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Mechanical waves in a driven granular medium with remote interactions.

Michael Berhanu[a*], Simon Merminod[b], Gustavo Castillo[c] and Eric Falcon[a]

a. MSC, Université de Paris, CNRS (UMR 7057), Paris, France
b. Harvard University, Cambridge, MA, USA
c. Universidad O'Higgins, Rancagua, Chile

* email : michael.berhanu@univ-paris-diderot.fr

In condensed matter, due to the thermal agitation and the interaction potential, the motions of atoms are described as the wave propagation of mechanical waves, the phonons. Here, we present at the laboratory scale, a macroscopic counterpart using a driven granular medium constituted of vibrated iron beads confined in a monolayer [1,2]. The particles can interact with each other by the means of an applied magnetic field. Due to the vibration of the substrate, particles move erratically like for a 2D Brownian motion. From high-speed video recordings, we analyze the velocity fluctuations of individual particles in stationary regime. After performing a statistical averaging, we find that these random displacements self-organize into collective motions characterized by dispersion relations in the frequency-wavenumber space, evidencing the presence of mechanical waves. For weak magnetic coupling, the waves are longitudinal as expected for a fluid-like phase. For stronger coupling, the beads arrange into a hexagonal ordered structure. We then report the presence of longitudinal and transverse waves, characteristic of solid-like phases. The shapes of the dispersion relations are explained by the spatial distribution of particles and the interaction potential. The extracted sound velocities provide a measurement of the mechanical parameters quantifying the rigidity of the granular assembly.

[1] Merminod, S., Berhanu, M., & Falcon, E. (2014). EPL (Europhysics Letters), 106(4), 44005.

[2] Castillo, G., Merminod, S., Falcon, E., & Berhanu, M. (2020). Physical Review E, 101(3), 032903.

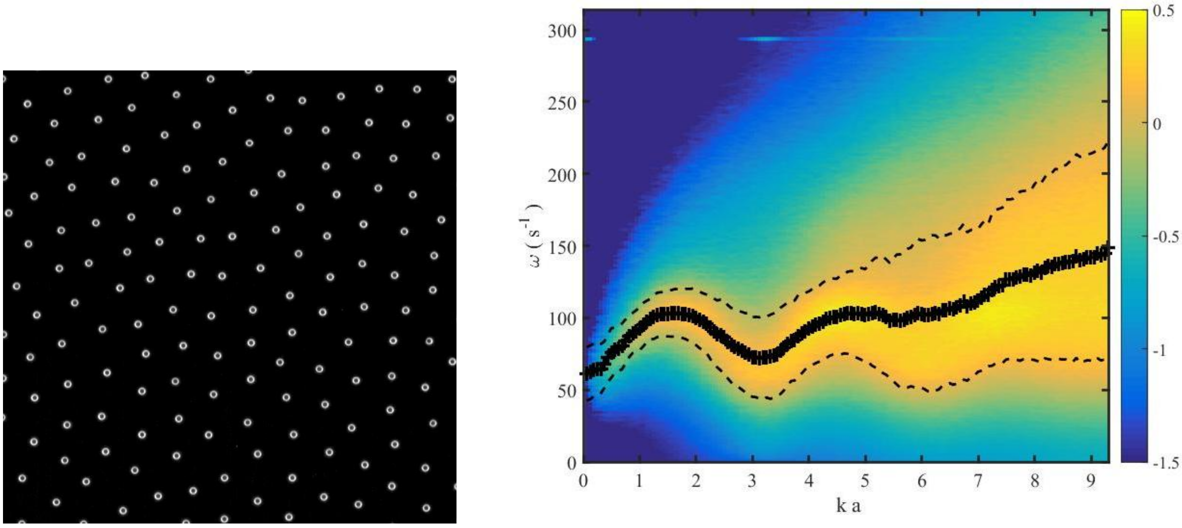

Figure 1: On the left, image of the beads (diameter 1 mm) in repulsive magnetic dipolar interaction, in the presence of agitation. On the right, space-time spectrum of longitudinal velocity fluctuations. The maxima of the spectrum define a relation of dispersion of the longitudinal waves.
Corresponding movie slowed down five times can be found at the link:
http://www.msc.univ-paris-diderot.fr/~berhanu/BerhanuGranularWavesSlowMotion5x.mp4