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New aspects of planetary plasma physics based on EHD (electrohydrodynamics) or EMHD (electromagnetohydrodynamics) and application to planetary atmospheres, ionospheres, magnetospheres, and interplanetary space

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NEW ASPECTS OF PLANETARY PLASMA PHYSICS BASED ON EHD (ELECTROHY-DRODYNAMICS) OR EMHD (ELECTROMAGNETOHY-DRODYNAMICS) AND APPLICA-TION TO PLANETARY ATMOSPHERES, IONOSPHERES, MAGNETOSPHERES, AND INTERPLANETARY SPACE

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Theory of planetary plasma physics is usually based on dynamics of neutral and charged particles, HD (hydrodynamics), MHD (Magnetohydrodynamics) or plasma kinetic theory. The first particle and the second fluid approach are well established apart from space charge, electric fields, displacement current and. polarization effects.. While the third distribution function approach is based on conventional plasmas without dust or even if dust dynamics is used, it does not take into account charged induced or po-larization effects of particles due to external charges or electric fields that become significant in most of cases of planetary environments. A new plasma physics that meets these demands has been established and developed for the last two

decades. It is EHD (Electrohydrodynamics). When this term was rarely used, it is not a kind of ‘dynamics’ but is just ‘Electrostatics’ in content. In other words,. EHD was very immature as a system of science in contrast to maturity and prosperity of HD and MHD. This paper aims to summarize a newly developed ‘EHD’ or EMHD (Electromagnetohydrodynamics) and a new ‘gravito-electrodynamics’ as its base and to apply them to ‘planetary plasmas’, particularly to a variety of dust-re- lated phenomena in the presence of ‘quadrupole-like charge configurations which are other-wise difficult to explain, Though the term of EHD is the same as EMHD in content, EHD is used pref-erably when electrical effects are significant compared with magnetic effects. A new equation of elec-tric transport considers effects of space charge and displacement currents, namely electromagnetic con- vection, radiation, and production. When electric Reynolds number defined newly is high enough, namely R_E » 1, the electric transport equation is reduced to the so-called Kelvin-Helmholtz equation just like fluid vortex transport for R » 1 in HD and magnetic field transport for R_M » 1 in MHD, physically implying that the frozen-in field concept holds for all of them. Polarization effects on neutral particles and fluids give rise to new equations of motion of particles and fluids, opening new electrodynamics which have not been considered as yet. For instance, the presence of an electric quadrupole generates heli- cal motion of even uncharged particles and fluid vortices. Invasion of a dust grain in- to an electric cusp, whether it is charged or uncharged, results in electric reconnec- tion, particle acceleration and/or EHD shock generation, for the latter case being fol- lowed by critical velocity ionization, discharge channel formation and a consequent main discharge. Specifically, when a background gas is beyond the breakdown threshold, a variety of discharge phenomena occur for invading dust into the electric cusp in the following ways. For an uncharged grain a discharge channel is formed to- wards each pole as a re- sult of X-type reconnection. For negatively or positively charged grain, I-type reconnection occurs be-tween the grain and positive or negative poles, respectively. For uncharged two grains, O-type recon- nection between both grains :could be involved in addition to X-type between each pole, while for op- positely charged two grains, Φ-type reconnection could be involved between grains in addition to I-type between each grain and a pole with opposite polarity. Applications to these basic processes to planetary discharge and lightning are numerous. As an ex- ample, quadrupole-like space-charge and electric field configurations in tornadic thunderstorms could be a source-origin of helicity and vortex generation be- sides thermohydrodynamic origin. Another example is quadrupole-like or cascade of quad- rupole-like space-charge and electric field configurations in planetary clouds is the possibility of diffuse dust layer or ring formation such as in Jupiter’s or terrestrial atmosphere or ionosphere.

Reference

H. Kikuchi, *Electrohydrodynamics in Dusty and Dirty Plasmas*, Kluwer Academic Publishers, Dordrecht/The Netherlands, 2001.