Acoustical tweezers: a tool to probe the local mechanical properties of soft and biological matter

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The controlled manipulation of matter using the radiation pressure of light is well established as a powerful tool in the physical and biological sciences: "optical tweezers" use a single laser beam to trap and manipulate individual particles with precisely controlled forces. The piconewton force range and nanometer spatial resolution make optical tweezers ideally suited to probe biomolecular interactions, colloidal systems, organelles, and even living cells. Despite the wide applicability of optical tweezers in biological and soft matter physics, probing bulk soft materials such as cell colonies or biological tissue, which require much larger stresses to be significantly deformed, remains a current challenge.

Using the radiation pressure of sound, rather than light, we have developed single-beam acoustical tweezers, which can exert forces on a variety of particles ranging in size from a few micrometers up to the macroscopic scale. The trapping mechanism relies on the so-called "gradient radiation forces" that arises wherever the local acoustic intensity rapidly varies in space, as is the case in highly focused beams. Compared to their optical counterpart, acoustical tweezers can exert forces orders of magnitude larger while drastically reducing the required intensity. The main characteristics of this technique open prospects to investigate mechanisms where large deformations and stresses are required, involving turbid or opaque-to-light media or fragile objects. We will present the basic physical mechanisms underpinning acoustical tweezers and their recent application to the manipulation of individual microbubbles, which we propose as local "radiation force transducers" to probe local and subtle mechanical properties of soft matter systems.

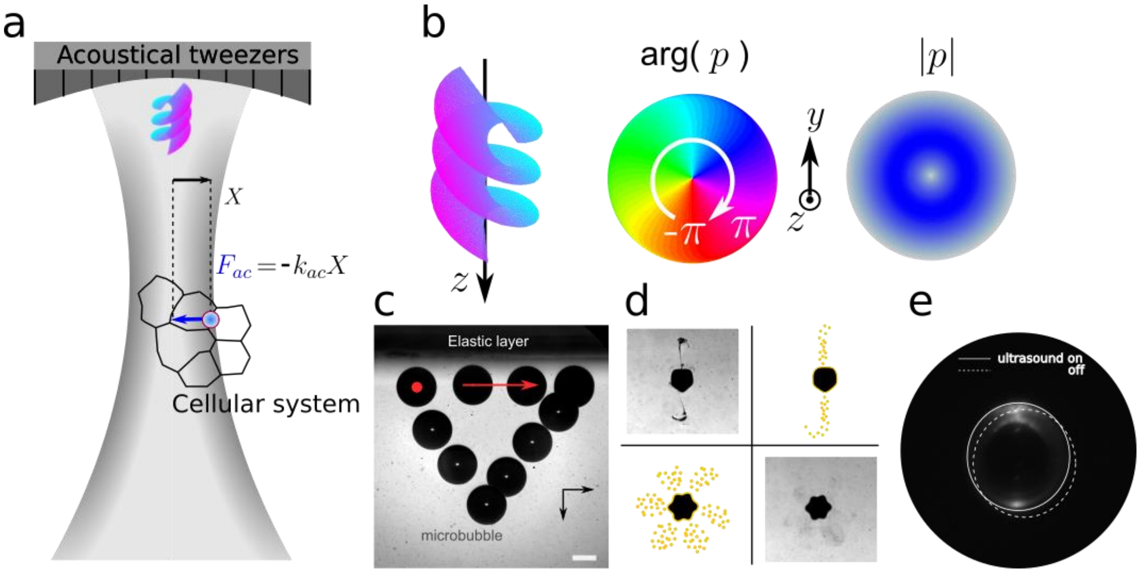

FIG. 1. a) Trapping radiation force exerted with acoustical tweezers. b) Incident trapping vortex beam (from left to right: wavefront, phase and magnitude). c) Time-lapse picture of a microbubble trapped and maneuvered in a liquid. d) Nanoparticle release from acoustically guided coated microbubbles. Bubble displacement of a microbubble induced in a soft hydrogel.