Dry systems forward look

Michel Louge,
virtual IFPRI AGM,
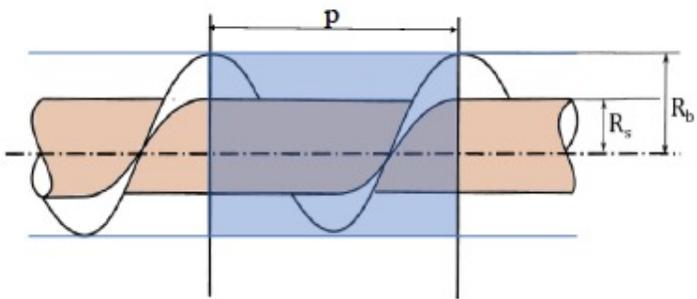June 21, 2021

Dry systems portfolio

- Indresan Govender (mixing)   renewal 2021
- Karen Daniels (dry rheology)   until 2022
- Prabhu Nott (screw feeding)   until 2023
- Arno Kwade (milling additives)   until 2023
- Kit Windows-Yule (round-robin)   renewal?
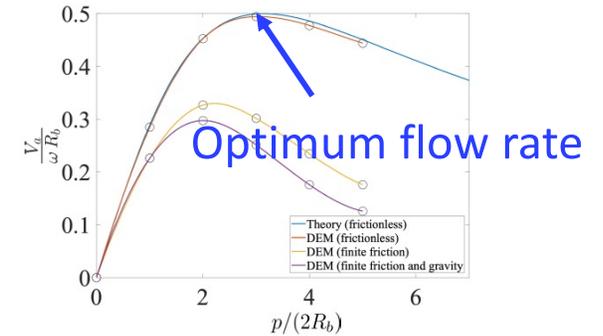- Csaba Sinka (powder adhesion)   delayed
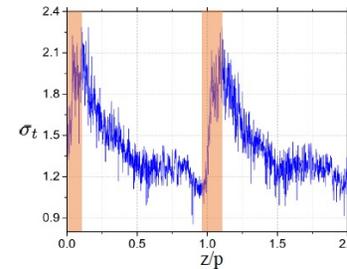
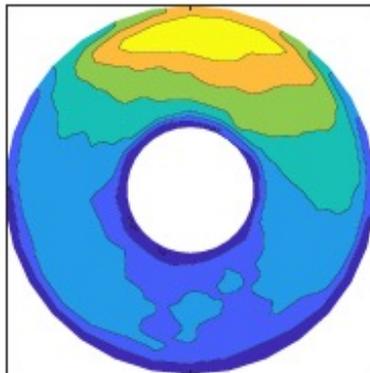# What we learned
screw feeders

Prabhu Nott's group

formal calculations
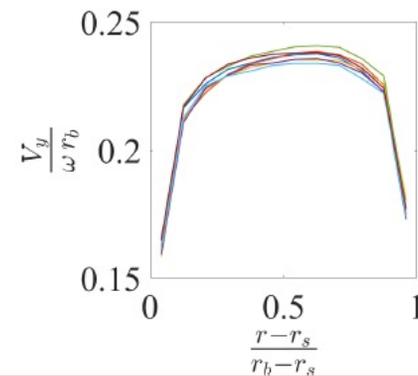Optimum flow rate

instrumented experiments
Janssen-like effect

DEM
role of cohesion

What we learned
challenge of fitting non-local rheology to data

Karen Daniels' group

non-local interaction
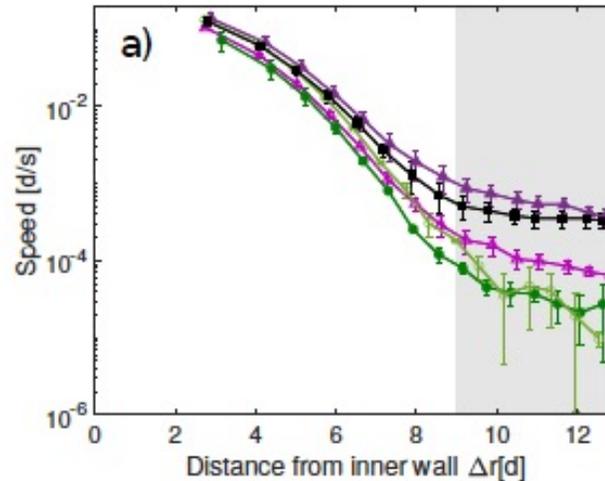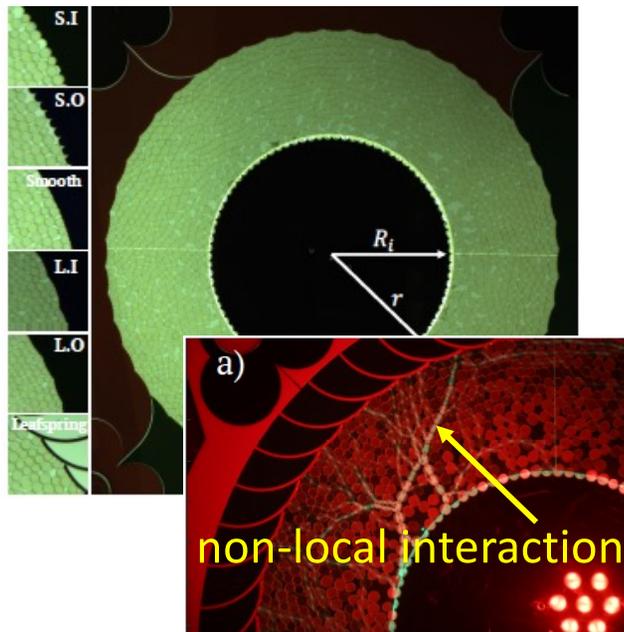
Boundaries are pervasive; non-local rheology parameters are NOT material properties.
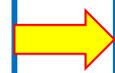
Pouliquen, Chevoir, Jop, et al

local   Inertial number I

$$\frac{S}{N} = \mu = f(I; \mu_s) \qquad I = \frac{d \times du/dr}{\sqrt{N/\rho}}$$

diameter d, velocity u, stresses S & N, density ρ

Kamrin, Claudin, et al

fluidity η, length scale ζ, friction μ

$$\mu = \frac{du/dr}{\eta} \qquad \nabla^2 \eta = \frac{1}{\zeta^2}(\eta - \eta_{local})$$

non-local $\zeta = A \dfrac{d}{\lfloor \mu - \mu_s \rfloor^{1/2}}$

Karen fits parameters A, μs and the function f to data

Collaboration?

Prabhu Nott and Karen Daniels

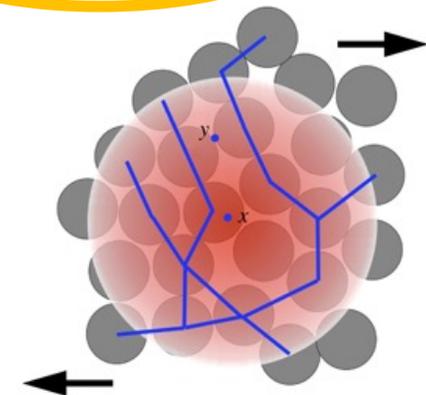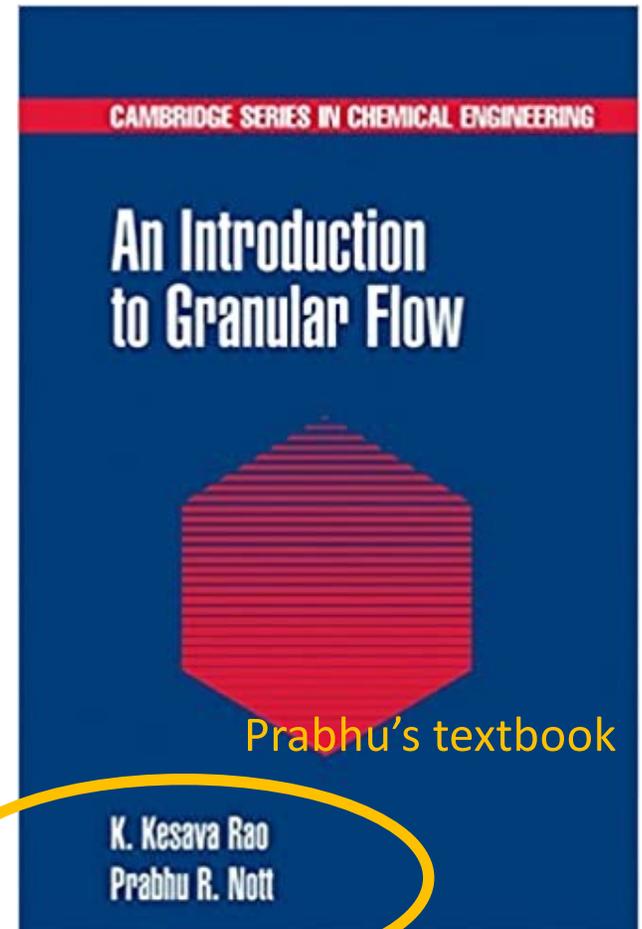*J. Fluid Mech.* (2020), *vol.* 888, R3, doi:10.1017/jfm.2020.62

JFM RAPIDS
journals.cambridge.org/rapids

A non-local constitutive model for slow granular flow that incorporates dilatancy

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(Received 5 November 2019, revised 27 December 2019, accepted 16 January 2020)

CAMBRIDGE SERIES IN CHEMICAL ENGINEERING

An Introduction to Granular Flow

Prabhu's textbook

K. Kesava Rao
Prabhu R. Nott
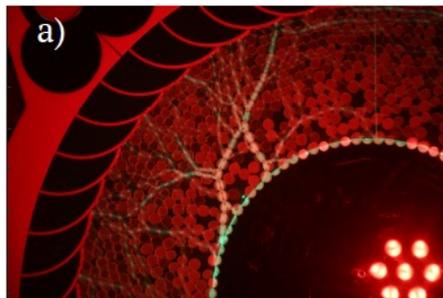
What we learned
heralding the birth of digital twins

Kit Windows-Yule
and Jonathan Seville

Granudrum

Granuflow

Granupack

Granuheap

FT4

DEM

PEPT experiments

good

DEM

not so good

DEM
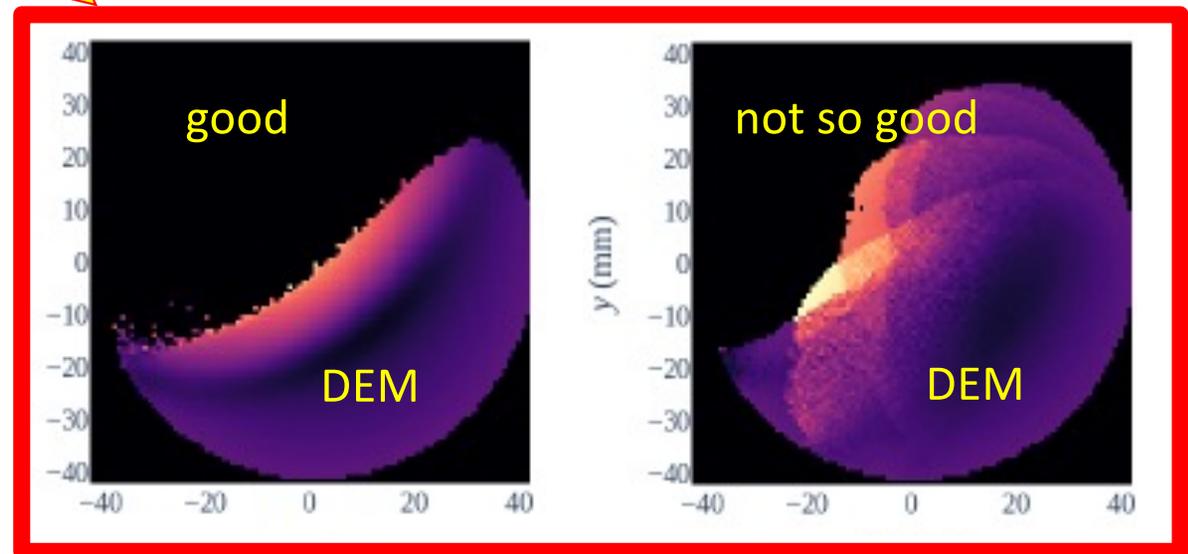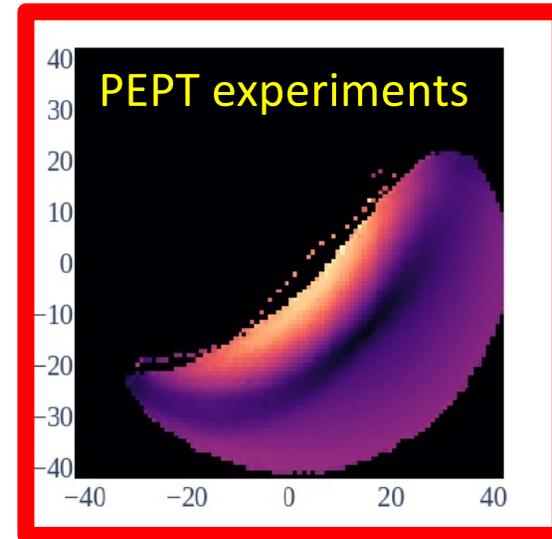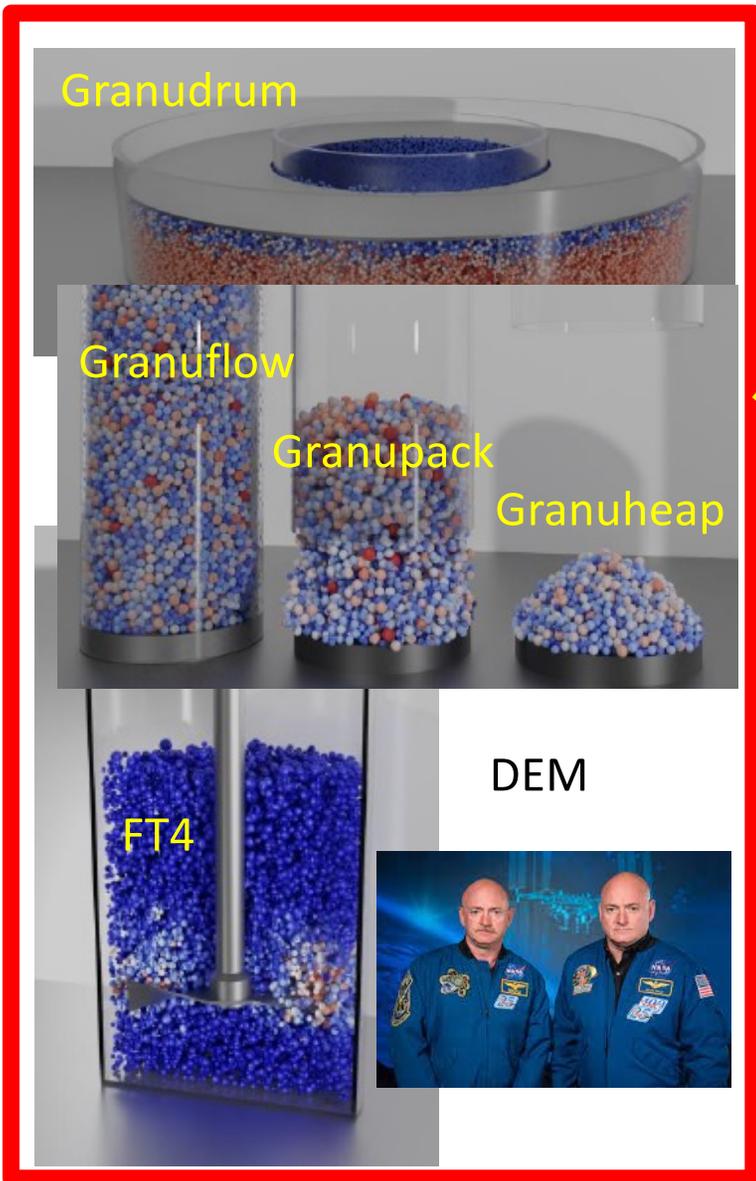
Should the PIs develop a new set of DEM
standard operating procedures?

What we learned
kinetic energy and mixing

Indresan Govender

The power of unique instrumentation

Theory   PEPT
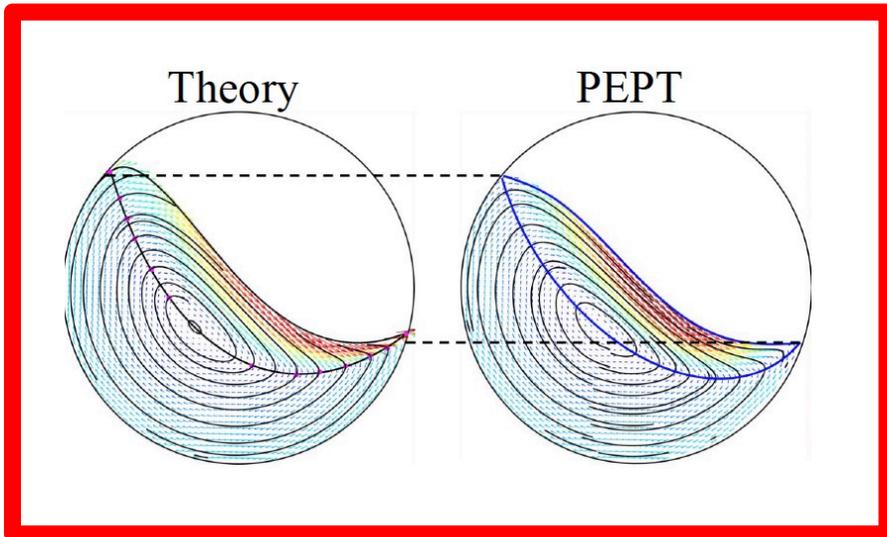
Adopt linearized local rheology of Jop, et al

$$\tau_{xz} = \mu_0\sigma + \chi D\dot{\gamma}_{xz}\sqrt{\rho\sigma}$$

solve governing equations

assume that mixing is correlated with local kinetic energy

derive a dimensionless number for mixing

$$\hat{\omega} = \frac{\omega R^{9/8}}{\sqrt{g_\perp}(\chi D)^{3/4}}\left(\frac{L}{\mu_W}\right)^{1/8}$$

What we learned

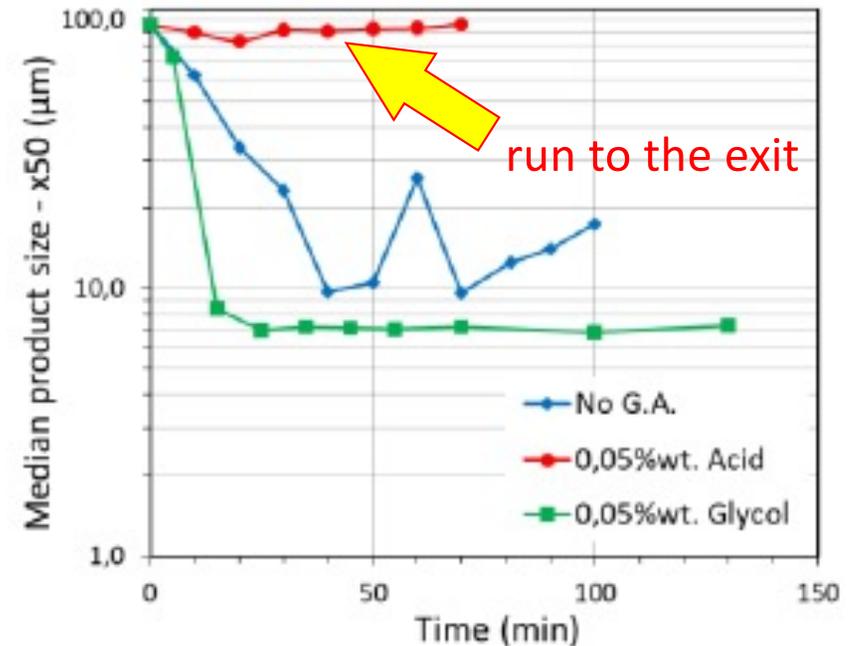Arno Kwade's group

additives in continuous milling and classification
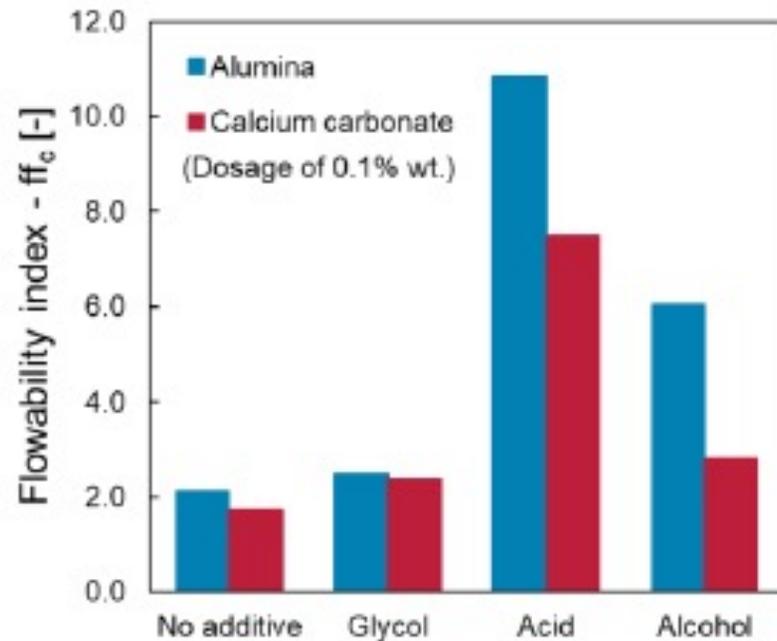
run to the exit

Trade-off of better flowability: less residence time in continuous ball milling
⟹ particles run to the exit…

Forward look:
recruit scholars with wide scientific bandwidth

gas-solid flows, role of cohesion

Olivier Desjardins

also Jesse Capecelatro (Michigan), Rodney Fox (Iowa State)

Sprays: X-ray vs high-fidelity simulations of atomization

Ashgriz' group
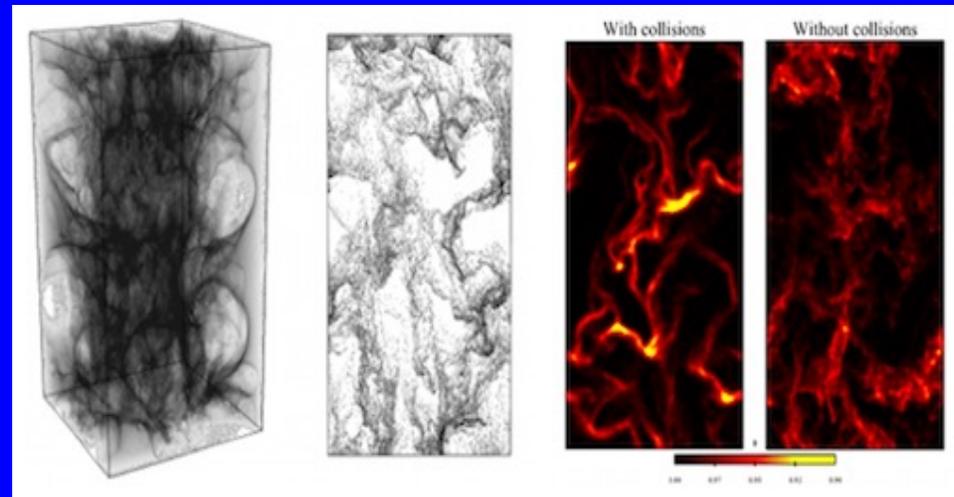
Olivier Desjardins leads a group with
Daniel Bodony (Illinois), Ted Heindel (Iowa State),
Balachandar (Florida), Alberto Aliseda (U. Washington)

	Time-averaged EPL from LES (Cornell)	Instantaneous image from LES (Cornell)	Instantaneous light attenuation image (UW)	White beam X-ray image (ISU/UW)	Time-averaged EPL from focused beam X-ray (ISU/UW)
$Re_g = 16,700$					
$Re_g = 36,600$					

Validation against X-ray imaging at Argonne (ISU & UW)

Suggested scientists

Alban Sauret (UCSB): particle suspensions, capillarity, dip coating, granular accretion.

Heather Emady (ASU): particle characterization, capillarity, DEM.

Heinrich Jaeger (Chicago): particle charging, granular impacts, dense suspensions.

Farhang Radjai (Montpellier): simulations, force chains, cohesion, granular theory.

Alexandre Valance (Rennes): experiments and DEM on inclined flows.

Atieh Moridi (Cornell): thin flow and rapid prototyping.

Roberto Zenit (Brown): capillary interactions.

Paul Umbanhowar (Northwestern): granular physics.

Axelle Hamon (Rennes): experiments on particle forces and localization.

Elisabeth Guazzelli (Paris-Diderot): granular suspensions.

Anthony Thornton (Twente): granular segregation.

Granular Matter Gordon Conference, June 26-July 1, 2022