The sound in Saturn's rings: Physicists explain nonlinear dust acoustic waves in dusty plasmas

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Dusty plasmas can be found in many places both in space and in the laboratory. Due to their special properties, dust acoustic waves can propagate inside these plasmas like sound waves in air, and can be studied with the naked eye or with standard video cameras. The Ruhr-Universitaet-Bochum physicists Prof. Dr. Dr. h.c. Padma Kant Shukla and Dr. Bengt Eliasson from the Faculty of Physics and Astronomy have published a model with which they describe how large amplitude dust acoustic waves in dusty plasmas behave.

The researchers report their new findings in the journal *Physical Review E*.

Dusty plasmas are composed of electrons, positive ions, neutral atoms, and dust grains that are negatively or positively charged. Only in plasmas containing electrically charged dust grains, dust sound waves emerge – the so called dust acoustic waves. These waves are supported by the inertia of the massive charged dust particles. The restoring force – causing the particles to oscillate and the wave to propagate – comes from the pressure of the hot electrons and ions. Recently, several laboratory experiments revealed nonlinear dust acoustic waves with extremely large amplitudes in the form of dust acoustic solitary pulses and shock waves, propagating in the plasma with speeds of a few centimeters per second. Padma Shukla and Bengt Elisasson have developed a unified theory explaining under which circumstances nonlinear dust acoustic shocks as well as dust acoustic solitary pulses occur in dusty plasmas.

Dust acoustic waves with large amplitudes interact among themselves thereby generating new waves with frequencies and wavelengths different from the ones of the original dust acoustic waves. Due to the generation of harmonics (i.e., waves with frequencies that are a multiple integer of the original frequency) and due to constructive interference between dust acoustic waves of different wavelengths, the waves develop into solitary, spiky pulses, or into shock waves. The solitary pulses arise from a balance between the harmonic generation nonlinearities and the dust acoustic wave dispersion. Shock waves, on the other hand, form when the dust fluid viscosity dominates over dispersion. This happens at high dust densities when the dust particles are close enough to interact and collide with neighboring dust particles.

The new Shukla-Eliasson nonlinear theory and numerical simulations of the dynamics of nonlinear dust acoustic waves successfully explain observations from laboratory experiments of three different groups world-wide, in the USA (Robert Merlino), Taiwan (Lin I), and India (Predhiman Kaw). These three international groups described the existence of large amplitudes dust acoustic solitary pulses and dust acoustic shocks in their low-temperature dusty plasmas. Applying the new nonlinear dust acoustic wave theory, one can infer the dust fluid viscosity from the width of the dust acoustic shock wave. "Our results may also be important as a possible mechanism for understanding the cause of dust grain clustering and dust structuring in planets and in star forming regions," suggests Prof. Padma Kant Shukla.

More than two decades ago, Prof. Padma Kant Shukla theoretically predicted the existence of linear and nonlinear dust acoustic waves in dusty plasmas, which since then have been observed in many laboratory experiments. His discovery has transformed the field of plasma physics, and has opened up a new interdisciplinary research field at the crossroad between condensed matter physics and astrophysics.

More information: P. K. Shukla, B. Eliasson (2012): Nonlinear dynamics of large-amplitude dust acoustic shocks and solitary pulses in dusty plasmas, doi: 10.1103/PhysRevE.86.046402

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