Dusty Plasmas

Coulomb solid of small particles in plasmas

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Small particles in plasmas can form a coulomb lattice. The conditions for solidification in a laboratory plasma are discussed.

Phys. Fluids **29**, 1764 (1986)

Laboratory observation of the dust-acoustic wave mode

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A laboratory observation of the dust-acoustic instability is reported. The results are compared with available theories. © *1995 American Institute of Physics.*

Phys. Plasmas **2**, 3563 (1995)

Solitary potentials in dusty plasmas

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It is found that a dusty plasma with inertial dust fluid and Boltzmann distributed ions admits only negative solitary potentials associated with nonlinear dust-acoustic waves. The dynamics of small-amplitude disturbances is governed by the Korteweg–de Vries (KdV) equation, the stationary solution of which assumes the inverted bell-shaped secant hyperbolic squared profile. The associated dust and ion density perturbations are, on the other hand, positive. The solitary potentials can be identified as nonlinear structures in low-temperature dusty plasmas such as those in laboratory and astrophysical environments. © *1996 American Institute of Physics.* [S1070-664X(96)00302-4]

Phys. Plasmas **3**, 702 (1996)

Experimental observation of very low-frequency macroscopic modes in a dusty plasma

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Images of a cloud of grains in a dusty plasma reveal a pair of very low-frequency modes, termed here the filamentary and great void modes. The plasma was a radio-frequency discharge formed between parallel-plate graphite electrodes. A cloud of 100 nm carbon particles was produced by accretion of carbon atoms produced by sputtering the graphite. The cloud was illuminated with a laser sheet and imaged with a video camera. The great void mode was a spoke-shaped region of the cloud that was free of dust and rotated azimuthally in the discharge. The filamentary mode had the appearance of turbulent striations, with a smaller amplitude than the great void. The filamentary mode sometimes appeared as a distinctive vortex, curling in the poloidal direction. Both modes had a very low frequency, on the order of 10 Hz. Two possible causes of the modes are discussed. The low phase velocity of the modes may be consistent with a dust-acoustic wave. Alternatively, the great void may be an ionization wave that moved the dust about, since a modulation in the glow was seen moving at the same speed as the void. It is argued that existing theories of waves in dusty plasmas assume weakly collisional plasmas, which may be unsuitable for explaining experimental results in laboratory dusty plasmas, since they are often strongly coupled. © *1996 American Institute of Physics.* [S1070-664X(96)02204-5]

Phys. Plasmas **3**, 1212 (1996)

Lattice waves in dust plasma crystals

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Techniques previously known from solid state physics are used to look at linear and weak non-linear wave propagation in dust lattices. These expansion techniques include only electrostatic interactions between neighbor particles in addition to assuming small vibrations in the dust lattice. As a simple model for the dust lattice, a one-dimensional Bravais lattice is considered. For this particular lattice, expressions for the linear phase velocity are compared to a quasi-particle simulation. The word quasi here means that only the dust particles are represented as diffuse objects, while the plasma is treated as a fluid. The simulation is also used to study the breakdown of the analytical theory and to investigate non-linear dust lattice waves. A very good agreement is found between the analytical expressions and the particle simulations, for cases where the average dust separation a is of the order of or larger than the plasma Debye length λ_D. This is a condition which very often applies to dust crystal in laboratory experiments. Application of this wave theory is therefore discussed with respect to recent laboratory experiments where dust lattice waves are excited. © *1996 American Institute of Physics.* [S1070-664X(96)03311-3]

Phys. Plasmas **3**, 3890 (1996)

Dust-acoustic soliton in a dusty plasma

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It is shown that a dusty plasma can admit dust-acoustic solitons on a very slow time scale involving the motion of dust grains, whose charge is self-consistently determined by local electron and ion currents. The solitons exist for a range of velocities and the peak amplitude increases almost linearly with the velocity. © *1997 American Institute of Physics.* [S1070-664X(97)00202-4]

Phys. Plasmas **4**, 253 (1998)

Dust acoustic waves in a direct current glow discharge

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An experimental investigation of dust acoustic (DA) waves in a dc glow discharge plasma is described. The glow discharge is formed between a 3 cm anode disk and the grounded walls of a 60 cm diameter vacuum chamber which is filled with nitrogen gas at a pressure of about 100 mTorr. Dust located on a tray in the chamber is attracted into the plasma where it is trapped electrostatically. The dust acoustic waves were produced by applying a modulation signal (5–40 Hz) to the anode. The wavelength of the DA waves was measured from single frame video images of scattered light from the dust grains. The measured dispersion relation is compared with theoretical predictions. © *1997 American Institute of Physics.* [S1070-664X(97)04907-0]

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Laboratory studies of waves and instabilities in dusty plasmas*

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Theoretical and experimental studies of low-frequency electrostatic waves in plasmas containing negatively charged dust grains are described. The presence of charged dust is shown to modify the properties of ion-acoustic waves and electrostatic ion-cyclotron waves through the quasineutrality condition even though the dust grains do not participate in the wave dynamics. If the dust dynamics is included in the analysis, new ''dust modes'' appear—dust acoustic and dust cyclotron modes. The results of laboratory experiments dealing with dust ion acoustic (DIA) waves and electrostatic dust ion cyclotron (EDIC) waves are shown. These modes are more easily excited in a plasma containing negatively charged dust. Finally, observations of dust acoustic (DA) waves are presented and measurements of the dispersion relation are compared with one obtained from fluid theory. © *1998 American Institute of Physics.* [S1070-664X(98)90505-5]

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A survey of dusty plasma physics*

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Two omnipresent ingredients of the Universe are plasmas and charged dust. The interplay between these two has opened up a new and fascinating research area, that of dusty plasmas, which are ubiquitous in different parts of our solar system, namely planetary rings, circumsolar dust rings, the interplanetary medium, cometary comae and tails, as well as in interstellar molecular clouds, etc. Dusty plasmas also occur in noctilucent clouds in the arctic troposphere and mesosphere, cloud-to-ground lightening in thunderstorms containing smoke-contaminated air over the United States, in the flame of a humble candle, as well as in microelectronic processing devices, in low-temperature laboratory discharges, and in tokamaks. Dusty plasma physics has appeared as one of the most rapidly growing fields of science, besides the field of the Bose–Einstein condensate, as demonstrated by the number of published papers in scientific journals and conference proceedings. In fact, it is a truly interdisciplinary science because it has many potential applications in astrophysics (viz. in understanding the formation of dust clusters and structures, instabilities of interstellar molecular clouds and star formation, decoupling of magnetic fields from plasmas, etc.) as well as in the planetary magnetospheres of our solar system [viz. Saturn (particularly, the physics of spokes and braids in the B and F rings), Jupiter, Uranus, Neptune, and Mars] and in strongly coupled laboratory dusty plasmas. Since a dusty plasma system involves the charging and dynamics of massive charged dust grains, it can be characterized as a complex plasma system providing new physics insights. In this paper, the basic physics of dusty plasmas as well as numerous collective processes are discussed. The focus will be on theoretical and experimental observations of charging processes, waves and instabilities, associated forces, the dynamics of rotating and elongated dust grains, and some nonlinear structures (such as dust ion-acoustic shocks, Mach cones, dust voids, vortices, etc). The latter are typical in astrophysical settings and in several laboratory experiments. It appears that collective processes in a complex dusty plasma would have excellent future perspectives in the twenty-first century, because they have not only potential applications in interplanetary space environments, or in understanding the physics of our universe, but also in advancing our scientific knowledge in multidisciplinary areas of science. [DOI: 10.1063/1.1343087]

Phys. Plasmas **8**, 1791 (2001)