Fate of Boltzmann's Breathers: Stokes Hypothesis and Anomalous Thermalization

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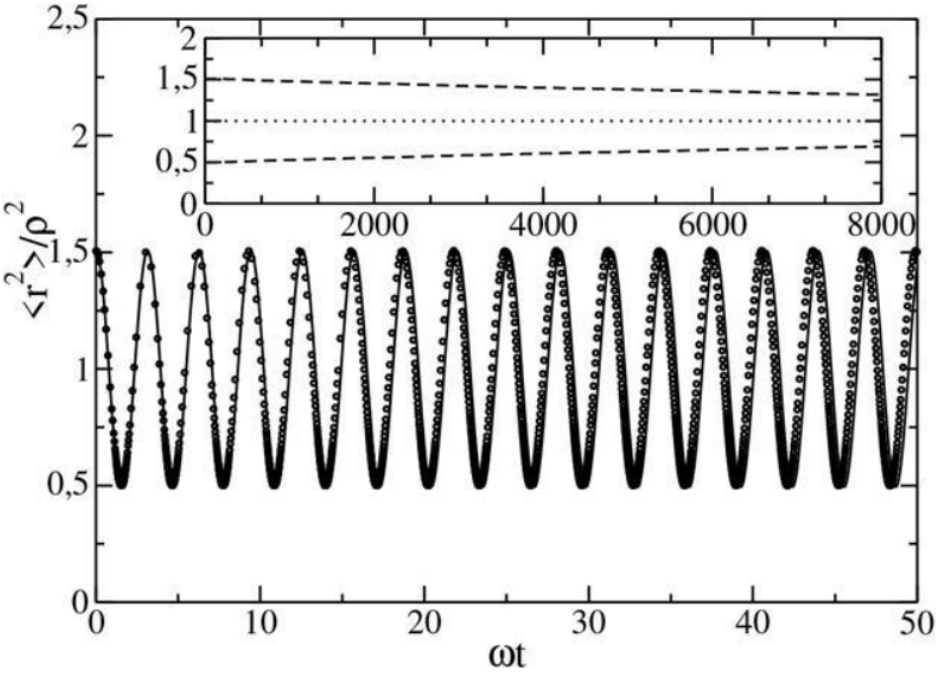
Boltzmann showed that in spite of momentum and energy redistribution through collisions, a rarefied gas confined in a isotropic harmonic trapping potential does not reach equilibrium; it evolves instead into a breathing mode where density, velocity and temperature oscillate. This counter-intuitive prediction is upheld by cold atoms experiments [1]. Yet, are the breathers eternal solutions of the dynamics even in an idealized and isolated system? We show by hydrodynamic arguments and also by kinetic theory that an original dissipative mechanism is at work, where the minute and often neglected bulk viscosity eventually thermalizes the system, that thus reaches equilibrium [2, 3].

To test our theoretical prediction, we have performed Molecular Dynamics simulations of a system of N hard disks confined by an isotropic harmonic potential of characteristic frequency, ω, measuring the mean value of the square of the distance of the particles to the origen, $\langle r^2 \rangle$, that describes the amplitude of the cloud particles. In the Figure, $\langle r^2 \rangle$ dimensionalized by its corresponding equilibrium value, ρ^2, is plotted as a function of the dimensioless time, ωt. The circles are the simulation results and the accuracy of the Boltzmann theoretical prediction (solid line) is seen. In the inset, the envelope of the oscillations (dashed line) is plotted on a much longer time scale showing that, in fact, the amplitude of the oscillations decays. The relaxation time of the approach to equilibrium of $\langle r^2 \rangle$ can be related to the bulk viscosity by hydrodynamics or kinetic theory arguments finding a good agreement between the theoretical and simulation results [2, 3]. In the low density limit, the bulk viscosity vanishes recovering the Boltzmann prediction, as expected.



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