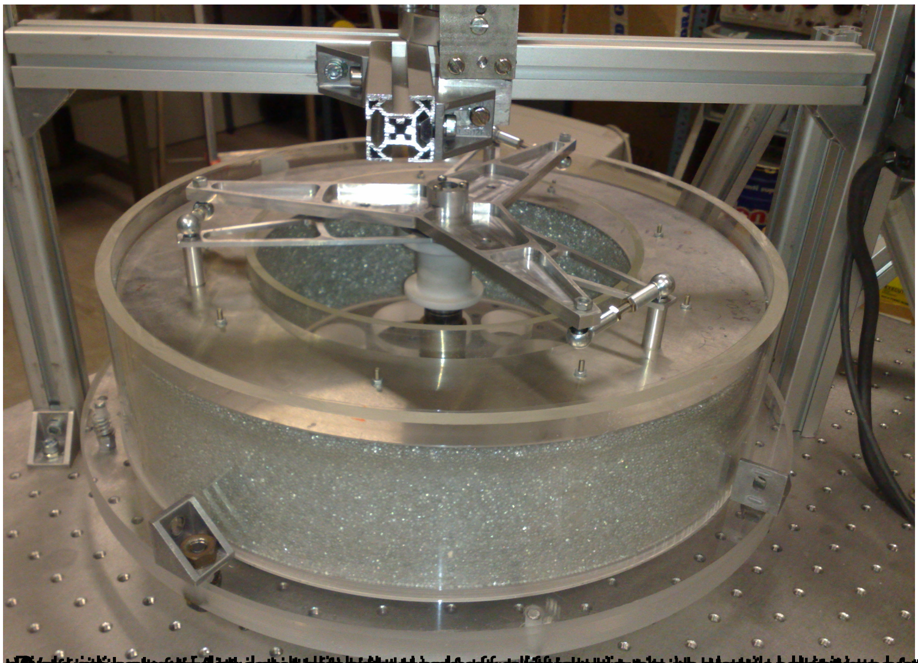
Granular shear Our group is presently studying the solid/fluid and stick-slip/steady sliding transitions in granular matter. Granualr materials are a fascinating juxtaposition of the 3 normal states of matter - solid, liquid and gas. A granular material can behave as a solid when it is at rest, a liquid when it flows down an incline, and a gas when violently shaken. In fact, it is possible that all three states can be simultaneously present in a single sample of the material.

Granular materials are generally considered to consist of many (i.e. thousands or millions) single particles which are at least mesoscopic in size - small microscopic particles can often suffer thermal excitation and so destroy the solid phase; thus the particles must be at least big enough so that thermal fluctuations (kT), or fluctuations due to background noise or vibration, are negligible compared to the energy scale typically required to move the particles. Thus a powder can be considered as a granular material, though one must also be careful to avoid (or treat) cohesive or repulsive forces between grains, such as electrostatic forces or choesive forces due to excessive ambient humidity; this latter can be relevant even for macroscopic grains such as sand. At the other end of the scale, granular materials can be composed of rocks and boulders of size up to 10 metres or more. It is widely suggested that plantary and stellar accretion disks are best treated as a granular material.

The size of granular particles means that the structures formed are not in thermal equilibrium with the surroundings. Furthermore, the nature of the contact forces between grains, a non-linear interaction with threshold, means that proagation of stress in a granular material is highly disordered. Few connected grains form 'force chains' which carry most of the load to the underlying support while most grains carry little or no load. This is in marked contrast to solids and fluids where the internal pressure is normally homogenous. By applying an external force to the granulate, these force chains can shift and change so as to adapt to the applied force. Eventually, the granular material is brought to a barely stable state in which the smallest increase in external force will trigger a macroscopic rearrangement of the force chains and the granules.

In our experiments, we apply a steadily increasing shear force to a granular material which is confined to a circular channel of diameter 40cm, width 6cm and height <8cm. The channel is filled to varying heights with 2mm glass beads, and an annular plate is forced to rotate over the top of the channel. The plate is driven by a motor via a torsion spring which slowly builds up the shear force between the overhead plate and the granular material until slip occurs.



[illegible]