Deformation and flow of soft matter: what can we learn from ultrasound?

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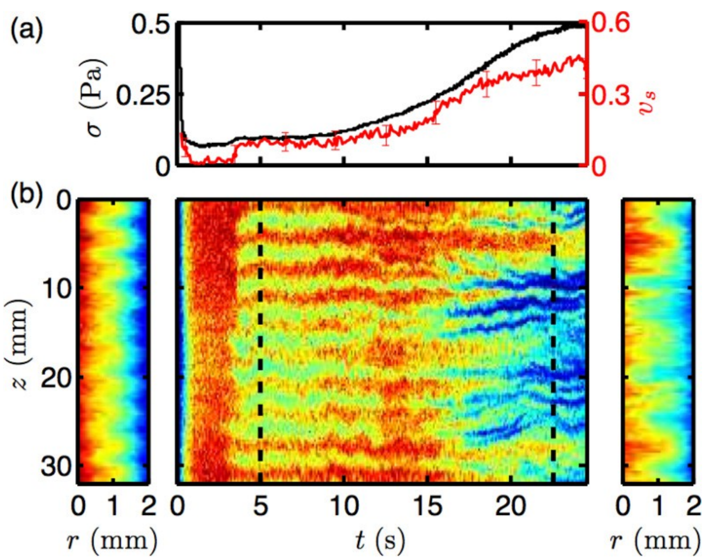
Ultrasound is commonly used in medicine both at low intensity for diagnosis (echography) and at high intensity for therapy (lithotripsy or tumour treatment). The goal of this talk is to show that these two sides of ultrasound may also provide key fundamental insights into the mechanical behaviour of soft condensed matter.

First, we have developed an ultrafast ultrasonic imaging setup that provides access to the local deformation and velocity fields in complex fluids and soft solids under simple shear. This technique will be illustrated on various examples, including shear-banding and elastic instabilities in surfactant solutions,[1] fracture in protein gels[2] and delayed yielding in colloidal gels.[3]



Flow instability in a surfactant solution under shear in a Taylor-Couette cell. (a) Stress response s (black) and apparent slip velocity v_s (red) as a function of time *t* after a shear rate of 50 s^{-1} is applied at *t*=0. (b) Velocity maps showing the initial Taylor-Couette vortex flow at *t*=5 s (left) and the final elastic turbulence at *t*=22.5 s (right) together with a spatiotemporal diagram (middle) showing the transition between the two regimes. *r* is the radial direction and *z* the vertical direction.

Second, I will show that ultrasound can also be used in the high-power regime to interact with the structure of a soft material. Indeed, it is well known that ultrasound generates acoustic radiation forces when impacting on a solid boundary. We build upon this property to (i) fluidise locally a wet granular packing[4] and (ii) study the effect of low-frequency ultrasound on the viscoelastic behaviour of a colloidal gel.

1. Fardin M. *et al.*, *Flow-induced structures versus flow instabilities*, Phys. Rev. E 89, 011001(R), 2014
2. Leocmach M. *et al.*, *Creep and fracture of a protein gel under stress*, Phys. Rev. Lett. 113, 038303, 2014
3. Kurokawa A. *et al.*, *Avalanche-like fluidization of a non-Brownian particle gel*, Soft Matter 11, 9026-9037, 2015
4. Lidon P. *et al.*, *Grains unchained: local fluidization of a granular packing by focused ultrasound*, Soft Matter 12, 2315-2322, 2016