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ICPDP

9th INTERNATIONAL CONFERENCE ON THE PHYSICS OF DUSTY PLASMAS

SPACE RESEARCH INSTITUTE (IKI)
MOSCOW · RUSSIA

MAY 23–27
2022

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edited by:
L.M. Zelenyi, S.I. Popel

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The history of ICPDP started in 1996 in Goa (India) as a response to growing interest in the topics of dusty plasmas, when the liquid and crystalline plasma was discovered. We continue a series of International Conferences on the Physics of Dusty Plasmas which take place (as a rule) every three years at different locations around the world (Goa, India 1996; Hakone, Japan 1999; Durban, South Africa 2002; Orleans, France 2005; Azores, Portugal 2008, Garmisch-Partenkirchen, Germany 2011, New Delhi, India 2014, Prague, Czech Republic 2017). The conference provides a unique opportunity for disseminating the present status of dusty plasma physics worldwide and especially to young researchers.

Ninth ICPDP conference is hosted by the Space Research Institute of the Russian Academy of Science (IKI), Moscow, Russia. IKI acronym comes from Russian “Institut Kosmicheskih Issledovanyi”, which is Space Research Institute, and is used in English as is. IKI designs and builds scientific instruments for space experiments, acts as principal organization for various scientific space projects and missions, and uses the data of space probes to deepen our understanding of space and Earth. At present a significant topic of research at IKI is the space dust and dusty plasmas.

The topics of the conference include: laboratory dusty plasmas, liquid and solid-like structures as well as phase transitions in plasmas, microgravity research, waves and instabilities in dusty plasmas, dusty plasmas in Earth’s environments, dusty plasmas in the Solar System, dusty plasmas in astrophysics and cosmology, dusty plasma applications including dusty plasmas for nanotechnology, etc.

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PROGRAM

ICPDP 2022 SCIENTIFIC PROGRAM

MONDAY, MAY 23, 2022

10.30–10.50*	**WELCOME & INTRODUCTION** Lev Zelenyi, Oleg Petrov, Anatoliy Petrukovich, Svetlana Fortova SESSION DEDICATED TO THE MEMORY OF V.E. FORTOV	
10:50–11:15	**Oleg PETROV**	Vladimir FORTOV space odyssey
11:15–11:30	**Lev ZELENYI**	V.E. FORTOV and the international project VEGA
11.30–12.00	COFFEE BREAK	
	THEORY AND MODELING OF DUSTY PLASMAS	
12:00–12:25	**Lin I** solicited talk	Rogue waves and acoustic vortices in dust acoustic waves: from weakly disordered waves to wave turbulence
12:25–12:40	**Nareshpal Singh SAINI** contributed oral talk	Super Rogue waves and Rogue wave triplets in a space dusty plasma
12:40–12:55	**Ajaz MIR** contributed oral talk	Bispectral analysis for nonlinear mixing in dusty plasma
12:55–13:10	**Mukhit MURATOV** contributed oral talk	Influence of the neutral shadowing force on properties of dusty plasma under cryogenic conditions
13:10–13:25	**Olga VAULINA** contributed oral talk	Active Langevin particle
13:25–14:10	LUNCH BREAK	
	DUSTY PLASMAS UNDER THE ACTION OF MAGNETIC FIELD	
14:10–14:40	**Tlekkabul RAMAZANOV** keynote talk	Computer simulation of complex plasmas under external magnetic field
14:40–14:55	**Nuriya BASTYKOVA** contributed oral talk	Behavior of plasma-dust structure in gas discharge with an external magnetic field
14:55–15:20	**Victor Yu. KARASEV** solicited talk	Dusty plasmas in conditions of a glow discharge under the magnetic field up to 2.5 T
15:20–15:50	**Edward THOMAS, Jr.** keynote talk	Plasma and dust pattern formation in the Magnetized Dusty Plasma Experiment (MDPX)
15:50–16:20	COFFEE BREAK	
	DUSTY PLASMAS IN FUSION DEVICES	
16:20–16:45	**Svetlana RATYNSKAIA** solicited talk	Dust generation, transport and remobilization in full-metal fusion reactors
16:45–17:00	**Vyacheslav BUDAEV** contributed oral talk	Dust dynamics over a real rough surface faced to plasma in fusion devices
17:00–17:15	**Merlan DOSBOLAYEV** contributed oral talk	Experimental modeling and study of a wall dust plasma in a tokamak

* Time zone: Moscow Standard Time (UTC/GMT +3)

17:15–19:15

POSTER SESSION

Madhurjya BORA	A simulation of dust charging process in plasma
Madhurjya BORA	Effect of micro dusts on lunar sheath
Sandip DALUI	Modulational instability of dust acoustic waves in strongly coupled dusty plasma
Tonuj DEKA	Investigation of nonlinear phenomenon of dust density wave in nano dusty plasma
Brandon DOYLE	Transmission impedance probes for dusty plasmas
Hao-Wei HU	Waveform dynamics in microscopic acoustic wave turbulence of cold 2D dusty plasma liquids
Sachin KAOTHEKAR	Jeans gravitational instability of dusty plasma with dust temperature, dust charge fluctuation, and radiative cooling functions
Sachin KAOTHEKAR	Gravitational instability of magnetized dusty plasma with dust charge fluctuation, dust temperature, and radiative cooling function
Manveet KAUR	Nonlinear excitations of dust ion acoustic waves in multispecies plasma
Arkar KYAW	Active Brownian dynamics of solitary particles in a RF plasma discharge
Prince KUMAR	Dust vortex flow analysis in weakly magnetized plasma
Myoung-Jae LEE	Growth rate for the electrostatic surface wave in a dusty plasma with collision-dominated ion stream
Shahzad MAHMOOD	A study of modulation instability and Rouge wave propagation of dust electrostatic waves in magnetized plasmas
Patrick MEIJAARD	Gravity as a variable; Using dust grains as probes in the plasma sheath
Armelle MICHAU	Nucleation and aerosol dynamics in different hydrogen-carbon containing plasmas
Tim STAPS	Probing the electron density dynamics in a dusty argon/HMDSO plasma using multi-mode microwave cavity resonance spectroscopy
Jeremiah WILLIAMS	Observation of particle dynamics at the onset of polarity switching in the PK-4 microgravity laboratory
Jeremiah WILLIAMS	Molecular dynamics simulations of the interaction of an electron beam with a plasma crystal
Alexandra ZAMPETAKI	Buckling in 2D complex plasma crystals

DUSTY PLASMAS IN NATURE

10:00–10:30	**Khare AVINASH** keynote talk	Numerical simulation of Coulomb shielding and dust charge reduction in high density dusty plasma
10:30–10:55	**Pralay Kumar KARMAKAR** solicited talk	Investigation of nucleus-acoustic waves in degenerate quantum plasmas in complex astroenvirons
10:55–11:10	**Tanushree BEZBARUAH** contributed oral talk	Nonlinear Jeans-Buneman instability in complex astroclouds
11:10–11:40	COFFEE BREAK	
11:40–11:55	**Zheng-yuan LI** contributed oral talk	Comparison of Stochastic and Continuous Dust Charging Models Appropriate to PMSE
11:55–12:10	**Sunidhi SINGLA** contributed oral talk	Existence of higher order magnetosonic solitons in Earth's magnetosphere
12:10–12:40	**Alexander ZAKHAROV** keynote talk	Dusty Plasmas in the Vicinity of the Moon: Current Research and New Vistas
12:40–13:05	**Sanjay MISHRA** solicited talk	A charge dissipation mechanism within permanently shadowed craters
13:05–13:20	**Trinesh SANA** contributed oral talk	Complex electrostatic structures within craters over sunlit Moon
13:20–14:20	LUNCH BREAK	
14:20–14:45	**Ilya KUZNETSOV** solicited talk	Lunar dusty plasma investigation instruments onboard "Luna-25" and "Luna-27" spacecrafts
14:45–15:00	**Attia KASSEM** contributed oral talk	The impact of the lunar magnetic anomalies and Earth's magnetic field on dust movements in the lunar dusty plasma
15:00–15:15	**Valentin BORZOSEKOV** contributed oral talk	Laboratory modelling of levitating plasma-dust cloud of a meteoroid impact by microwave (gyrotron) discharge in lunar regolith
15:15–15:40	**Nilolay BORISOV** solicited talk	Mechanisms of formation of the Jupiter's Gossamer Rings and their Extensions
15:40–15:55	**Egor GODENKO** contributed oral talk	Charging of interstellar dust in the heliospheric environment
15:55–16:10	**Olga KHABAROVA** contributed oral talk	Impact of dusty plasma on current sheets at different heliocentric distances. Observations from Ulysses and Parker Solar Probe
16:10–16:25	**Roman KISLOV** contributed oral talk	Theoretical aspects of the cosmic dust impact on the heliospheric current sheet
16:25–16:55	COFFEE BREAK	
16:55–17:10	**Yurii DUMIN** contributed oral talk	On the physical mechanism of anomalous stability of the gas-dust clouds near the Galactic Center
17:10–17:25	**Yulia IZVEKOVA** contributed oral talk	Dusty plasma and Schumann resonances in Martian atmosphere
17:25–17:40	**Yulia REZNICHENKO** contributed oral talk	Dusty plasma system in the Martian ionosphere
17:40–17:55	**Tatiana MOROZOVA** contributed oral talk	Some aspects of modulational interaction in Earth's dusty ionosphere including dusty plasmas of meteor tails

18:00–20:00 POSTER SESSION

Andrey DUBINSKII	On some features of dust particle sedimentation in the Martian atmosphere
Preetam Singh GOUR	Geomagnetic storm and there associated solar activities
Yulia IZVEKOVA	Dust Acoustic Perturbations in Martian Atmosphere
Attia KASSEM	Modified Zakharov-Kuznetsov equation for description of nonlinear perturbations in plasma of dusty lunar exosphere
Rajneet KAUR	Higher corrections to nonlinear structures in polarized space dusty plasma
Alexander KOZLOVSKY	Signatures of aerosol particles detected by the VHF meteor radar in the mesosphere – low thermosphere region
Renata LUKIANOVA	Occurrence and altitude of the non-specular long-lived meteor trails
Ashish Kumar MEENA	Electron density of ionosphere E and F region during solar flare
Tatiana MOROZOVA	The size distribution of dust in protoplanetary disks and the effects of charging dust particles
Stanislav PEROV	Energy saturated aerosols in the Earth’s atmosphere
Dmitrii SHOKHRIN	Localized wave structures in the dust-filled Saturn’s magnetosphere
Geetika SLATHIA	Dust acoustic shock waves in Jupiter’s atmosphere

9:30–9:55	**Abhijit SEN** solicited talk	Some Experimental and Theoretical Studies of Propagating Nonlinear Structures in Dusty Plasmas
9:55–10:20	**Chengran DU** solicited talk	The interfacial phenomena in binary complex plasmas: experiments and simulations
10:20–10:50	COFFEE BREAK	
11:00–18:00	EXCURSION TO THE MUSEUM OF LAVOCHKIN RESEARCH AND PRODUCTION ASSOCIATION (NPO LAVOCHKIN)	

EXPERIMENTAL RESEARCH ON DUSTY PLASMAS

10:00–10:25	**Bidyut CHUTIA** solicited talk	Coulomb screening and wave propagation in nanodusty plasmas
10:25–10:40	**Almasbek UTEGENOV** contributed oral talk	Dusty plasma with carbon nanoparticles: Advances and application
10:40–10:55	**Feng HUANG** contributed oral talk	Dust growth process and spatial distribution in an RF plasma system
10:55–11:10	**Yoshiko BAILUNG** contributed oral talk	Study of dust dynamics in strongly coupled dusty plasma medium
11:10–11:40	COFFEE BREAK	
11:40–12:10	**Oleg F. PETROV** keynote talk	Evolution of charged active Brownian grains in superfluid helium
12:10–12:35	**Mikhail VASILIEV** solicited talk	Active Brownian Particles in Gas Discharges Plasma
12:35–13:00	**Evgenii LISIN** solicited talk	Effective interaction between dust particles in a gas discharge plasma
13:00–14:00	LUNCH BREAK	
14:00–14:15	**Fedor TRUKHACHEV** contributed oral talk	Dust-acoustic waves in a near-ideal (gas-like) cryogenic dusty plasma
14:15–14:30	**Pavel KRAINOV** contributed oral talk	Dust particle lofting from substrate exposed to low-energy electron beam and low-temperature plasma
14:30–14:45	**Roman BOLTNEV** contributed oral talk	Multimodal dusty plasma in DC glow discharge at temperatures below 2 K
14:45–15:00	**Eduard SAMETOV** contributed oral talk	Method for measuring nonreciprocal effective forces of interactions using the spectral density of random processes
15:00–15:15	**Aleksandr USACHEV** contributed oral talk	Application of optical emission spectroscopy in the “Plasma Kristall-4” space experiment
15:15–15:45	COFFEE BREAK	

THEORY AND MODELING OF DUSTY PLASMAS

15:45–16:00	**Sergey POPEL** contributed oral talk	Manifestations of anomalous dissipation in dusty plasma systems
16:00–16:15	**Dmitrii ZHUKHOVITSKII** contributed oral talk	Unified theory of the dust ionization and dust acoustic waves in the complex plasma of gas discharge
16:15–16:30	**Ilnaz FAIRUSHIN** contributed oral talk	Modeling of Brownian dynamics of macroparticles in a plasma-dust monolayer under the influence of laser radiation
16:30–16:45	**Xeniya KOSS** contributed oral talk	Extensive active Brownian systems in colloidal plasmas: Dynamic entropy and fractal dimension
16:45–17:00	**Alexey TIMOFEEV** contributed oral talk	Unique properties of the dusty plasmas system

17:00–18:00

POSTER SESSION

Anastasia ALEKSEEVSKAYA	Self-excited dust-acoustic waves in gas phase of a dusty plasma
Anna GORBENKO	Fractal analysis of the surface of melamine-formaldehyde dust particles
Elena DZLIEVA	Modification of melamine-formaldehyde dust particles in heavy inert gas
Ilnaz FAIRUSHIN	Self-consistent relaxation theory of collective particle dynamics in one-component Yukawa liquid
Ilnaz FAIRUSHIN	Description of the characteristics of a Yukawa liquid based on a two-step approximation for the radial distribution function
Ilnaz FAIRUSHIN	Influence of ionization potential of buffer gas on the charge value of macroparticles in thermal dusty plasma
Sergey KHRAPAK	Ionic mobility in parent rare gases
Daniil KOLOTINSKII	Fast multi-GPU Python code for self-consistent calculation of forces, acting on dust particles in a plasma environment
Victor KRASOVSKY	Calculation of the electron distribution function perturbation by an electric field in a weakly ionized gas on the basis of Boltzmann equation
Vladislav NIKOLAEV	Inhomogeneity of phase state in a dusty plasma crystal
Leontiy NOVIKOV	Method for controlling the particle size in dusty plasma in gas mixtures with different ionization potentials
Sergey PAVLOV	Investigation of the dynamics of rotation of a dust structure in a striation depending on the number of particles in a magnetic field
Roman PYASKIN	Generation of microdroplet plasma crystals
Viktor RESHETNIAK	Nucleation and crystal growth in supercooled Yukawa fluids
Vladimir SEMYONOV	Energy transfer between degrees of freedom and temperature inhomogeneity in dusty plasma monolayer
Aleksandr SHEMAKHIN	Simulations of rf plasma flow in discharge tube at low pressures
Fedor TRUKHACHEV	Dynamics of dust-acoustic soliton breaking
Ilya VORONOV	Inhomogeneity of oscillation properties in a dusty plasma monolayer

18:00–21:00 CONFERENCE DINNER

THEORY AND MODELING OF DUSTY PLASMAS

10:00–10:15	**Anshika Chugh** contributed oral talk	Ratchet driven transport – a novel paradigm of statistical thermodynamics in 2D Complex Plasmas
10:15–10:30	**Soumen De KARMAKAR** contributed oral talk	Molecular dynamics of active complex plasmas
10:30–10:45	**Pawandeep KAUR** contributed oral talk	From Rayleigh-Bénard convection cells to shear flows: a molecular dynamics study of 2D Yukawa liquids
10:45–11:00	**Suruj KALITA** contributed oral talk	Perturbed plane Couette flow in 3D Yukawa liquids: A molecular dynamics study
11:00–11:15	**Prince KUMAR** contributed oral talk	Strongly coupled rotating dust flow analysis within the Quasi-Localized Charge Approximation (QLCA) framework
11:15–11:45	COFFEE BREAK	
11:45–12:00	**Vishal KUMAR** contributed oral talk	Lane formation dynamics in 3D strongly correlated pair-ion plasmas
12:00–12:15	**Amit KUMAR** contributed oral talk	Gyrating ion beam driven dust acoustic wave instability in a complex plasma
12:15–12:30	**Pushpender Kumar GANGWAR** contributed oral talk	Spherical imploding shock waves in a weakly conducting dusty gas with the effect of solid body rotation
12:30–12:45	**Smriti ROY** contributed oral talk	Nonlinear electrostatic streaming instabilities in viscoelastic quantum dusty plasmas
12:45–13:00	**Punit KUMAR** contributed oral talk	Propagation of electromagnetic wave in quantum dusty magnetoplasma with two different electron spin states
13:00–14:00	LUNCH BREAK	
14:00–14:25	**Gennadii SUKHININ** solicited talk	Wake formation in a polarized dusty plasma: solitary dust particle case
14:25–14:50	**Anatolii FILIPPOV** solicited talk	Thermodynamic stability of dusty plasmas
14:50–15:15	**Alexander M. IGNATOV** solicited talk	Plasma Crystal as a Time Crystal
15:15–15:45	COFFEE BREAK	

15.45–17.00

CONFERENCE CLOSING

Lev Zelenyi, Oleg Petrov, Sergey Popel

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ABSTRACTS

SELF-EXITED DUST-ACOUSTIC WAVES IN GAS PHASE OF A DUSTY PLASMA

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We, for the first time, carried out an experiment to study dust-acoustic waves in weakly coupled glow discharge plasma ($\Gamma<1$). The main feature of the experiment is the cryogenic temperature of the buffer gas. The main parameters of plasma and waves are measured. The theoretical model is created.

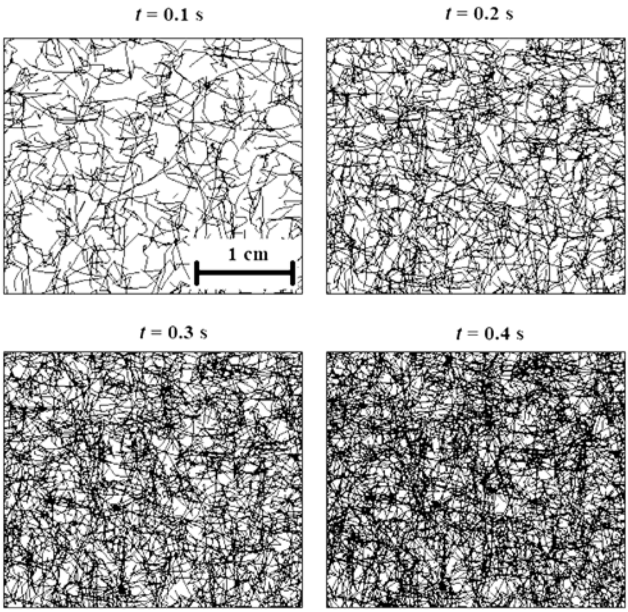

Fig. 1. Tracks of dust particles for different periods of time

As can be seen from Figure 1, dust particles do not form a crystal lattice. An analysis of the correlation functions also indicates that the experimentally observed plasma is close to the gas phase.

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ACTIVE BROWNIAN DYNAMICS OF SOLITARY PARTICLES IN A RF PLASMA DISCHARGE

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Active Brownian movement is widespread in nature, observed in the Earth's atmosphere, in biological and colloidal solutions, in plasma with a condensed dispersed phase, as well as in financial models [1]. In contrast to passive Brownian particles, active particles, also known as self-propelled Brownian particles or micro- and nanoswimmers, are able to absorb energy from the environment and transform it into directional movement. Active particles can be both biological and artificial objects [2]. For example, motile cells and bacteria or artificial micro-swimmers [1,2]. In our work, we present the results of an experimental study of the behavior of a solitary dust particle in an electrostatic trap in plasma of a high-frequency capacitive low pressure discharge under effect of laser radiation with different power output. Within the framework we studied the dynamics of microparticles with various surface properties, including: non-absorbing laser radiation melamine formaldehyde (MF) particles; copper-coated MF laser absorbing particles; and Janus particles. Depending on the type of surface of the particles, their active Brownian motion was established. The trajectories, linear displacements, mean square displacements, and kinetic energies of dust particles were obtained depending on the driven laser radiation.

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NUMERICAL SIMULATION OF COULOMB SHIELDING AND DUST CHARGE REDUCTION IN HIGH DENSITY DUSTY PLASMA

K. Avinash[1], **S. Kalita**[2], **R. Ganesh**[2], **and P. Kaur**[2]

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[2] *Institute for Plasma Research, Bhat, Gandhinagar 382428, India*

In “Coulomb shielding” predicted in high density dusty plasma [1,2], the electric field of a dust particle is shielded by other neighbouring dust particles. The scale length of Coulomb screening λ_C is given by $\lambda^2_C=1/4\pi n_d r_d$ (n_d, r_d are the dust number density and size) and resu lts in dust charge reduction in high density dusty plasmas. This regime has been recently accessed in nano dusty plasma experiments [3,4]. In this paper, we construct a model for the Coulomb screening and charge reduction which is numerically implemented via a MD code having Yukawa particles confined in a box with reflecting walls. The charges are moved by solving equations of motion and the equilibrium charge of particles is updated after each time step using charging dynamics, thus bringing in a time dependence for each particle. Constant density runs are made for given values of particle temperature T_d, Debye length λ_d, Coulomb length λ_C, and location of particles r_i (i=1...N_d). Preliminary results from the code show that in the regime $\lambda_C \gg \lambda_d$ the Coulomb screening is weak. The mean charge reduction is negligible e.g., all particles have same charge which is equal to the charge on an isolated particle. However in the regime $\lambda_C<\lambda_d$, where Coulomb screening is dominant, there is a reduction of the mean charge with particles having different charges depending on the location. These results and results from further investigations in the strong Coulomb shielding regime $\lambda_C \ll \lambda_d$ will be presented and discussed.

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STUDY OF DUST DYNAMICS IN STRONGLY COUPLED DUSTY PLASMA MEDIUM

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Charged dust particles in plasma introducing a number of interesting static and dynamical structures, such as plasma crystal formation, shocks, voids and vortices etc. have been witnessed in laboratory studies [1-4]. Study of such structures with micron sized dust particles facilitates to understand the behaviour of dust particles in kinetic level and various dusty plasma forces involved in their formation. In our experiment, we have modelled a study on strongly coupled dusty plasma fluid flow past an obstacle. Capacitively coupled RF discharge of frequency 13.56 MHz and power ~ 5 W is applied to produce the plasma. Argon gas is injected to maintain the chamber pressure at $\sim(1\text{–}5)\cdot 10^{-2}$ mbar. A cylindrical Langmuir probe is used to estimate the plasma parameters. The experiment is designed in such a manner that monodisperse gold coated silica dust particles (5 micron diameter) are directed towards a cylindrical pin (0.1 mm diameter and 1.5 cm length) with different velocities to examine the flow dynamics [5]. A dust void is produced around the pin at the boundary of which outward electric field force and inward ion drag force balances. The characteristics of the void have been studied both by applying different bias voltages to the pin and at different dust densities. The force balance condition at the respective void boundaries have been estimated. This void is then used as an obstacle in the path of a dusty plasma flow at a range of velocities ~ (3–10) cms^{-1}. The dynamics of individual dust particles around the obstacle have been studied using a MATLAB based open access Particle Image Velocimetry code [6]. Molecular dynamics simulation is also performed, the observations of which agrees with the experimental results. Spontaneous generation of two Mach cones by a single heavier dust particle have also been observed in our experimental configuration. PIV analysis is performed to understand the cause behind the formation of both the cones.

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BEHAVIOR OF PLASMA-DUST STRUCTURE IN GAS DISCHARGE WITH AN EXTERNAL MAGNETIC FIELD

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The effect of a homogeneous magnetic field on the behavior of plasma dust structures has been thoroughly studied. However, their behavior in a nonuniform magnetic field may lead to new phenomena and is therefore of interest. In this work, the behavior of the plasma-dust structure in a gas discharge in the presence of a magnetic field was investigated both experimentally and theoretically. Experiments were carried out in argon plasma in a nonuniform weak magnetic field. Linear and angular velocities of rotational motion of dust structures were analyzed. It was found that the directions of rotation are opposite in the regions above and below the Helmholtz coil [1,2]. Also, it was found that the magnetic field leads to the formation of ring-shaped dust structures in the DC gas discharge [3]. In this connection, a theoretical model was developed to explain the behavior of plasma dust structures in an inhomogeneous magnetic field. The results of theoretical calculations have good agreement with experimental data.

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NONLINEAR JEANS-BUNEMAN INSTABILITY IN COMPLEX ASTROCLOUDS

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A natural form of instabilities excited in self-gravitating complex nebular cloud plasmas responsible for diversified structure formation is the so-called Jeans instability [1]. Alongside it, the background equilibrium flows comparable to the bulk acoustic modal phase speed give rise to the Buneman instability drastically modifying the above [2]. The nonlinear excitation dynamics of the said composite Jeans-Buneman instability in such dusty plasma media in the presence of viscous dissipative effects is semi-analytically studied herein. The proposed model consists of tiny electrons and ions; and, heavy charged dust grains of identical geometric shape. The cloud macroscopic state is initially considered to be in a quasi-hydrostatic homogeneous equilibrium configuration. Such complex plasma situations are practically realizable in the H_{II} regions of the star-forming dust molecular clouds in the interstellar media extensively.

A weakly nonlinear perturbative analysis against the defined equilibrium, which is performed using the standard technique of the reductive perturbation method [3,4], yields a unique analytically conjugational pair of coupled extended Korteweg-de Vries (e-KdV) equations on the gravito-electrostatic fluctuations. It contains a new coupled pair of self-consistent nonlinear sources arising due to the nonlocal gravito-electrostatic linkage relevant in diversified structure formation mechanisms in different astrophysical circumstances [3-5]. We herewith develop a numerical illustrative platform to study the nonlinear gravito-electrostatic fluctuation dynamics governed by the derived conjugate e-KdV system. Accordingly, the numerical analysis performed here shows that the electrostatic fluctuations evolve as compressive oscillatory dispersive shocks; whereas, the self-gravitational fluctuations evolve as rarefactive oscillatory dispersive shocks. In both the cases, we, however, see that the magnitude of wave amplitude enhances nonmonotonously with the distance against the center of the entire self-gravitating plasma mass distribution; and so forth. A detailed sketch of the corresponding relevant geometrical features of the nonlocal potential fluctuations is graphically presented. The main results investigated here in the Jeans-Buneman fabric could be consistently useful to understand self-gravitational collapse dynamics and subsequent structure formation in complex dust molecular clouds in realistic astronomical circumstances.

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MULTIMODAL DUSTY PLASMA IN DC GLOW DISCHARGE AT TEMPERATURES BELOW 2 K

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Experimental studies of ultracold multimodal dusty plasma in a positive column of the glow discharge are discussed. A multimodal complex plasma formed by a spheroidal dusty structure consisting of polydisperse CeO_2 particles superimposed with a cloud of nanoclusters and solid helical filaments was observed and studied at the temperatures below 2 K and pressure ≈4 Pa [1].

Formation of a liquid-like dusty plasma structure occurred after injection of polydisperse cerium oxide particles in the glow discharge cooled with superfluid helium. It was found that the balance of the gravity and electrostatic forces was matched only for the fraction of particles with sizes from 1 to 6 μm while the initial very broad size distribution spanned from 0.1 to 100 μm. The particle concentration in the structure was estimated of order 10^5 cm^{-3}. The coupling parameter ~ 10 determined for the dusty plasma structure corresponds very well to its liquid-like type. The electron concentration in the plasma was estimated ~ 10^8 cm^{-3} [2]. The cloud of nanoparticles (with the sizes less than 80 nm) and non-linear waves within the cloud were observed within the temperature range 1.6÷2 K [1]. The nanocluster concentration was found as high as 10^6÷10^7 cm^{-3} [3]. Charging of nanoclusters in plasma produced a stable uprising nanocluster flow (~ 10^8 cluster/s) driven by external electrostatic field and observable due to laser light scattering on dust acoustic waves developed within the flow. Temporal variations of the nanocluster concentration caused changes of the interparticle distance in the dusty plasma structure composed of CeO_2 particles. Solid helical filaments with the lengths up to 5 mm, diameters up to 22 μm, total charges ~ 10^6 e, levitating in the gas discharge were synthesized at the temperatures ≤ 2 K. It was revealed that intense sputtering of the clay insert due to focused beams of low energy electrons and ions produces a total flow ~ 100 ng/s of sputtered materials at the power released in the discharge less than 0.1 W.

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A SIMULATION OF DUST CHARGING PROCESS IN PLASMA

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The process of dust charging is investigated with an *h*-PIC-MCC (*hybrid*-Praticle-in-Cell-Monte-Carlo-Collision) scheme. The findings are compared with theoretical estimates and the effect of dust-charge fluctuation on dust-ion-acoustic wave is investigated.

EFFECT OF MICRO DUSTS ON LUNAR SHEATH

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The effect of micro and nano-dusts are investigated in the context of lunar plasma and lunar day-time sheath, especially for a space-charge-limited (SCL) sheath. The resultant model is a four-fluid plasma model with which the dust levitation parameters are estimated, which clearly show the formation of dust streaks above the daytime lunar surface.

MECHANISMS OF FORMATION OF JUPITER'S GOSSAMER RINGS AND THEIR EXTENSION

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The Jovian dust ring system consists of the main ring, the halo, two gossamer rings and the extension. Gossamer rings are rather faint structures stretched beyond the main ring. There exists also a very faint outward extension. Collisions of meteorites with the corresponding moons are considered as a main source of dust in the gossamer rings. It is usually accepted that the dynamics of dust in the gossamer rings and in the extension is determined mainly by electric forces (the so-called shadow resonances can describe qualitatively not only the distribution of dust in the gossamer rings [1] but also in the extension [2]). It should be mentioned that the mechanism of shadow resonances is efficient only if the concentration of plasma and its temperature are small enough. At the same time according to the well-known model of plasma in the inner magnetosphere of Jupiter (the Divine model) in the vicinity of Thebe and Amalthea plasma is rather dense and warm [3]. We discuss how dust formation in the gossamer rings and their extension can be described if the Divine model is valid. It is shown that in this case the Thebe extension is not formed by the shadow resonances and also the gossamer rings become rather narrow. That is why another formation mechanism should be included. We take into account that dust grains ejected from the surfaces of Thebe and Amalthea by micrometeorites acquire additional orbital and radial velocities and also electric charges determined by the fluxes of electrons and ions. It is shown that large dust grains ejected outwards of Thebe and Amalthea play the role of additional moons that supply the extensions of both moons by fine dust [4]. Also dust grains ejected inwards together with the shadow resonances contribute to the formation of the gossamer rings.

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LABORATORY MODELLING OF LEVITATING PLASMA-DUST CLOUD OF A METEOROID IMPACT BY MICROWAVE (GYROTRON) DISCHARGE IN LUNAR REGOLITH

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Interest in the study of plasma–dust clouds over the lunar surface is determined by the possibility of new observations during future lunar missions. Understanding the physical processes of interaction between dust and various materials is important for designing equipment for the future lunar missions.

We have developed a laboratory method for creating a plasma-dust cloud from the laboratory regolith powder, whose chemical composition and particle size distribution is similar to that of the lunar regolith [1,2]. The method is based on the similarity between the physical (Coulomb repulsion of charged particles) and chemical (chain reactions) processes in the reactor and in regolith under real conditions of the bombardment of lunar surface by micrometeoroids. These processes were experimentally created under the action of pulsed microwave radiation from the high-power gyrotron on regolith, and led to formation of levitating ensembles of charged particles over the surface of powders (Fig. 1). The work [3] shows the effect of levitation plasma-dust particles on the surface of stainless-steel plates.

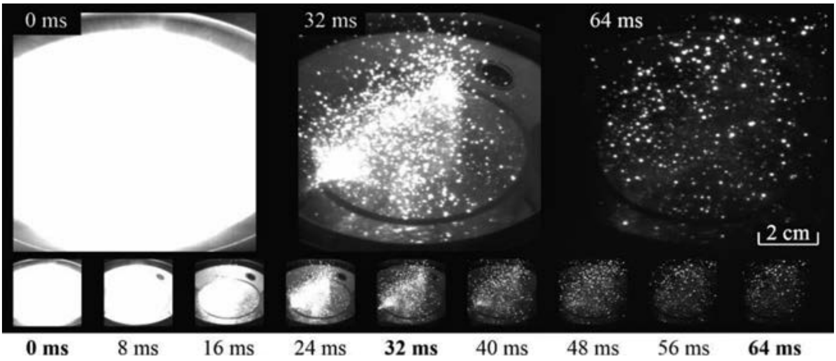

Fig. 1. Levitating particles over the regolith surface (time t=0 ms corresponds to the end of the microwave pulse).

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DUST DYNAMICS OVER A REAL ROUGH SURFACE FACED TO PLASMA IN FUSION DEVICES

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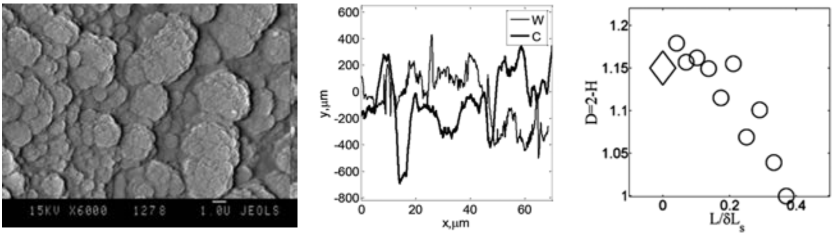
The electric field close to a surface contacted with plasma in a fusion device influences the property of edge plasma and a motion of small dust particles. A smooth shape of a material surface bounded the edge plasma is typically considered in simplified models of edge plasma. Contrary to this, real surfaces in fusion devices are corrugated. High-temperature plasma irradiation leads to an inhomogeneous stochastic clustering of the surface with self-similar granularity – fractality on the scale from nanoscale to macroscales. Cauliflower-like structure of tungsten and carbon materials are formed under high heat plasma load in fusion devices on the plasma-facing components (vacuum chamber, divertor plates and limiters) [1], Fig. 1a,b. We consider a sheath plasma layer bounded by a real fractal surface and a flat boundary. The real profile of the surface formed in a fusion device was used in numerical solving the Poisson's equation to find a potential field [2]. The rough surface influences the equipotential lines over the surface. We characterized a shape of equipotential lines by a fractal dimension, Fig. 1c. The long-range correlation in the potential field is imposed by the fractal structure of the surface. Dust particles bounced in such irregular potential field can accelerate due to the Fermi acceleration.



a b c

Fig. 1. (a) Micrograph of tungsten irradiated with high heat plasma [1]. Height profiles of tungsten (W) from the QSPA-T and the carbon (C) from the T-10 tokamak [1]. (c) Fractal dimension of equipotential lines (circles) vs a minimal distance L from the surface normalized by a maximal scale of surface irregularity δL_s. Diamond – fractal dimension of the real surface profile.

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RATCHET DRIVEN TRANSPORT – A NOVEL PARADIGM OF STATISTICAL THERMODYNAMICS IN 2D COMPLEX PLASMAS

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It is well known that transport in macroscale systems occur due to gradients in the system (concentration gradient, chemical gradient, temperature gradient etc). However, transport in microscale systems becomes challenging due to noise or fluctuations being dominant. At such small scales, the power available for transport or directed motion gets continually washed out by thermal noise. However, we are aware of several examples where transport or directed motion is achieved in noise dominated non-equilibrium statistical mechanical systems, example being, protein motors in our body which are able to transport material within living cells in the face of inevitable thermal noise [1]. An important paradigm that has emerged for understanding transport in such noise dominated system is a “Ratchet’’. In particular, in the absence of any non-zero, space and time average macroscopic forces, are there ways of generating directed motion?

In the present work, we have addressed this important question. In our study [2], we have performed Langevin simulations of 2D system of Yukawa particles in the setting of a Ratchet which is rocked periodically through a time periodic drive. Our findings confirm the presence of directed motion in the absence of any non-zero macroscopic force. The dynamics is explored over a parameter space where average velocity or strength of directed motion is found to be a non-monotonic function of strength and frequency of external time periodic drive. It is proposed that two-dimensional Complex plasmas can act as an interesting ‘‘test bed’’ for investigating Ratchet dynamics, owing to its ease in tuning interaction via screening parameter and the fact that phase space of all the dust grains can be measured. Our findings may be validated in Complex plasma experiments and would be of importance in understanding a wide variety of systems such as vortices in superconductors, cold atoms in optical lattices, transport of ions through nanopores [3] and in general, in driven-dissipative systems.

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COULOMB SCREENING AND WAVE PROPAGATION IN NANODUSTY PLASMAS

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Nanometer sized dust grains immersed in plasma produce heavily dense dust cloud where the ratio of dust to ion densities i.e., Havnes parameter [1] becomes very large, $P \gg 1$. Such a dust cloud of larger volume is achieved in laboratory using reactive gas discharge using acetylene and argon gas mixture. The average charge on each nanodust particle is estimated using various non-invasive techniques [2] which is found to be strongly reduced to a few tens to hundreds elementary charges. One of the omnipresent wave modes observed in nanodusty plasma is the self-excited dust density waves. The measured wave properties are used to estimate spatially resolved plasma parameters and dust charge in such an exotic environment up to great accuracy [3]. It has been shown theoretically by Avinash *et al.* [4],[5] that in high dust density regime, dust particles screen each other not by usual Debye screening but by a new screening mechanism called "Coulomb Screening". This is shown to cause dust charge reduction. A characteristic scale length $\lambda_c = \sqrt{1/4\pi n_d r_d}$ for Coulomb screening is obtained where n_d, r_d are the dust density and dust radius, respectively. It is shown that Coulomb Screening gives rise to a new acoustic mode called Coulomb acoustic mode in high density nanodusty plasma. In this particular work, the observations and results of an experiment [6] on the propagation of a self-excited dust density wave under strong Havnes effect will be presented based on these theoretical predictions. The experiment is performed in a vertically extended, highly dense nanodust cloud which is produced by using rf discharge of argon-acetylene gas mixture. The dust density wave appears spontaneously in the medium at a suitable set of discharge parameters. A new dispersion relation is formulated using Avinash *et.al* [4],[5] model and utilized to characterize the propagation of the wave. Average dust charge and other plasma parameters are also estimated.

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MODULATIONAL INSTABILITY OF DUST ACOUSTIC WAVES IN STRONGLY COUPLED DUSTY PLASMA

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Combining the well-known quasi-localized charge approximation [1] method and reductive perturbation method one after another, we have derived the linear dispersion relation, and consequently, the nonlinear Schrödinger equation to study the modulational instability [2] of dust acoustic waves in strongly coupled dusty plasma consisting of negatively charged dust grains, and Maxwell-Boltzmann distribution of electrons and ions. We have investigated both the cases, i.e., weakly coupled limit of the dust acoustic waves and strongly coupled limit of the dust acoustic waves. And consequently, we have seen that the stable region increases due to the effect of the strongly coupled limit of the dusty plasma although, a very small unstable region also exists for strongly coupled dusty plasma system. Finally, we have seen that the region of existence of maximum modulational growth rate of instability decreases with increasing number of dust particles.

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INVESTIGATION OF NONLINEAR PHENOMENON OF DUST DENSITY WAVE IN NANO DUSTY PLASMA

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The investigation of dust density wave in dusty plasma with micron dust particles is an active field of research [1]. The individual tracking of the particles combined with the low frequency waves have resulted in thorough study of these waves. These waves have been used as indirect measurement of the dusty plasma parameters in various experiments [2]. Recently, dusty plasma research with nanometer sized dust particles has grown immensely due to its wide application in nanotechnology [3,4]. Hence, the study of waves and instabilities holds an immense scope leading to a new domain of research. The task of particle detection and the negligible effects of gravity hold new challenges in nano dusty plasma research.

Here, in this work, we observe the self-excited dust density wave (DDW) in dusty plasma containing 50 nm size dust particles. The experiment is performed in cylindrical glass chamber of 15 cm in length and 3 cm in diameter at chamber pressure of 0.015 mbar. Argon Plasma is produced by capacitive coupled rf discharge (power = 10–15 W and frequency = 13.56 MHz). Langmuir probe is used to characterize the plasma parameters and hence measure the potential profile. Laser light (532 nm, 50 mW) is used for illuminating the dust cloud. The dynamics of the dust particles are recorded by a high resolution camera at a high frame rate of 240–420 fps. A dust void is observed at the center, just above the rf live electrode and DDW of characteristics frequency ~ 78 Hz is observed propagating from the void boundary due to the ion streaming instability. The dusty plasma parameters are estimated from this wave parameters. An external sinusoidal signal is applied to the DDW by a circular exciter from a function generator. The ion streaming is modulated by the external signal. At a modulation frequency closer to the natural frequency, the suppression of the DDW is observed. This nonlinear phenomenon of synchronization is studied in details.

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EXPERIMENTAL MODELING AND STUDY OF A WALL DUST PLASMA IN A TOKAMAK

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Testing materials and studying their behavior under conditions of high thermal, radiation, and plasma loads plays an important role in the development, design, and lifetime extension of operating and future fusion power reactors [1]. In this work, the dust formation on the surface of a carbon target is experimentally investigated on the basis of a pulsed plasma stream. Carbon with high thermal conductivity is used as a diverter facing material, especially in areas with high thermal loads [2]. That is why the study of dust formation on the surface of carbon is a very relevant task. For the irradiation of the carbon target, a pulsed plasma accelerator was used [3]. Dust collector and copper substrates were installed near the target. Figure 1 shows the formation of dust on the surface of a carbon target after plasma irradiation.

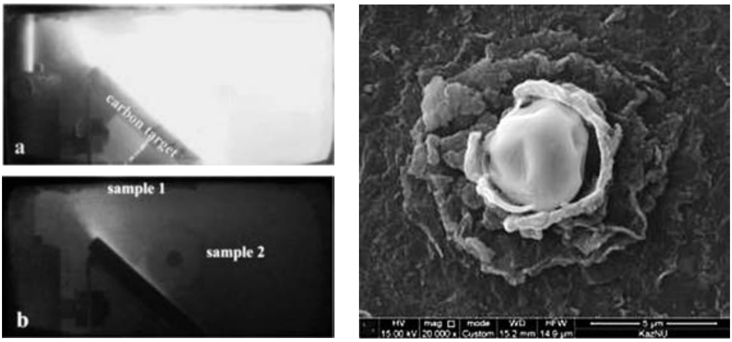

Fig. 1. Dust formation on the surface of a carbon target irradiated by a pulsed plasma stream

The morphology and elemental composition of dust particles collected in the dust collector and deposited on copper substrates were investigated. Dust particles are spherical in shape with diameters of several tens of microns. In the composition of the dust the following elements were found: Fe, Cu, Al. They appear as a result of evaporation of structural materials of vacuum chamber, accelerator electrodes and dust collector. In addition to thermal effects, projectile dust particles were detected on the surface of the carbon target after irradiation is one of the main mechanisms of dust formation on the material surface (Figure 1). The projectile particles can accelerate up to v_{max} ~ 427 m/s and when they hit the surface they can destroy it.

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TRANSMISSION IMPEDANCE PROBES FOR DUSTY PLASMAS

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Active Plasma Resonance Spectroscopy (APRS) is a broad category of diagnostic techniques which utilize plasma resonances at or near the electron plasma frequency, ω_{pe}. We present a two-port impedance probe implementation of APRS using the transmission (S_{21}) of RF signals, and we discuss its use in dusty plasmas. One potential use of this diagnostic technique is to estimate the charge collected by a cloud of dust particles immersed in plasma.

Dust particles in laboratory plasma are typically highly negatively charged because of the relative masses of ions and electrons. The charge of a dust particle, typically in the range of 10^3–10^5 electrons for μm particles, is difficult to measure but has a strong influence on many dusty plasma phenomena.

Impedance probe measurements are sensitive to changes in ω_{pe}. Adding dust to a plasma tends to lower ω_{pe} as the dust becomes charged; the negative dust charging leads to a reduction in the surrounding electron density and, therefore, a reduction in ω_{pe}. The measurement of downward frequency shifts of plasma resonances can be used to infer an upper limit for the charge collected by the dust cloud. In future works, we will combine this with ion density measurements to infer the true charge collected by the dust cloud.

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THE INTERFACIAL PHENOMENA IN BINARY COMPLEX PLASMAS: EXPERIMENTS AND SIMULATIONS

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A binary complex plasma is a weakly ionized gas containing electrons, ions, neutral atoms and mesoscopic particles of two sizes. Due to the spinodal decomposition and ion flows, the particle cloud was phase separated with an interface between the small and big particles. In this talk, we present experiments and simulations on the interfacial phenomena in a phase-separated binary complex plasma.

In this talk, the relevant experiments were performed in PK-3 Plus laboratory under microgravity conditions on board the International Space Station (ISS). Density waves were self-excited due to two-stream instability by turning down the gas pressure. By studying the dynamics of wave crests at the interface, we recognized a “collision zone” and a “merger zone” before and after the interface, respectively [1]. To resolve the motions of individual particles, a dissipative solitary wave was excited by a pulse signal applied on the electrode. The propagation of the solitary wave across an interface was studied. An interfacial effect was observed by measuring the deceleration of particles in the wave crest. The results were compared with a Langevin dynamics simulations and theory based on KdV equations [2,3]. In several experiment runs, penetrations of a supersonic extra particle were observed in the phase-separated binary complex plasma. Inspired by the experiment observations, numerical simulations were performed. The lateral wave behind the extra particle was deformed at the interface and its dependence on the penetration speed and direction was studied [4]. In the end of the talk, some experiment results from the recent campaigns in the PK-4 laboratory on the ISS will be discussed briefly.

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ON SOME FEATURES OF DUST PARTICLE SEDIMENTATION IN THE MARTIAN ATMOSPHERE

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In certain periods of time at altitudes of about 90–110 km, the pressure of carbon dioxide vapor exceeds its saturated vapor pressure. As a result, just as it happens in the Earth's ionosphere, a phenomenon similar to noctilucent clouds can also be observed on Mars. However, on the red planet, the settling of such layered structures occurs several times faster – in 5–10 min and is more complex than that under terrestrial conditions. The reason for this is the fact that CO_2, which condenses on the surface of the particle, is the main gas in the Martian atmosphere. In this regard, first of all, it is necessary to take into account the deceleration of the particle by adhering CO_2 molecules initially immobile on average. Secondly, the force of viscous friction from the atmosphere is also inapplicable in its original form, since the interaction of carbon dioxide molecules with a dust particle will be mainly inelastic. Under the conditions of the Earth's atmosphere, water vapor makes up a small fraction of the gase mixture, so these effects are insignificant for the dynamics of dust particles. On Mars, on the contrary, CO_2makes up a 95% share, so these effects have a significant influence and should be taken into account at modeling of the dust particles dynamics.

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ON THE PHYSICAL MECHANISM OF ANOMALOUS STABILITY OF THE GAS-DUST CLOUDS NEAR THE GALACTIC CENTER

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One of surprising features in the dynamics of Galactic center is the excessive stability of the gas-dust clouds (or the so-called G-objects) orbiting about the central black hole [1, 2]. Namely, they are not disrupted by the tidal forces in the pericenter of their orbits. This leads to the assumption of existence of the point-like massive objects (stars) inside such clouds, while no such stars were actually detected by observations.

It is the aim of the present report to demonstrate that the anomalous resistance of G-objects to tidal perturbations can be well explained solely by the plasma effects. Namely, a layer of hot electrons at the boundary of a cloud accumulates an excessive electrostatic energy when the cloud is gravitationally deformed, thereby producing the effective "surface tension". Then, when the cloud leaves the region of strong gravitational perturbation, this surface tension acts as an elastic membrane and tends to restore the original shape of the cloud, similarly to the ordinary liquid droplet experiencing an external perturbation [3]. As follows from the detailed calculations, the proposed mechanism provides a self-consistent explanation of the stability of G-objects, without any need for postulating the additional massive bodies to stabilize them.

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MODIFICATION OF MELAMINE-FORMALDEHYDE DUST PARTICLES IN HEAVY INERT GAS

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Low-temperature plasma with hot (heavy) ions is today a tool in surface treatment of various materials from metals to polymers. This method of measuring surface texture finds application in technological processes and medicine. In dusty plasma, it is possible to suspend particles with sizes of several microns and to carry out a comprehensive modification of their surface. At the same time, low-temperature plasma is a rather gentle tool capable of precision machining.

Today, there are only a few experimental works where the discussed modification of particles was carried out in dusty plasma [1-5]. Basically, polymeric particles of melamine-formaldehyde are used in research. The dynamics of the modification of dust particles in a neon glow discharge in the size range from 1 μm to 12 μm has been fairly well studied. It has been established that the modification has two phases: slow heating/softening and fast degradation process. A time correlation has been found between the processes of size degradation and surface structure modification. For a detailed study of the effects of changes in the surface structure, it is important to carry out experiments in different types of plasma-forming gases, in particular, with heavier ions than neon ions.

In the presented work, the process of degradation and modification of the structure of the surface of melamine-formaldehyde particles with sizes of 4 μm and 7 μm is experimentally studied using argon and krypton ions. The particles in the dust trap were studied in an electron microscope. Regularities of the change in size with the time spent in the plasma are obtained. A comparison is made with the changes recorded in neon; a qualitative interpretation of the results is given.

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MODELING OF BROWNIAN DYNAMICS OF MACROPARTICLES IN A PLASMA-DUST MONOLAYER UNDER THE INFLUENCE OF LASER RADIATION

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Using the molecular dynamics method, we have simulated the action of light pressure of laser radiation and the effect of the photophoretic force on a quasi-2D dust system with characteristics corresponding to experimentally observed ones in the high frequency discharge plasma. Numerical experiments have been performed for different values of the nonideality parameters of the dust subsystem. In the case of act of the force of light pressure force we have detected intensification of diffusion of macroparticles in the laser radiation region; the diffusion increases the more intensely the larger the initial nonideality parameter. For example, at Γ=156 and a radiation power of 1200 mW, the average kinetic energy of particles in the laser action region exceeds the initial diffusion by more than two times. For Γ=35 under the same conditions, the increase in the average kinetic energy of particles does not exceed 30%. It is found that as a result of interaction of macroparticles, their kinetic energy increases not only in the region of action, but also beyond its limits, where a more intense increase in the average kinetic energy is also observed for large values of the nonideality parameters. These processes directly depend on the radiation power and on the initial parameters of the system. In the case of act of photophoretic force it was found that the effect of laser radiation can lead to the appearance of the nature of particle motion inherent in the so-called active matter. In the work, the time dependences of the mean square and average linear particle displacements are calculated. It is established that when a photophoretic force acts on a colloidal dust system for the mean square displacement of particles in such a system, sections corresponding to ballistic, transition, and diffusion regimes are observed. Moreover, the average linear displacement for the particles is nonzero, which also characterizes them as active [1]. It also depends on the initial non-ideality parameter of the dust system and the power of the laser radiation acting on it.

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DESCRIPTION OF THE CHARACTERISTICS OF A YUKAWA LIQUID BASED ON A TWO-STEP APPROXIMATION FOR THE RADIAL DISTRIBUTION FUNCTION

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In this paper we proposed two-step approximation to a radial distribution function (RDF) of particles of one-component Yukawa liquid, which is determined by basic parameters of the system: nonideality parameter and structure parameter. This approximation allows one to calculate many physical properties based on the corresponding microscopic expressions, where the characteristic parameters of the Yukawa system (non-ideality parameter and structure parameter) are used as input parameters. The two-step approximation proposed in this work for the RDF produces good agreement with the simulation results for such quantities as total internal energy, internal pressure, excess entropy, and dispersion dependences of longitudinal acoustic-like collective excitations. It turns out that in the case of low-temperature states, detailed information on the local structure is not essential for the correct reproduction of the dispersion law $\omega_L(k)$ of the Yukawa liquid.

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INFLUENCE OF IONIZATION POTENTIAL OF BUFFER GAS ON THE CHARGE VALUE OF MACROPARTICLES IN THERMAL DUSTY PLASMA

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In this paper, we consider an equilibrium thermal dusty plasma containing charged metallic dust particles. Using the Richardson-Deschman model and using the Saha formula, the charge of particles was calculated for different values of their size, concentration, system temperature, chemical composition of particles and buffer gas. It was found that, ceteris paribus, in buffer gases with a low ionization potential, the charge on the particles reaches lower values than in gases with a high gas ionization potential.

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THERMODYNAMIC STABILITY OF DUSTY PLASMAS

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Using the Ornstein-Zernike integral fluid equations for multi-component plasma, the dielectric properties and thermodynamical stability of dusty plasmas are studied. For the most non-ideal dust plasma subsystem, a transition to the one-component approximation is carried out [1,2]. It is shown that the effective pseudo-potential for determining the correlation functions in the selected subsystem should not include the contribution of this subsystem to the screening constant, but should take into account the condition of total plasma quasineutrality. It is demonstrated that when the coupling parameter of the dust subsystem is smaller than unity, $\Gamma_{00}<1$, the interaction potential between the charged plasma particles is fairly well described by the Debye potential with a full screening constant. Here the coupling parameter of the dust subsystem is defined as

$$\Gamma_{00}=\frac{e^2 z_0^2}{aT}, \; a=\frac{1}{n_0^{1/3}},$$

Where e is the elementary charge, z_0 is the charge number of dust particles, n_0 is their number density and T is their temperature in energy units.

For $\Gamma_{00}>1$, the static dielectric function in the long wavelength domain becomes negative, and this domain expands when Γ_{00} increases. This leads to the appearance of attraction of particles with charges of the same sign and repulsion of particles with charges of the opposite sign. In this case, both the total pressure and isothermal compressibility in the entire studied range of the coupling parameter $\Gamma_{00}<250$ remain positive, but the isothermal compressibility of the dust subsystem becomes negative at $\Gamma_{00}\approx 2$ within the studied range of variation of the plasma parameters. The sign of the derivative of the chemical potential with respect to the total number of dust particles, the positiveness of which is the third condition for the thermodynamic stability, is shown to coincide with the sign of the isothermal compressibility of the dust subsystem. Therefore, it is concluded that the equilibrium dusty plasma at $\Gamma_{00}>2$ is thermodynamically unstable.

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SPHERICAL IMPLODING SHOCK WAVES IN A WEAKLY CONDUCTING DUSTY GAS WITH THE EFFECT OF SOLID BODY ROTATION

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In the present work, the problem of shock wave propagation in a weakly conducting dusty gas under the effect of solid body rotation have been carried out by using the CCW[1-3] method. The gaseous medium is assumed to be seeded a large number of small spherical solid particles of uniform size. The solid particles are assumed to be inert and they are uniformly distributed in the medium. Equilibrium flow conditions has been maintained during the entire study. For the exponential varying initial density distribution the impact of variation of initial density, the mass concentration of solid dust particles, the specific density of the mixture, and the presence of magnetic induction, on the shock velocity, the shock strength, the pressure and flow velocity profiles are explained through the graphs. The correction to the CCW predictions for the problem on the inclusion of flow behind the shock front at same density distribution. It is found that dust presence in the gaseous medium has significant effects on all the flow parameters. The results obtained here been compared with those for freely propagating shock as well as for the dust free ideal gas.

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CHARGING OF INTERSTELLAR DUST IN THE HELIOSPHERIC ENVIRONMENT

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Due to the relative motion of the Sun in the interstellar medium (ISM), the interstellar dust (ISD) particles, being one of the components of the ISM, can penetrate into the heliosphere. Their chemical and morphology properties are quite uncertain and of great interest, because these particles may provide the constraints on the nearest interstellar material. The dynamics of the ISD particles is governed by the gravitational attraction, radiation pressure and electromagnetic force. At large heliocentric distances, where the influence of the gravitational and radiation pressure forces is negligibly small, the ISD particles are predominantly affected by the electromagnetic fields. As a result, the smallest ISD grains can be filtered out at the heliospheric boundaries, although big particles pass this region almost freely. The magnitude of the electromagnetic force is proportional to the electric charge of a dust grain, which is formed under the interplay of different physical processes. The goal of this talk is to present the results of detailed modeling of the ISD charging, especially in the heliospheric interface, and to demonstrate the behavior of their trajectories passing through this region.

We consider four main physical processes influencing the ISD charging: 1) sticking of particles from surrounding plasma on the surface of a dust grain; 2) secondary electron emission due to the bombardments by high-energy electrons; 3) photoelectric emission due to the solar and interstellar background photons; 4) effects of cosmic ray electrons. The surrounding plasma and radiation conditions are such that a steady-state charge is quite good approximation. We estimate the relaxation time required for dust grains to reach an equilibrium and conclude where this approximation is valid for particles of each size. Also, we present the results of modeling of charge probability distribution based on the statistical equilibrium assumption [1]. However, more precisely, to solve a distinct differential equation for charge along the ISD trajectory and we show how it influences the shape of trajectories, especially in the heliospheric interface. Our computations are based on plasma distributions from the global 3D kinetic-MHD heliosphere model presented in [2].

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FRACTAL ANALYSIS OF THE SURFACE OF MELAMINE-FORMALDEHYDE DUST PARTICLES

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Plasma treatment is now widely used for modifying polymer surfaces properties such as adhesion, friction, penetrability, wettability and biocompatibility [1-2]. The possibility of "trapping" polymer microparticles in the vertical part of a gas-discharge tube in a non-uniform electric field of a glow discharge opens new perspectives in this area. The authors of [3-5] obtained data on the modification of calibrated spherical particles of melamine-formaldehyde (MFR) with a diameter of 7.3±0.4 μm in neon plasma (Ne, p=40 Pa, i=2.5 mA, exposure time from 5 to 25 min). The experimental technique is described in detail in [4]. Subsequently, the authors of [6] managed to modify microparticles of larger diameter 11.6 ± 0.4 μm in the same discharge tube (Ne, p=25 Pa, i=2.1 mA, exposure time from 5 to 40 min). Extracted particles were examined by electron microscopy (SEM method). The obtained 2D Tiff images of various scales were analyzed using software: Smart tiff – for measuring the particle diameter, Gwyddion – for studying the properties of the surface. Following results were obtained: under the influence of plasma, particles decrease in size, maintaining a spherical shape; the surface of the particles changes its properties, which is manifested in a change in the roughness Ra depending on the residence time in the plasma.

The construction of a model of processes under the influence of which MFR particles are modified in a glow discharge plasma requires an assessment of the rough surface area. Fractal analysis methods allow making such estimates. Many randomly rough surfaces belong to the class of random objects that exhibit the properties of affine self-similarity and are treated as affine-like statistical fractals. The fractal analysis of such surfaces makes it possible to obtain the value of the parameter Df, which acts as a power factor in estimating the area of a rough surface S~aDf.

In this report we present an estimate of the Df value for the surface of plasma treated particles of two sizes 7.3±0.4 μm and 11.6±0.4 μm. This result shows that the calculation of the surface area of particles when modelling processes in the dusty plasma without taking into account its topology can lead to significant errors. The values of the parameter Df are given for plasma particles processed for 20 minutes, which were used in the experiments.

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WAVEFORM DYNAMICS IN MICROSCOPIC ACOUSTIC WAVE TURBULENCE OF COLD 2D DUSTY PLASMA LIQUIDS

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In the cold liquid around freezing, crystalline ordered domains (CODs) with different lattice orientations and rearrangeable structures coexist. Their solid like structure can support or frustrate the propagation of thermally excited phonons. In this work, by viewing these phonons in a quasi-two dimensional dusty plasma liquid as thermally excited microscopic acoustic wave turbulence, we experimentally investigate the spatiotemporal coherent behaviors of different scale modes [1]. Through multidimensional complementary ensemble empirical mode decomposition, the relative transverse displacement, exhibiting continuous power spectrum, of each adjacent particle pair is directly decomposed into multiscale wave modes with the information of instantaneous local amplitude and phase. The coherent waveform structure can be identified from the iso-phase surface plots in the xyt space. The intermittent coherent excitation, propagation, scattering and annihilation of each mode, in the form of clusters in the xyt space, with cluster sizes exhibiting self-similar power law distribution are found. The local amplitude of each wave mode tends to increase at the site with poor structure order, especially for the slower modes. The switching of the particle motion from cage rattling to cooperative hopping is induced by the sudden phase synchronization of the slow wave modes with gradually increasing amplitudes at the site with poor structure order.

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DUST GROWTH PROCESS AND SPATIAL DISTRIBUTION IN AN RF PLASMA SYSTEM

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The dust growth process and spatial distribution both in horizontal and vertical planes are investigated in a radial constraint rf discharge plasma system. Dust particles with different topological shapes (including spherical, long rod-like, branch-like and block fractals) with different sizes were formed under different plasma discharge conditions and the growth process was characterized by the evolution of dust cloud distribution, laser scattering intensity and the fractal dimension with time [1-3]. A 2D dipolar dust particle model with forming the multiple long dust chains was used to simulate the growth mechanism of the millimeter-sized rod-like and branch-like dust structures obtained in horizontal planes [2]. The coagulation process of larger dust particles with centimeter-sized and stable fractal structure was also investigated in our experiment [1]. In addition, the distribution characteristics of dust particles were studied from experiments and simulations. The 3D distribution of dust particles is related to discharge electrode structures and gravity effect. As the rf power increases, the distribution range as well as the levitation height of the dust cloud above the powered electrode decreased [4]. It was attributed the dependence on a combination of the enhanced sheath electric field and the ion drag force. Especially, ion drag force played an important role so that dust particles were subjected to a continuously increasing downward force as the discharge power increases. For a horizontal monolayer of dust particles, the influence of ion flow can make the dust distribution presenting a "bowl" shaped structure, which can be simulated by the "Yukawa/point-wake" model [5].

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PLASMA CRYSTAL AS A TIME CRYSTAL

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The nonlinear development stage is studied of the instability of coupled waves in the planar plasma crystal in the external confining force field. It is assumed that the particles are located in plasma consisting of the Maxwellian electrons and the directed flow of cold ions. The nonreciprocal interparticle force is calculated by numeric methods.

It is demonstrated that the effect of nonlinearity results either in acceleration of the instability development or in the formation of a time crystal consisting of one or three stable nonlinear waves. In the space of external parameters, the domains of existence of different phases are constructed.

We also investigate the stability of the plane dust clusters in the form of a regular polygon with the number of particles from two to five. It is shown that, in such clusters, the oscillatory instabilities can develop along with the aperiodic instabilities. The ranges of plasma parameters are determined, within which the oscillatory instability of the five-particle cluster becomes saturated at the weakly nonlinear stage. As a result, the cluster forms a time crystal, which can be a chiral crystal.

DUSTY PLASMA AND SCHUMANN RESONANCES IN MARTIAN ATMOSPHERE

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Dust and dusty plasma play significant role in the atmosphere and ionosphere of Mars. Electrification in dust events such as dust devils and dust storms can presumably lead to electric fields large enough for discharges to take place and for existence of oscillations in Schumann cavity. We discuss the role of dust and dusty plasma in the excitation of the Schumann oscillations on Mars and provide comparison with the situation of the Schumann oscillations in the atmosphere of the Earth.

DUST ACOUSTIC PERTURBATIONS IN MARTIAN ATMOSPHERE

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It is shown that the horizontal winds in Martian ionosphere, at the initial stage of their interaction with dusty plasma clouds at altitudes of about 100 km, can cause conditions for the excitation of dust acoustic waves due to the development of kinetic instability. The dispersion relationship of the dust acoustic waves is determined as well as their growth rate in the conditions under study. It is noted that the generation time of the dust acoustic wave is substantially long to allow the formation of nonlinear plasma wave structures, e.g., solitons. Dust Acoustic solitons that propagate in Martian ionosphere in the dusty plasma clouds at altitudes of about 100 km are studied. It is shown that the increase in dust particle number density or decrease in electron number density by one order of magnitude leads to the increase of the amplitude of dust acoustic solitons by one order of magnitude. The possibility of generation of dust acoustic perturbations in Martian ionosphere should be taken into account during processing and interpretation of observation data.

PERTURBED PLANE COUETTE FLOW IN 3D YUKAWA LIQUIDS: A MOLECULAR DYNAMICS STUDY

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Turbulence is one of the unsolved problems, wherein beyond a critical amplitude of perturbation, a linearly unstable equilibrium generates multiple unstable modes which eventually leads to turbulence. Unlike above said supercritical transition, a linearly stable equilibrium, also can exhibit turbulence, if perturbed at finite amplitudes, leading to co-existence of laminar and turbulent regions [1]. Such systems are called subcritical, which often lead to structure formation. A well known example is a 3D Plane Couette Flow (PCF), where a velocity shear is produced in a fluid by moving the top and bottom confining plates at a differential speed.

Using Complex plasmas as a prototype, which are often modeled using Yukawa potential, we perform a classical "first principles" 3D molecular dynamics simulation of grains interacting with Yukawa potential of a PCF. In the first part, we consider a homogeneous Yukawa liquid between two moving plates at uniform density at a certain Γ, K values and demonstrate, for the first time, the formation of localized turbulent spot formation. Apart from Γ dependency, it is also shown that the nature of the spot strongly depends on the interaction scale,K [2]. In the second part of this work, we investigate the role of density in-homogeneity by subjecting the 3D PCF to external gravity. When such a system is perturbed, it is shown to not only exhibit laminar-turbulent coexistence but also large scale structure formation under a new class of perturbations [3], the details of which will be presented.

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JEANS GRAVITATIONAL INSTABILITY OF DUSTY PLASMA WITH DUST TEMPERATURE DUST CHARGE FLUCTUATION AND RADIATIVE COOLING FUNCTIONS

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A theoretical investigation has been carried out to show the effects of dust charge fluctuation, dust temperature and external magnetic field on radiative condensation instability in self-gravitating magnetized hot dusty plasma. We assume a three component plasma having electrons, ions and charged dust grains, in which electrons are inertialess having finite thermal conductivity and ions are inertialess having infinite thermal conductivity. The medium consists of extremely massive hot dust grains with variable charge. The basic equations of the problem are constructed and linearized. A general dispersion relation is obtained using the normal mode analysis method. The Jeans condition of instability is modified by dust charge fluctuation, dust temperature and radiative effects. Numerical calculations have been performed to show the effect of various parameters on the growth rate of radiative condensation instability.

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GRAVITATIONAL INSTABILITY OF MAGNETIZED DUSTY PLASMA WITH DUST CHARGE FLUCTUATION DUST TEMPERATURE AND RADIATIVE COOLING FUNCTION

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The problem of radiative condensation instability of gravitating dusty plasma, including the effects of dust temperature, dust charge fluctuations and the magnetic field, is investigated. The medium consists of extremely massive, negatively charged hot dust grains and Boltzmann distributed ions where the electrostatic force is much smaller than the gravitational one. We assume a three-component plasma having electrons, ions and charged dust grains, in which ions are inertia-less having infinite thermal conductivity and electrons are inertia-less having finite thermal conductivity with dust charge fluctuations. Quasi-neutral equilibrium is considered in which there is no electric field and free energy due to the gravitation field of dust grains. The basic equations of the problem are constructed and linearized. A linear dispersion relation is obtained using the normal mode analysis. The Jeans criterion of instability is determined, which depends on dust temperature, dust charge fluctuations and radiative cooling effects. The presence of magnetic field has no effect on the condition of Jeans instability. Numerical calculations have been performed to show the effects of various parameters on the growth rate of Jeans instability and radiative condensation instability. It is observed that radiation cooling, magnetic field and dust temperature increase the acoustic stabilization of Jeans instability. The presence of magnetic field and dust temperature stabilizes the growth rate of the system under consideration.

DUSTY PLASMAS IN CONDITIONS OF A GLOW DISCHARGE UNDER THE MAGNETIC FIELD UP TO 2.5 T

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Magnetic field acting on plasma particles creates the anisotropic medium in plasma with emphasized direction along power lines [1]. In dust traps in the glow discharge the dust structures can be created in an anisotropic environment and reveal new unusual properties. For example, in the glow discharge in the magnetic field of 2 T in a neon at a pressure of the fractions of a Torr, the radial diffusion step length of electrons is comparable to the dust particle size of 5 μm, while the longitudinal diffusion step length a thousand times greater. The diffusion coefficients of neon ions under these conditions differ by 5 times for longitudinal and transverse directions.

Earlier we showed [2,3] that dusty plasma in experiment in glow discharge can be created in magnetic field up to 1 T in dust traps of two types: in standing strata and in the area of narrowing of discharge current channel. It is very promising to obtain the volume dust structures in the substantially anisotropic environment; this is, for example, the gas discharge in a long discharge tube in the magnetic field. Such data will significantly advance the understanding of physical processes in gas-discharge plasma in the strong magnetic field and will complement the interesting results already obtained in dusty plasma [4-8].

In this report we present the first experimental results of the investigation of dusty plasma in the glow discharge in the magnetic field up to 2.5 T. Dusty plasma was created in two types of dust traps. A dynamics of rotational motion of dust structures were investigated by measuring a dependence of angular rotation velocity on magnetic induction. Changes in the geometric characteristics of the dusty plasma and in the glow discharge itself in the imposed magnetic field were observed.

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MOLECULAR DYNAMICS OF ACTIVE COMPLEX PLASMAS

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Active matter is the system consists of motile entities (particles) that self-propel using energy from internal energy source or consuming energy from their surrounding environment. Examples of active matter span over a vast range of scales, from macroscopic flock of birds to microscopic bacteria to molecular motors inside cells at nano scales. A large number of active entities when put together perform several intriguing collective properties [1]. In past two decades, there has been a great effort to produce artificial active or self-propelled objects that propel using several propulsion mechanisms [2]. Often, artificial self-propelled particles (SPPs) at micro scales are immersed in a background solvent, such as water. They are modeled by overdamped or non-inertial active Langevin equations [3,4]. Decrease in background density drastically increases the propulsion speeds of the SPPs, and, hence, their motion becomes underdamped or inertial. Numerical simulations of inertial SPPs demonstrate difference in many properties from that of non-inertial simulations.

Complex plasma is one of the candidates, where inertial SPPs are beginning to be realized [5]. We dub such systems as “Active Complex Plasma”, which is an important emerging area of research where fundamental physics of active matter and related numerical predictions in inertial as well as over damped limits can be put to test, using “kinetic level” experimental precision. Moreover, it could lead to numerous applications. In this presentation, we will discuss some of the novel simulation results of inertial SPPs, and indicate possible new ways to realize active complex plasma in a laboratory.

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INVESTIGATION OF NUCLEUS-ACOUSTIC WAVES IN DEGENERATE QUANTUM PLASMAS IN COMPLEX ASTROENVIRONS

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We present a theoretic model formalism methodologically constructed to investigate the stability behavioural dynamics of the nucleus-acoustic waves (NAWs) excitable in astrophysical gyrogravitating degenerate quantum plasma fluids. The explorative complex plasma model setup consists of non-degenerate heavy nuclear species, lighter nuclear species treated classically; – and quantum-mechanically treated degenerate tiny electronic species, – all coupled conjointly through the non-local long-range gravito-electrostatic interplay [1-2]. It specifically considers the active influences of the linear viscoelasticity and the nonlinear electrostatic confinement pressure (scaling quadratically with the constitutive number density). A standard normal spherical mode analysis is executed over the destabilized quantum plasma system to obtain a generalized linear dispersion relation (septic in mathematic shape) highlighting the dependency of various atypical parametric constants without any quasi-classic approximation [3]. Clearly, it gets revealed herewith that the NAWs here under exploration are the propagatory longitudinal mechanical disturbances set up collectively due to the interplay between the nuclear inertia (by heavy nuclei) and the thermal elasticity (by degenerate electrons) amid the combined action of the included dynamic factors. It is seen that the relative nuclear charge-mass coupling parameter acts as a destabilizing agency. The ratio of the charge density of heavy-to-light nuclear species acts as a stabilizing agency in both the non-relativistic (NR) and ultra-relativistic (UR) limits, respectively. It is conjectured from our study that, in both the non-relativistic and the ultra-relativistic domains, the rotational force introduces a destabilizing influence on the system (via the NAW behaviours), and so forth. A comparative analysis of the new findings is presented in correlation and consistency with the different predictions available in the literature [1-2]. Finally, we highlight the asteroseismic applicability of our analysis, essentially to see diverse wave-instability behaviours in complex degenerate quantum plasmas, mimicking practically the complex interiors of various compact astrophysical objects [1-3], such as white dwarfs, neutron stars, etc.

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THE IMPACT OF THE LUNAR MAGNETIC ANOMALIES AND EARTH'S MAGNETIC FIELD ON DUST MOVEMENTS IN THE LUNAR DUSTY PLASMA

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One-fourth of the Moon's orbit passes inside the Earth's magnetotail. However, the influence of the magnetic field of the Earth's magnetotail on the movements of the dust particles in the lunar dusty plasma is not yet clearly known. In our work, the dynamics of the dust grains in dusty plasma are studied under the effect of the magnetic field of the earth's magnetotail, where the typical magnetic fields in the magnetotail are of the order of 10^{-5}–10^{-4} G [1]. In addition, there are so-called areas of magnetic anomalies on the Moon associated with magnetic matter in the lunar crust that measured by the Apollo 12, 14, 15 and 16 missions, and amounted to $3.8 \cdot 10^{-4}$, $1.03 \cdot 10^{-3}$, $3 \cdot 10^{-5}$ and $3.27 \cdot 10^{-3}$ G, respectively [2]. Moreover, from satellite measurements [3], the largest magnetic fields are present on the invisible side of the Moon. For this purpose, a physical-mathematical model for a self-consistent description of dust grains and photoelectrons in the presence of the magnetic field is developed. Trajectories of motion of dust grains above the lunar surface are considered. It is shown that a distinguishing feature of the trajectory of a dust grain motion is the presence of oscillations. Also, one of the aims of this research is to analyze the role of variation in the charges of dust particles in the processes of formation of the dusty plasma near the Moon's surface. The behaviour of dust particles in the near-surface layer is described by the equations for their dynamics and charging. Calculations, allow the determination of dust particle trajectories. The parameters characterizing the motion of a dust particle with the radius a=105 nm and the charge $q_d = eZ_d$ for the subsolar angle θ=87° are shown in Fig. 1. Finally, the study of the influence of the Earth's magnetic field on the dust transport above the surface of the Moon performed here shows the possibility of the existence of positively charged dust and correspondingly, the presence of dusty plasmas at the sunlit side of the Moon for the whole range of the lunar latitudes. On the other hand, the influence of the magnetic anomaly regions on the dynamics of charged dust particles over the Moon does not lead to new qualitative effects.

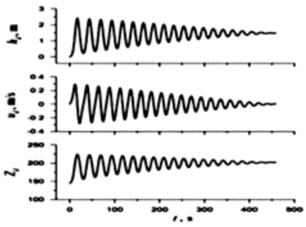

Fig. 1. Parameters characterizing the trajectory of the dust particle with the radius a=105 nm and with a variable charge above the Moon at θ=87°.

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MODIFIED ZAKHAROV-KUZNETSOV EQUATION FOR DESCRIPTION OF NONLINEAR PERTURBATIONS IN PLASMA OF DUSTY LUNAR EXOSPHERE

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Modified Zakharov-Kuznetsov equation describing nonlinear dynamics of nearly one-dimensional wave structures in magnetized dusty plasma above illuminated part of the Moon in the regions of lunar magnetic anomalies [1] is derived. The equation differs from the ordinary Zakharov-Kuznetsov equation [2] by the nonlinear term being non-analytical. An analytical expression governing one-dimensional soliton solution of the modified Zakharov-Kuznetsov equation is obtained. The solution differs from the well-known one-dimensional soliton solutions of the Korteweg–de Vries and ordinary Zakharov-Kuznetsov equations. The stability of the soliton solutions of the modified Zakharov-Kuznetsov equation is investigated by the method of small-k perturbation expansion. It is found that the character of the stability is dependent mainly on the magnetic field and the propagation directions of both the nonlinear waves and their perturbation modes.

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NONLINEAR EXCITATIONS OF DUST ION ACOUSTIC WAVES IN MULTISPECIES PLASMA

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The omnipresence of dusty plasmas has engendered a conspicuous interest since the preliminary observations of Saturn's rings by the Voyager spacecraft. Dusty plasmas have been under intense scrutiny by plasma physicists for comprehensive research in various nonlinear structures under different velocity distributions. So, it is of paramount importance to analyze different nonlinear excitations in dusty plasma. In the present investigation we have studied the characteristics of two-dimensional small amplitude dust-ion-acoustic wave in Vasyliunas-Cairns (VC) distributed plasma. Using appropriate transformation, the KP equation is transformed into nonlinear Schrödinger equation (NLSE) and its different order solutions are used to study the characteristics of breathers such as the Akhmediev breather and the Kuznetsov–Ma breather. It is remarked that all different physical parameters have great influence on the characteristics of breather waves. The findings of this investigation may be useful in understanding the nonlinear structure in space dusty plasma like Saturn's magnetosphere.

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FROM RAYLEIGH-BÉNARD CONVECTION CELLS TO SHEAR FLOWS: A MOLECULAR DYNAMICS STUDY OF 2D YUKAWA LIQUIDS

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Rayleigh-Bénard convection cells (RBCCs) are considered as one of simplest paradigms of a non-equilibrium driven-dissipative system. Using “first principles” classical molecular dynamics simulations, RBCCs have been observed under the effect of external forces viz., temperature gradient and gravity (both acting along same direction) in 2D Yukawa liquids [1]. Such RBCCs can further be used as a model system to understand non-equilibrium processes such as negative entropy production rate [2]. One can also study formation of RBCCs in inhomogeneous charge-mass Yukawa liquids, where the inhomogeneity is introduced at particle-level [3].

Large scale vortices or convective cells are found in a wide range of problems, such as from Tokamaks to Solar interiors to Planetary atmospheres to Tea pots and more [4]. Thus understanding the stability of such structures is of paramount interest.

In present study, we investigate the stability of RBCCs, using classical “first principles” molecular dynamics simulation, under a class of particle-level velocity perturbations, where the RBCCs are shown to become unstable, leading to one-dimensional (1D) shear flows in a direction perpendicular to both external temperature gradient and external gravity [5]. It is found that the nature of the emerged 1D shear flows depends on the type of the perturbation introduced, the system’s aspect ratio, correlation strength, as well as other system parameters, the details of which will be presented [6].

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HIGHER CORRECTIONS TO NONLINEAR STRUCTURES IN POLARIZED SPACE DUSTY PLASMA

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Dust is a ubiquitous component in space and different astrophysical environments. Dusty plasma has wide range of applications in various fields (viz. medical field, microelectronic, industry etc.). Since from Voyager spacecraft observations, radial spokes in Saturn's rings, it becomes very fascinating topic for theoretical as well as experimental research [1]. So, it is of paramount importance to analyze different nonlinear structures in dusty plasma. Due to deformation of Debye sheath around the dust particles, the polarization force comes into play and have great influence on the characteristics of nonlinear dust acoustic modes. In present work, we have derived the expression polarization force for Cairns-Tsallis (CT) distributed ions and studied the higher order corrections to dust acoustic (DA) shock structures under the influence of polarization force in a dusty plasma composed of negatively charged dust fluid, Maxwellian electrons and CT distributed ions. Our work is basically inspired from the difference in theoretical and experimental results and also due to role of CT distribution that provides a better way to explicate in various space and astrophysical regions. By imposing reductive perturbation method, the Burger and linear inhomogeneous Burger-type equations are derived and using tanh method their solutions are derived. It is remarked that contribution of higher order corrections and CT distributed ions may play an important role on the characteristics of DA dressed shock waves. It is augmented that the findings of present theoretical investigation actually effectuate in laboratory experiments and in space/astrophysical environments, in particular in Saturn's magnetosphere.

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IMPACT OF DUSTY PLASMA ON CURRENT SHEETS AT DIFFERENT HELIOCENTRIC DISTANCES. OBSERVATIONS FROM ULYSSES AND PARKER SOLAR PROBE

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We report observational evidence for a strong impact of dust on variations of plasma parameters, in particular, the solar wind temperature at current sheets in the heliosphere from the smallest heliocentric distances of tens solar radii ever reached by a spacecraft to several AU. Despite the common knowledge that (i) dust grains are charged, (ii) current sheets represent specific sites at which there is a change of the direction and parameters of the local magnetic field, and (ii) the change of the field polarity causes variations of the spatial characteristics of small dust grains, very limited number of studies considers dust as a source of noticeable effects at current sheets in the solar wind. We analyze plasma and dust observations from the two unique spacecraft, one of which, namely recently launched Parker Solar Probe, has measured parameters of the young solar wind as close to the Sun as several tens solar radii, and the other, Ulysses, is the only spacecraft that observed heliosphere far above the ecliptic plane. It has been known from observations with the resolution of a second made at the Earth orbit and further downstream that thin current sheets (TCSs) may be observed hundreds times per day. According to recent high-scale observations from Parker Solar Probe obtained with a microsecond resolution, TCSs occur up to tens thousands times a day. We have found that the solar wind temperature drops, sometimes significantly, at the heliospheric current sheet and TCSs simultaneously with the decrease in the small-size dust grain flux associated with the TCSs crossing, while the density of larger-size dust grains increases. We suggest that, on one hand, the occurrence of the heliospheric current sheets and TCSs impacts spatial distribution of dust significantly, especially at low heliolatidues and small heliocentric distances, and, on the other hand, the presence of dust dramatically changes parameters of the solar wind plasma at current sheets and leads to poorly investigated effects such as the temperature decrease. The latter may contribute to the explanation of puzzling variations of the solar wind temperature throughout the heliosphere.

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IONIC MOBILITY IN PARENT RARE GASES

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A very important characteristic of low-ionized plasmas is the mobility of ions under the action of an electric field. Often a simplified assumption is made that the ionic mobility is constant. This is not consistent with experimental measurements, which have shown that, for the most interesting case of atomic rare gas ions in their parent gases, the mobility decreases with increasing electric field strength. No general expression for the dependence of the ion mobility M on the electric field strengths E and the neutral gas number density N is known. At the same time, several theoretical approxi-mations have been suggested in the literature. Among the approximations that have been put forward, one of the most simple and convenient for practical use is the semi-empirical formula proposed by Frost [1]:

$$M_F = A\left[1 + B\frac{E}{N}\right]^{-1/2}.$$

The semi-empirical Frost formula represents just one particular simple way to interpolate between the limiting regimes of weak and strong electric fields. Generally, it is in a rather good agreement with experimental results on the drift velocities of rare gas ions in their parent gases. There is, however, some room for improvements. The purpose of this work is to demonstrate that a modest modification of the Frost formula allows us to reach excellent agreement with numerical data for different gases in the entire range of electric fields and gas temperatures, where experimental data is available. The expression we put forward is

$$M = A\left[1 + \left(B\frac{E}{N}\right)^{C_1}\right]^{-1/2C_2},$$

where C_1 and C_2 are the parameters of order unity (for C_1=C_2=C=1, M=M_F), as well as at normal and low temperatures. This formula is correct in the corresponding limits of weak and strong electric fields. The new expression is almost as simple as the original one, but agrees considerably better with experimental results for different systems considered in the wide regime of parameters investigated.

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THEORETICAL ASPECTS OF THE COSMIC DUST IMPACT ON THE HELIOSPHERIC CURRENT SHEET

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Most of solar wind models suggest the existence of maximum of both the solar wind density and temperature at low heliolatitudes. However, observations show that the solar wind density behaves in agreement with models, while the temperature has two maxima with a minimum at the heliospheric current sheet (HCS). Surprisingly, none of theoretical effects associated with current sheets can explain the observed temperature decrease. We claim that the occurrence of cosmic dust at the HCS is responsible for the observed phenomenon. Indeed, according to in situ observations (see Khabarova et al., this meeting), the concentration of medium-size space dust is significantly enhanced at current sheets in the solar wind. We provide estimations of the possible impact of dust on the solar wind plasma temperature in the vicinity of the HCS, taking into account that particles of dust possess a magnetic moment and a nonzero electric charge. Collisions between dust and solar wind plasma particles make possible the energy exchange between them. Since dust particles can be far slower than solar wind ions, dust cools the solar wind plasma and takes its energy away. The results obtained in the study are in a good agreement with observations.

We are grateful to RFBR grant no. 19-02-00957.

FAST MULTI-GPU PYTHON CODE FOR SELF-CONSISTENT CALCULATION OF FORCES, ACTING ON DUST PARTICLES IN A PLASMA ENVIRONMENT

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During the last decades several codes for self-consistent calculation of forces, acting on dust particles in a plasma environment, have been presented: SCEPTIC [1], COPTIC [2], DRIAD [3], MAD [4], DUSTrz [5], Dip3D [6]. The main problem of the direct simulation of dusty plasma for self-consistent calculation of the forces, acting on the dust particles, is the resource intensity of such simulations. For example, calculation of the ion drag force, acting on a solitary dust particle in a plasma flow, with COPTIC code takes from 1 hour to several days. In addition, source code is available only for two of listed packages, SCEPTIC and COPTIC.

Here, we present a new multi-GPU based Python code for self-consistent calculation of forces, acting on dust particles in a plasma environment. That code is very fast and makes it possible to calculate ion drag force, acting on a solitary dust particle in a plasma flow, in a time from several seconds to a few minutes. In addition, the code supports simulation of dusty plasma systems with an arbitrary number and configuration of dust particles, making it possible to self-consistently calculate forces, acting on dust particles, in complex systems like chain structures, dusty plasma crystals, monolayers, etc. The code is distributed under MIT license and is available at GitHub. The code can be simply installed via conda installer, it has user-friendly Python interface and is illustrated with the growing list of examples. We have verified our code against previous dusty plasma simulations.

The developed code will make it possible to make a qualitative breakthrough in the study of complex plasma.

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UNIQUE PROPERTIES OF THE DUSTY PLASMAS SYSTEM

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Dusty plasmas is an ionized gas containing macroscopic particles of condensed matter. In such systems, the properties of the dust component are actively studied, especially under conditions when dust particles acquire a significant charge and interact strongly. Due to the strong interaction, the dust subsystem can have a high degree of nonideality and be characterized by various states of aggregation - gaseous, liquid and crystalline. Kinetics of particles in these states can be observed directly by video microscopic methods.

Dust particles in gas discharge plasma are subject to a number of various elementary processes. This leads to several properties, for example, to fluctuations of particle charge and fluctuations of mass of dust particles, and to their dependence on the environment, as well as to changes in time. The charge of a dust particle affects the surrounding plasma and interaction with surrounding dust particles, which leads to the number of instabilities. The interaction of a charged dust particle with an ion flow under conditions of a gas discharge leads to the appearance of a wake potential, the development of coupled-mode instability, and several other effects. The mentioned effects in plasma cause the anisotropy of the dusty subsystem. When the discharge temperature changes, the distance between dust particles can decrease by several times, which significantly corrects the set of phenomena that determine the properties of the dust subsystem. The presence of an electrostatic trap often leads to inhomogeneity of the structural and dynamic properties of the subsystem.

The fundamental openness and self-consistency of the plasma-dust system, the variability of the charge of dust particles and the dependence of the charge on the parameters of the environment, the high dissipativity and significant influence of stochastic processes, the non-Hamiltonianity and observed self-organization, as well as the ease of obtaining and observing the system in a wide range of parameters and conditions make it a unique object of study and open up great opportunities for the study of such complex self-consistent systems and mutual influence of the mentioned unique properties.

This work considers a number of properties of dusty plasma and phenomena in it, which look unusual and even unique in the physics of ordinary matter, and it also considers some effects of these unique properties.

ACTIVE BROWNIAN MOTION OF PARTICLES IN A PLASMA INDUCED BY LASER RADIATION WHEN MODIFYING THE SURFACE OF THE PARTICLES

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Plasma containing microparticles is widespread in nature – in space, in technological processes [1]. In the plasma of an RF discharge, it is possible to form levitating Coulomb systems using micron-sized particles differing in shape and composition, as well as to observe a wide range of effects. The action of such an active medium as plasma can lead to the development of unique properties by macroparticles. As a result, their behavior in the Coulomb system can change dramatically: passive Brownian particles can become active. Active Brownian particles are capable of autonomously converting the available environmental energy (chemical, electromagnetic, thermal, etc.) into their own mechanical motion, which may allow observation of various phenomena in the structures of such particles, such as phase transitions, clustering, self-organization, etc.

The results of an experimental study of the composition and surface structure of polymer particles during their exposure in a quasi-dimensional structure formed in a capacitive radio-frequency discharge plasma [2], as well as the results of the analysis of the trajectories and mean square and linear displacements of such particles during their movement in the Coulomb system under the influence of laser radiation [3] are presented. Exposure of polymer particles in the Coulomb system leads to deposition of metals on their surface - a metallic island film is formed on the surface of the particles. When exposed to laser radiation, particles with a modified surface begin to exhibit properties characteristic of active Brownian particles. A metallic film on the surface of the particles can effectively absorb the laser radiation, resulting in a significant photophoretic force that contributes to the movement of macroparticles. The mechanism of conversion of laser radiation energy into motion energy, resulting from surface modification, allows the polymer particles to change their motion dynamics and the degree of their activity when varying the power of the acting laser radiation.

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LOCALIZED WAVE STRUCTURES IN THE DUST-FILLED SATURN'S MAGNETOSPHERE

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The possibility is considered of propagation of localized wave structures, such as dust acoustic solitons, in the plasma of the dust-filled Saturn's magnetosphere, which contains electrons of two sorts (hot and cold) subject to kappa distribution, ions, and charged dust grains. The ranges of possible velocities and amplitudes of the solitons are determined. Soliton solutions for different sizes and concentrations of dust grains in the dust-filled Saturn's magnetosphere are found.

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EXTENSIVE ACTIVE BROWNIAN SYSTEMS IN COLLOIDAL PLASMAS: DYNAMIC ENTROPY AND FRACTAL DIMENSION

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Recently, the problems considering the dynamics of so-called active Brownian, or self-propelled, particles, become more and more essential. These particles possess the unique property to convert external energy into the kinetic energy of their motion [1]. The nature of these particles may be various: colloid grains in buffer media, protozoa and bacteria, chemically activated particles and even mechanical objects [1]. Active Brownian particles and structures made of them, thanks to their ability to transform energy, have some exceptional properties and features which are interesting both for the fundamental science and for the practical tasks – in biology, medicine, engineering [1].

The entropy and other instruments used in the framework of physics of dissipative systems are universal, and they can be successfully applied to study the evolution of active Brownian systems. In this work we use the approach proposed in [2] – the calculation of the mean first-passage time (MFPT) dynamic entropy. With this approach, one can describe the motion of each separate (active or passive) Brownian particle with the help of several parameters (such as the fractal dimension of its trajectory and the size of the localization area), compare the different regimes of motion with each other.

We have analyzed the experimental data on the motion of active Brownian micrograins in RF-discharge plasmas. Two types of microparticles were considered: 1) plastic grains fully covered with metal; 2) Janus particles with a thin metal cap. The trajectories of separate grains were obtained, pair correlation functions of the structures were plotted. We have studied the dependencies of the MFPT dynamic entropy on the coarsening parameter, the fractal dimension of the system on its mean kinetic temperature, the mean localization area of the grain on its mean kinetic temperature. Based on the obtained results, we conclude that the character of motion of our active Brownian systems changes as the power of illuminating laser (and therefore the mean kinetic temperature of the grains) increases. We have revealed two critical points for metal-covered particles. For the Janus particles, we have observed the monotonous growth of the mean localization area and the decrease of the mean fractal dimension of their trajectories with increasing kinetic temperature T. That is the evidence that the motion of Janus particles becomes less chaotic and more directed as the system warms up.

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SIGNATURES OF AEROSOL PARTICLES DETECTED BY THE VHF METEOR RADAR IN THE MESOSPHERE – LOW THERMOSPHERE REGION

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The VHF (36.9 MHz) meteor radar operating at high latitudes in Sodankylä Geophysical Observatory (SGO, 67° 22' N, 26° 38' E, Finland) sometimes detects meters-scale electron density irregularities with lifetime of the order of 0.1 s, which are associated with aerosol or dust particles at the meteor height (70–110 km). First, such irregularities were detected at the height of noctilucent clouds (at 81–83 km) in the cold high-latitude mesosphere in summer time. This phenomenon is a kind of the polar mesosphere summer echo (PMSE) originated due to ~100-nm ice particles in the presence of the enhanced ionization by tens-keV electron precipitation. Second, similar irregularities are created during intense meteor showers when meteor smoke particles play the role analogous to the ice in the PMSE. Third, a similar, although much stronger, effect was observed on 9 December 2009 when a 36.8 metric tons solid propellant ballistic rocket was self-destroyed at a distance about 500 km from SGO, at an altitude of 170–260 km. In this case the meteor radar received unusual echoes, which indicated turbulence of ionospheric plasma (irregularities of electron density) with temporal scale of the order of 0.1 s and spatial scale of a few to tens meters. Obviously, aerosol particles of the missile remains (presumably composed of aluminum oxide) played a key role in producing the electron density irregularities. Such electron density irregularities can be qualitatively explained by the presence of charged dust (aerosol) particles immersed in a turbulent flow. An alternative mechanism is that sedimented by gravity and, hence, moving with respect to the air, charged aerosol particles might produce meter scale irregularities (electrostatic waves) via dissipative instability, which mechanism is analogous to that of the resistive beam-plasma instability.

DUST PARTICLE LOFTING FROM SUBSTRATE EXPOSED TO LOW-ENERGY ELECTRON BEAM AND LOW-TEMPERATURE PLASMA

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Several experiments showing that a particle can be lifted off a surface by a plasma, an electron beam or their combination were conducted last three decades [1,2]. Researchers suggested several mechanisms of such a lofting [1,2] and used simple numerical models to investigate the phenomenon, but a satisfactory explanation is still missing.

In this work, we carried out the simulation of a single micrometer-sized dust particle lofting from a substrate exposed to a low-energy electron beam (70 eV, flux ~10^{12} $cm^{-2}s^{-1}$) and a low-temperature plasma (n_e ~10^8 cm^{-3}, T_e~1 eV) by means of the particle-in-cell numerical model [3]. As a result we assumed the combined effect of electron and ion accumulation between the substrate and the particle (see fig. 1) to be the mechanism of partricle lofting. By varying the electron beam – plasma ratio, we investigated a range of conditions and found that a plasma addition to an electron beam drastically changes the mechanism of particle lofting from electron accumulation to ion accumulation. The simulated lifting force equals to several nanoNewtons and diminishes with the rise of the plasma density. The simulated lifting force has stochastic nature that is consistent with a fluctuation mechanism suggested by previous experimental works as responsible for the lofting phenomenon [1]. The independence of the lifting force on the substrate thickness and the particle size was established. The independence on the substrate thickness makes the lofting possible from a substrate as thin as a naturally formed oxide layer. The independence on the particle size was used to estimate the maximum size of the particles can be lofted (~10 um).

The results can be of interest for dust mitigation in the semiconductor industry, the lunar exploration, and the explanation of the dust levitation.

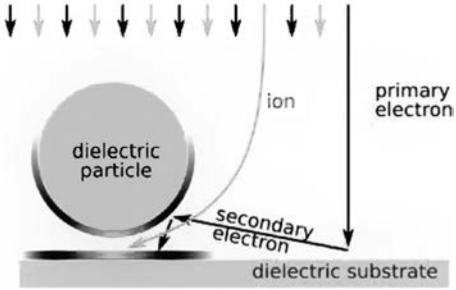

Fig. 1. The mechanism of charge accumulation and electrostatic lofting.

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CALCULATION OF THE ELECTRON DISTRIBUTION FUNCTION PERTURBATION BY AN ELECTRIC FIELD IN A WEAKLY IONIZED GAS ON THE BASIS OF BOLTZMANN EQUATION

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Anisotropic component of electron distribution caused by a weak electric field is determined by means of solving Boltzmann kinetic equation. The Boltzmann's collision term has been substantially simplified by applying the well-known simple model of the electron collisions with neutral particles of a gas as elastic encounters between rigid spherical balls. In doing so, effective cross section for the elastic scattering and electron mean free path are constant. Within the framework of such a model of the discrete electron-neutral particle interactions, the loss part of the collision term is calculated exactly without resorting to any approximate techniques, including usually applied Fokker-Plank approximation. In its turn, the gain part can be transformed to an ordinary integral with a certain kernel function instead of the original 5-fold integral. It is shown that contribution of the gain term to electron balance in velocity space is small, as applied to the calculation of the anisotropic part of the electron distribution function. Physically, by this is meant that the perturbation of the electron distribution due to the electric field is almost completely compensated by the loss of electrons due to collisions in steady state. As a result, the solution of the seemingly complicated Boltzmann's kinetic equation is found almost automatically. Refinement of the well-known expression for the anisotropic part of electron distribution obtained with the help of Fokker-Plank diffusion approximation of the collision term can be done by a simple multiplication of the corresponding formula by a certain function of electron velocity. The essential difference between the solutions of the Boltzmann and Fokker-Plank equations is manifested in behavior of the distribution function at electron velocities comparable with thermal velocity of the neutral particles of the gas. In particular, in contrast to the solution of the kinetic equation based on the Fokker-Plank representation of the collision term, the anisotropic component of the true distribution function vanishes at electron velocity equal to zero, since an electron at rest cannot contribute to flux and current density. In the course of the calculations carried out, explicit expressions for the kernel functions of the integral kinetic equations necessary for solving similar and other problems of physical kinetics have been found in the form of expansions in powers of small electron-neutral particle mass ratio within the framework of the accepted model of collisions.

GYRATING ION BEAM DRIVEN DUST ACOUSTIC WAVE INSTABILITY IN A COMPLEX PLASMA

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Through Cerenkov interactions, a low-frequency electrostatic dust acoustic waves (DAWs) have been driven to instabilities by negatively charged dust grains comprised in a plasma cylinder, where a Gyrating ion beam having velocity $\vec{v}=(v_{\perp}\hat{\theta}+v_{b0}\hat{z})$ has been propagating. For the typically existing parameters of dusty plasma, numerical calculations of phase velocity, unstable wave frequency and growth rate have been performed. With relative density $\delta(=n^{0i}/n^{0e})$ of negatively charged dust grains, an enhancement in the unstable wave frequency and in the growth rate have been noticed. This is due to the fact that adding of dust into plasma increased the instability, so our growth rate will grow up. Consequently, with the beam density, an increment in the growth rate of unstable dust acoustic wave mode has been reported. It is scaled as 1/3rd of the beam density. Additionally, with the beam energy, an enhancement in the real part frequency of the unstable mode has also been reported. It is scaled as 1/2nd power of beam energy. In laboratory as well as in astrophysical plasmas, the outcome of this work shall find useful applications.

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STRONGLY COUPLED ROTATING DUST FLOW ANALYSIS WITHIN THE QUASI-LOCALIZED CHARGE APPROXIMATION (QLCA) FRAMEWORK

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Rotational flow has been observed in magnetized [1] and unmagnetized [2] laboratory dusty plasma experiments. It is also an inseparable ingredient of the dynamics of most astrophysical objects. Recent experiments on strongly coupled rotating dusty plasma demonstrate a remarkable dynamical analogy between the effects of rotation and magnetization, as the Coriolis force mimics the effects of the Lorentz force in a rotating frame[3,4]. It is of immediate interest therefore to work out a Quasi-localized charged approximation (QLCA) formulation that explicitly accounts for dust rotation in a strongly coupled Yukawa system, and analyze the combined effects of strong coupling, dust rotation, and a strong magnetic field. For that, we have constructed a full QLCA theory [5] for the strongly coupled rotating dusty plasma and analyzed their collective modes dispersion characteristics which are strongly dependent on the strength of the Coriolis force acting exactly as Lorentz force. The obtained longitudinal dispersion relations show a finite jump of a frequency (2Ω) at $k \rightarrow 0$ which corresponds to the cyclotron frequency (ω_c) in the presence of a magnetic field. The close correspondence, at a higher rotational frequency (Ω), between the strong and the weak coupling limit of the theory has been emphasized in their dispersion relation concludes rotation tends to reduce the coupling among the dust particles as observed in recent rotating dusty plasma experiments [3,4]. These results from theory predict that strong coupling effects compete with the strong magnetic effects in the rotating dusty plasma viz strong coupling effects are limited by rotation rate.

Moreover, nonlinear excitations in their inertial (non-rotating) frame have also been investigated, for the first time, within the QLCA framework. The analytical and numerical results have been compared with phenomenological models.

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DUST VORTEX FLOW ANALYSIS IN WEAKLY MAGNETIZED PLASMA

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Vortex solutions of dust cloud suspended in magnetized plasma are relevant to numerous laboratory and astrophysical situations. The dust vortex flows studied in the context of unmagnetized situations essentially involve non-conservative, drag or friction – like fields. Considering vortex flows in magnetized situations dust vortex flow model driven by a combination of pure conservative fields, is presented. A 2D hydrodynamic approach is considered in presence of a non-uniform magnetic field. A drift based mechanism is considered, in which ambipolar electric field generated by the polarization of electron E×B drift, drives the dust vortex flow. A sheared E×B drift flow is facilitated by the ambient magnetic field gradient. The analytical stream-function solutions have been analyzed with varying magnetic field strength, its gradient and the kinematic viscosity of dust fluid. Considering its non-laboratory applications, the effect of B field gradient is analyzed complementing the effect of E field gradient usually present in the plasma sheath.

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PROPAGATION OF ELECTROMAGNETIC WAVE IN QUANTUM DUSTY MAGNETOPLASMA WITH TWO DIFFERENT ELECTRON SPIN STATES

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Dusty plasma is an ionized gas containing dust particles. Dusts are micron-sized particles that become electrically charged through interaction with the background plasma causing them to act as a third charged plasma species. The dust particulars are quite common in different environments of space and astrophysical plasmas such as interstellar medium, interplanetary space, molecular clouds, planetary rings, Earth's environments and in low-temperature laboratory dusty plasmas devices [1,2]. The evolution of intrinsic spin effects of electrons in dusty plasma is significant when it is cooled down to an extremely low temperature such that the de-Broglie thermal wavelength [3,4] associated with the charged particle is comparable to or larger than the inter-particle distance. In such a condition, the Fermi temperature which is related to equilibrium density of charge particle must be greater than the thermal temperature of the system. Till now, the plasma electrons in dusty plasma were considered as a single fluid. In the present paper, we consider the existence of two electrons population namely spin-up and spin-down relative to the background magnetic field. The spin state of particles will be also perturbed by the presence of electromagnetic waves. The separation of spin is well defined provided the force associated with spin flip [5,6] can be neglected.

The present paper is devoted to the study of propagation of electromagnetic wave in quantum dusty magnetoplasma with two different spin states of electrons. The effects of quantum Bohm potential, electron Fermi pressure and spin magnetic momenta has been analyzed taking into account the difference in spin-up and spin-down concentration of electrons caused by external magnetic field. The longitudinal dispersion relation for electromagnetic waves in dusty magnetoplasma has been setup. The right circularly polarized, left circularly polarized wave, ordinary mode and extra-ordinary mode have been analyzed. Growth rate has been calculated and effect of spin polarization has been studied.

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LUNAR DUSTY PLASMA INVESTIGATION INSTRUMENTS ONBOARD "LUNA-25" AND "LUNA-27" SPACECRAFTS

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One of the complicating factors of the future robotic and human lunar landing missions is the influence of the dust. The upper insulating regolith layer is electrically charged by the solar ultraviolet radiation and the flow of solar wind particles. Resulted electric charge and thus surface potential depend on the lunar local time, latitude and the electrical properties of the regolith.

Recently we have some reemergence of the interest of Moon investigation. Number of governments, space agencies and collaborations declared their intentions to build manned orbit stations or surface bases in next decades. In Russian space program developing the polar lunar base is also stated.

In the following years several missions are also under development, including "Luna-25" lunar lander project (to be launched in 2022) and "Luna-27" lunar lander.

Dust analyzer instrument PmL for future Russian lander missions intends for investigation the dynamics of dusty plasma near lunar surface. PmL consists of three parts: Impact Sensor and two Electric Field Sensors.

Impact sensor purpose is to investigate the dynamics of dust particles near the lunar surface (speed, charge, mass, vectors of a fluxes).

Possible detectable events may occur with:

a) high speed micrometeorites

b) secondary particles after micrometeorites soil bombardment

c) levitating dust particles due to electrostatic fields.

PmL instrument will measure dust particle mechanical momentum. Also Impact Sensor will measure the electrical charges of dust particles. In case the charge and impulse of a dust particle are measured with properly timestamps of events, we can calculate the velocity and mass of the particles.

Electric field Sensor will measure the value and dynamics of the electric fields near the lunar surface. The measurement technique is based on classic Langmuir probe plasma investigation method. Two Electric Field Sensors allow to measure the concentration and temperature of charged particles (electrons, ions, dust particles). Using Langmuir probes near the surface through the lunar day and night, we can obtain the energy spectra photoelectrons in various periods of time.

For the "Luna-27" mission a lot of the PmL instrument improvements proposed. One of the most important is to develop a mechanical Boom to deliver dust and plasma sensors as far as 1 m from the spacecraft body as well as to locate the dust sensors near the lunar surface and plasma sensors at the different levels above the surface.

GROWTH RATE FOR THE ELECTROSTATIC SURFACE WAVE IN A DUSTY PLASMA WITH COLLISION-DOMINATED ION STREAM

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The streaming instability has attracted much attention in various plasmas and astrophysical environments since it can be used to explain the various physical dynamic phenomena including the heating mechanism in plasma systems or the mechanism for the formation of planetesimals in space [1,2]. It has been shown that when collisions are important, as is often in the case of complex plasmas, the susceptibilities of the collision species must contain the appropriate collisional effects [3,4]. Thus, in this work, we investigate the influence of electron-ion collision frequency and dust charge on the growth rate of two-stream instability of the electrostatic surface wave propagating at the interface of semi-bounded complex plasma composed of electrons, negatively charged dusty particles, and streaming ions. We find that the surface wave can be unstable if the multiplication of wave number and ion flow velocity is greater than the total plasma frequency of electrons and dusty particles. The analytical solution of the growth rate is derived as a function of collision frequency, dust charge, and ion-to-electron density ratio. We also find that the growth rate is inversely proportional to the collision rate, but it is enhanced as the number of electrons residing on the dusty grain surface is increased.

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COMPARISON OF STOCHASTIC AND CONTINUOUS DUST CHARGING MODELS APPROPRIATE TO PMSE

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Polar Mesosphere Summer Echo (PMSE) is a phenomenon associated with electron density irregularities caused by nano-meter sized dust particles (ice crystals). The charging of the dust particles is an important issue. For micro-meter sized particles, continuous (OML) charging model was well developed [1]. For nano-meter sized aerosols, stochastic charge fluctuation is important and discrete charging model [2] is more appropriate. Furthermore, the effect of polarization [3,4] should be accounted for nonmetallic dust particles.

This paper compares the average dust charge numbers calculated using the discrete and continuous charging models with and without considering the effect of polarization. The results show that, for sub-micrometer sized dust particles in the PMSE regions (typical dust radius r_d~10 nm, electron and ion temperatures T_e = T_i ~150 K, and ion mass ~50 atomic mass unit), the average charge number Z_d is significantly higher when considering the polarization effect than that without considering the polarization effect as shown in figure 1(a). Furthermore, for small particles (r_d < 10 nm) the discrete model predicts a flat region of Z_d≈1 that is almost independent of r_d (see inset of figure 1(a)). For larger particles (r_d >10 nm), both models predict linear increase of Z_d with r_d and the difference between the two models is small (within 11%). For micrometer-sized particles of typical laboratory dust plasma (T_e~1 eV, T_i~0.1 eV, Ar plasma), on the other hand, the stochastic charge fluctuation is insignificant since a dust particle carries at least several thousand elementary charges, and the difference between the results with and without considering the effect of polarization is very small (only about 2%), as shown in figure 1(b).

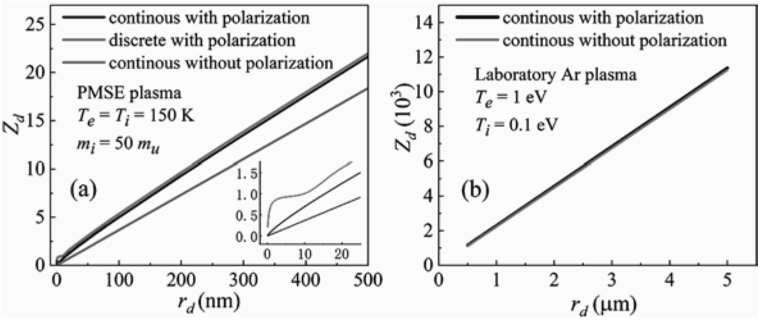

Fig. 1. Variations of average dust charge number Z_d with its radius r_d for (a) sub-mircrometer and (b) micrometer sized particles.

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ROGUE WAVES AND ACOUSTIC VORTICES IN DUST ACOUSTIC WAVES: FROM WEAKLY DISORDERED WAVES TO WAVE TURBULENCE

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The transition from the ordered plane wave through the weakly disordered state with unstable single-scale waveforms to the wave turbulent state with multiscale fluctuations, ubiquitously occurs in various nonlinear wave media, such as chemical waves, water surface waves, optical waves, acoustic waves. In the unstable states, rogue waves (the extremely large amplitude localized events which uncertainly occur), and topological defects (the null amplitude localized events with undefined phases), are the basic coherent singular excitations for characterizing wave dynamics. Past studies on the above excitations mainly based on the Modulation instability for one dimensional nonlinear waves but to a less extent on higher dimensional waves.

The advantages of video monitoring dust density evolution and tracking single dust motion over a large area make the dust acoustic wave (DAW) a good platform to construct Lagrangian-Eulerian pictures for understanding the generic spatiotemporal dynamical behaviors of nonlinear unstable waves. In this talk, our past following experimental studies on the generic dynamical behaviors of the high and low amplitude singular coherent excitations in the unstable dust acoustic waves will be reviewed: a) the observation, generation, and correlation of rogue waves and acoustic vortices (AVs) with helical wave fronts winding around defect filaments in weakly disordered single-scale DAWs, b) decomposing wave turbulence into multi-scale modes and viewing turbulence as a zoo of multiscale interacting AVs, and c) rogue wave generation in DAW turbulence through synchronization and focusing of multi-scale waves [1-6].

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EFFECTIVE INTERACTION BETWEEN DUST PARTICLES IN GAS DISCHARGES

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When micron-sized particles are immersed in a gas discharge with ion flow, they acquire significant negative charges and can create ion wakes by the flow of ions past particles. The resulting "particle–particle" interaction is effectively nonreciprocal: a microparticle experiences an electrostatic repulsion from the like-charged adjacent particles and an effective attraction to their ion wakes. In the general case, the effective force acting on one particle from another is a complex function that depends on the parameters of the dust, surrounding weakly ionized gas and electric fields, as well as on the relative position of the dust particles.

In this report, the results of several experiments investigating the interaction between dust particles in gas discharges are presented. Several non-intrusive methods were used to determine the interparticle interaction forces, including: the spectral density analysis of random processes [1], correlation approach [2], and solution of the inverse Langevin problem for an underdamped system [3]. The experiments were carried out in two types of discharges: the capacitively coupled RF discharge and stratified glow DC discharge. The interaction between a pair of particles in the direction along and across the ion flow was investigated depending on the parameters of gas discharges and the plasma-forming gas composition. For multiparticle quasi-two-dimensional plasma-dust systems, the effect of structure ordering on the interparticle interaction was found.

An experimentally observed feature of dispersed systems with non-reciprocal interparticle interactions is a higher kinetic energy of particles compared to the temperatures of all components of the surrounding medium. Theory predicts that the average kinetic energy per particle in such systems consists of an effective thermal energy due to the translational noise acting on the particles from the environment (noise-induced heating) and additionally pumped energy due to the work of the effectively non-reciprocal forces of interparticle interaction (nonreciprocity-induced heating). The kinetic heating of particles with non-reciprocal interparticle interaction was experimentally studied on the example of two microparticles suspended in the stratified glow DC discharge. Using the spectral method [1], we were able to determine the contributions of different heating mechanisms to the total kinetic energy of the dust particles. We proposed and experimentally verified analytical equations to calculate the magnitude of heating caused by the non-reciprocity.

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OCCURRENCE AND ALTITUDE OF THE NON-SPECULAR LONG-LIVED METEOR TRAILS

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Meteoroids entering the Earth's atmosphere produce the ionized trails, which are detectable by radars. Majority of such radar detections are the echoes from cylindrical ionized trails, which occur if the radar beam is perpendicular to the trail, i.e., the reflection is specular. Typically such echoes last less than one second. However, sometimes meteor radars observe unusually long-lived meteor echoes and these echoes are non-specular. The long-lived non-specular (LLNS) echoes last up to several tens of seconds and show highly variable amplitude of the radar return. The LLNS echoes are received from trails of bright meteors and it is believed that key role in their generation belongs to the aerosol particles arising due to fragmentation and burning of large meteoroids. The dust particles forming from the meteoric material are immersed in a turbulent flow, which leads to the meter-scale electron density irregularities, similar to what ice particles do for the polar mesospheric summer echoes. We have analyzed data of the meteor radar operating in the Sodankylä Geophysical Observatory (SGO, 67° N, 26° E, Finland) since 2008, and found that usually about 3% of all meteor radar detections are LLNS echoes, however during peaks of some major meteor showers (Geminids, Perseids, Quadrantids, Arietids or/and Daytime ζ-Perseids, and Lyrids) the percentage is larger, up to 7–10%. On average, the LLNS echoes occur ~2 km higher than other echoes, and even higher (up to 3–6 km) during Lyrids, η-Aquariids, Perseids, Orionids, and Leonids. These meteor showers are clearly identified in the occurrence and height distributions of LLNS meteor trails because of the specific properties of the meteor dust particles.

A STUDY OF MODULATION INSTABILITY AND ROUGE WAVE PROPAGATION OF DUST ELECTROSTATIC WAVES IN MAGNETIZED PLASMAS

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The modulational instability (MI), envelope soliton formation and rogue/freak wave creation of dust acoustic wave (DAW) and dust cyclotron wave (DCW) are investigated in a magnetized dusty plasma. The electron and ions are assumed to follow the Boltzmann distribution, while the negatively charged dust is taken to be dynamic. Using Krylov-Bogoliubov-Mitropolsky (KBM) method, the nonlinear Schrödinger equation (NLSE) is derived and criteria of MI (or unstable regions in terms of wave number) of modulated DAW and DCW are investigated numerically which depends on dusty plasma parameters such as electron, ion and dust densities ratio and magnetic field intensity and electron-ion temperature ratio and wave propagation angle with respect to the external magnetic field. The product of dispersion and nonlinear interaction coefficients (appear in NLSE) is obtained which depends on magnetized dusty plasma parameters and corresponding stable and unstable regions in terms of wave number of modulated dust-acoustic and dust cyclotron waves are determined numerically for the dark and bright envelope soliton structures. It is also found that within the unstable regions, a random perturbation of the amplitude grows and thus leads to a creation of a rogue wave. The rational solution of NLSE is also presented with its numerical analysis to study the effect of dusty plasma parameters on the DAW and DCW rogue wave profiles. The higher order or super rogue wave solutions of the modulated DAW and DCW are also discussed. The results are applicable to understand nonlinear wave propagation or energy transport phenomenon in magnetized dusty plasma environment which can exist in space and laboratory plasmas.

CONTROLLED PHOTO-DISCHARGING IN A DUSTY PLASMA

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Photoelectric charging of dust particles in a plasma has been investigated in the past and is a primary charging mechanism in astronomical dusty plasmas. However, photoelectric charging of dust in low-temperature, laboratory plasmas is difficult due to the high work functions and poor photoelectron yields of most conventional dust materials (like silica) and the substantially larger particle fluxes onto the dust in laboratory LTPs compared to astronomical plasmas. A new experiment at Auburn University utilizes lanthanum hexaboride (LaB_6) powder and a high intensity near-UV source to try and demonstrate controlled photo-discharging of dust in a weakly ionized, argon, DC glow discharge. Data extracted from dust videos along with Langmuir and emissive probe data are presented.

ELECTRON DENSITY OF IONOSPHERE E AND F REGION DURING SOLAR FLARE

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Using the Thomson scatter, it's been possible to look at detailed ionospheric effects because of solar flares. Observations are limited to four 2B flares, and two of those events are examined intensively. The two events that are studied exhibit very similar characteristics, i.e., a powerful and long-lasting E-region electron density enhancement, a moderate and shorter duration Fx-region enhancement, and a moderate F2-region enhancement characterized by a long-duration 'tail.' Flare X-ray data, available within the 2- to 12-angstrom band, shows excellent agreement with electron density fluctuations within the lower E region. The Fx-region enhancement is believed to follow the time history of the EUV ionizing radiations. The F-region tail is attributed to the much smaller recombination rate at these heights. Plasma-line observations, permitting unequivocal measurement of electron density, are possible within a limited height range. Comparison of electron density, as deduced from the plasma lines, with back scattered power measurements corrected for the consequences of absorption, has resulted in estimates of flare-associated changes within the ratio of electron to ion temperature.

GRAVITY AS A VARIABLE; USING DUST GRAINS AS PROBES IN THE PLASMA SHEATH

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The plasma sheath is highly interesting because most applications rely on the processes that take place in this region. Experimental characterization of the elementary processes and parameters in the sheath region of a radio frequency driven low pressure argon discharge is to a large extent impossible using traditional techniques, such as Thompson scattering or Optical Emission Spectroscopy. An alternative manner to study this region is to use a single micro meter sized particle immersed in the plasma's sheath as a diagnostic probe. Micro particles have been used as probes extensively in research studies over the last decade.

Major issue that comes with the usage of such 'probes' is that only the net result of all (plasma-induced) forces together on the microparticle can be observed and that none of these forces can be studied individually. One of these forces is the mysterious thermophoretic force which is induced when a local gradient in the gas temperature is present.

In this work we apply 1–11g hypergravity conditions in a centrifuge to explore thermophoresis due to plasma-heating of the electrodes while keeping all other forces on the particle-probe unchanged.

NUCLEATION AND AEROSOL DYNAMICS IN DIFFERENT HYDROGEN-CARBON CONTAINING PLASMAS

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Particle formation in dusty reactive plasma is the consequence of precursors molecular growth [1]. Once nucleation occurs growing particles are charged and can play a key role in the plasma equilibrium [2].

We propose to study these phenomena using a modeling approach that takes into account molecular growth, nucleation process, aerosol dynamics along with the plasma dynamics in different discharge conditions and for different precursors. We will compare situations where particles are formed (i) by the sputtering of a graphite cathode in DC discharge, (ii) in MW acetylene discharge and (iii) and RF C_2H_2 discharges. We will especially discuss the possible nucleation pathways and the competition between the different phenomena involved in the aerosol dynamics : effect between nucleation, growth through surface deposition and coagulation. We will also show how the presence of magnetic field can enhance nucleation routes involving positively charged ions

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BISPECTRAL ANALYSIS FOR NONLINEAR MIXING IN DUSTY PLASMA

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Bispectral analysis [1] is a statistical tool to predict the origin of modes due to the mixing of fundamental modes based on the phase information that is otherwise lost in a power spectrum analysis. This work utilises bispectral analysis to confirm the nonlinear mixing [2,3] in dusty plasma. The medium's dynamics is governed by a periodically driven Korteweg-de Vries (KdV) equation in the weak nonlinearity regime. Physically, our model represents the mixing of two dust acoustic modes originating in different spatial locations in the medium and then propagating to mix with each other.

For this driven KdV representation, we have provided a semi-analytic form of the solution. The model equation admits an exact analytic solution for a time-dependent sinusoidal forcing. The analysis confirmed the predominant three-wave mixing leading to a rich spectrum of modes comprising fundamental modes, harmonics, subtraction and addition frequencies.

The time-dependent forcing (sinusoidal and cnoidal) based KdV model shows considerable similarity with experimentally obtained wave-spectrum [4]. However, a second harmonic mode was found absent, and a few additional modes were reflected theoretically. This gap was filled when a travelling waveform of the forcing was employed with the KdV model. Thus, a travelling wave driven KdV system provided the best representation of experiments [4]. Our results provide a model that can also be explored for other dispersive fluid mediums.

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A CHARGE DISSIPATION MECHANISM WITHIN PERMANENTLY SHADOWED CRATERS

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The Moon undergoes different phases under solar illumination. However, some parts near the poles never see sunlight, called permanently shadowed regions. The craters near the poles (e.g., Shoemaker, Shackleton) have been of particular interest, which are supposed to be in the dark for billions of years, and are like cold traps. These cold trap regions might not only be confining the water and hydrogen-based compounds but also the pristine signatures of the Moon's evolution. Hence, these locations are the focus of forthcoming lunar exploration programs. However, under the influence of the orographic effect, the solar wind constitutes mini-wakes and induces a complex and exotic electrical environment within the permanently shadowed craters (PSCs) [1-5] – it has been the quest for how sensitive the maned/ robotic missions are in such a scenario.

In fact, the plasma neutrality breaks down near the crater flank edge, and low inertia (randomized) electrons create an electron cloud (ion-free) region on the leeward side – it may be extended to a few km within the crater. In this electron-rich region (ERR), the crater (or object) surface may acquire an indefinite negative charge, and the charge dissipation from the surfaces has been an open question for a long.

We propose that the fine particles lying on the surface act as field emission (FE) centres (just like field emitters) [2]. Under a high electric field, as in ERR, these FE centres become the significant source of electrons that can prevent the crater surface from acquiring a large electric charge/ potential. This return FE current can efficiently neutralize the electron collection and maintains the surface at a finite potential. For instance, PSC having ~100 nm dust with 1% of the areal coverage, the crater surface may acquire a negative potential of ~100's V. This phenomenon is also pertinent with a fine irregular structure on the crater surface to dust scale (e.g., the amorphous ice within polar craters).

This concept not only resolves the fundamental issue of charge dissipation in PSCs but also suggests a solution for the instrument/ human operations near the leeward face and ERR. The massive charge buildup can be remediated by introducing microstructure tips (through surface engineering) on the fabric/ surface of the moving object. In this context, we particularly discuss the surface drilling operation within ERR [5], where the object suffers massive triboelectric charging effects. The concept has potential implications for the forthcoming robotic/ human missions to the Moon.

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SELF-CONSISTENT RELAXATION THEORY OF COLLECTIVE PARTICLE DYNAMICS IN ONE-COMPONENT YUKAWA LIQUID

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A one-component plasma is the most suitable multiparticle system for the development of the microscopic theory of liquids. This is mainly due to the specific potential of interparticle interaction, as well as due to available experimental data and the results of molecular dynamics simulations, which can be used to verify the correctness of theoretical conclusions. In this work, we will present the microscopic theory of the collective dynamics of particles (ions) of a single-component plasma, where only the interaction potential – the Yukawa potential – and the structural characteristics – the particle pair distribution function and the structure factor – are used as input parameters. It will be shown that the microscopic theory is realized on a wide range of wave vectors; it generalizes the hydrodynamic theory and reproduces the known hydrodynamic expressions in the long-wavelength limit. The theory correctly reproduces all the known features of the spectra of the dynamic structure factor for a wide range of wave numbers, as well as the dispersion law of acoustic-like collective excitations. The theoretical results obtained are compared with the results of known theoretical models and approaches.

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THE SIZE DISTRIBUTION OF DUST IN PROTOPLANETARY DISKS AND THE EFFECTS OF CHARGING DUST PARTICLES

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The processes of dust charging in the plasma of protoplanetary disks are considered. Self-consistent numerical simulations of the dust particles dynamics in ambient plasma together with X-rays radiation transfer in various regions of protoplanetary disks using a combination of Monte Carlo and particles-in-cell methods are performed. We show that in the atmosphere of the disk dust grains can acquire anomalously high positive charges, which can lead to their destruction in the process of the Coulomb explosion. The charging occurs as a result of the combined effects of radiation from a protostar, electron and ion currents from the surrounding plasma. The size distribution of dust particles in different regions of protoplanetary disks is calculated. The effects of influence of radiation of explosive stars on the dust particles charging in protoplatenary disks are discussed.

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SOME ASPECTS OF MODULATIONAL INTERACTION IN EARTH'S DUSTY IONOSPHERE INCLUDING DUSTY PLASMAS OF METEOR TAILS

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Development of modulational instability involving dust acoustic perturbations in dusty ionospheric plasma and in dusty plasmas of meteor tails in Earth's ionosphere was considered. The effect of collisions of electrons, ions, and dust grains with neutrals at different altitudes was estimated. It is shown that, in this case, the influence of collisions of electrons and ions with neutrals is usually less significant than the influence of collisions between dust grains and neutrals. It is demonstrated that the effect of the modulational instability on the propagation of electromagnetic waves in the dusty ionospheric plasma is the most significant at heights of 100–120 km. The values of the wave vectors of the electromagnetic pump wave at which inelastic collisions with neutrals are important for the development of modulational interaction are calculated. The modulational interaction in the dusty ionosphere is important for the explanation of different phenomena such as ground-based observations of low-frequency ionospheric radio noises with frequencies below 60 Hz. The absence of observations of low-frequency ionospheric radio noise during such phenomena as noctilucent clouds and polar mesosphere summer echoes caused by the presence of dusty plasmas at heights of 80–95 km is explained by suppression of the development of the modulational instability at these heights. The role of inelastic collisions with neutrals in meteor tails is also discussed. It is shown, that for typical parameters of dusty plasmas of meteor tails such collisions do not influence the development of the modulation instability in meteor tails. It is shown there is a good agreement of the theory amplitude of modulational magnetic fields perturbations in the meteoroid tails with the observed magnetic fields during meteoroid passes.

INFLUENCE OF THE NEUTRAL SHADOWING FORCE ON PROPERTIES OF DUSTY PLASMA UNDER CRYOGENIC CONDITIONS

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This work is devoted to the investigation the influence of the neutral shadowing force on the properties of dusty plasma under cryogenic conditions at low gas pressure and temperature [1,2]. The results of computer modeling on the basis of molecular dynamics methods are presented. Calculations were made for different values of the coupling and screening parameters. A significant deviation of properties was observed with increasing of the strength of neutral shadowing force. Temperature ratio of the dust particle surface to that of the surrounding gas, in low-pressure weakly ionized complex plasmas, was used to study a dust particle heating at cryogenic conditions [3]. Electron as well as ion fluxes to the dust particle surface in a weakly collisional case are considered [4]. It was shown previously, that at distances comparable with average inter-dust distance, the neutral shadowing interaction appearing due to large temperature difference between the grain surface and surrounding gas can lead to a significant changes in the structural properties of a cluster of dust particles [5].

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INHOMOGENEITY OF PHASE STATE IN A DUSTY PLASMA CRYSTAL

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Dusty plasma has long been considered as a toy model system for the condensed state of matter. Micron-sized dust particles forming ordered structures in gas-discharge plasma are available for direct observation, photo- and video imaging. This makes it possible to study transport processes, crystal lattices, behavior of active particles and even phase transitions in such systems.

In most studies, dusty plasma structures are considered to be spatially homogeneous, like infinite Yukawa matter. Kinetic temperature, inter-particle distance and non-ideality parameter are often averaged over an entire structure. For this reason, properties and phase diagrams of 2D and 3D Yukawa systems are often applied to dusty plasma systems that are observed in experiments.

Still, non-uniformity is characteristic of dusty plasma crystals. In [1] it is discussed that density profile of a harmonically trapped Yukawa structure is principally non-uniform: the further from the center of the system, the higher the value of inter-particle spacing. Outer shells of a Yukawa ball are less dense than inner ones. Further analysis [2] shows that non-uniformity of structural properties in such systems directly leads to inhomogeneity of dynamic ones, for example, Lindemann parameter. Lindemann parameter is often used for the melting criteria, and its nonuniformity points at the possibility of a non-uniform phase transition in a system with a uniform temperature distribution. Non-uniform melting has been recently reported in a harmonically confined Yukawa system in [3] by means of molecular dynamics simulations.

In this work, inhomogeneity of a classical Yukawa system in a parabolic trap is further analyzed. Its melting is currently under consideration. The obtained results are applied to dusty plasma systems in an approach that additionally takes into account anomalous heating of particles, charge fluctuations, and interaction of particles with the surrounding gas. It is shown that effects of inhomogeneity are manifested in dusty plasma also. New methods of experimental analysis are proposed, comparison with experimental results of another groups [4] is discussed.

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METHOD FOR CONTROLLING THE PARTICLE SIZE IN DUSTY PLASMA IN GAS MIXTURES WITH DIFFERENT IONIZATION POTENTIALS

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During the formation of dusty plasma in a plasma trap the injected particles that can be retained in the dust structure are selected. In the most general case, for a quantitative study of the particle selection process, it is necessary to use polydisperse particles of arbitrary shape in a wide size range, as well as to use a dust trap capable of retaining a bulk dust structure. There are studies in the literature concerning the problems of selection of particles in discharges, for example [1], but the use of polydisperse particles was studied only in works [2-3].

For a systematic study of the problem of selection of dust particles during the formation of dusty plasma, a method for controlling the parameters of plasma (dust trap) is proposed in this paper. Such characteristics of a low-temperature low-pressure plasma as the electron temperature and the longitudinal electric field depend on the type of discharge gas (its ionization potential). By adding a small amount of heavy gas Xe to the lightest inert gas He, one can actively control the parameters of the trap, and hence the size of levitating dust particles.

In this paper, we present experiments in which dust particles were selected from the trap in standing stratum of a glow discharge by the method proposed in [2,4] (with the addition of a small amount of Xe to the main working gas He). Particle size distributions were constructed, and the average particle sizes and distribution widths were determined depending on the amount of Xe additive. For example, the size of dust particles in traps varies from 3.4 μm to 6.5 μm under experimental conditions. The conditions for particle levitation depending on the observed size are estimated, based on a cycle of theoretical calculations [5-6]. The influence of impurities on the characteristics of ions and electrons, the discharge parameters and the charge of dust particles were taken into account.

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INVESTIGATION OF THE DYNAMICS OF ROTATION OF A DUST STRUCTURE IN A STRIATION DEPENDING ON THE NUMBER OF PARTICLES IN A MAGNETIC FIELD

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In the study of dusty plasmas, various threshold effects are observed. For example, when observing a single particle in a striation in a magnetic field, the particles own rotation was observed [1,2]. The threshold for the appearance of a flow of plasma formations under laser shear effects was observed [3,4]. As well as the effect of the appearance of rotational motion of plasma-dust structures [5,6].

In this work, we studied the behavior of a dust cluster in a glow discharge striation in a magnetic field in two gases Ne and Ar. The dependence of the angular velocity of cluster rotation on the number of particles in the cluster cross section is obtained. A non-monotonic nature of the dependence of the angular velocity of rotation in both gases was found. In Ar, a threshold character of cluster rotation is observed, while in Ne, rotation occurs in a cluster consisting of two particles.

A possible reason for the appearance of rotation under these conditions may be the action of the ion drag force, which appears due to an increase in the electron temperature inside the dust structure.

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ENERGY SATURATED AEROSOLS IN THE EARTH'S ATMOSPHERE

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Rocket and balloon experiments in the middle atmosphere (10–100 km) at different latitudes of both hemispheres of the Earth, including the geomagnetic equator, made it possible to estimate the spatiotemporal variability of the lower ionosphere, its relationship with cold gaseous and dusty atmospheric plasma, atmospheric aerosol, and galactic cosmic ray fluxes.

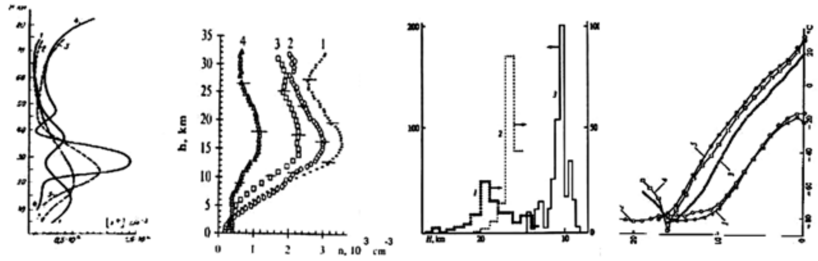

Fig. 1. Left: latitudinal variations in ionic concentration. after and before noon (dotted line)). 1 – 0°, 178° E, 2 – 1° N, 165° E, 3 – 35° N, 151° E, 4 – middle latitudes [1]. Left 2nd: ion concentration profiles at the stations of rocket sounding of the atmosphere of the Central Aerology Observatory: s. Molodezhnaya, curve 1 (0.4 GV), curve 3, s. Balkhash, Kazakhstan (5.3 GV), curve 4 TERLS (Thumba Equatorial Rocket Launching Station), India (17.3 GV) and the balloon test site of the Central Aerology Observatory: in Rylsk, curve 2 (3.3 GV). [1].
3rd: the number of energy-saturated aerosol particles N that passed through the flow reactor during parachuting of the payload of the M-100 rocket and calculated for 1 km in a free atmosphere: curve 1 – December 3, 1987 (day); curve 2 – December 5, 1987 (night); s. Thumba, 8° N; curve 3 – August 25, 1987 (early morning, sun 10 degrees above the horizon); s. Molodyozhnaya, Antarctica, 68 S 4th: temperature profiles according to radiosonde data: at Molodezhnaya station (August 19 and 26, 1987 (curves 1 and 2); at Thumba station (November 25, December 5 and 7, 1987 (curves 3, 4 and 5, respectively) [1]

For the first time, energy-saturated aerosols were detected in the air, which were emitted during their flight from a cold (-600C) atmosphere through a warm (~400) flow reactor. It is necessary to evaluate their role in the mechanism of operation of the global electrical circuit as well as at UV transients observed from satellites of Moscow State University.) [2]. We have established for the first time that these light phenomena are associated with lunar-solar gravitational tides.

Experiments with thermal catalytic sensors [1] confirmed the existence of layers of energy-saturated particles in the stratosphere and mesosphere. Data obtained by others are given, which confirm their existence and other indirect experimental data confirming their existence.

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EVOLUTION OF CHARGED ACTIVE BROWNIAN GRAINS IN SUPERFLUID HELIUM

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The observation of processes in nature and social phenomena shows that many complex structures, consisting of a large number of interacting subsystems, under certain conditions have the ability to self-organize and evolve. The structures are called dissipative, provided that the scattering of energy coming from outside provides a stationary ordered structure with an entropy less than the equilibrium one. The dissipative structures are capable of self-organization and evolution while increasing the flow of entropy into the environment [1,2].

In recent years, active Brownian motion has attracted great interest in biology, physics, sociology, material science, and epidemiology. While passive Brownian grains are in thermal equilibrium with their environment, active Brownian grains are able to absorb energy from their environment and turn it into their kinetic energy that displaces them from thermodynamic equilibrium [3]. Thus, the systems of active Brownian grains can be considered as open systems, and the structures of grains themselves are systems far from thermodynamic equilibrium.

Active Brownian grains can be charged particles suspended in plasma or levitated in a cryogenic liquid (cryogenic colloid), the kinetic motion of which is induced by laser radiation. In this case, the state of grains is maintained by the free energy of radiation.

We provide experimental evidence for the active Brownian motion and evolution of structures driven by quantum effects for micron-sized grains levitating in superfluid helium. One of the fundamental problems here is the role of quantum phenomena in the evolution of macroscopic objects.

The active Brownian motion of grains was induced by quantum turbulence during the absorption of laser irradiation by grains. The intensity of Brownian motion associated with quantum vortices increased by 6-7 orders of magnitude compared to the values from the Einstein formula. We observed the grain structures in a state far from thermodynamic equilibrium and their evolution to more complex organized structures with lower entropy due to the quantum mechanism of exceedingly high entropy loss in superfluid helium.

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MANIFESTATIONS OF ANOMALOUS DISSIPATION IN DUSTY PLASMA SYSTEMS

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Anomalous dissipation is an important aspect that should be taken into account when considering the problems of dusty plasmas. It is not possible to take into account the anomalous dissipation in a universal way. Sometimes it is associated with the processes of dust particle charging (a). Sometimes more important processes are the absorption of plasma particles (electrons and ions) on dust particles (b). When considering nonlinear wave structures, case (a), as a rule, corresponds to a shock wave, while case (b) fits weakly damped solitons. If the intensities of the processes of dust particle charging and the processes of absorption of plasma particles are comparable, then the soliton-like perturbation is transformed into shock wave. There are different dusty plasma systems in our Solar system, where anomalous dissipation can determine the character of dusty plasma processes (the Moon, dusty coma of a comet, etc.). Here, dusty plasma problems, where anomalous dissipation is important, are discussed.

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LANE FORMATION DYNAMICS IN 3D STRONGLY CORRELATED PAIR-ION PLASMAS

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Lane formation is an example of non-equilibrium structure formation. We investigate the dynamics of lane formation in 3D strongly correlated pair-ion plasmas (PIP) under the influence of external electric and magnetic forces using extensive 3D Langevin Dynamics (LD) simulation. In our model, positively charged particles (say, type A) are pulled by external force component $\vec{F}_A$ while the negatively charged particles (say, type B) are pulled by external force component $\vec{F}_B$. Interestingly, when $\vec{F}_A$ and $\vec{F}_B$ are parallel, the system undergoes a phase transition to Lane state parallel to applied external forces beyond a critical external field strength. Lanes of like species of particles are formed which move collectively along the field direction; while lanes of positive and negative particles move opposite to each other. Appropriate diagnostic technique like instantaneous order parameter [1,2] is implemented to detect lane formation. Further, in presence of time varying fields, spontaneous formation and breaking of lanes is not observed for all values of field strengths, as previously reported in 2D cases [1,3,4]. However, in 3D case, such effect is observed for applied field strengths close to critical field strength value. A critical frequency ω_c of the applied field also exists above which the lane state breaks and the system transits to a disordered state. Furthermore, the study in presence of external magnetic field reveals the existence of a drift of lanes in a direction perpendicular to both electric and magnetic fields. However, the presence of magnetic field delays lane formation process. In this work, several of the above said results will be discussed in detail.

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COSMIC MICROWAVE BACKGROUND RADIATION IS NOT A RELIC OF UNIVERSE EXPANSION BECAUSE OF COSMIC DUST

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The CMBR evolved from models of the Big Bang by Gamow beginning in 1948. Only later in 1965 did Penzias and Wilson discover the microwave radiation coming from space. Dicke and others concluded the CMBR would still be present in the Universe as blackbody EM radiation with a expansion of the Universe. Today, the CMBR is thought to be blackbody radiation at temperature ~2.7 K at 160 GHz. However, the Oort Cloud is spherical about the Sun having a blackbody temperature T depending only on the distance D from the Sun having radius Rs and temperature Ts by,

$$T=Ts\sqrt{\frac{Rs}{2D}}.$$

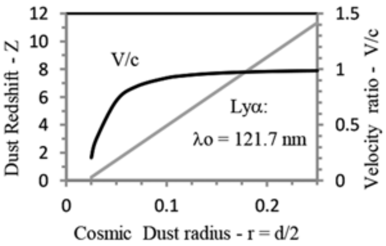
For Ts = 5800 K, Rs = $693\cdot10^6$ m, au=$150\cdot10^9$ m, and D=10,000 au at the inner radius of the Oort Cloud, the T ~ 2.72 K.

The Oort Cloud blackbody temperature T ~2.72K at 10,000 AU was not recognized as the CMBR temperature because redshift measurements suggested the CMBR exists at distances >> 10,000 AU.

Cosmic dust permeates the Solar System and absorbs galaxy light prior to reaching the Earth. Today, dust absorption is thought [1] to increase temperature to produce IR spectra. But dust is nanoscopic that by the Planck law lacks the heat capacity to increase in temperature. By the theory of simple QED, conservation of an absorbed galaxy photon [2] proceeds by the emission of a photon observed on Earth as a redshifted galaxy photon. For a galaxy photon of wavelength λ_o absorbed in a dust particle of diameter d and refractive index n, the observed photon wavelength 2nd gives the dust redshift z,

$$z=\frac{V}{c}=\frac{2nd-\lambda_o}{\lambda_o},\ 2nd>\lambda_o,$$

where V is galaxy velocity and c the speed of light. Hence, dust redshift overstates the velocity of galaxies in the Universe. For n=1.5, and galaxy light taken by the Lyman-α line, cosmic dust redshift is shown below.



What Penzias and Wilson were measuring in 1965 was likely blackbody radiation from the Oort cloud that today is known as CMBR given by the black body temperature of ~2.7 K at frequency 160 GHz. Gamow's Big Bang model advanced by Dicke and concluding the CMBR was the relic of Universe expansion is highly questionable as the CMBR created in the Oort cloud of our Solar system suggests the Big Bang never happened.

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GENERATION OF MICRODROPLET PLASMA CRYSTALS

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Dusty plasma is a plasma containing particles suspended in it [1]. Practically in all experiments carried out in a glow discharge at low gas pressure, solid particles are used to form a dusty plasma structure. This work is a continuation of research [2] on obtaining dusty plasma structures from liquid microdroplets.

The purpose of this work is to develop a bench for controlled generation of liquid plasma-dust structures with a given size and number of microdroplets injected into DC plasma at low gas pressure (10–100 Pa). The solution of this problem will make it possible to obtain and study a new class of plasma-dust structures.

The created stand consists of a gas discharge tube, a system for providing vacuum and supplying a working gas, a laser system for visualizing a dusty crystal, a high-voltage power source for igniting a gas discharge, a high-speed video camera with a lens system for controlling the process of building a dusty crystal, and a device for injecting microdroplets.

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COMPUTER SIMULATION OF COMPLEX PLASMAS UNDER EXTERNAL MAGNETIC FIELD

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Complex plasmas at ordinary conditions (i.e. unmagnetized or weakly magnetized dust particles and neutrals (ions) at room temperature) have been experimentally as well as theoretically investigated in details. Further development of the field is towards new domain with extreme conditions such as strong magnetic field [1], ultracold temperatures [2], and microgravity [3,4]. Clearly, theoretical and simulation analysis of complex plasmas at these extreme conditions are in demand. Therefore, we have performed theoretical investigation of complex plasma at extreme conditions. The recent results of this investigation will be presented in this contribution. Among them are the results of MD/Langevin simulation based study of the waves, particles caging characteristics and particle charging in strongly coupled magnetized dusty plasmas [5-8], and characteristics of wakefield [9]. Interesting observations are the novel effects due interplay between friction and magnetization, anomalous wakefield and plasma polarization around charged grain, to mention but a few. In addition to the new results, problems for further investigations and open questions will be discussed.

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DUST GENERATION, TRANSPORT AND REMOBILIZATION IN FULL-METALL FUSION REACTORS

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Modelling of the interface between the plasma and the fusion reactor wall is a highly challenging task as the problem involves various aspects of disparate physics disciplines. On one side of 'the border', complicated plasma effects are dictated by classical electromagnetism. Near the interface, intense plasma-material interactions are governed by quantum mechanics. On the other side, the metallic melt (produced by incident heat loads) evolves according to the fluid mechanics laws. In addition to solid or liquid material boundaries surrounding plasmas, there are also dust particles, a by-product of plasma-surface interaction, whose remobilization from surfaces and collisions with the vessel are described by contact mechanics and impact mechanics.

The design, licensing and operation of magnetic confinement fusion reactors impose various limitations on the amount of metallic dust particles residing inside the plasma chamber. In this context, predictive studies of dust production and migration constitute one of the main sources of relevant data. These are mainly conducted using dust transport codes, which rely on coupled dust-plasma and dust-wall interaction models, and require external input on the dust and droplet initial conditions. In this talk, we discuss some of the microscopic processes occurring on the plasma-material boundaries in fusion-relevant scenarios and modelling approaches for predictive studies of metallic dust transport and in-vessel accumulation [1].

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NUCLEATION AND CRYSTAL GROWTH IN SUPERCOOLED YUKAWA FLUIDS

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The rate of formation and growth of the crystal phase in the supercooled Yukawa fluid was studied numerically and analytically. The analytical model was based on the classical nucleation theory and used the parameters calculated by the method of molecular dynamics (MD): the specific energy of the phase interface γ and the difference of the chemical potentials $\Delta\mu=\mu_{bcc}-\mu_{liq}$. The value of Δμ was calculated for the point of crystallization using the results of [1]. The linear temperature dependence of the chemical potentials in the conditions of the phase transition was assumed both for a liquid and for a crystal. The value of γ was calculated similarly to [2] for the (100) crystal surface.

The obtained data were compared with the results of MD simulation of crystal phase formation and growth in supercooled Yukawa fluid. The approach proposed by Y. Sun [3], based on the use of an external harmonic potential for a small part of the ensemble's atoms, was applied to accelerate the critical nucleus formation process. The simulations were performed for four different points along the melting line at a constant temperature of T=300 K.

The results were used for estimation of the parameters γ and Δμ, which were applied for prediction of the velocity of motion of the crystal-liquid interface in a process of supercooled liquid crystallization.

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DUSTY PLASMA SYSTEM IN THE MARTIAN IONOSPHERE

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We present a self-consistent model of dusty plasmas in the Martian ionosphere. Our model is based on theoretical models of the Earth's atmosphere from [1-3] and is supported with experimental data from [4-6]. We describe formation and evolution processes of dusty plasmas clouds and investigate thoroughly condensation processes near the condensation zone boundary. We calculate typical values of dust particle sizes and charges in such clouds. Our theoretical results are in agreement with the data of observations. We explore temporal variations of electron and ion number densities in cases of presence and absence of photoelectric effect.

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NONLINEAR ELECTROSTATIC STREAMING INSTABILITIES IN VISCOELASTIC QUANTUM DUSTY PLASMAS

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The field of quantum dusty plasmas is an immensely growing field of research due to its broadband applications ranging from nanoscales to astrophysical scales of space and time. Apart from diverse nanoelectro-mechanical devices, the quantum degenerate matter is found to exist naturalistically in many astrophysical compact objects, such as the interiors of white dwarfs, neutron stars, giant planets, and core-collapse supernovae [1,2]. The constituent particles in such circumstances form a degenerate system under the extreme physical conditions of high density and low temperature [1]. The streaming instability arises here due to the relative motion (Doppler-shifted) of the compositional plasma fluids to relax towards the plasma equilibrium via the collective electrostatic wave excitation processes [2,3]. The instability is switched-on by the kinetic energy available with the flowing species in the form of free energy towards a relaxed state. It is triggered by the zeroth-order electric currents and their dynamical coupling processes. Such instabilities widely exist in varied conditions of laboratory, space, and astrophysical fluids. The proposed model treats the inertialess electrons as degenerate quantum fluid; whereas, the inertial ions and dust particles classically as linear viscoelastic fluids. Besides, it considers a dimensionality-dependent parameter, $\gamma=[(D-2)/3D]$, termed as the Bohmian quantum correction prefactor, D being the system dimensionality.

A theoretic model is herein developed to investigate the nonlinear electrostatic streaming instability modes acceptable in viscoelastic quantum dusty plasmas consisting of weakly correlated electrons, ions, and strongly correlated dust grains. A weakly nonlinear perturbative analysis against the defined equilibrium is employed using the standard multiple scaling techniques. As a consequence, the perturbed plasma system reduces to a unique form of the Korteweg-de Vries (KdV) equation with atypical multi-parametric coefficients. A numerical analysis results in diversified solitary pulse-like structural patterns. The pulse amplitude increases with dust grain mass and vice-versa. A reliability checkup is put forward in light of the current astronomical scenarios [1-3]. Finally, we coherently stress on the varied astronomical circumstances consistent and relevant to this presented study.

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SUPER ROGUE WAVES AND ROGUE WAVE TRIPLETS IN A SPACE DUSTY PLASMA

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Over the last many years, study of linear and nonlinear phenomena in dusty plasmas has been frontline arear of research. A different kinds of wave modes formed in dusty plasmas have been studied by the numerous scientists to understand the underlying physics in various laboratory, space and astrophysical environments. Polarization force plays very important role to influence the wave dynamics in weakly/strongly coupled plasmas. Among variety of nonlinear structures, rogue waves have been found to occur under different situations in space/astrophysical environments and also observed in laboratory experiments. In the present investigation, the effect of polarization force and other plasma parameters have been studied on the characteristics of freak waves in dusty plasmas comprising of hot electrons and ions obeying non-Maxwellian distribution. Multiple scale perturbation technique has been employed to derive the non-linear Schrodinger equation (NLSE). Further, its rational solutions have also been determined to study the propagation properties of freak waves. We have determined the critical wave number threshold where the modulational instability sets in. The variation of this critical wave number has been analysed under the influence of various physical parameters. The combined effects of polarization force, and other plasma parameters significantly influence the amplitude and formation of rogue waves. Further, We have studied the super rogue waves and rogue wave triplets in this investigation This study may be helpful in understanding the formation of coherent nonlinear structures in Earth's polar cap boundary layer, where high energy electrons and ions have been observed. This study may also be of great importance to understand the formation of nonlinear structures in Saturn's rings environments.

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METHOD FOR MEASURING NONRECIPROCAL EFFECTIVE FORCES OF INTERACTIONS USING THE SPECTRAL DENSITY OF RANDOM PROCESSES

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Recently, quite a few studies have appeared on the so-called "violation" of the interaction symmetry. Such a formal failure to comply with Newton's third law may arise, for example, when a particle subsystem in a medium is considered while the medium itself is indirectly taken into account through the potential of interparticle interaction, dissipative forces or as a source of particle kinetic energy. A striking example of such systems are some types of soft matter e.g., flowing colloidal suspensions, active colloids and gas-discharge complex (dusty) plasmas where the geometry of interactions between particles plays a key role in the processes of self-organization, self-assembly, transfer and redistribution of energy, and nonequilibrium phase transitions. In addition to the fundamental physics that can be examined, the study of these systems is also of particular interest for nano- and micro-technological applications.

To study this phenomenon, an experimental method based on an analysis of the spectral density of random processes in an open dissipative system was developed. The method makes it possible to measure the stiffness of the interaction forces and the external (from the side of the electrostatic trap) forces, the particle friction coefficient and the temperatures quantifying the translational noise intensity (thermal source) in the gas discharge. In contrast to previous investigations, the proposed method takes into account random and dissipative processes in the system, does not require a special design of the experimental setup and any external perturbations, pre-measurements of external fields and any assumptions about the type of interaction.

A comparative analysis of the spectral method with other non-perturbing methods was also carried out. Significant advantages of the spectral method are noted. The development of a method for studying multiparticle chain structures of dust particles was proposed. For the first time, interaction forces were obtained by direct measurement. There was a significant violation of the symmetry of the interaction, as well as a fundamental difference in the nature of the interaction between the lower and upper neighbors.

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COMPLEX ELECTROSTATIC STRUCTURES WITHIN CRATERS OVER SUNLIT MOON

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The horizontal glow observed during Surveyors and Apollo missions were the very first signatures of the electrostatics environment over the Moon [1-2]. Being an airless body, the Moon's sunlit surface directly interacts with the solar radiation and solar wind plasma. Solar radiation in the EUV and UV range knocks out photoelectrons from the surface. Due to dominant photoemission flux, the sunlit lunar surface generally acquires positive charge and the photoelectrons form a sheath in its vicinity. The lunar surface, however, is full of craters/ boulders/ highland structures. The presence of such surface relief results in non-trivial effects on the sheath features and give rise to complex electric potential and electric field within the sheath [3].

Here, we present, an analytical formulation and numerical simulation of the photoelectron sheath formation within a crater. The justified solar spectrum, solar wind flux, Fermi Dirac distribution of the photoelectrons have been taken into account. The sheath's potential and electric field profiles are determined by numerically solving Poisson's equation with appropriate boundary conditions [4-5]. The effective photon flux causing photoemission depends on the inclination angle with respect to the crater floor. This causes different photoemission and different surface potential throughout the crater. The different photoelectron density throughout the crater gives rise to a complex screening effect which results in complex potential and field structures within the sheath (See Figure 1). In addition to that, the angle of incidence of solar radiation makes the scenario even more complicated. Because at some angle of incidence, the incoming solar radiation illuminates limited portion of the crater – in this case, the sunlit surface acquire a positive charge while the shadowed portion is to be filled with wind plasma population, and might acquire a negative potential. In this scenario, complex physical effects are expected near sunlit-shadowed boundaries. These complex sheath features may give rise to non-trivial dust/ plasma dynamics and transport within the crater. This study could be useful in planning test trials for future lunar crater exploration missions.

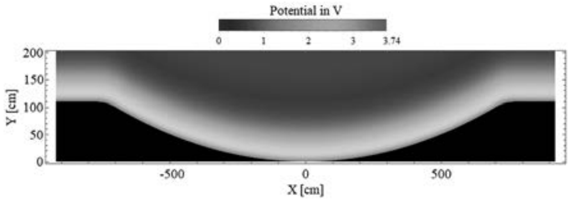

Fig. 1. The electric potential above the surface of the Moon with a 14 m diameter crater for normal solar illumination.

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ENERGY DISSIPATION IN A MICROGRAVITY COMPLEX PLASMA

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In complex plasmas under microgravity conditions, the micron-sized, plastic “dust” particles can fill the entire plasma volume. This allows the study of smaller interparticle forces that are masked by gravity. To overcome the gravitational influence, we use the dc glow discharge Plasma Kristall-4 (PK-4) microgravity laboratory on the International Space Station (ISS).

When dust particles are injected into PK-4, they flow along an axial electric field until stopped by the application of a periodic oscillation of that electric field - an action known as polarity switching. This oscillation modifies the local space potential around the dust particles and creates a change in the spatial ordering and thermal state of the dust system. We seek to understand the redistribution of kinetic energy of the dust particles at the onset of this periodic oscillation. This presentation will focus on comparing data obtained using three experimental setups: the ground science reference module, a PK-4 model on a parabolic flight, and the ISS microgravity experiment.

Initial results show that there is a substantive difference in the shape of the velocity distribution functions between ground and flight data. While the distribution function from ground data is reasonably well described using a Maxwellian distribution, the distributions from flight data show evidence of extended, skewed tails and other non-Maxwellian features. This presentation will focus on how to account for the modification of velocity distribution shape and the subsequent determination of the thermal properties of the dust component of the plasma.

ENERGY TRANSFER BETWEEN DEGREES OF FREEDOM AND TEMPERATURE INHOMOGENEITY IN DUSTY PLASMA MONOLAYER

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The possibility of dust particles acquiring abnormal average kinetic energy is a well-known feature of the dusty plasma [1-3]. Number of experiments shows that average kinetic energy of their vertical and horizontal motion can differ greatly [2,3]. One of mechanisms of energy transfer between degrees of freedom which can lead to such difference is based on parametric resonance [4]. It strongly depends on interparticle distance and is used to explain temperature inhomogeneity in dusty plasma monolayer with radially changing interparticle distance observed in [5]. Decrease in the mean kinetic energy of horizontal energy caused by increase in the mean distance between dust particles is demonstrated through computer simulations [6]. Obtained results are in good comparison with the experimental data.

The research is carried out using the hybrid computing system k-100 of Keldysh Institute of Applied Mathematics of Russian Academy of Sciences.

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SOME EXPERIMENTAL AND THEORETICAL STUDIES OF PROPAGATING NONLINEAR STRUCTURES IN DUSTY PLASMAS

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In this talk I will provide a brief overview of some of the experimental and theoretical work carried out at our Institute on the dynamics of nonlinear dispersive structures in stationary and flowing dusty plasmas. In a series of experiments that exploited the unique capabilities of a specially designed glow discharge device [1], the first ever observation of precursor solitons in a plasma medium was obtained [2]. These were created by a dusty plasma supersonically flowing over an electrostatic barrier. The propagation properties of these nonlinear structures as a function of the shape and size of the barrier were also delineated [3]. Further experiments established the existence of `pinned' solitons [4] – a unique class of nonlinear solutions associated with a driven Korteweg de Vries (KdV) equation. The electrostatic potential barrier was subsequently usefully exploited to experimentally demonstrate the first ever observation of the reflection of a dust acoustic soliton in a stationary plasma [5]. The experimental observations of the dynamics of these coherent structures under various conditions were well explained by numerical and analytic solutions of theoretical model equations based on the KdV and its variants. A first principles molecular dynamics study then shed further light on the formation condition and propagation characteristics of precursor solitons and precursor dispersive shock structures [6]. At the end, I will mention some of the potential practical applications of these precursor nonlinear structures e.g. in tracking small sized space debris in the Low Earth Orbit region or in the interpretation of nonlinear phenomena in space plasmas.

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SIMULATIONS OF RF PLASMA FLOW IN DISCHARGE TUBE AT LOW PRESSURES

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The dependence of the parameters of an inductively-coupled radio frequency (RF) plasma [1] on the electromagnetic field frequency at low pressure (113 Pa) by numerical simulation studied. The study was carried out in a 2D axisymmetric time-dependent setting, implemented in the Comsol software [2] using the Navier-Stokes and Maxwell equations and the continuity equation for electrons. The distributions of the electron density, carrier gas temperature, electron temperature, ion density and metastable argon atoms at the center of the discharge tube are obtained. The optimal parameters of the listed quantities depending on the frequency of the electromagnetic field are determined.

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EXISTENCE OF HIGHER ORDER MAGNETOSONIC SOLITONS IN EARTH'S MAGNETOSPHERE

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The physics of dusty plasma is a widespread area of research and has resulted in a great deal of interest due to its phenomenal applications in various regions of space and astrophysical environments, viz., comet tails, asteroid zones, planetary rings, interstellar medium, the lower part of the Earth's ionosphere and magnetosphere. Magnetosonic waves are low frequency magnetohydrodynamic (MHD) waves and are ubiquitously observed in Earth's magnetosphere both inside and outside the plasma pause. The study of different kinds of magnetosonic nonlinear structures in a magnetized multicomponent dusty plasma having cold dust fluid and non-Maxwellian ions as well as electrons is presented. Also to remove the discrepancies between theoretical predictions and experimentally observed characteristics of nonlinear waves, many authors have proved the requirement of inclusion of higher-order nonlinearity and dispersion effects in studying nonlinear structures in plasma. The reductive perturbation method is employed to derive the Korteweg-de Vries (KdV) and KdV-type inhomogeneous equations. From the solution of KdV-type inhomogeneous equation, it is seen that a new type of higher order structure named as "dressed soliton" is observed due to higher contributions. The effects of various plasma parameters on the characteristics of different kinds of magnetosonic nonlinear structures are analyzed numerically. The findings of the present investigation may be helpful in describing the characteristics of various nonlinear excitations in Earth's magnetosphere and space/astrophysical environments, where many space observations by various satellites confirm the existence of dust grains, highly energetic electrons and high plasma-β.

DUST ACOUSTIC SHOCK WAVES IN JUPITER'S ATMOSPHERE

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The omnipresence of dust in most of laboratory, space and astrophysical plasma environments has been an extensive area of research and has attracted numerous researchers for comprehensive study of different kinds of nonlinear structures [1]. A variety of waves are excited in the multicomponent plasmas. Dust acoustic wave is one of the important acoustic modes which is occurring in dusty plasmas. Shock waves have been studied by numerous researchers for the last many years due to their occurrence in various plasma environments. They are formed when the dissipation effects dominate over the dispersion effects in given nonlinear medium. In this investigation, the evolution of nonlinear oscillatory and monotonic dust acoustic shock waves (DASWs) has been studied in a dusty plasma comprising of positive dust grains, streaming solar wind protons and superthermally distributed electrons, isothermal ions and solar wind electrons. Various wave phenomena occur when the dusty plasma in Jupiter's atmosphere interact with the solar wind [2]. The Korteweg-de Vries-Burgers (KdVB) equation which describes the dynamics of the nonlinear shock wave structures is derived by using amplitude reductive perturbation technique. The numerical analysis is performed in context with observations in Jupiter's atmosphere. The influence of various plasma parameters viz., superthermality of ions, concentration of dust, ion to electron temperature ratio, number density ratio etc. has been observed on the characteristics of DA shock waves. The findings of this work maybe useful to understand the underlying physics of nonlinear phenomena for existence of nonlinear excitation in astrophysical environments like in Jupiter's rings.

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PROBING THE ELECTRON DENSITY DYNAMICS IN A DUSTY ARGON/HMDSO PLASMA USING MULTI-MODE MICROWAVE CAVITY RESONANCE SPECTROSCOPY

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Dusty plasmas remain a key research topic due to their elementary processes (e.g., crystallization) and industrial applications (such as material deposition). In particular, plasmas involving a mixture of argon and hexamethyldisiloxane (HMDSO) have been used for the purpose of barrier sterilization or plasma-enhanced chemical vapor deposition at both low and atmospheric pressure. Under most conditions, these plasmas are subject to powder formation.

We use microwave cavity resonance spectroscopy to probe the electron density evolution in a pulsed complex argon/HMDSO plasma under low pressure conditions for varying argon/HMDSO ratios (19:1–1:1). These measurements are associated to plasma impedance monitoring and laser light scattering measurements to image growing dust particles a few hundred nanometers and larger in size. By combining the time-resolved electron density with electrical plasma impedance measurements, the complex plasma behavior can be monitored throughout the dust growth process. This process resembles several features of the dust growth process which have been observed earlier in mixtures consisting of argon and different precursors such as acetylene, silane or methane. A comparison to literature reveals similarities such as the cyclic formation of dust particles and the rapid decay of the electron density briefly after plasma ignition. Moreover, it also demonstrates that additional spatial information obtained by using multiple resonant (microwave cavity) modes may further deepen the understanding of the cyclic behavior and the internal dynamics of the dust cloud.

WAKE FORMATION IN A POLARIZED DUSTY PLASMA: SOLITARY DUST PARTICLE CASE

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The formation of wake behind a dust particle immersed in low density plasma is the traditionally important problem of dusty or complex plasma. Plasma parameters around a dust particle in an external field (or in a plasma flow) are usually investigated with the help of two numerical methods: Linear Response (LR) [1] and “Particle-in-Cell” (PIC) [2]. However, linear response method deals only with point-like particles and takes into account collisions of ions with neutrals only at a qualitative level. In the mean time the PIC method is very resource-consuming [2]. It is also worth noting a very small number of works devoted to the self-consistent calculation of the plasma potential near non-spherical particles.

In this work, a recently developed [3] self-consistent iterative method which uses mean-field approximation is applied for determining plasma parameters in collisional plasma for different ions mean free path lengths. Time consumption of this method is relatively small and with the help of parallel computing architectures (utilized recently) the speed of calculation is improved significantly.

As a result, in this model, the general dependences of the wake main parameters, the dust particle charge, and the plasma dipole moment on the geometry of the dust grains, the mean free path of the ions, and the external field are obtained. The received data are found to be in good agreement with recently obtained results for the collisionless case [2].

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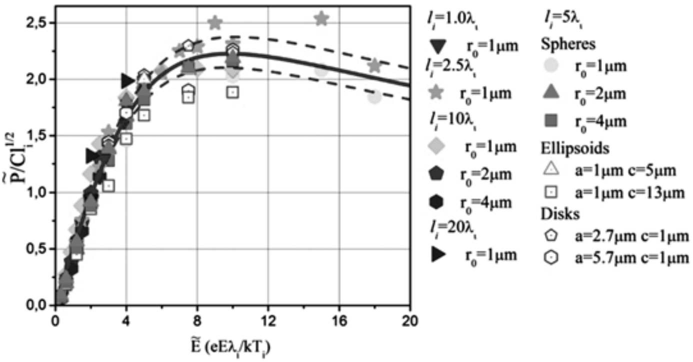

Fig. 1. A normalized dipole moment of an ion-electron cloud around a dust particle in an external electric field (C is the dust particle capacity, li is the mean free path).

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PLASMA AND DUST PATTERN FORMATION IN THE MAGNETIZED DUSTY PLASMA EXPERIMENT (MDPX)

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Experiments on plasmas and dusty plasmas using the Magnetized Dusty Plasma Experiment (MDPX) device have shown that both the plasma and the suspended microparticles can exhibit a wide variety of self-organized and imposed spatial structures [1-4]. Many of these phenomena begin to emerge when the magnetic field is sufficiently large (generally, $B \geq 1.0$ T) where both the ion and electron dynamics become substantially modified by the magnetic field. Experimental and computational studies are providing evidence that it is the restricted cross-field transport of the electrons and ions, combined with the boundaries imposed by the parallel-plate, capacitively coupled plasma generation configuration used in many of these experiments that allow the patterns to form. This presentation will summarize recent experimental and computational studies using the MDPX device that show that extended plasma sheath structures formed at electrode surfaces are strongly dependent on the degree of ion magnetization and can give rise to many of the observed patterns.

Support for this work is provided by the National Science Foundation and the US Department of Energy.

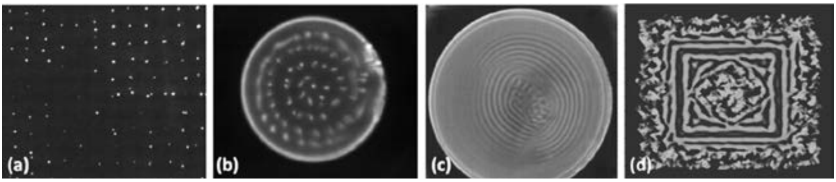

Fig. 1. Pattern formation in MDPX (viewed from the top): (a) dust particles, (b) single filaments, (c) filament rings, and (d) simulation of filaments.

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DUST-ACOUSTIC WAVES IN A NEAR-IDEAL (GAS-LIKE) CRYOGENIC DUSTY PLASMA

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Dusty plasma is a plasma containing charged particles of micron or submicron size along with electrons and ions [1]. Such a plasma has many practical and fundamental. Laboratory studies of dusty plasma are carried out mainly in DC and RF discharges. The dust fraction in plasma can demonstrate the properties of various states of aggregation, namely: crystal, liquid, gas. The first two states, as well as phase transitions between them, have been well studied to date [2]. At the same time, the properties of the gaseous state of dusty plasma have not been studied in details. The main parameter characterizing the state of aggregation is the coupling parameter Γ, which is equal to the ratio of the kinetic energy of dust particles and the potential energy of their interaction [1,2]. Crystals correspond to the condition Γ>170, liquids Γ~1-170, gases Γ≤1. Another criterion for plasma non-ideality is the parameter $\sigma_d=T_d/T_i$, where T_d is the kinetic temperature of the dust fraction, $T_i \sim T_n$ are the temperatures of ions and buffer gas. For a near-ideal plasma, as a rule, $\sigma_d >> 1$. Note that, in most cases, the discharge dusty plasma is strongly coupled (nonideal) [2] (the aggregate state is a crystal or liquid). Thus, the study of the “gas” state of dusty plasma is an urgent task.

In the proposed work, an experiment is described in which dust-acoustic waves were observed for the first time in a near-ideal dusty plasma [3]. By processing the video image, it was shown that the movement of charged particles was random, which is typical for gases. A pair correlation function was constructed and analyzed, the shape of which had no local maxima, which is also characteristic of the gas phase. The kinetic temperature of the dust fraction was also found, while the estimate of the ratio T_d/T gave $\sigma_d=27>>1$. And finally, the analysis of the coupling parameter gave us an estimate of its value Γ≤1. The observed periodic dust-acoustic wave caused a weak modulation of the dust density, and the wave process was apparently close to the linear stage. Also, in our experiment, a dust structure was observed, which did not have clear boundaries, which also indicates the gas-like state of the dust fraction.

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DYNAMICS OF DUST-ACOUSTIC SOLITON BREAKING

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The evolution of a plane self-exited dust-acoustic soliton in a dc discharge dusty plasma is studied in detail [1]. Main macroscopic plasma properties near the wave crest as well as dust particles trajectories (and velocities) were experimentally determined. Analysis of the particles trajectories revealed the evolution of a soliton, including its breaking and the appearance of multi-streaming flow. It was found that after reaching the critical amplitude soliton front accelerates the particles to its own speed, which significantly exceeds the "thermal" velocity of dust particles. In theory, this process is called soliton breaking [2]. After the wave breaks, the dust density profiles save their shape for some time. The velocity of motion of the accelerated particles after breaking is approximately equal to the initial velocity of the soliton. This phenomenon is called "multistreaming flow" [2]. Both dissipative and non-dissipative theoretical models are created to interpret experimental results. In the dissipative case, the velocity of the accelerated particles and the velocity of the dust-acoustic soliton are equal. Also particles experience damped oscillations when interacting with the soliton, which reasonably agrees with the experimental results. In the non-dissipative case, dust particles during the soliton breaking are accelerated to speeds twice higher comparing with the wave speed, which fully agrees with the experiments in a collisionless plasma [3,4].

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APPLICATION OF OPTICAL EMISSION SPECROSCOPY IN THE "PLASMA KRISTALL-4" SPACE EXPERIMENT

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The "Plasma Kristall-4" (PK-4) is a new experiment for investigation of complex plasma in a low pressure combined direct current and radio frequency (DC/RF) discharge on board the International Space Station under microgravity conditions [1]. To control the experimental conditions during the experiments the PK-4 setup is equipped by a wide view plasma observation camera (PGO), which can observe a discharge glow from the experimental part of the discharge glass tube via narrow band interference optical filters near 585,2 nm and 703,2 nm, and in all visible range as well. These wavelengths correspond to two secluded neon spectral lines corresponding to electron transitions with different upper levels – 18,96 eV and 18,38 eV, correspondingly. In addition to PGO camera, an OceanOptics2000+ minispectrometer can record plasma emission spectra from one chosen point at the tube axis in the spectral range of 350–1100 nm with a spectral resolution of 1,5 nm. These two spectral systems were used for next purposes: to detect possible impurities in the discharge plasma originating from dust particle and glass wall decomposition under action of plasma, long term discharge plasma stability and influence of dust particle cloud on electron temperature in direct current positive column using nonlocal kinetic model of neon positive column [2]. The results of these experiments with the PK-4 setup on board the ISS will be reported.

All authors greatly acknowledge the joint Roscosmos-ESA experiment "Plasma Kristall-4" on board the International Space Station.

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DUSTY PLASMA WITH CARBON NANOPARTICLES: ADVANCES AND APPLICATION

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This work is devoted to the study of the glow intensity of radio-frequency capacitive discharge plasma with nanoparticles for further use in lighting devices. The process of carbon nanoparticles synthesis in the radiofrequency discharge was investigated (Fig. 1), and the influence of plasma parameters on the formation and growth of the material was also studied. A method for determining the diameter of nanoparticles based on self-bias voltage and electron density is considered. It is revealed that the diameter of nanoparticles has a considerable influence on the optical properties of the plasma, in particular, on the emission intensity. Based on the obtained data, laboratory samples of lighting devices with improved luminous intensities were developed.

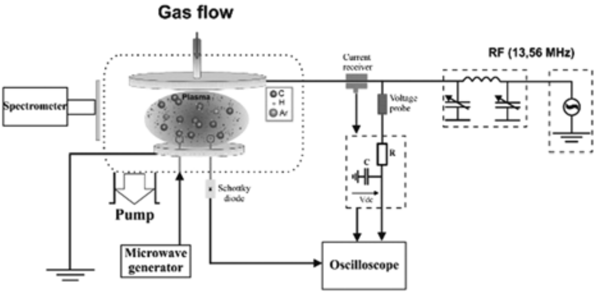

Fig. 1. Scheme of the experimental setup for generation of RF discharge plasma with nanoparticles.

The influence of the carbon nanoparticles synthesized in the RF discharge on the emission intensity of the discharge plasma itself was investigated. According to the experimental results, the increase of the diameter of nanoparticles in the plasma volume leads to the change of the self-bias voltage. This makes it possible to determine the diameters of the nanoparticles by monitoring the self-bias voltage. It was determined that the particle nucleation time and coagulation processes depend on the discharge power. This allows us to control the characteristics of the synthesized nanoparticles. During the investigation of the plasma intensity, it was revealed that the nanoparticles with diameter of 60 nm lead to the strongest glow intensity enhancement. It should be noted that up to this value of diameter the intensity increases steadily, and after that with further increase in the diameter of nanoparticles a decline in the glow intensity takes place. Eventually, taking into account this fact, we developed an experimental illumination lamp with nanoparticles of diameter 60–70 nm inside. The presence of nanoparticles results in twice as much light emission as conventional fluorescent lamps [1].

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CLUSTERED MICRO-PARTICLE (DE)CHARGING IN SPATIAL PLASMA AFTERGLOWS

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Particle contamination control becomes an increasingly significant research area. Not only because of the world-wide raise in air pollution, but also because of processing on the nanoscale, for instance in the semiconductor industry, where more and more stringent levels of cleanliness are desired. One option is to control particle contamination with the aid of plasmas because of their ability to both electrically charge particles and to control the particle trajectories by the high electric fields induced by the discharge itself.

In almost all applications where particle contamination control is needed the particles are irregularly shaped, whereas most fundamental research is focused on monodisperse spherical particles. In order to understand the charging of non-spherical particles, the behavior of clusters of monodisperse spherical particles is investigated. These clusters naturally occur as a result of the chosen particle injection method. We have developed an in situ cluster size detection technique based on the settling velocity of these clustered particles. Using this method, the charge of single, double and triple micro-particle structures has been measured in the late afterglow of an inductively coupled plasma and compared to the relevant theoretical considerations. SEM measurements have been performed to confirm the existence and configuration of the clustered micro-particles.

ACTIVE BROWNIAN PARTICLES IN GAS DISCHARGES PLASMA

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Recently, there has been a significant amount of interest in the study of active Brownian motion [1]. Opposed to the classical (passive) Brownian motion of microparticles that are in thermal equilibrium with the environment, active Brownian particles can convert energy from the environment into the kinetic energy of their own motion. As a result, they are far from equilibrium with the environment.

Systems of active Brownian particles in gas discharge plasma are open systems in which one can observe the energy and matter transfer with the environment. In open dissipative structures, the export of entropy to the environment can lead to their self-organization and evolution into a more sophisticated organized state [2,3].

In our work, we present the results of an experimental study of the evolution of dissipative structures of active Brownian particles in a gas discharge plasma. The photophoretic force acts as the driving force to move active Brownian grains. Photophoresis occurs as a result of the absorption of laser radiation by the particle surface and is associated with inhomogeneous heating of its surface [4]. We present the results of experimental observations confirming the active nature of the Brownian motion of such particles in gas discharge plasma. An analysis of the Brownian motion patterns for grains on different time scales and the change in the intensity of grain motion (their kinetic energy and diffusion) depending on the laser radiation power is presented.

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GEOMAGNETIC STORM AND THERE ASSOCIATED SOLAR ACTIVITIES

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Recent studies have indicated that the occurrence of the maxima of geomagnetic storm rate was nearly related with coronal mass ejection and solar flares. We find that the ten-year of geomagnetic storm rate manifests with the solar flares and coronal mass ejection are correlated (2010–2020). Although the solar cycle number 24 start in December 2008, data were taken such that it includes also the rising phase of solar cycle 25 that to increase the sample number which gives better statistics Analysis of CMEs with speeds greater than the average speed. The linear speed of coronal mass ejection of more than 1000 Km/s is taken in duration of 2010 to 2020. Emissions of CMEs can occur at any time during a solar activity but increase with solar activity and solar energy. Analysis of the linear speeds of CMEs further indicates that during the descending phase of the solar cycle the loss more frequent and less energetic CMEs. CMEs are considered as the major natural hazardous happening at the surface of sun because this event can cause several other phenomena like solar Aurora and Geomagnetic Storms and many more. In this work, we report a statistical observation of the relationship of Dst index of geomagnetic storm and CMEs having linear speed more than 1000 km/s, and the correlation between Dst index of geomagnetic storm (nT) and solar flare flux along with its different classes of flare. We find the relation between Dst index of geomagnetic storm and CME is 0.25, which is moderate relation and that with solar flare flux is .21. We also find correlation of Dst index of storm with linear speed of CME's which very low –0.09 means storm intensity does not depend on linear speed of CME, also the correlation of Dst index and X class solar flare flux is .97 which is very high means chance of storm increases strongly during eruption of X class flare towards earth but in 10 years very few X class flares are seen although the correlation of Dst index and flux of M class flare is low but maximum numbers of geomagnetic event 14 out of 28 event (>–100 nT) nearly 50% occur due M class flare (2010–2020). The present results foreshowed a high affiliation relation between geomagnetic storm and Flares especially X class Flare and also there is a good relation of geomagnetic storm and CMEs as some flares convert into CMEs which is also noted in this study.

ACTIVE LANGEVIN PARTICLE

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A colloidal plasma is a nontrivial instance of soft condensed matter [1]. Under certain conditions, the colloidal plasma becomes a thermodynamically open, non-Hamiltonian system that can exhibit the properties of active matter [2-4]. A distinctive feature of such a system is an extremely low viscosity at which the inertial effects play a significant role and the overdamped approximation of active Brownian motion is not justified [5]. Inertial self-propelled particles have become a hot topic of the last few years [6]. They extend active Brownian motion to the underdamped case, i.e., to active Langevin motion [6,7].

In the framework of the two-dimensional active Langevin particle model, we have succeeded in getting the generalized analytical equations for the mean kinetic energy, mean-square displacement and noise-averaged trajectory of a free and confined self-propelled particle with any moment of inertia in a medium with any dynamic viscosity [7]. This study fills a gap in the theory of active Brownian motion in the field where rotational inertia significantly affects the random walk of active particles on all time scales. The results can be useful in the statistical description of self-propelled particles in a gas, plasma and superfluid helium, field-controlled active colloids and interfacial active droplets, vibration-driven granular particles and autonomous mini-robots, motor-driven macrobiomolecules and etc.

This work was supported by the Russian Science Foundation under grant № 22-22-00899.

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INHOMOGENEITY OF OSCILLATION PROPERTIES IN A DUSTY PLASMA MONOLAYER

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In [1] inhomogeneity of a harmonically confined Yukawa system is discussed with the focus on both its structural and dynamic properties, including inter-particle separations, Lindemann and coupling parameters. In [2] inhomogeneity of the melting process in a confined Yukawa system is described for the first time. The present work provides a deeper research of inhomogeneity of such systems, mainly of their oscillation properties.

A monolayer of particles interacting by Yukawa potential and confined in a parabolic trap is under consideration. Particle charge, trap parameter and screening length constancy is assumed. In order to study oscillation properties of the system, molecular dynamics simulations are conducted with a system of a few hundred particles in non-periodic boundary conditions. Oscillation spectra of particles located at different distances from the center of the system are quantitatively compared. The main quantity of interest in the performed spectral analysis is average frequency of particle oscillations which is called Einstein frequency. It is demonstrated that inhomogeneity of Einstein frequency is characteristic of finite Yukawa systems: it decreases with radial distance from the center of the structure due to the growth of inter-particle distance. To understand the dependence of Einstein frequency on inter-particle spacing, values obtained for subsystems of a finite monolayer are compared with calculated frequencies for infinite Yukawa matter with the same value of inter-particle separations. Thermal oscillation amplitude and Lindemann parameter are also included into comparison. Analogy between the cases of finite and infinite Yukawa matter is discussed. This research is important for the study of phase transitions in dusty plasma systems [3,4].

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MOLECULAR DYNAMICS SIMULATIONS OF THE INTERACTION OF AN ELECTRON BEAM WITH A PLASMA CRYSTAL

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The kinetic effects on the dust particles in a plasma crystal locally irradiated by a narrow, pulsed electron beam (EB) with energies from 10–15 keV have recently been presented. [1,2] These studies have revealed that the EB pushes the dust particles in the irradiation zone, leading to both laminar and turbulent flow. Further, these studies have examined interaction of the EB is described in terms of the electron penetration depth, deposited energy and heating of the MPs, as well as resulting motion of the dust that has been irradiate by the electron beam. In this, we report on molecular dynamic simulations of this interaction. These simulations reproduce many of the observed experimental results and provide new insight into the interaction of the dust grains in a plasma crystal and an externally applied electron beam.

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OBSERVATION OF PARTICLE DYNAMICS AT THE ONSET OF POLARITY SWITCHING IN THE PK-4 MICROGRAVITY LABORATORY

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In the PK-4 microgravity laboratory [1] on the International Space Station, particles are injected into a dc glow discharge plasma and flow along an axial electric field. Upon the application of a periodic oscillation of the electric field (polarity switching), the microparticles become trapped in a subregion of the plasma. As a result, this provides a flexible platform for studying a wide variety of dusty plasma phenomena under conditions where the multiple influences on structure and dynamics of the system are otherwise masked under gravity conditions. At the onset of polarity switching, the unidirectional flow of particles is halted and the particles are rapidly brought to rest, resulting in a rapid dissipation of the kinetic energy of the particles and a change in the spatial ordering the microparticles. By applying PIV analysis techniques, [2] one is able to quantify the motion of the microparticle component and observed the redistribution of energy from the bulk (macroscopic) motion to the particle (microscopic) motion. In some cases, this has led to an observed change in the thermal state of the dust component. This presentation will present a preliminary analysis of what occurs at the onset of polarity through a comparison of ground-based studies using the PK-4 science reference module, parabolic flight data performed on the PK-4 at Justus-Liebig-Universität in Geißen and microgravity experiments using the PK-4 laboratory on the International Space Station.

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DUSTY PLASMAS IN THE VICINITY OF THE MOON: CURRENT RESEARCH AND NEW VISTAS

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A renaissance is being observed currently in investigations of the Moon. The Luna 25 and Luna 27 missions are being prepared in Russia. At the same time theory research of dust and dusty plasmas at the Moon is being carried out. Here, the corresponding results are reviewed briefly. We present the main our theory results concerning the lunar dusty exosphere. We show that dusty plasma system above the Moon includes charged dust, photoelectrons, and electrons and ions of the solar wind. We present the distributions of the photoelectrons and the characteristics of the dust which rise over the lunar regolith. We show that there are no significant constraints on the Moon landing sites for future lunar missions that will study dusty plasmas in the surface layer of the Moon. We consider magnetic fields of the Earth's magnetotail and demonstrate that they provide a possibility of dust transport above the lunar surface, which can result in the existence of positively charged dust and correspondingly dusty plasmas at the sunlit side of the Moon for the whole range of the lunar latitudes. We discuss also physics of dusty plasmas and electric fields at the lunar terminator region. Furthermore, we formulate new problems concerning the dusty plasma above the lunar surface. The work was supported by the Foundation for the Advancement of Theoretical Physics and Mathematics "BASIS".

BUCKLING IN 2D COMPLEX PLASMA CRYSTALS

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The existence of the so-called 'plasma wakes' is the source of some exciting phenomena in complex plasma crystals. These include an intriguing non-Hamiltonian behavior [1], the exhibition of a mode-coupling instability [2] and a novel melting mechanism [3]. The existing studies usually consider as an object of investigation a monolayer hexagonal complex plasma crystal.

Here we will present our latest theoretical results about the effect of the plasma wakes on the structure of a 2D complex plasma crystal under a harmonic confinement. Our main focus is on the buckling transition from a 2D hexagonal monolayer to bi- or triple-layer complex plasma crystals, taking place by tuning the confinement frequency or the particle density. Within distinct regimes of the above mentioned parameters, we find stable equilibrium crystalline structures of both a hexagonal and a square order. Interestingly enough although the latter square structures appear to be stable in a relatively wide parameter regime, they are still elusive from experimental observations.

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UNIFIED THEORY OF THE DUST IONIZATION AND DUST ACOUSTIC WAVES IN THE COMPLEX PLASMA OF GAS DISCHARGE

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The theory of dust ionization waves (DIW) found in the recent experiment [1] is proposed. DIW belong to a previously unexplored type of spatial oscillations of dust particles observed in complex plasmas under microgravity conditions. In contrast to known dust acoustic waves (DAW), DIW arise due to oscillations in the rate of electron–ion recombination on the surface of dust particles, and not due to the proper compressibility of the dust cloud. The theory is based on the equations of motion and continuity for dust particles, the balance equation for cold ions, the Boltzmann distribution for hot electrons, and the Poisson equation. With the help of these equations, a dispersion relation is derived, which provides an interpretation of the DIW features and unifies them with DAW. In particular, it is shown that both modes are obtained from the dispersion relation and they merge at the minimum wave propagation frequency. The wave number for DIW is determined by the plasma parameters and it is almost independent of the frequency. The phase velocity of the DIW increases with increasing frequency and significantly exceeds the DAW velocity. The DIW group velocity is negative, as is the case for the conventional ionization waves in a pure gas. Note that the characteristic frequency of the latter is three orders of magnitude higher than for DIW. The decay length of the DIW turns out to be an order of magnitude longer than that for the DAW, but there exist no mechanism of DIW self-excitation. Therefore, in the experiment it is possible to observe the propagation of excited, but not self-excited DIW. On the contrary, under appropriate conditions, self-excitation of DAW is possible, but the observation of DAW excited by an external source is questionable.

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9

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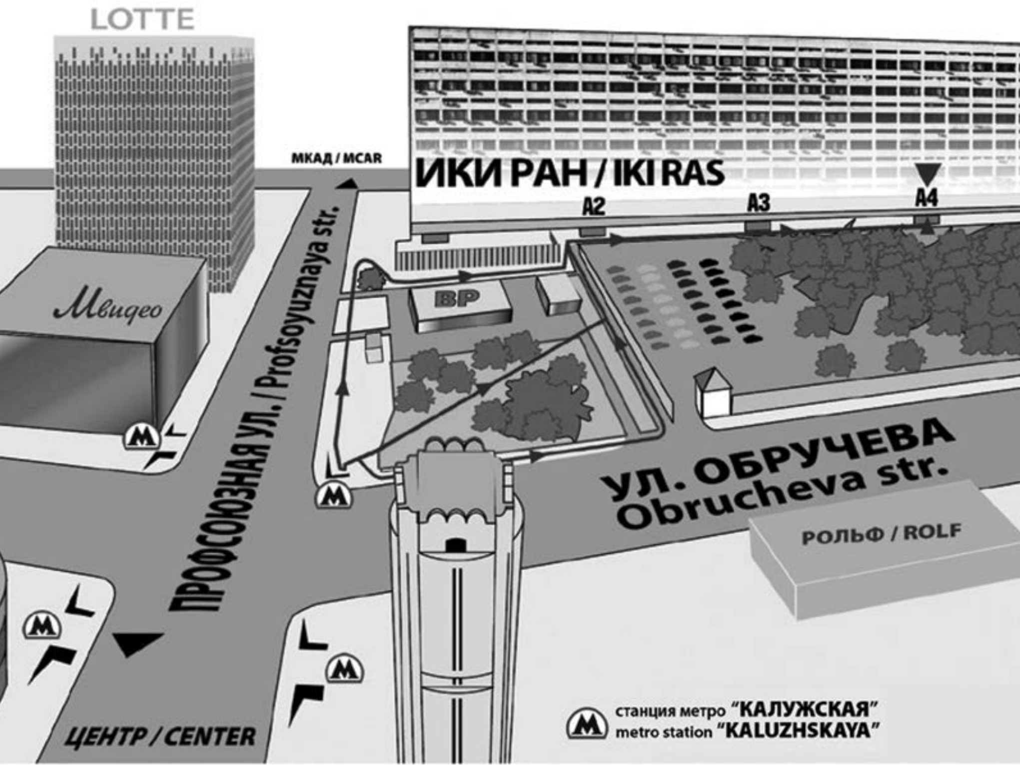

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REGISTRATION AND INFORMATION DESK

location: IKI, entrance A-4

time (GMT 3+):

23 May 2022	**9:00–18:00**
24–26 May 2022	**9.30–18.00**
27 May 2022	**9.30–17.00**

ORAL SESSIONS

location: IKI conference hall, second floor

POSTER SESSIONS

online discussion or
IKI exhibition hall, ground floor

COFFEE BREAKS

location: IKI conference hall, second floor

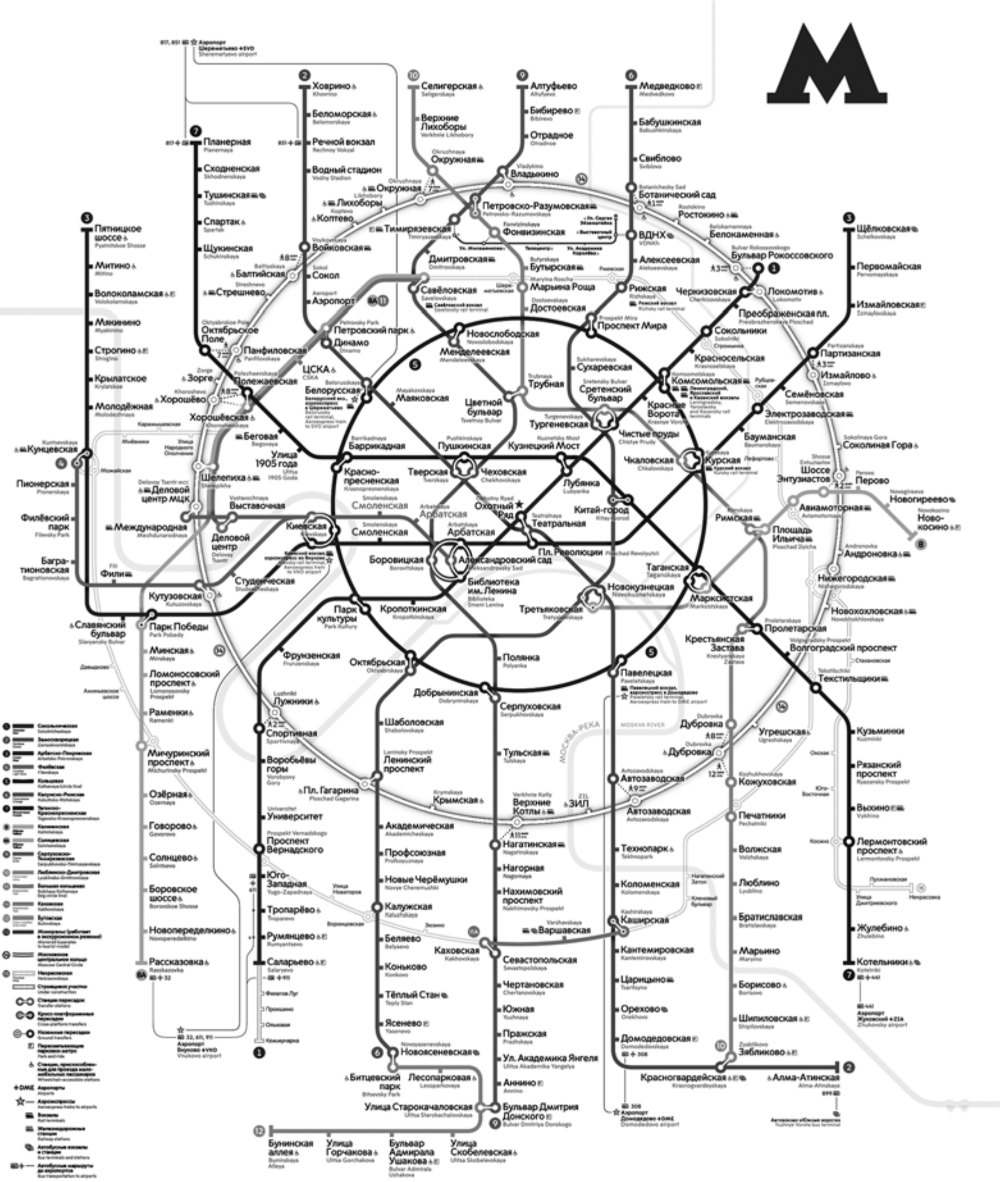
CONFERENCE DINNER

location: IKI exhibition hall, ground floor

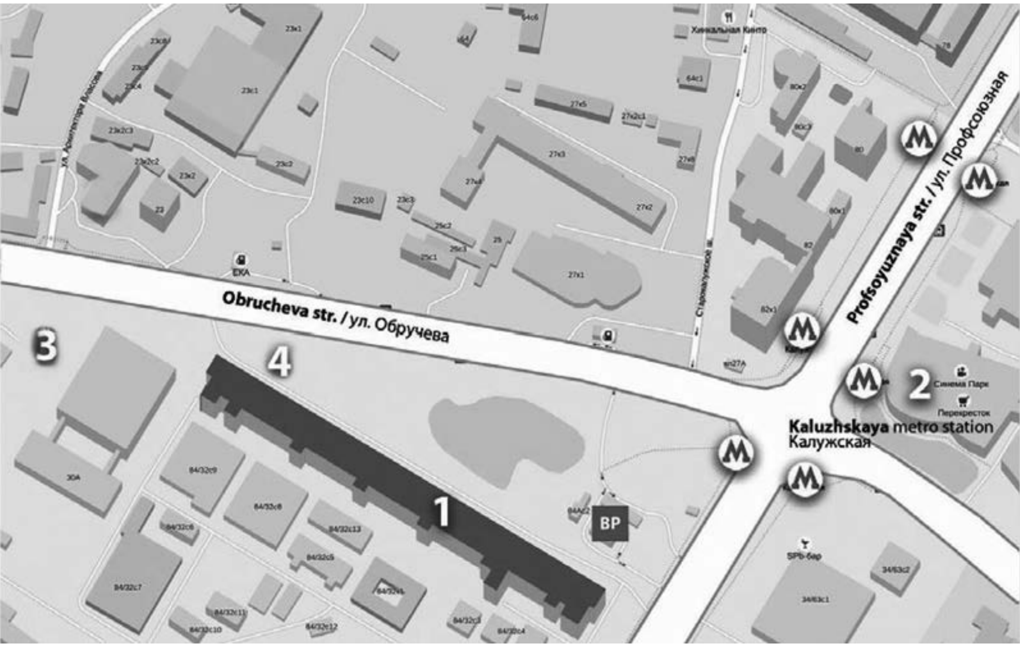
INTERNET ACCESS AND WIFI

there is Internet access in and near the conference hall

MOSCOW METRO MAP



LUNCH POINTS NEAREST TO IKI



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