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Possibilities of lightning-induced processes in gas-dusty atmosphere of water-containing bodies of Solar System

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Abstract. Lightning is considered as one of energy sources for synthesis of biochemical compounds. Numerous theoretical and experimental researches of gas-grain chemistry show that chemical reactions on the gas - ice boundary play a considerable role in such synthesis. In this connection the greatest interest represents studying lightning in gas-dusty atmospheres of water-containing bodies (comets, ice satellites of Jupiter and Saturn).

Keywords. Astrobiology, plasmas, comets: general, planets and satellites: individual (ice satellites)

1. Lightning in water-containing bodies of the Solar system?

Modern theories of charge accumulation and separation in thunderstorm clouds are based on the study of the microphysics of ice (Rakov & Uman 2003). The size and the sign on a charge formed during the collision of ice crystals and snowflakes does not depend on electric fields and is defined by a profile of temperatures and physical characteristics of the colliding grains. At the altitude 6 – 8 km and temperatures of about $-15°$, there exists a negatively charged layer (so-called charge reverse by thickness some hundreds meters). The separation of charges occurs at collisions between ice crystals falling downwards and snowflakes rising upwards. The ice crystals are charged positively below the charge reverse layer, and negatively above. Above this layer the snow pellets are charged positively, and below negatively. Thus, the negatively charged layer consists of negatively charged ice crystals and snow pellets. Positively charged snow pellets form a charge at the top of the cloud, and positively charged ice crystals form positive charge in the bottom of the cloud.

The majority of terrestrial lightning discharges are connected to participation of water (see Table 1). Another, significantly smaller group, includes discharges caused by the accumulation of charges on dust (discharges in dust storms) or ashes (volcano lightning).

So, there are two reasons for considering lightening in waterless atmospheres. It follows from Table 1 that the huge volumes and amounts of material in sprites gives a reason to speak about their large possibilities for synthesis of organic compounds.

2. Lightning-induced processes in gas-dusty atmospheres

It is possible that conditions exist for electrostatic charging of grains in atmospheres of two bodies: jets from the surfaces of comets, and geysers on Enceladus. The atmosphere of comets are complicated dynamic objects in which there is a directional motion of particles, convection, melting of ice, and fracture of large particles. The temperature profile of the Enceladus geysers is very similar to a profile of temperatures in thunderstorm clouds near their charge reverse layer. In these conditions charging of ice grains is

Table 1. Properties of the terrestrial lightnings.

Type of discharge	Number (in year)	Energy MJ	Volume km^3	Matter in volume, ton	Matter in year, ton
Cloud-cloud,cloud-ground lightning	$\approx 3 \cdot 10^9$	$\approx 5 \cdot 10^9$	≈ 0.001	$\approx 1 \cdot 10^3$	$\approx 3 \cdot 10^{12}$
Sprites* (lightning in mesosphere)	$\approx 3 \cdot 10^7$	≈ 10	$\approx 1 \cdot 10^4$	$\approx 2 \cdot 10^6$	$\approx 6 \cdot 10^{13}$
Lightning at tornado and volcano	$\approx 1 \cdot 10^3$?	≈ 10	≈ 0.0001	≈ 100	$\approx 1 \cdot 10^5$

Notes:
* Sprites are the most frequent and powerful lightning-induced events in the mesosphere and occur above thunderstorms after about one percent of lightning (Pasko *et al.* 1997). The duration is several ms. Sprites can extend about 50 km in horizontal and vertical directions. The brightest region takes place in the altitude of 65-75 km.

possible, and conditions for separation of charges which can lead to discharges in area of geysers. For estimates of parameters of plasma of hypothetical discharges we will assume that physical characteristics of the atmosphere over an active spot of comets and in the area of geysers are close to characteristics of terrestrial atmosphere at heights of 90 – 100 km. The electric discharges in rarefied gas-dusty atmospheres will serve not only as energy sources for synthesis of biochemical compounds. It is possible that the more important consequences for gas-grain organic chemistry will be the presence the properties of dusty plasma ordered structures (plasma crystals) (Tomas *et al.* 1994). Under certain conditions in dusty plasmas it is possible to form helical dust structures (Tsytovich *et al.* 2007). The plasma of sprites and hypothetical lightning's discharge in gas-dusty atmospheres on Mars and comets can also be a medium for the formation of ordered structures (Serozhkin 2005b).

The criterion of the first step to formation of ordered structure in dusty plasma is the Coulomb coupling parameter. It is determined as the relation of a potential energy of interaction of charged particles to a kinetic energy of particles in a center-of-mass system of dust particles. For example, the estimation of the requirement to energy of micron-size grains with concentration 10^3 cm^{-3} and charge 1000e (in case of an ingress of a dusty component into an area of sprites) for transition in a Coulomb liquid (Coulomb coupling parameter greater than 2) gives a value of kinetic energy less than 10^{-12} erg, which corresponds to a velocity dispersion of less than 0.5 cm s^{-1} (Serozhkin 2005a).

Can such ordered structures play the role of matrices for the formation of pre-biological compounds? Can conditions exist on the Earth or in the Solar System for the formation of plasma crystals? The research of the synthesis of organic compounds in dusty plasmas of discharges would submit additional capabilities for understanding of processes of formation and self-organizing of pre-biological compounds.

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