**A. A. Galeev.** *The mechanism of magnetosphere substorms.* A magnetosphere substorm is a complex set of phenomena that accompany the development of the global instability that is internally inherent to the magnetosphere as a dynamic system. The main source of energy for these processes is the energy of the magnetic field in the extended magnetospheric tail.

Specialists have long believed that the nonequilibrium nature of the tail of the magnetosphere is due to the presence of a neutral layer, on opposite sides of which the force lines of the magnetic field have opposite directions (toward the Earth in the north half of the tail and away from the Earth in the south half). Therefore Compi, Laval and Pellat, and, later, Schindler proposed that a "tearing" instability is responsible for the dissipation of the energy free of the tail which is known from controlled thermonuclear fusion research. The physical mechanism of the instability is easily perceived by imagining a distributed current in the form of a set of current filaments that is responsible for the magnetic-field reversal in the neutral layer. Such current filaments have a tendency to "stick together," since the attractive force between adjacent filaments rises rapidly as they approach one another, while their bonds to the other filaments are weakened because of the increasing distances. This results in a change in the topology of the magnetic field: part of the magnetic flux, which had previously been directed along a flat current layer, is reconnected to form lines of force that close around a pair of currents stuck together. However, it is clear that reconnection is possible in the presence of finite dissipation, when freezing of the force lines into the plasma no longer holds. In the proposed theories, dissipation is provided by Cherenkov interaction of the "tearing" mode with particles moving in the neutral layer, where the magnetic field is small and therefore not an obstacle to resonant interaction.

It was possible to explain the striking stability of the magnetospheric tail during the many hours between substorms in this approach, recognizing that part of the flux of magnetic force lines still crosses the neutral layer in the magnetospheric tail (in which sense, strictly speaking, it is no longer neutral). The explanation for the stability of the actual configuration is that as the current filaments approach one another, it is necessary to expend energy to compress the electron component of the plasma frozen into the magnetic force lines crossing the neutral layer.[1] Since the disturbance of electron density $n_{1e}$, which is inversely proportional to the magnetic field component normal to the layer $B_{\perp 0}(n_{1e}/n_0 = B_{\perp 1}/B_{\perp 0})$, the stability of the tail decreases as this component increases. Later expermental studies[2] showed that magnetic-field fluctuations with a characteristic dimension of the order of the "tearing"-mode wavelength actually do develop in the magnetospheric tail during active periods (this length is of the order of the plasma-layer thickness in the tail, which is 0.5–2 Earth radii). Also confirmed is the conclusion of Ref. 1 that a magnetic-field disturbance of finite magnitude may act as a "trigger" for development of magnetosphereic-tail instability.[3]

However, recent experimental studies have confronted the theory with new questions. It developed that high-velocity plasma fluxes appear as a result of this instability with a characteristic time in the tens of minutes.[4] On the other hand, energetic particles appear in the tail after a time of the order of a few minutes.[5] Therefore if it is assumed that the global dynamics of the plasma in the tail has characteristic times of the order of the reciprocal linear instability increment (as is confirmed by simple estimates), the time to accelerate the particles to high energies should correspond to faster ("explosive") processes. Theoretical investigations of the nonlinear "tearing"-mode stage[6] have shown that it does indeed assume an explosive character. The physical explanation for this is that the magnetic islets surrounding the stuck current filaments become much larger at the nonlinear stage than the Larmor radius of the ions. In this case, the magnetic field prevents resonant energy exchange between the particles and the "tearing" mode everywhere except in a small neighborhood of the neutral lines. Since the size of this neighborhood decreases with increasing amplitude, the magnitude of the vortical electric field $(E_1 \sim \partial B_1/\partial t)$ must increase in the "tearing" mode in order to ensure the necessary dissipation of free energy. This corresponds to explosive amplitude buildup of the "tearing" mode. Solution of the problem of particle acceleration by the "tearing"-mode electric field in the neighborhood of neutral lines can explain the observed characteristics of magnetospheric energetic-particle bursts (spectrum, energy cutoff threshold, evolution in time).[7]

Construction of substorm theory must include, in addition to the processes described above, investigation of the electrodynamic coupling of magnetospheric-tail processes with processes in the auroral ionosphere (auroras, auroral currents, radio emission, etc.), study of the nonlinear dynamics of the plasma configurations formed as a result of development of the "tearing" mode (nature of fast plasma fluxes—"fireballs," injection of particles into a ring current, etc.).

[1] A. A. Galeev and L. M. Zelenyĭ, Zh. Eksp. Teor. Fiz. **70**, 2133 (1976) [Sov. Phys. JETP **43**, 1113 (1976)].

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