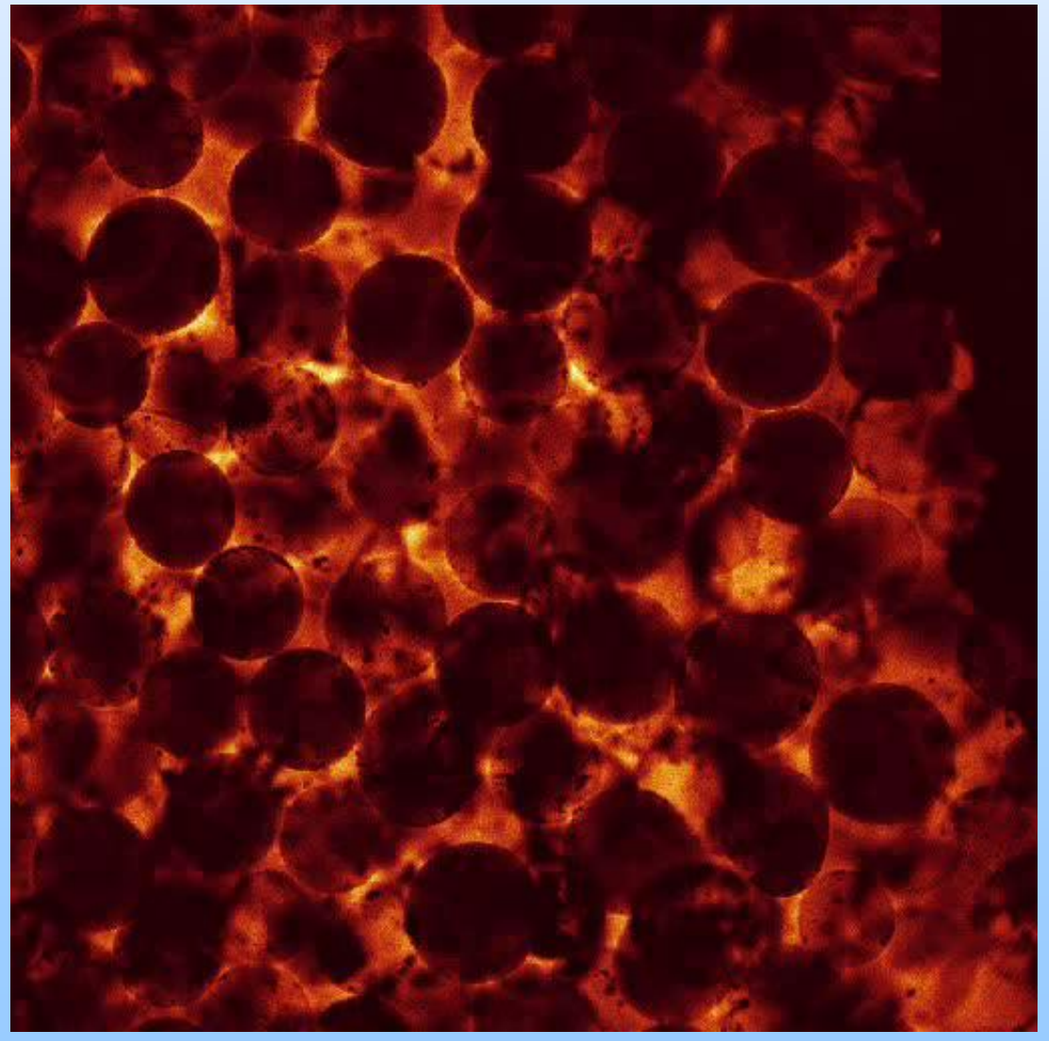
# *Dense granular flows*
# *3D imaging of collective motion*


Wolfgang Losert

Department of Physics, University Of Maryland


Mitch Mailman

Kerstin Nordstrom

Steven Slotterback

Matt Harrington

# Summary

Our question is how granular flows start and stop

- Measuring Mesoscale Dynamics via 3D imaging

  *Trajectories for all (almost all) particles for flows under steady shear, cyclic shear, segregation*

- Developing Mesoscale Metrics of collective motion (e.g. broken links network) to connect macroscale & microscale

*Can be applied to other flow geometries*

# Our Question:
# How does granular flow start and stop?

- ❑ Deformation under Impact

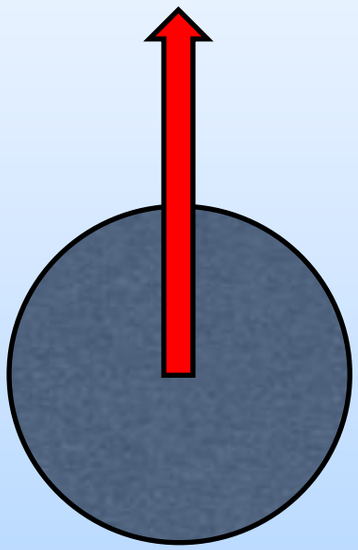
- ❑ Failure and flow under cyclic forcing

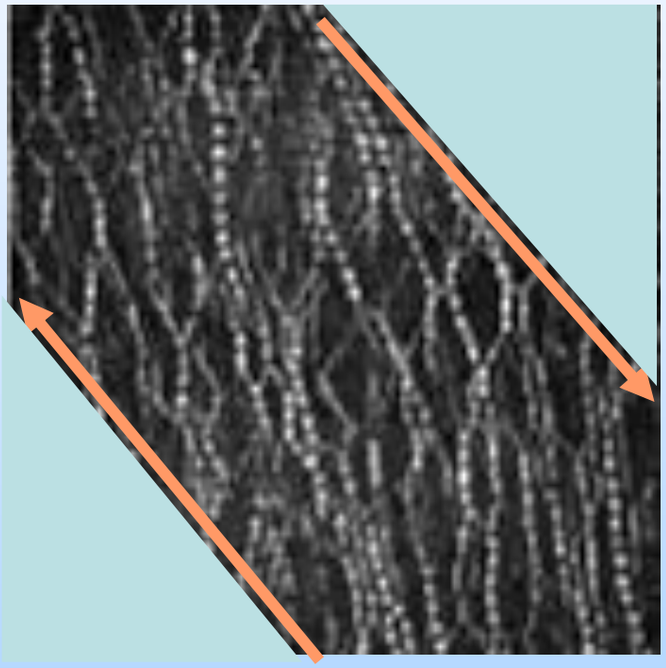
Examples of cyclic forcing

- Tidal forces, e.g. on spinning asteroids
- External vibrations, e.g. due to earthquakes

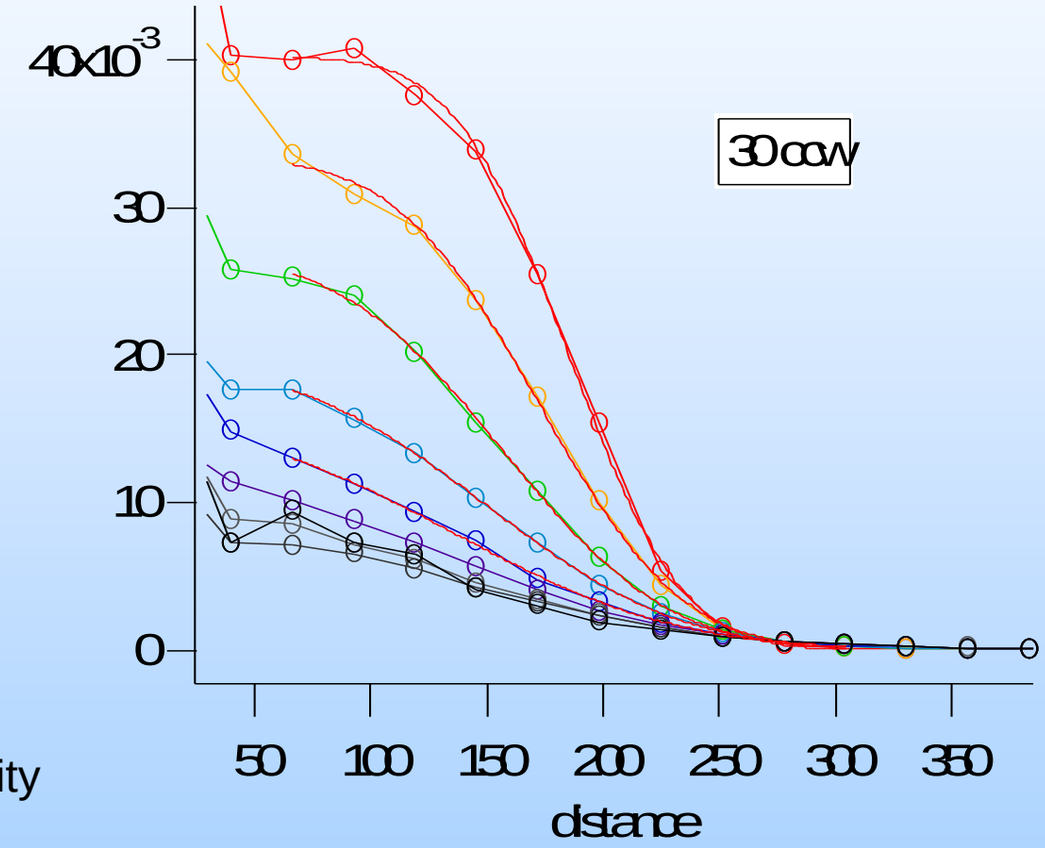
Fluidization of sandy soil during earthquake

# Granular Flow Descriptions on Micro-,Meso-, and Macroscales





Behringer group Duke University




Particles Motion

*Velocity,*

*Restitution Coefficient*

1 Dia

Mesoscale

*Static Force Chains*

*Dynamic Clusters*

5-15 Dia

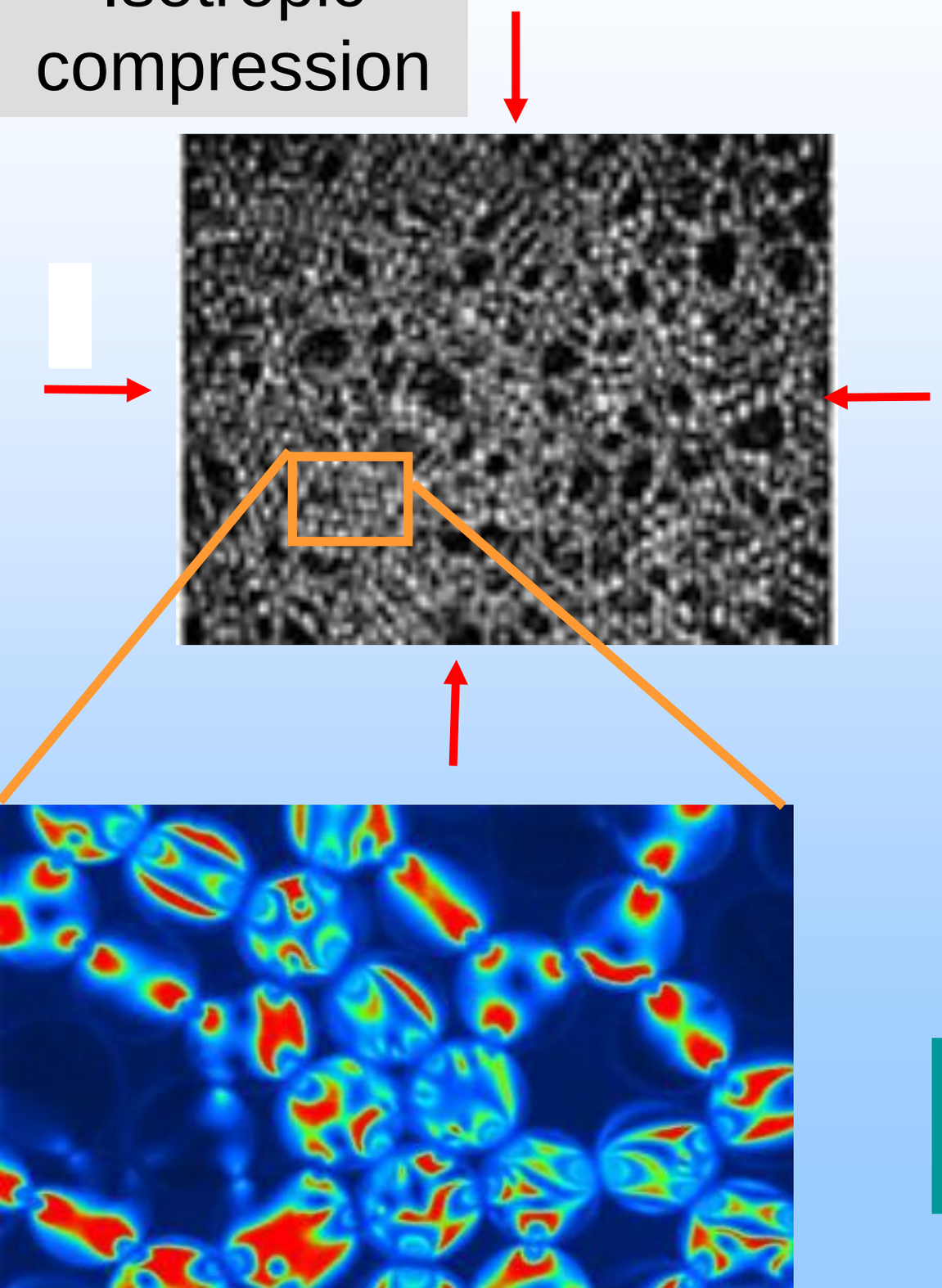
Macroscale

*Velocity Field*

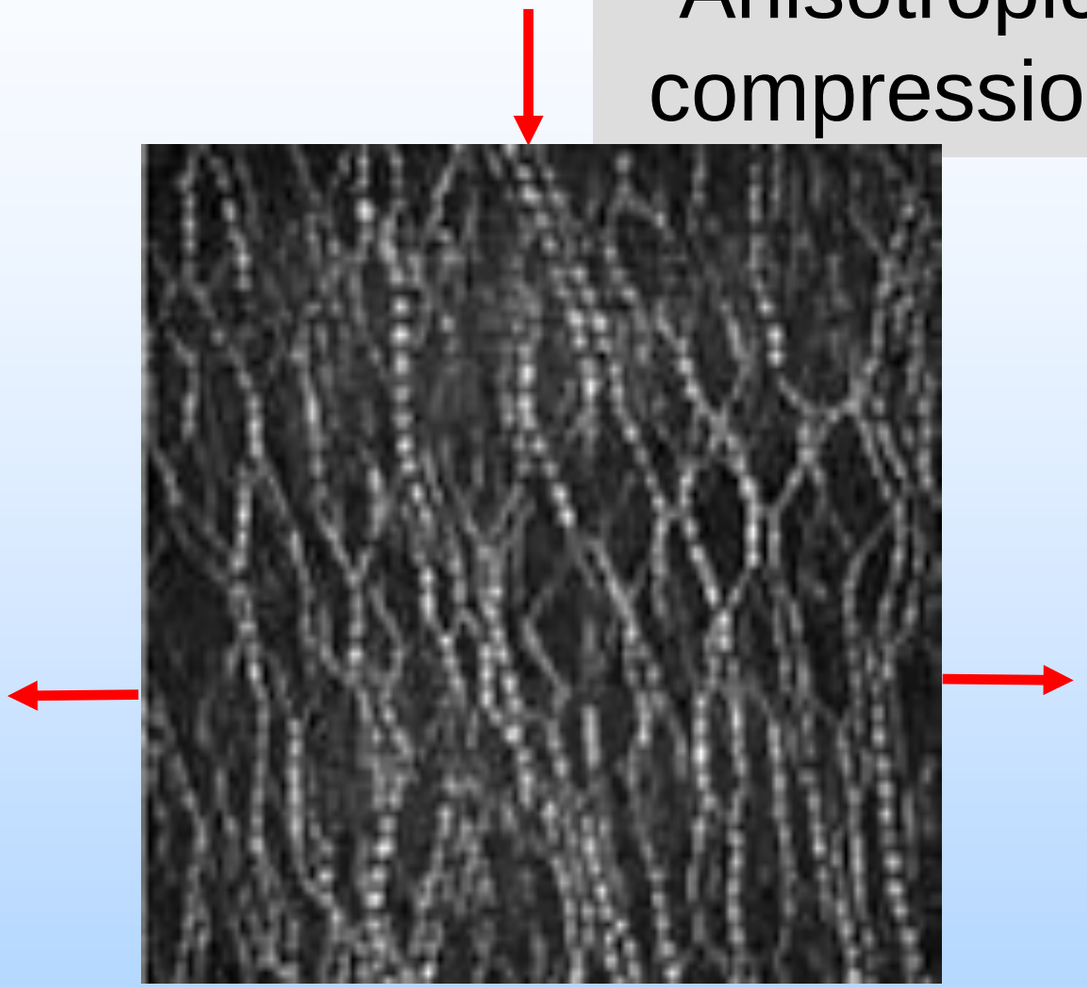
10-100s Dia

# Mesoscale Structure is sensitive to Strain

Isotropic compression



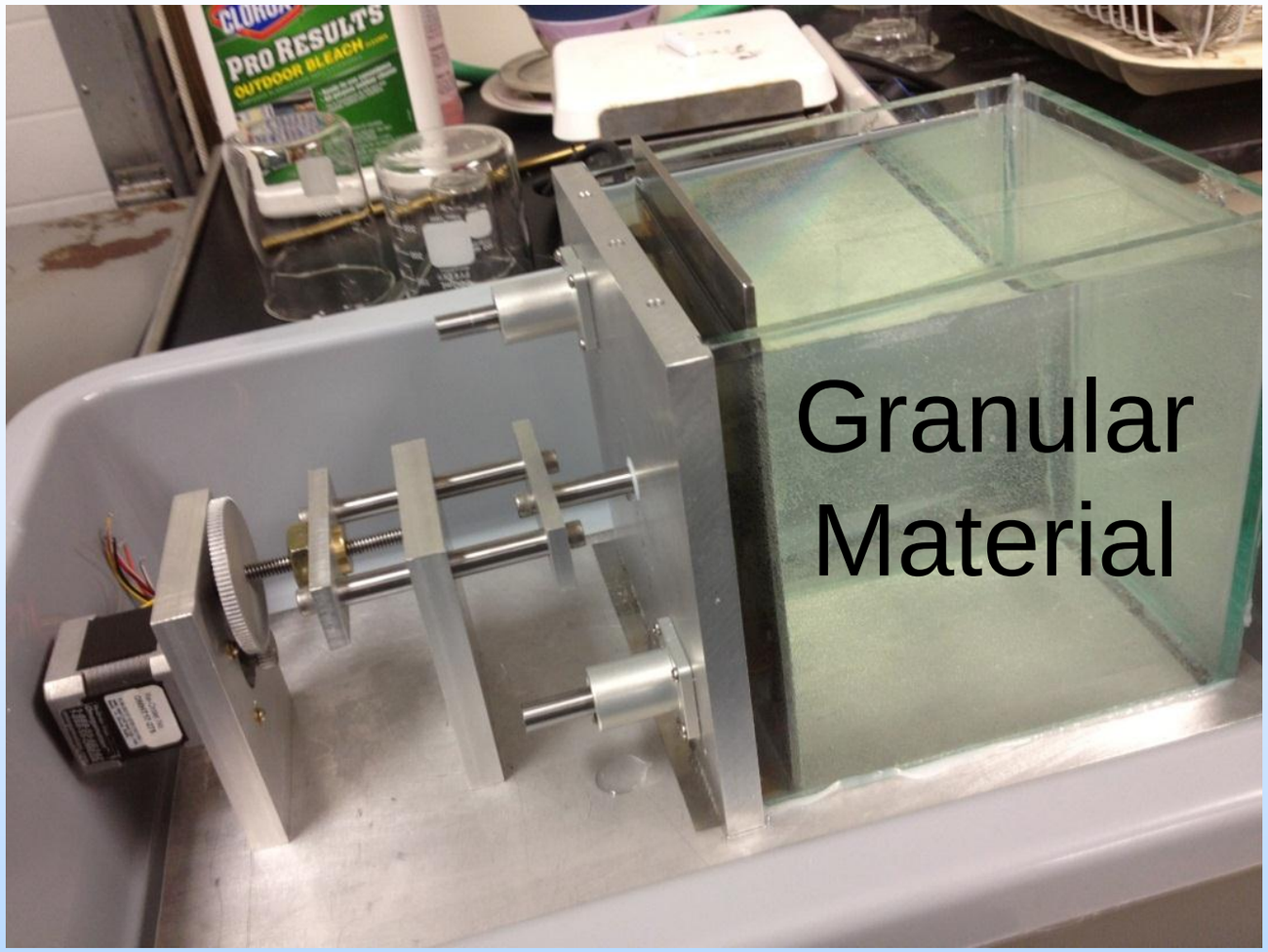
Anisotropic compression



**Direct imaging of forces in 2D**

From Majumdar/Behringer, Nature, 2005

# Tuning mesoscale structure with strain




Compresses sample up to a strain of ~ 1%.

How does the preparation of the sample change failure and flow?

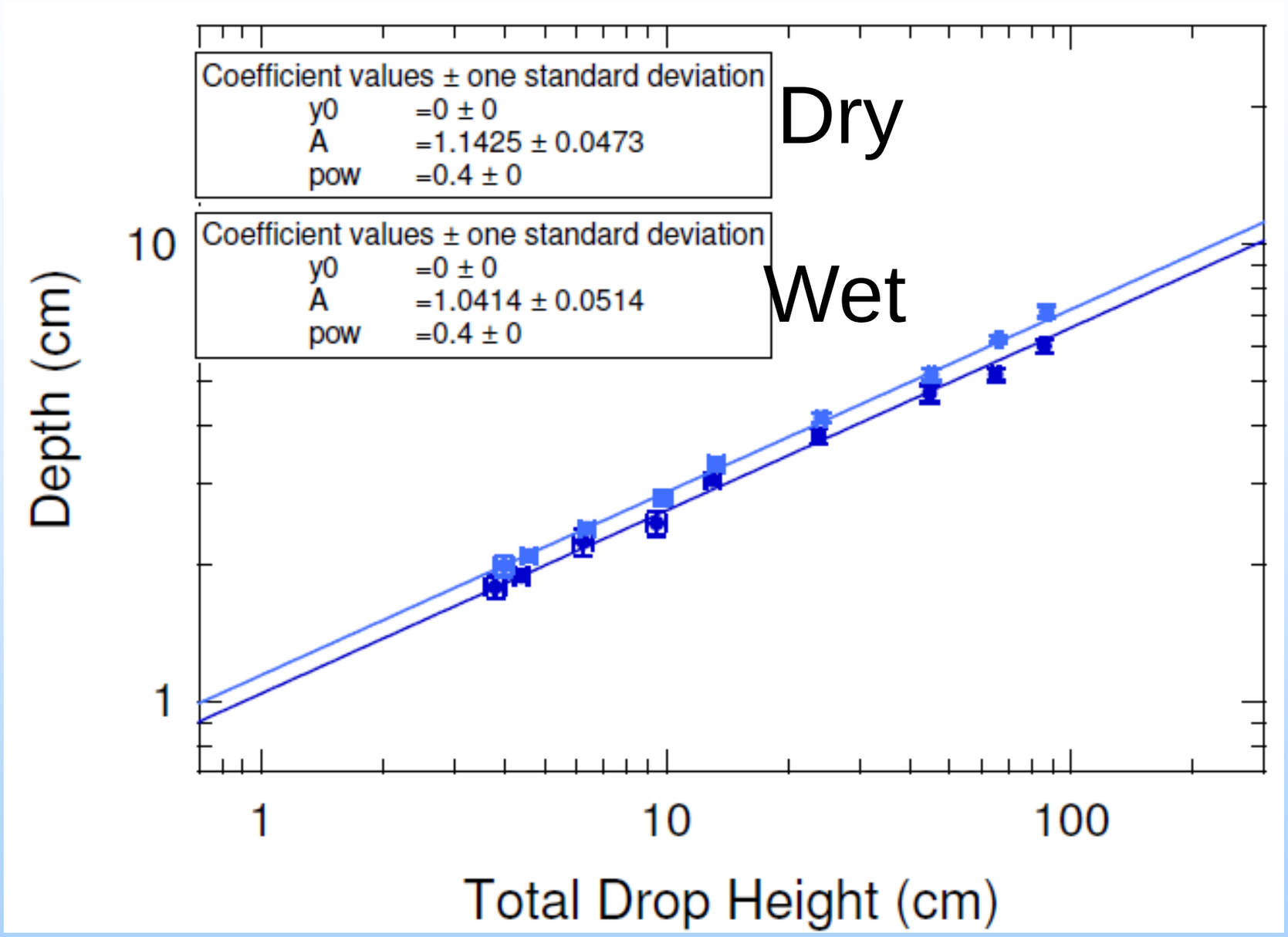
# Triggering failure and flow: Impact experiments

- 1 inch steel sphere

- Photron fastcam @ 2000 fps

- Drop heights 1-100 cm
  - Wet vs Dry
  - Vary strain to tune mesoscale struture

# Interstitial fluid does not alter scaling




- Our wet and dry systems show consistent exponent

- Similar prefactor, note larger A = deeper impact – interesting!

# Our Goal is to characterize granular flows on the mesoscale

Measure particle motion inside a 3D granular material

Characterize mesoscale structures and mesoscale dynamics

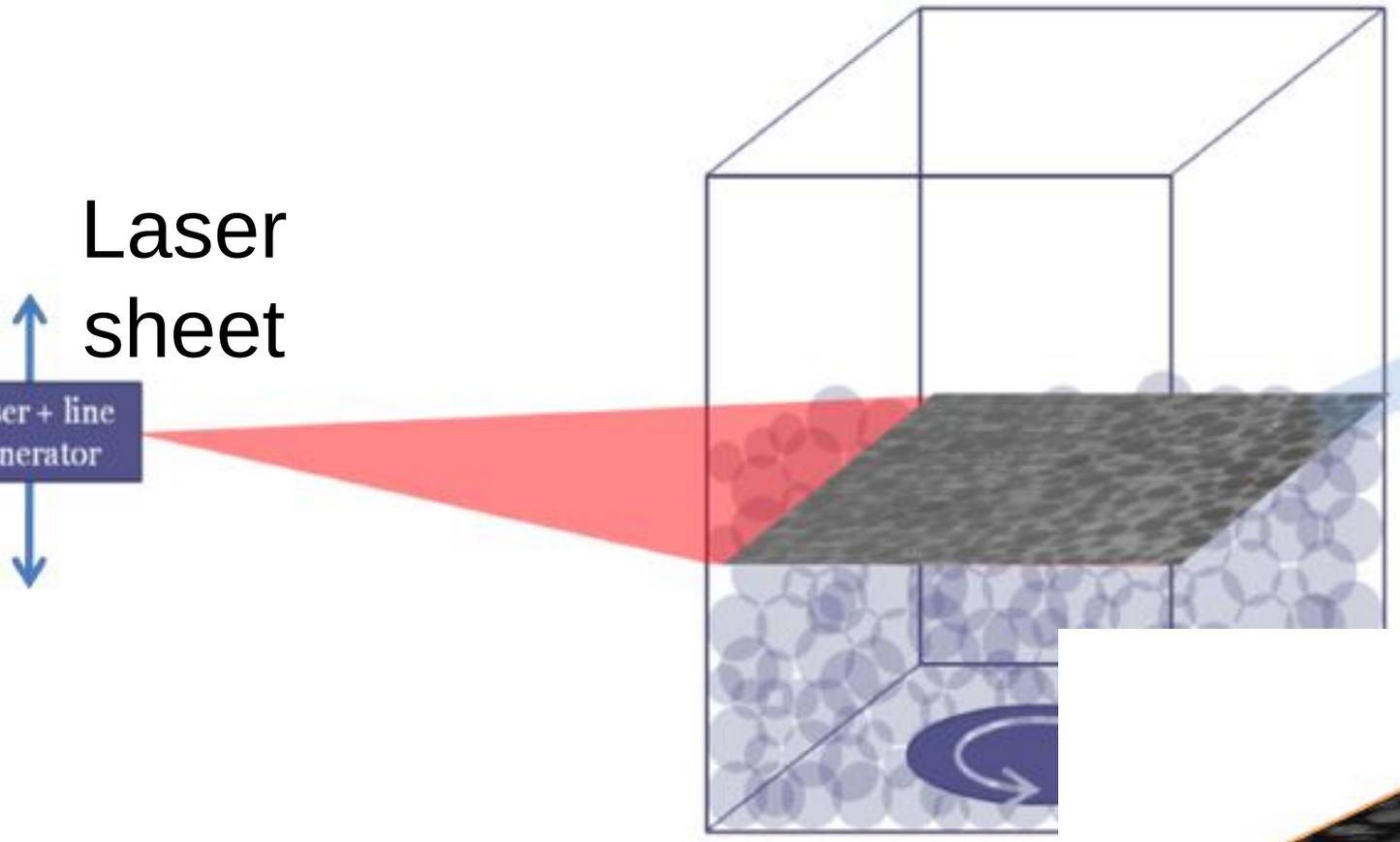
# 3D imaging of granular shear flow

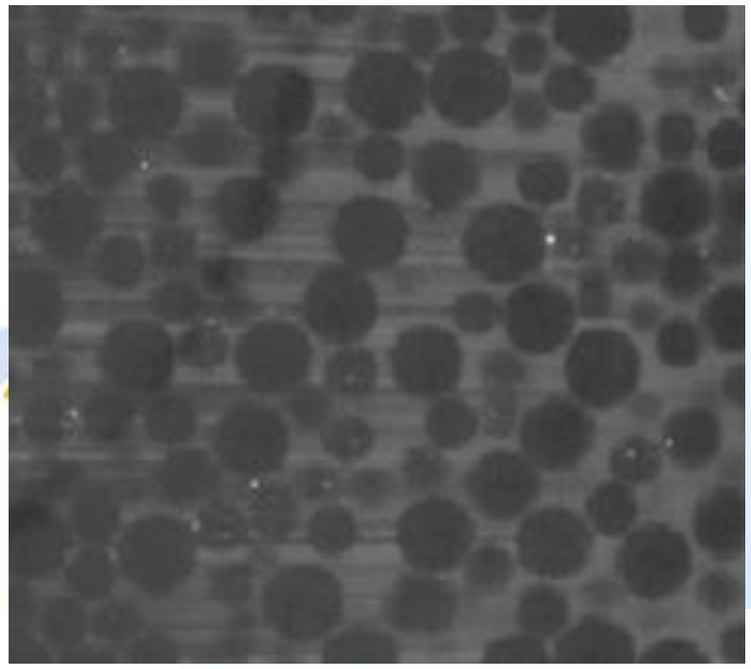
Steven Slotterbac

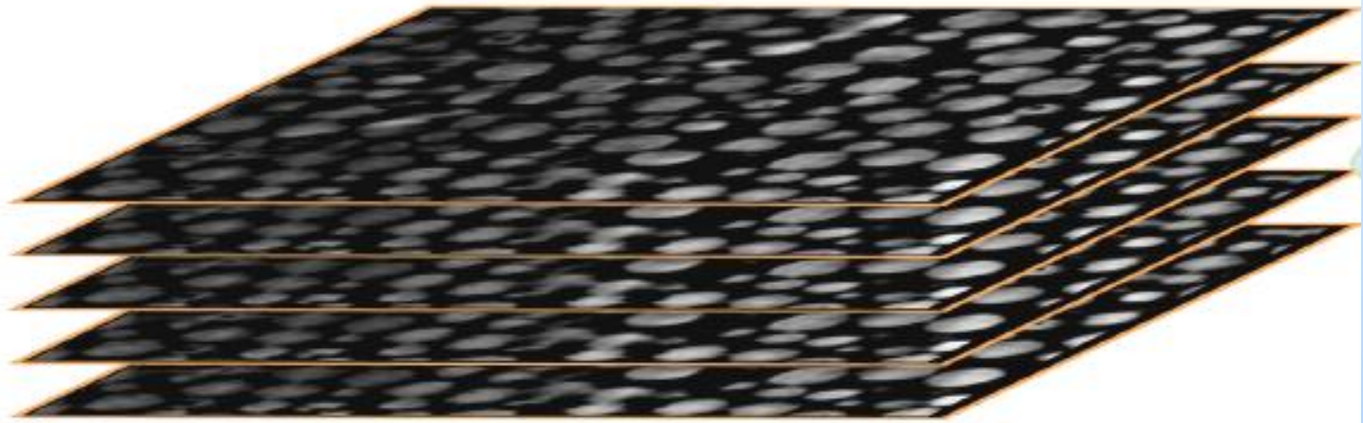
Joshua Dijksman

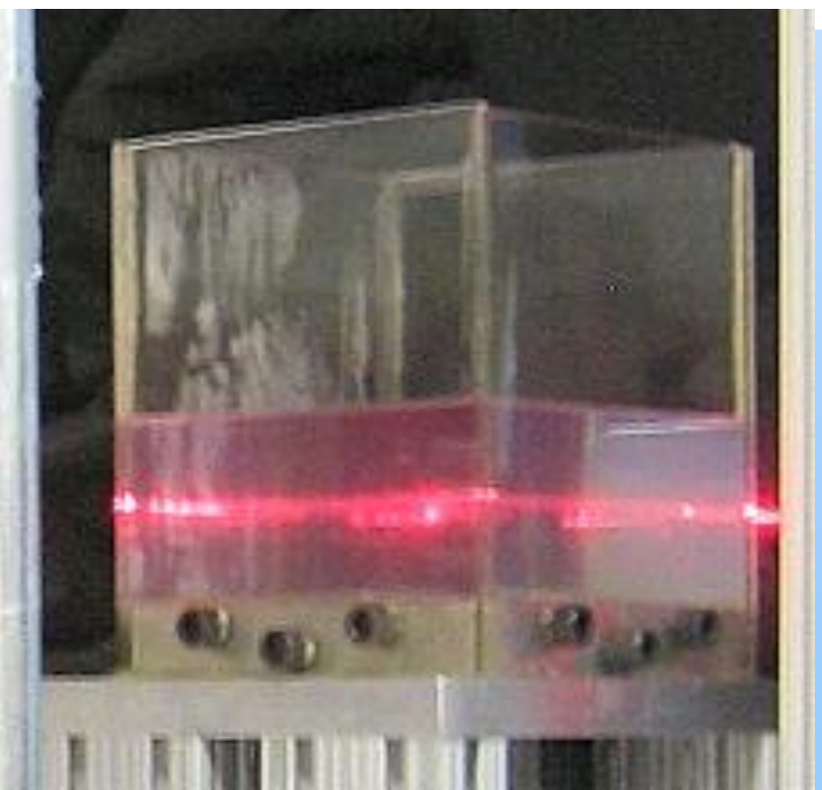
Laser sheet

er + line
nerator







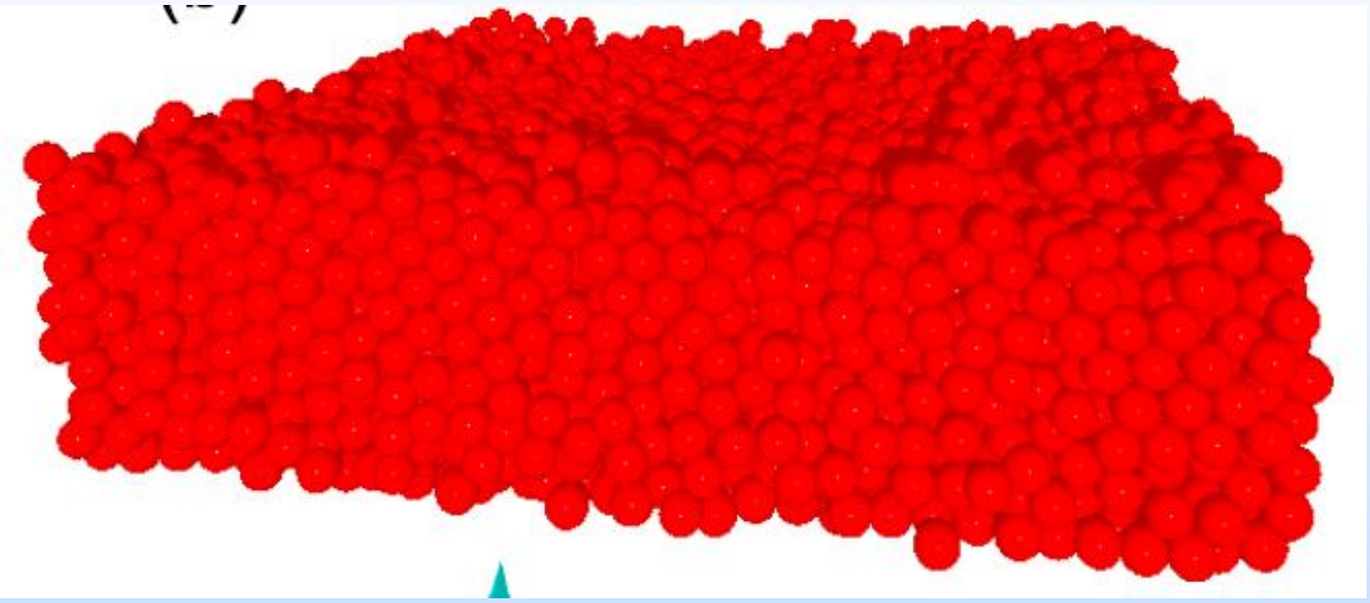


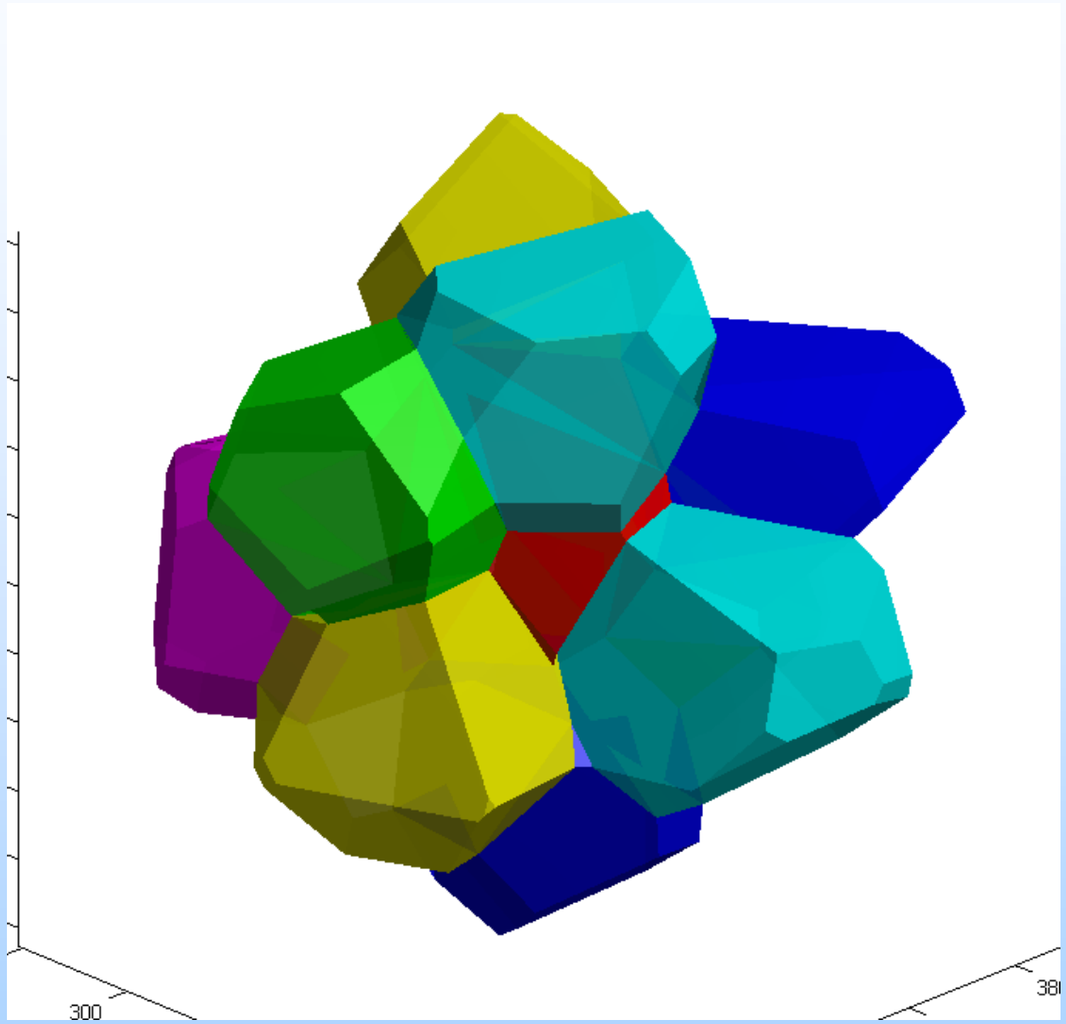
Toiya *et al.*
*Granular Matter (2007)*
Slotterback *PRL (2008)*

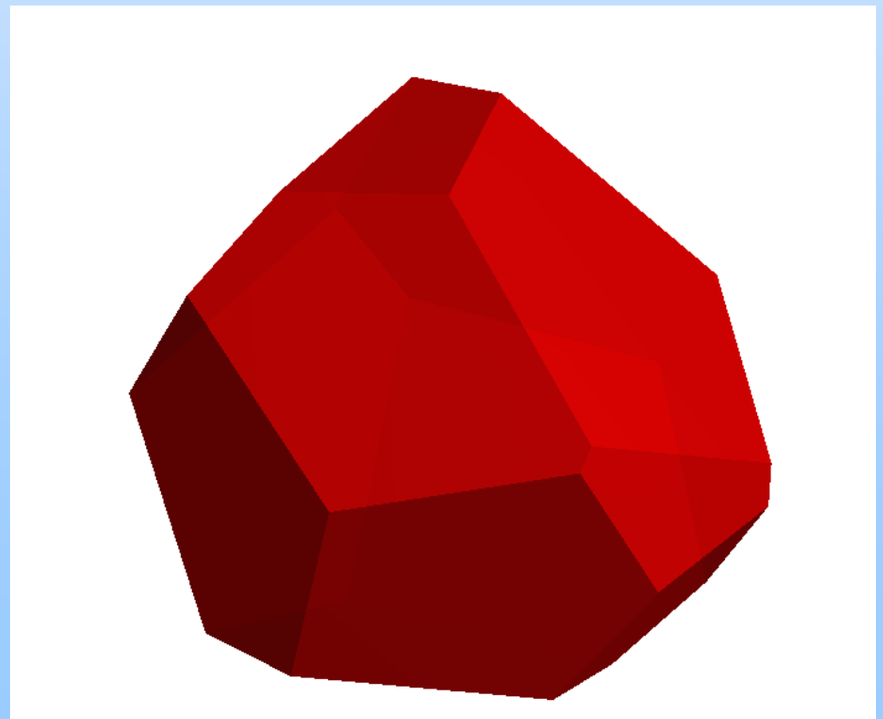
Steven Slotterback

Masahiro Toiya

# 3D imaging yields complete internal structure and dynamics

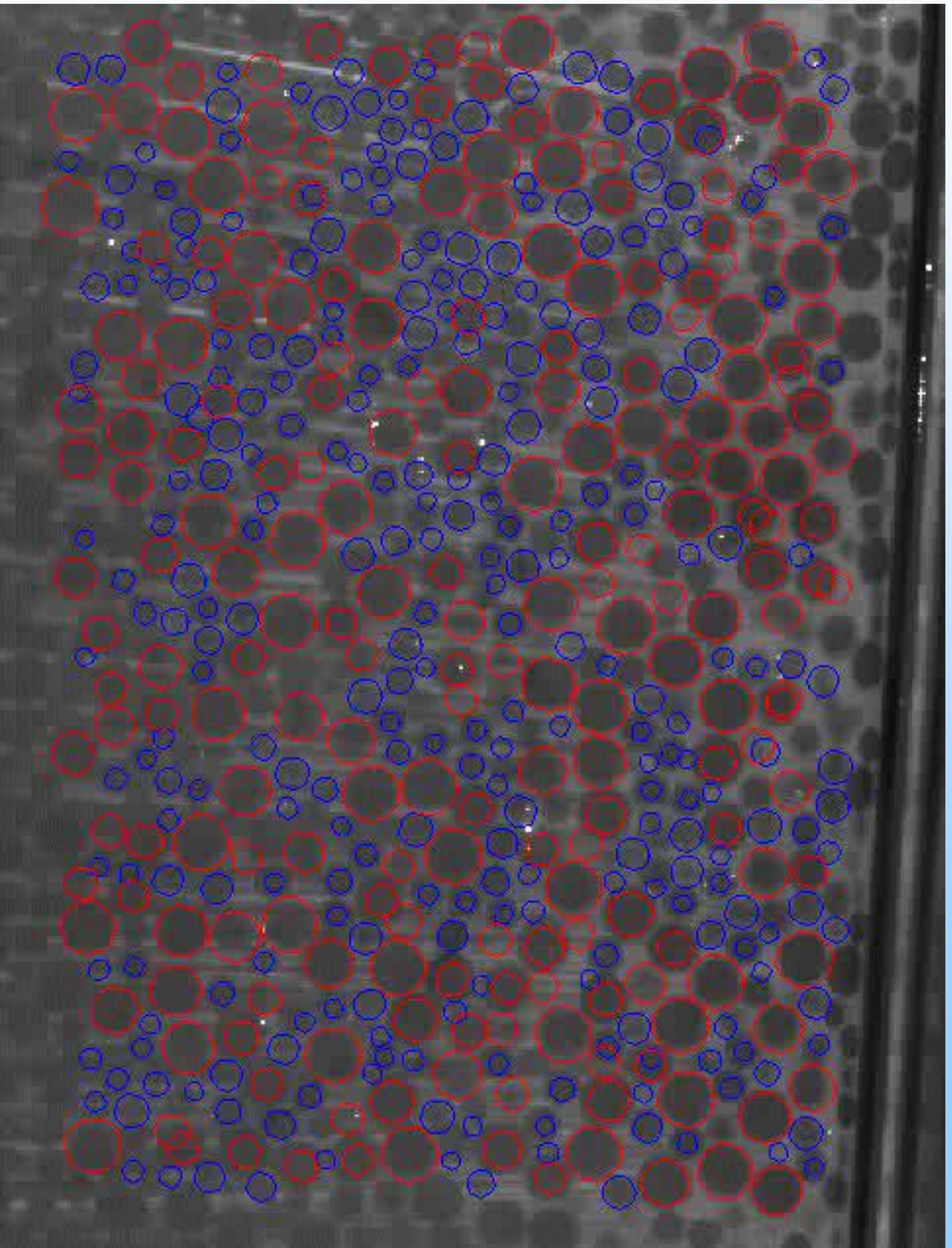




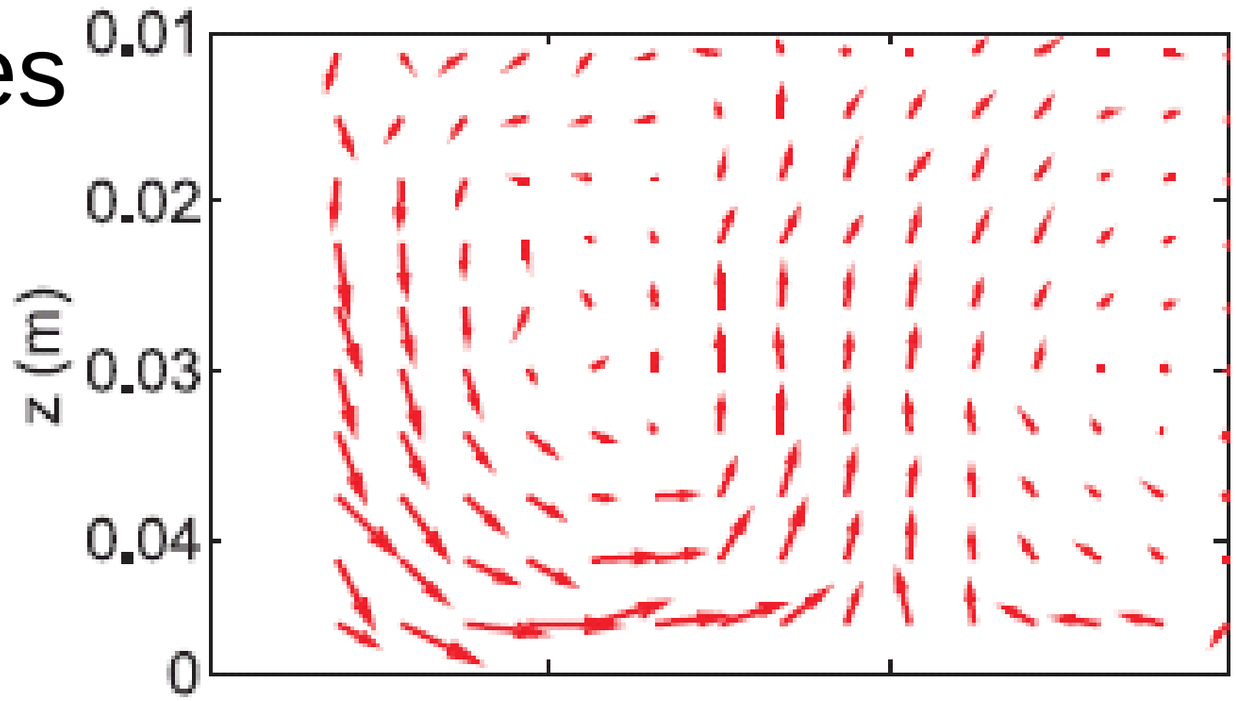



Slotterback *et al* PRL (2008)

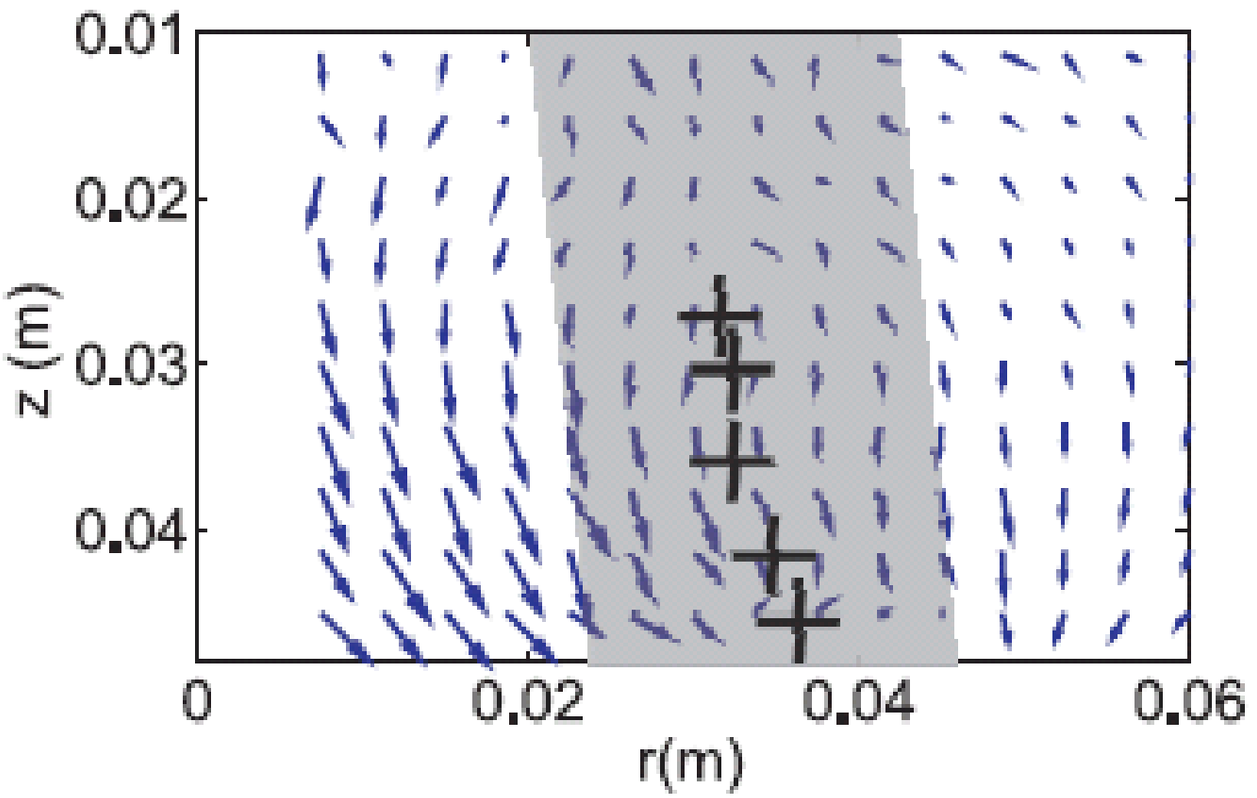
# Example of internal dynamics: Convection Rolls during segregation of binary mixtures



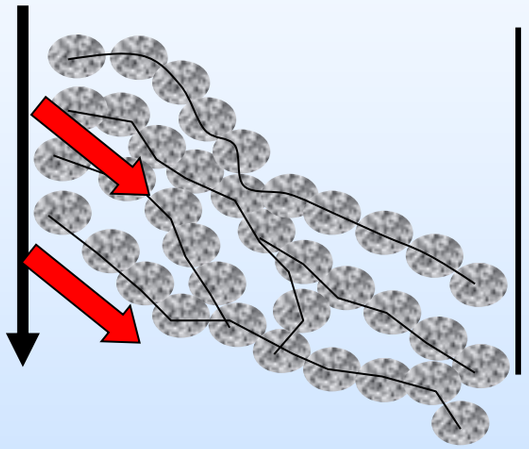
## Large Particles



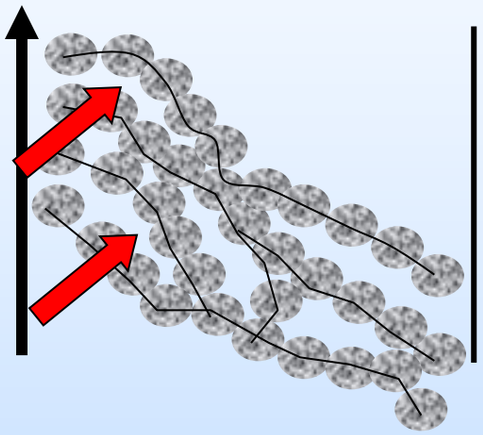

## Small Particles



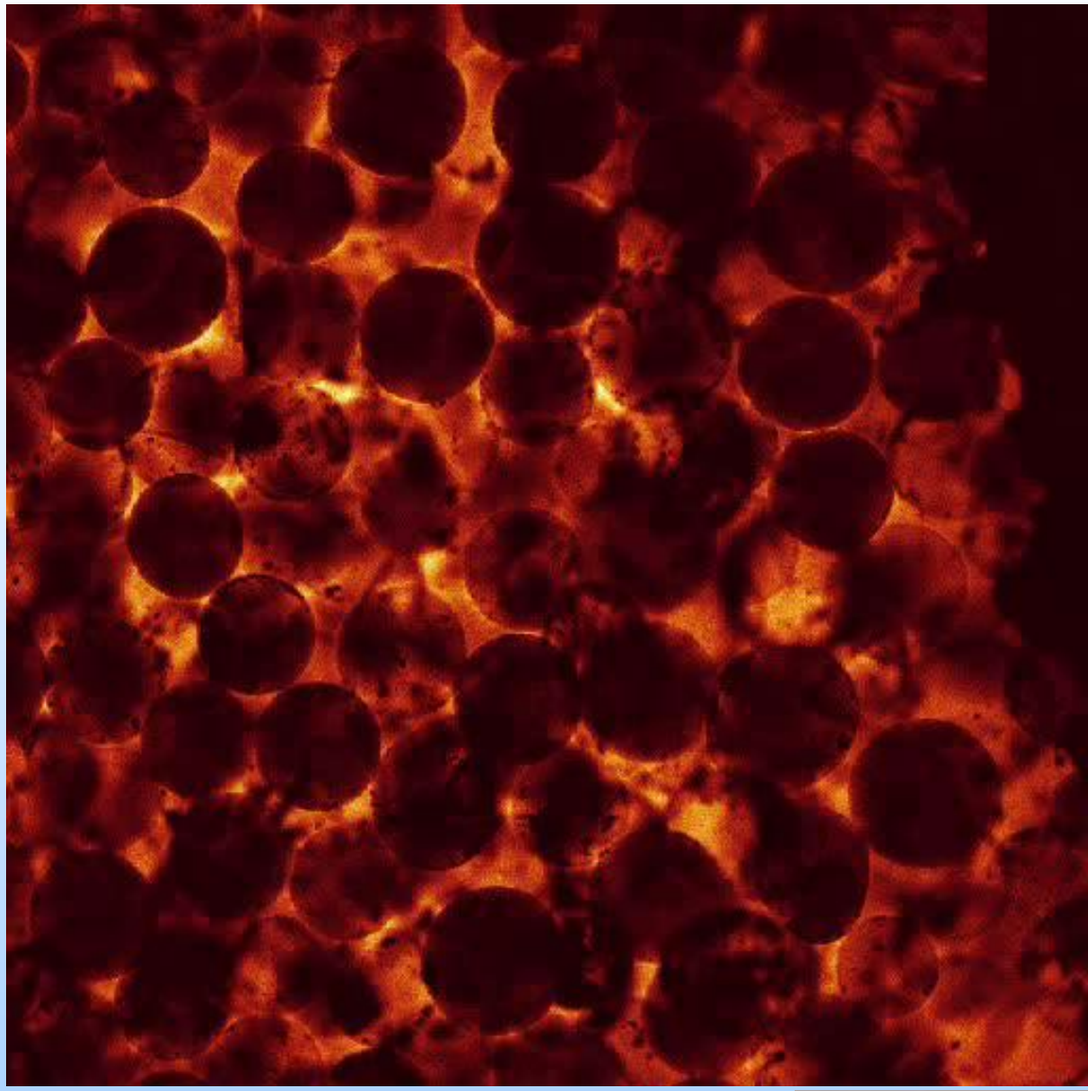
# Effects of mesoscale structure on granular flow



*Schematic*
Contact network
**steady shear**



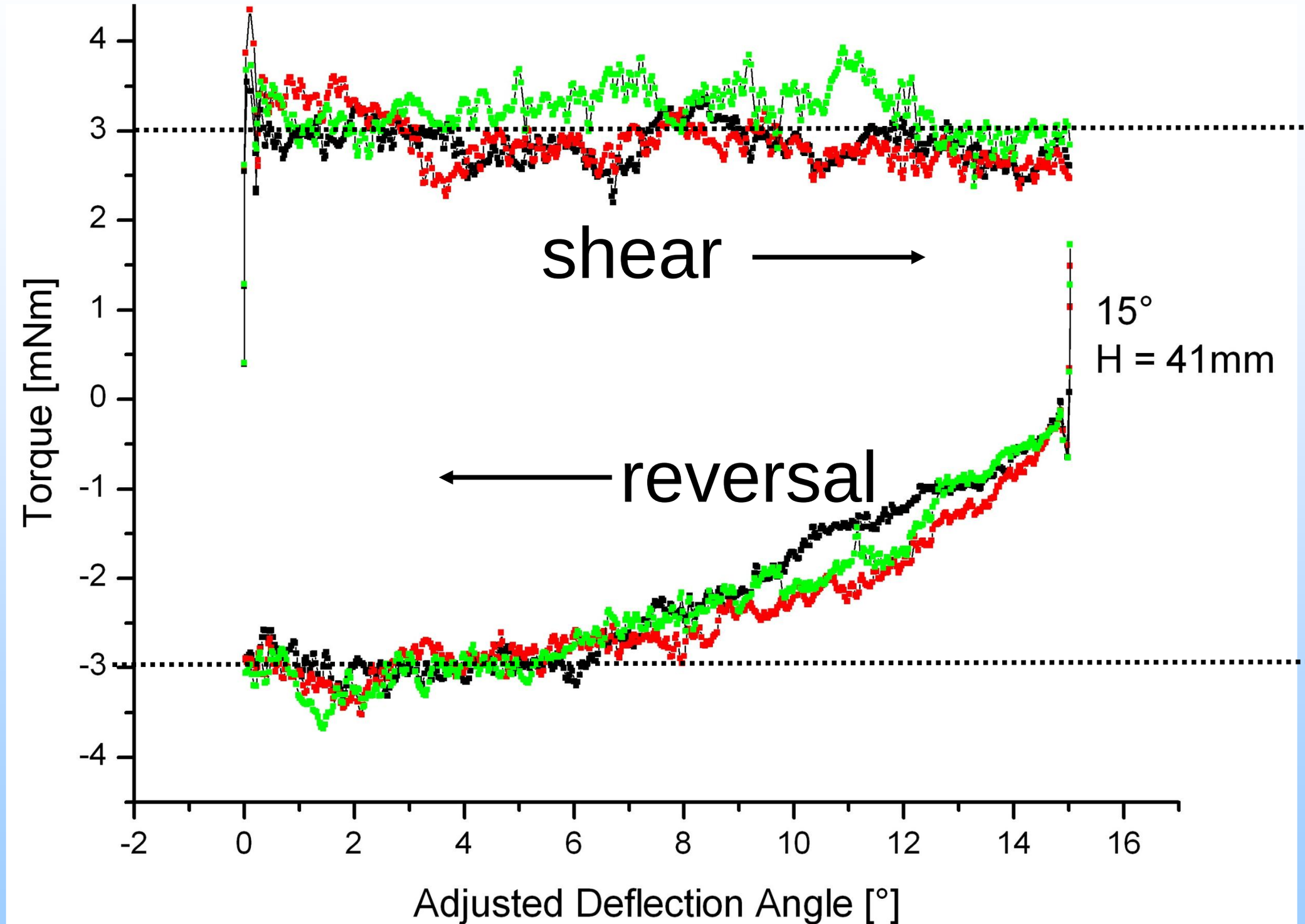
*Schematic*
Contact network
**shear reversal**



Toiya *et al.* PRL 2004

Masahiro Toiya

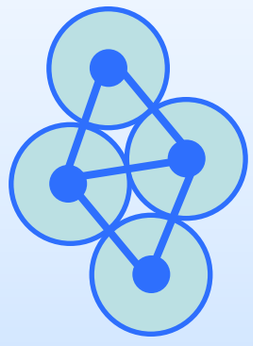
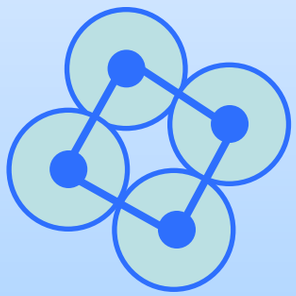
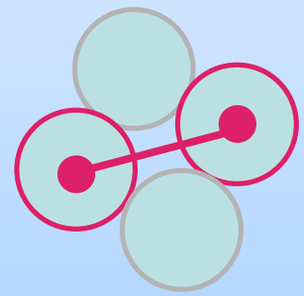
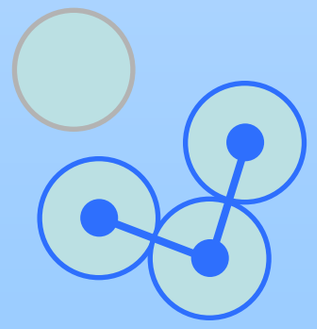
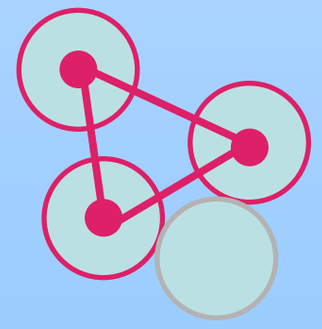
# Small initial torque during shear reversal



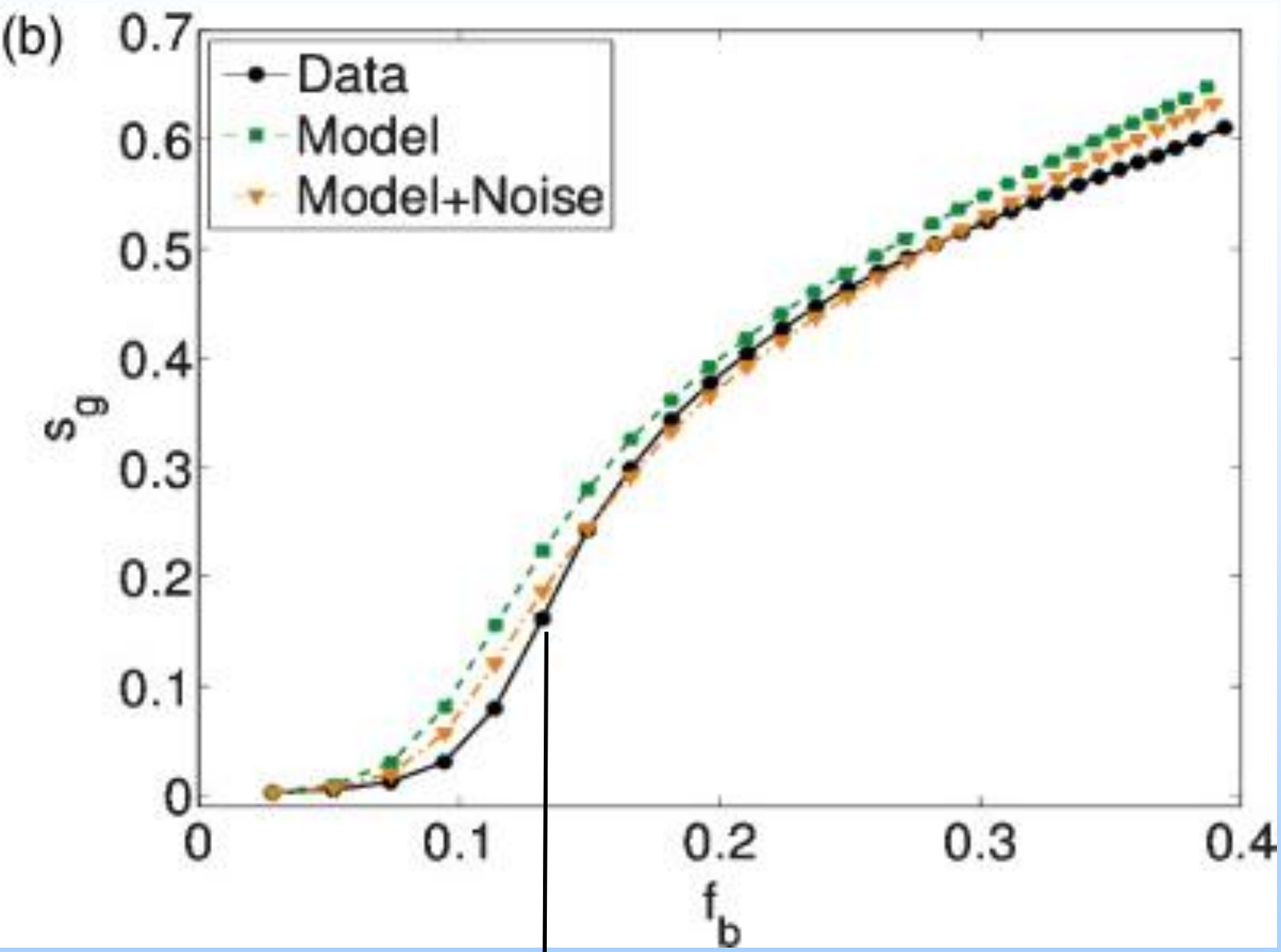

**Derek Updegraaf** with
E. Wandersman, J. Dijksman, M. van Hecke

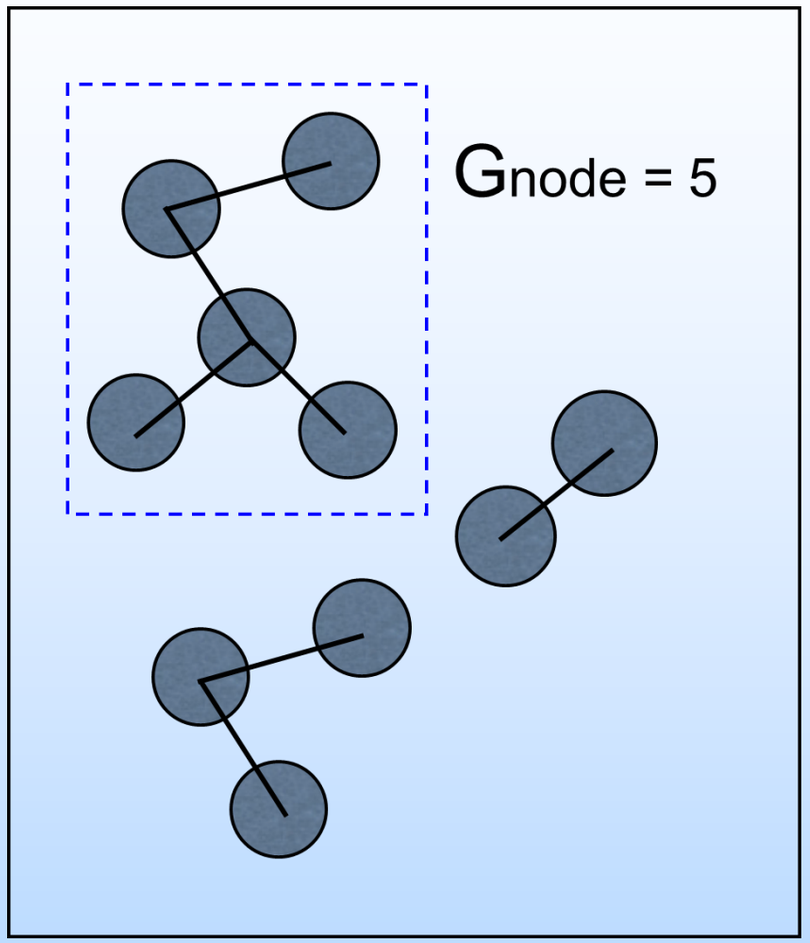
Mark
Herrera

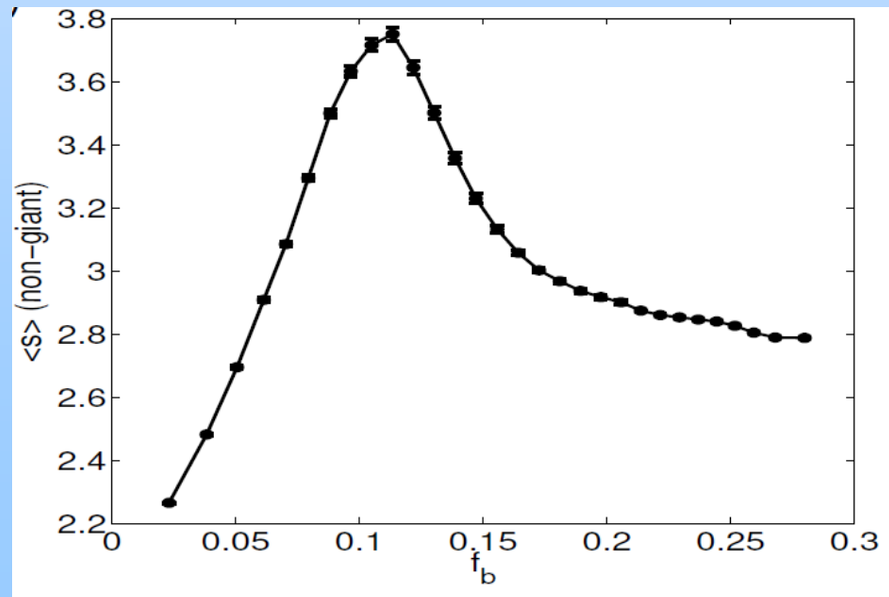
# Network characterization of granular **dynamics**

| Persistent Network | Broken Link Network |
| --- | --- |
|  | Reference Frame |
|  |  |
|  |  |

# Giant Component of the Network

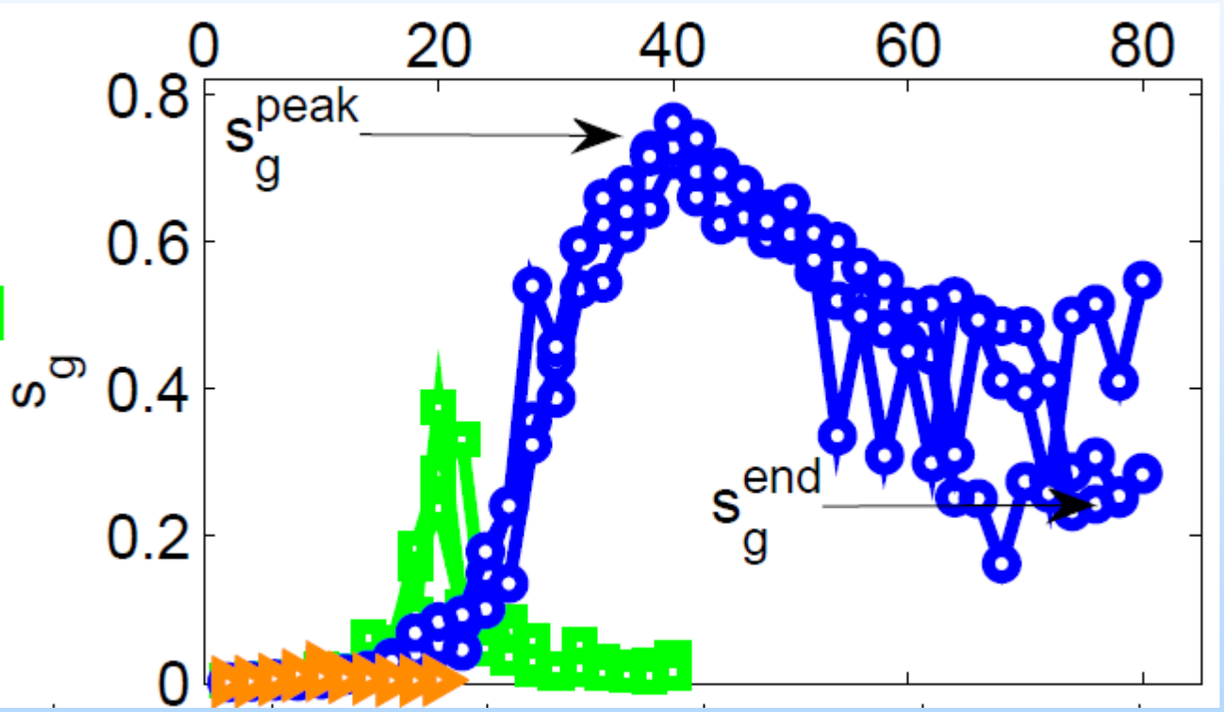


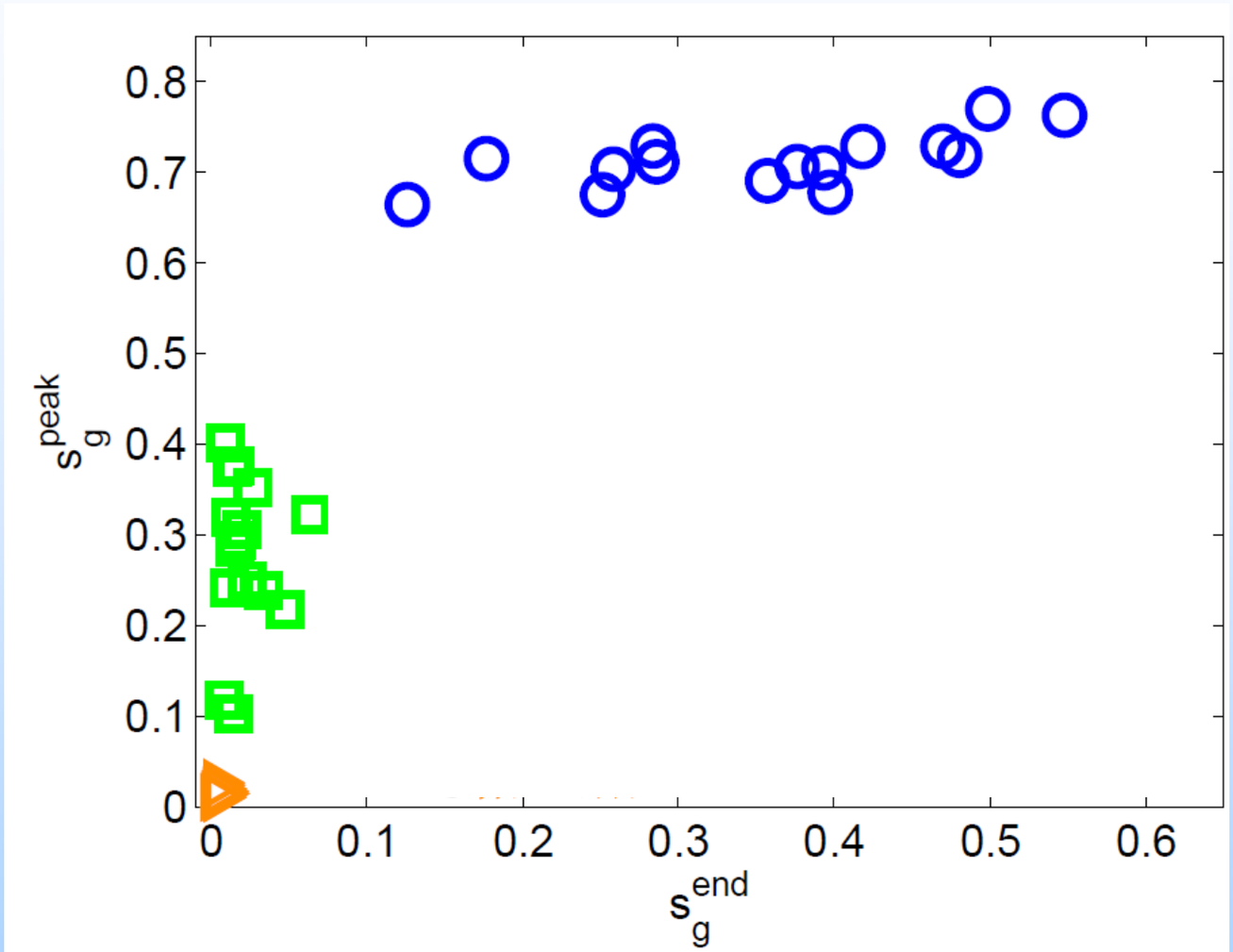



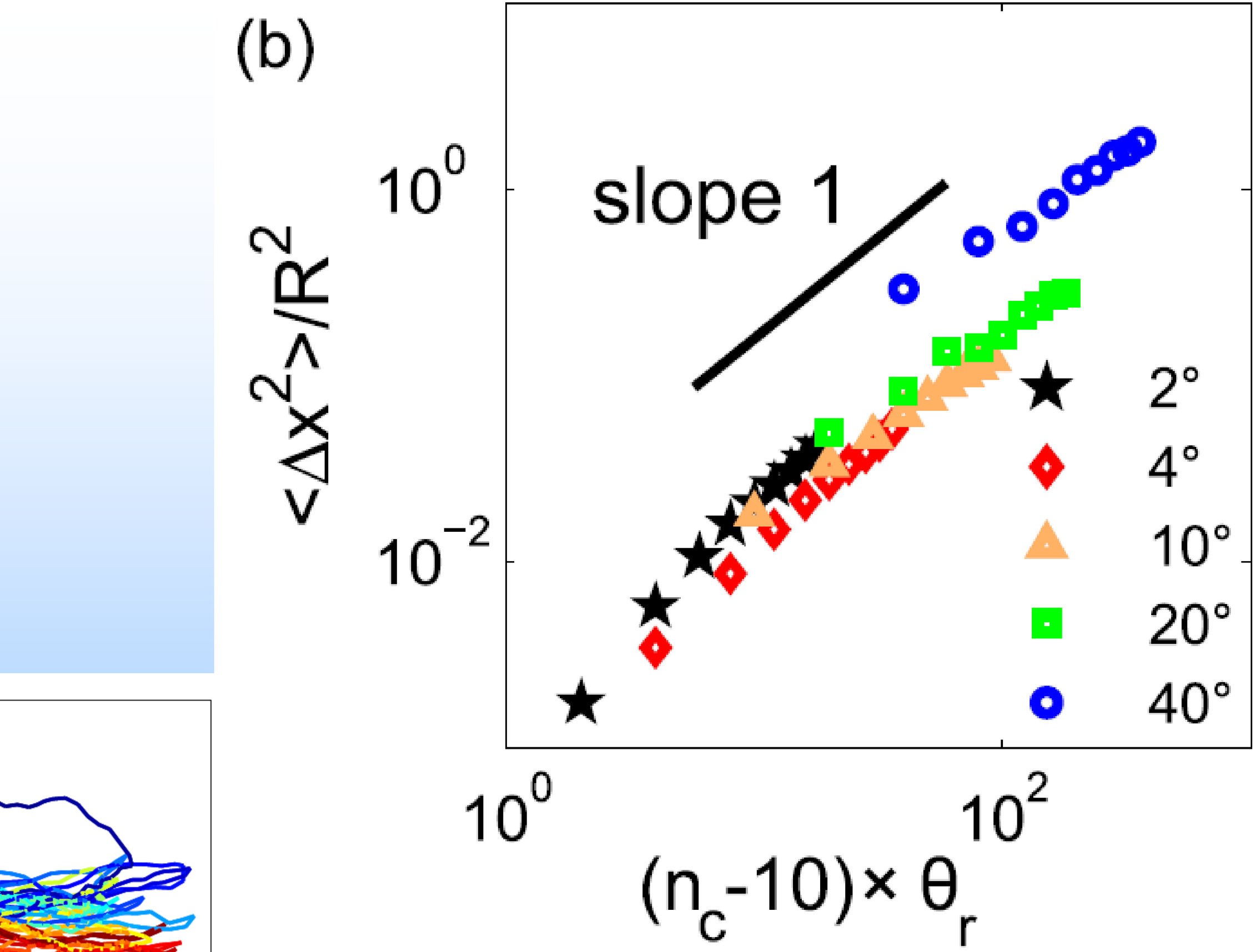

Percolation transition

# Cyclic Forcing



(b)




From cycle 10

# Summary

Our question is how granular flows start and stop

- Measuring Mesoscale Dynamics via 3D imaging

  *Contact me if you like to get trajectories for all particles for steady shear, cyclic shear, segregation*

- Developing Mesoscale Metrics of collective motion (e.g. broken links network) to connect macro & microscale

  *Can be applied to other flow geometries*

*Wolfgang Losert* wlosert@umd.edu

*Mitch Mailman, Steven Slotterback,*
*Kerstin Nordstrom, Matt Harrington*