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Statistical Physics Experiments Using Dusty Plasmas[1]

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Compared to other areas of physics research, Statistical Physics is heavily dominated by theory, with comparatively little experiment. One reason for the lack of experiments is the impracticality of tracking of individual atoms and molecules within a substance. Thus, there is a need for a different kind of experimental system, one where individual particles not only move stochastically as they collide with one another, but also are large enough to allow tracking. A dusty plasma can meet this need. A dusty plasma is a partially ionized gas containing small particles of solid matter. These micron-size particles gain thousands of electronic charges by collecting more electrons than ions. Their motions are dominated by Coulomb collisions with neighboring particles. In this so-called strongly coupled plasma, the dust particles self-organize in much the same way as atoms in a liquid or solid. Unlike atoms, however, these particles are large and slow, so that they can be tracked easily by video microscopy. Advantages of dusty plasma for experimental statistical physics research include particle tracking, lack of frictional contact with solid surfaces, and avoidance of overdamped motion. Moreover, the motion of a collection of dust particles can mimic an equilibrium system with a Maxwellian velocity distribution, even though the dust particles themselves are not truly in thermal equilibrium. Nonequilibrium statistical physics can be studied by applying gradients, for example by imposing a shear flow. In this talk I will review some of our recent experiments with shear flow. First, we performed the first experimental test to verify the Fluctuation Theorem for a shear flow, showing that brief violations of the Second Law of Thermodynamics occur with the predicted probabilities, for a small system. Second, we discovered a skewness of a shear-stress distribution in a shear flow. This skewness is a phenomenon that likely has wide applicability in nonequilibrium steady states. Third, we performed the first experimental test of a statistical physics theory (the Green-Kubo model) that is widely used by physical chemists to compute viscosity coefficients, and we found that it fails.

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