Powdered Snow

No change in constituent property, yet entirely different behavior.

So many things to explore!
Dry Granular Solids

Typical grain size ~ 1 um to km

Typical air molecule ~ 1 Angstrom

- States are controlled by boundary and driving
- No thermal fluctuations. $T = 0$
- Purely repulsive contact interaction. $\Rightarrow$ Dry
Externally Controlled States

Unjammed states are ill-defined!

Dapeng Bi et al Nature (2011)

Jie Zhang et al. Soft Matter 2010
Zero Temperature System

- The jammed system is at mechanical equilibrium.
- Complete force and torque balance at the granular level.
- Newton's third law is satisfied.
Repulsive Interaction

- Frictionless system $\rightarrow$ All tiles must be convex.
- Frictional system $\rightarrow$ Most tiles are convex.

Non-convex tiles play a very interesting role!
The Big Question

Given the three “laws” of granular materials:

1. Externally controlled states => There are jammed states which are well defined.

2. Zero temperature states => We can construct force tiles for the jammed states.

3. Positivity of forces => The constructed tiles are mostly convex.

Can we explain the observed rigidity in these systems?
Rigidity?

Amorphous & Crystalline Solids

- Overall structure is preserved under small perturbation.
- Non-uniform density
Evolution of Jammed Systems

Evolution of Real Space Network

Evolution of Force Tile Network
Measure of Rigidity

Point Pattern

Coarse-Grain

Pattern #1 + Pattern #2 = Overlap or Number in [0,1]

Density Field

Superimpose
Order in Jammed System

Jamming is entirely described by the behavior of the system in the height space!
Origin of Plasticity in Height Space
Origin of Rigidity?

Stable

Unstable

Questions?