Force Propagation and Friction in Granular materials

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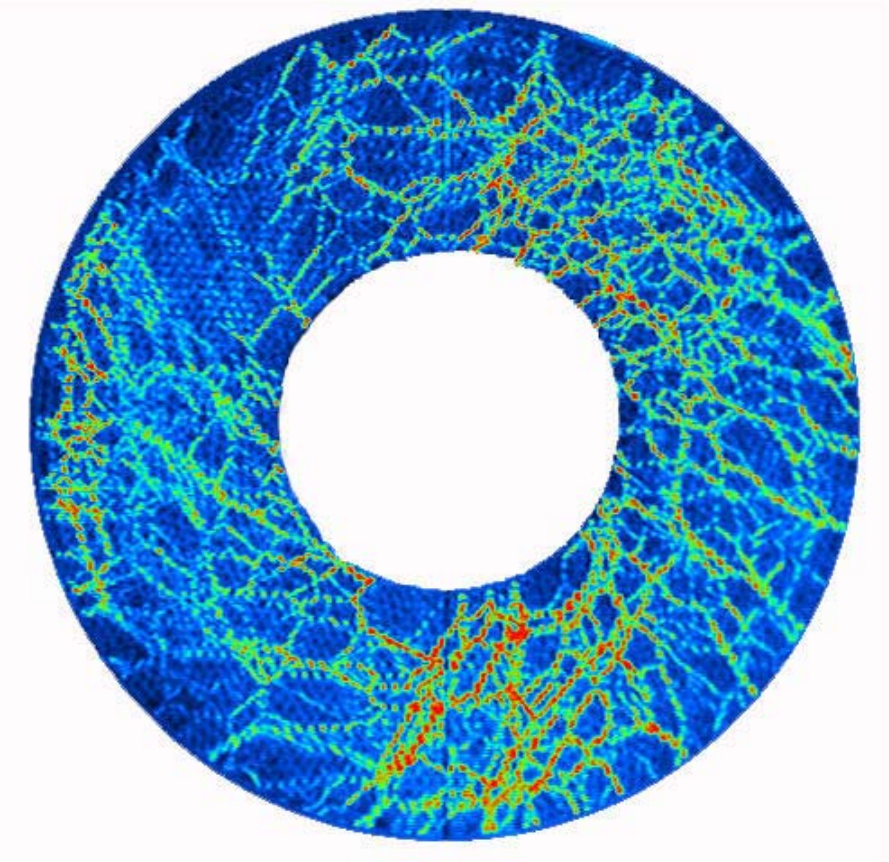
Results on Rate-dependence for sheared granular materials

- **A large variety of physical systems involve friction, including earthquake faults, objects sliding on surfaces, nanoparticles, and granular materials. This last group includes materials that appear in a vast array of important technical or agricultural processes, including the handling of food grains, pharmaceuticals, coal, ores, etc. In many cases, the frictional forces change with the rate or speed of sliding. In earthquake dynamics, for example, this is highly important for predicting faulting. In granular materials, it is crucial for the accurate design of commercial devices, including but by no means limited to silos, pharmaceutical processing plants, etc. In recent experiments, we have shown that rate-dependence occurs for granular materials (Nature, 421, 928 (2003). The apparatus is shown to the right. We visualize forces at the grain scale using photoelasticity. Here, red corresponds to large force on a grain, and blue to low force. These experiments show that forces in granular materials are carried preferentially on local, strand-like structures known as force chains, that break and reform, causing large force fluctuations that strongly impact granular flows.**



Education/Training: The work above formed part of the Ph.D. thesis of Robert Hartley, who successfully defended in March, 2003. He is now employed by a technical firm near Washington, D.C. that works on defense-related projects. Additional work on a related part of this project has been carried out by Junfei Geng, who has carried out state-of-the-art tests of models for how forces are carried in static granular assemblies. Dr. Geng successfully defended his Ph.D. thesis in August, 2003, and is now employed by an economic market forcasting company. Work in progress on this project is being carried out by Trush Majmudar, Brian Tighe and John Wambaugh, (all Ph.D. candidates) and Dr. Brian Utter (post-doc). Post-docs Karen Daniels and Jean-Philippe Matas carry out closely related work.
Dr. Meenakshi Dutt completed related work on this project and earned her Ph.D. from Duke University in September, 2002. She is currently pursuing post-doctoral studies at the University of Cambridge, England.

Outreach: Several very recent outreach activities have been 1) a series of three student-directed lectures at the Physbio NATO Summer School program *From Pattern Formation to Granular Physics and Soft Condensed Matter*, and 2) a similar series of six lectures at the Isaac Newton Institute-University of Cambridge programme on *Granular and Particle-Laden Flows*.

Additional Community Contributions: The PI's are part of the organizing committee for the international meeting, Dynamics Days. The PI is a member of the organizing committee for Powders and Grains, 2005, andfor the NATO summer school above. The PI is chair and the co-PI is an excecutive committee member of the APS Group on Statistical and Nonlinear Physics. The PI is also editor or has editorial responsibilities for the journals *Physics of Fluids, Granular Matter, Physica D, and SIADS.*