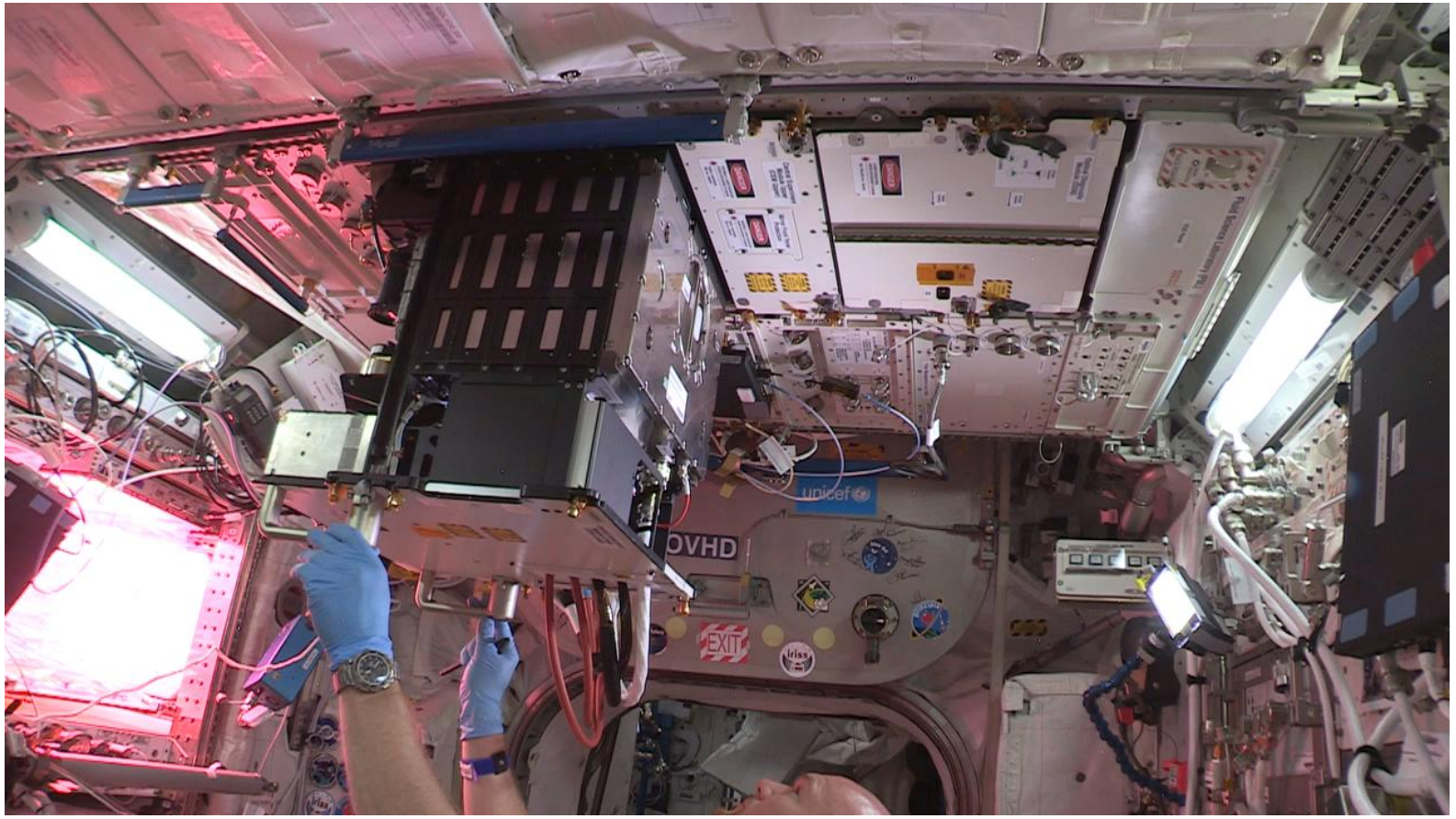
DLR Celebrating the Legacy of the Fluid Science Laboratory

Matthias Sperl, Jan Philipp Gabriel, Christopher Mayo

09/10/26

Soft-Matter Dynamics, July 19th 2018



Alexander Gerst, 19. June 2018, Light Scattering from Granular Matter

Experiments on ISS: Soft-Matter Dynamics



Alexander Gerst, 19. June 2018, Light Scattering from Granular Matter

Soft-Matter Dynamics, A Brief History

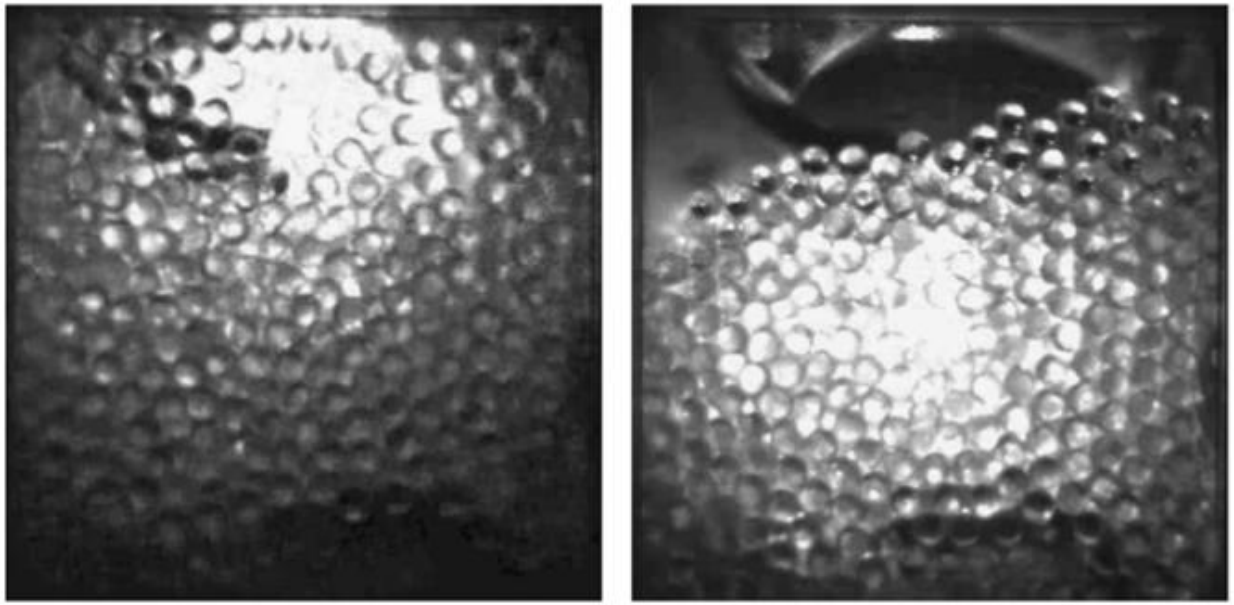
2009	ESA Announcement of Opportunity (AO-2009-0943): Compaction and Sound in Granular Matter (CompGran) original Pis: Behringer, Clement, Luding, Sperl, Schröter; additional Pis: Ammon, Crassous, Durian, Egelhaaf
2010 Oct	Parabolic Flight campaign ESA-53
2010 Nov	Parabolic Flight campaign DLR-16
2011 Aug	Drop Tower campaign, piezo and magnetic agitation
2011 Sep	Parabolic Flight campaign DLR-18
2012 May	Parabolic Flight campaign ESA-56
2012	Feasibility Study for granular cells in carousel
2013 Feb6	Soft-Matter Dynamics approved by ESA program board for ELIPS-4
2013/14	Drop Tower campaigns, air fluidization
2018 Jun	Drop Tower campaign with Engineering Model
2018 Jun29	launch SpaceX-15, 11:41am (CEST)
2018 Jul19	installation on ISS 11:30-13:00, followed by commissioning FSL switched on 14:53(CEST)
2018 Aug2	kick-off Science, Phase 1 (piezo agitation) parameter scan

Bob Behringer Memorial

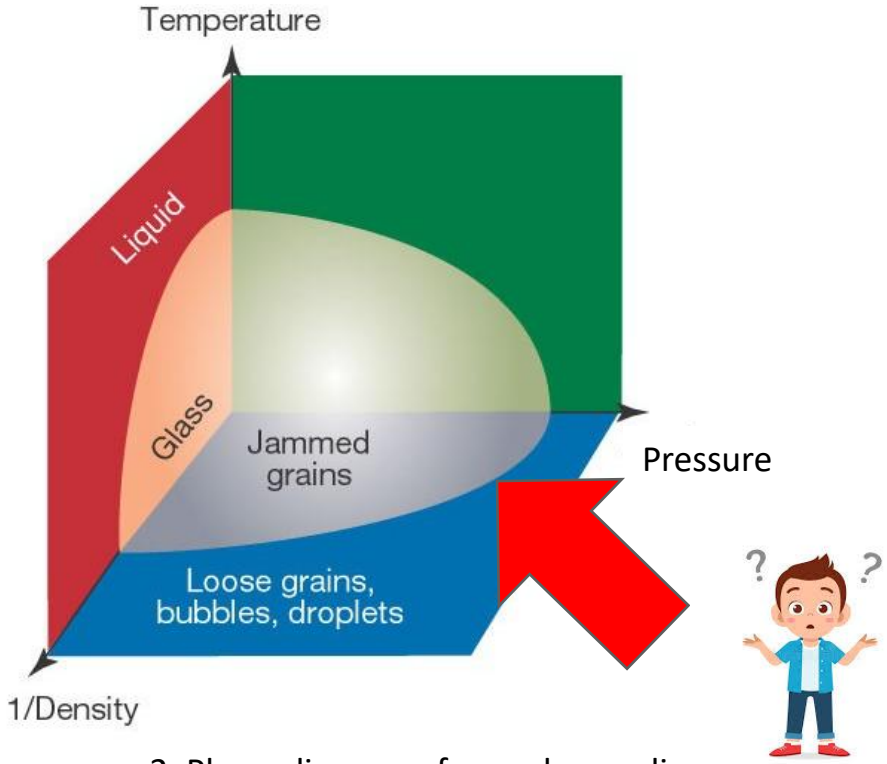


COMPGRAN 3 2024

Motivation



1. Comparison of the fluidized granular medium in microgravity and on the ground at a low- filling fraction Φ of 0.48.

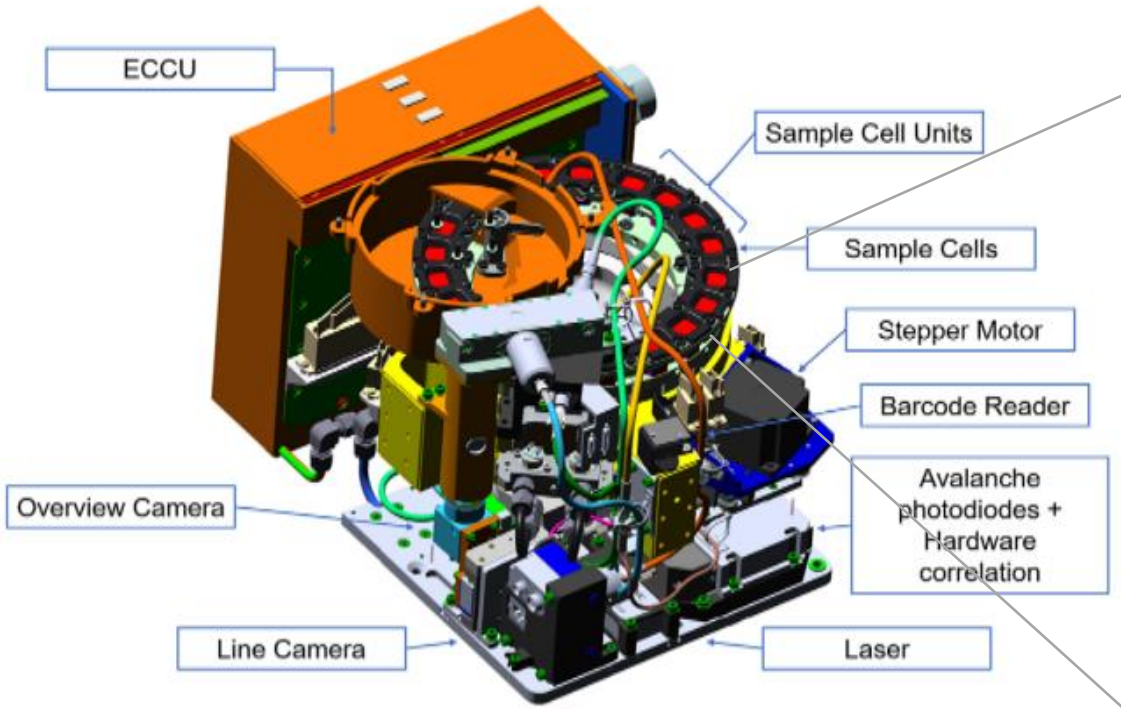


2. Phase diagram of granular media

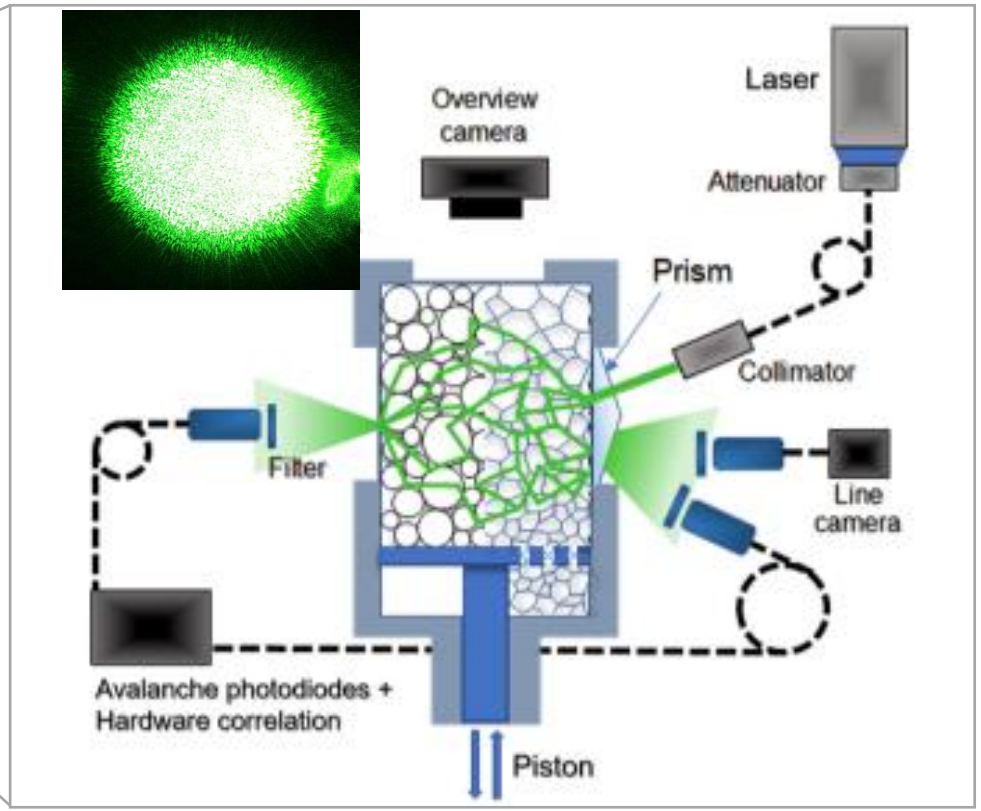
1. Born, P., Schmitz, J. & Sperl, M. Dense fluidized granular media in Zhang, Yong & Liu, Jun & Chen, Shuying & Xie, Xie & Liaw, Peter & Dahmen, Karin & Qiao, Jun & Wang, Yan. (2017). Serration and Noise Behavior in Materials. Progress microgravity. *npj Microgravity* **3**, 27 (2017). https://doi.org/10.1038/s41526-017-0030-z
2. in Materials Science. 90. 10.1016/j.pmatsci.2017.06.004.

Experimental setup

3. FSL Experiment Container



4. CompGran experiment schematic

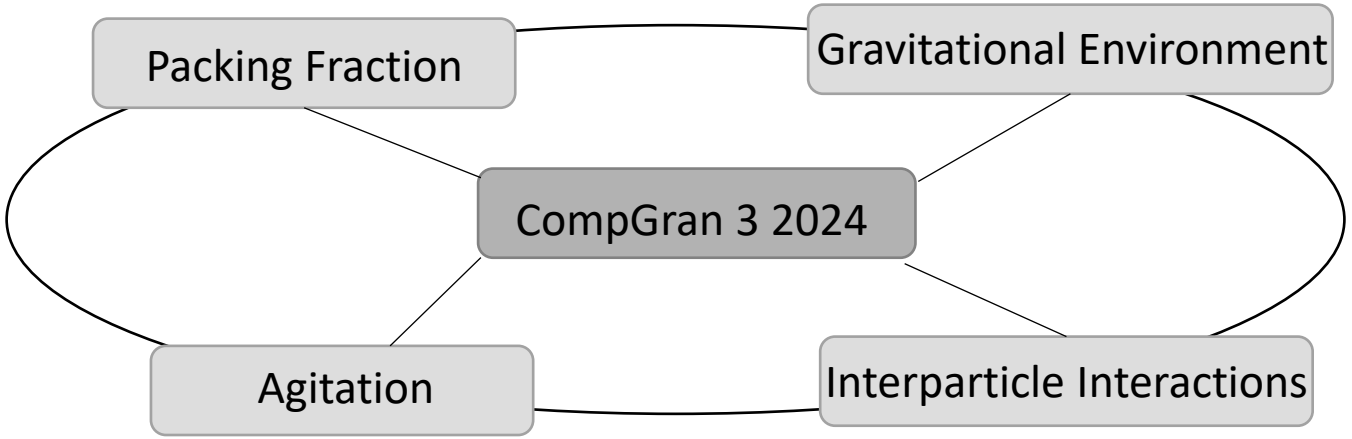


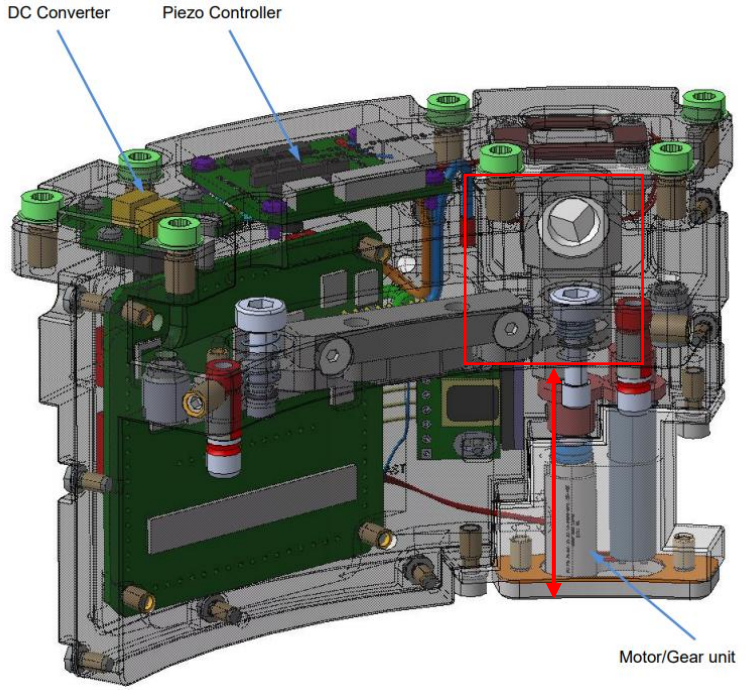
3 & 4. P. Born, M. Braibanti, L. Cristofolini, S. Cohen-Addad, D. J. Durian, S. U. Egelhaaf, M. A. Escobedo-Sánchez, R. Höhler, T. D. Karapantsios, D. Langevin, L. Liggieri, M. Pasquet, E. Rio, A. Salonen, M. Schröter, M. Sperl, R. Sütterlin, A. B. Zuccolotto-Bernez; Soft matter dynamics: A versatile microgravity platform to study dynamics in soft matter. *Rev. Sci. Instrum.* 1 December 2021; 92 (12): 124503. https://doi.org/10.1063/5.0062946

The Samples

The 4 sample cells used during the campaign:

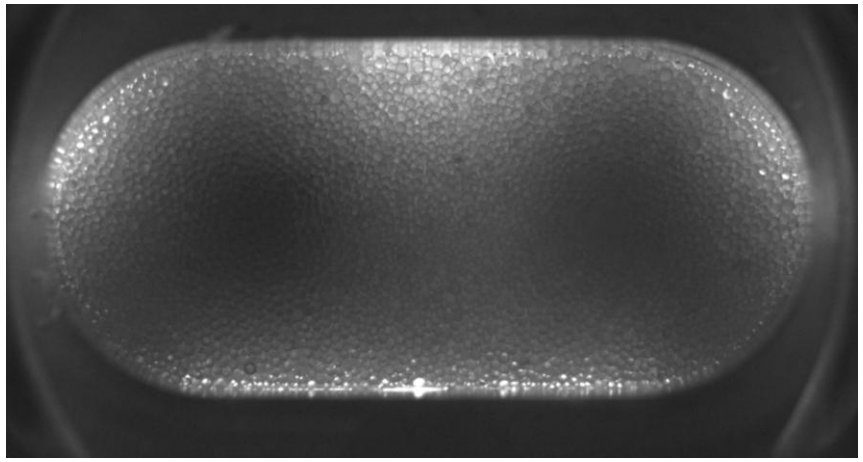
- FM01-140 micron polystyrene spheres with rod piezos
- FM02-140 aerosol coated polystyrene spheres with cubic piezos
- FM03- Lunar simulant with cubic piezos
- FM04- 140 micron polystyrene spheres with rod piezos

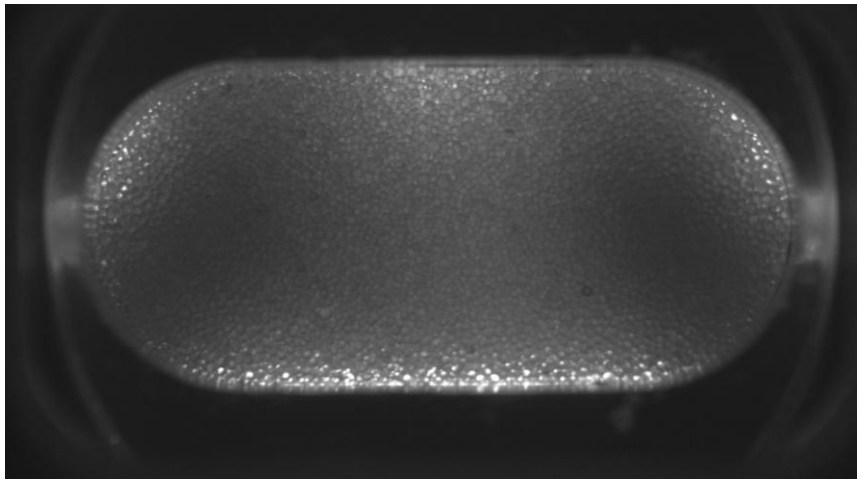




Overhead Camera

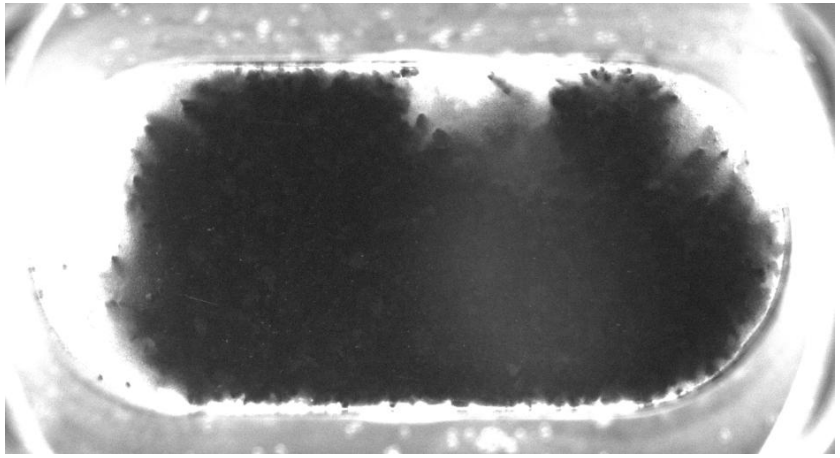
Fm01

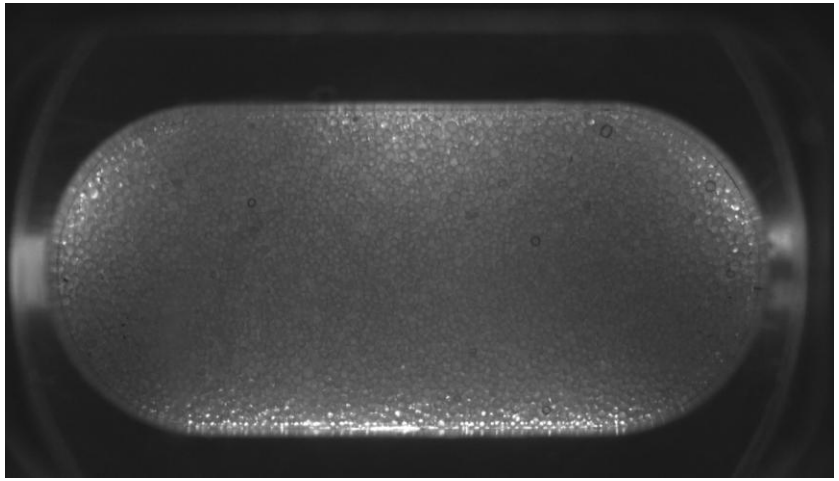




Fm02

Fm03





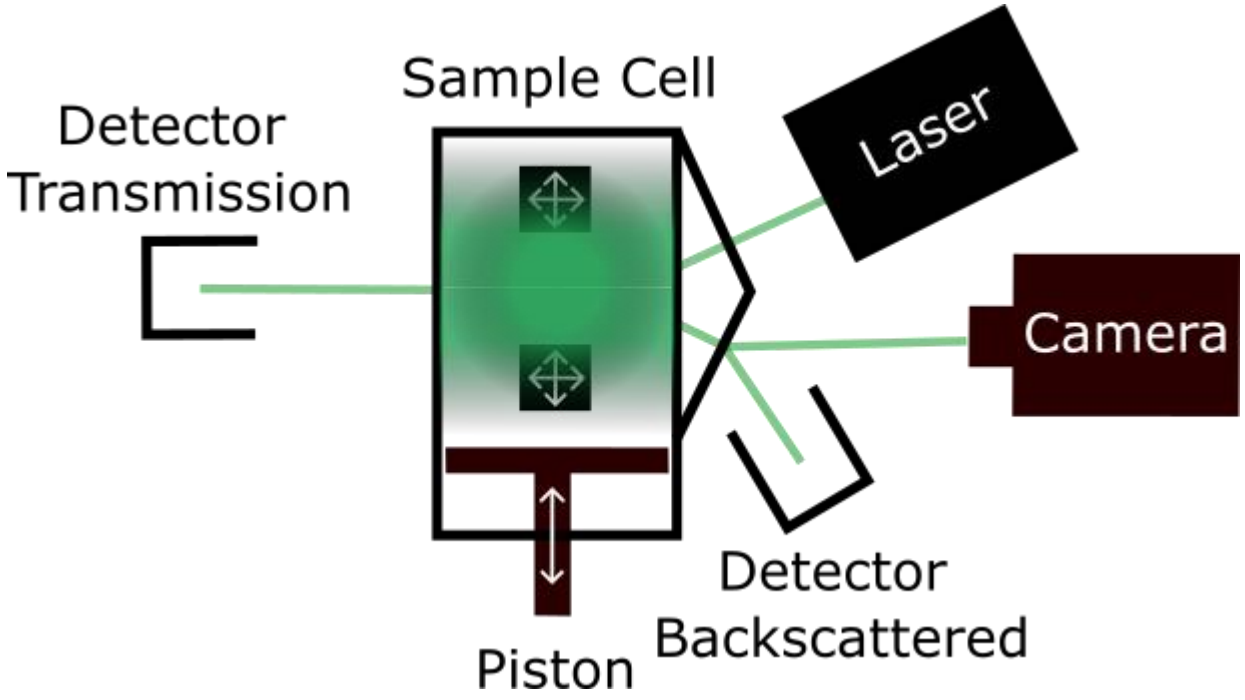
Fm04

Campaign Breakdown

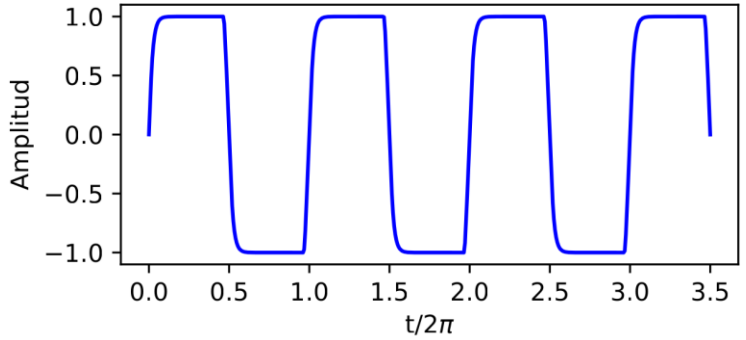
- 29 April – 14 August 2024
- 399 Total science measurements - 1742.1h – 73 days
- 5.40 TB of Total Data
- Longest individual run, 11 h 5 min 28 s

Sample cell	Measurements	Total run time	Share of time
FM01	99	235.74 h	13.5%
FM02	101	660.70 h	37.9%
FM03	8	22.31 h	1.3%
FM04	191	823.38 h	47.3%
Total	399	1,742.13 h	100%

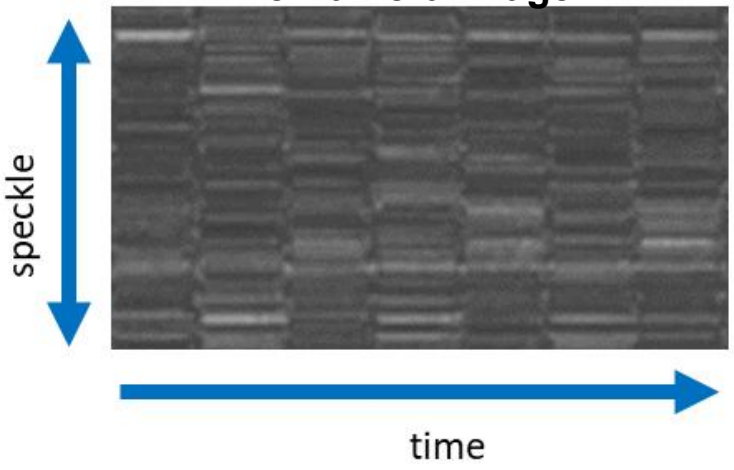
Agitation Mechanism



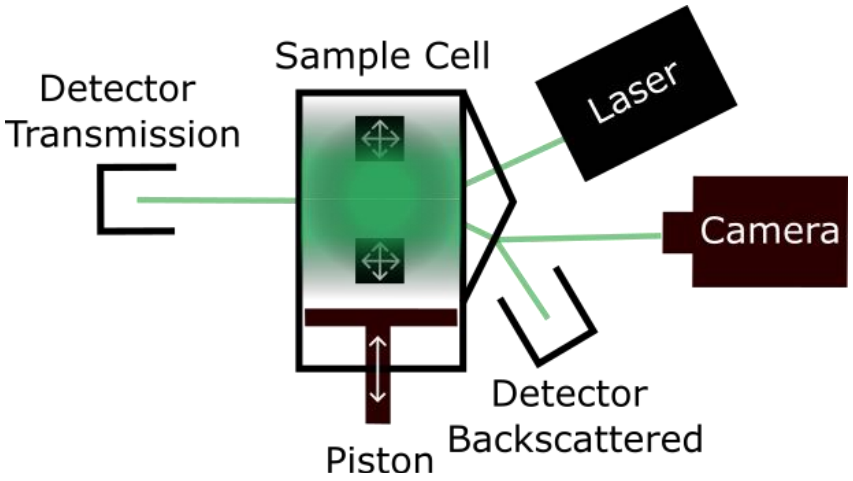
Agitation Profile

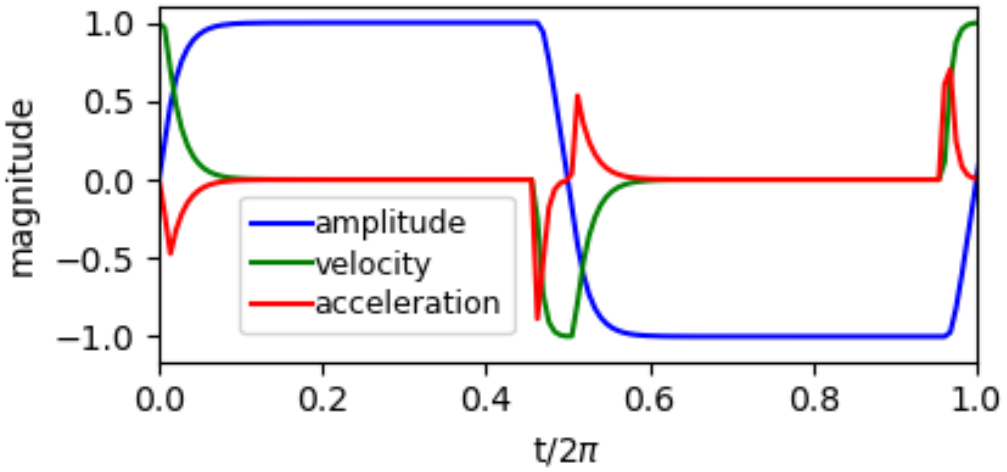


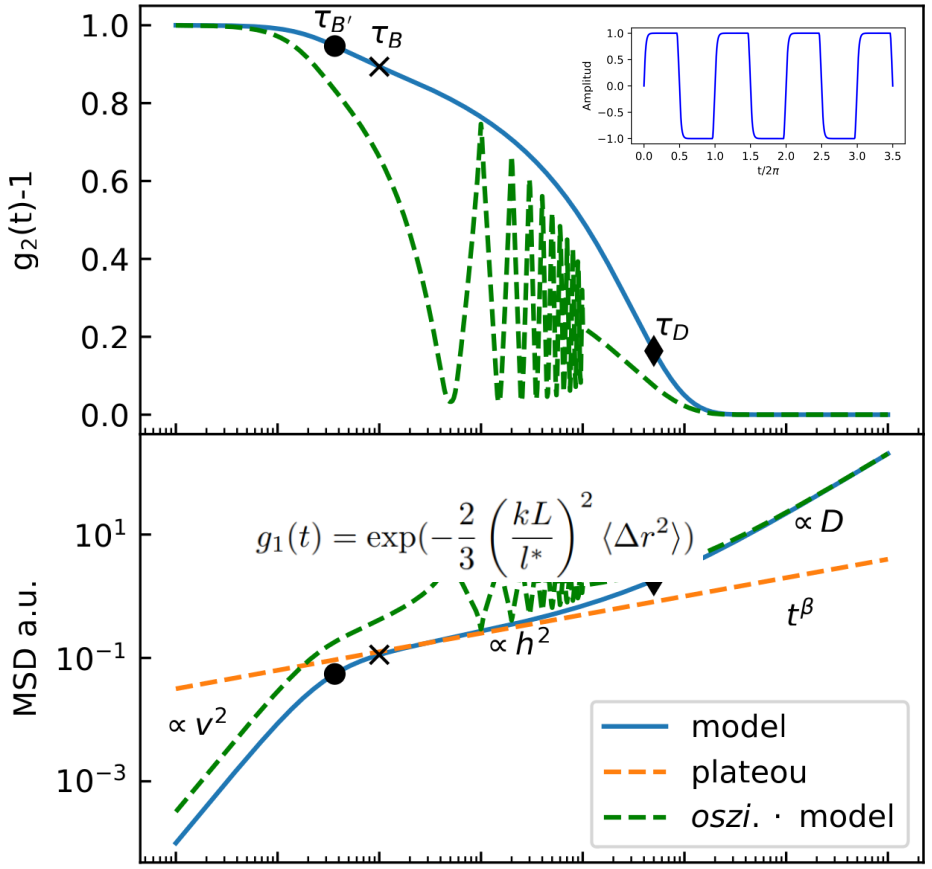
Line Camera Image



Modelling

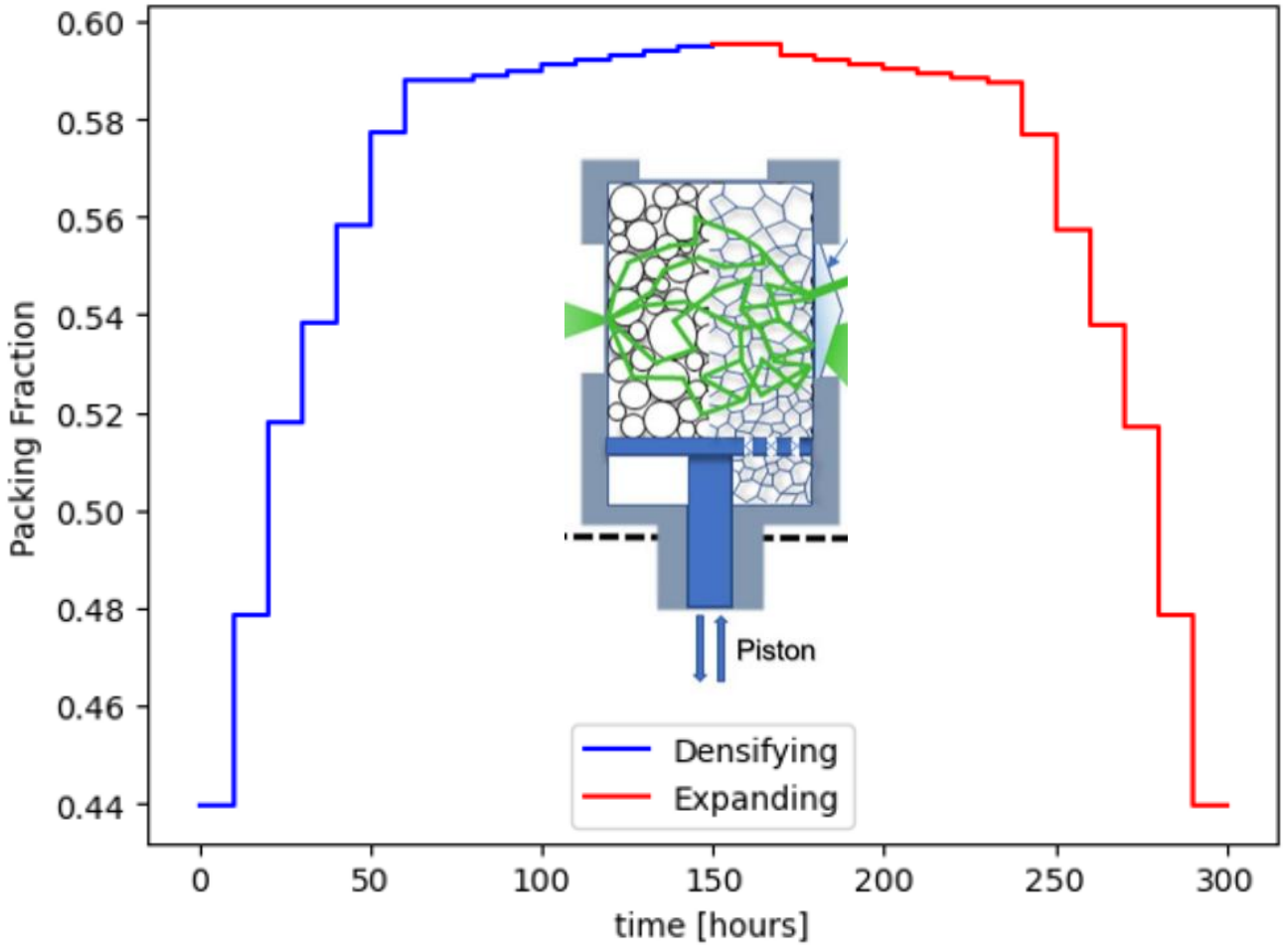






$$O(t) = \frac{1}{T}\int_0^T \exp\left[-\kappa^2 A^2 \left(P[\omega(t+t')] - P(\omega t')\right)^2\right] dt'$$

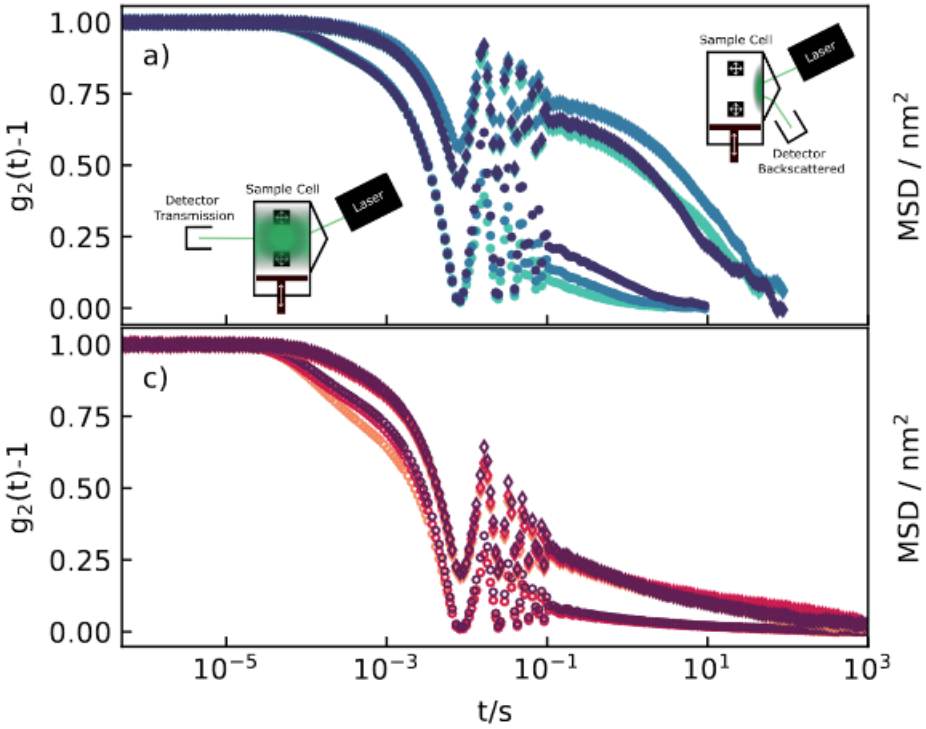
Experiment Protocol Example

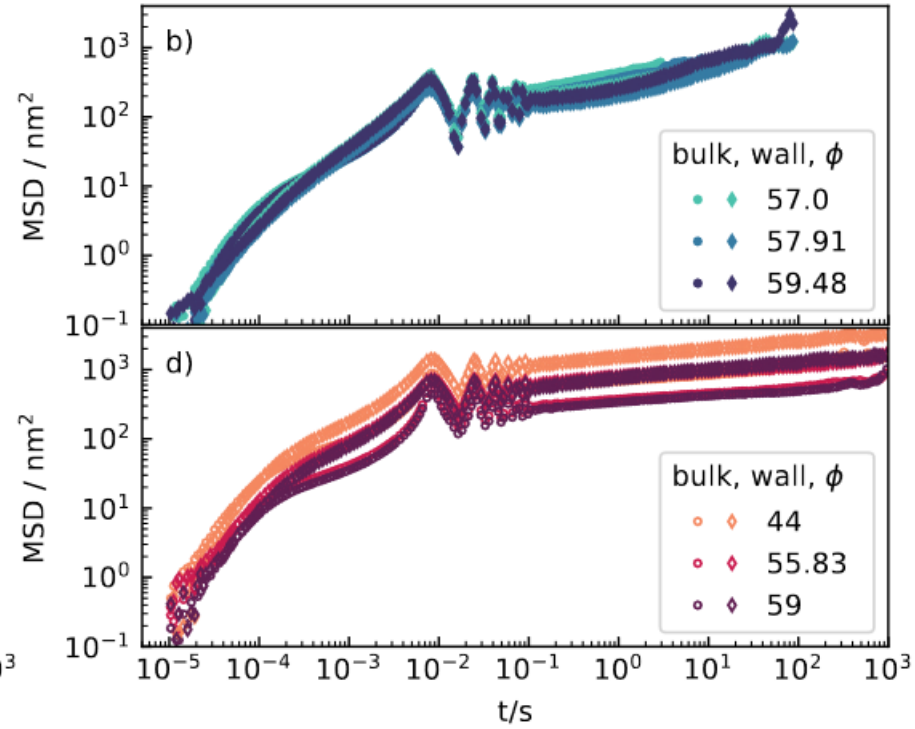


Ground vs Microgravity

Ground

Microgravity

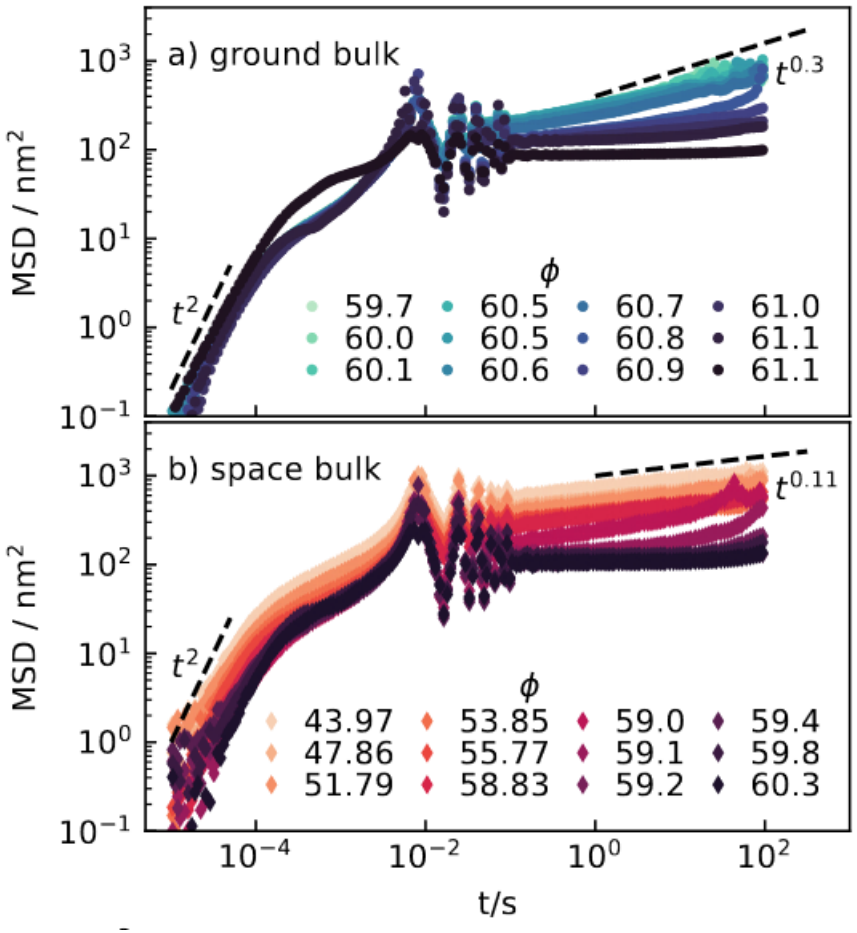


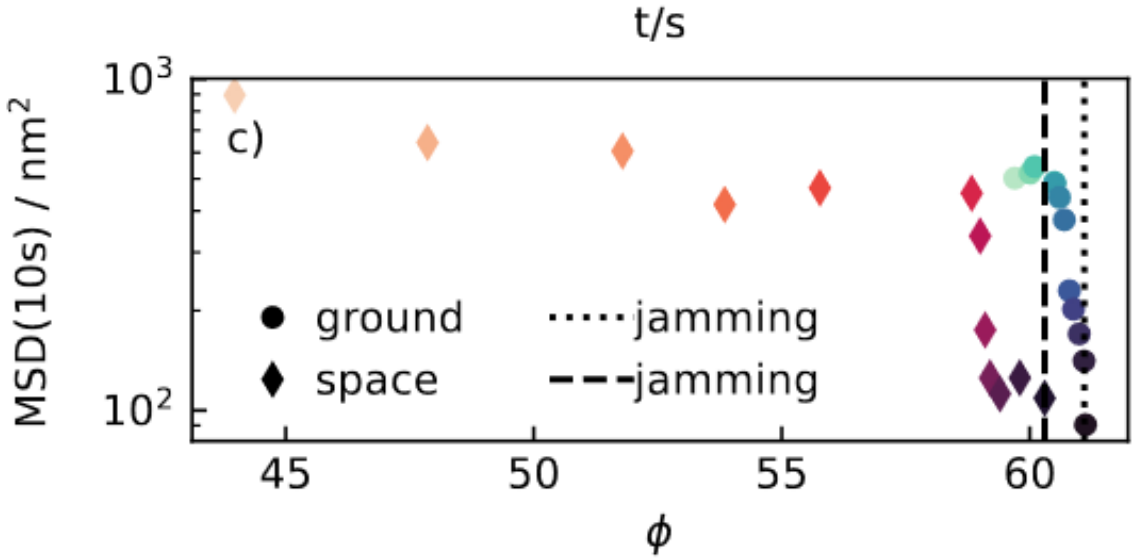


$$g_2(\Delta t) - 1 = \frac{\langle I(t) I(t+\Delta t) \rangle_t}{\langle I(t) \rangle_t^2} - 1$$

$$\langle \Delta r^2(\Delta t) \rangle = \frac{3}{4} \left(\frac{\ell^*}{k_0 L} \right)^2 \ln \left(\frac{\beta}{g_2(\Delta t) - 1} \right)$$

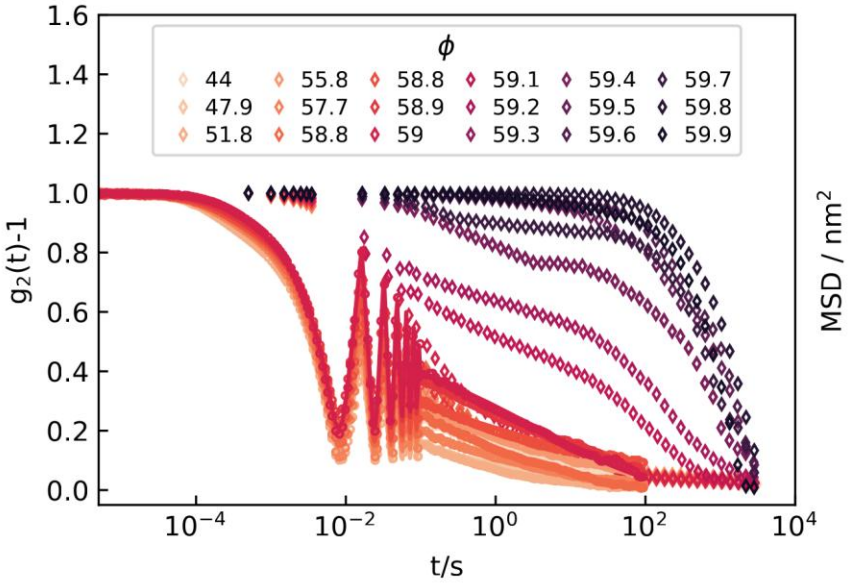
Jamming in Microgravity vs Ground

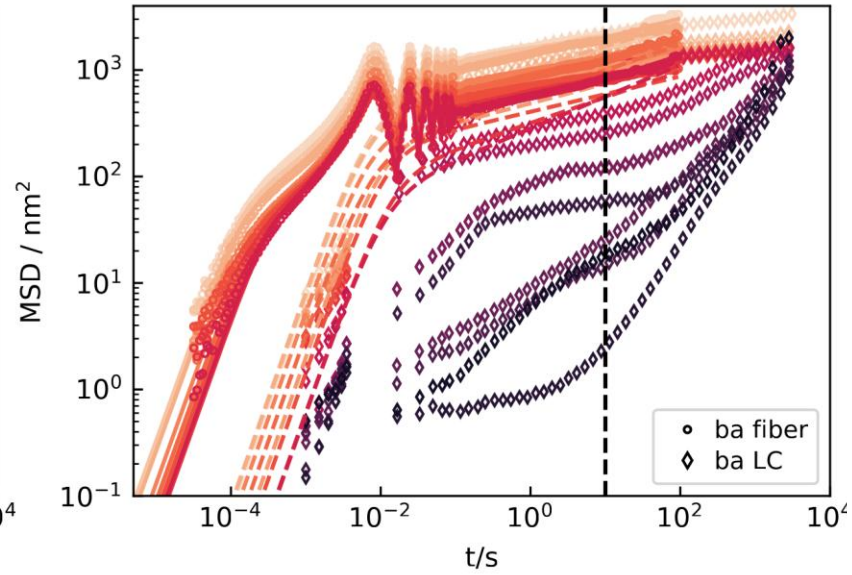


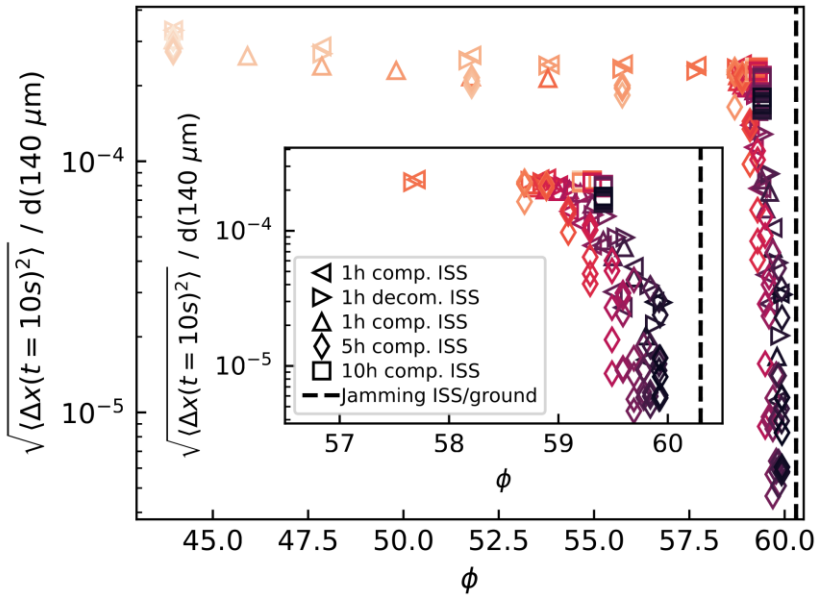


Transition	Microgravity (ISS)	Ground
Glass transition	59.0%	60.6%
Jamming transition	60.6% ± 0.1%	61.1% ± 0.1%
Difference	1.6 percentage points earlier in space	0.5 percentage points earlier in space

Jamming +







$$g_2(t) = \frac{g_{2,m}(t)}{CO(t) + (1 - C)}$$

$$\langle \Delta r^2(t) \rangle = \frac{h^2}{(\tau/t)^2 + (\tau/t)^\beta} + 6Dt + 6D\tau(e^{-t/\tau} - 1)$$

CompGran Summary







Drop Tower Setup for Dynamic Light Scattering in Dense Gas-Fluidized Granular Media

General information

Publication type
Journal Article

DOI
10.1007/s12217-016-9496-7

Journal
2016, Microgravity Science and Technology, № 4, p. 413-420

Publisher
Springer Science and Business Media LLC

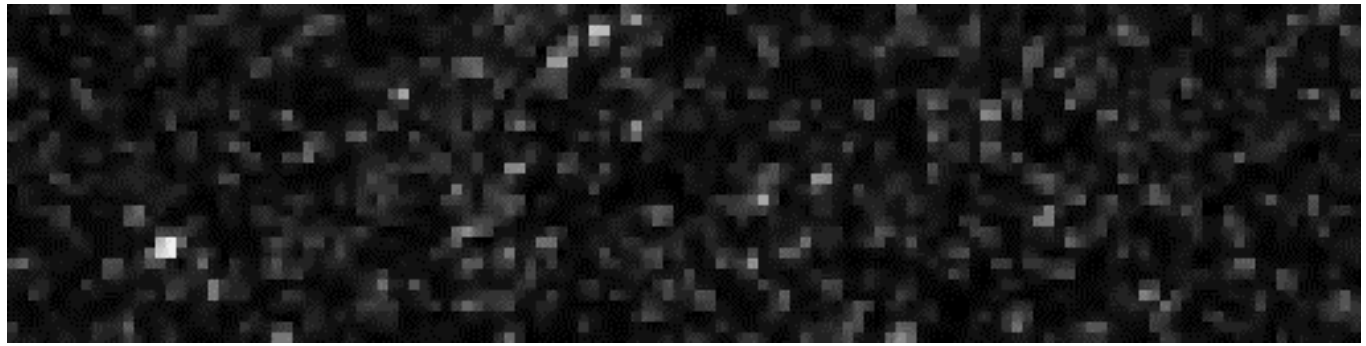
Authors
Philip Born, Johannes Schmitz, Michael Bußmann, Matthias Sperl

What’s New?

More Ground Measurements…

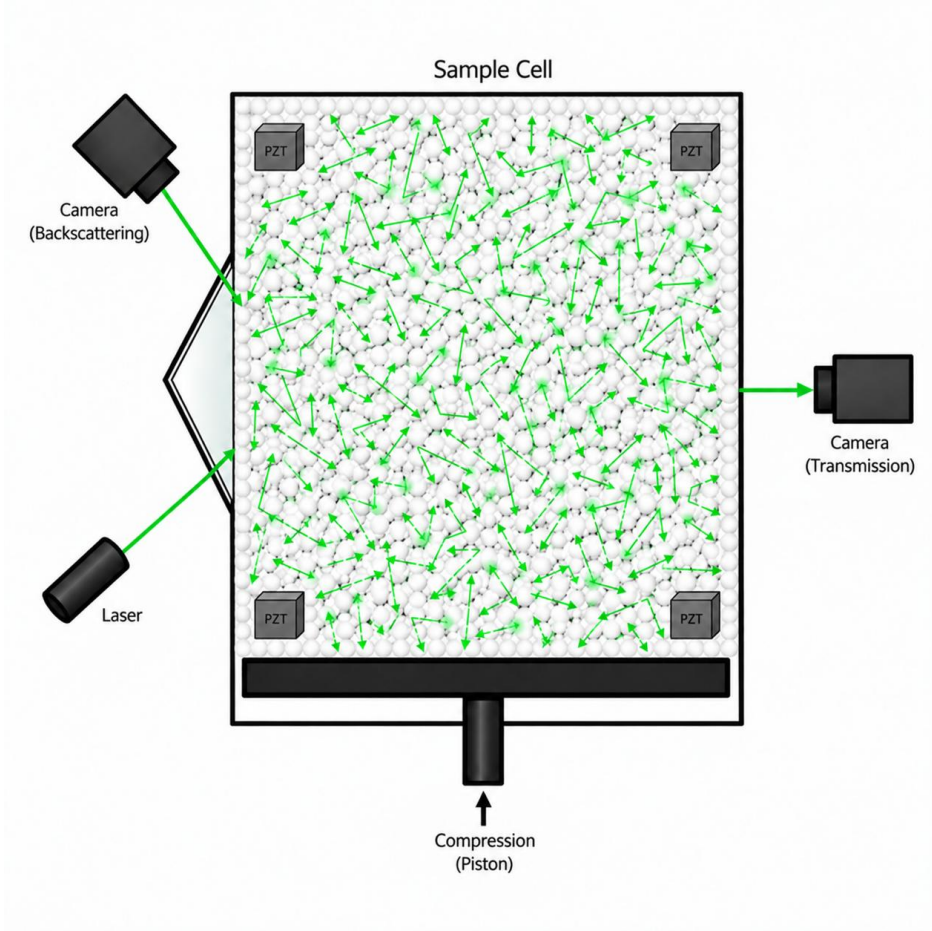
- More samples
- More Agitation frequencies
- Longer Measuements
- Better Detection
- More detailed analysis

4000 Fps

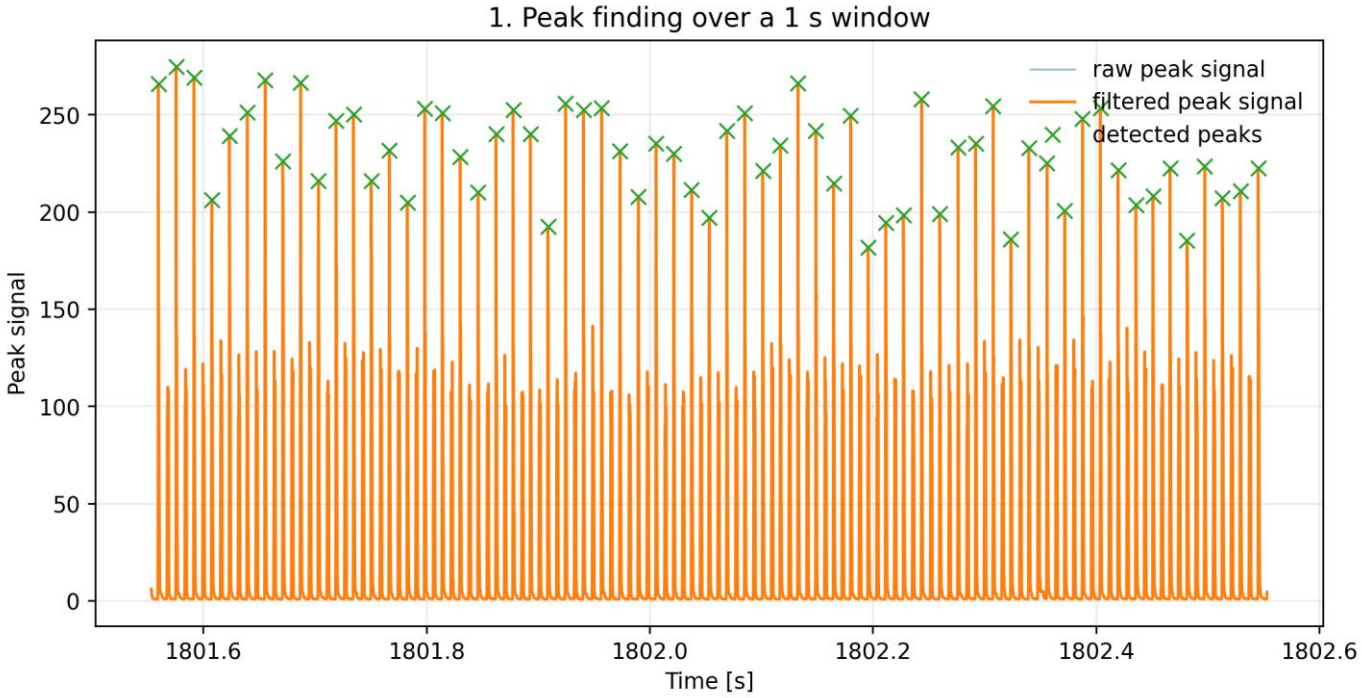


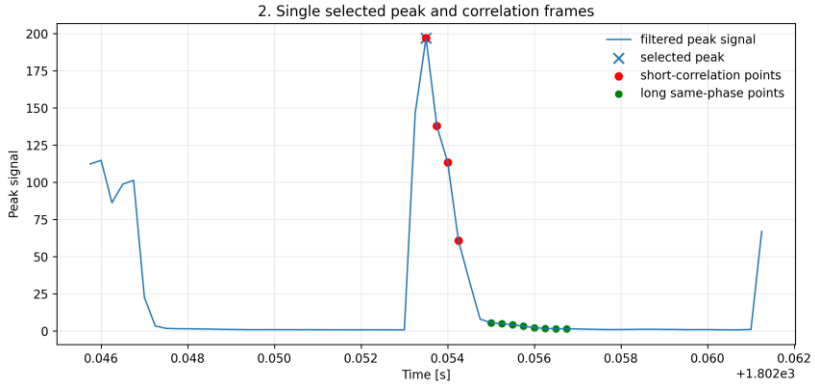
32 pixels

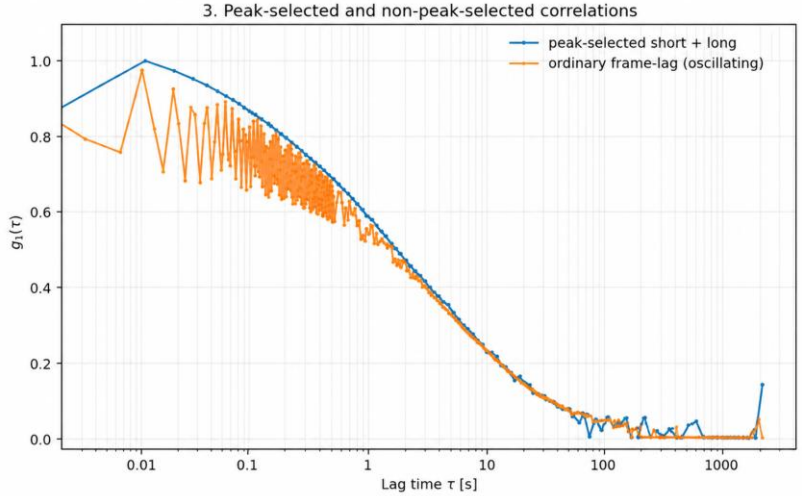
128 pixels



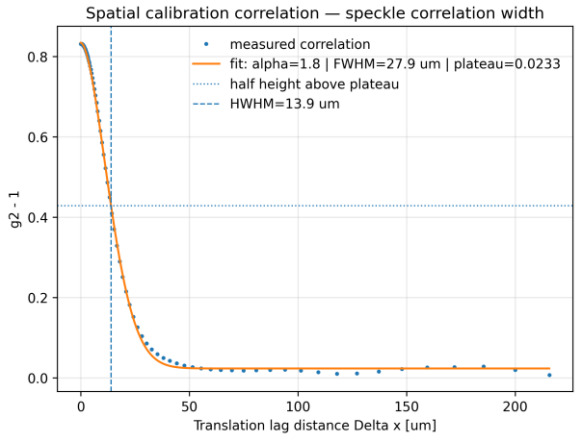
Agitation Management

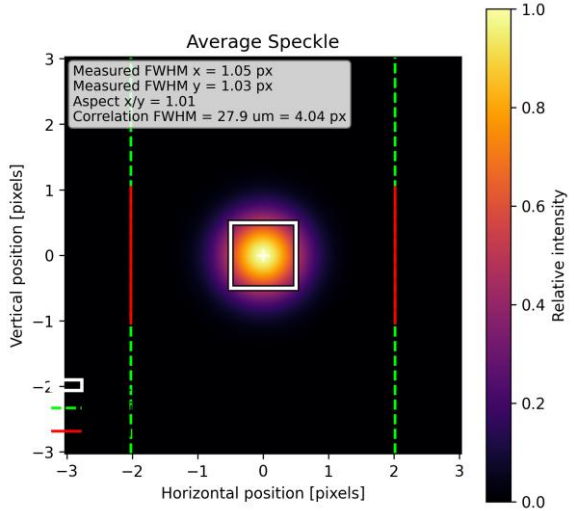


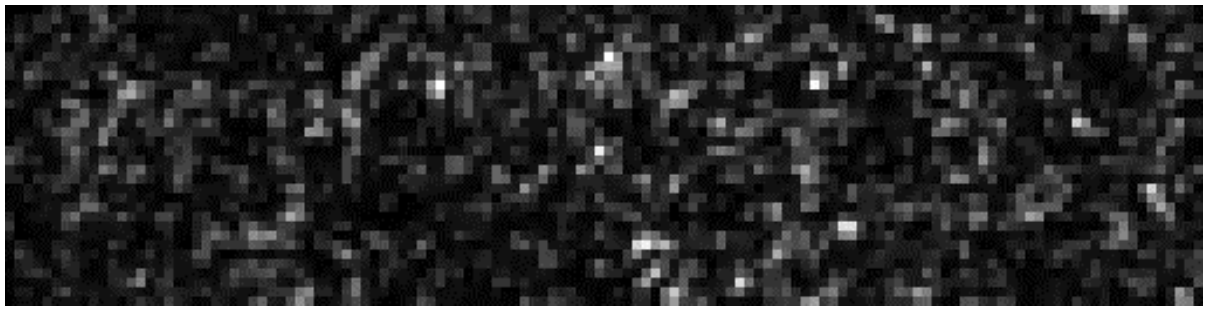


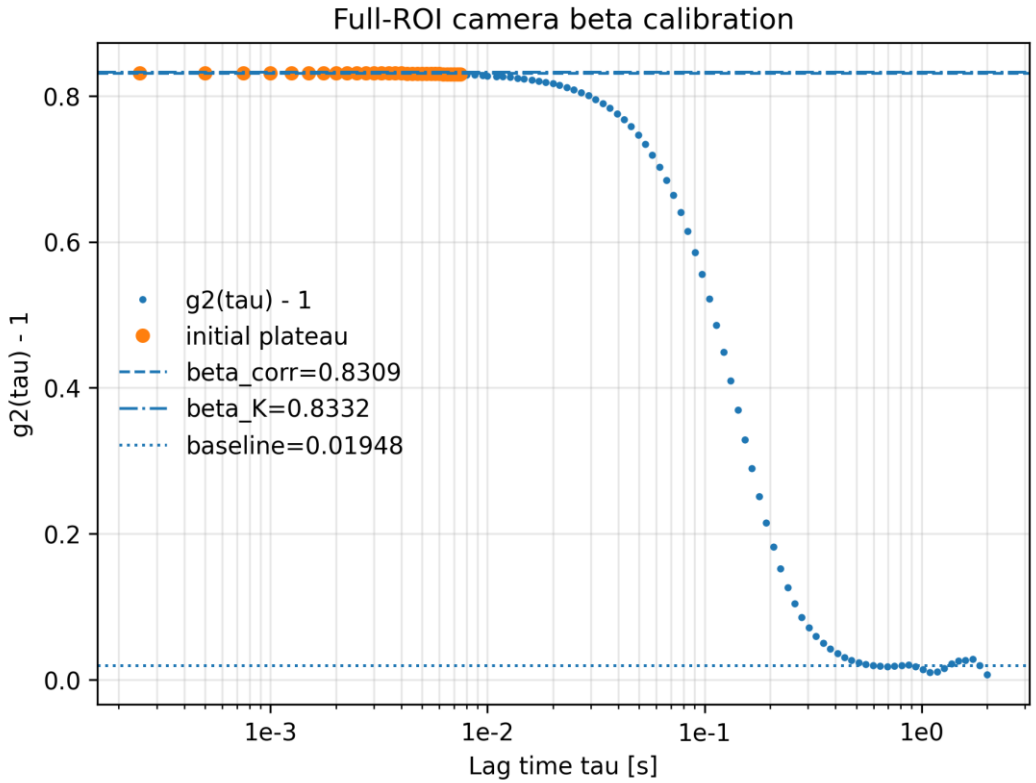


Calibration Method

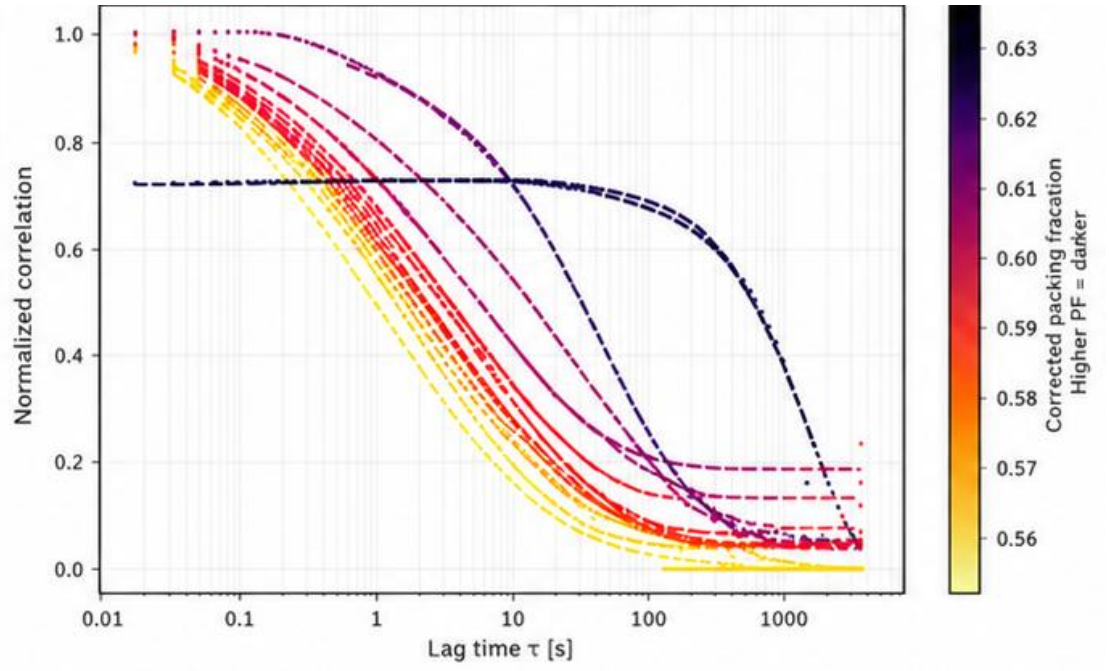


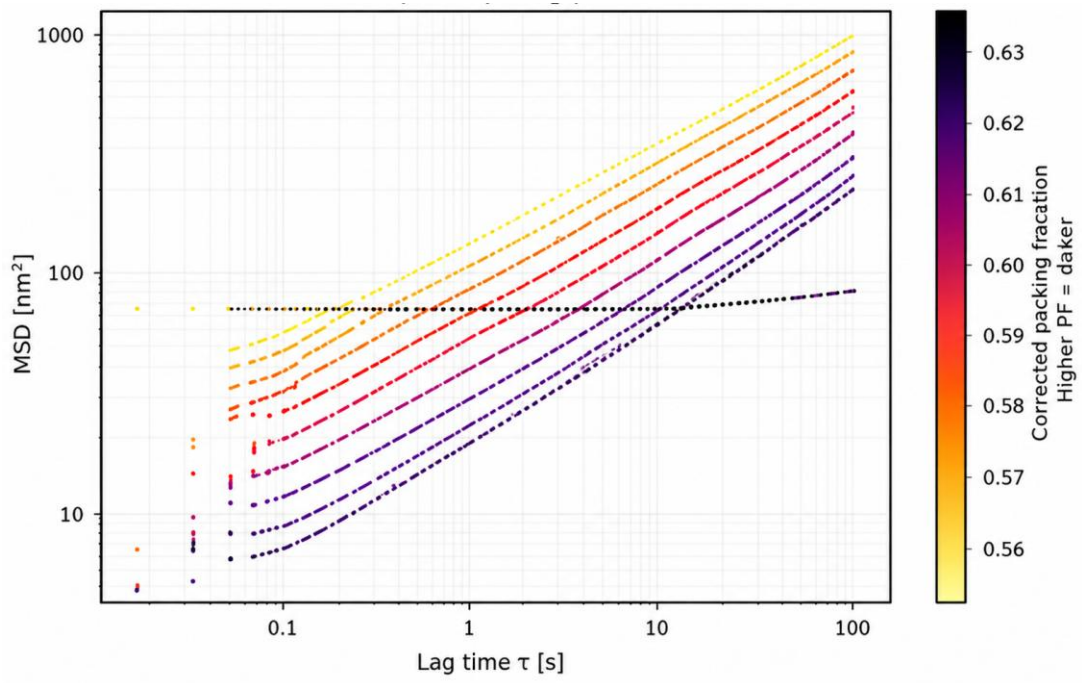






Coated Particles



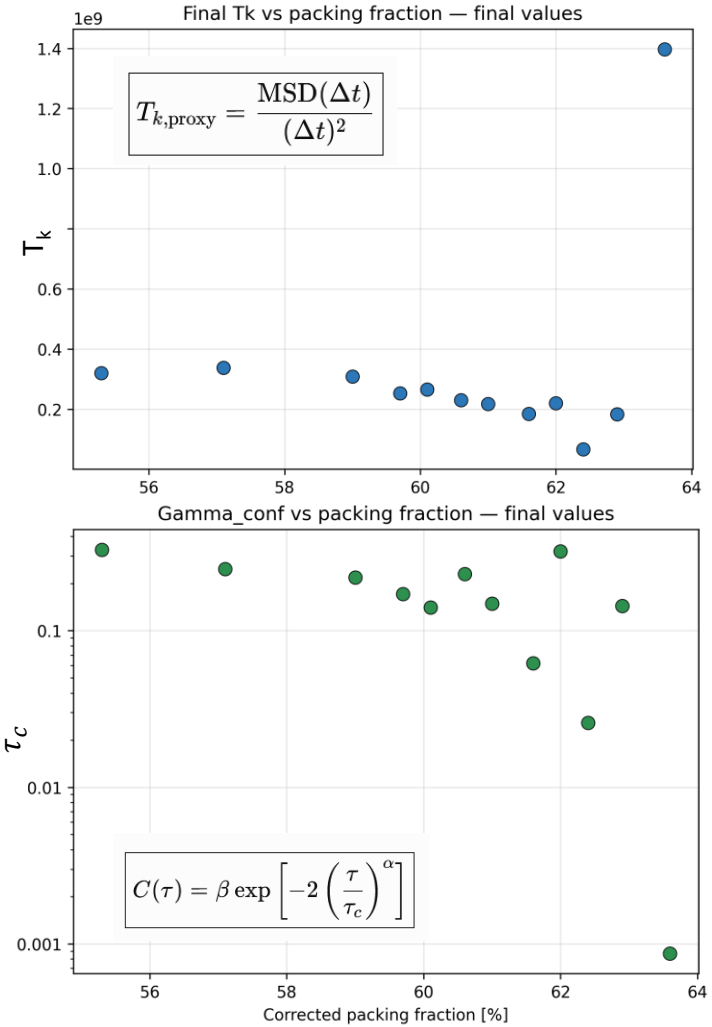


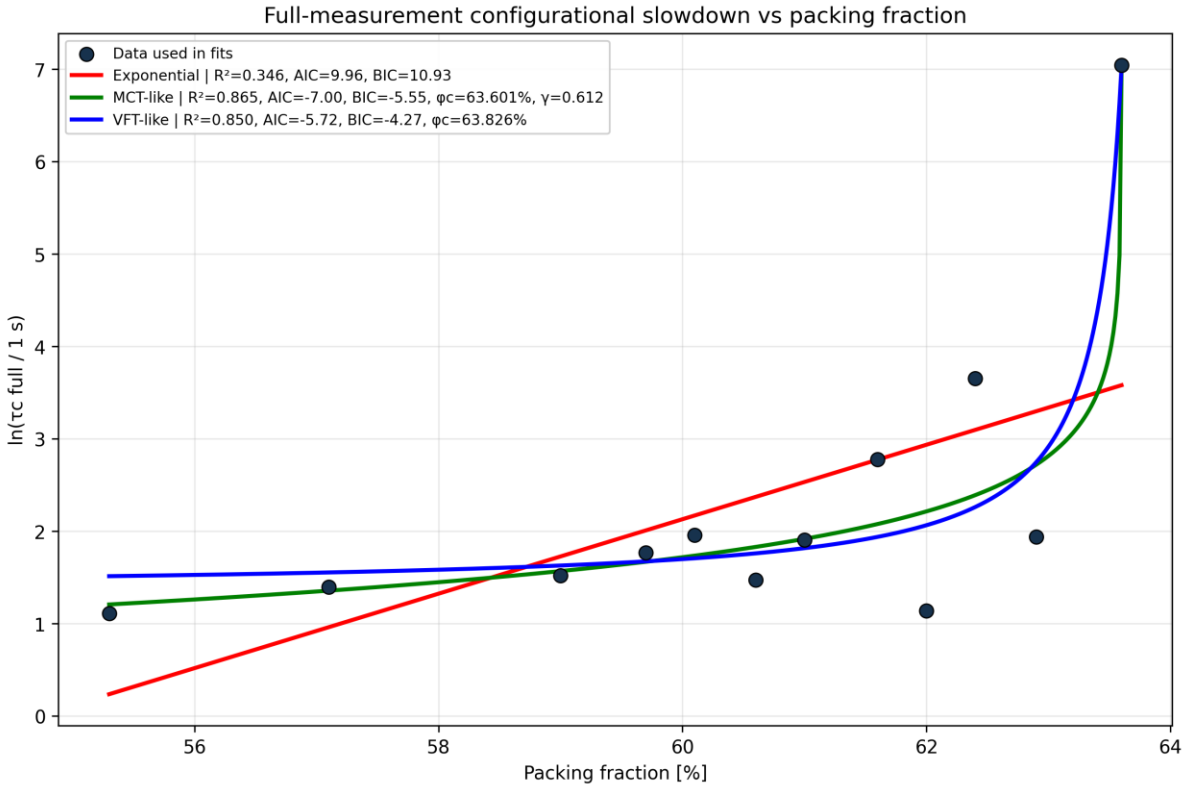
$$g_2(\Delta t) = \frac{\langle I_p(t) I_p(t+\Delta t) \rangle_{p,t}}{\langle I_p(t) \rangle_{p,t}^2}$$

$$|g_1(\Delta t)| = \sqrt{\frac{g_2(\Delta t) - 1}{\beta}}$$

$$\langle \Delta r^2(\Delta t) \rangle = 3 \left(\frac{\ell^*(\phi)}{k_0 L} \right)^2 \ln \left(\frac{1}{\sqrt{|g_1(\Delta t)|}} \right)$$

Further Analyses…

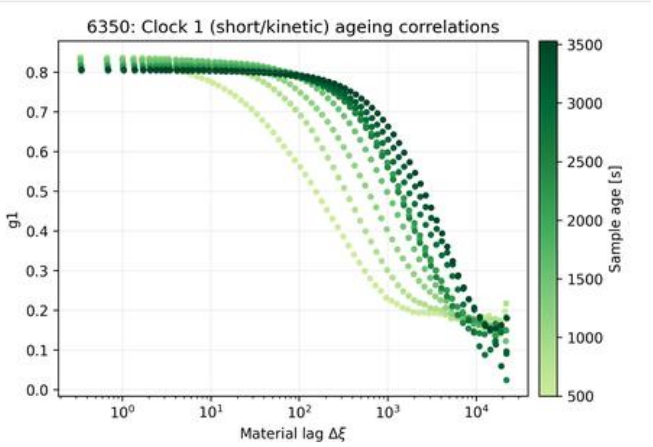


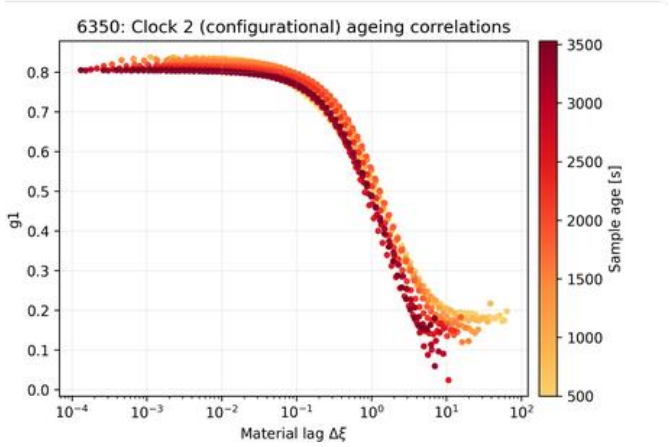


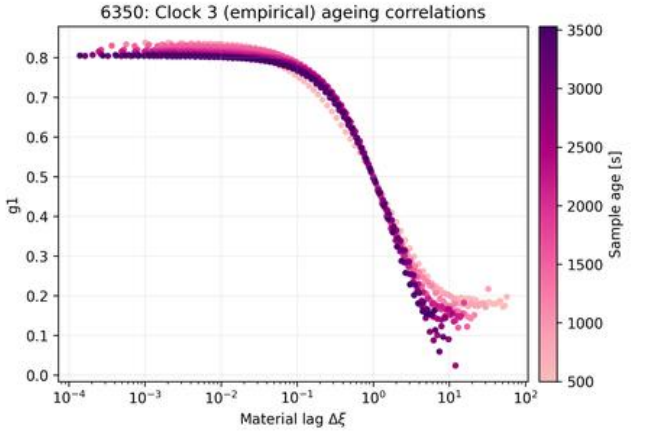
$$\tau_c(\phi) = \tau_0 \left(\frac{\phi_c - \phi}{\phi_c}\right)^{-\gamma}$$

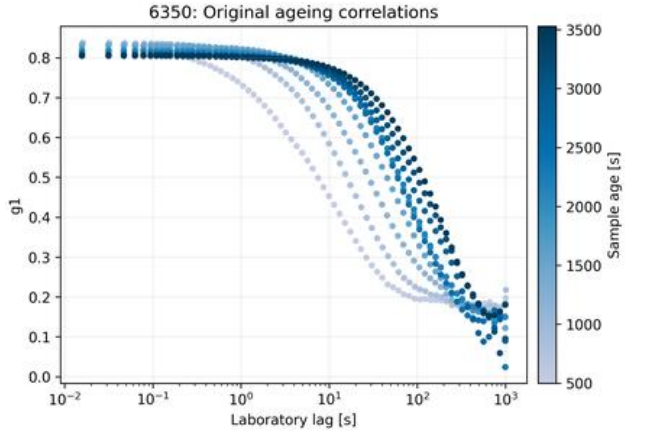
$$\tau_c(\phi) = \tau_0 \exp\left(\frac{A\phi}{\phi_c - \phi}\right)$$

Ageing and Material Clocks









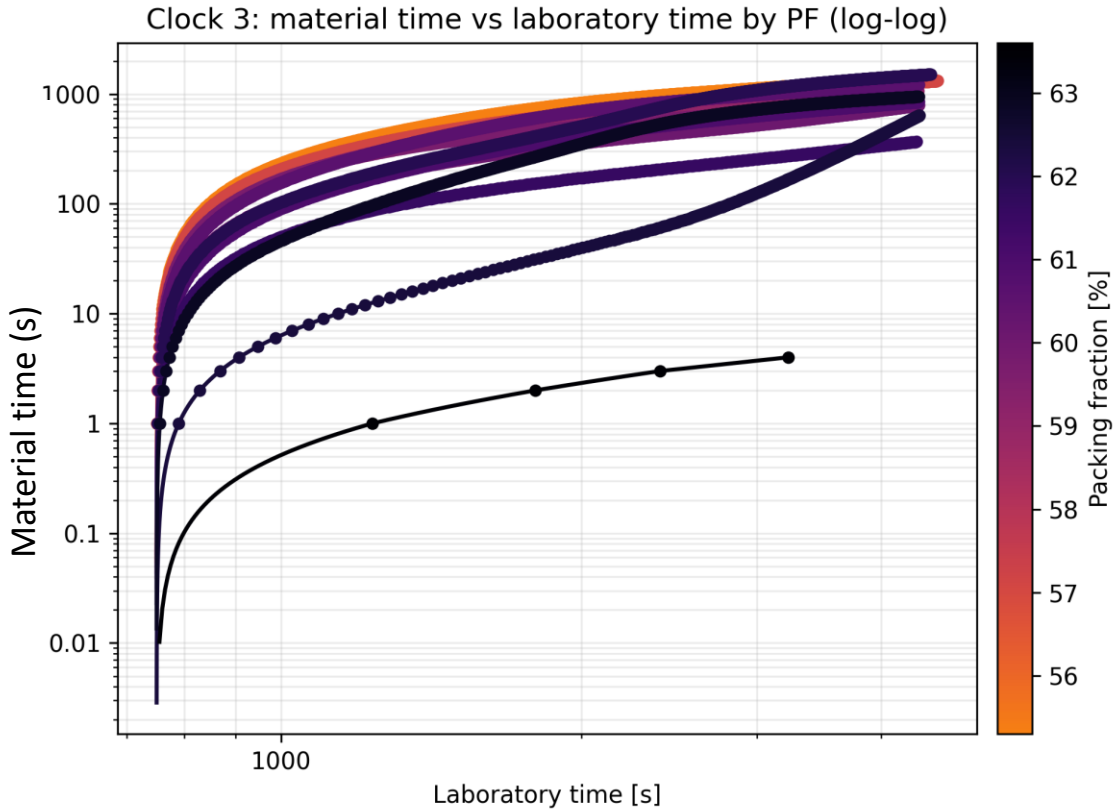
$$\frac{d\xi}{dt} = \gamma(t)$$

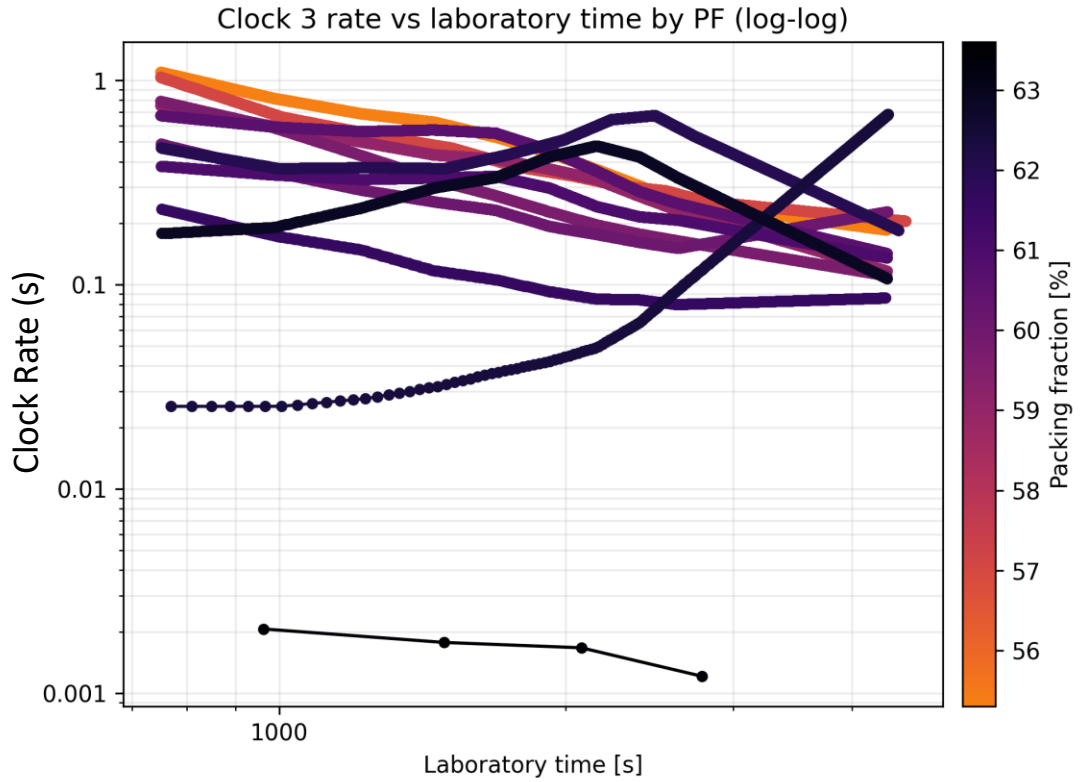
$$\xi(t) = \int_0^t \gamma(t')\, dt'$$

$$\Delta\xi(t_w, \Delta t) = \int_{t_w}^{t_w+\Delta t} \gamma(t')\, dt'$$

- No ageing in space?
- State dependancy?
- Interparticle interactions dependancy?

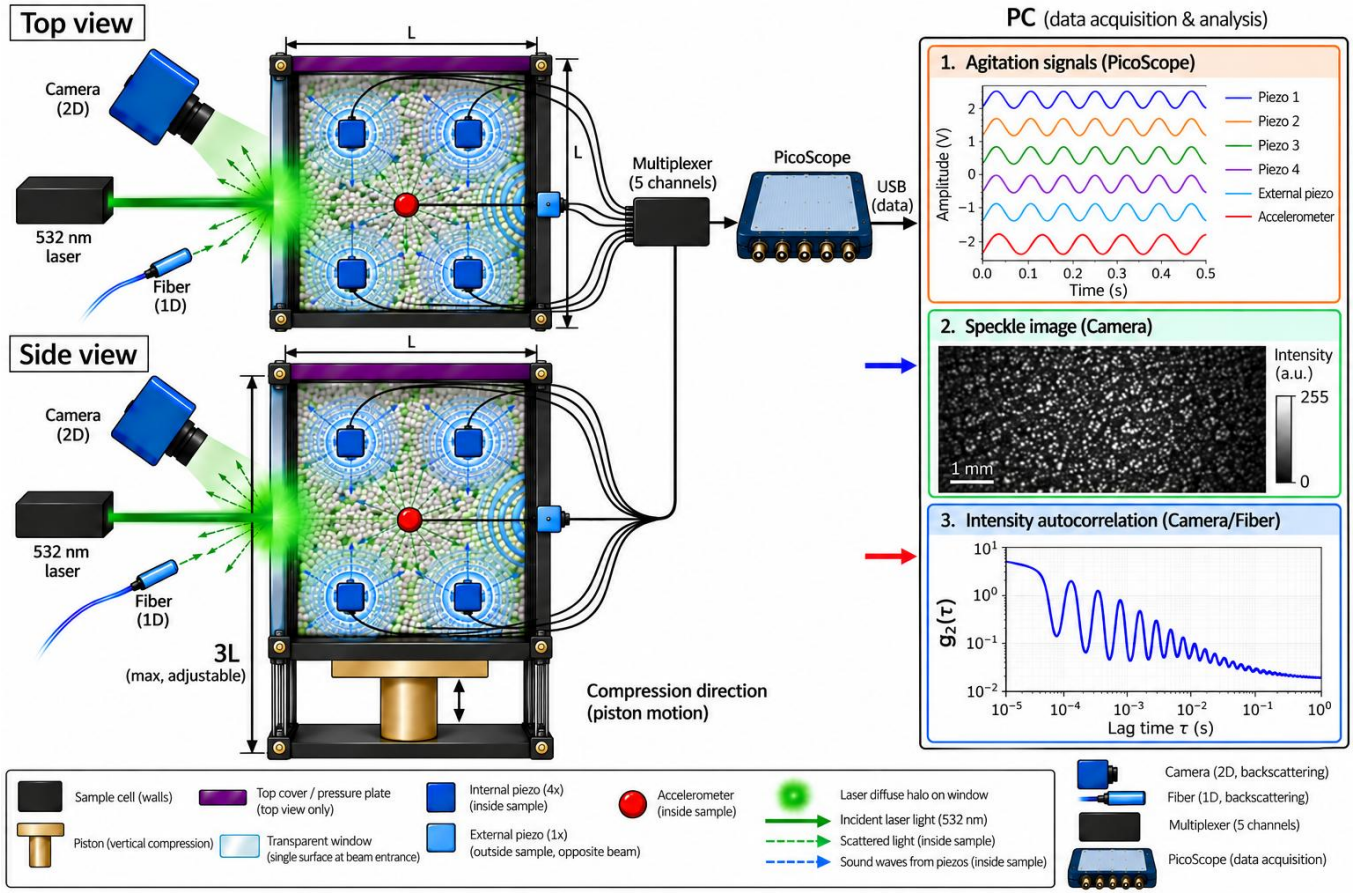
Ageing and Material Clocks



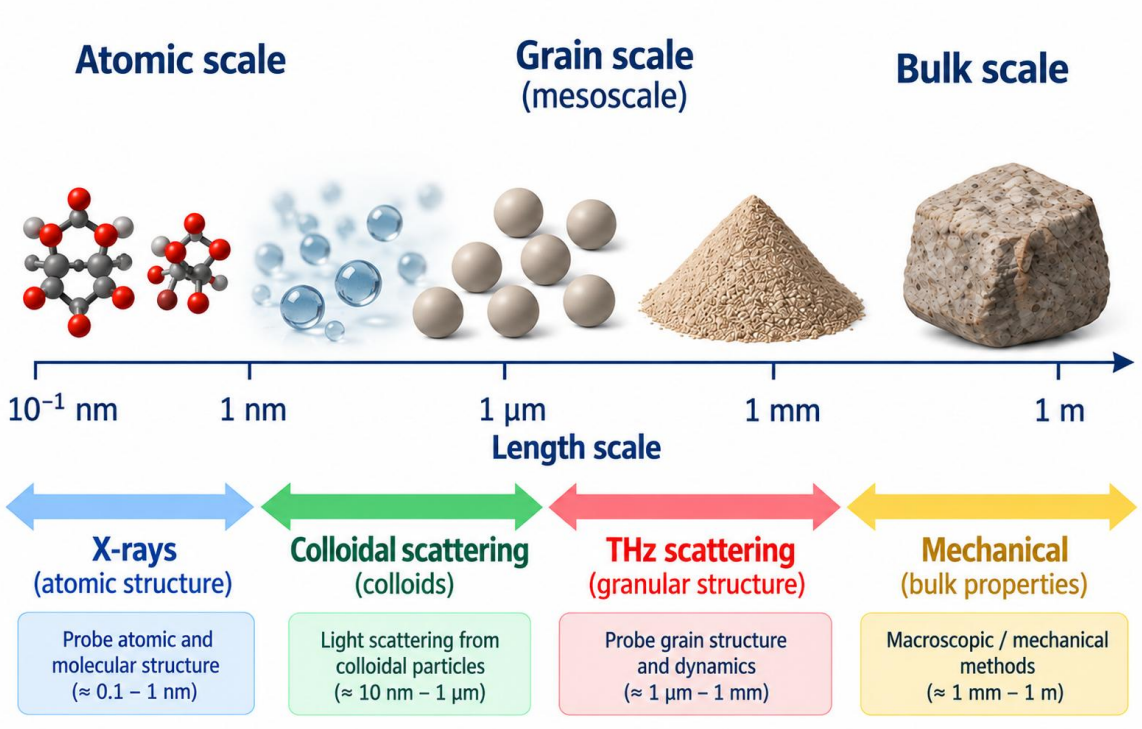


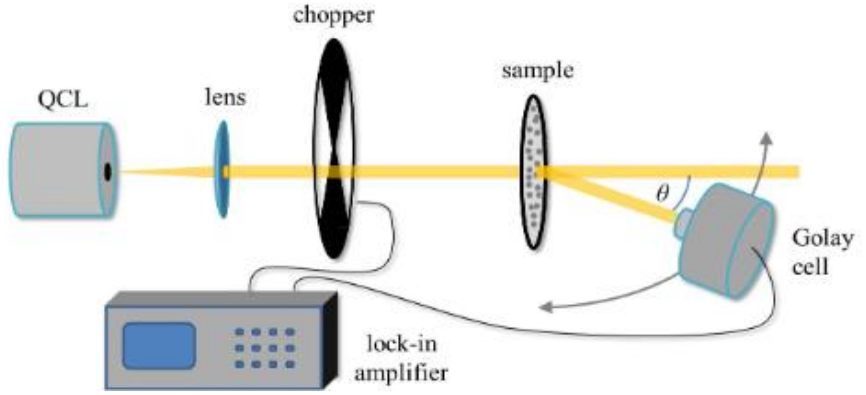
New Prodjects

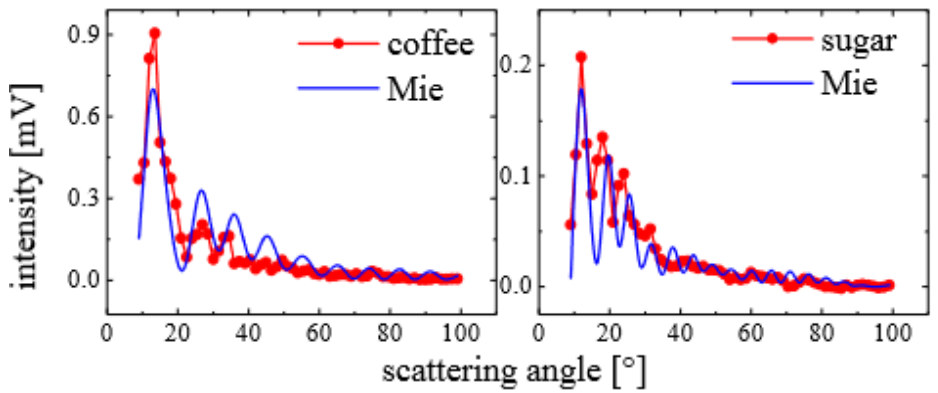
Light Scattering + Granular Sound



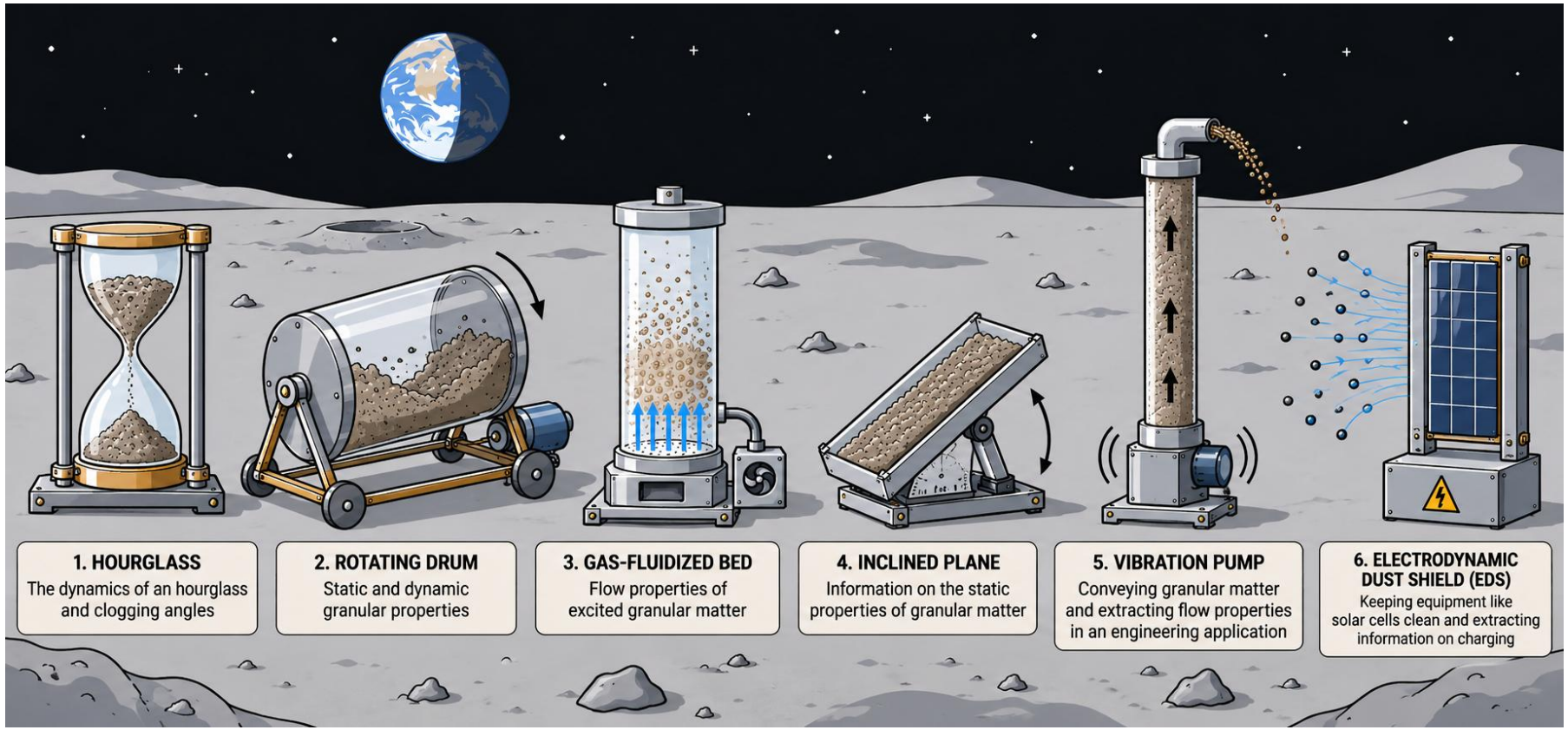
THz Light Scattering







Lunar Projects



Any Questions?