The dynamics of dust particles in the atmosphere of white dwarfs

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The white dwarfs atmospheres containing dust particles are the natural objects for studying the properties of dusty plasmas. In this paper, the calculation of the potential of dust particles in the atmosphere of white dwarf stars with a low ionization coefficient is given. The calculation of heating and lifetime of the dust particles in the white dwarfs atmosphere has been carried out. Particles with sizes ranging from tens of nanometers to tens of micrometers were considered.

The data of astrophysical observations obtained by special devices Spitzer Space Telescope and IRAC imager identify that white dwarfs atmospheres contain metals (C, Si, Fe, etc.), due to external sources, such as accretion of matter from the interstellar medium, the fall of comets on the surface of white dwarfs [1-3]. Due to radiation, dust particles can levitate in an atmosphere of white dwarfs. At an effective temperature of T_{eff} > 20 000 K, the particle can either evaporate or melt. And at temperatures below 20 000 K, gravitational sedimentation of dust particles takes place [4].

To explore the dynamics of dust particles in stellar atmospheres, it is necessary to establish the main parameters of the medium: temperature, pressure, chemical composition and density. To describe the substance of white dwarfs, various theoretical models of the atmosphere have been constructed. For example, in the model built for the star G2938 [5] with an effective temperature limit of 2500 to 60 000 K, the pressure is 4 < log P (dyne cm^{-2}) < 19. The total pressure of the atmosphere includes gas pressure and radiation pressure. The pressure depends on the degree of ionization and temperature. The density of the atmosphere is considered within 10^{-2}-10^{-5} g / cm^3.

Strong gravity leads to a high density of neutral hydrogen atoms, of the order of 10^{18} cm^{-3} [5].

In this paper, the composition of the white dwarf atmosphere plasma is calculated using the Saha equation and the potential of a charged dust particle is obtained. Figure 1 shows that the calculated value of the degree of ionization for hydrogen in the atmosphere of white dwarfs is very low at temperatures below 20 000 K, therefore the plasma in such atmosphere is considered to be weakly ionized.

The distribution of the electric potential around a dust particle of radius a_d, charge $Z_d|e|$ has the form:

$$\varphi_d(r) = \frac{Z_d|e|}{r(1+\frac{a_d}{\lambda_D})} e^{-(r-a_d)/\lambda_D}, \qquad (1)$$

where r is the distance to the center of the particle, λ_D is the screening length. Potential (1) satisfies the Poisson equation $\Delta\varphi = 4\pi e\left[n_e(r) - n_i(r)\right]$ with the boundary conditions [6]: $\varphi_\infty = 0, \quad \varphi(a_d) = \varphi_s$ (φ_s - being a surface potential) and

$$\left.\frac{d\varphi}{dr}\right|_{r=a_d} = -\frac{Z_d e}{a_d^2}.$$

The Fourier transform of this potential (1) has the form:

$$\tilde{\varphi}_d(k) = \frac{4\pi Z_d|e|}{(k^2+k_0^2)(1+\frac{a_d}{\lambda_D})} e^{a_d/\lambda_D}, \qquad (2)$$

where $k_0^2 = \frac{1}{\lambda_D^2}$ - is the screening parameter.

The micropotential of the interaction of charged particles and a neutral hydrogen atoms with a centrally symmetric distribution of electron density has the form:

$$\varphi_{nn}(r) = \frac{Ze^2}{r} e^{-\sqrt{2}r/a_B}. \qquad (3)$$

where a_B - is the Bohr radius.

Using the relationship between screened potential and dielectric function

$$\tilde{\Phi} = \frac{\tilde{\varphi}_d}{\varepsilon} = \frac{\tilde{\varphi}_d}{1+\frac{n_n}{k_B T}\tilde{\varphi}_{nn}}, \qquad (4)$$

we obtain the potential of a dust particle in a weakly ionized medium with a high gas density.

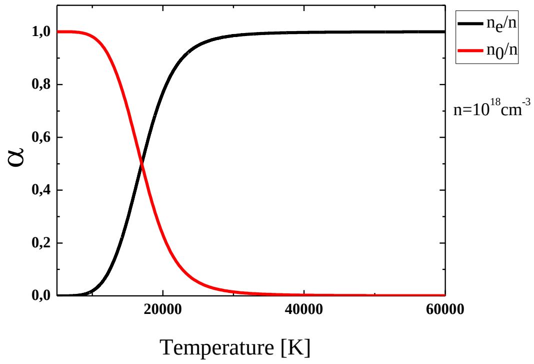

Fig.1. Dependence of the degree of ionization on temperature

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