To my peers.

Granular Gas & 2^{nd} principle of thermodynamics:

a "hard" gas, a "quarrel" gas, a gas of missed debate

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Abstract :

This paper explains within simple arguments why the physics of granular gas has to be understood in a new way, different to the one proposed by P. Haff, and able to describe the energy delivered to it and dissipated by it. This requires to take into account the difference in the mean particle speed in the + and – ways of the excitation direction. These different means V_+ (= $\Sigma mv_+/\Sigma m$) and V_-(= $\Sigma mv_-/\Sigma m$) exist mainly everywhere in the sample as shown in P&G**17**, 577 (2009) and P&G**18**, 1,(2010). In steady excitation, which imposes ($\Sigma m v_+ + \Sigma m v_-$) =0, this generates the existence of a new force $|P^+|-|P^-|$, where $P^\pm$ (= $m\Sigma v_\pm{}^2$) are the mean kinetic pressures in the two ± directions , due to the fact that the "pressures" $P^\pm$ on the two sides of a fixed plane are different. This new force was not taken into account; it is due to the speed asymmetry, combined with a particle-particle restitution coefficient e smaller than 1. In the scientific literature, everything is treated has one did want to deliver energy to the granular gas: the granular system at a local uniform temperature at the boundary, so that it cannot make any work (second principle of thermodynamics. It gets heat only from the boundary. If this was true, it would help mining excavation and treatment. This article tries to understand how we arrived there there. So the paper proposes a new writing of dissipation in granular fluid (liquid or gas).

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In English

1. Introduction:

Some persons would like that I retire, or that I change subject. My recent scientific results show, and will show, that I think correctly. They are they, and the scientific ethics too; they both force me to act so.

In my opinion, it is unreasonable to hope that my results are false. The worst in this situation is that I think I can explain to everybody why my scientific results allow disregarding the models using hydrodynamics of granular gases. And it is what I intend to do here. A granular gas is a dissipating gas, i.e. which loses some energy by collision. This is a work which can produce breaking... As a work engine, it has to obey the Carnot principle of thermodynamics, which tells that a working engine has to be coupled to two thermostat at least to produce work. In the Literature papers most theoretical models use only a single temperature. How can such an engine produce any work? Using 2d & 3d simulations and analysing 2d experimental data in weightlessness, we found that data should indeed incorporate two temperatures. The previous sentence explains this last one.

The paper is built as follows: I postpone in the appendix the presentation of the mechanical rules of collision between wall and particle or between two particles, since these rules are simple and relatively known. To simplify also the talk, the presentation will consider only identical spherical particles with same mass m.

So the paper begins with a simple presentation of the problem (part 2): what a granular gas is. Then it introduces the case of a classic gas (part 3), which does not dissipate by collision between balls, excited by vibrating *athermal* [1] walls; these ball-wall collisions can either be perfect (i.e. elastic collisions), or to be inelastic. The paper considers then local thermal dissipating systems in part 4; these dissipaters are coupled to the gas locally to mimic the collision losses in granular gas, when one assumes that the collision losses can be treated as thermal losses only. From this the paper describes the thermal solution which they generate. This is the solution proposed at present by the scientific community to describe granular gases, as one will understand.

In the following, part 5 describes differences between this solution and the one that one observes really either in the simulations of really dissipating gas, or in experiments on macroscopic gases with real balls or spheres. It shall exemplify the differences and shall give an plausible explanation which takes into account real distributions of speeds and parameters for energy waste.

In next part (6), the paper interprets the difference using the Boltzmann equations, introducing a energy waste term at second order that explains the non uniform pressure P_+ and P_- and treat it as a long range effect of the vibrating boundaries. Part 7 discusses the results interprets them as linked to the second principle of thermodynamics: A machine cannot generate works if not related to two external thermostat at different temperature.

The paper ends with some ethic consideration (part 8) which described "normal relationship" with other scientists and the support one gets frm the administrative authorities…

2. Simple presentation of a "granular" gas and its physics:

A granular gas is a dissipating gas, which loses some energy by collision between particles. To exist, these dissipating gases must be constantly excited. Their behaviour are known still not enough badly and raise important theoretical problems. Are these systems homogeneous? Do they obey in classic macroscopic laws as classic gases? How to characterize their speed distribution, at a global scale

[1] Athermal: I use this word "athermal" to describe a wall which is not related to a temperature and whose action is purely to transfer a mechanical motion.

and at a local position? Do they depend on the kind of supplied excitation (sinus, saw-tooth… vibrations of walls)?

Indeed, we could suppose first that such a gas takes some energy everywhere within the cell thanks to an effective coupling in any place with the same thermostat. In that case we would find that the distribution of the speeds of particles would be the one that the thermostat imposes, that is it would correspond to the compulsory temperature; hence it would be isotropic and Gaussian, all this been supplied by the thermostat. And the problem is solved. But is this plan true all the time?

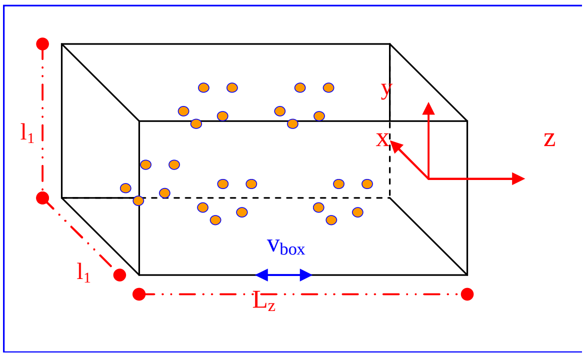

Figure 1: Scheme of an experiment allowing to study a granular gas: a rectangular box which is shaken periodically [amplitude b, speed V_{box} (t)] contains balls of the same size d and of the same mass m.

One could also envisage local couplings with various thermostats with various temperatures.... One can generalize this vision to any other system. For example, if one puts some spherical grains with equal mass m in a box (length L_z, sides l_1) and as one shakes the latter periodically (period T) with a low amplitude b and a frequency f=1/T, what does one observe?

Suppose, to simplify, that $L_z >> b$ and that the gravity g is 0. What can one say? The reader who wishes it can see this phenomenon in a movie, on the web site of the "Palais de la Découverte", (Paris museum, in the section "un chercheur-une manip" from Février 27 -to- Mars 27, 2008; http: // www.palais-decouverte.fr / index.php? Id=1662).

But here one can try to think by oneself, and tries to find the steady regime, i.e. the one which is stable in the time. Lets one proceed by step by decomposing the problem.

First of all, when the excitation is generated by vibrating walls (in the case for example of a vibrated cell), balls (of speed V) arrive probably less fast to the active walls than they leave it, because this shock allows them to get back some energy that they will transfer to the gas, step by step to supply energy to it by collisions. We can thus plan that the balls of the centre will be less excited than the balls which restart from walls, when balls do not pass through the gas in one breath from a wall to the other one without meeting the other balls.

Thus we can envisage *a priori* that in that case, and near the active walls, the speeds of the ball V_- and V_+, before and after the shock with walls are such as

$$|V_-| < |V_+|$$

(Where $|u|$ represents the absolute value of u); and where V_- (and V_+) are the components of speed of the ball in the direction normal to the wall before- (and post-) wall collision; these two components are of opposite signs, because balls are reflected on the wall.

But is it always true? Let us look first at the case of a real perfect gas when the collisions do not dissipate.

3. Perfect gas excited periodically by athermal vibrating boundaries

The problem which one wants to approach on this section is: here, can one use the classic reference to the perfect gas, which one knows well? Maybe, but one has to consider a "quite odd" case, because walls do not have to play the role of thermostat, but must supply to the system the energy generated by the vibrations of walls: indeed, the classic view would consider that the gas is at temperature T, driven by boundary, and the surrounding vibrating wall would generate complementary excitation, which one can characterize by the waves of pressures produced by the vibrations. In this case one would define the speed of sound in the gas, then the propagating and standing waves, then the quality factor of the cell,.....

This is not at all what one wants to do here; in the current case, the problem would look like more a Fermi problem, a purely theoretical one in our case, because it concerns only “thought” experiment, impracticable in the practice, but appropriate for the pedagogy. (Fermi was considered as setting during his lecture in the United States some “simple” educational problems in reality, “the question is simple”, but seeming impossible to solve if one cannot make realistic hypotheses. One of the numerous examples is the following question: which is the approximate number of piano tuners in New York [2]).

Here Fermi would have asked the following question: what is the likely temperature of a particle (or of a collection of particles) contained in a vibrated box, all the ball-ball collisions being elastic. The answer has to take into account wall-ball collisions conditions. My answer is:

3.a. Condition for elastic ball-wall collisions:

When the waste by ball-ball collision is 0, the energy conservation is imposed during collision that means the speed distribution is everywhere the same. Furthermore, the H theorem [6] imposes that this distribution is a Gaussian, i.e. exp $(-V^2/V_o^2)$.

But what value of temperature shall one use? Answer: the typical average energy of a ball, i.e. $E_o=k_BT=v_o^2/(2m)$. It is related to the speed distribution, which is related to the limit conditions. If the collisions with walls conserve the energy, one

[2] The answer to this Fermi problem is approximately the following one: as the population of New York is 10 000 000 inhabitants about, as the proportion of this one to hold(detain) a piano is 1/100, the number of pianos is 100 000 about, what requires 100 000 working hours to grant them once a year, thus in the work from 50 to 100 tuners. To apply in Paris, the yellow pages give 21 to 30 tuners' names as we incorporate the inner suburbs or not.

shall get $V_+ = V_- + 2V_{box}$. But steady state and energy conservation impose that $V_+ = V_-$, which imposes in turn V_{box} to be very small compared to V_+ and V_-. Thus the temperature of the gas has to aim towards the infinity, because V_{box} is finite. Indeed, the only acceptable solution for the gas is the following: the balls have so much chance to gain some energy from the wall that it has to lose it during the shock; as this probability of shock is proportional in the difference $(V - V_{box})$, this is possible only for infinite V_-.

3.b. Condition for inelastic ball-wall collision:

When the collision with walls dissipates the energy, one defines the restitution coefficient e (see Annex) by the relation $(V_+ - V_{box}) = - e\,(V_- -V_{box})$. (This relation tells the part of relative speed lost in every collision); and the gain of speed in the direction of collision is $V_-+ V_+ = (1+e)\,V_{box} + (1-e)\,V_-$. Now considering the steady condition for the average speeds is $V_+ =V_-$, one thus has to have $V_+ = - V_- = (1+e)V_{box}/(1-e)$. The average speed of balls is thus connected to that of the wall via $(1+e)/(1-e)$. It can thus become very large (when e is close to 1, and it gets infinite when e=1).

It would also be necessary to continue this discussion with a series of comments to complete the study. First of all one should discuss the possibility of seeing sound waves propagating (or standing still) with the frequency of oscillation, as one can see them with a system with vibrating thermostat. Does a specific coupling exist here between the sound waves and the previous basic way of functioning, (which is described in the last paragraph)? Is there a possibility of getting no steady cases also? can one found generation of chaos, or more complex regime?...

It is not possible to answer seriously these questions without being able to test them experimentally. To exemplify the difficulty, it is needed to describe shortly the “simple case” of an isolated ball replacing the perfect gas. In that case the ball crosses the box without meeting the other balls; the ball movement is thus propagating from one edge to the other, where it bounces (so it is not diffusive as in a real gas where ball-ball collisions make it to appear). The (diffusion/propagation) nature can be seen also in the Boltzmann equation, which describes the evolution of the distribution function f(V) of the speeds of the ball at some position in the cell, for which the distribution function does propagates linearly step by step until the ball meets the wall, when f(V) is reflected with some gain (or loss) of speed lost (or gain) from the wall [3].

Let us consider the problem of an unique ball more in detail to see if one can allow simple reasonings. The case of a ball in a box does not depend any more on conditions of collision between balls, but depend on those conditions of ball-wall collision. We can thus use inelastic balls in these experiments. What does one observe?

[3] In the case of a gas of balls, this distribution function f “propagates randomly” from collision to collision (between balls). This gives a diffusive character to the Boltzmann equation of f.

3.c. The case of a single inelastic ball:

As one has just said it, this case should not be too different from the previous one a *priori*, especially if one can consider inelastic balls. Indeed as these balls do not meet any other ball, one thinks one can use directly the case of §-3.b. In fact, this is wrong and it is worth to check from experiment. We did it and we were quite surprised with the results; furthermore we shall recognize that the experiment was made at first only to calibrate our balls and our gauges of measurement.

In fact, our experiments showed [7] that the box and the walls can play the role of resonator for some amplitude range, so that ball collisions occur repeatedly at the frequency T of excitation, so that the ball takes a periodic movement with conditions such as $T\ V_+ = T\ V_- = L_z/k$ in walls, where k is a small integer. If one puts 2 balls together in this configuration, both balls travel without colliding. This periodic regime is observed only with large vibration amplitude, i.e. $b/L_z > 1/20$ about. This is the rule obtained from collision rules using finite restitution coefficient e, and imposing periodicity; but it is the one that one observes very often in the practice, because b is large compared to L_z. In this regime, one also observes short chaotic periods (but we have not still had the opportunity to study these irregularities and their statistics).

At lower regime of excitation, simulations show that the ball goes into a more chaotic regime, with a large distribution of speed, changing in every bounce; however its trajectory remains essentially linear, with little gitter perpendicular to the excitation [7]. The mean speed of the ball is quite smaller than L/T.

It is "surprising" that these regimes reduce strongly the number of degrees of freedom of the ball (2 degrees of translation and 2 or 3 of rotation). In fact, the existence of parallel or almost parallel walls blocks these movements in the directions perpendicular to the axis of vibration. We used these effects to measure exactly the ball-wall restitution coefficient e of our balls [8]. It allowed measuring a normal ball-wall restitution coefficient e close to 0.95, and rather independent from the speed of the impact (this finding was in disfavour to the predictions of some published 2d or 3d simulations). It demonstrates that the collisions between balls dissipate probably much more because of the solid friction, because it reduces lateral motion during collision that decreases the number of efficient degrees of relative freedom at the time of the shock.

So, this problem looks sharply harder than it seemed to us first [7].

Furthermore, when one increases the number of balls in the box, but keeps them in small number not to allow too many ball-ball collisions to happen often compared to ball-wall ones, the gas remains in some Knudsen regime with small number of ball-ball impacts. In such a case, one observes more incoherent motions, in different directions, and many more irregularities in space and times. The speed distribution broadens also. We did not study the transition between case where balls move periodically from one edge to the other one “together” and the more random evolution.

It would be necessary also to study less specific configurations, where the direction of vibration is not perpendicular to one of the walls, or when particles are not spherical any more, or when the surfaces of the container are not flat, or when one add fixed obstacles in the cell..... We know that N. Vandewalle and his colleagues of Liège recently reanalyzed this kind of cases in a particle and found a part of these results as well as the other similar phenomena.

When the number of particles is increased slightly more, the system begins to look like a gas, the transverse motion of balls (in directions perpendicular to vibration) becomes sharply bigger and more erratic also; the observed speed distribution is of the exponential type, i.e. varying as $\exp(-V/V_o)$. One cannot assert thus that this distribution is equivalent that one of a perfect gas, i.e. $\exp(-V^2/V_o^2)$. Is this distribution connected to the shape of the excitation (giving "energy" through impulse), or in the geometry of the container? It may be also connected to the existence of a collision waste, which breaks the conservation rule of preservation of the total energy during the collisions, but not that on of the total impulse. The fact that one introduce a coefficient $e<1$ translate this breaking on Σmv^2 and non breaking of Σmv. All this remain to be clarified.

Let us return now to the case of a perfect gas of balls, with elastic balls-ball collisions; and let us look for the other possible solutions, mimicking a waste of local energy.

4. "Perfect" gas excited periodically by athermal [1] vibrating walls and dissipating calories

We can restart from §-3.a and §-3.b model to describe the evolution of a slightly different system, capable of dissipating calories. Examples are known:

4.a Case including a plane in the cell centre with fixed temperature T_m

We saw in paragraph §-3.a and §-3.b that the limit conditions imposed by the walls is to select a single temperature T_o; T_o was either equal to the infinity (in §-3.a) or was finite (in §-3.b).

When one adds some internal plane at temperature T_m , one will observe some temperature change in the cell; when the difference of temperature T_o-T_m is small enough one can linearize the equations. One finds: The pressure p remains constant everywhere in the cell to ensure the mechanical balance of the gas; the temperature T (and the density ρ of particles) varies one against the other one, (if T vary linearly between T_o and T_m, as it shall do, ρ obeys the law of perfect gas $T \rho / p$=constancy) ; the heat is transported from the warm source to the cold well, thus from T_o to T_m if $T_o > T_m$, or the opposite from T_m to T_o if $T_o < T_m$.

Convection: If one adds the effect of the gravity and if the vibration direction vibration is vertical, one shall observe in more some natural convection in half the bottom or top cell as $T_o > T_m$ (or $T_o < T_m$), following the classic rules of convection when some threshold is over passed[9].

In this particular case, the waste (i.e. transfer towards the outside) of calorific energy is local, concentrated on the central plan if $T_o > T_m$. The gaseous system thus serves only to transfer the calorific energy from the warm source to the cold one.

4.b Cas d'un gaz parfait simulant une dissipation thermique locale

One can modify also the previous model to introduce a local waste connected to existence of collisions between particles, to ensure some thermal loss. We can then consider that i) the temperature of the system exists everywhere, ii) that it verifies the equation of state RT ρ / p = constancy, iii) that p = constant (without gravity) otherwise it would impose a mechanical imbalance (iv) then that the heat energy is dissipated locally by the collisions, according to certain rules of collision between particles.

We can find a realistic solution which takes into account the condition at the edges ($T=T_o$). It is represented on Fig. 2. The temperature T decreases until a minimum (which is in the centre of the cell), the particle density ρ grows until a maximum (also at the centre of the cell). The pressure, p, remains a constant in the cell.

If one is interested in the speed distribution, this one is locally Gaussian; it is imposed by the local thermodynamics laws; but the temperature and the density of the system vary according to z as on Fig. 3. The global distribution is a sum of Gaussian; so it is not Gaussian as we show it in the following remark:

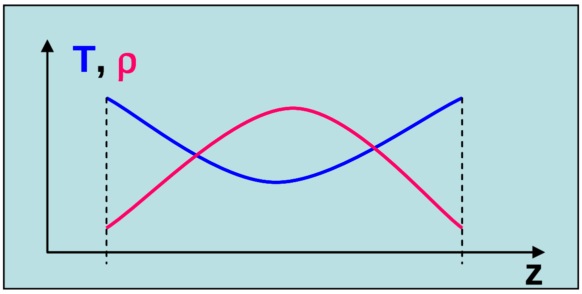

Figure 2: Temperature and the particle distributions in the cell containing a gas in thermodynamics equilibrium and evolving according to the model of § - 4.b, that is in which one extracts locally a heat proportional to the local energy of the local collisions

Remark: the pressure has to remain constant in the cell (in the absence of gravity); the law of perfect gas thus imposes ρT=Constancy. So, from classic kinetic theory of gases, the distribution f (V, T) is of the kind:

$$f(V,T)= A\, [n_T /(T^{d/2})] \exp(-V^2/(BT))$$

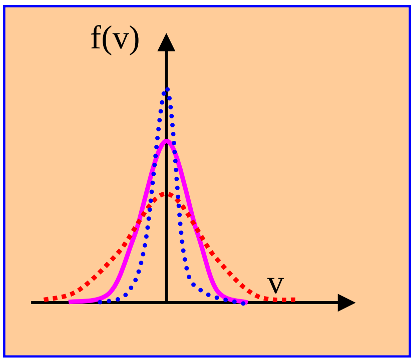

Figure 3: Local distribution of the speeds of particles in the model of § - 4.b. The three curves represent various places, at different temperatures of gas (blue at the cell centre, purple at a distance of a quarter cell from the wall, red in the edge). The distribution which dominates in high speed is the broadest corresponding to the highest temperature.

Where n_T is the local density at temperature T, and where d is the space dimension (i.e. d=1, 2, or 3), with $n_T \sim 1/T$.

The global distribution $f_g(v)$ is the one which adds the contributions from the various points of the cell, thus at various temperatures. We can thus write $f_g(v) = \int dt\, f(V,T)$. By making the change of variable $u= 1/T$, $du = -dt/T^2$, one has to calculate:

$$\int f(V,T)\, dT = -2\, A \int_{u_{min}}^{u_{max}} \{u^{(d-2)/2}\, du\}\ \exp(- uV^2/B)$$

In the case when the dimension d is 2, which is the simplest case, the distribution becomes the difference between two Gaussians; and the tail of distribution will thus be Gaussian, dominated by the u_{min} term, i.e. T_{max}.

We shall stop in the discussion of this case there, to pass in the discussion of the case of a really dissipative gas, i.e. for which the laws of collision between balls bring in some waste through a restitution coefficient e different from 1.

5. Real gas excited periodically by athermal [1] vibrating walls and dissipating by collision

Let us try to approach this problem from the various studied cases.

The previous model (§-4.c) is the one that the literature retains [1, 10, 11] for a granular gas. It does not really present any other model. This model seems coherent and efficient. Is it exact?

From what one gets from the literature, a puzzling question is really to understand the part plaid by the boundaries: what are the limit conditions of the system? These are never told clearly, except in very few cases [11].

Yet one can see from §-3 end that the rule for the collision in walls was supposed to allow different ball speeds before and after wall collision so as the speed V_+ and V_- were different, according to the chosen limit condition. This one is defined by the restitution coefficient e (which is lower than 1) and by the V_{box} value at the collision time; when e=1 the situation becomes again that of § 4, for which $V_+ = V_-$. These situations are not studied, and their consequences not described. What is it really?

5.a. Is that V_+ equals $-V_-$ everywhere in the cell?

Only very few articles really speak about the limit conditions. Many of them say that there is no problem, but give no measure. The main paper [11] which speaks about this problem in detail, considers it only as a problem of pure limit condition, without any possible global consequence, without possibility of generalization to the whole gas behaviour. So it remains a side effect, which becomes null very short in the gas "bulk"; but no proof is given, either from experimental data, or from numerical simulations. Let us show that it cannot be true:

To demonstrate the fact, one can not use only global measure of distribution; one has to measure the local speed distributions completely, at different locations in the cell; doing so, one gets Figs.5, for which one finds then inhomogeneous distributions, not looking like Gaussians (cf. Fig 5). Can one understand this effect?

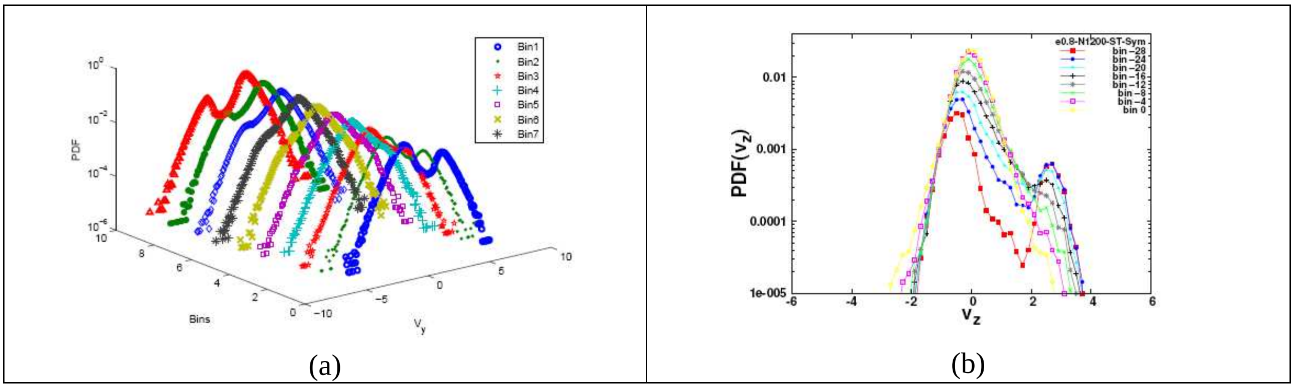

Figure 5: Local speed distributions V_z in the cell as a function of the z position (Oz is // to vibration). (a) : 2d case ; (b): 3d case, in the left-hand half cell. [2,4,13.b]

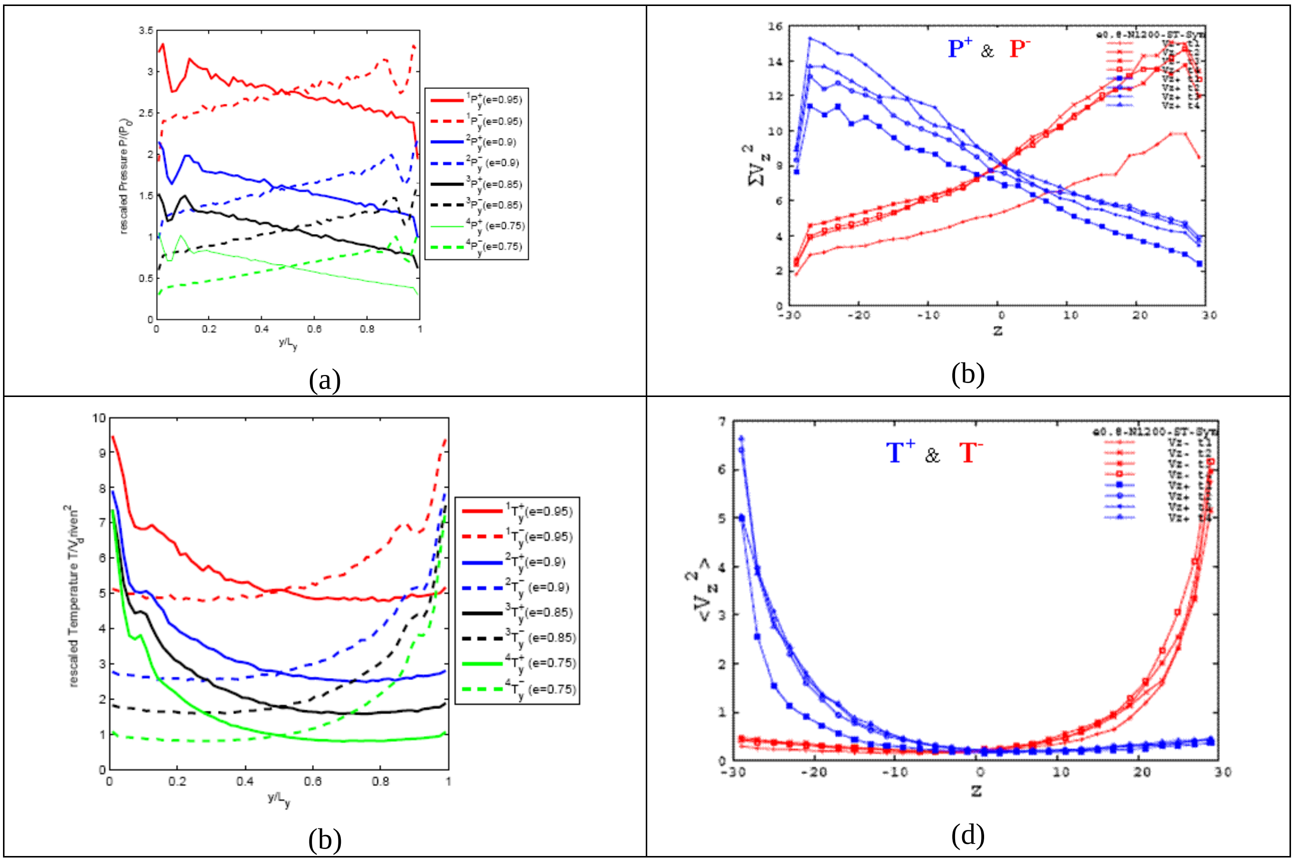

Figure 6: (a,b) Pressure P_+ et P_- distribution in the cell as functions of the z position; they vary symmetrically with the distance to the excitation. Saw-teeth excitation. (a) : 2d case. (b): 3d cas. (c,d) temperature T_+ et T_- distribution as functions of the z position; they vary symmetrically with the distance to the excitation. (c) : 2d case. (d): 3d case. [2,4,13.b]

Indeed, if the average speed V_+ is equal to the average speed V_- and if one imposes a steady gas, which states $N_+V_+ + N_-V_- = 0$, the mechanical energy brought from the left to the right is null and mutually. Yet, let us consider the walls at first, if one needs to excite the system from the walls, it means some energy transfer step by step some mechanical energy. Thus $V_+ \neq -V_-$ at walls. But if this is true at walls, how cannot it be true also somewhere else (further in the bulk)? So $V_+ \neq -V_-$ everywhere (in the bulk); the difference $(V_+ + V_-)$ varies from place to place to account of local dissipation of course; and the $(V_+ + V_-)$ difference shall be null in the cell centre, due to symmetry, under the precise condition of the experiment.

It is just what one sees from our digital 2d & 3d simulations (Figs.5 & 6) [3,4]; and their report is in accordance with the theory developed by Villain [5]. Our Airbus results seem to deviate from the above rule [5], but it is probably connected to the large number of particles and collisions, which oblige probably to take account of 3- or 4- body collisions also.

Our simulations show also the appearance of the second peak at higher speed near the vibrating walls. This peak is quite smaller than the other one, but it contributes strongly to the excitation of the system, because these are the high-speed event generated by wall collisions. This peak merges into the other one as the distance to the centre cell diminishes, (or as one progresses inside the gas). Its effect remains however visible everywhere, because the difference in the local dynamic pressures P_+ and P_- stays not null everywhere, except at the centre of the gas. These two different dynamical P_+ and P_- pressures coincides with two different local temperatures T_+ and T_-.

As one shall see in the conclusion, the existence of these two different temperatures at the same location for this gas is likely the very consequence of the second principle of thermodynamics. All in all, the model captured in Fig.2, where the gas is connected only to a single temperature, is not possible because it does not allow the gas to furnish some work. Yet he supplies it, either only by friction and heat, or also by grinding.

5.b : Is The global distribution of speeds is Gaussian, i.e. $\exp(-v^2/V_o^2)$

Contrary to the modelling proposed in the literature (Fig.3), all the measurements published in articles show that the speed distribution of granular gas is not exponential [1,11], but often one finds exp $[-(V^2/v_o^2)^{3/4}]$ law, or an exp-(v / Vo) law from time to time; anyway, it is always in disagreement with the model. But this is never taken into account to invalidate the model of the literature.

In the cases which we studied [2-4, 7, 8, 13], we observed a distribution close to exp-(v/Vo). We proposed an explanation for this law, connected in our opinion to the collision rules, which allow the preservation of the total impulse during the collisions, but not that of the total kinetic energy.

However this non Gaussian distribution is a new proof for more incompatibility with the theoretical model developed in §-4.

6. How can one interpret these results:

Setting ε =(1-e)/2, and using the formalism of the Boltzmann equation [6, 10, 11, 15, or 16], one obtains the Boltzmann equation for the density $\rho(v, x,t)$ under a gravity g, of a particle of mass m in a point x, at time t, and having a speed v. This equation spells:

$$\partial\rho/\partial t + v\,\partial\rho/\partial x - g\,\partial\rho/\partial v =$$
$$- \int du\, du'\, dv'\, |u-v|\, \rho(v,x,t)\, \rho(u,x,t)\, \delta\{u'-v+\varepsilon(v-u)\}\, \delta\{v'-u+\varepsilon(u-v)\}$$
$$+ \int du\, du'\, dv'\, |v'-u'|\, \rho(u',x,t)\, \rho(v',x,t)\, \delta\{v-v'+\varepsilon(v'-u')\}\, \delta\{u-u'+\varepsilon(u'-v')\}$$

Here, the right term represents only the two-body collisions. One noted v and u the two speeds before the shock and u' and v' those after the shock, so that u'=εv+ (1-ε)u & v'= εu+ (1-ε)v. In [10], the terms of upper order are introduced (in particular those which control diffusion). One shall not consider them now and shall focus only on the term which misses in the §-4 model. It consists of both terms of the right part of the equality, which can spell also in the first order in ε : $\varepsilon\,\partial\{\int du\,(v-u)\,|v-u|\,\rho(v,x,t)\,\rho(u,x,t)\}/\partial v$,, so that this equation becomes:

$$\partial\rho/\partial t + v\,\partial\rho/\partial x - g\,\partial\rho/\partial v = \varepsilon\,\partial\{\int du\,(v-u)\,|v-u|\,\rho(v,x,t)\,\rho(u,x,t)\}/\partial v \quad (1)$$

Where term [$\varepsilon\,\partial\{\int du\,(v-u)\,|v-u|\,\rho(v,x,t)\,\rho(u,x,t)\}/\partial v$] give the $(|P_+|-|P_-|)/m$ term after summation of the $\rho_1\rho_2(v-u)\,|v-u|$ on u.

In [10], the right-hand side of Eq. (1) is noted "a" (to see Eq. (14) of [10]). It is assumed to be 0 in [10] by using a principle of symmetry, but this is wrong and not verified here. This term also exists in [11], without approximation.

Same Eq. (1) also appears in [15]. In this article, the title is explicit, and it proves the agreement of the authors with the present positions. The article does not describe explicitly the error of [10], but its title speaks about himself(itself) and the discussion relative to the equation of Boltzmann is coherent with the rest of the article … I am sorry not to have understood the "allusions" in the first reading of [15], what made me probably classifying this article as " an unusable theoretical point of view ", before I revised this position these last months, when I left in search of a term [$\varepsilon\,\partial\{\int du\,(v-u)\,|v-u|\,\rho(v,x,t)\,\rho(u,x,t)\}/\partial v$] having the good effect.

It is likely that the effect of the term {[$\varepsilon\,\partial\{\int du\,(v-u)\,|v-u|\,\rho(v,x,t)\,\rho(u,x,t)\}/\partial v$] } exists whatever is the space dimensionality d (d=1, 2 or 3) of the gas. It is in any case that we see experimentally there 2d [13], and numerically there 2d 13.b and 3d [2-5], and that Fig. 10 of the [11] let suppose also. Still it will be necessary to quantify the effects according to d and to compare their values …

Higher order: One can develop the Boltzmann equation in higher orders (see [6, 10]) as usual: the first term of upper order [6, 10] corresponds to the diffusivity, a well known term and never null; it could be however perturbed by the waste.

But the most essential effects should correspond to terms with odd power, such as $(v-u)^{2n+1}$ $|v-u|$, which are non null when the speed distribution is non symmetric? $f(v, x) \neq f(-v, x)$, but which are not null in case of asymmetric distribution. …

Clustering: If one introduces a fictitious plane P or a large fictitious ball into the system, one can calculate or evaluate the mean action caused to them. One notices that the term of Eq. (1) acts as a centripetal force on this plane or this particle [2]. This thus explains the concentration of balls in the centre of the cell by a centripetal force, which explains the phenomenon of " clusterisation ". This action is the result of wall effects, that have here an infinite-length range, that is up to the centre of the box. Indeed, this force decreases towards the centre but nullifies only in the centre.

This has probably numerous consequences that is discussed in [2].

The excitation of the system by the walls starts at the wall, but is passed through the system step by step while decreasing, from collisions to collisions. This can be measured everywhere by measuring the pressure difference P_+-P_-everywhere, by measuring also the local average speeds V_+ and V_-, whose sum V_++V_- decreases, and equals 0 only in the centre.

7. Discussion and scientific conclusion

If one refers to the scientific literature, this machine can thus shake and break / crush grains by being in relation only with a single source of heat. This goes against the second principle of Carnot! Having said that, if it is true the cement or concrete manufacturers and the mines should use it on a large scale!

This phenomenon seems to be validated by some contemporary academicians, even if this kind of machines, producing some work from a single source of heat, is the only topics which has been disapproved unanimously by the French science academy since 1880, because the academicians refuses even to examine such article based on such a concept; they deny the discussion of these systems a priori.

Having said that, never say never. We can always evolve

Did not Sadi Carnot publish his book at the author's own expense; This is probably quite a good reason for invalidating this work by our “new” thinkers, such as the committees of the French CNRS and of the French AERES, who decided not to think but just to make the machine counting, to be more objective!

Let us become again more down-to-earth.

Let us return to recent scientific articles the results of which seem correct and not biased [17,18]; they published simulation results made using our experimental conditions in MiniTexus. Figs. 3-6 and 8 of the article [18] give the probability of speed distributions (pdf) obtained there for the complete distributions on the total volume of the system when the cell is in median position (i.e. when $v_{box} = b\omega$ and $-b\omega$) [4]. The choice is voluntary; because one would have not the same distributions as those in Figs 3-6, 8 of [18] if one did chose to study that only the half top cell (or the half bottom cell) and/or if one did not have to average on the two positions in opposition of phase. For example the tail of distribution when u >> 0 (or when u << 0) would be visible only for the half bottom cell (or half top one). It is a simple and effective artefact to mask the real heterogeneousness, and the real difficulty which has to be understood. It is a simple way not to accept declaring the incapacity of the hydrodynamics approach. An analysis of data by drawing the pdf of the speeds of particles by using different horizontal slices would have allowed to raise all the ambiguity and to demonstrate the heterogeneousness of distribution of the granular gas.

In this article we focused on an example of dysfunction of the scientific community. It is abnormal that a healthy debate was not able to build up between the scientific protagonists, during these last ten years. It is probably connected to the lobbying, to the will of power and recognition of these lobbies and to the editorial strength of the scientific publishers. But let us make no mistake, it is probably also the inevitable ascent of the incomprehension between human beings, that reappears here after the a few centuries of lights transcended by the science. One observes this revival of the incomprehension incommunicability in the society at every level: One observes it from time to time and more and more that administration or politician tries to make respect rules the sense and the utility of which we do not understand any more. When these rules make too oppressive, one observes a partial rebellion (in cities, in suburbs, in class room, towards the administrative rules).

The science tried to be held remote from this kind of conflict, by lauding the allegiance in its scientific ethics and in the ascendancy of the confrontation in the reality. It seems that the wills of misplaced vanities and the allegiance of the academics and the researchers in the "any noise", in the advertising, in the fame and in the financing does not allow any more the restraint necessary for the community, which is transformed.

However, this is not possible : Our scientific community is not allowed go to a real racism, (which is to invent a different species where there is not, to be brilliant and to deify some of their contemporaries). The fact of inventing more and more separated ramifications, make interconnections between different approaches quite difficult to dominate, so that these ramifications generate some refusal of discussing

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[4] (go and see [18] p:1, par:2, l:4-5) The dissipative character of the collisions implies a constant external energy supply and microgravity to subsist .
([18] p:7, par:2, l:7-8) the appearance of such a dynamical regime for b = 0:3 mm requires the presence of additional phenomena such as inelastic collapse. The excitation is parallel to $V_{z,box}$ and pdf distribution is measured at maximum cell speed in + and - .

the legitimacy from outside the disciplines or in between disciplines; it is maybe there the big pitfall (stumbling block)...

Where is the multi-disciplinarity in all this?

Generalisation: To take into account the Carnot principle in a dissipative fluid, one has to consider the granular fluid or the granular gas as a system that dissipates energy. To do so one has to consider the system as made by two phases at to different local temperatures that produce the work (i.e. dissipation). These two phases exchange heat, the first one (δQ_1) from temperature T_1 and the second one (δQ_2) from temperature T_2 so that the work δW is equal to the dissipated energy that means $\delta Q_1+\delta Q_2=\delta W$; the efficiency of work is $\delta W= (\delta Q_1+\delta Q_2)/\delta Q_1$, where T_1 is the hotter temperature, or is $\delta W= 1-|\delta Q_2|/|\delta Q_1|$, since dQ_2 and dQ_1 has not the same sign.

8. Acknoledgments & Motivations:

Some persons would like that I retire, or that I change subject. My recent scientific results show, and will show, that I think correctly. They are they, and the scientific ethics, which force me to act so.

In my opinion, it is unreasonable to hope that my results are false. It is unreasonable also to think that my laboratory, his bosses, its regulatory authorities have no means to estimate seriously my comments, and finally to think that I am subject to an involuntary "hallucination"; so we can conclude later that the laboratory, its bosses and its regulatory authorities underwent a hallucination that they will say "involuntary".

But this "involuntary" word deserves to be put in quotation marks, because for me if there is hallucination, this one is voluntary and masks a major dysfunction of the system, connected to an incompatibility of the administrative rules which everybody refuses to see.

For me, this refusal of identification is an inhuman concept, deifying totally the administration. It is the refusal by the administrative technocracy of the scientific truth, to simplify its life and not to be able to be punished for lack of realism. This refusal is also stupid as to refuse $f = m\,\gamma$. Thus this method of decision, if it is perpetuated, will have catastrophic consequences, in our world where the reasonable is more and more disputed because it is more and more complex. The worst is that the "new" technocrats will be incapable to argue correctly even when the case will remain simple, because they "*will also analyze very complex cases*" and will thus be formed in to "*understand*" the unpredictable (for them) acquiescent silly, because they will think that this "*unpredictable*" is all the same predictable to "big IQ human" (i.e. for some other, the " happy few" scientists, who will assure the administration and the world to master it).

The problem is that in the complex situations depend on small modifications which can change things (butterfly effect of meteorology), and that the scientists can themselves have difficulty in analyzing correctly the system in action and in interactions. From there, this new administrative rule allows and will allow an incompetent (administrative) man to decide, by disciplinary submission, to insure his thirst of power, without questioning for his incapacity of handling the concepts. The director of a department having learnt to use and to justify this rule, he will become incapable to recognize the simplicity of certain cases and will apply his protocol everywhere without concern, and he will become incapable to avoid even unrefined errors.

The scientific example which I present here is a very simple case of "unrefined" error, which we can analyze easily. Having said that, this error continues for twenty years now in the scientific community, and it is not sure that it will not continue longer, the authorities accepting the absence of debate on the subject. It is thus necessary of my duty to analyze it correctly and to try to convince the maximum of persons, to make them to understand the new results and the contradictions with the previous interpretations, published in many scientific newspapers. The PhD thesis of 2011 of H. Wang [1] (Experiments and simulations one to granular gases, One. Massachussetts, Ahmerst, 1/2/2011) can serve as reference to the past state of the art, whereas my articles of 2009-à-2012 in *Poudres & Grains* [2-4], will allow to encircle better the reality (in my opinion) (P&G = http://www.poudres-et-grains.ecp.fr). If you also want an opinion of an authority, to simplify yourselves the life, please consult the paper by J. Villain in *Poudres & Grains* [5] (J. Villain; Shaken sand, stress and test particles, P&G 20, 29-36 (2012)).

Where from we shall conclude (since “*Errare humanum is, sed perseverare diabolicum*”) that we reached the demonic regime since a long time; (here, the devil is of the poly-deism type, because we pretend to believe in the Boltzmann law (or in any other partial truth) even when it is not verified).

The worst in this situation is that I think I can explain to everybody why my scientific results allow disregarding the models using hydrodynamics of granular gases. And it is what I intend to do now. A granular gas is a dissipating gas, i.e. which loses some energy by collision it can be used to erode grains and crushing; so it is an engine a machine. It has to obey the Carnot principles, which requires to get work a machine has to be connected to 2 source of heat. What is fun in the present exemple is that the two sources are located at the same place. The vibrating walls are ubiquous, being at the two temperature at the same time. However these two set of temperature is just way of thinking: the real distribution is more complex….

Annex: collision rule

1. ball-wall collision rule

If one considers a plan $\mathcal{P}$ perpendicular to the excitation (vibration) next to the wall, the steady state condition imposes an equal flow of particles in a sense(direction) and in the other one; so $\Sigma_{V_+} n_+ V_+ + \Sigma_{V_-} n_- V_- = 0$. One can also define the dynamic pressure of the gas in both side of the plane $\mathcal{P}$ by ($P_\pm = m\Sigma_{+or-} V^2$), where P represent the flow of the impulse mV, and sign Σ indicates the sum on all the particles which crosses the plane $\mathcal{P}$ at the moment t by unit of time. One also define $N_+ = \Sigma_{V_+} n_+$ et $N_- = \Sigma_{V_-} n_-$

So $P_+ = \Sigma_{V_+} m\, n_+ V_+^2$ & $P_- = \Sigma_{V_-} <m\, n_-V_-^2>$ are different, since $<mN_+ V_+> + <mN_- V_-> = 0$ and because $V_+ > V_-$.

In fact when one writes N_+V_+ , it is a sum which is computed, the sum mΣ V of all the speeds of the particles which strike the wall by unit of time, or $N_+ <V_+>$ for particles + (which restart) or $(N_- < V_- >)$ for particles - (which arrive). These ssum represents the number of particles which are going to strike the wall $(N_- < V_- >)$ or which struck her $N_+ <V_+>$. These two numbers must be identical, but of opposite signs (in steady condition).

The collision rules use a restitution coefficient e_{box} and the relative movement between the two bodies which meet (ball and wall), when writing the rules in the barycentric frame, which is here the wall because it is supposed to have an infinite mass; or here, because the axis of z is the one of the vibration of the box, one has in z direction:

$$(V_{+,z} - V_{box}) = - e_{box} (V_{-,z} - V_{box})$$

Or z direction

$$V_{+,z} = - e_{box} V_{-,z} + (1+ e_{box}) V_{box}$$

here z is the vibration direction; it corresponds to the cell length L_z. Besides, V_{box} is the box speed which is time-periodic (as a sinusoid for example, or as a saw tooth, oras. The expression here works at any time, it has to be averaged on the various possible configurations of the balls and of the wall; it has to be balanced by the immediate probability of striking, which also depends on the relative speed.

In the x y directions, one can introduce a term of waste (or not) as the contact can be rubbing (or not). These rules also depend on the coupling between movements of translation and of rotation at the time of the shock.

We shall use the simplest rule here, which is to choose complete transmission of speed in directions perpendicular to shock.

$$V_{+x} = V_{-x} \quad \text{et } V_{+y} = V_{-y}. \qquad \text{x \& y directions}$$

2. ball-ball collision rule:

Inside the cell, ball-ball collisions dissipate the energy given by walls; so the excitation propagates through balls and decreases by collisions; this allows exciting next particles, more and more inside the cell. Here, one shall describe the ball-ball collisions as those collisions with walls; hence, one uses the 2-ball barycentric frame (instead of the wall frame) and one decomposes the relative speeds into normal and tangential components …

One also writes the speed continuity of the barycentric frame. (In fact if one considers the equation of Boltzmann of the barycentric frame, one should impose an acceleration to it, which action depends on both speeds of particles and on the collision time, but this has no consequence if one can consider the collisions between balls very fast).

If one considers a plane P anywhere in the cell, but perpendicular to the excitation vibration, and fix in the laboratory frame, the steady-state condition imposes an equal flow in the positive direction and in the negative one; so $N_+ < V_+ > + N_- < V_- > =0$. Since the dynamic pressures are $P_- = < m\, n_+ V_+^2 >$ and $P_- = < m\, n_- V_-^2 >$, they are different if the averages of V_+ and of V_- are different. As Figs. 5 and 6 show it, this is true everywhere, except in the centre only where $< V- > = < V + >$ by symmetry reason.

One also notices that the sum rule discussed by Villain [5],i.e. $P_+ + P_-$=constant in the whole cell, is approximately verified. This does not still seem true in every experimental case, as in Airbus experiment, maybe because of a too large number of collisions or of the existence of 3- or N- body collisions.

References:

[1] Wang Hongqiang, "Experiments and Simulations on Granular Gases" (2011). *Open Access Dissertations.* Paper 348. http://scholarworks.umass.edu/open_access_dissertations/348

[2] P. Evesque, «Hydrodynamics with dissipation. Towards mixing or demixing ? », *poudres and grains* **20**, 1 (2012)

[3] P.Evesque, « Microgravité et Gaz Granulaire Dissipatif dans un système vibré : un gaz à vitesse dissymétrique, mais à moyenne nulle », *Poudres & Grains* **17**, 577-595 (2009)

[3.bis] P.Evesque, « Microgravity and Dissipative Granular Gas in a vibrated container: a gas with an asymmetric speed distribution in the vibration direction, but with a null mean speed everywhere », *Poudres & Grains* **18**, 1-19 (2010),

[4] R. Liu, M. Hou, P. Evesque, Simulation of 3d granular dissipative gas under different kinds of excitations & with different number of balls N, *Poudres & Grains* **17**, 1-561 (2009)

[5] J.Villain, Shaken sand, stress and test particles, *Poudres & Grains* **20**, 29-36 (2012

[6] N. Pottier, Cours de Physique statistique hors d'équilibre (1997-98) DEA Physique des solides

[7.a] P. Evesque: The Thermodynamics of a Single Bead in a Vibrating Container, *Poudres & Grains* **12,** 17-42 (2001);

[7.b] P. Evesque, Snapshots on Some Granular States of Matter: Billiard, Gas, Clustering, Liquid, Plastic, Solid,In GRANULAR MATERIALS: fundamentals and applications. pp. 29-62 (Ed by S. Antony, ed. Royal Society of Chemistry, 2004) .

[7.c] P. Evesque, F. Palencia, C. Lecoutre-Chabot, D. Beysens and Y. Garrabos, Granular gas in weightlessness: the limit case of very low densities of non interacting spheres, Microgravity sci. technol. XVI-1, 280-284 (2005);

[7.d] Y. Garrabos, P. Evesque, F. Palencia, C. Lecoutre & D. Beysens, Coherent behavior of balls in a vibrated box , ArXive: cond-mat/0611613

[8] M. Leconte, Y. Garrabos, F. Palencia, C. Lecoutre, P. Evesque, D. Beysens, Inelastic ball-plane impact: An accurate way to measure the normal restitution coefficient, Appl. Phys. Lett. 89, 243518 (2006)

[9] L.Landau, E Fifchitz, *Physique Téorique*, tome 6 (Mécanique des fluides) (Mir, Moscou,1989),

[10] S.MacNamara & W.R.Young, « kinetic of a one-dimensional granular medium in the quasi-elastic limit»**,** *Phys. Fluids* **A 5** , 34 (1993)

[11] O. Herbst, P. Müller, M. Otto, A. Zippelius, « Local equation of state and velocities distributions of a driven granular gas », *Phys. Rev.* **E 70**, 051313, (2004)

[12] YP. Chen, P.Evesque, M.Hou, Chin. Phys. Lett.. **29**, (N°7) 074501, (2012),

[13] a)YP. Chen, P. Evesque, M. Hou, C. Lecoutre, F.Palencia and Y. Garrabos,J. of Physics: Conference Series 327 (2011) 012033 doi:10.1088/1742-6596/327/1/012033 In ISPS 2011, Bonn, Germany, (11-15/7/2011) (accepté , 10/2011);
b) these YP Chen (2013) paraître

[15] Y.Du, H.Li, L.P.Kadanoff, « Breakdown of hydrodynamics in one-dimensional system of inelastic particles »**,** *Phys. Rev. Lett.* **74**, 1268 (1995)

[16] B.Bernu, F.Delyon, R.Mazighi, "steady state of a column of shaken inelastic beads", *Phys. Rev.* **E 56**, 4551, (1994)

[17] E.Opsomer, F.Ludewig, N. Vandewalle, « Phase transitions in vibrated granular systems in microgravity » , *Phys. Rev.* **E 84**, 051306 (2011)

[18] E. Opsomer, F. Ludewig and N. Vandewalle, "Dynamical Regimes of a Granular Gas in Microgravity: a Molecular Dynamics Study", Journal of Physics: Conference Series 327 (2011) 012035, doi: 10.1088/ 1742-6596/327/1/012035