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Interaction between grains in plasma

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We consider here a new effect, namely, the appearance of a repulsion force between dust grains due to ions collisions. The mechanism of this force rests on collisions of bound ions with buffer gas atoms and on the momentum transfer by atoms (that were ions before a resonance charge exchange collision). This force is an inverse square force, like the Coulomb force. The mechanism of the occurrence of recombination force is discussed first time in the present paper. The magnitude of this force is evaluated.

1. Introduction

In paper [1] in was found for the first time that the number of bound ions located on orbits around the dust particle (and correspondingly their effect on screening) do not practically depend on the frequency of ion-atom collisions. Under conditions typical of dust plasma experiments the collisional relaxation with atoms leads to the formations of a cloud of bound ions around negatively charged dust particle, which has a notable effect on dust particle charge screening. Furthermore, bound ions increase the ion flow onto the dust particle, and accordingly its charge is reduced [2, 3].

We consider here a new effect, namely, the appearance of a recombination force between grains. The mechanism of this force rests on resonance charge exchange collisions of bound ions with a cold gas atoms and on the momentum transfer from the ions accelerated in the dust particle field to the gas atoms (upon resonance charge exchange collisions of ions with gas atoms). As a result, from the “ions + dust particle” system the atoms (that were ions before resonance charge exchange) take off a larger momentum than they had brought in, which creates a recombination pressure.

2. The recombination force

Let there exist a motionless negatively charged sphere having radius *a* and charge $Q=-eZ<0$. We shall assume that dust particle radius, the screening length, and the mean free path of the ion before charge exchange with atom satisfy the conditions

$$a << \lambda_D << \lambda_{st} \qquad (1)$$

and the temperatures of electrons, ions, and atoms satisfy the conditions

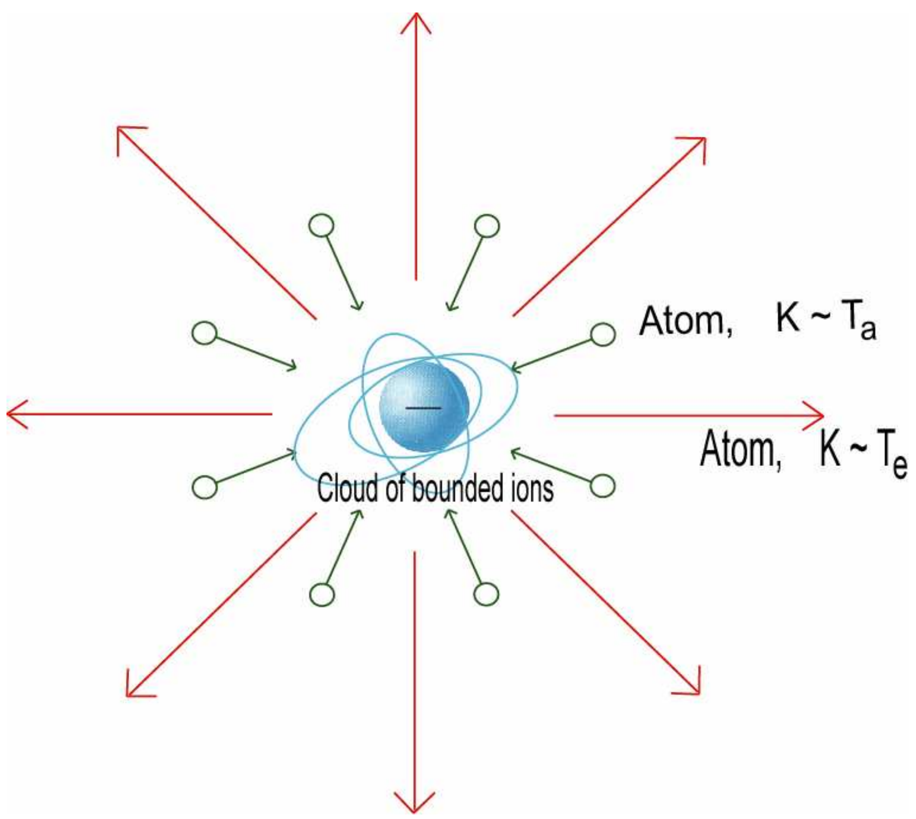
$$T_e >> T_i \approx T_a \,. \qquad (2)$$

A dust particle is so charged that its charge creates a considerable Coulomb barrier for electrons. When conditions (1) and (2) are met, the surface potential of the dust grain has the value

$$e|\varphi(a)| \sim (2 \div 4)T_e \,. \qquad (3)$$

Under certain conditions, around a negatively charged dust particle a cloud of bound (trapped) ions may appear which may have a considerable effect on the dust particle charge screening. The effect of weak collisional relaxation of the ion component in a gas-discharge plasma on the dust particle charge screening has recently drawn great attention. But independence of the number of bound ions (and, accordingly, of their influence upon screening) on the collision frequency was first discovered in paper [1]. Consequently, a large number of bound ions can be accumulated even in a collisionless plasma because of arbitrarily rare collisions.

The mechanism of this force: momentum transfer by atoms (that were ions before a resonance charge exchange collision).



The momentum transfer by atoms in radial direction (that were ions before a resonance charge exchange collision) through unit area (recombination pressure):

$$P_{rec} \approx \frac{\Delta p_1 J_{i\,rec}}{4\pi r^2}$$

We obtain the following estimate for the mean momentum transfer due to a single collision at an arbitrary point of the volume V_0 :

$$\Delta p_{1s} = \sqrt{2MK(r_s)} - Mv_0 \sim \left|2e\varphi(r_s)M\right|^{1/2}.$$

A momentum transfer due to one act of trapped ion recombination is equal

$$\Delta p_1 \sim \sqrt{2MT_e}\,,$$

recombination flux to the grain is defined by collisions near grain

$$J_{rec} = \int_a^{r_0} \frac{n_i\,\mathrm{v}}{\lambda_{st}} 4\pi r^2 dr \approx \frac{4\pi r_0^3 n_{i0}\,\mathrm{v}_0}{3\lambda_{st}}$$

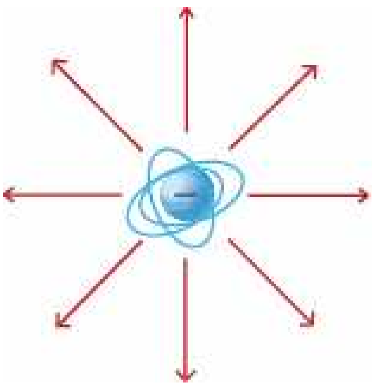
$$r_0 = a\frac{e\left|\varphi(a)\right|}{T_a} \sim 3a\frac{T_e}{T_a}$$

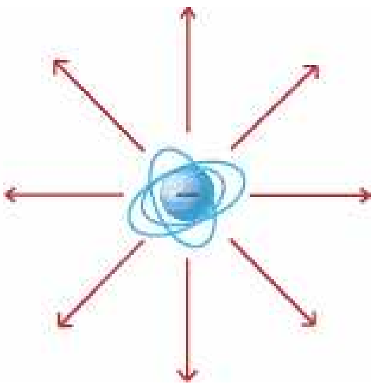
and recombination pressure is equal

$$P_{rec} \approx n_{i0} T_e \frac{a^3 z^3 \tau^{5/2}}{\lambda_{st} r^2}$$

Repulsion of grains due to recombination pressure is

$$F_{rec} = \pi a^2 P_{rec} \propto a^5$$





Comparison with Coulomb force

$$F_{coul}(r) = \frac{e^2 Z^2}{r^2} \propto a^2 :$$

$$\frac{F_{rec}}{F_{coul}} \sim 3\pi a^3 n_{i0} \frac{a}{Z\lambda_{st}} \left(\frac{T_e}{T_a}\right)^{5/2} \propto a^3 ,$$

and with shadow force [3-5]

$$F_{shad} = -\frac{3\pi n_{i0} T_i a^4 z}{2r^2}\left[z^2\tau^2 - z\tau + 3/8\right] \sim \frac{3a^2}{8\lambda_{Di}^2}\frac{e^2 Z^2}{r^2} \propto a^4$$

1) λ_{st} *= 500 mkm, Q /e = - 3000*

$F_{rec} / F_{coul} \sim 10^{-3}$ $F_{rec} / F_{shad} \sim -1$

2) λ_{st} = 100 mkm, Q /e = - 2000

$F_{rec} / F_{coul} \sim 10^{-2}$ $F_{rec} / F_{shad} \sim -10$

3. Conclusions

The mechanism of the occurrences of the recombination force between dust particles in a plasma is described. This force is associated with the resonance charge exchange collisions of trapped ions and a parent gas atoms near the dust particle. This force is an inverse square force, like the Coulomb force.

4. Acknowledgments

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5. References

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