Solar Streamer and Magnetotail under Analytical Three Dimensional Kinetic Consideration: Reconfiguration, CME and Substorm Driving by SW VDF Reshaping

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We give example of self-consistent 3D analytical approach in terms of the Vlasov and Maxwell equations (non MHD approach) to formation of a separate solar streamer and of the magnetosphere magnetotail. We give new kinetic approach to their dynamics appeared as CME and as magnetic substorm.

We consider 3D streamer as a result of solar corona expansion over solar magnetoactive region. Corona here is a hot collisionless media forming solar wind (SW). The wind flow outside of streamers has prescribed shape of the velocity distribution function (VDF) and the flow inductively interacts with e.m. fields originating from 3D magnetoactive region. Similar physics is applied to the 3D magnetosphere formation. The incoming solar wind before magnetosphere is treated as hot rarified nonmagnetized plasma with prescribed “core” and “halo” elements which are considered in terms of a “kappa” VDF. Perturbed motion of directly moving particles in the “outer” magnetosphere and their VDF is selfconsistent with inductive e.m. fields originating from the prescribed “internal” magnetosphere. There are three e.m. regimes of the flow velocity relative to thermal velocities of ions and electrons: subsonic, supersonic and superthermal to electrons. The first regime is realized in solar corona and the second near magnetosphere. Both regimes are subthermal to electrons.

A solar active region magnetization has orthogonal magneto dipole and toroid components, models a 3D separated helmet-like structure near solar surface with initial 3D “X” point. Magnetization of the “internal” magnetosphere has magnetodipole moment and toroidal moment vectors which are orthogonal to each other and to the flow direction. The toroid models asymmetry provided by partial ring current. The ratio of the toroidal to the magnetodipole circular currents in the active region defines ratio of the “dipole” to the “toroidal” components in the internal structure of the elongated streamer. Streamer is a stationary radial structure developed near the initial 3D “X point”. In the magnetosphere the ratio defines ratio of the mantle “two wire” current configuration with multi rope current structure to the “theta” current configuration with multi current sheets structure.

Plasma flow in subsonic and supersonic regimes we characterize by the “momentum” and “energy” dimensionless anisotropies which are new e.m. kinetic parameters reflecting conductive and diamagnetic properties of flow and providing friction and pressure drag. Parameters are differently expressed via shape characteristics of the VDF. The ratio of these anisotropies is a new governing e.m.

plasma flow parameter G called “quality”, it is independent from Mach number M. Parameter G characterizes e.m. (transversal fields) properties of flow and formation of streamer/magnetotail, but M as a governing parameter characterizes acoustic (longitudinal fields) properties of flow and formation of shock wave. Parameter G varies with reshaping of the VDF. By G we define variation of the e.m. properties of plasma flow. Collisionless hot plasma in inductive interaction under constant hydrodynamical parameters of the flow can behave as a conductor for the low G state or it behaves as a diamagnetic for the high G state. The resulting large-scale kinetic (LSK) streamer/magnetotail structure can be in the “elongated” low G state with 3D LSK multiray elements and multicurrent sheets. The structure adiabatically transforms topology to the “compact” helmet like/dipolized high G state. Conductivity of the flow is related with resonance LS interaction of some group of flow particles and e.m. fields. Remaining particles provide LS diamagnetic effects.

Nonadiabatic transition from the “elongated” state to the “compact” state is governed by fast time change of G value and appears as the CME effect in the streamer or as the magnetic substorm effect in the magnetotail. The LS are defined via induced by flow new “thin” and “thick” dispersion plasma scales expressed via flow anisotropy parameters. The scales named “anomalous skin” scale and “magnetic Debye” scale. Calculations of G we made for "kappa" shapes of the “core” and “halo” VDFs as well as for the maxwellian VDF.

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