FLUCTUATIONS AND ION-ACOUSTIC WAVES IN COLLISIONAL DUSTY PLASMA WITH VARIABLE GRAIN CHARGE

A.I. Momot[1], A.G. Zagorodny[2], O.V. Momot[1]

[1]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine;
[2]Bogolyubov Institute for Theoretical Physic, Kyiv, Ukraine

E-mail: momot.andriy@gmail.com

The kinetic theory of electric fluctuations in a collisional weakly ionized dusty plasma is formulated with regard to the grain charg variations. The spectra of ion-acoustic wave and of electron density correlation in nonisothermal plasmas are calculated for various values of grain density and grain size.

PACS: 52.27.Lw

INTRODUCTION

The theory of fluctuations in the ordinary collisional plasma is well developed [1-5]. The problem of generalization of this theory to the case of dusty plasma has a number of issues remained open. The dust grains acquire electric charges due to absorption of electrons and ions from the surrounding plasma i.e. grains are charged by the plasma currents that flow toward its surface. In the stationary state, the flux of electrons on the grain surface is equal to the flux of ions, thus the total current is equal to zero. The fluctuations of the charging current lead to the fluctuations of the stationary grain charge. Moreover, since the grain charges depend on electromagnetic field via charging currents, they generate additional dielectric response of the medium, which can influence the propagation of electromagnetic waves in dusty plasma.

The major part of the results for fluctuations [6-9] and ion-acoustic waves [10-12] are obtained for collisionless dusty plasmas. However, this approximation is not applicable for dusty plasma experimental conditions [13, 14].

The purpose of the present paper is to give a consistent linear kinetic description of electric fluctuations and dielectric response in collisional weakly ionized dusty plasma with regard to the absorption of electrons and ions by grains and grain charge variations.

1. GRAIN CHARGE FLUCTUATIONS

The charge density fluctuations in a dusty plasma include fluctuations related to electrons and ions $\delta\rho_\alpha(\mathbf{r},t) = e_\alpha \delta n_\alpha(\mathbf{r},t), \quad \alpha = e,i,$ as well as the grain charge density fluctuations

$$\delta\rho_g(\mathbf{r},t) = e_g \delta n_g(\mathbf{r},t) + n_g \delta e_g(\mathbf{r},t), \qquad (1)$$

where e_g is the stationary grain charge and n_g is the mean number density of grains. Such representation is valid for fluctuations that satisfy the condition $n_g R^3$? 1, where R is the spatial scale of perturbation. The number density fluctuations of charged particles have the form

$$\delta n_\alpha(\mathbf{r},t) = n_\alpha \int dv \delta f_\alpha(\mathbf{r},\mathbf{v},t), \quad \alpha = e,i,g, \qquad (2)$$

where $\delta f_\alpha(\mathbf{r},\mathbf{v},t)$ are the fluctuations of distribution function. In the case of electrons or ions, they can be found in the same way as in ordinary plasma [5], but regarding the collisions of electrons and ions with grains in addition to collisions with neutrals.

Fluctuations of electron and ion distribution functions satisfy the equation [5]

$$\left\{\frac{\partial}{\partial t} + \mathbf{v}\frac{\partial}{\partial \mathbf{r}}\right\}\delta f_\alpha(X,t) + \nu_\alpha\{\delta f_\alpha(X,t) -$$
$$- f_{0\alpha}(\mathbf{v})\int d\mathbf{v}\delta f_\alpha(X,t)\} = -\frac{e_\alpha}{m_\alpha}\frac{\partial\delta\phi(\mathbf{r},t)}{\partial \mathbf{r}}\frac{\partial f_{0\alpha}(\mathbf{v})}{\partial \mathbf{v}}, \qquad (3)$$

where $X = (\mathbf{r},\mathbf{v})$, $\delta\phi(\mathbf{r},t)$ is the fluctuation of electrostatic potential, $f_{0\alpha}(\mathbf{v})$ is the unperturbed distribution function, $\nu_\alpha = \nu_{\alpha n} + \nu_{\alpha g}$, and $\nu_{\alpha n}$, $\nu_{\alpha g}$ are the effective collision frequencies between particles of α species with neutrals and grains. We assume that the electrons and ions absorbed by the grain recombine on its surface and form the neutral gas atoms that evaporate into the surrounding plasma and can be ionized again. Such assumption makes it possible to use the Bhatnagar-Gross-Krook (BGK) collision integral [16] in Eq. (3).

The averaging of the equation for microscopic phase density of grains results into kinetic equation with collision integral that can be expressed in terms of the correlation functions of microscopic quantities [5]. The linearized equation for the fluctuations of grain distribution function has the form of Eq. (3) with $\alpha = g$, where ν_g is the effective collision frequency between grains and other particles.

The formal solution of Eq. (3) is given by

$$\delta f_\alpha(X,t) = \delta f_\alpha^{(0)}(X,t) -$$
$$-\frac{e_\alpha}{m_\alpha}\int_{-\infty}^{t} dt' \int dX' W_\alpha(X,X';t-t')\frac{\partial\delta\phi(\mathbf{r}',t')}{\partial \mathbf{r}'}\frac{\partial f_{0\alpha}(\mathbf{v}')}{\partial \mathbf{v}'}, \qquad (4)$$

where $\delta f_\alpha^{(0)}(X,t)$ is the general solution of the homogenous Eq. (3), $W_\alpha(X,X';t-t')$ also satisfies the homogenous Eq. (3), but with the initial condition $W_\alpha(X,X';0) = \delta(X-X')$.

We also need to describe the dynamics of grain charge fluctuations $\delta e_g(\mathbf{r},t)$. Following the Ref. [15], we assume that

$$\frac{\partial e_g(\mathbf{r},t)}{\partial t} = \sum_{\alpha=e,i} I_{\rm ch}^{\alpha}\left(n_\alpha(\mathbf{r},t), e_g(\mathbf{r},t)\right). \qquad (5)$$

For the small fluctuations of the grain charge $\delta e_g(\mathbf{r},t)$ from its stationary value e_g, which is determined by the condition of zero total charging current $I_{\rm ch}^i + I_{\rm ch}^e = 0$, (5) gives the equation for $\delta e_g(r,t)$

$$\frac{\partial \delta e_g(\mathbf{r},t)}{\partial t} + \nu_{\rm ch}\delta e_g(\mathbf{r},t) = \sum_{\alpha=e,i} \frac{\partial I_{\rm ch}^{\alpha}(n_\alpha, e_g)}{\partial n_\alpha}\delta n_\alpha(\mathbf{r},t), \quad (6)$$

where $\nu_{\rm ch}$ is the charging frequency

$$\nu_{\rm ch} = \sum_{\alpha=e,i}\nu_{\rm ch}^{\alpha}, \quad \nu_{\rm ch}^{\alpha} = -\frac{\partial I_{\rm ch}^{\alpha}(n_\alpha, e_g)}{\partial e_g}. \qquad (7)$$

Now, the explicit form of charging currents $I_{\rm ch}^{\alpha}(n_\alpha, e_g)$ in collisional plasma is needed. Since the mean free path of electrons l_e is, usually, about two orders higher than l_i, we use the expression

$$I_{\rm ch}^{e} = e_e n_e\sqrt{8\pi}a^2\upsilon_{Te}\exp(-\alpha), \qquad (8)$$

which is obtained in orbit motion limited (OML) approximation, i.e. the collisions of electrons with neutrals are neglected.

For ionic charging current we use the interpolation formula [17], which reproduce with high accuracy the results of kinetic calculations [18]

$$I_{\rm ch}^{i} = e_i n_i\sqrt{8\pi}a^2\upsilon_{Ti}\frac{I^{\rm WC}I^{\rm SC}}{I^{\rm WC}+I^{\rm SC}}, \qquad (9)$$

where

$$I^{\rm WC} = 1+\alpha\tau + 0.1(\alpha\tau)^2\lambda_D / l_i, \qquad (10)$$

$$I^{\rm SC} = \sqrt{2\pi}\alpha\tau l_i / a, \quad \tau = T_e / T_i. \qquad (11)$$

Here $\alpha = e_e\phi_s / T_e$ (not to be confused with subscript α that denotes the plasma particle species), ϕ_s is the surface potential, a is the grain radius, $k_D^2 = k_{De}^2 + k_{Di}^2$, $k_{D\alpha}^2 = 4\pi e_\alpha^2 n_\alpha / T_\alpha$, $\lambda_D = 1/k_D$ is the Debye length, $\upsilon_{T\alpha} = \sqrt{T_\alpha / m_\alpha}$ is the plasma particle thermal velocity, $l_i = \upsilon_{Ti}/\nu_i$ is the ion mean free path, ν_i is the collision frequency of ions with other particles. WC stands for weakly collisional and SC is for strongly collisional.

It is reasonable to assume [18-22] that the electrostatic potential near the grain is described by the Derjaguin-Landau-Verwey- Overbeek (DLVO) potential, then

$$\alpha = \frac{e_e e_g}{aT_e(1+ak_D)}. \qquad (12)$$

The space-time Fourier transform (FT) of Eq. (1) for the grain charge fluctuations along with (6) gives

$$\delta\rho_{g\mathbf{k}\omega} = e_g\delta n_{g\mathbf{k}\omega} + \frac{in_g}{\omega + i\nu_{\rm ch}}\sum_{\alpha=e,i}\frac{I_{\rm ch}^{\alpha}}{n_\alpha}\delta n_{\alpha\mathbf{k}\omega}. \qquad (13)$$

We substitute (4) in (2) and after FT obtain

$$\delta n_{\alpha\mathbf{k}\omega} = \delta n_{\alpha\mathbf{k}\omega}^{(0)} - \frac{k^2}{4\pi e_\alpha}\chi_\alpha(\mathbf{k},\omega)\delta\phi_{\mathbf{k}\omega}, \ \alpha = e,i,g, \ (14)$$

where $\chi_\alpha(\mathbf{k},\omega)$ is the dielectric susceptibility.

And substituting (14) with $\alpha = g$ in the first term of (13) and with $\alpha = e,i$ in the second one, we obtain

$$\delta\rho_{g\mathbf{k}\omega} = \delta\rho_{g\mathbf{k}\omega}^{(0)} - \frac{k^2}{4\pi}\chi_g(\mathbf{k},\omega)\delta\phi_{\mathbf{k}\omega} + \frac{i}{\omega+i\nu_{\rm ch}}\times$$

$$\times\sum_{\alpha=e,i}\nu_{\alpha g}\delta\rho_{\alpha\mathbf{k}\omega}^{(0)} - \frac{k^2}{4\pi}\frac{i}{\omega+i\nu_{\rm ch}}\sum_{\alpha=e,i}\nu_{\alpha g}\chi_\alpha(\mathbf{k},\omega)\delta\phi_{\mathbf{k}\omega}, \ (15)$$

where $\nu_{\alpha g} = n_g I_{\rm ch}^{\alpha}/(e_\alpha n_\alpha)$ is the frequency of plasma particle collisions with grains.

Thus,

$$\delta\phi_{\mathbf{k}\omega} = \frac{4\pi\delta\rho_{\mathbf{k}\omega}^{(0)}}{k^2\varepsilon(\mathbf{k},\omega)}, \qquad (16)$$

where

$$\delta\rho_{\mathbf{k}\omega}^{(0)} = \sum_{\alpha=e,i,g}\delta\rho_{\alpha\mathbf{k}\omega}^{(0)} + \frac{i}{\omega+i\nu_{\rm ch}}\sum_{\alpha=e,i}\nu_{\alpha g}\delta\rho_{\alpha\mathbf{k}\omega}^{(0)}, \qquad (17)$$

$$\varepsilon(\mathbf{k},\omega) = 1 + \sum_{\alpha=e,i,g}\chi_\alpha(\mathbf{k},\omega) + \frac{i}{\omega+i\nu_{\rm ch}}\sum_{\alpha=e,i}\nu_{\alpha g}\chi_\alpha(\mathbf{k},\omega). \ (18)$$

We see that the presence of grains lead to renormalization of the dielectric response and collisions with grains should be taken into account on equal footing with the collisions with neutrals, i.e. $\nu_\alpha = \nu_{\alpha n} + \nu_{\alpha g}$.

2. FLUCTUATION AND WAVE SPECTRA

It follows from (14), (16) and (17) that

$$\langle\delta\rho_e^2\rangle_{\mathbf{k}\omega} = \left|1 - \frac{\chi_e(\mathbf{k},\omega)}{\varepsilon(\mathbf{k},\omega)}\left(1+\frac{i\nu_{eg}}{\omega+i\nu_{\rm ch}}\right)\right|^2\langle\delta\rho_e^{(0)2}\rangle_{\mathbf{k}\omega} +$$

$$\left|\frac{\chi_e(\mathbf{k},\omega)}{\varepsilon(\mathbf{k},\omega)}\left(1+\frac{i\nu_{ig}}{\omega+i\nu_{\rm ch}}\right)\right|^2\langle\delta\rho_i^{(0)2}\rangle_{\mathbf{k}\omega} + \left|\frac{\chi_e(\mathbf{k},\omega)}{\varepsilon(\mathbf{k},\omega)}\right|^2\langle\delta\rho_g^{(0)2}\rangle_{\mathbf{k}\omega}$$

$$(19)$$

where $\langle\delta\rho_\alpha^{(0)2}\rangle_{\mathbf{k}\omega} = T_\alpha k^2\,{\rm Im}\,\chi_\alpha(\mathbf{k},\omega)/(2\pi\omega)$ [23].

For the dielectric susceptibility of collisional plasma we use the results obtained [16] on the basis of kinetic equations with the BGK collision integral

$$\chi_\alpha(\mathbf{k},\omega) = \frac{k_{D\alpha}^2}{k^2}\frac{(\omega+i\nu_\alpha)W(z_\alpha)}{\omega+i\nu_\alpha W(z_\alpha)}, \qquad (20)$$

where $z_\alpha = (\omega+i\nu_\alpha)/k\upsilon_{T\alpha}$ and $W(z)$ is the plasma dispersion function.

The propagation of longitudinal waves in plasma can be studied by solving the dispersion equation

$$\varepsilon(\mathbf{k},\omega) = 0, \qquad (21)$$

which determines the eigenfrequency as a function of wave vector $\omega(\mathbf{k})$. For the real $\mathbf{k}$, the eigenfrequency is complex $\omega(\mathbf{k}) = \omega_{\mathbf{k}} + i\gamma_{\mathbf{k}}$, where $\gamma_{\mathbf{k}}$ is the damping rate.

Below we present , the results of numerical solution of the dispersion equation (21) with dielectric permittivity (18) disregarding $\chi_g(\mathbf{k},\omega)$ and numerical calculations of electron density fluctuation spectra given by (19) for nonisothermal argon plasma $(\tau = 100)$.

The charging currents are the functions of parameter α (12), which can be referred as normalized grain charge, it, in turn, is determined by the condition of zero total current on the grain surface $I_{\rm ch}^i + I_{\rm ch}^e = 0$

$$\frac{n_e}{n_i}\sqrt{\tau\frac{m_i}{m_e}}\exp(-\alpha)=\frac{I^{\mathrm{WC}}I^{\mathrm{SC}}}{I^{\mathrm{WC}}+I^{\mathrm{SC}}}. \qquad (22)$$

The ratio n_e/n_i in Eq. (22) is defined by the quasineutrality condition, which in the case of dusty plasma has the form $e_e n_e + e_i n_i + e_g n_g = 0.$ For the singly charged ions $n_e/n_i = 1-P$, $P = e_g n_g / e_e n_i$, where P is the Havnes parameter, which describes the part of electron charge collected by dust.

Spectra and damping of ion-acoustic waves in dusty plasma with regard to grain charge fluctuations (solid lines in Fig. 1,a,b) are studied using the numerical solution of the dispersion equation where dielectric permittivity is given by the expression (18) disregarding $\chi_g(\mathbf{k},\omega)$.

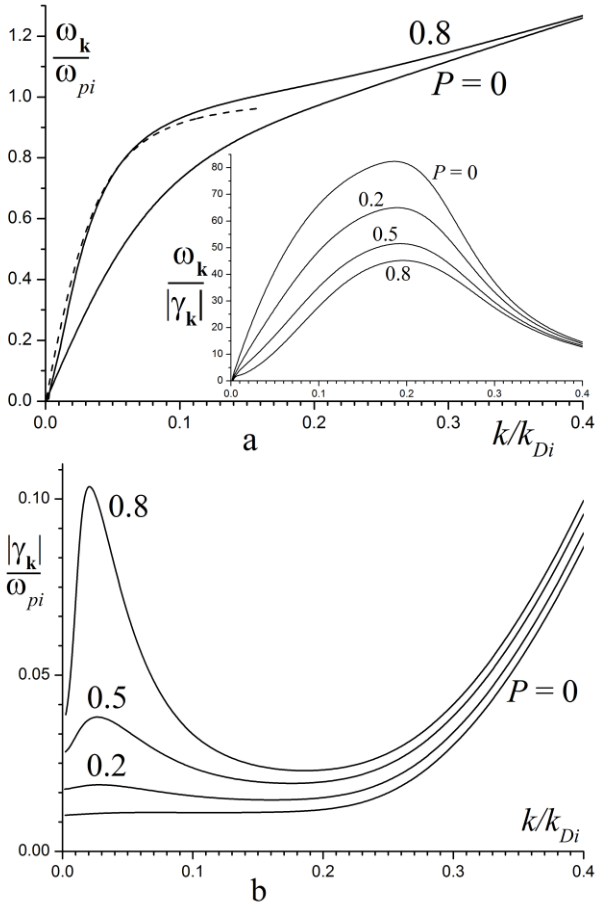

Fig. 1. Eigenfrequencies $\omega_{\mathbf{k}}$ (a) and absolute values of damping rates $|\gamma_{\mathbf{k}}|$ (b) of ion-acoustic waves in nonisothermal $(\tau=100)$ argon dusty plasma vs wave number for $\nu_{in}=0.02\omega_{pi}$, $ak_D=0.15$, $P=0, 0.2, 0.5, 0.8$ (solid lines). Dashed lines coresponds to ordinary plasma, but with $P=0.8$, insert is the ratio $\omega_{\mathbf{k}}/|\gamma_{\mathbf{k}}|$

The possibility of the existence of ion-acoustic waves in isothermal collisionless dusty plasma was discussed for the first time in Ref. [24] and later they were discovered experimentaly [25]. The Fig 1a shows that dispersion in dusty plasma is close to that one for ordinary plasmas, but with account to the change of n_e/n_i (see dashed line in Fig. 1,a). Thus, grain charge fluctuations and the increase of ν_i due to collisions with grains do not affect the dispersion of ion-acoustic waves for the parameters under consideration.

Since the phase velocity of ion-acoustic wave is much higher than thermal velocity for $\tau=100$, then the Landau damping is small for $k \ll k_{De}$, the additional increase of phase velocity due to the decrease of n_e/n_i does not affect the wave damping. In contrast, grain charge fluctuations and the increase of ν_i lead to a considerable increase of the absolute value of damping rate (per order for $k/k_{Di}\approx 0.02$) and to a decrease of the $\omega_{\mathbf{k}}/|\gamma_{\mathbf{k}}|$ ratio accordantly (see insert in Fig. 1,a).

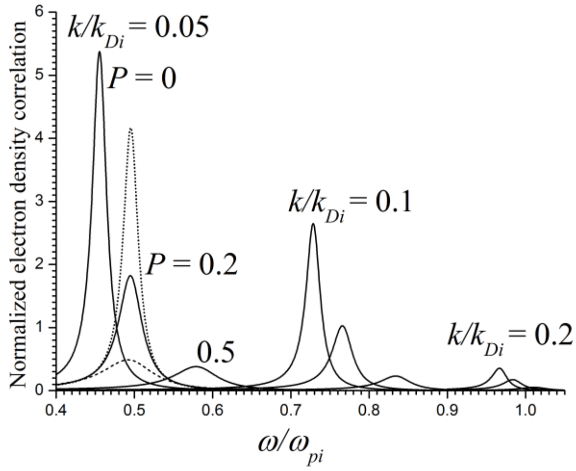

Fig. 2. Normalized electron density correlation spectra $\langle\delta n_\alpha^2\rangle_{k\omega}\omega_{pi}/n_i$ in nonisothermal ($\tau=100$) argon plasma for $\nu_{in}=0.02\omega_{pi}$, $a/\lambda_D=0.15$, $k/k_{Di}=0.05, 0.1, 0.2$, $P=0, 0.2, 0.5$, $a/\lambda_D=0.01$ (doted line) and $a/\lambda_D=1$ (dashed line)

The fluctuation spectra in strongly nonisothermal $(\tau=100)$ plasma, which are presented in Fig. 2, show that positions and intensities of maxima depend on the wave number k/k_{Di} and coincide with eigenfrequency of ion-acoustic waves (see Fig. 1,a). The presence of grains leads to the shift of fluctuation maxima toward higher frequencies and to decrease of fluctuation intensity

CONCLUSIONS

The electron density correlation spectra are strongly affected by the presence of grains with variable charge. In the case of nonisothermal plasmas the positions of the ion-acoustic resonances and their intensities depend on Havnes parameter. Namely, the fluctuations of grain charges along with the increase of ion effective collision frequency suppress the electron density correlations. This effect is considerably depends on the grain size and is more pronounced for bigger grains. The decrease of electron to ion density ratio n_e/n_i in dusty plasma leads to the shift of fluctuation maxima to higher frequencies.

The dispersion of ion-acoustic waves is mostly affected by the decrease of electron to ion density ratio n_e/n_i in dusty plasma. The collisions between plasma particles and grains as well as the charge fluctuations are additional mechanisms of wave energy dissipation and lead to a considerable growth of the absolute value of damping rate.

This work is supported by the SFFR of Ukraine (project F76/33256).

REFERENCES

1. A.G. Sitenko, A.A. Gurin. Effect of particle collisions on plasma fluctuations // *J. Exp. Theor. Phys.* 1966, v. 22, p. 1089.
2. R.H. Williams, W.R. Chappell. Microscopic theory of density fluctuations and diffusion in weakly ionized plasmas // *Phys. Fluids*. 1971, v. 14, p. 591.
3. Yu.L. Klimontovich. *Kinetic theory of nonideal gas and nonideal plasma*. Pergamon Press, 1982.
4. I. Holod, A. Zagorodny, J. Weiland. Anisotropic diffusion across an external magnetic field and large-scale fluctuations in magnetized plasmas // *Phys. Rev. E*. 2005, v. 71, 046401.
5. A.I. Momot, A.G. Zagorodny. Fluctuations in collisional plasma in the presence of an external electric field // *Phys. Plasmas*. 2011, v. 18, p. 102110.
6. A.G. Sitenko, A.G. Zagorodny, Yu.I. Chutov, et al. Statistical properties and relaxation of dusty plasmas // *Plasma Phys. Contr. F.* 1996, v. 38, p. A105.
7. V.N. Tsytovich, U. de Angelis. Kinetic theory of dusty plasmas. I. General approach // *Phys. Plasmas*. 1999, v. 6, p. 1093.
8. V.P. Kubaichuk, A.G. Zagorodny. Influence of grain charging dynamics on electromagnetic fluctuations in dusty plasmas // *Phys. Scripta*. 1999, v. 60, p. 549.
9. U. de Angelis, G. Capobianco, C. Marmolino, C. Castaldo. Fluctuations in dusty plasmas // *Plasma Phys. Contr. F.* 2006, v. 48, p. B91.
10. J.-X. Ma, M.Y. Yu. Self-consistent theory of ion acoustic waves in a dusty plasma // *Phys. Plasmas*. 1994, v. 1, p. 3520.
11. R.K. Varma. A kinetic description for low frequency longitudinal waves in a dust plasma including charge fluctuations // *Phys. Plasmas.* 2000, v. 7, p. 3505.
12. A.I. Momot, A.G. Zagorodny. Kinetic theory of ion-acoustic waves in dusty plasmas with grains of different sizes // *Phys. Scripta.* 2005, v. 71, p. 543.
13. S. Ratynskaia, M. de Angeli, U. de Angelis, et al. Observation of the effects of dust particles on plasma fluctuation spectra // *Phys. Rev. Lett.* 2007, v. 99, p. 075002.
14. S. Ratynskaia, M. de Angeli, E. Lazzaroet, et al. Plasma fluctuation spectra as a diagnostic tool for submicron dust // *Phys. Plasmas*. 2010, v. 17, p. 043703.
15. A.I. Momot, A.G. Zagorodny, O.V. Momot. A kinetic description of ion-acoustic waves in collisional dusty plasma: effects of grain charge fluctuations // *Phys. Plasmas*. 2018, v. 25, p. 073706.
16. A.F. Aleksandrov, L.S. Bogdankevich, A.A. Rukhadze // *Principles of plasma electrodynamics*. Springer, 1978.
17. S.A. Khrapak, G.E. Morfill. An interpolation formula for the ion flux to a small particle in collisional plasmas // *Phys. Plasmas*. 2008, v. 15, 114503.
18. I.L. Semenov, A.G. Zagorodny, I.V. Krivtsun. On the effect of ion-neutral collisions on dust grain screening in a low-pressure gas discharge plasma // *Phys. Plasmas*. 2012, v. 19, 043703.
19. A.V. Filippov, A.G. Zagorodny, A.F. Pal', et al. Kinetic description of the screening of the charge of macroparticles in a non-equilibrium plasma // *JETP letters*. 2008, v. 86, p. 761.
20. S.A. Khrapak, B.A. Klumov, G.E. Morfill. Electric potential around an absorbing body in plasmas: effect of ion-neutral collisions // *Phys. Rev. Lett.* 2008, v. 100, 225003.
21. A.G. Zagorodny, A.I. Momot, A.V. Filippov, et al. About the influence of plasma particles collisions on the effective grain potential // *Ukr. J. Phys.* 2009, v. 54, p. 1089.
22. A.I. Momot, A.G. Zagorodny. Toward analytical description of the electrostatic potential of charged macroparticle in weakly ionized plasma // *EPL*. 2016, v. 114, 65004.
23. Yu.L. Klimontovich, H. Wilhelmsson, I.P. Yakimenko, A.G. Zagorodny. Statistical theory of plasma-molecular systems // *Phys. Rep.* 1989, v. 175, p. 263.
24. P.K. Shukla, V.P. Silin. Dust ion-acoustic wave // *Phys. Scripta.* 1992, v. 45, p. 508.
25. A. Barkan, N. D'angelo, R.L. Merlino. Experiments on ion-acoustic waves in dusty plasmas // *Planet. Space Sci.* 1996, v. 44, p. 239.

Article received 16.10.2018

ФЛУКТУАЦИИ И ИОННО-ЗВУКОВЫЕ ВОЛНЫ В ПЫЛЕВОЙ СТОЛКНОВИТЕЛЬНОЙ ПЛАЗМЕ С ПЫЛИНКАМИ ПЕРЕМЕННОГО ЗАРЯДА

А.И. Момот, А.Г. Загородний, О.В. Момот

Кинетическая теория электрических флуктуаций в столкновительной слабоионизированной пылевой плазме сформулирована с учетом переменного заряда пылинок. Рассчитаны спектры ионно-звуковых волн и корреляций электронной концентрации в неизотермической плазме для разных значений концентрации и размеров пылинок.

ФЛУКТУАЦІЇ ТА ІОННО-ЗВУКОВІ ХВИЛІ В ЗАПОРОШЕНІЙ ЗІТКНЕННІЙ ПЛАЗМІ З ПОРОШИНКАМИ ЗМІННОГО ЗАРЯДУ

А.І. Момот, А.Г. Загородній, О.В. Момот

Кінетична теорія електричних флуктуацій в зіткненній слабкоіонізованій запорошеній плазмі сформульована з урахуванням змінного заряду порошинок. Розраховані спектри іонно-звукових хвиль і кореляцій електронної концентрації в неізотермічній плазмі для різних значень концентрації і розмірів порошинок.