Flow in Amorphous Systems

Understanding Dynamics Across Scales

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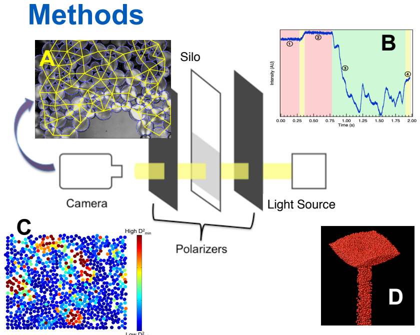
Research Objective

Granular materials are ubiquitous and yet we still lack a complete understanding of them. Our lab takes a multiscale approach to studying their clogging and flow. We can simultaneously measure the bulk flow and clogging statistics, particle motions, and the intermittent force network. It has been proposed that clogging may be akin to a phase transition, but more work is needed to discover the control parameters that govern this transition. Our hypothesis is that altering the topology of the contact network will change how the system flows and clogs. Our experiments will lay groundwork for testing the notion of the clogging phase diagram. Our particle-scale measurements will also let us confront old microscopic models that fit the data, but seem unphysical. Insight into granular flow often yields insight into other systems of crowded particles, such as traffic, blood flow, and pedestrians.

Methods

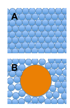


We take high speed (16,000 fps at HD res) videos of 2D gravity driven flows. We use photoelastic disks as our particles. Particles are tracked and tracks are further analyzed (A). We also perform simulations using LAMMPS (D). For each experiment we can measure:

- Bulk Properties: Flow rate and fluctuations in flow rate (above critical outlet size) / Clogging probability and avalanche size (below critical size)
- Crystal Structure: Real-time measurements of metrics such as the radial distribution function and bond-order parameter
- Networks: Proximity network, contact network, force network (B)
- Dynamical Structures: soft spots, shear transformation zones (C), dynamical heterogeneities.

Agenda

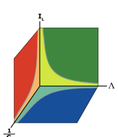
- Systematically vary 1) the outlet size both above and below the critical outlet size and 2) the packing, detailed below.
- Flow of crystalline packing with obstacle Recent work has shown obstacles increase flow, we hypothesize this is due to frustration of local jamming.



- Flow of crystalline packing with intruder We hypothesize obstacles need not be fixed to generate flow enhancement.
- Crystal to Amorphous We introduce multiple obstacles to create a disordered packing.

Implications

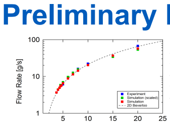
- We conjecture that we can characterize the "incompatible load" in the proposed clogging phase diagram in terms of the crystallinity and presence of multiple length scales in the packing.



Clogging phase diagram (Zuriguel 2014)
- *Compatible Load (driving)*
- *Incompatible Load (prevents arching)*
- *Length Ratio (Outlet vs Paritcle)*

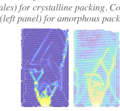
- This work will directly test a new granular flow model (Kamrin 2017) in terms of the stress field.

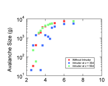
Preliminary Results



Flow rate vs outlet size for crystalline experiment and simulation. Results are consistent with empirical Beverloo equation.

Shear transformation zones (linear and log scales) for crystalline packing. Contrast to D (left panel) for amorphous packing



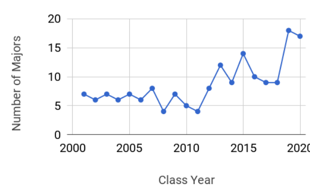


Avalanches for different obstacle positions. In clogging regime (D/d < 5), obstacle can impede flow, rather than enhance flow (recall flow enhanced in free flow regime).

Educational Objective

Overview

- **Mount Holyoke** is a women's liberal arts college with strong STEM departments and outcomes (e.g. for bacc. colleges in last 50 years had the greatest number of women who earn doctorates in STEM disciplines).
- **Mount Holyoke physics is strong and growing,** our class size is very high for a school our size, and we generate more women physics majors than most institutitions, ***regardless of size***.
- **How?** Multiple entry points into the major, small class sizes and inclusive teaching, early research experiences, strong sense of physics community = strong physics identities.



However…

- Our domestic majors do not reflect the diversity of Mount Holyoke (27% domestic students of color).
- Supporting underrepresented minority (URM) women can make a difference in *national* statistics. (e.g. 12 URM women physics PhDs in 2013)

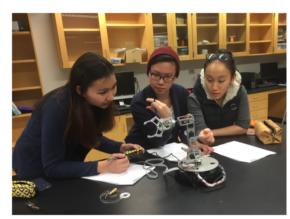
Program

MHC Launch is a pre-college program designed to recruit more students into physics (at MHC many students find out they like physics too late) and build physics identities and networks.

1) Cohort 10 admitted students with interest in physical science/engineering participate in project based lab activities in afternoons for 2 weeks before the fall semester. Mornings dedicated to seminars and discussions about how college/science works. Cohorts are not exclusively URMs, but at least must match/ exceed US demographics in representation.

2) Cohere In their first year, the first cohort will organize several workshops open to all majors and interested students, led by faculty. Topics might include preparing a resume/CV, preparing for graduate school, etc.

3) Connect Throughout their college career, cohort members will be given work-study jobs to strenghten their network as well as the department's, such as gathering data about REU experiences and interviewing alumnae.



References

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