Evidence for speed-symmetry breaking in steady state of dissipative granular gas in 0g

P. Evesque, MSSMat, ECP, France
R. Liu, "", & IOP-CAS, China
M. Hou, "", & IOP-CAS, China

Thanks to ESA, CNES, CNSA

The flights:

<table>
<thead>
<tr>
<th>Start</th>
<th>Mini Texus 5</th>
<th>Airbus A300 0g</th>
<th>Maxus 5</th>
<th>Maxus 7</th>
</tr>
</thead>
</table>

Satellite SJ8

VIP-Crit
VIP-Gran

ISS
chinese Satellite

chinese Satellite SJ10

French Team: P. Evesque, M. Leconte ECP; Y. Garrabos, F. Palencia & C. Lecoutre ICMCB; D. Beysens, ESPCI-CEA; S. Fauve, ENS Paris; E. Falcon, ENS Lyon- CNRS

Europe: N. Vanderwall, A. Garcimartin, D. Maza, X. Jia, M. Sperl, J. Blum

China: M. Hou
Why Studying Granular Matter in Micro-gravity.

Experiments on vibrated granular matter in micro-gravity

Behaviour of granular dissipative gas under vibration gas, cluster formation?
Test on foundations of statistical Mechanics

More Generally: to learn How to handle grains in 0-g to generate industrial processes.... & allow human life in space

Grains in 0g may be dangerous (breath - command)

P. Evesque et al., Evidence for speed-symmetry breaking in steady state of dissipative granular gas in 0g

P. Evesque et al. - Symmetry breaking in granular gas/ P&G-2009/ Golden, Co, USA/ Jul 13-17, 2009
Granular Gas: State of the art on simulations and theoretical predictions

Hypotheses

- No Rotation or rotation (no matter)
- Boundary conditions (no matter)
- Restitution coefficient

Inhomogeneous collapse and clustering

Conclusion: Right parameters

- Effective temperature
- constant Pressure
- Kinetic theory works with thermal balance for dissipation

\[ T_1, T_2, \rho(z), T(z), f(v) \propto \exp[-(v^2/kT)^a] \]

with \( a \) not far from 1
Incompatibility of our experimental results in 0g compared to simulations

- $n_{\text{layer}} > 1$: particle speed < wall speed $\Rightarrow$ « supersonic excitation »
- but No Shock waves
- bad coupling when $V_{\text{ball}} << V_{\text{wall}}$ - boundary effect

So we have shown that accurate study of experimental results lead to a series of puzzling questions that are not yet understood / described by theorists of hydrodynamics and of disordered systems nor by simulations.

However it requires to look in details to what does not work

How to confirm, confort or test our results? with simulations?
What to test?
Simulation from others:
averaging over whole cell

5.1 the pressure.

J. J. Brey et al [arXiv:0906.0747] found some stationary states with constant pressure, like that in classical gases. But they also observe wings in the velocity distribution. Their system is quite near elasticity ($\varepsilon = 0.9 - 0.99$). For a strongly dissipative system, whether the constant pressure can be kept is still undiscussed. And it is difficult to calculate the pressure in the simulations if the local mean free path is too short. $\Sigma v^2$ does not give any information about the pressure if too many collisions there.

5.2 the stability of the cluster.

E. Khain and B. Meerson [Europhys. Lett., 65 (2), pp. 193-199 (2004)] discussed an oscillating phenomenon of the cluster in the center of the container. These results indicate that steady state sometimes is difficult to reach for large number of particles $N$.

Three states of the cluster, i.e. a static cluster(singular), a dynamical but steady cluster, and an oscillating cluster, may be found.

5.3 wings and double-peak structures in velocity distribution.

Morgado and Mucciolo [Physica A 311 (2002) 150-168] discussed the density and velocity distributions in a 2D system with their DSMC results. Wings are found in the longitudinal velocity distributions.

J. F. Boude et al [PRL 101, 254503 (2008)] observed a similar double-peak structure near the shock front of an obstacle, which indicates the area includes two kinds of particles, in a granular flow.

![Graph showing velocity distributions](image)

**FIG. 3.** The vertical (longitudinal) velocity distributions for the same parameters as in Fig. 2. The solid lines are only guides for the eyes.

2d case (W. Morgado & Eduardo R. Mucciolo)

Simulations:

Cell: 20d*20d* 60d

Parameters:

\[ e = 0.7, 0.8 \text{ and } 0.9 \]
\[ N = 100, 500, 1200, 1600, 2000, 3000, 4000, 4500 \]

Wall Motion kinds

+ Thermal wall

Measurements:

\[ n(z) \]
PDF \( V_z \) at different \( z \), PDF of \( V_x \) at different \( z \)

\[ <V_z>, \Sigma V_z=\text{flow}; <V_+>, <V_->, F^+ \text{ et } F^- \]

\[ p=\Sigma v_z^2, p^+=\Sigma v_z^2^+, p^-=\Sigma m v_z^- \]

\[ T=\Sigma m v_z^2/\Sigma m; T^-=\Sigma m v_z^-/\Sigma m; T^+=\Sigma m v_z^2^+/\Sigma m \]
Simulation $N=1200$; PDF $V_z$, $V_x$

$V_z^+ \neq V_z^-$; steady state $\Rightarrow n^+v_z^+ + n^-v_z^- = 0$
PDF $V_z$ in log shoulder is amplified at large $z$

- The shoulder disappears at half the cell (bin $\pm 12$ over $\pm 30$)
- The maximum goes to left of $z=0$

Merely exponential
\[ V_z^+ \neq V_z^- ; \text{steady state} \Rightarrow n^+ V_z^+ + n^- V_z^- = 0 \]
If $V_z^+ \neq V_z^-$ and steady state $\Rightarrow n^+v_z^+ + n^-v_z^- = 0$

\[ p_z^+ \neq p_z^- \quad \text{and} \quad T^+ \neq T^- \]

\[ P_z^\pm (z) = \sum_v \rho(v_z^\pm, z) \, V_z^\pm \, v_z^\pm = \text{sum}_z (V_z^\pm)^2 \]

\[ T^\pm (z) = \sum_v \rho(v_z^\pm, z) \, V_z^\pm \, v_z^\pm / \left[ \sum_v \rho(v_z^\pm, z) \right] \]

\[ = \langle V_z^\pm \rangle \]
Difference between sawtooth and sinus

\[ V_z \]

\[ \text{sawtooth} \]

But still: \( n^+ \neq n^-; P^+ \neq P^-; T^+ \neq T^- \)
Difference of PDF $V_z$ between sawtooth, sinus, thermal wall (in log scale)

PDF $V_z$ is non symmetric
+ depends on $z$
It has 2 peaks only for sawtooth

Figure 4: bi-parabolic vibration $N = 1200$

Figure 5: thermal wall $N = 1200$
Interpretation / Conclusion:

Impact with moving boundary $\Rightarrow V_+ >> V_-$ on $-L$ & $V_+ << V_-$ at $+L$

**Steady state** $\Rightarrow \sum \rho_+ V_+ = \sum \rho_- V_-$ $\Rightarrow \rho_+/\rho_- = V_-/V_+$

This makes the **speed-symmetry breaking** at $\pm L$, that propagates with decrease to 0 at $z=0$

**Characteristics:**

- 2 different temperatures $T_{\pm}$ in any given position ($z$) for $V_{+z}$ and $V_{-z}$.
  
  since $kT_\pm/m = <\rho_\pm V_{\pm}^2>/<\rho_\pm> \propto |V_\pm|^2$

- 2 different pressures $P_{\pm}$ in any given ($z$) since $P_{\pm} = <\rho_{\pm} V_{\pm}^2> \propto |V_{\pm}|$

► This seems to be coherent with what we observed experimentally and not coherent/described in other simulations and theoretical description ($P=$cst)

**Generalisation**

+ This may happen very often for any flow with local jump and/or hydrodynamic discontinuities.

+ i.e. **Leidenfrost effect**
Conclusion:

Complex non linear systems need large amount of data for analysis (non mean field)

And correct analysis

Number of curves studied: 6000 (3e *8N* 5 boundaries* 4t *12 plots(v, v²,..)

Poudres & Grains 17 (2009) (550 pages)

Generalisation

+ This may happen very often for any flow with local jump and/or hydrodynamic discontinuities.

+ i.e. Leidenfrost effect

This work uses concepts from our previous works:

- boundary = thermostat or velostat
- Problem of diffusive or/propagative Boltzmann equation
- True effect of fast boundary

physical idea: \( V_+ \neq V_- \)