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DUSTY PARTICLES — POSSIBLE SOURCE OF RYDBERG STATES FORMATION IN LOW IONOSPHERE

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It is shown that recombination of free ion with electron on the surface of dusty particle forms the neutral molecule or atom in Rydberg (high-excited) state. The concentration of such neutrals can be higher than concentration originated from usual plasma volume recombination.

During the last few years several works that deal with observation of highly intensive radiation in far infrared and radio frequencies of low ionosphere at disturbance periods appeared. Highly excited atoms or molecules are one of the possible sources of this radiation. Authors [1] had investigated formation of highly excited atomic or molecular state during the solar flares. These states can be one of the potential sources of the above-mentioned radiation. Photoelectrons (and/or electrons born during magnetic storms) were found to be a cause of formation of the strongly excited atoms and molecules. It should be noted that usually atoms with principal quantum number $n \geq 10$ are referred to as Rydberg's states. However the respective value for atmospheric gases (N_2, O_2, NO_x) is $n > 3$ due to the following fact: energy of these states for atmospheric gases appears to be some 2—3.5 eV less than the ionization potentials. In [1] it is shown that there are two maximums for excitement rate constant of molecular Rydberg's states: at the heights of $\approx$ 200 km and $\approx$ 100 km; the values are connected with different parts of the solar spectrum.

Disturbance in the ionosphere may also result from changes in geoelectric field [2—3], thus it is reasonable to consider an additional source of Rydberg's states formation. It is connected with the peculiarities of aeronomy of the area but should also be taken into consideration when analyzing influence of the solar flares. It is known [4] that in the latter case an excursion of electron concentration may also occur at the above-mentioned heights due to floods of high-energy particles. Thus an analysis should allow for recombination processes that also lead to formation of highly excited neutrals.

As it was reported in [5], there are some layers of dust particles 1—5 km in thickness at heights of 80—100 km. The density of these particles varies from 0.5 to 10 cm^{-3}. Unfortunately, our knowledge regarding dust origination, composition, and particle sizes is far from perfect. However, we can make some evaluations based on the experimental data mentioned above. At heights about 80 km, the dust is probably composed of ice, sometimes with metallic impurity [6]. At higher altitudes (90—100 km), the main components of dust are meteor ablation, rocket exhaust products, and materials from destroying part of spacecraft's. The average size of such dust particles (a) is ~ some microns. Such layer of dust overlaps plasma layer of increased electron temperature and concentration. It is known that electron charge of particle surface can be increased by geoelectric field perturbation [2].

We assume that the surface states of electrons on a dust particle are analogous to those on the surface of condensed noble gases and some other dielectric [7]. Therefore, electrons are bound in the normal direction to the surface of the particle and practically free in the tangent directions. The attractive part of surface potential connected with interaction of electron with its «mapping» in dielectric. The origination of repulsion can change in various dielectrics, but usually it is connected with presence of amorphous structure and low (or negative) affinity to electron. It can be shown that energy spectrum (E_n) of such states is close to hydrogen-like one if dusty particle consists of dielectric only [7]:

$$E_n = -Z^2 \mathrm{Ry}/n^2,$$

where $Z = 1/4(\varepsilon - 1)/(\varepsilon + 1)$ — effective charge of electron mapping in dielectric with permeability ε, Ry is Rydberg constant. Distance of electron from the surface is $l \sim b/Z$, where b — Bohr radius. This distance meets inequality $l \ll N^{-1/3}$, where N is concentration of neutral particles on these altitudes. This inequality provides a possibility to ignore the neutral particles influence on the surface electron spectrum. This hydrohen-like spectrum is more complicate if dielectric has metallic impurities. One needs more detailed information about dusty particle parameters in both cases. Data from [8] provide following magnitude epsilon for chemical substances, mentioned above:

a) Materials with hydrocarbones, $\varepsilon \sim 2.5 — 11$;

b) Metallic oxides (f.e. Al_2O_3, etc.), $\varepsilon \sim 8.5 — 25$;

c). Ice (temperature below −40 °C), $\varepsilon \approx 95$;

We can evaluate a bonding energy of electron on the dusty particle surface as 0.5—0.9 eV. This energy is higher then the thermal energy of surface (near ~ 0.02 eV on these altitudes at night). Thus we can neglect its influence on the first level population.

When an ion collides with a charged dusty particle the electron-ion heterogeneous recombination with particular excited states occurs [9]. This is caused by the peculiarity of the decay of a quasi-molecule: surface electron — ion with formation of neutral particle. This process obviously has dominant probability if the surface electron energy is close to the energy of the particle. The bound energy of a dust surface electron is of the order of 1 eV. Therefore, a neutral particle appears in a highly excited (Rydberg state).

Rydberg state formation also takes place during usual recombination process. Characteristic time of this process is inversely proportional to the charged particles concentration, so an importance of this process is increasing during the time interval of electron concentration disturbances by high-energy particles stream. Analytical solutions for equations, which describe space-temporal structure of electron concentration disturbances by high-energy particles stream [4], can be used for evaluation of Rydberg states concentration. We will assume that Rydberg states are formed by recombination processes on the dusty particles or by «ion — electron» processes and vanish in radiation process. The following ratio between concentration of Rydberg states from dusty particles recombination N_r and usual two-bodies recombination N_r^* results from the balance equations

$$N_r/N_r^* \sim k_{rec}/k_{rec}^* \cdot N_d/N_e,$$

where k_{rec} is the rate of ion-surface electron recombination; k_{rec}^* is the rate of ion-free electron recombination. Concentration of dusty particles is N_d and concentration of free electrons is N_a. It follows from results [4,8] that inequlity $N_r/N_r^* \geq 10$ can exist in low ionosphere (nighttime) and dusty particles make an important contribution to the Rydberg states formation. Evaluation of spectrum and intensity parameter requires specific data about dusty substance and probabilities of transitions in states, mentioned above.

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