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Dipole Confinement

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Magnetospheres are self-organized structures found commonly in the Universe. A dipole magnetic field sets the stage for charged particles to cause a variety of interesting phenomena [1–4]. The nontrivial nature of magnetospheres is primarily due to the strong inhomogeneity of the field strength. The motion of a single particle is not very complicated; it coils around an arching magnetic field line and bounces between the polar regions. Yet, the physics of magnetospheric plasma is very rich and even strange. For example, magnetized particles are normally diamagnetic, but the magnetosphere attracts some of the particles and produces a clump. These particles diffuse toward the higher density inner region and steepen the density gradient. Such a process is seemingly contradictory to the conventional idea of diffusion, which usually diminishes any gradient.

Hasegawa [5-7] explains the uniqueness of the magnetospheric configuration by comparing Cartesian and magnetic coordinates; the latter, consisting of the action variables pertaining to periodic motions of magnetized particles, are strongly distorted with respect to the former by the inhomogeneity of the field strength. The motions of magnetized particles, obeying the adiabatic constraints, are embedded in the magnetic-coordinate space. Hence, mapping from the magnetic-coordinate space onto Cartesian space (the laboratory frame) will produce strange images—the Jacobian weight will yield a strong heterogeneity in the Cartesian perspective. This theory can be put into a perspective of the general theory of Hamiltonian mechanics [8]; the adiabatic invariants foliate the phase space, imparting topological constrains, and the relevant statistical mechanics is based on the particular entropy to be evaluated by the invariant measure on the immersed symplectic manifold.

At University of Tokyo, a “laboratory magnetosphere” has been constructed to prove the idea of dipole confinement and related magnetospheric phenomena [9-13]; the RT-1 device levitates a superconducting ring magnet in a vacuum chamber and produces a magnetospheric configuration (Fig. 1). Ultra high-beta confinement of 10 keV level electrons with confinement time of order 1 sec. has been proven. Experimental evidence of inward diffusion was obtained by measuring the temperature anisotropy. A recent experiment has demonstrated laboratory chorus emission [14].

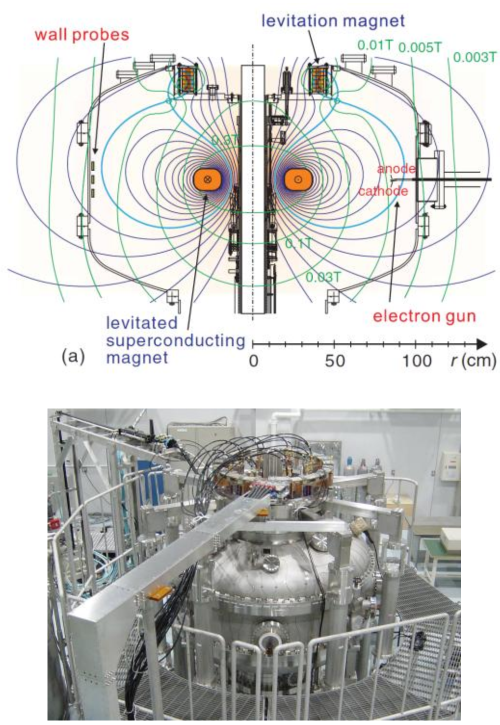

Fig. 1 The RT-1 magnetospheric plasma system. A dipole magnetic field is produced by the levitating superconducting ring magnet. The magnetic field lines (contours of the flux function) and the field-strength contours are shown. The field strength in the confinement region varies from 0.5 to 0.01 T.

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