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Experiments on long-time effective temperatures in granular fluids[1]

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Studies of effective temperatures to describe the state of fluidization of a granular medium have emphasized kinetic granular temperatures determined from the instantaneous motions of grains. In this talk, I will focus on experiments that study effective temperatures derived from long-time grain dynamics. One formulation to extract long-time effective temperatures is via the fluctuation-dissipation relation, which is valid for linear response to small perturbations to near-equilibrium states; I will report briefly on experiments that study the applicability of this relation to vibrated and flowing granular media. I will then discuss in greater detail an effective temperature that emerges from consideration of the statistics of the power input to maintain the granular fluid in its nonequilibrium steady state. The analysis is done in the context of recent Fluctuation theorems[2] that are proven for dynamical steady-states arbitrarily far from equilibrium. We have performed experiments[3] and simulations which show that power fluxes in our system satisfy the Fluctuation relation and that the pertinent effective temperature is an intensive variable. In the dilute, nearly-elastic regime, this effective temperature and the kinetic temperature follow each other as experimental parameters are varied. Beyond this regime, these temperature scales depart from each other. We speculate that the effective temperature remains a useful variable even in the regime where kinetic approaches to granular fluids no longer apply.

[1]This work was done with H. Wang, K. Feitosa, K. Facto and R. Lychev. We acknowledge support from NSF DMR 0305396.

[2]G. Gallavotti, E.G.D. Cohen, Phys. Rev. Lett. **74**, 269 (1995).

[3]K. Feitosa, N. Menon, Phys. Rev. Lett. **92**, 164301 (2004)