2007

Spatially Heterogeneous Dynamics in a Granular System Near Jamming

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Recommended Citation

Abate, A. R., & Durian, D. J. (2007). Spatially Heterogeneous Dynamics in a Granular System Near Jamming. *Chaos: An Interdisciplinary Journal of Nonlinear Science, 17* (4), 041107-041107-1. http://dx.doi.org/10.1063/1.2786011

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Abstract

In supercooled liquids and dense colloidal suspensions, strings of correlated motion represent a dynamical correlation length that grows as the glass transition is approached. Here, we present a granular system driven close to the jamming transition that shares this hallmark dynamical feature. In analogy, it exhibits a dynamical length scale that grows as the jamming transition is approached.

Keywords

Granular systems, glass transitions, vector fields, topology, spatial dimensions

Disciplines

Physical Sciences and Mathematics | Physics

Spatially heterogeneous dynamics in a granular system near jamming

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(Received 23 August 2007; published online 27 December 2007)
[DOI: 10.1063/1.2786011]

In supercooled liquids and dense colloidal suspensions, strings of correlated motion represent a dynamical correlation length that grows as the glass transition is approached.[1–3] Here, we present a granular system driven close to the jamming transition that shares this hallmark dynamical feature. In analogy, it exhibits a dynamical length scale that grows as the jamming transition is approached.

The granular system we have studied consists of a bidisperse mixture of steel ball bearings fluidized by air and free to roll in two dimensions.[4–6] At low densities it behaves like a simple liquid. At high densities it exhibits hallmark structural and dynamical features that signal the onset of jamming. The mean squared displacement develops an intermediate time long-lived plateau that is representative of caged granular dynamics. The lifetime of the cage is found to depend on the system density so that at $\phi_j = 83\%$, all motion stops. Below ϕ_j, the long time motion is diffusive and homogeneous throughout the entire system. This is illustrated by the motion of a single grain in the first column of Fig. 1.

While the long time diffusive motion is homogeneous, correlations can develop at intermediate times, particularly near the onset of cage breakup. We see this in column 2 of Fig. 1, where we plot the average velocity vector fields for an averaging time close to the crossover from subdiffusive to diffusive dynamics. Note the string-like swirls of correlated motion. The system is so packed that no single particle can move without taking a large region of its neighbors with it.

To quantify this correlated motion, we introduce the persistent area. In column 3 of Fig. 1 we show persistent area diagrams that are the result of summing Voronoi diagrams over the time interval τ_A. The persistent area is defined such that area that persists within a single Voronoi cell over this time interval is colored black and area that has been swept over by a border is colored white. Comparison with the average velocity vector fields in column 2 show that there is a strong correspondence. By measuring the average $A(\tau)$ and variance $\chi_A(\tau)$ of the distribution of white and black area the size of the dynamical correlation length can be measured as a function of timescale.[6] The results are found to be similar to standard measurements such as the overlap order parameter and four-point susceptibility $\chi_4(l,\tau)$, except that the cutoff function is fixed uniquely by the structural topology.

We thank Aaron Keys and Sharon Glotzer for their contributions to Ref. 5 and for helpful discussions regarding Ref. 6. Our work was supported by the National Science Foundation through Grant Nos. DMR-0514705 and DMR-0704147.

[1] M. D. Ediger, Annu. Rev. Nucl. Part. Sci. **51**, 99 (2000).
[2] S. C. Glotzer, J. Non-Cryst. Solids **274**, 342 (2000).
[3] L. Cipelletti and L. Ramos, J. Phys.: Condens. Matter **17**, R253 (2005).
[4] A. Abate and D. J. Durian, Phys. Rev. E **74**, 031308 (2006).
[5] A. S. Keys, A. R. Abate, S. C. Glotzer, and D. J. Durian, Nat. Phys. **3**, 260 (2007).
[6] A. Abate and D. J. Durian, arXiv:cond-mat/0707.4178v1.

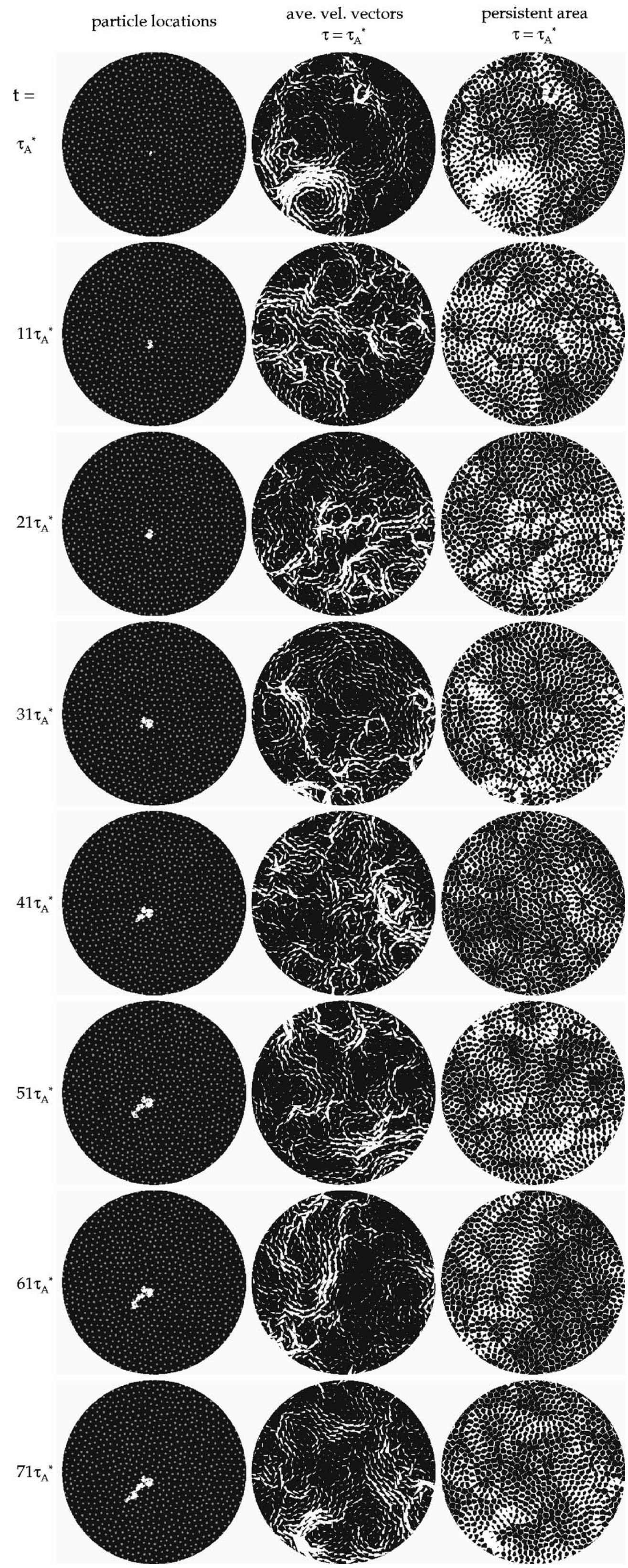

FIG. 1. Dynamics at bead packing fraction $\phi = 0.792$. Rows show later times. Column 1: bead locations with one trajectory colored in white. Column 2: average velocity vectors for the delay time τ_A. Column 3: persistent area images for the delay time τ_A at which the variance of persistent area, i.e., $\chi_A(\tau)$, is maximum. (Enhanced online.)

