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Probing Phenomena Hidden by Gravity or Terrestrial Limitations

Exciting Fluids

Decadal Report Response | Kevin Crosby | March 20, 2024

Fluids and Phenomena

Complex Fluids

Emulsions, Foams, Suspensions, Colloids

Interfacial Dynamics

Stability, Mixing, Phase Separation

Non-Newtonian Dynamics

Multicomponent Fluids

Critical Mixing/Demixing

Phase Separation

Anomalous Transport

Supercritcal Phases

Rheology

Extreme Conditions

High Pressure Phase Transitions

Cavitation in Propellant Commodities

Supercritical Fluids

Fluids Coupled to External Excitations

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Fluids Interacting with an Acoustic Field

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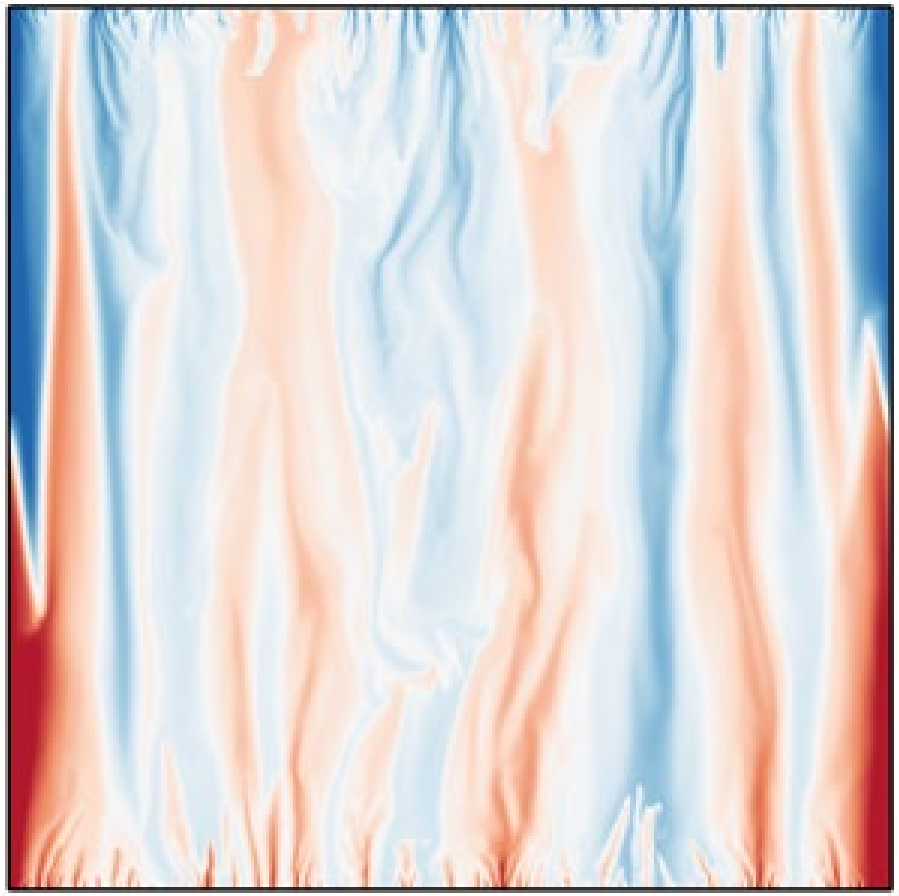

Thermal Vibrational Convection

Guo X-L, Wu J-Z, Wang B-F, Zhou Q, Chong KL. Flow structure transition in thermal vibrational convection. Journal of Fluid Mechanics. 2023;974:A29. doi:10.1017/jfm.2023.666

Fluids Interacting with an Acoustic Field

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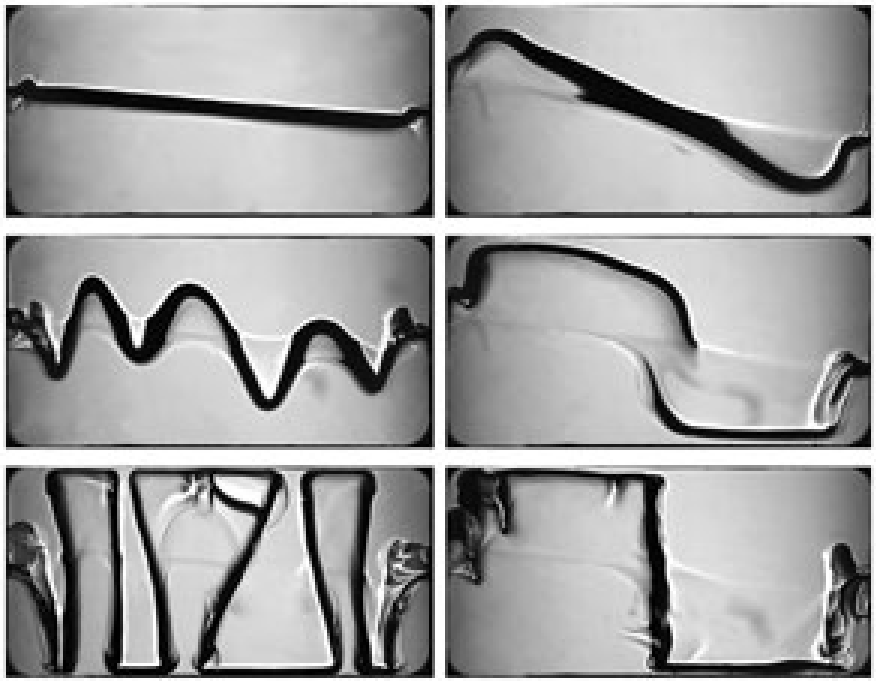

Instability in vibrated fluid-fluid interface

Salgado Sánchez P, Gaponenko Y, Yasnou V, Mialdun A, Porter J, Shevtsova V. Effect of initial interface orientation on patterns produced by vibrational forcing in microgravity. Journal of Fluid Mechanics. 2020;884:A38. doi:10.1017/jfm.2019.955

Fluids Interacting with an Acoustic Field

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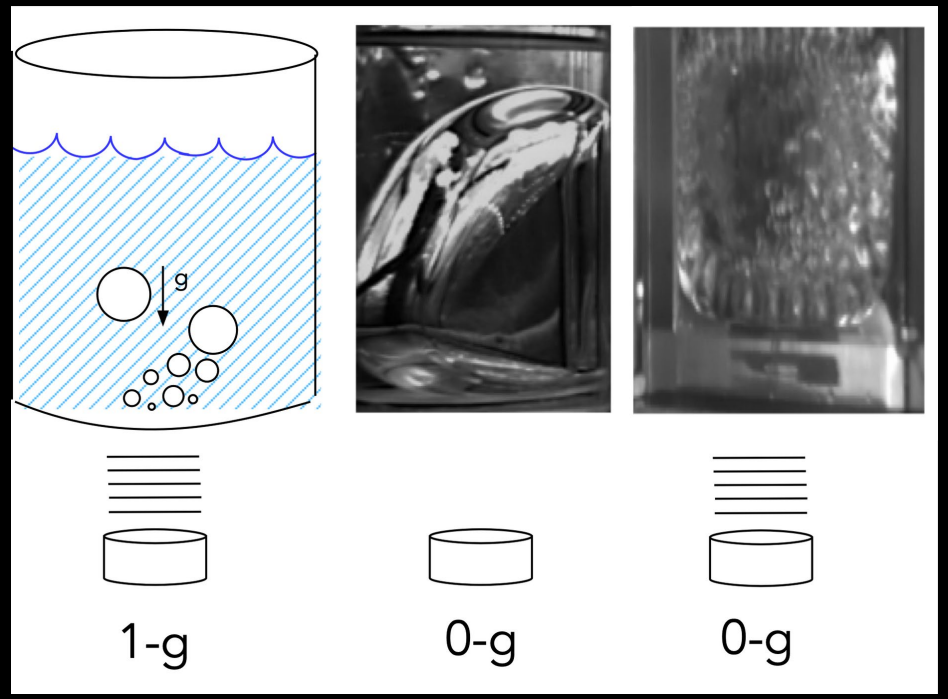
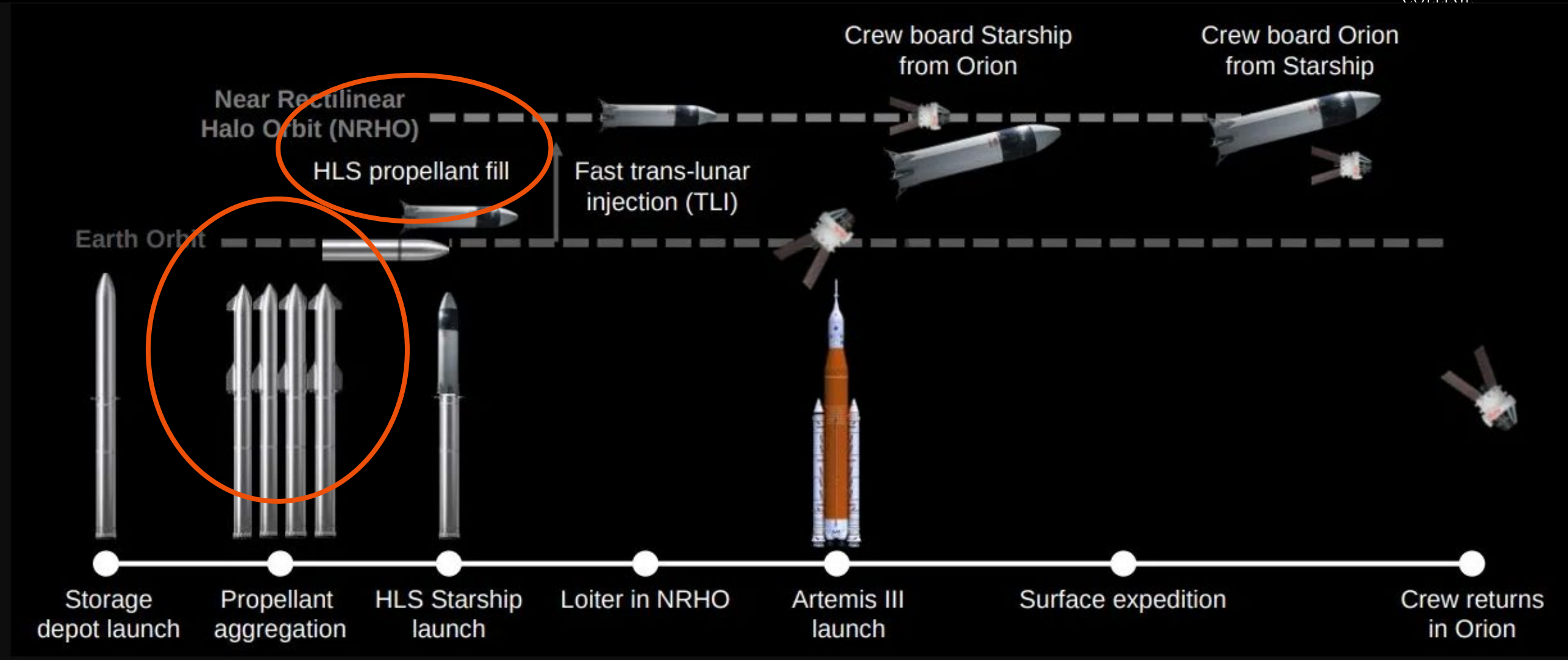
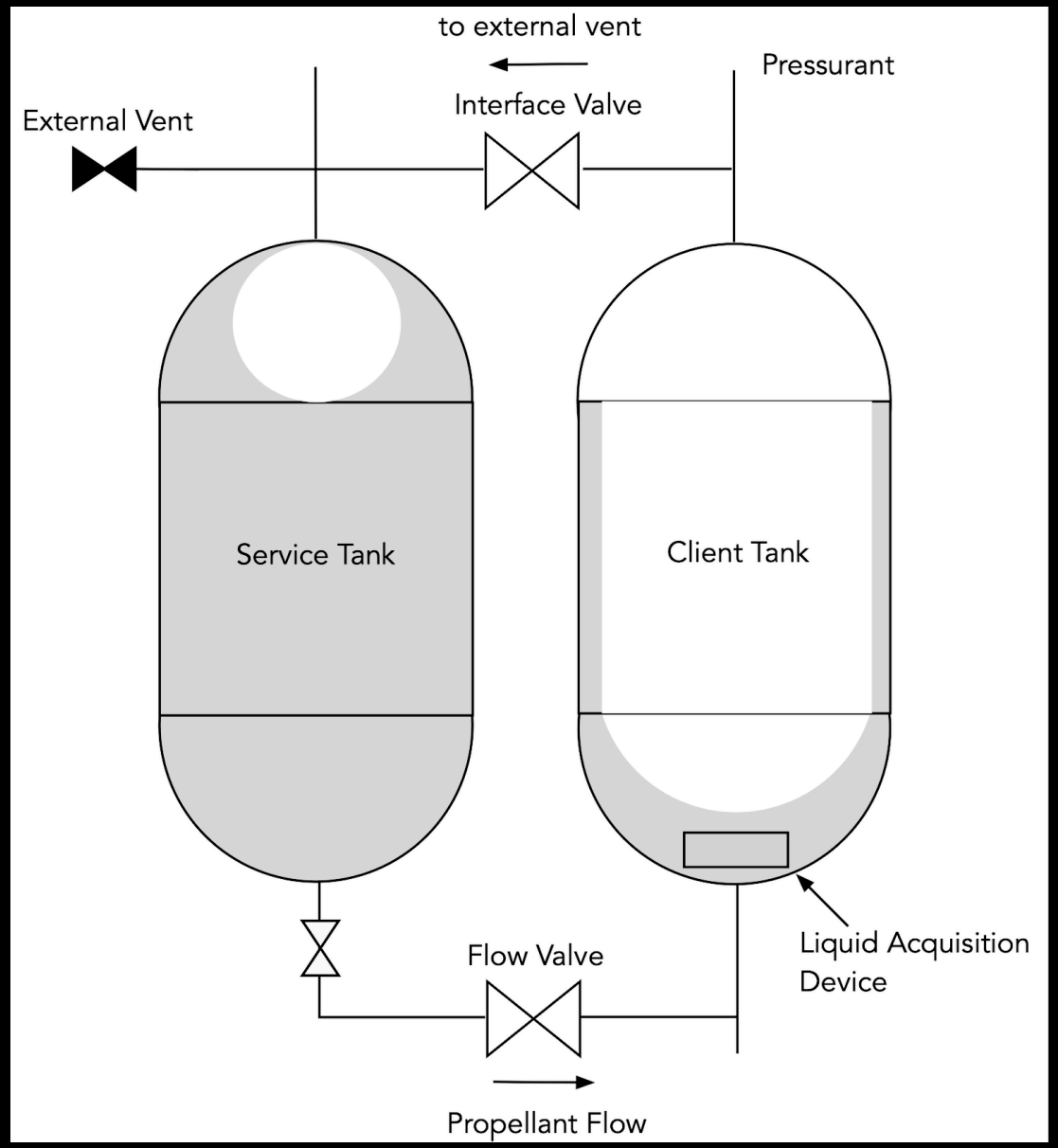


Phase Ordering of fluids

Fernandez J, Sánchez P-S, Tinao I, *et al*. The CFVib Experiment: Control of Fluids in Microgravity with Vibrations. *Microgravity Sci. Technol.* **29**, 351–364 (2017). https://doi.org/10.1007/s12217-017-9556-7


Crew board Starship from Orion
Crew board Orion from Starship
Near Rectilinear Halo Orbit (NRHO)
HLS propellant fill
Fast trans-lunar injection (TLI)
Earth Orbit
Storage depot launch
Propellant aggregation
HLS Starship launch
Loiter in NRHO
Artemis III launch
Surface expedition
Crew returns in Orion



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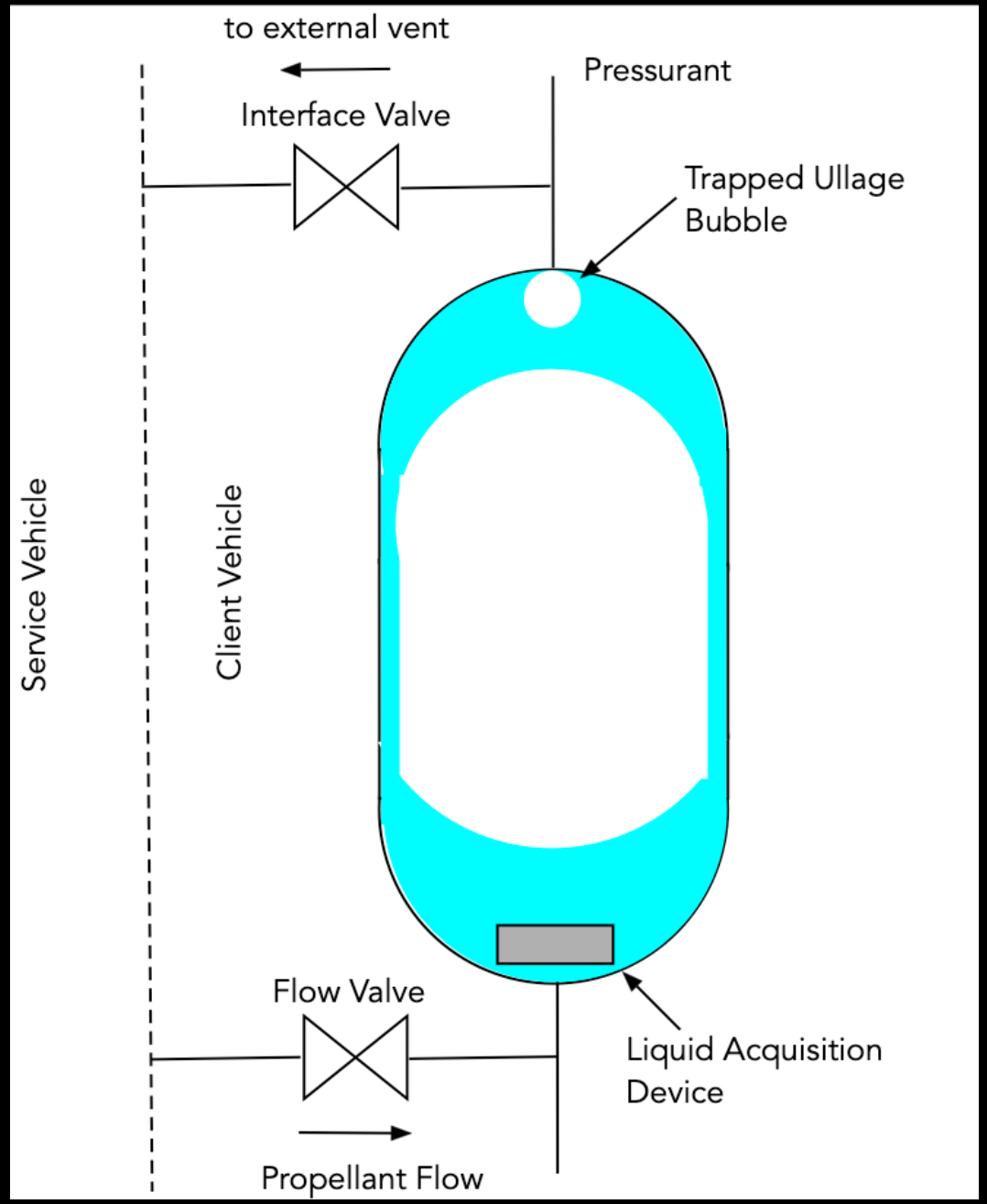
Refueling requires positioning the ullage bubble at the vent port



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Refueling requires positioning the ullage bubble at the vent port

Generate an ullage bubble from saturated helium in the propellant; trap the ullage bubble at the vent port using phased array acoustic field.

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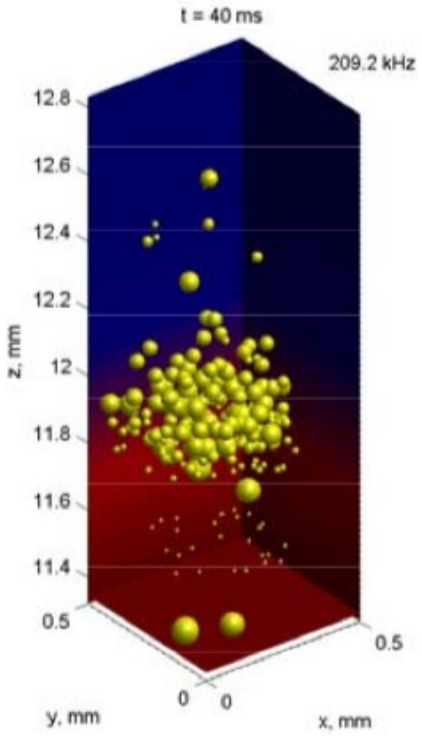
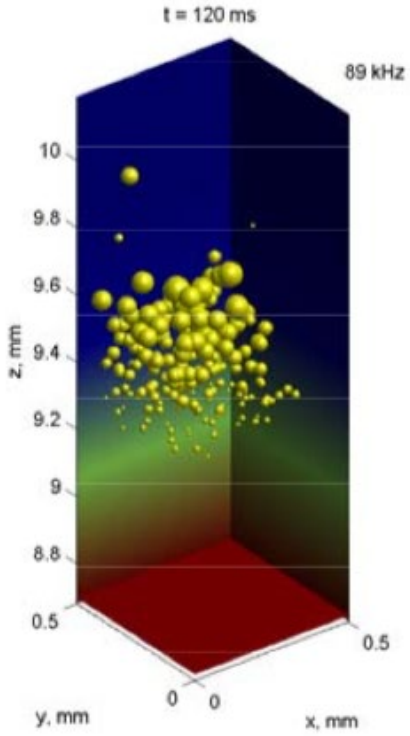
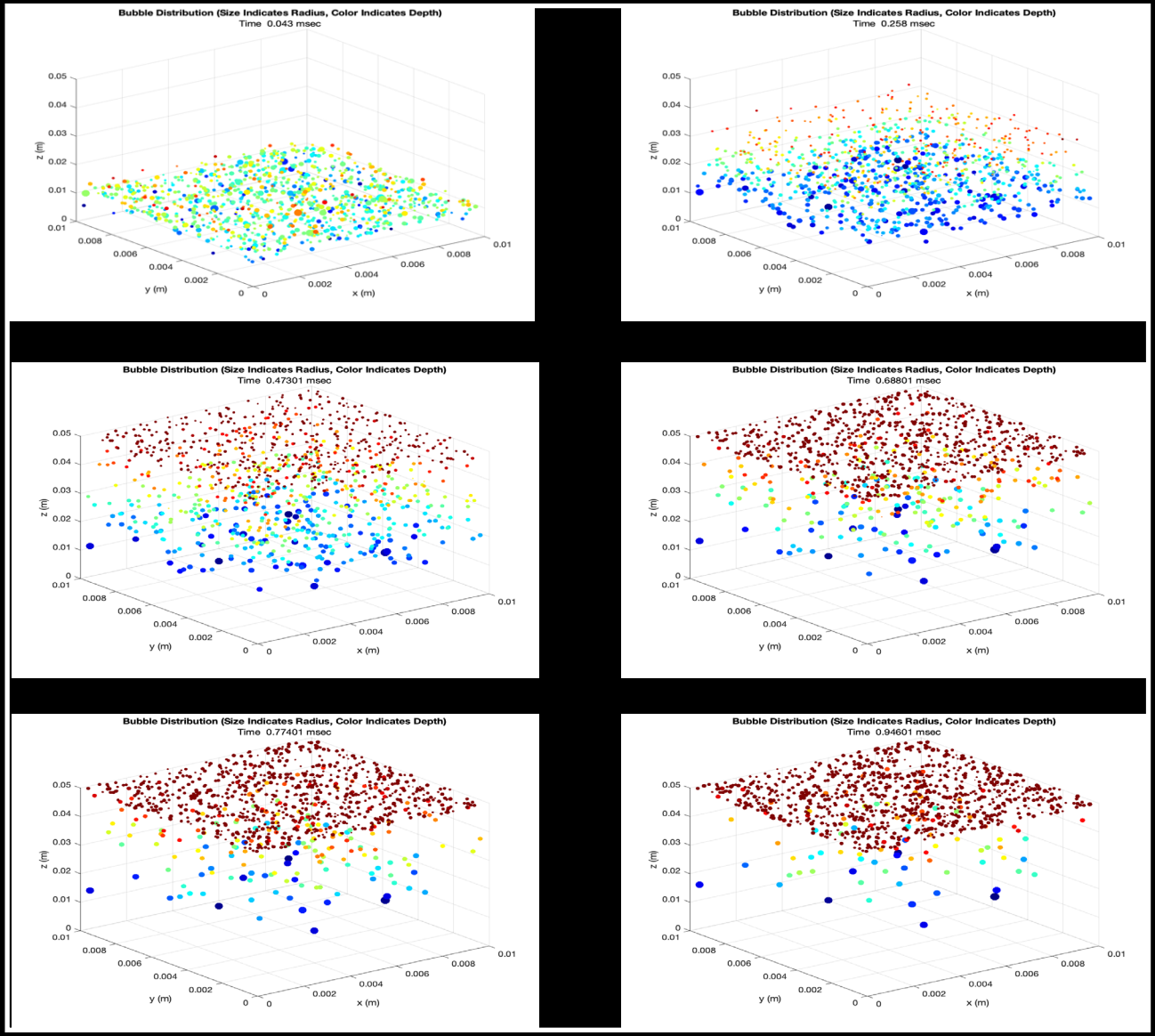




Sub-cavitation acoustic fields can induce and migrate bubble fields over macroscopic distances

Gumerov N, Ohl C, Akhatov I, Sametov P, Khazimullin M. Waves of acoustically induced transparency in bubbly liquids: Theory and experiment. *J. Acoust. Soc. Am.* 1 May 2013; 133



Sub-cavitation acoustic fields can induce and migrate bubble fields over macroscopic distances

Crosby, K; Romero-Calvo A.

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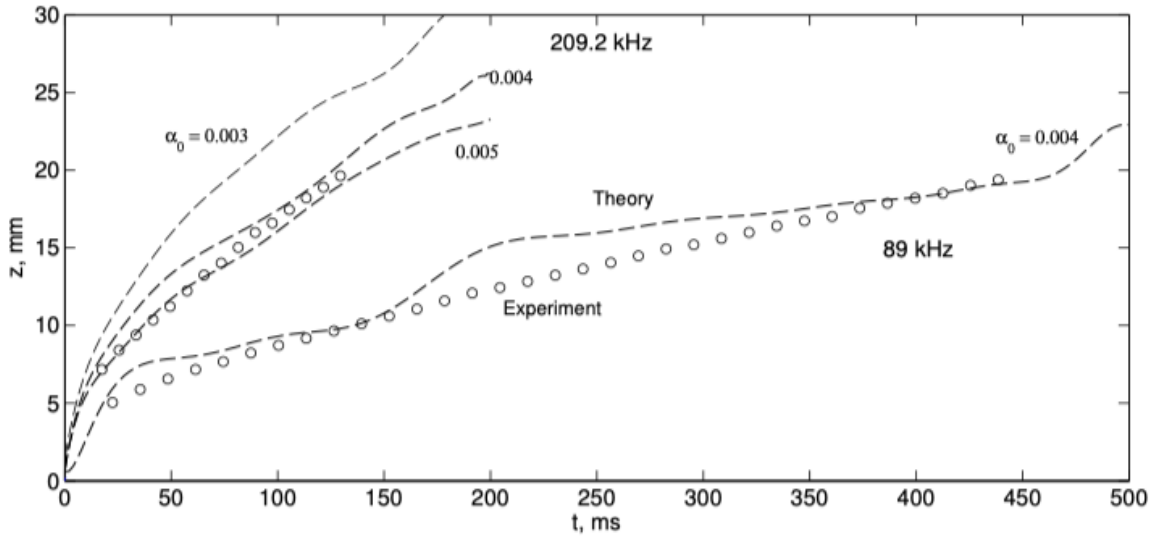

Bubble distribution migrates along acoustic field pressure gradient for both sub- and super-resonant bubble sizes.

Gumerov, *et al.*

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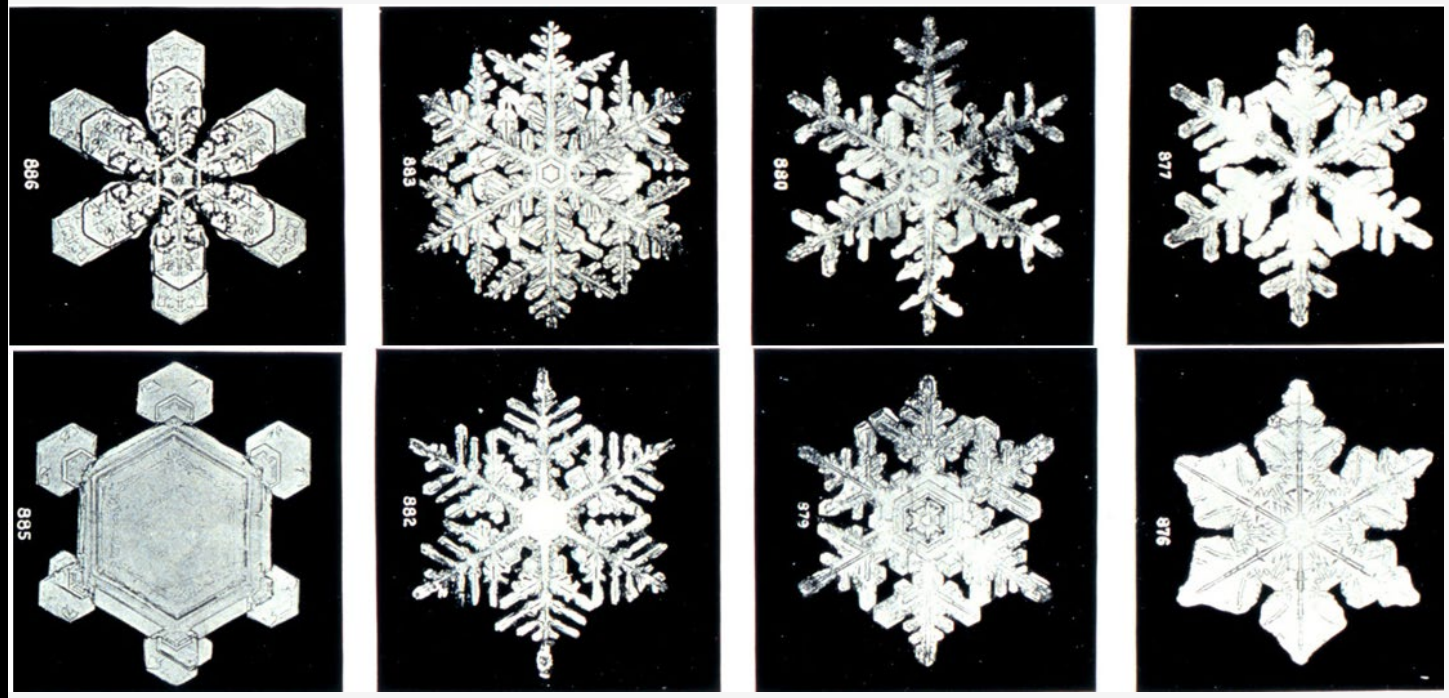

Wilson Bentley. From the Annual Summary of the Monthly Weather Review for 1902.

Snowflakes form when latent heat battles surface energy

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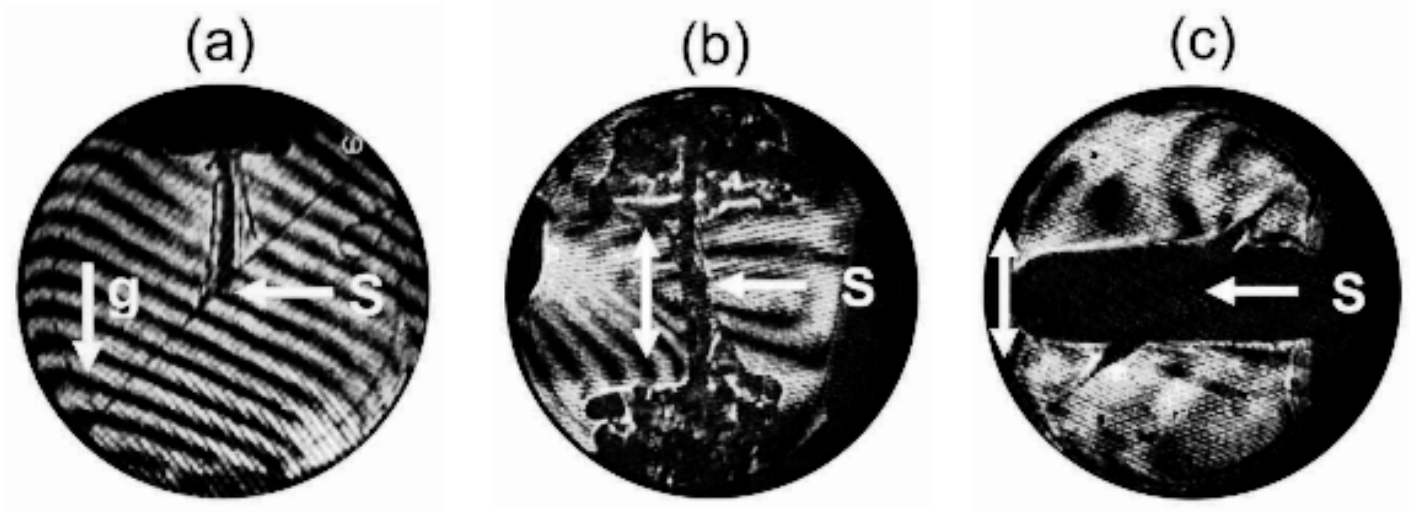
1-g 0-g



Convective flow in supercritical CO2 when heated by a point source

Quettier L, Felice H, Mailfert A, Chatain D, Beysens D. Europhys. Journal of Applied Physics 32, 167 (2005)

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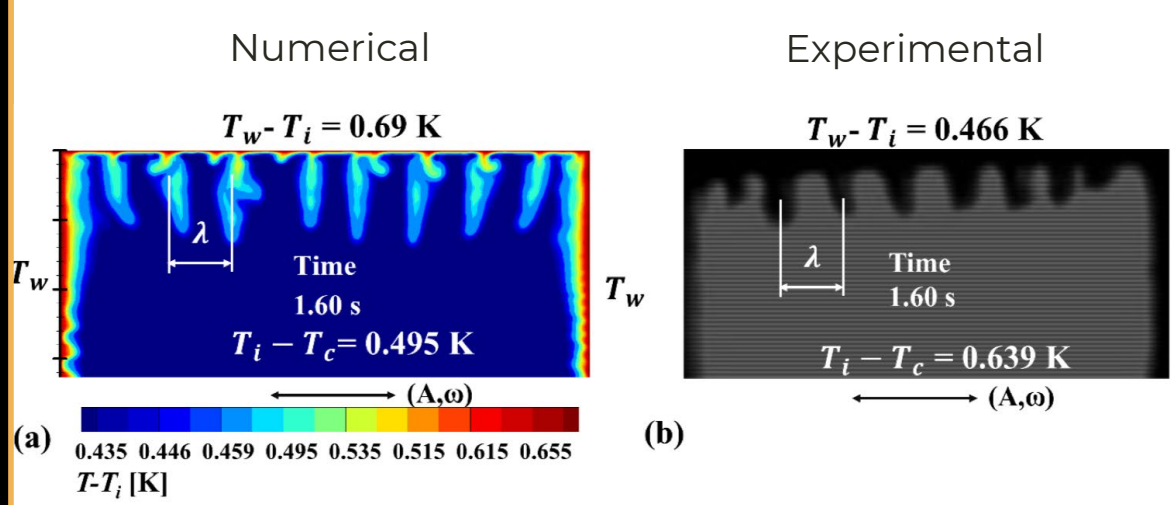
R-T Instabilities Induced in Supercritical CO2 @ 20 Hz.



Sharma D, Erriguible A, Gandikota G, Beysens, D, Amiroudine S (2019). Vibration-induced thermal instabilities in supercritical fluids in the absence of gravity. Physical Review Fluids. 4. 10.1103/PhysRevFluids.4.033401

Summary

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Fluid systems are where the effects of microgravity are most pronounced.

Can external excitations, such as vibration, effectively replace the useful aspects of a gravitational field (phase ordering, convective transport, etc.) in some systems?

Externally excited fluids is a promising area of study across a range of applications

- Ullage positioning and bubble control
- Convective Transport
- Transport in Multicomponent Fluids
- Microfluidics and Lab-on-Chip
- Materials Processing
- Critical Phenomena Studies