Granular materials are marginal solids

With the support by the National Natural Science Foundation of China, the research group led by Prof. Wang YuJie (王宇杰), Shanghai Jiao Tong University (SJTU), has significantly advanced the understanding about the relaxation dynamics of granular materials on the level of the particles. This work, obtained in collaboration with Prof. Zhang Jie (张洁) from SJTU, Dong HaiPeng (董海鹏) from Ruijin Hospital, SJTU School of Medicine and Prof. Walter Kob from the University of Montpellier, France, was published in *Nature* (2017, 551: 360—363).

Granular materials (sand, powders, etc.,) behave quite differently from traditional continuous media such as elastic solids and simple liquids, because granular materials are by nature out of equilibrium systems owing to the inelastic collisions and nonlinear friction between particles. Despite the great need to have an accurate theoretical description of granular materials for engineering and geotechnical applications, there exist so far only empirical macroscopic descriptions of these materials. Therefore it is of fundamental importance to develop a theory for granular materials starting from its microscopic dynamics.

To probe the microscopic dynamics of granular materials their group used the X-ray computational tomography (CT) technique to probe the positions of all the particles in a cell that was sheared. They found that the distribution of the displacements of the ellipsoids is well described by a so-called "Gumbel law" (which is similar to a Gaussian distribution for small displacements but has a heavier tail for larger displacements), with a shape parameter that is independent of the amplitude of the shear strain and of the time. Despite this universality, the mean squared displacement of an individual ellipsoid does not exhibit the cage effect—the mechanism that slows the dynamics in glass-forming systems, whereby particles are temporarily trapped by their nearest neighbors. Instead, this mean squared displacement follows a power law as a function of time, with an exponent that does depend on the strain amplitude and time. They argue that these results are related to the presence of two relaxation mechanisms on different length scales—the length scale of particle's surface roughness and of diameter.

Their experiments demonstrate that the relaxation dynamics of such "frictional" systems is qualitatively different from that of "thermal" systems and that granular materials are "marginal solids", i. e. stable if unperturbed but fluid under the slightest external perturbation. The mechanism that leads to this behavior is very general which indicates that these frictional out-of-equilibrium systems obey a new class of microscopic dynamics.

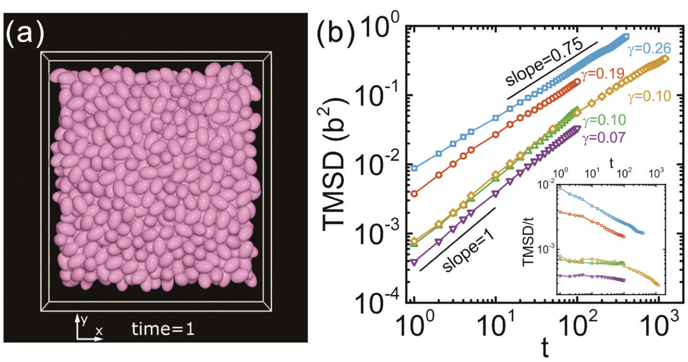

Figure (a) Snapshot of the 3D ellipsoid system.; (b) time dependence of the translational mean squared displacement for different strain amplitudes γ.

These findings will help the development of a new continuum theory for granular materials based on the microscopic motion of the particles and hence allow to make progress in many research fields such as geoscience (e. g. earthquakes, landslide, and debris flow).