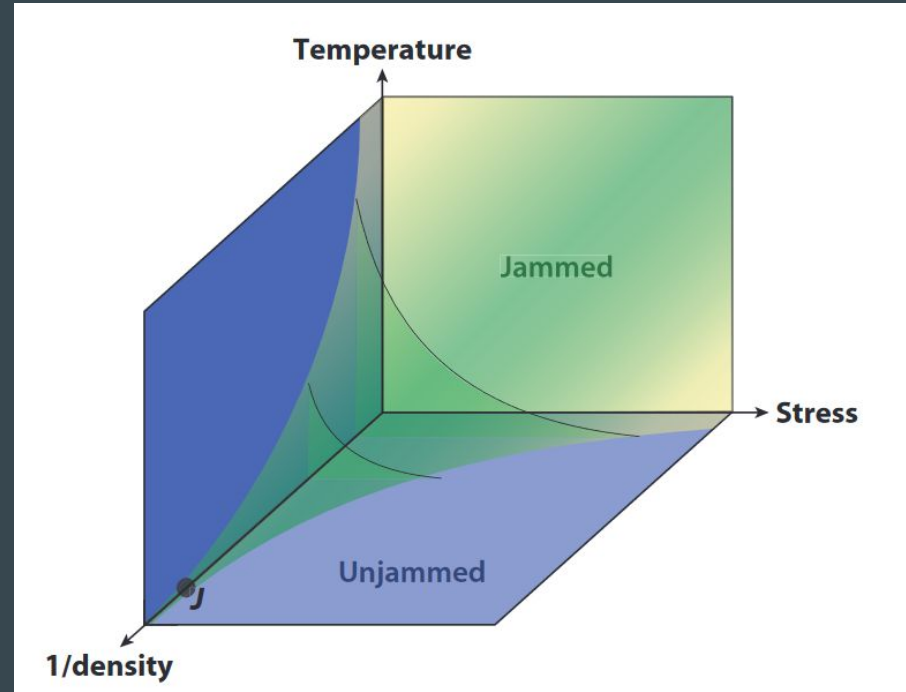
*“The world, the very emblem of all that is solid has moved  
beneath our feet like crust over a fluid”*

*- Darwin on the 1835 Chile Earthquake*

# The Jamming Transition

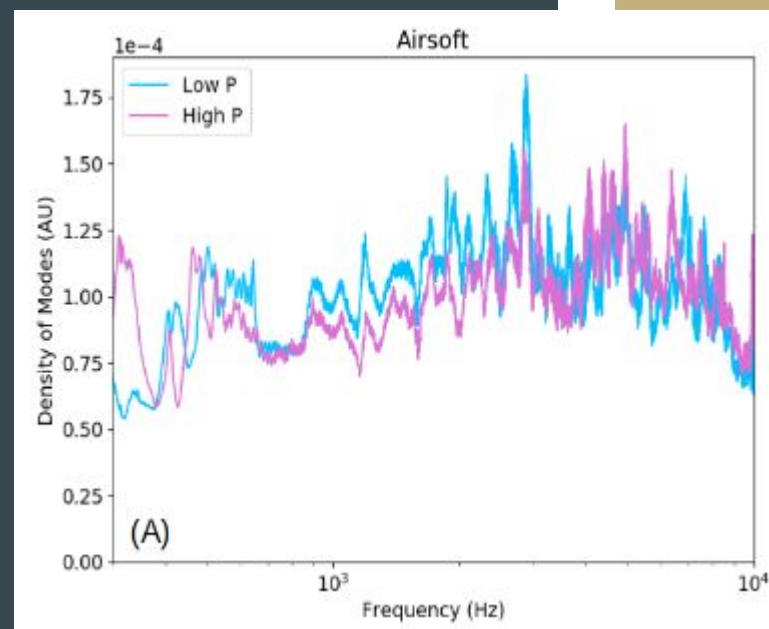
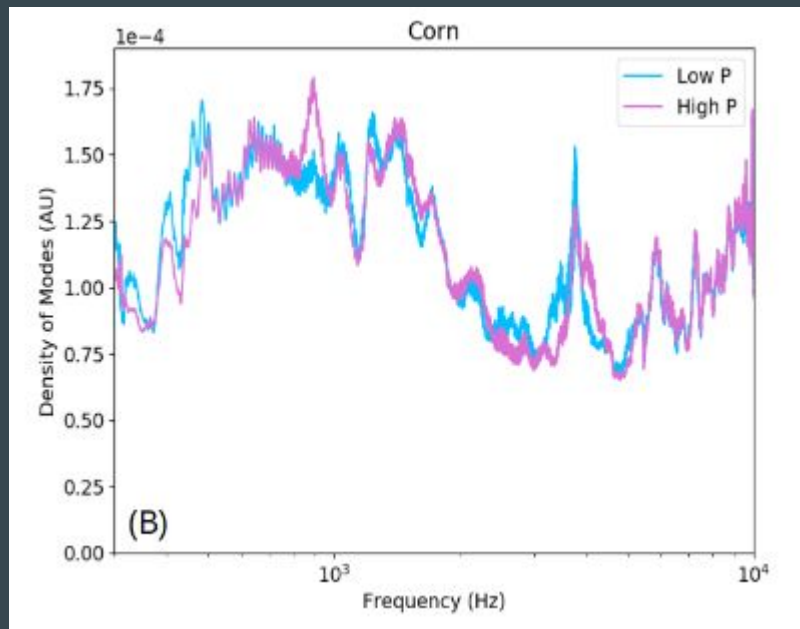
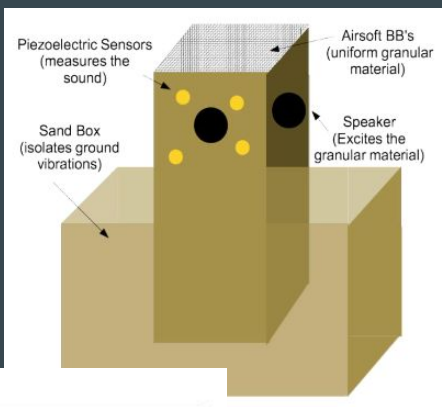


Liu's Hypothesis[1] :

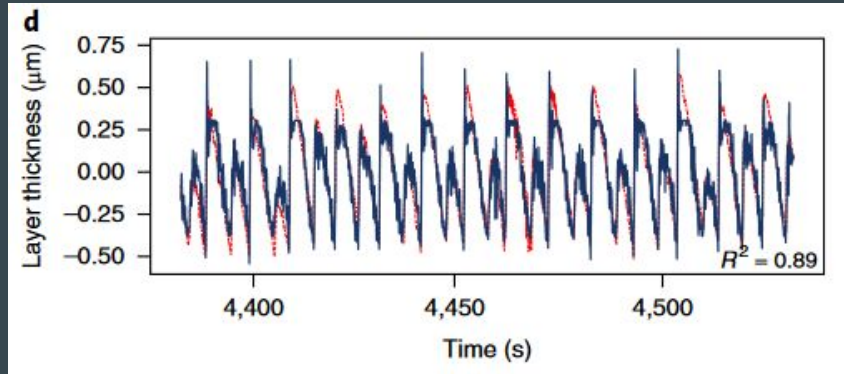
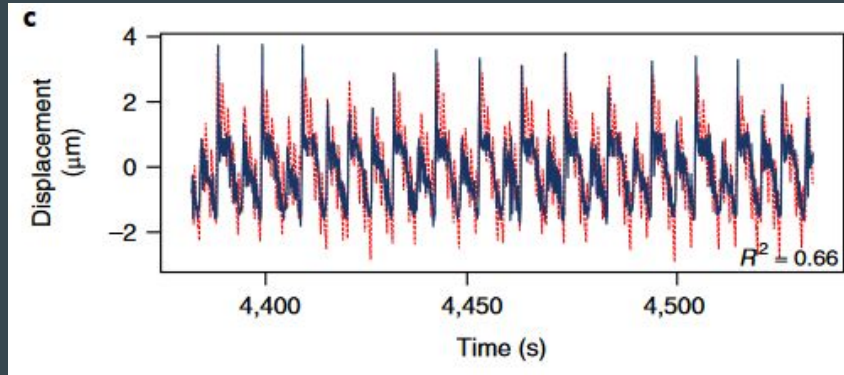


Liu, Nagel, O'Hern, etc. 20 Years  
Later[11] :

# Airsoft BBs and Corn [10]



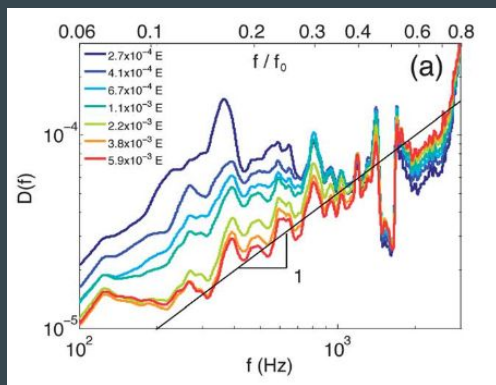
# Geohazard Forecasting[12]



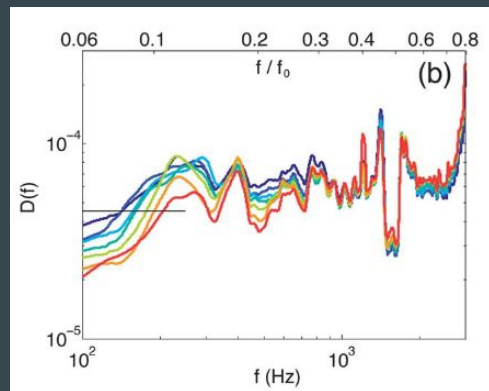


# Crystalline vs Amorphous[8]

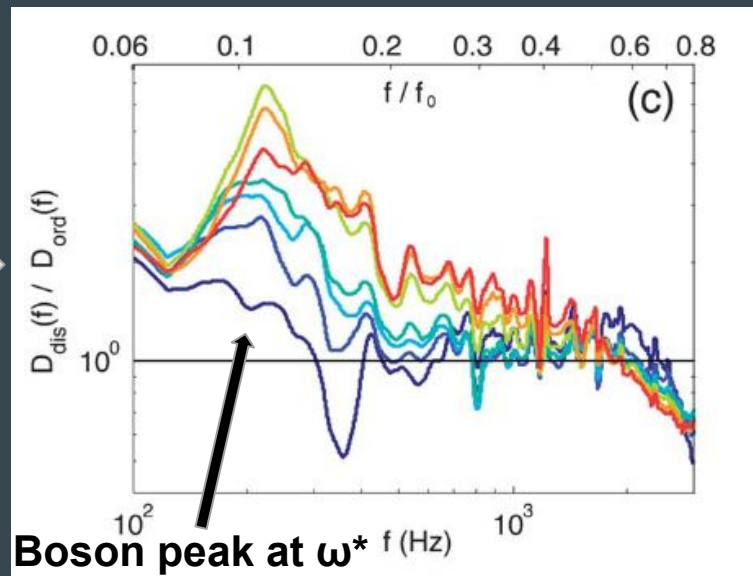
Crystalline



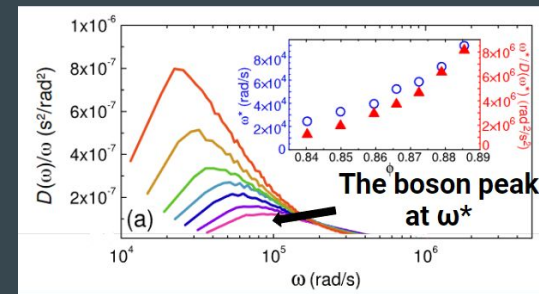
Amorphous



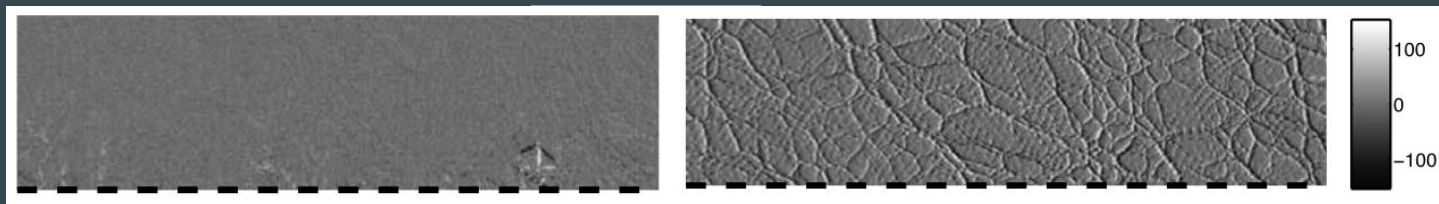
Amorphous/Crystalline



# Thermosensitive Hydrogels (Colloidal)



Localized Modes Vs Extended Modes [18]



$$p(\omega_n) \sim 1/N$$

$$p(\omega_n) \sim \mathcal{O}(1)$$

Athermal Frictionless Spheres[4]



$$(\phi - \phi_c)^{(\alpha-1)(d/2)-1/2}$$