UNIVERSITY OF TWENTE.
Multi Scale Mechanics

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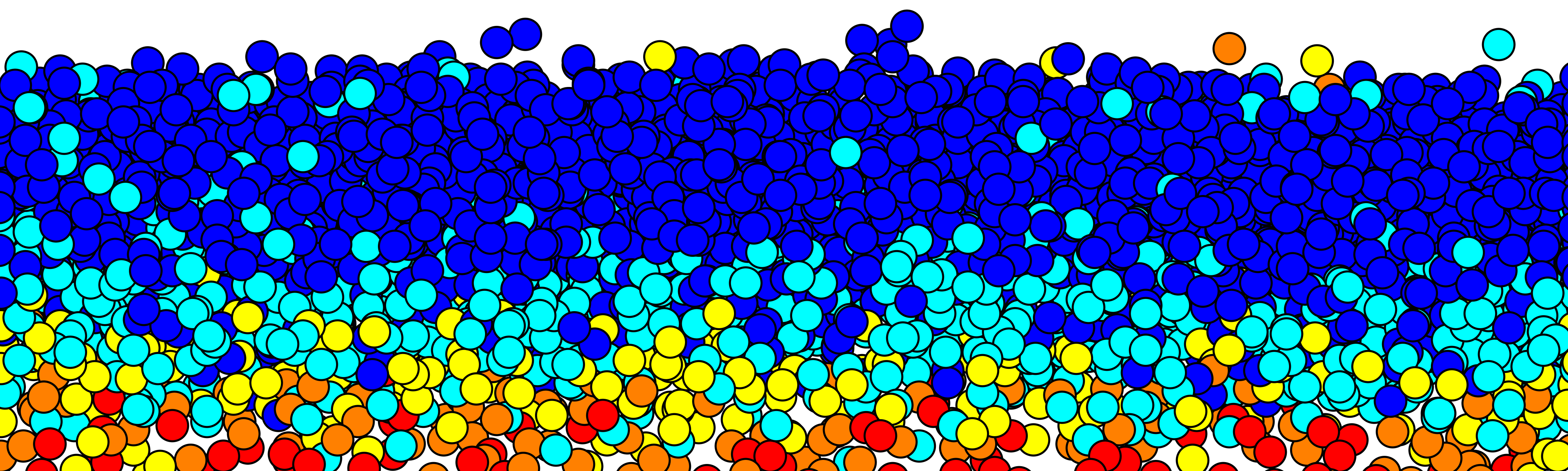
Physics of glassy and granular materials
Kyoto, Japan, July 2013

Low-frequency oscillations and convective phenomena in a density-inverted vibrofluidised granular system

S. Luding, A.R. Thornton,
C.R.K. Windows-Yule, D.J. Parker, N. Rivas





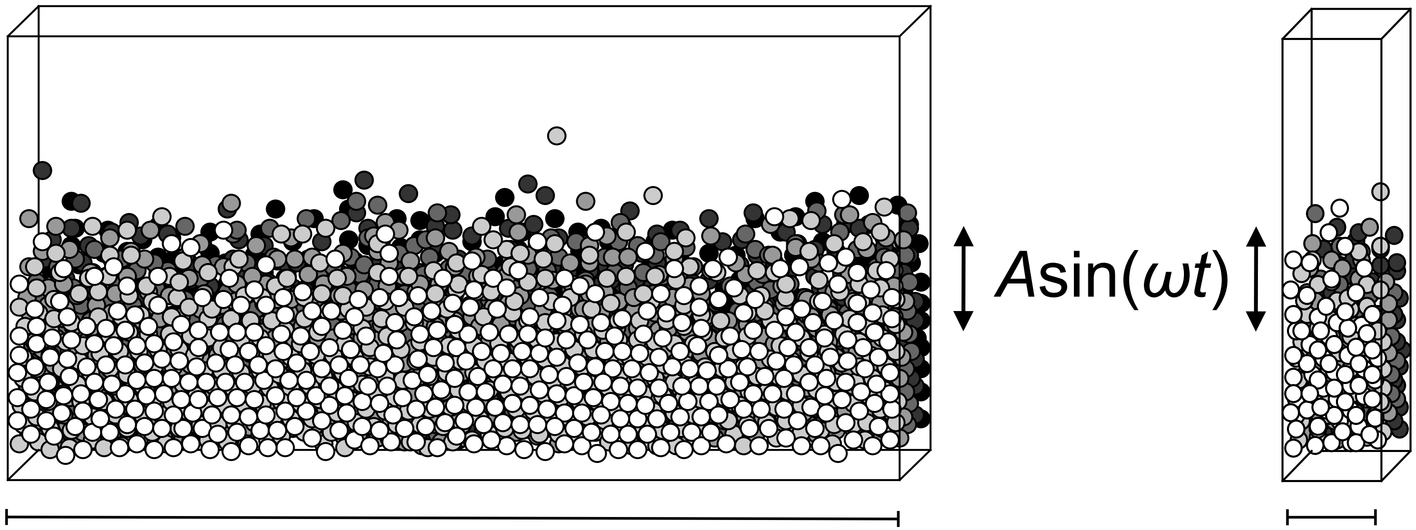



MOTIVATION

- When/how do granular materials flow?
- Discrete to continuum transition
- Collective dynamics of many-particle systems

SYSTEM GEOMETRY

Wide | Column



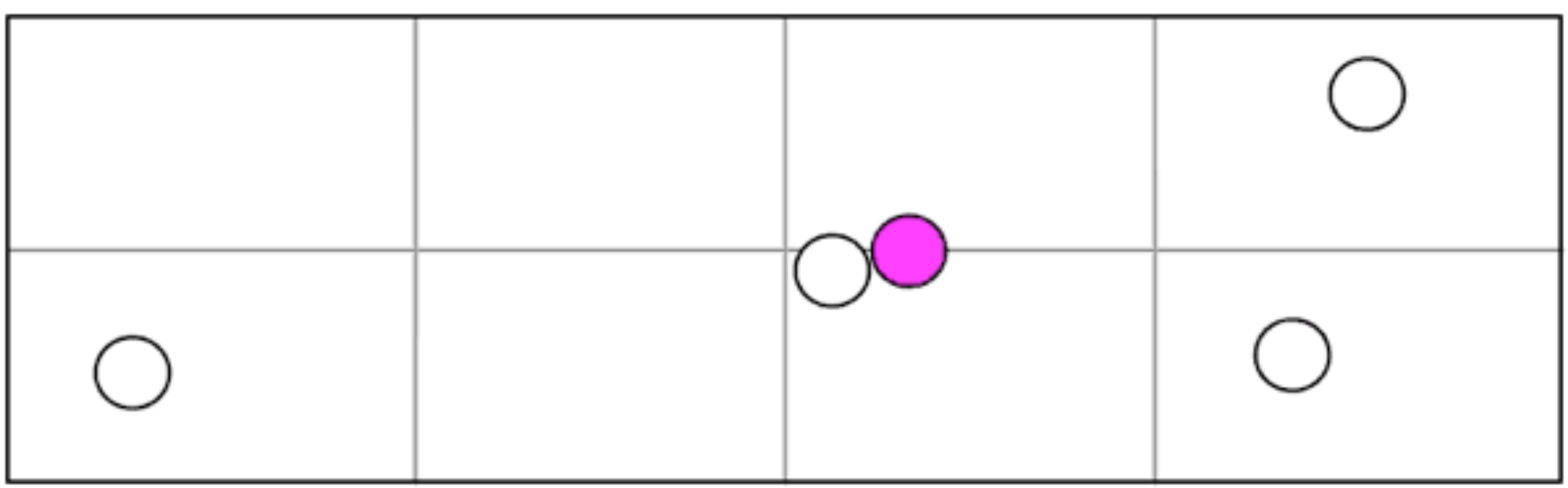
Wide: $L_X = 50d$, $N = 3000$

Column: $L_X = 5d$, $N = 300$

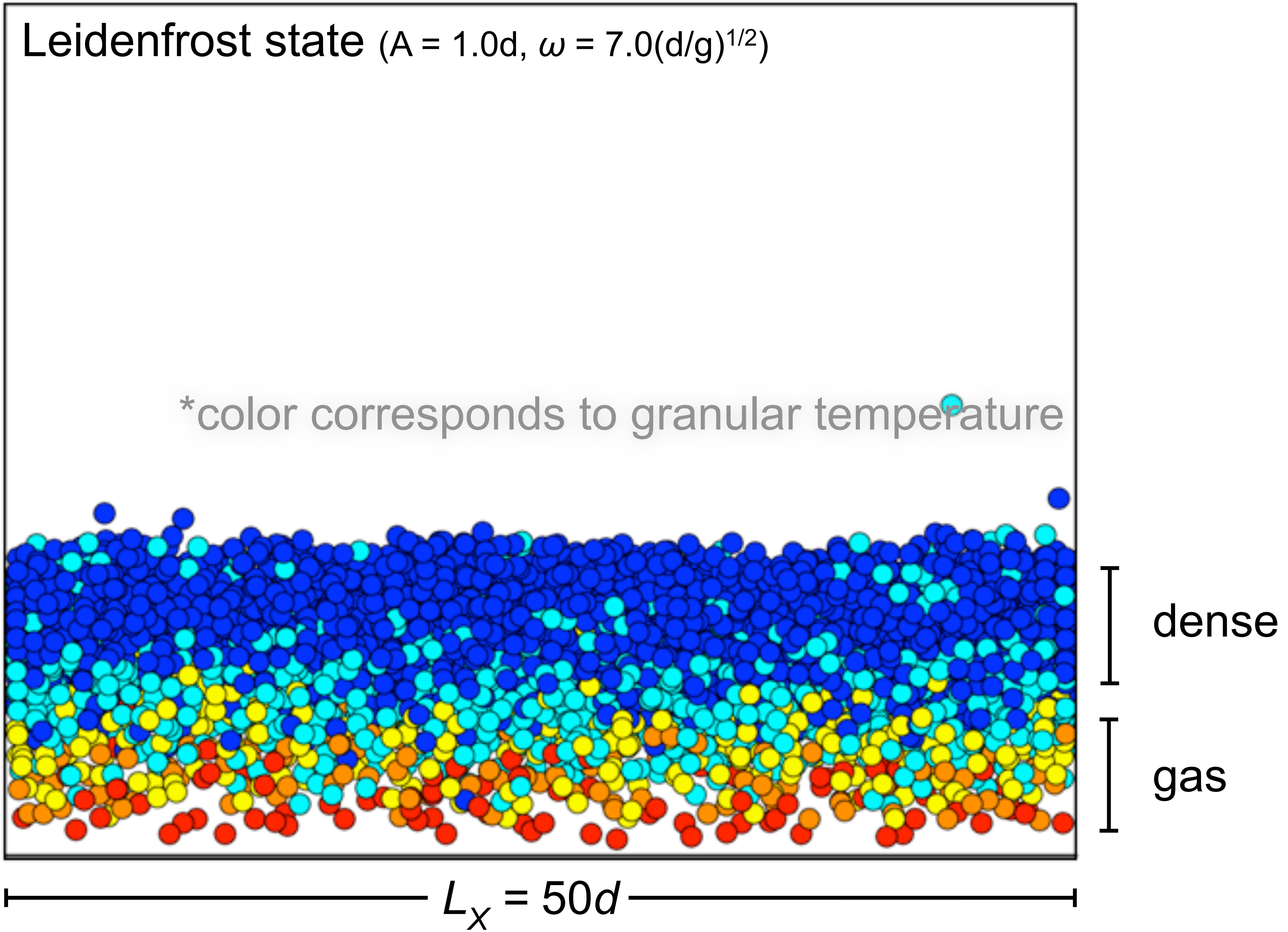
control parameter $S \equiv A^2\omega^2/gd \in (20{,}400)$

SIMULATIONS

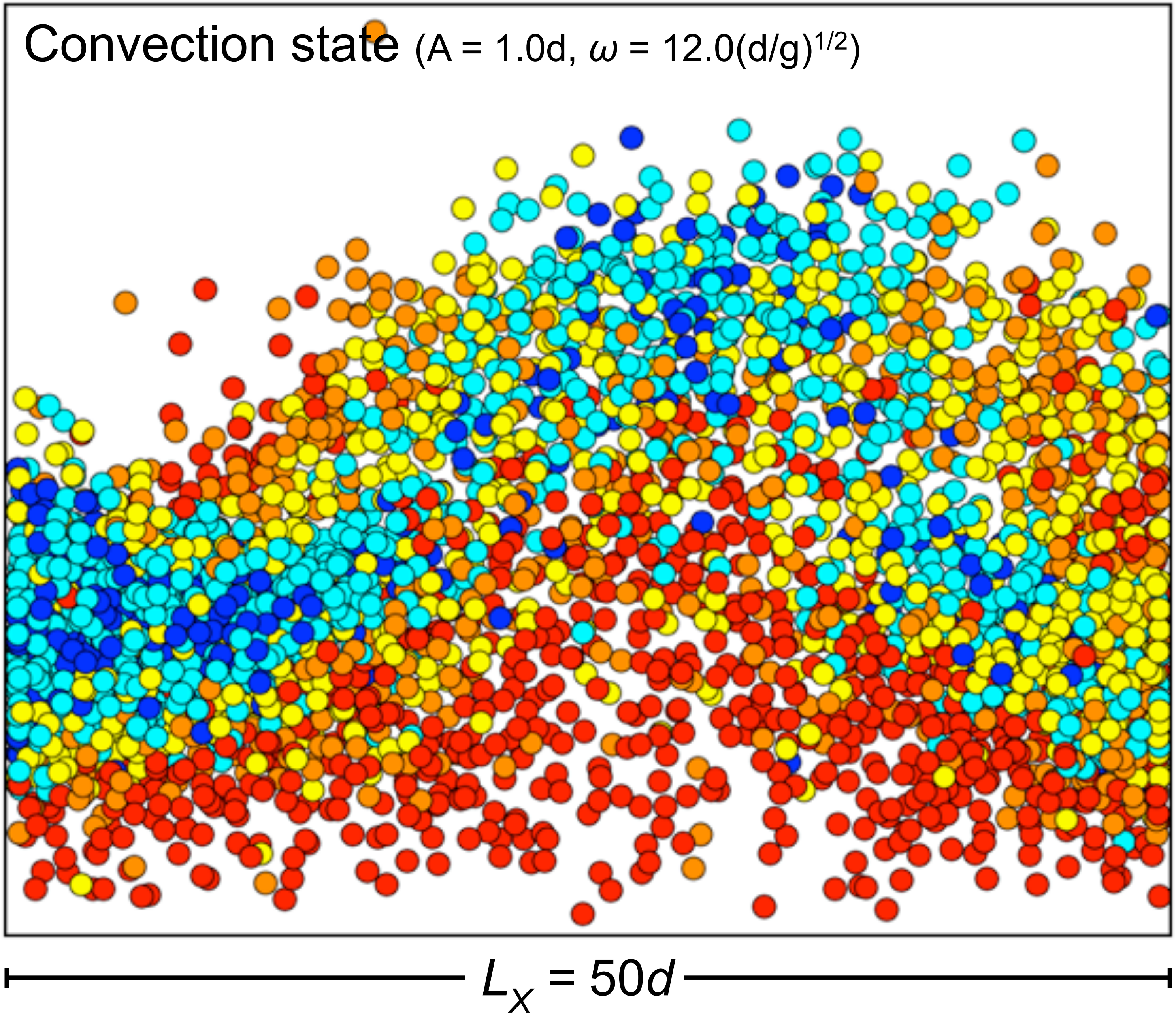
- Event-driven algorithm
- Perfect hard spheres
- Collisions modeled by γ_N, γ_T and μ_S, μ_D,
- Solid walls boundary conditions (no top)
- Bi-parabolic sine interpolation



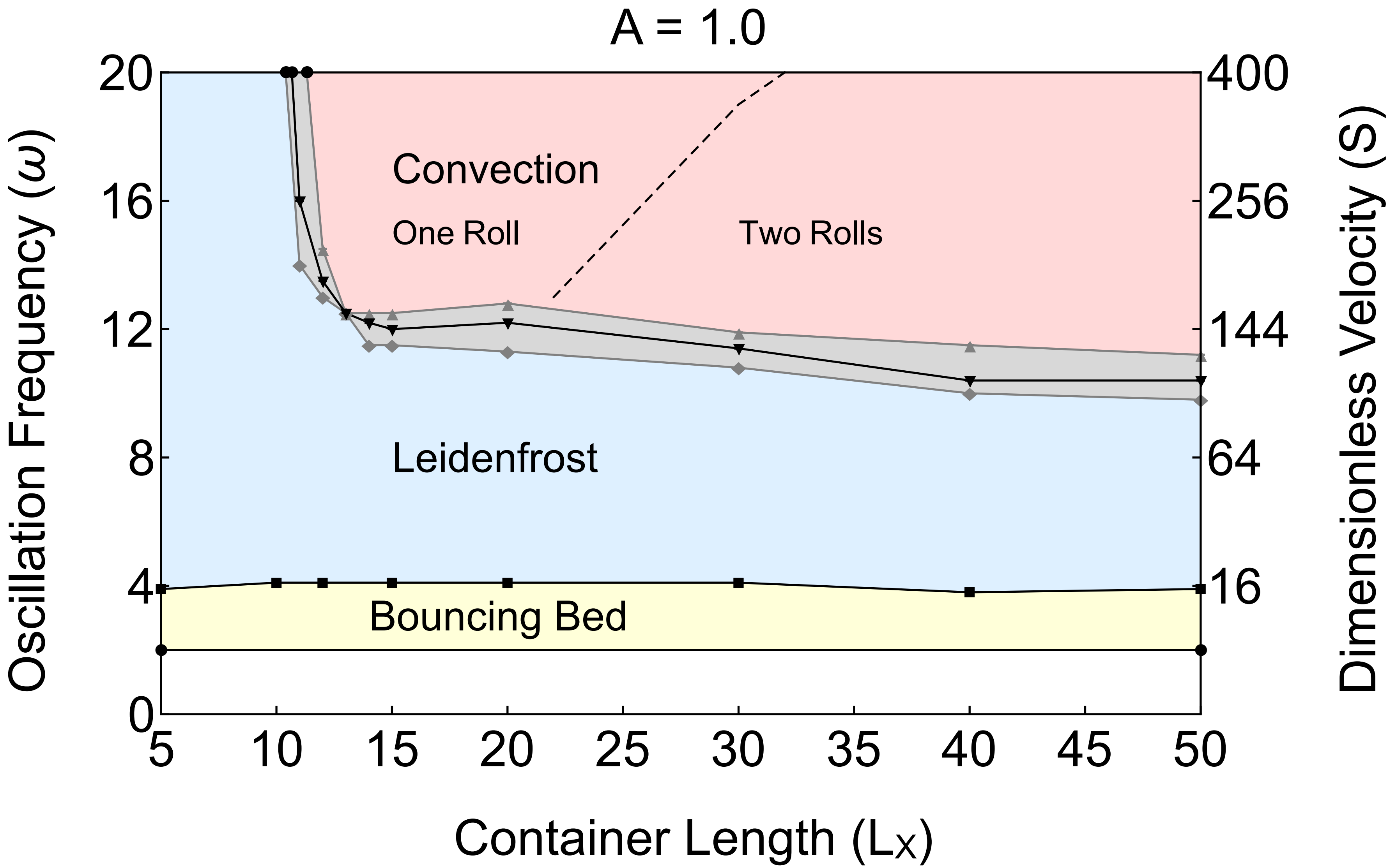
PHASES


Leidenfrost state (A = 1.0d, ω = 7.0(d/g)^1/2)
*color corresponds to granular temperature
dense
gas
L_x = 50d

PHASES

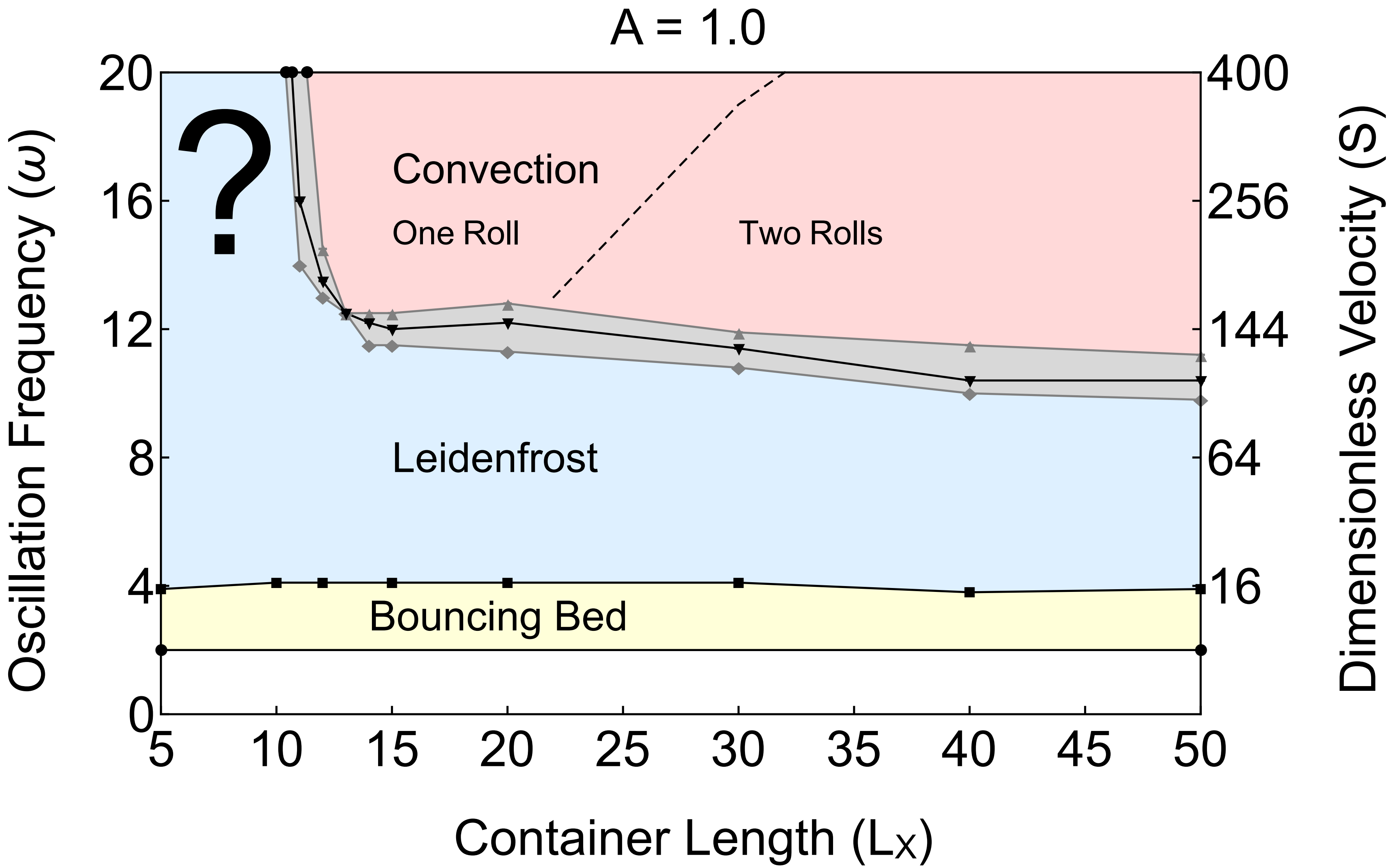


PHASES



A = 1.0
Convection
One Roll
Two Rolls
Leidenfrost
Bouncing Bed
Oscillation Frequency (ω)
Dimensionless Velocity (S)
Container Length (Lx)
0
4
8
12
16
20
16
64
144
256
400
5
10
15
20
25
30
35
40
45
50

PHASES


A = 1.0
20
16
12
8
4
0
400
256
144
64
16
?
Convection
One Roll
Two Rolls
Leidenfrost
Bouncing Bed
Oscillation Frequency (ω)
Dimensionless Velocity (S)
5
10
15
20
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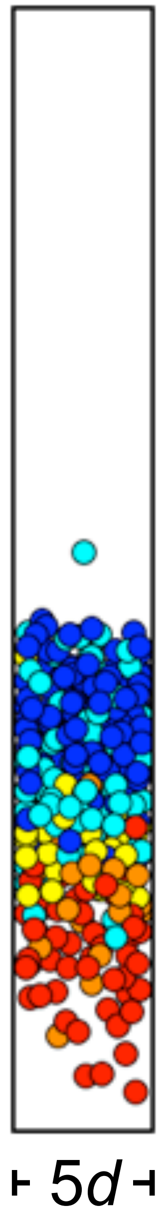
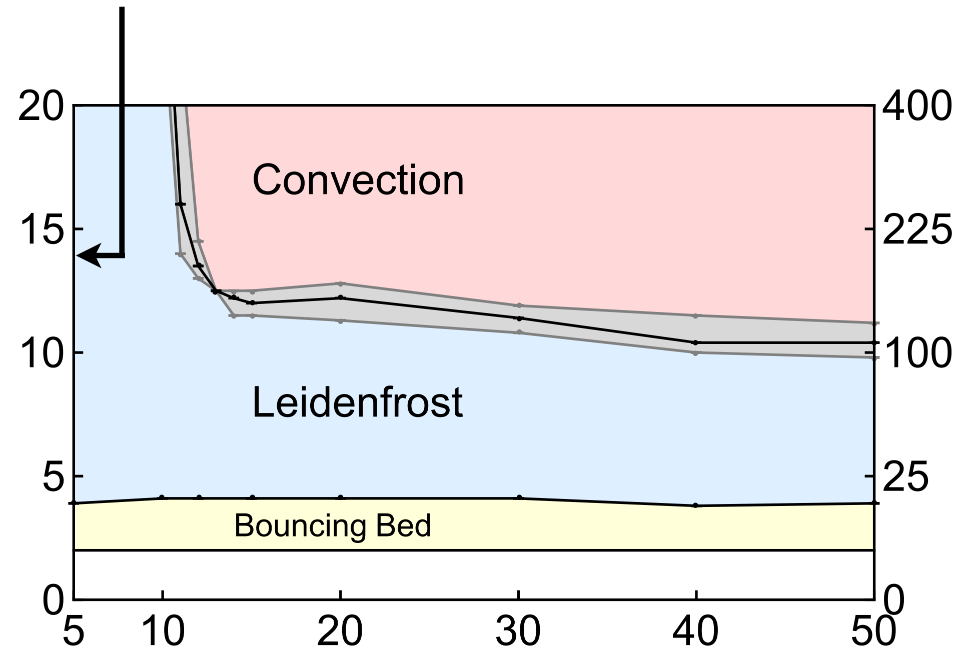
30
35
40
45
50
Container Length (Lx)

LOW-FREQUENCY OSCILLATIONS



A = 1.0d, ω = 14.0(d/g)$^{1/2}$

(40 Hz for 5mm particles)



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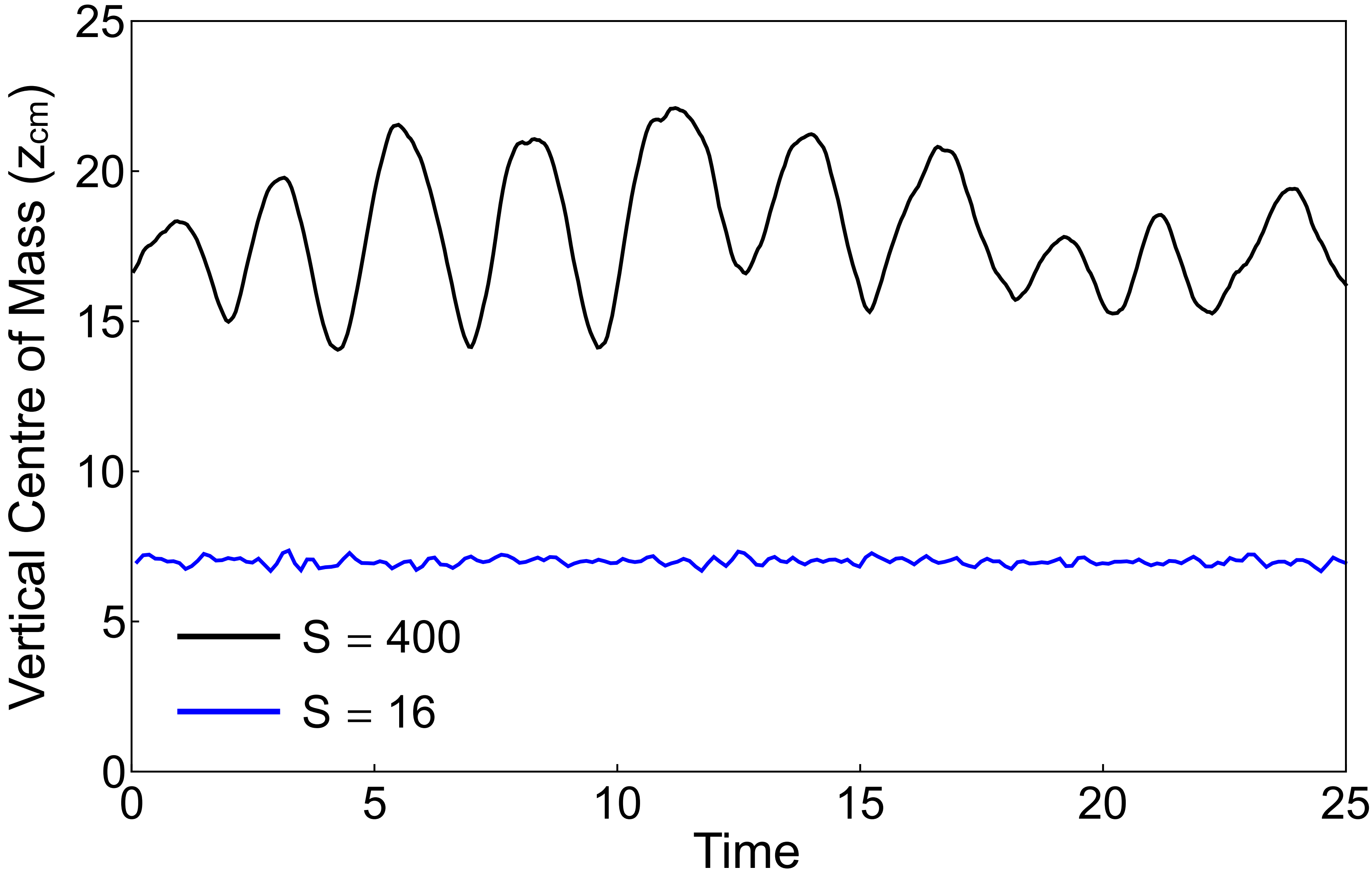

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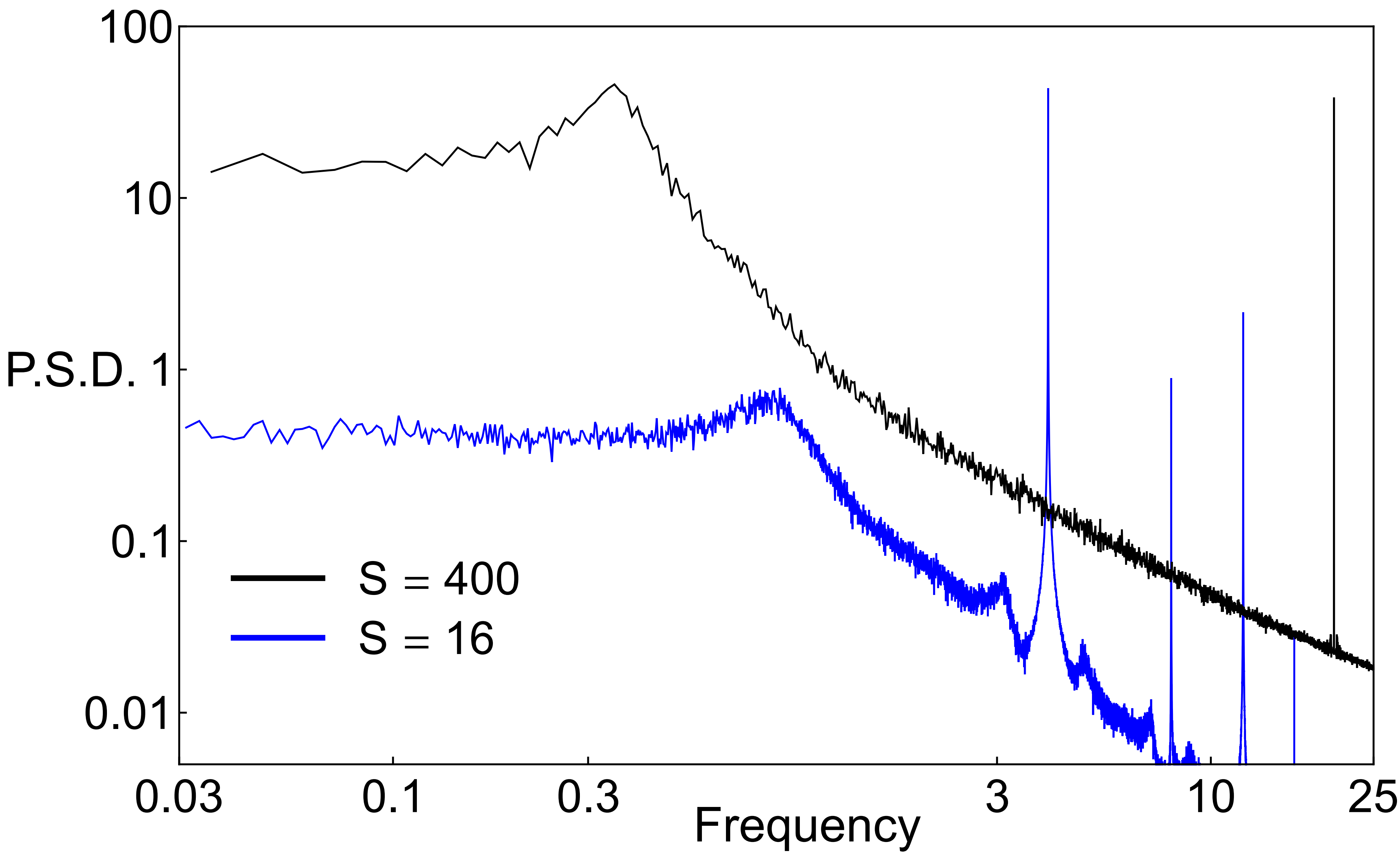

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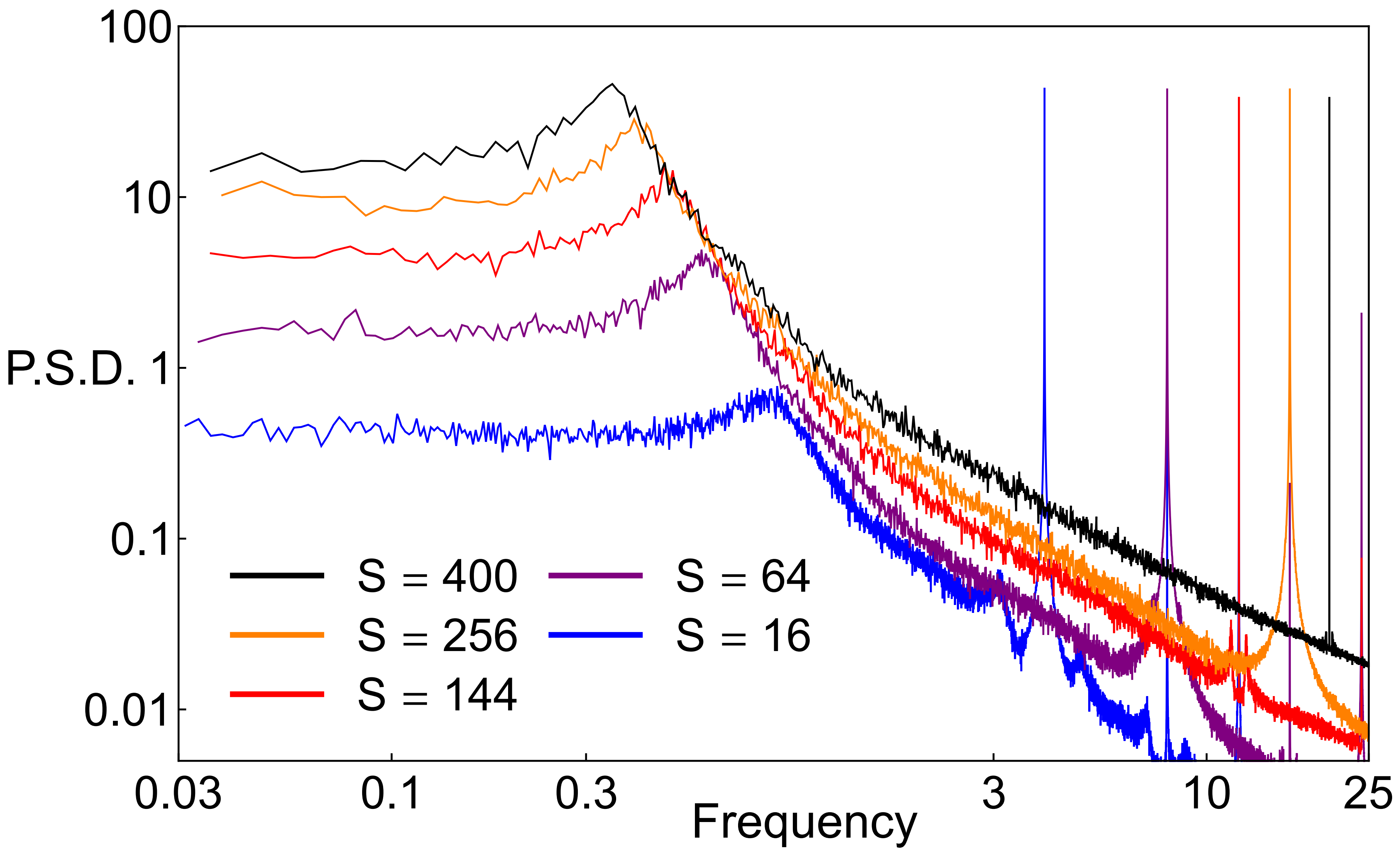

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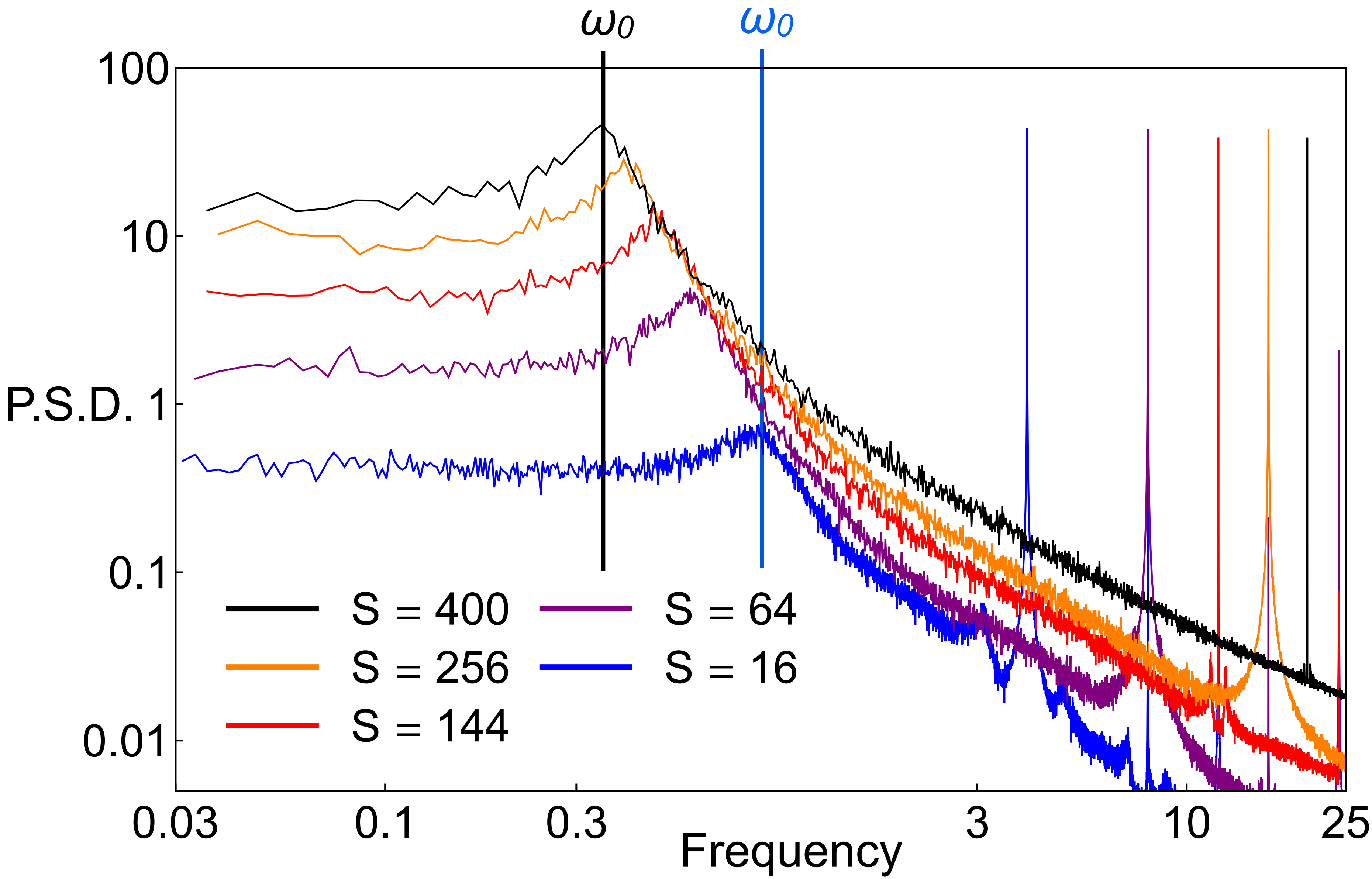

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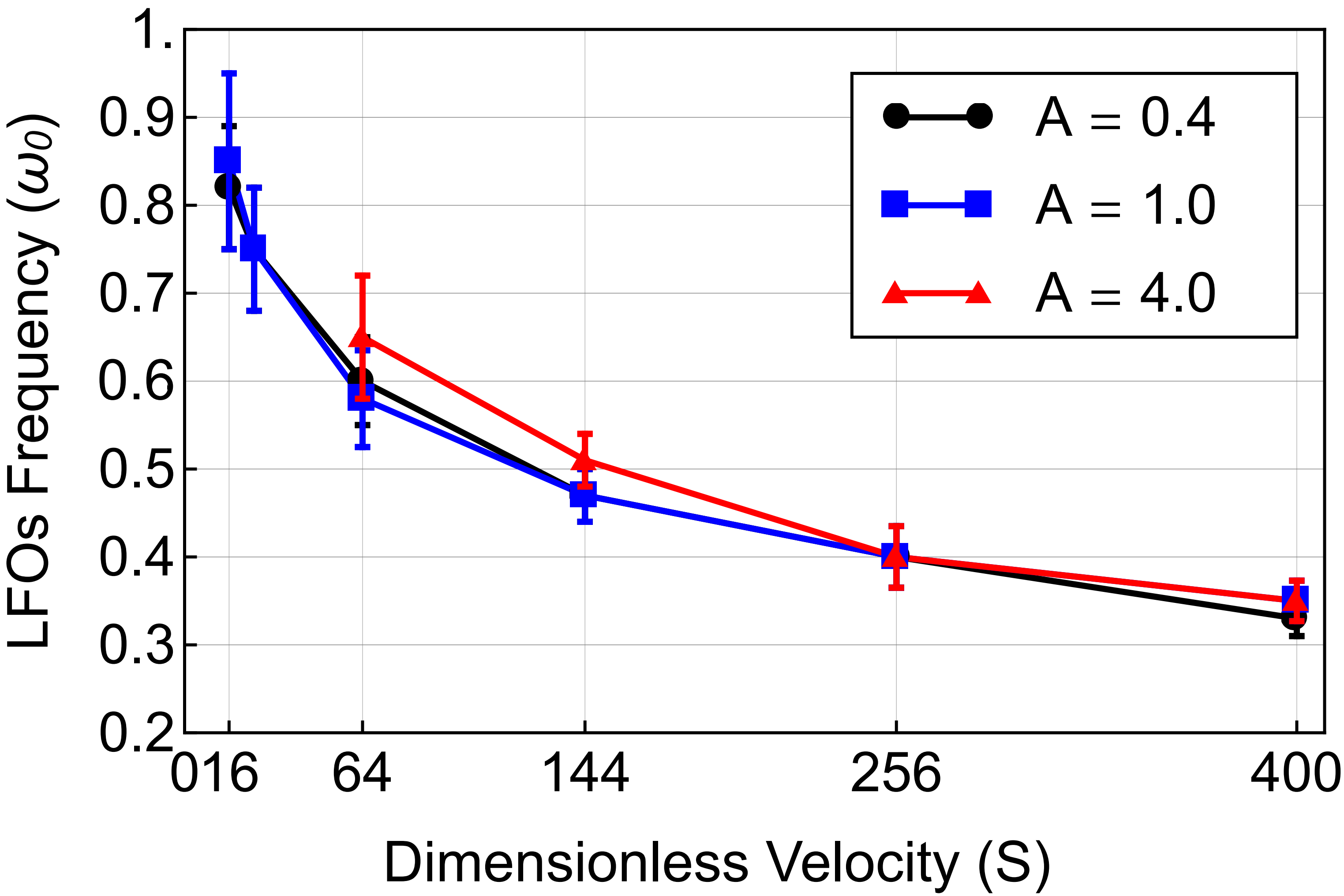

LFO's MODEL

Cauchy's equations

$$D_t\tilde{\rho} + \rho(\nabla \cdot \vec{\tilde{u}}) = 0,$$
$$D_t(\rho\vec{\tilde{u}}) = \nabla \cdot \tilde{\sigma} + \rho\vec{B},$$

→

Forced harmonic oscillator

$$\ddot{\xi} + \omega_{0_m}^2 \xi = \frac{1}{m_s} A_{f_m} \cos(\omega_{f_m} t) + C,$$

$$\omega_{0_m}^2 = \frac{g\rho_g}{m_s}$$

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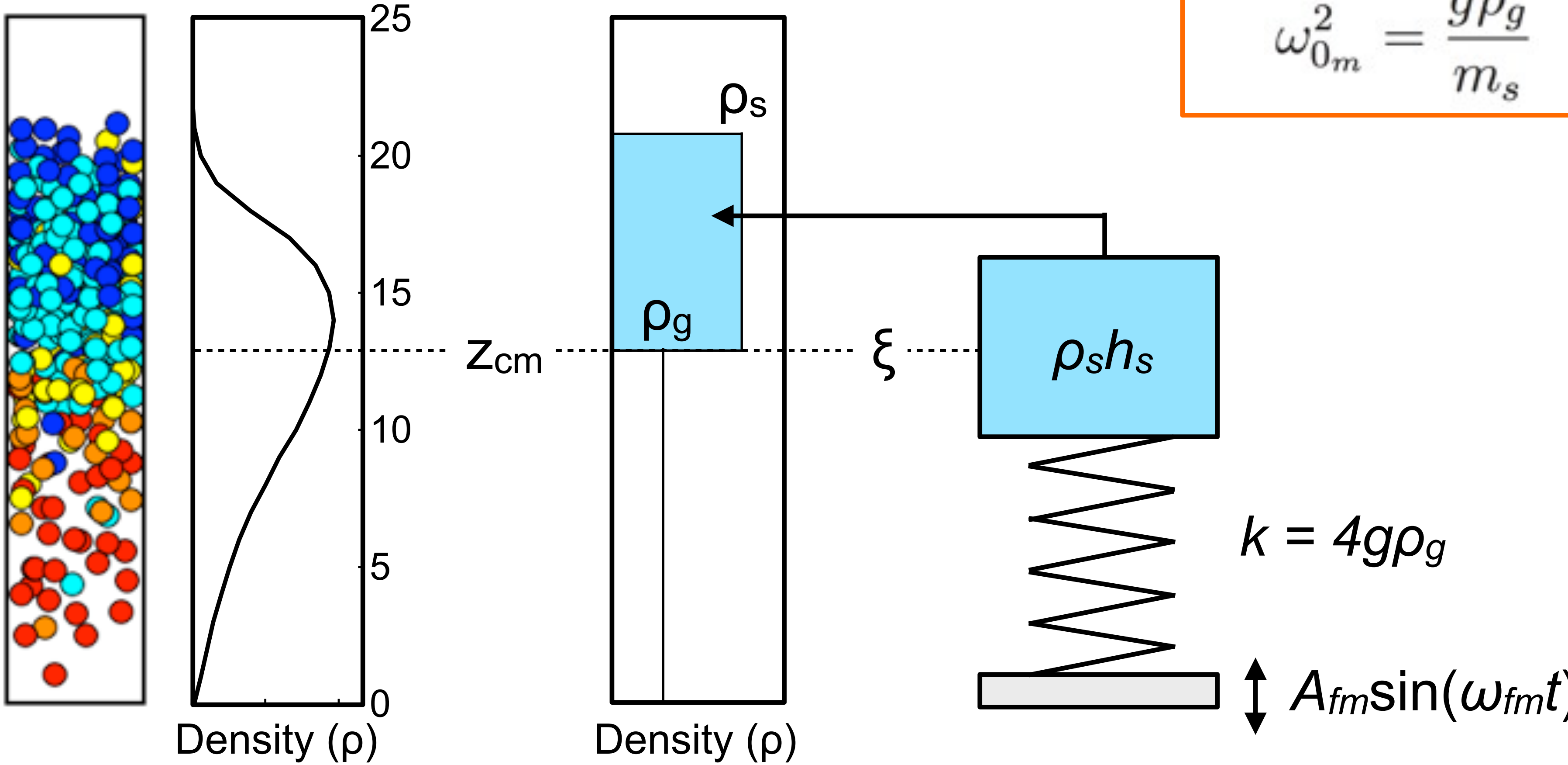

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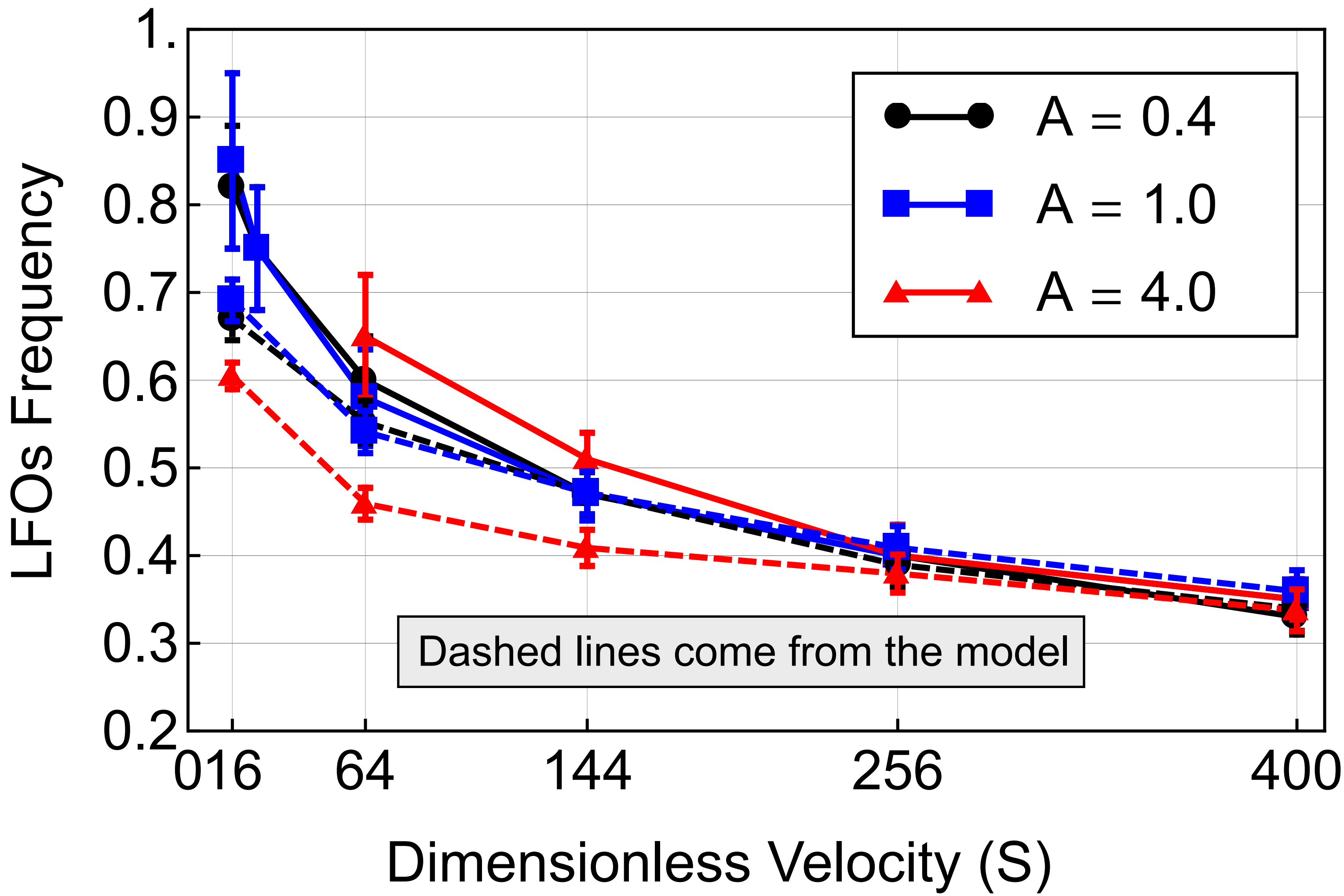
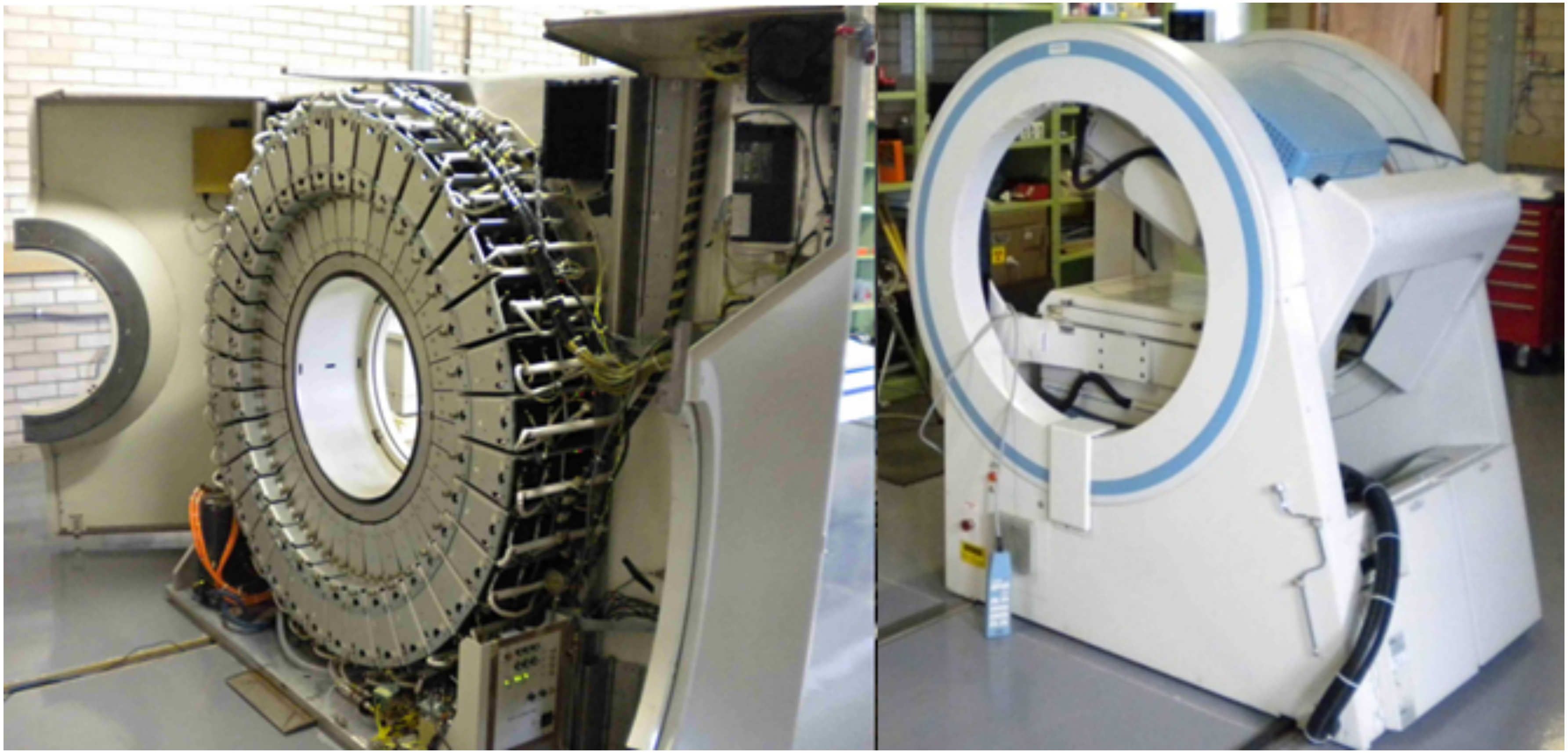


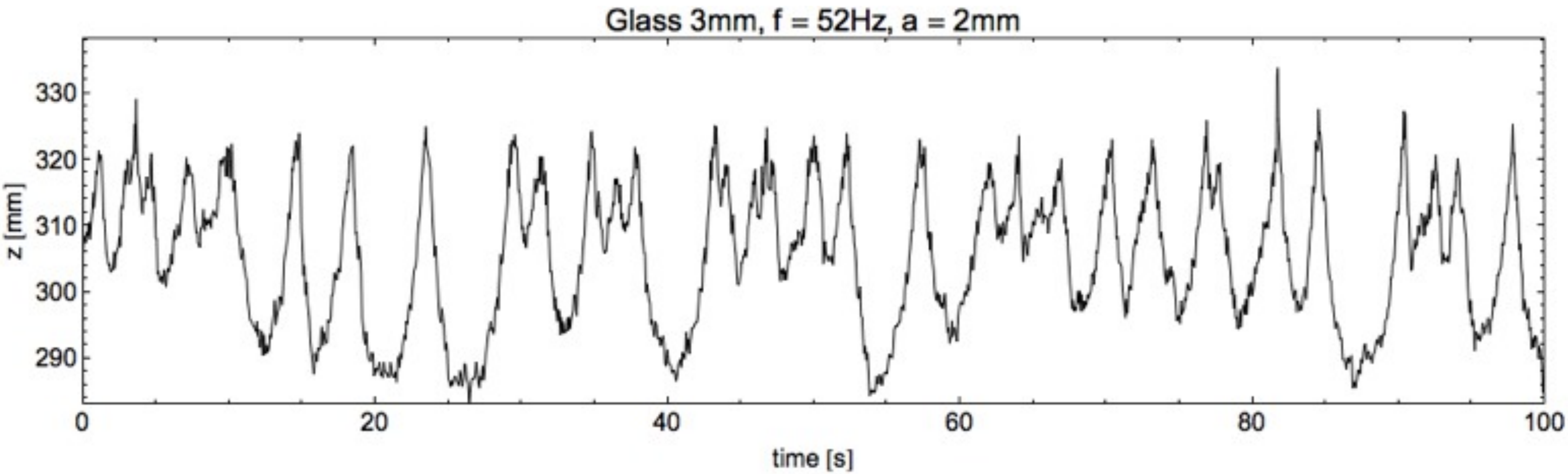
EXPERIMENTS

We use PEPT (Positron Emission Particle Tracking) to track ONE particle

Submilimeter, milisecond resolutions

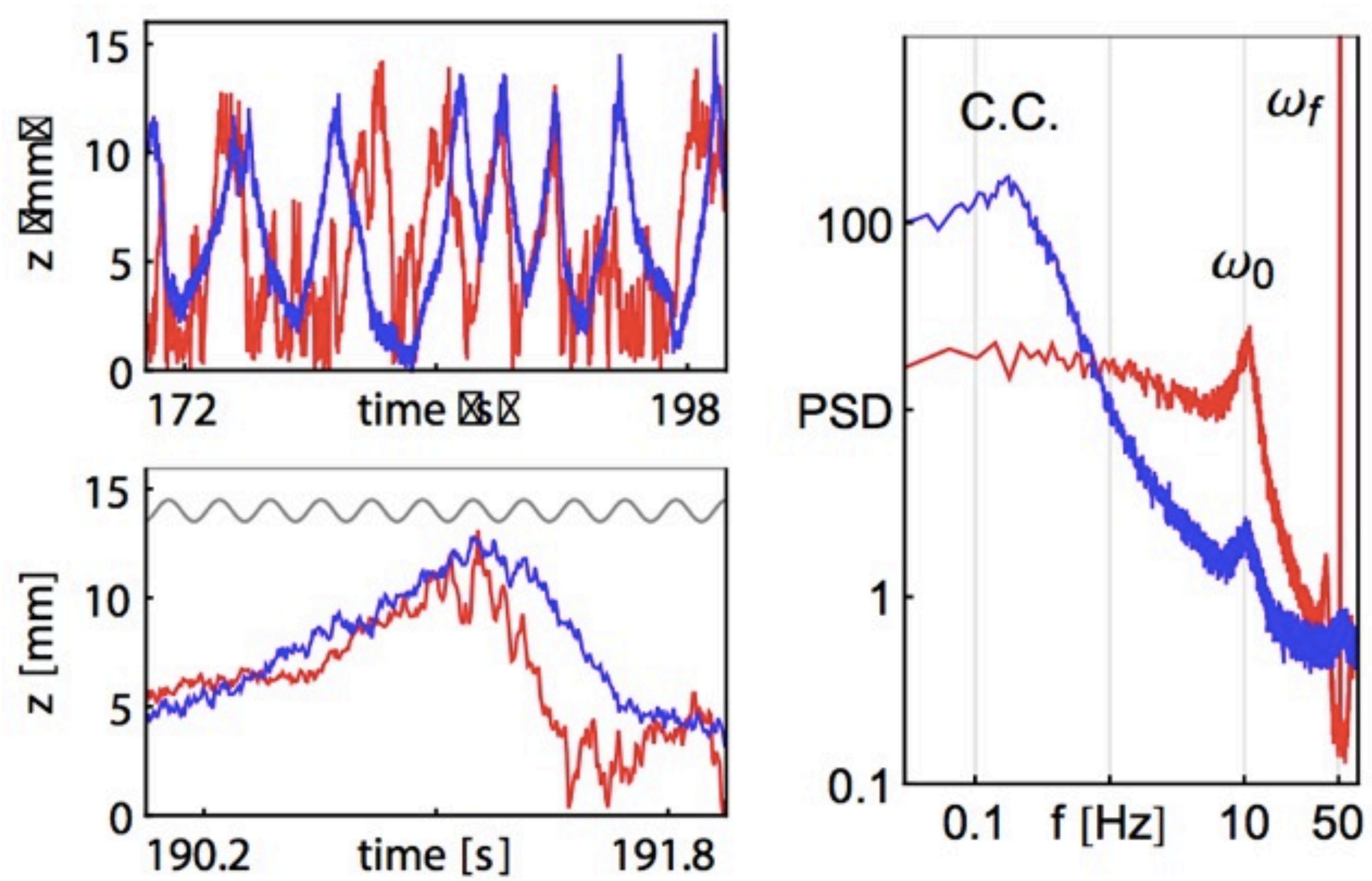


EXPERIMENTS

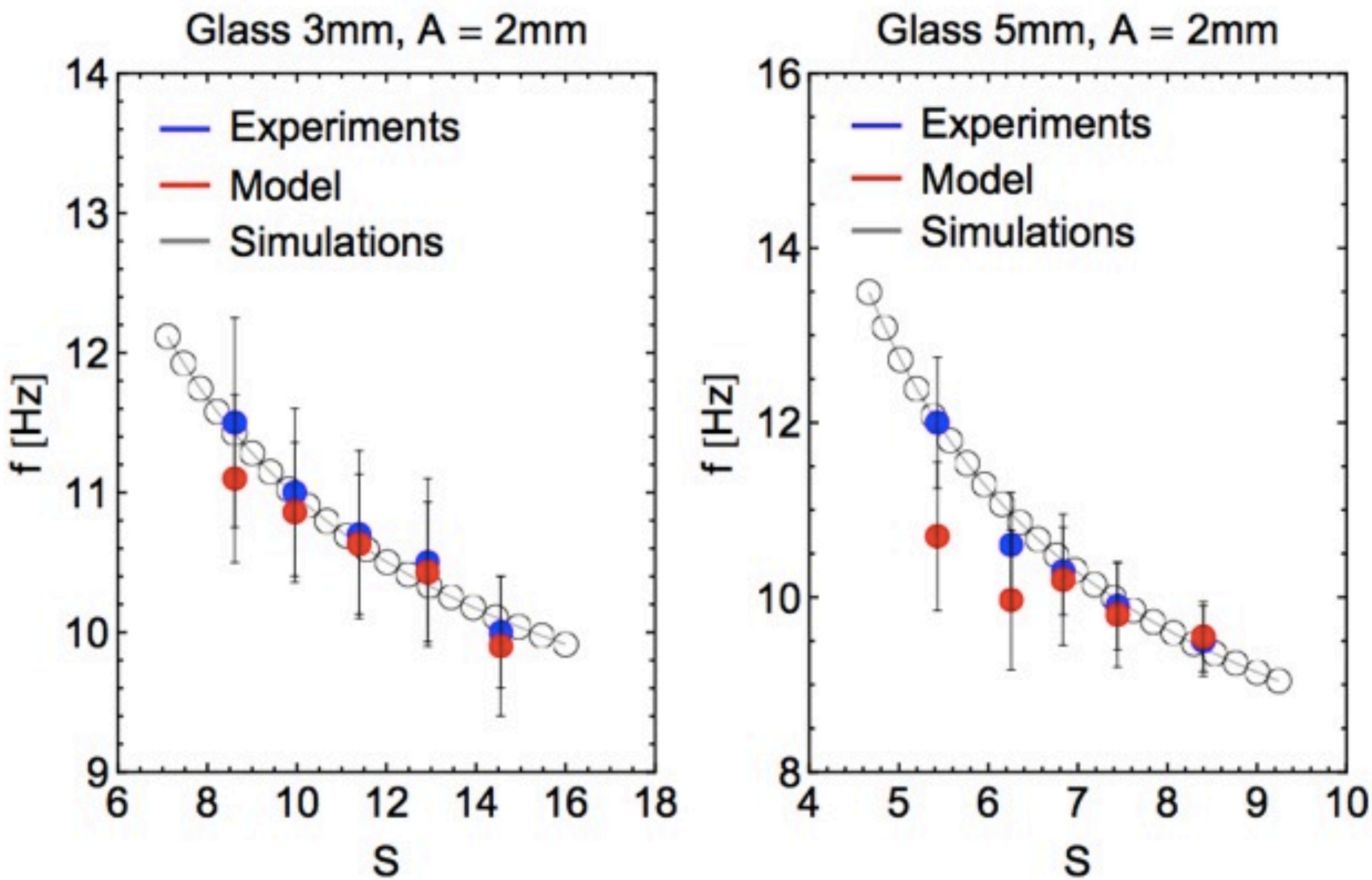


EXPERIMENTS

- Red = Simulations
- Blue = Experiments



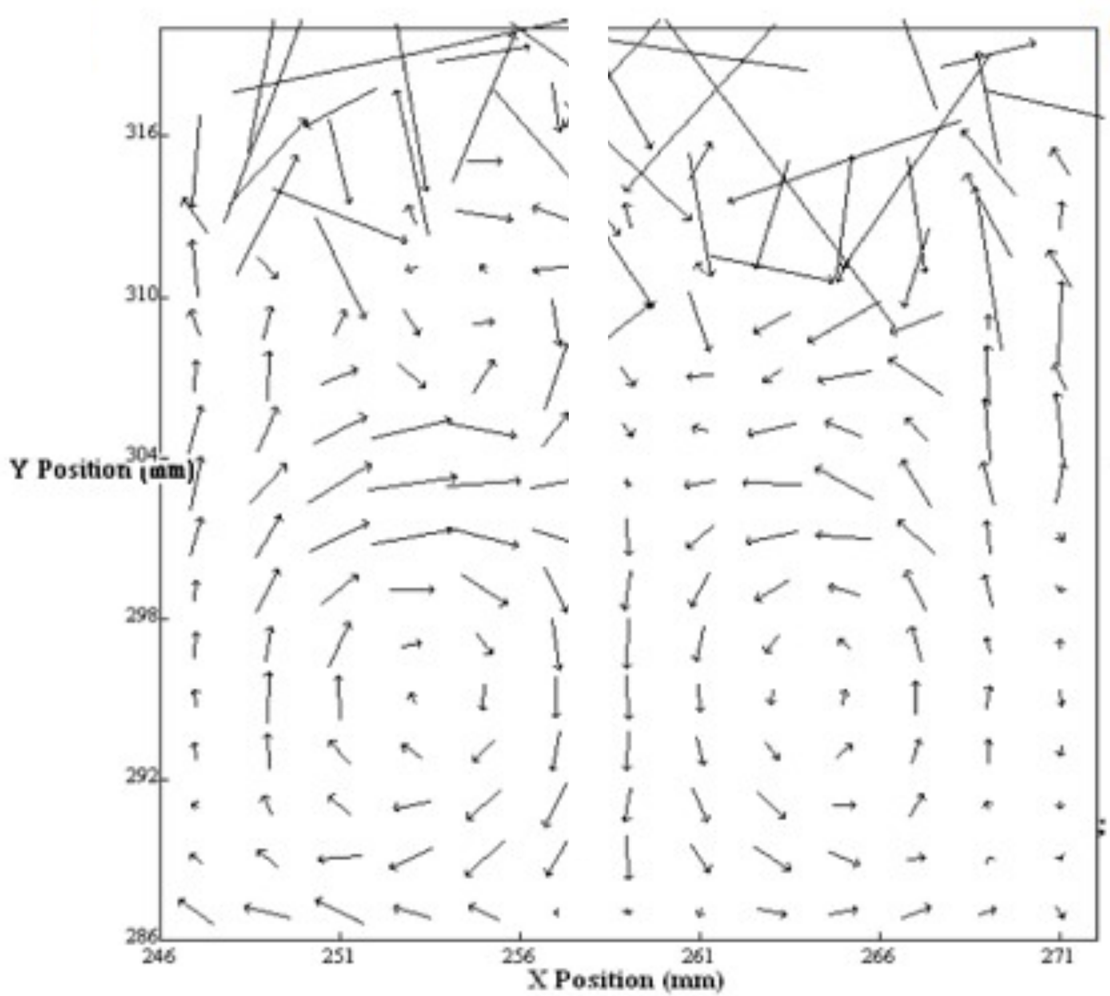
EXPERIMENTS



EXPERIMENTS

Observed convection phenomena

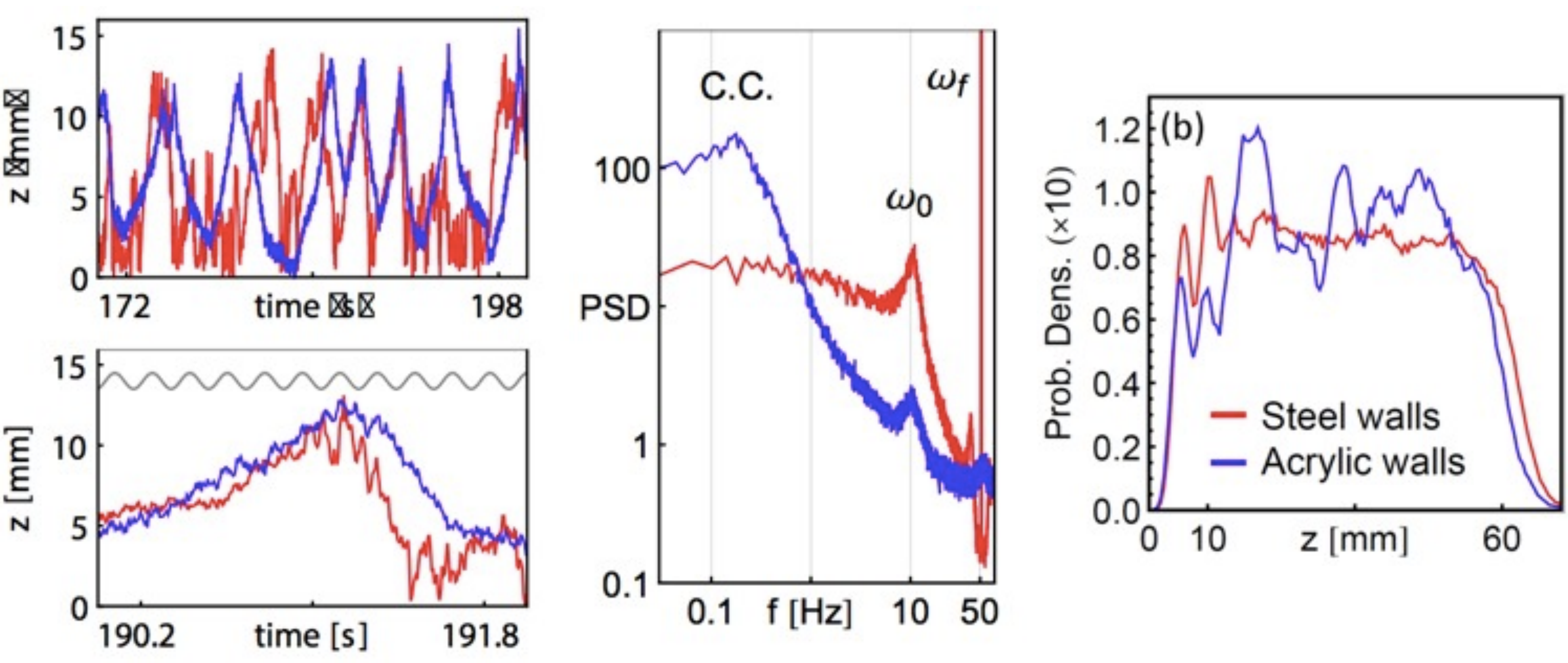
Inverse convective state



EXPERIMENTS

Observed convection phenomena

"Crystalline convection"



Conclusions

- Vertically driven granular matter in density inverted states present low-frequency oscillations (LFOs).

- A forced oscillator model, obtained from considering a two phases continuum medium, agrees with simulation and experimental measurements.

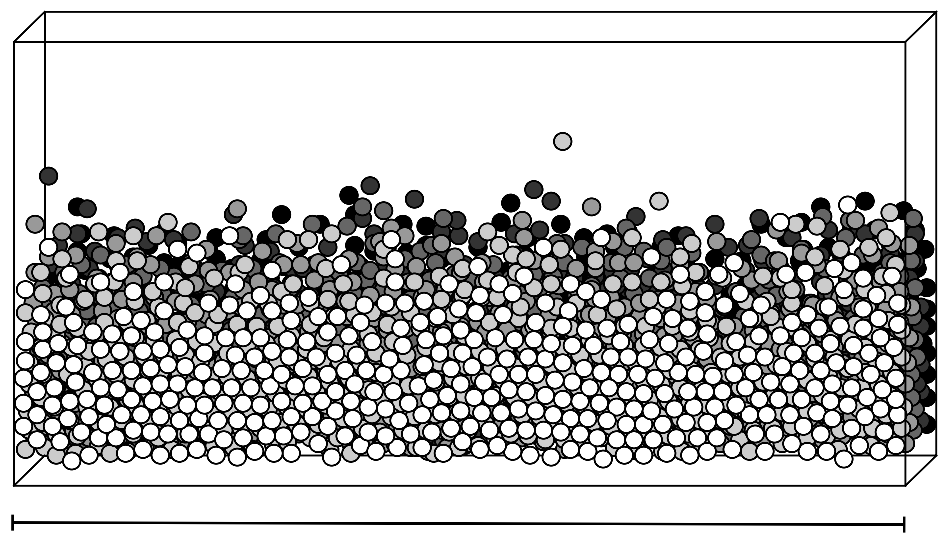
LFO's

Prospective work

- Expand the model:
  - Consider energy equation
  - Solve full non-linear equation
- Study relevance of LFOs in wider systems

BINARY MIXTURE

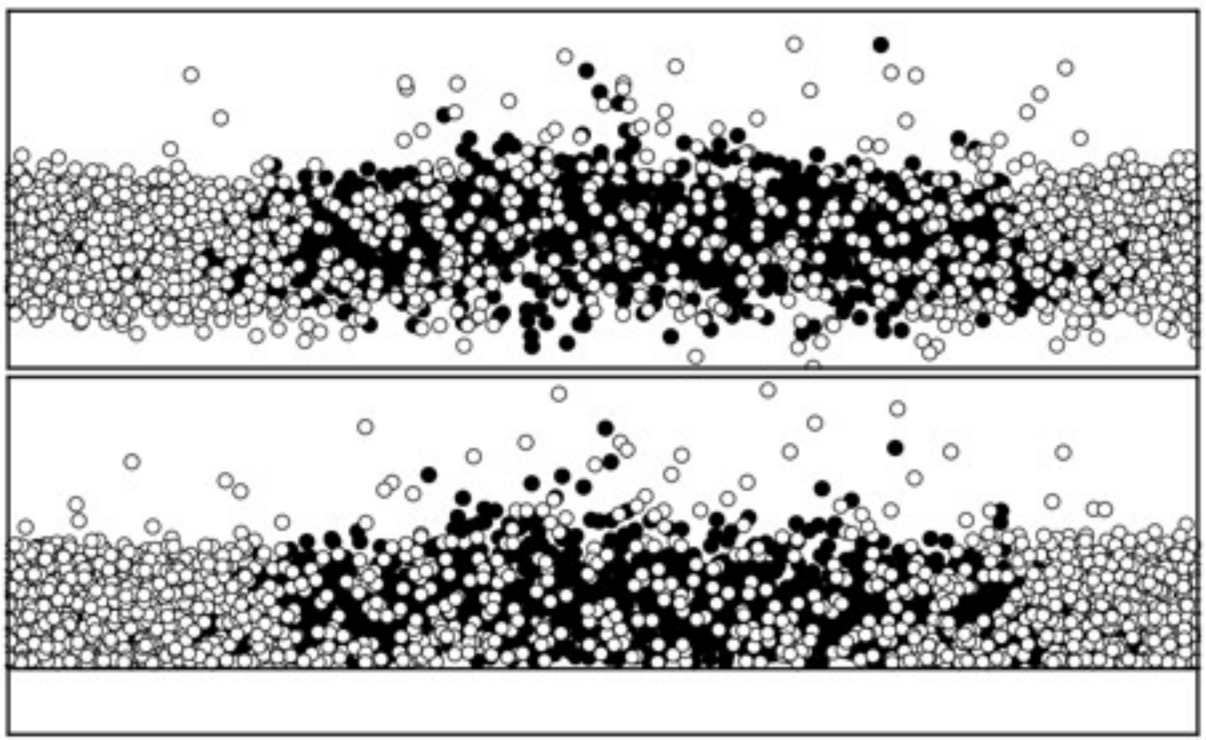
Back to **Wide** Geometry



$L_X = 50d$

$N = 3000$

BINARY MIXTURE



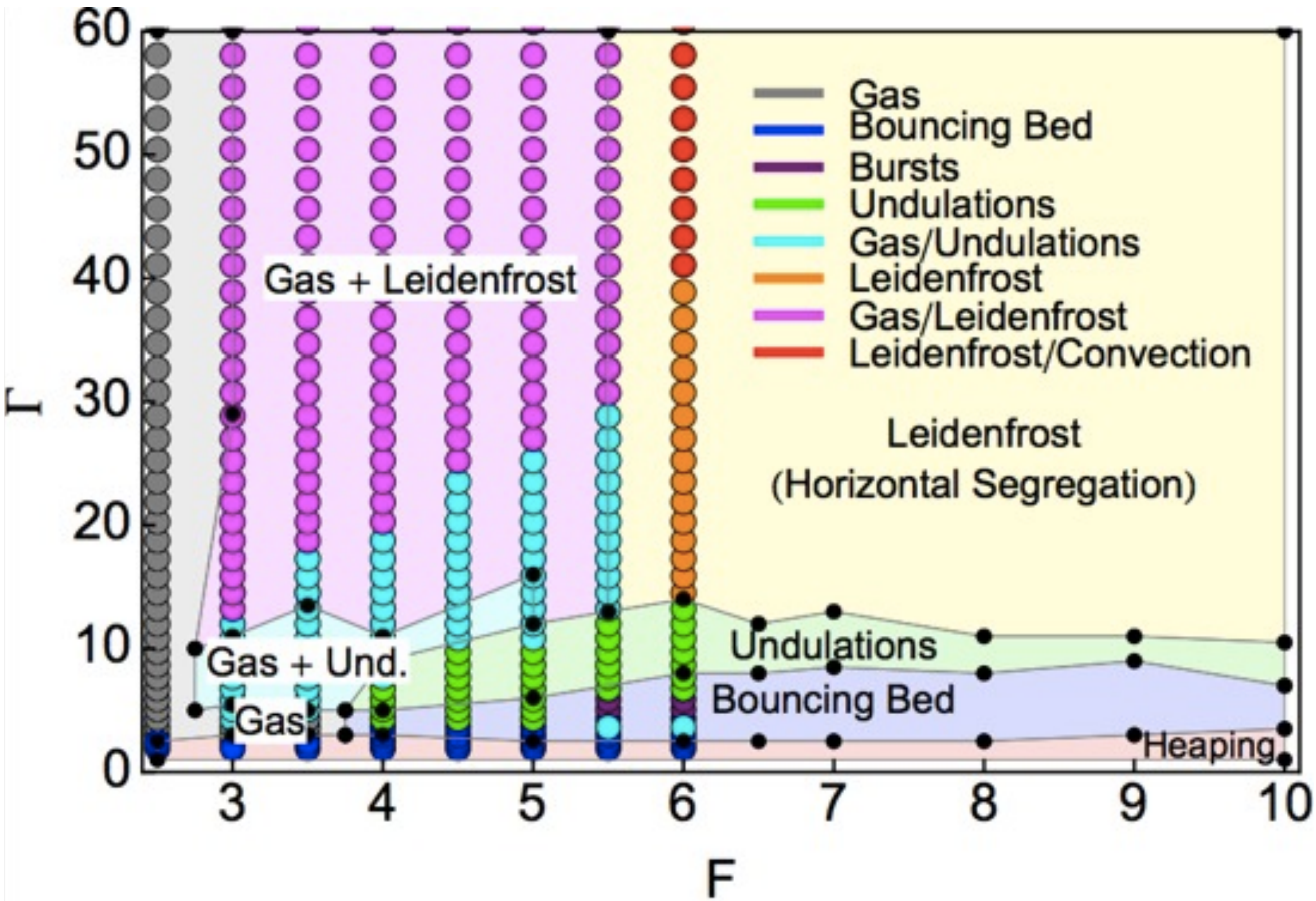
- Black particles are heavy
- White particles are light

Mass ratio = 3

Same size

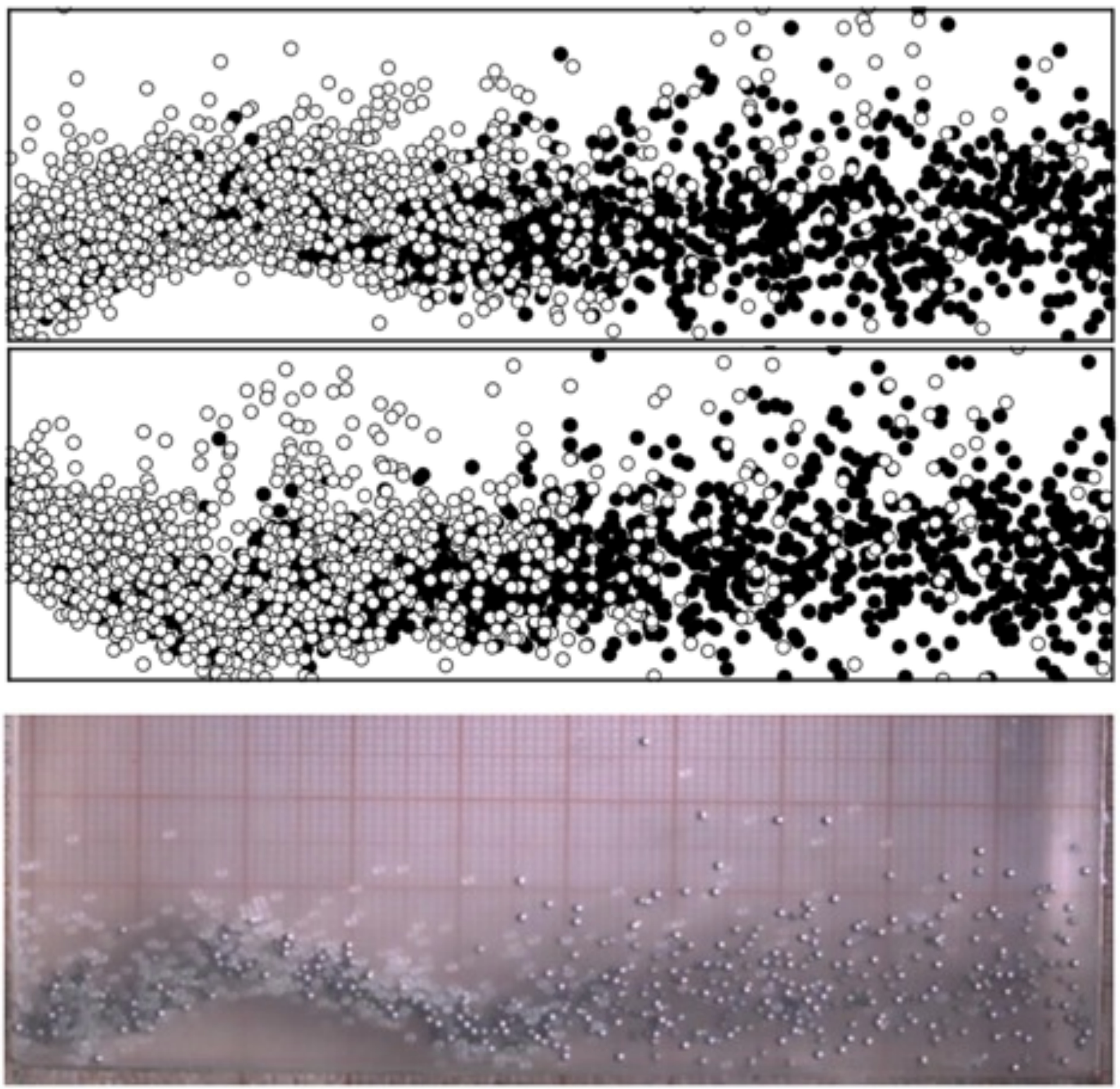
BINARY MIXTURE

Phase-Coexisting Patterns with Segregation in Vertically Vibrated Binary Granular Mixtures
I.H. Ansari, N. Rivas and M. Alam



BINARY MIXTURE

Undulations + Gas



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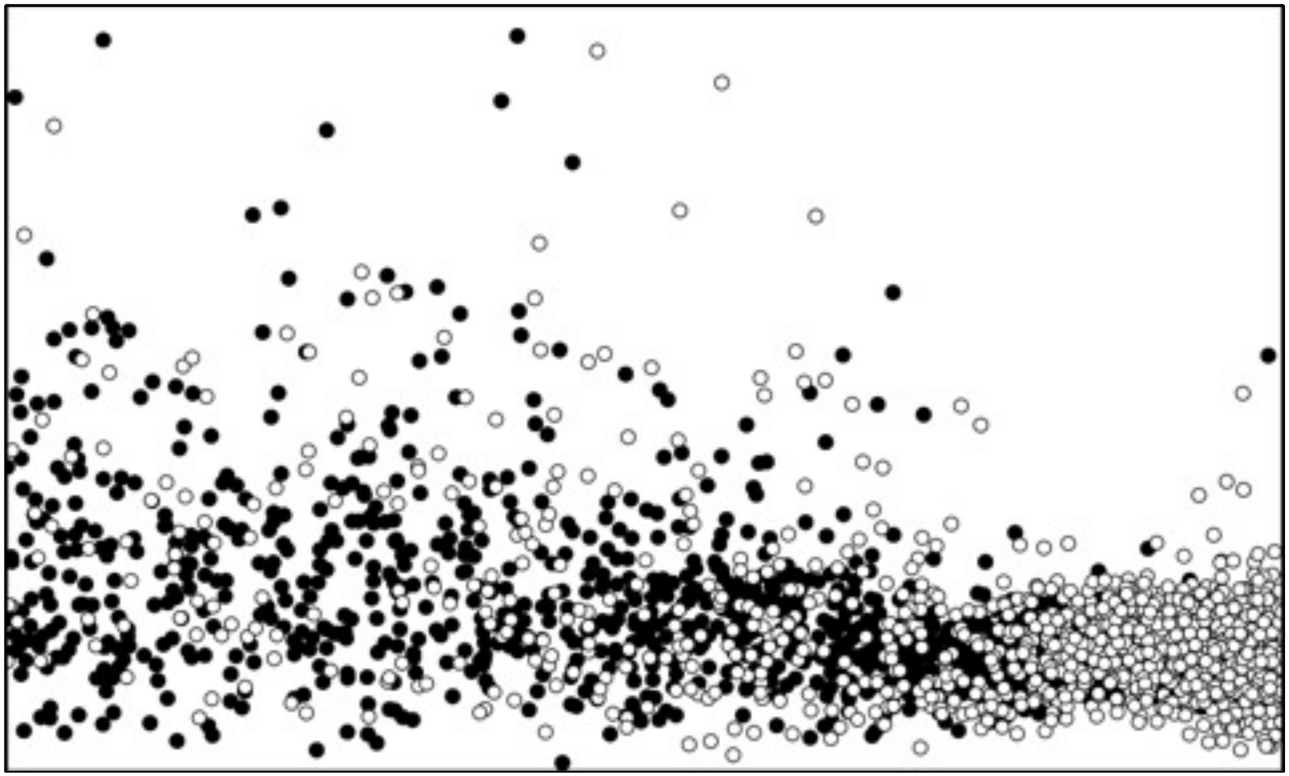
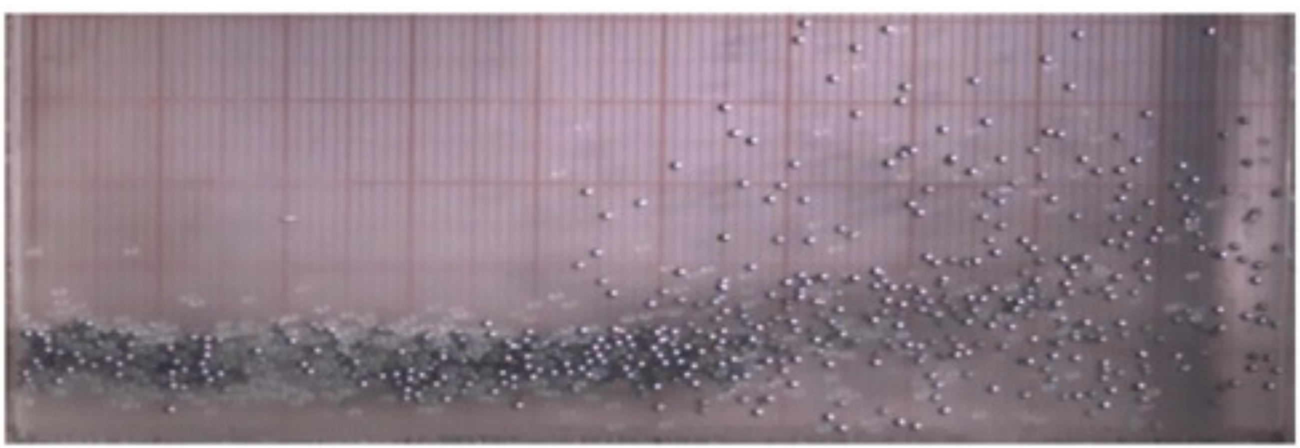
BINARY MIXTURE

Leidenfrost + Gas





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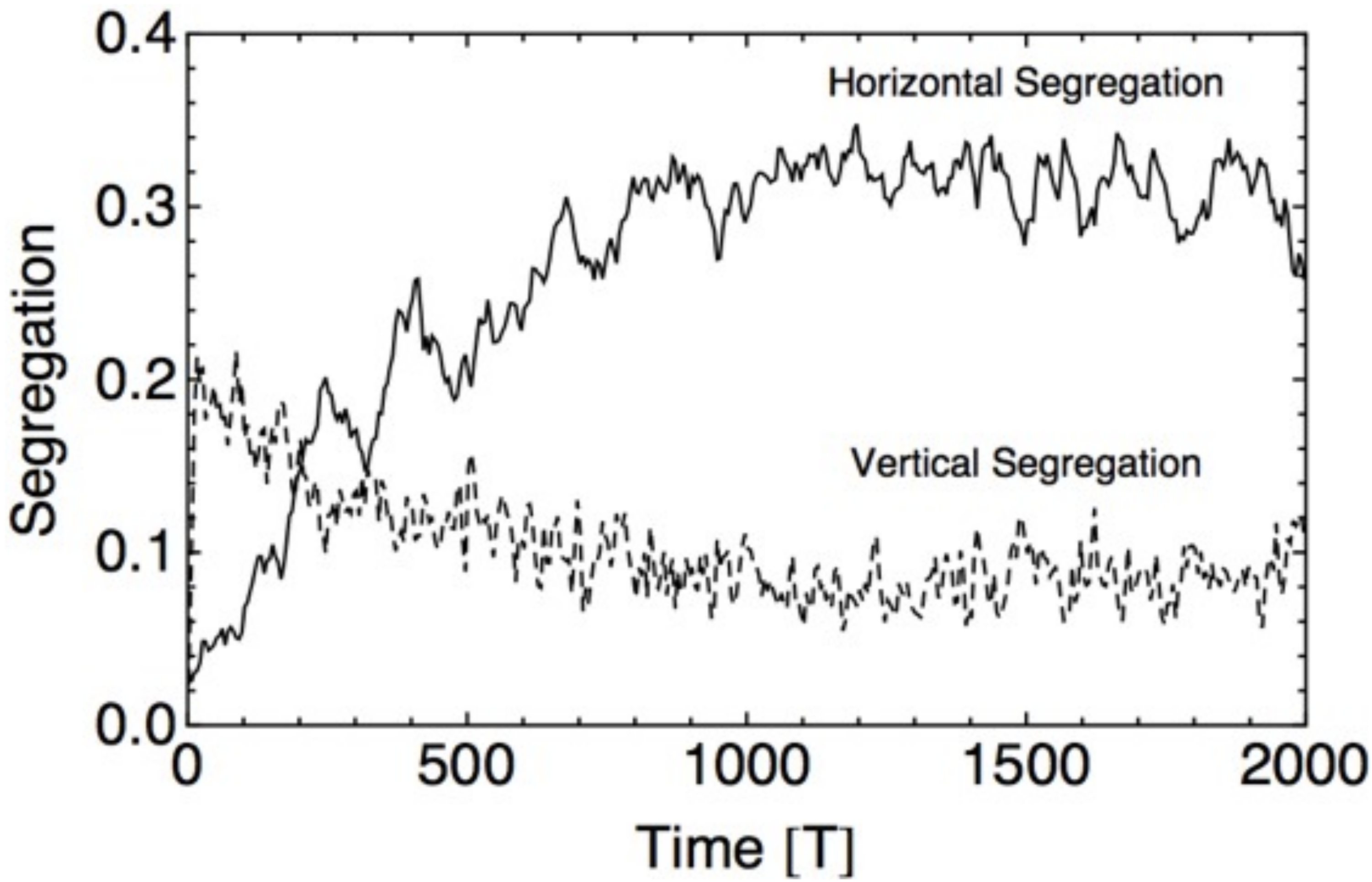

BINARY MIXTURE

Conclusions

- Known phases can coexist in the vertical vibrated narrow box geometry, when mass binary mixtures are considered.
- Segregation occurs in most cases, although mixed states are also observed.