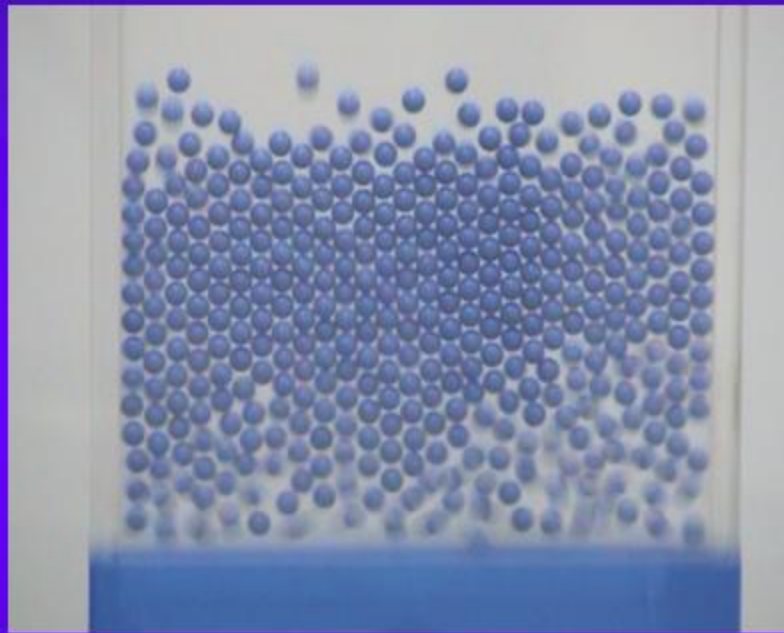


Granular Leidenfrost Effect

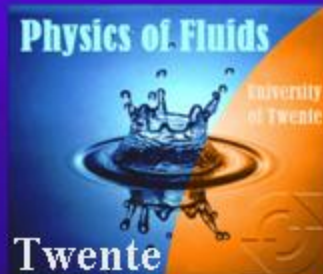


Peter Eshuis

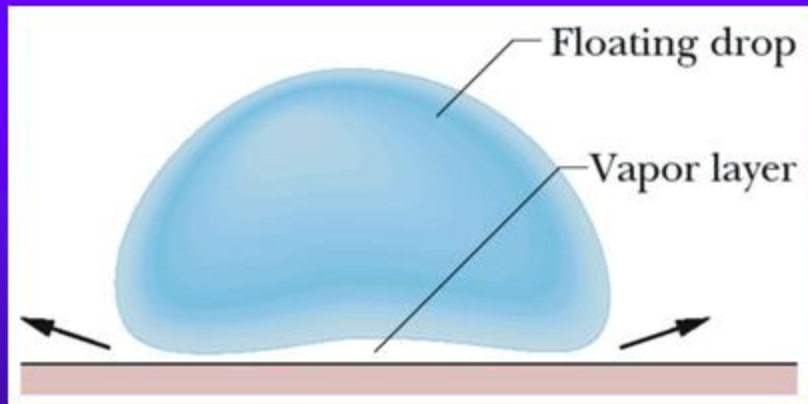
Ko van der Weele

Devaraj van der Meer

Detlef Lohse

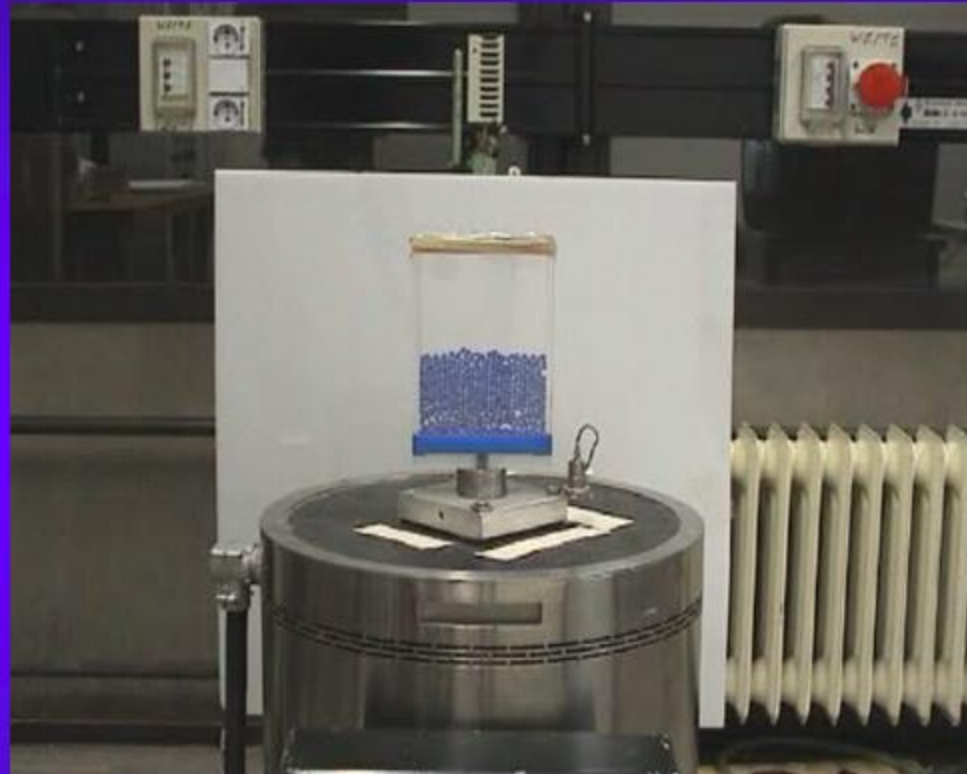


Johann Gottlob Leidenfrost (1756)



Drop of water on a hot plate ($\geq 220^{\circ}\text{C}$)

Granular version



Granular temperature at bottom \sim Shaking strength

2D container: $10 \times 0.45 \times 14$ cm, Glass beads: $d = 4$ mm, $\rho = 2.5$ g/cm³, $e \approx 0.9$

What are the dimensionless control parameters?

$\Gamma = a(2\pi f)^2/g$ = shaking acceleration

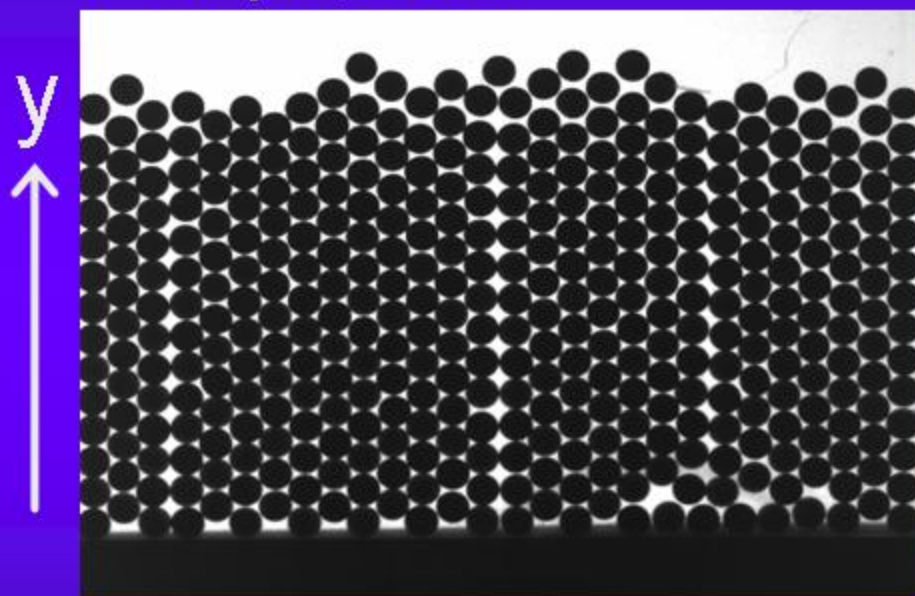
F = number of particle layers

$A = a/d$ = shaking amplitude

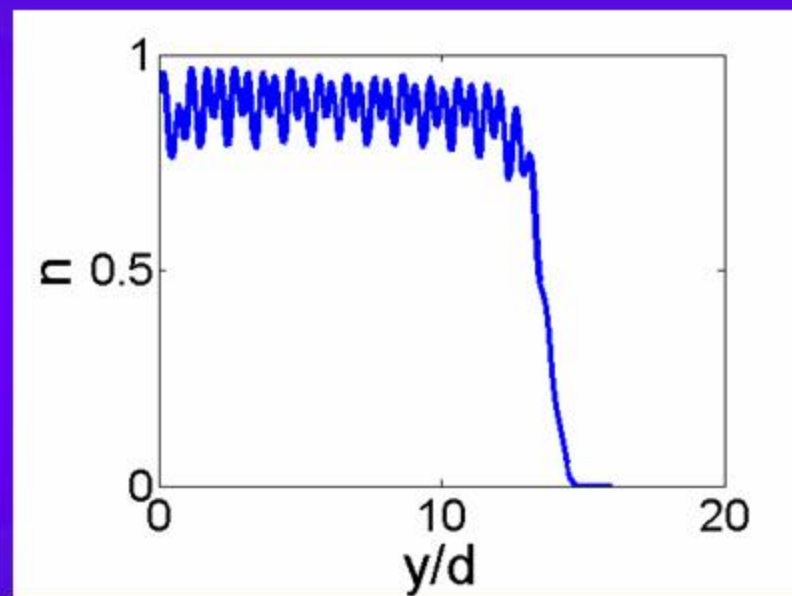
$\varepsilon = (1-e^2)$ = inelasticity (≈ 0.1)

Leidenfrost state beyond critical acceleration Γ_c

F=16 layers, f=80Hz



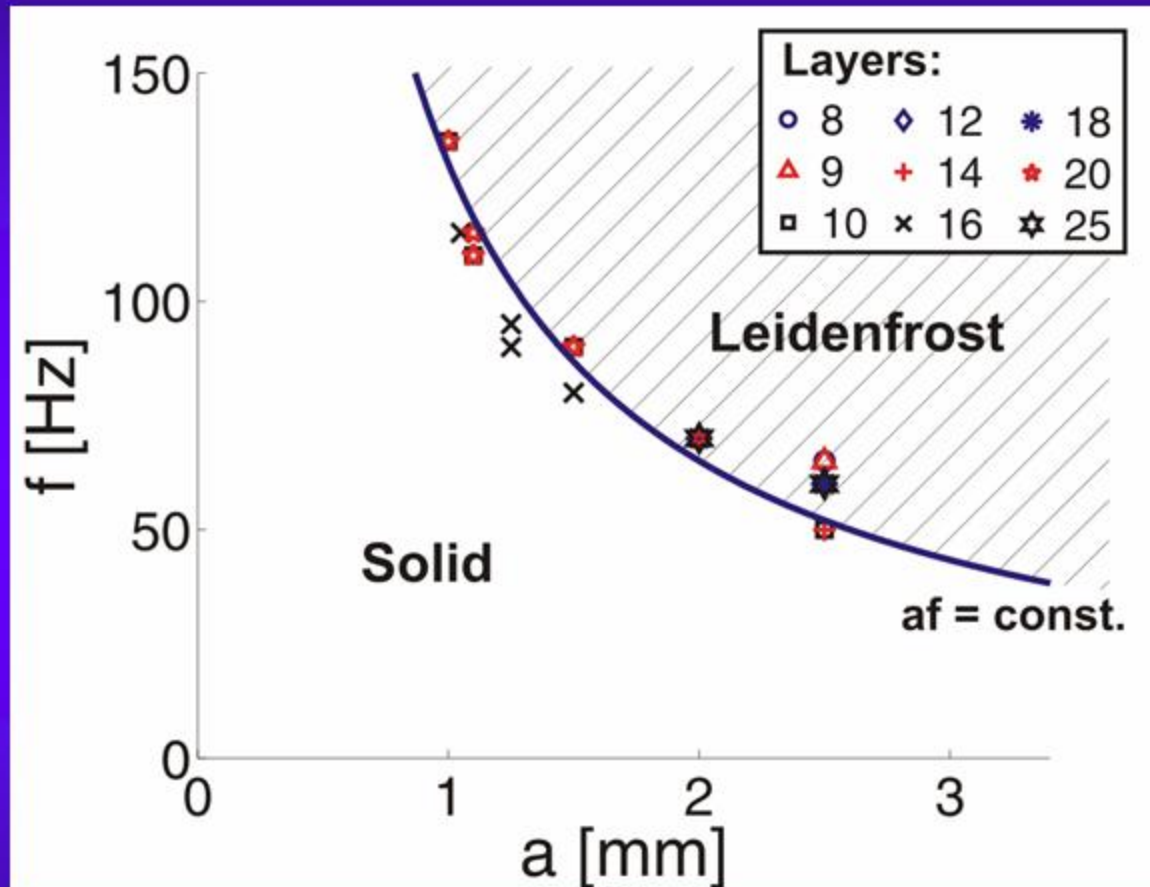
$$\Gamma = 25.75$$



Leidenfrost state

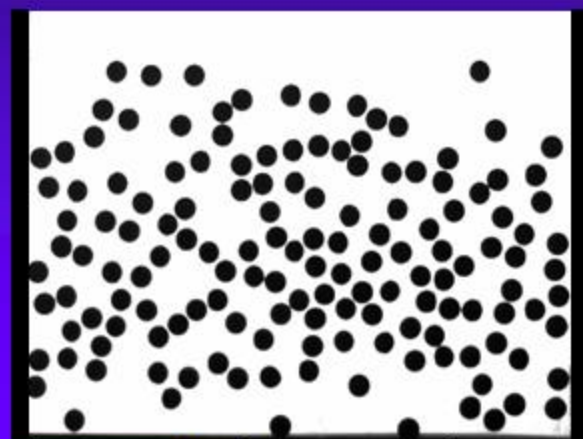
$$\Gamma_c \approx 25 \quad (\text{for } F = 16 \text{ layers})$$

Leidenfrost threshold

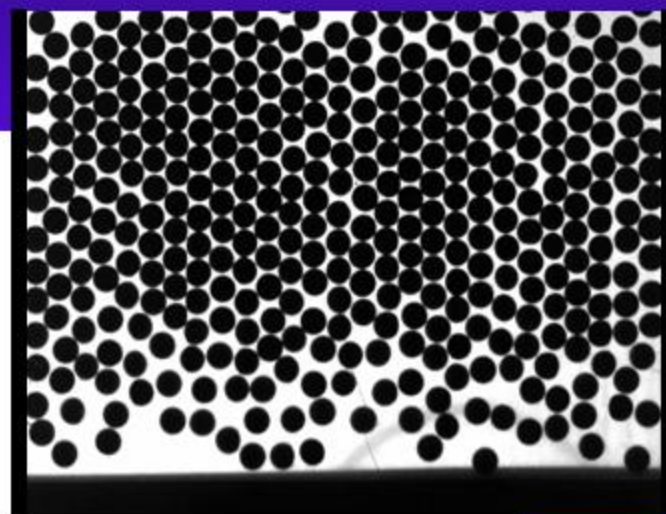


Transition at constant $(af)^2 \propto \Gamma A \equiv S$

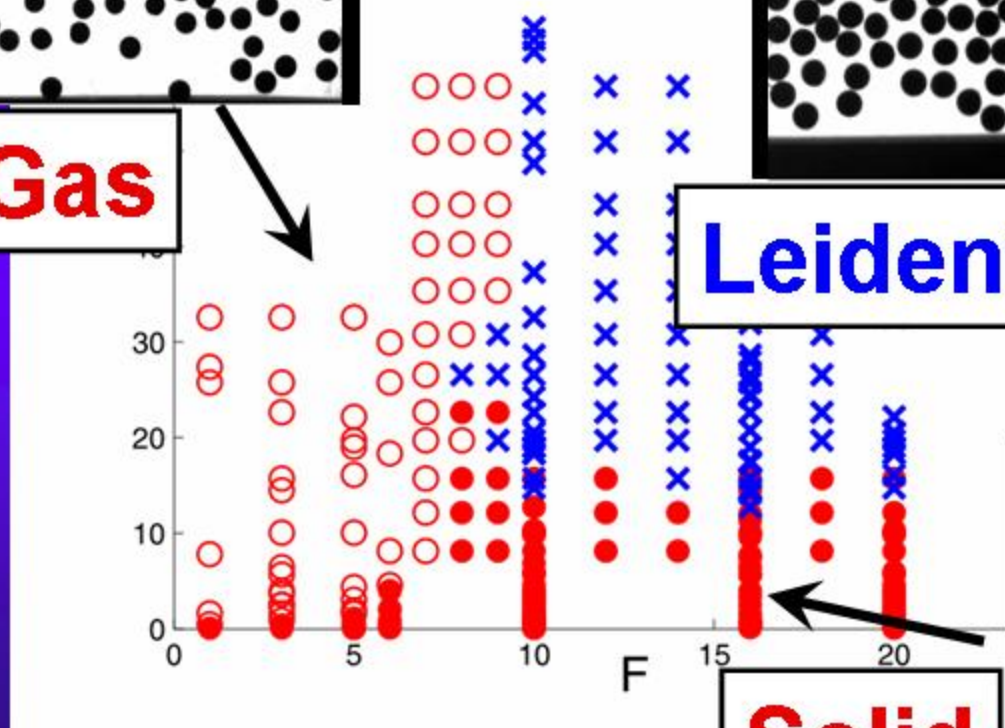
Phase diagram in S-F plane



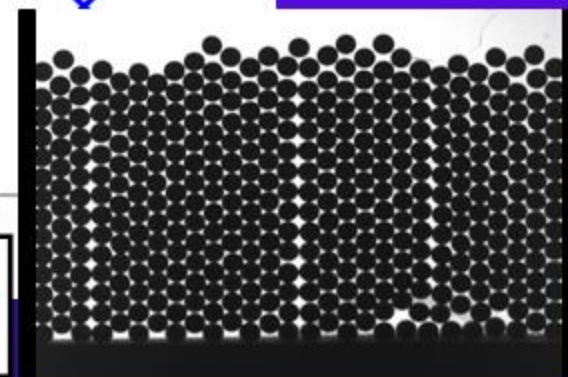
Gas



Leidenfrost state



Solid



Hydrodynamic model

(1) Force balance: $\frac{dp}{dy} = -mgn$

(2) Balance between heat flux and dissipation:

$$\frac{d}{dy} \left\{ \kappa \frac{dT}{dy} \right\} = \frac{\mu}{\gamma l} \varepsilon n T^{3/2}$$

(3) Equation of state: $p = nT \frac{n_{cp} + n}{n_{cp} - n}$

3 Boundary conditions

- Prescribed granular temperature at bottom:

$$T_0 \propto (af)^2$$

- Zero heat flux at top:

$$\lim_{y \rightarrow \infty} \left(\kappa(y) \frac{dT}{dy} \right) = 0$$

- Conservation of total number of particles:

$$\int_0^{\infty} n(y) dy = F n_{cp} d$$

Dimensionless control parameters

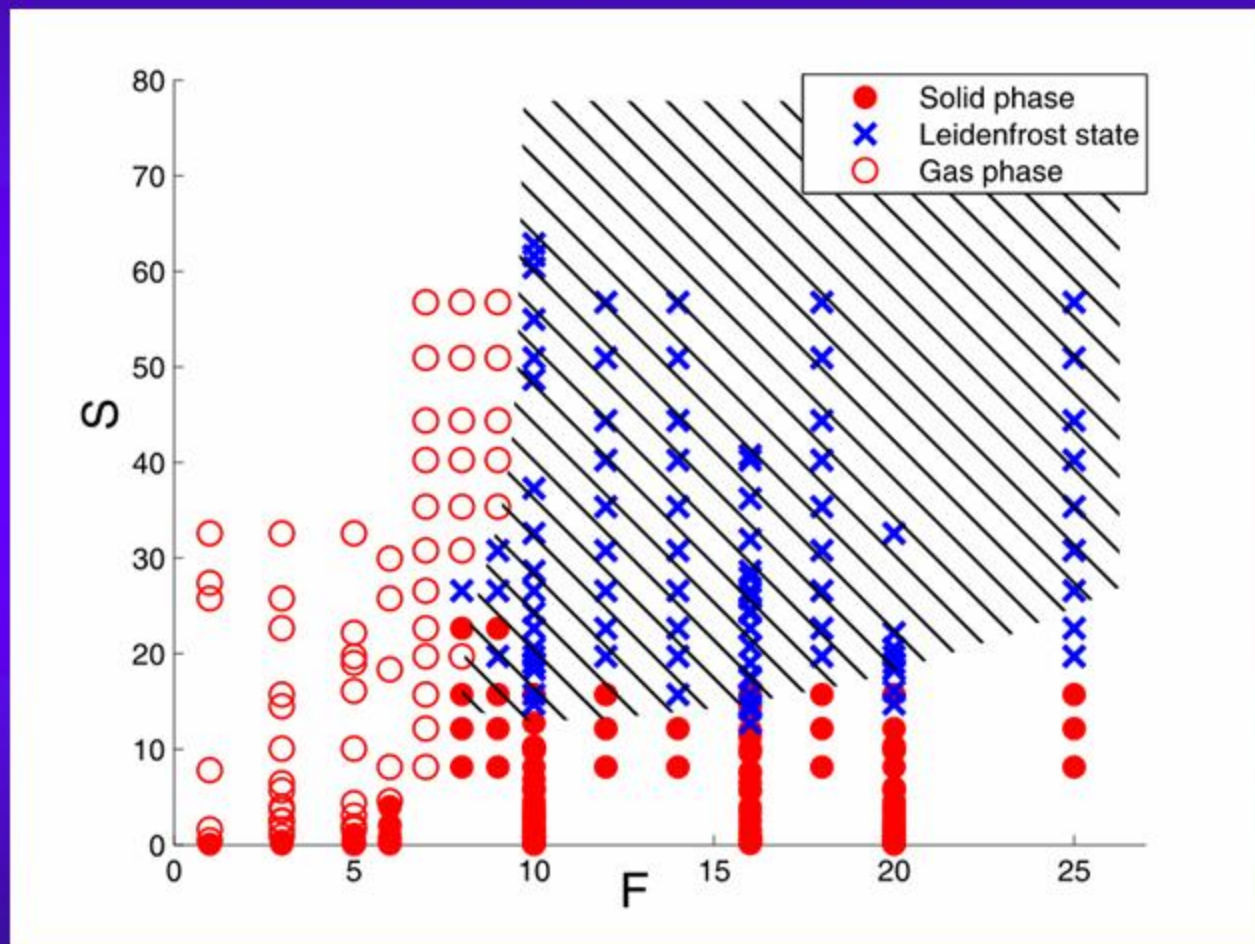
Energy input: $S = \frac{4\pi^2 (af)^2}{gd}$

Inelasticity: $\varepsilon = (1 - e^2)$

Number of layers: F

Just as in experiment, the relevant shaking parameter is $S \equiv \Gamma A$ (not Γ)

Experimental phase diagram and theoretical!



P. Eshuis, K. van der Weele, D. van der Meer, D. Lohse, *Granular Leidenfrost effect: Experiment and theory of floating particle clusters*, PRL 95 (in press, 2005).

Conclusions

- ◆ Granular Leidenfrost effect observed in experiment.
- ◆ Three relevant control parameters: S , ε , F in experiment *and* theory.
- ◆ Phase diagram from experiment and theory quantitatively agree.