Nonlinear dusty plasma instabilities

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In this work, some strongly nonlinear instabilities occurring in dusty plasmas are experimentally observed and characterized. Their similarity with mixed-mode oscillations (MMOs) is investigated.

Dusty (or complex) plasmas (complex, in analogy with complex fluids) are partly ionized gases containing solid dust particles with sizes ranging from a few nm to cm[1]. In the plasma, dust particles acquire a negative electric charge that determines their interaction with the plasma and induces collective effects in the dust cloud. These multi-component systems have many similarities with colloidal suspensions or granular media. They are encountered in many environments such as astrophysics, industrial processes and thermonuclear fusion.

In experiments, dust clouds are often characterized by a central dust-free region (void)[2] maintained by two forces of opposite directions. Self-excited oscillations of the void size can appear due to a break in this equilibrium[3]. This "heartbeat" instability (due to its apparent similarity with a beating heart) can stop by its own through an ending phase characterized by the occurrence of more and more failed contractions. During this phase, electrical or optical measurements show well-defined behaviors recently identified as mixed-mode oscillations (MMOs)[4]. MMOs consist of an alternation of small and large (spikes) amplitude oscillations often considered as subthreshold oscillations and relaxation mechanisms. They exist in a wide variety of fields such as chemistry (e.g. in the Belousov-Zhabotinskii reaction) and natural sciences (e.g. in the Hodgkin-Huxley model of neuronal activity). MMOs are intensively studied with dynamical system theories (canards, subcritical Hopf-homoclinic bifurcation, ...).

Here, we report on the first experimental evidence of MMOs in dusty plasmas. A particular attention is paid to the evolution of the number of small amplitude oscillations in between spikes. This work highlights new situations of MMOs that could be of interest for improving dynamical system theories. We also underline close similarities with MMOs observed in neuronal activity and oscillating chemical systems. These fields use well-known sets of equations giving rise to MMOs and this scientific background could be used to explore the dusty plasma dynamics. This aspect is currently underway through several theoretical approaches[5].

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