Highly Resolved Fluid Flows - "Liquid Plasmas" at the Kinetic Level

Fluid flow around an obstacle was observed at the kinetic (individual particle) level using "complex (dusty) plasmas" in their liquid state. These "liquid plasmas" have bulk properties similar to water (e.g., viscosity), and a comparison in terms of similarity parameters suggests that they can provide a unique tool to model classical fluids. This allows us to study "nanofluidics" at the most elementary – the particle – level, including the transition from fluid behaviour to purely kinetic transport.

The experiments were carried out in a radio-frequency (rf) plasma chamber. A temperature gradient was used to compensate for gravity. The microparticles (diameter 3.7µm) develop a steady axially symmetric flow pattern with an upward flow at the perimeter and a homogeneous uniform downward flow of diameter 2 cm along the chamber axis (Fig. 1,2). The mean separation between the particles is 90 µm.

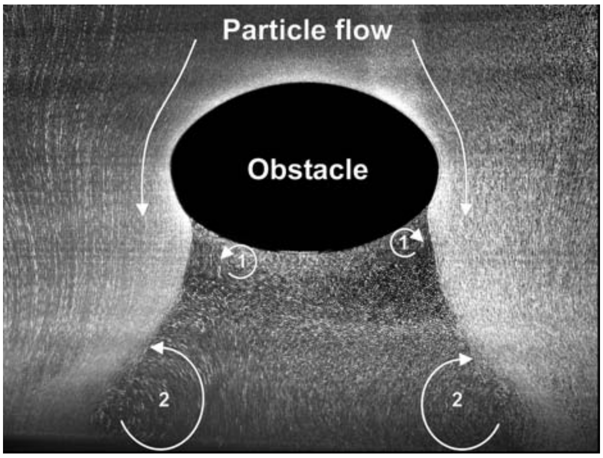

Fig. 1: Topology of the particle flow around the "void".

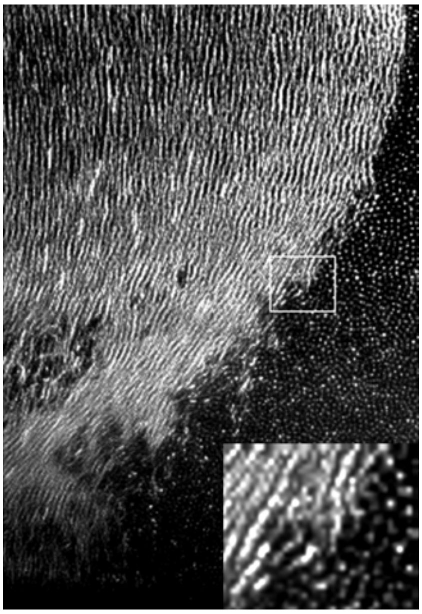

Fig.2: An example of the mixing layer – an enlargement of the left side of the flow regime shown in Fig. 1

The "obstacle" is a lentil shaped "void" – a region in which plasma processes prevent particle penetration. Surrounding the void upstream, a laminar boundary layer is formed. Behind the obstacle a "wake" is formed, which is separated from the laminar flow region by a mixing layer. Some momentum has to be transferred into the wake region, since adjacent to its boundary a vortex flow is established, with a rotation direction suggesting that the energy source is in the flow. Further downstream there is a second vortex (torus) in the wake, which rotates in the same way, also suggesting the flow as the energy source.

The mixing layer between the flow and wake exhibits instability growth on scales much smaller than the hydrodynamic scale, if we identify this as the density or shear velocity gradient along the flow lines. The solution to this puzzle is probably due to the curved flow driving a collisional instability, which has been observed for the first time at the kinetic level.

References:

Morfill, G. E., M. Rubin-Zuzic, H. Rothermel, A. V. Ivlev, B. A. Klumov, H. M. Thomas, and U. Konopka, Highly Resolved Fluid Flows - "Liquid Plasmas" at the Kinetic Level, Phys. Rev. Lett., **92** (2003)

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