Self-organized confinement in dipole magnetic field

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Magnetospheric plasmas (the naturally occurring ones such as the planetary magnetospheres [1], as well as their laboratory simulations [2]) are self-organized around the dipole magnetic fields in which charged particles cause a variety of interesting phenomena: the often observed inward diffusion (or up-hill diffusion) of particles injected from the outer region is of particular interest. This process is driven by some spontaneous fluctuations (symmetry breaking) that violate the constancy of angular momentum. In a strong enough magnetic field, the canonical angular momentum P_θ is dominated by the magnetic part $q\psi$: the charge multiplied by the flux function. The conservation of $P_\theta \approx q\psi$, therefore, restricts the particle motion to the magnetic surface (level-set of ψ). It is only via randomly-phased fluctuations that the particles can diffuse across magnetic surfaces. Although the diffusion is normally a process that diminishes gradients, particles do exhibit preferential inward shifts through random motions. An equilibriun that maximizes entropy simultaneously with bearing steep density gradient is formulated as a grand-canonical distribution on a leaf of foliated phase space that represents a macro-hierarchy [3]. In a strongly inhomogeneous magnetic field (typically a dipole magnetic field), the phase-space metric of magnetized particles is distorted; thus the projection of the equipartition distribution onto the flat space of the laboratory frame yields peaked profile because of the connecting inhomogeneous Jacobian weight.

The RT-1 device produces a *laboratory magnetosphere* by which stable confinement (particle and energy confinement time ~ 0.5 s) of high-β (local electron $\beta \sim 1$, electron temperature ~ 10 keV) is achieved [4]. Using RT-1, we can also produce a pure-electron non-neutral plasma by injecting electrons from an electron gun placed at the periphery of the confinement region that is bounded by a magnetic separatrix. The confinement time is about 300 s.

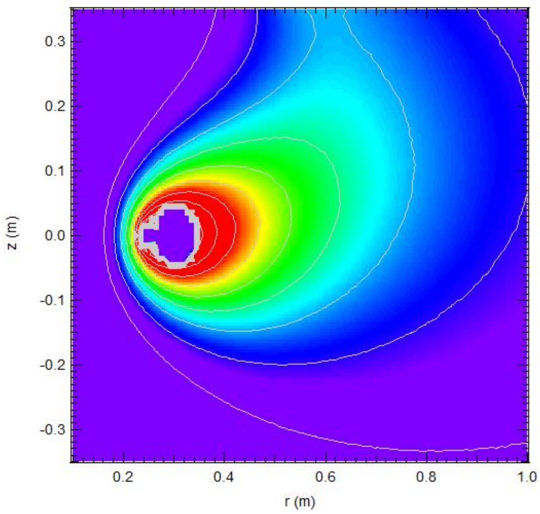

Fig. 1: Self-organized density clump in the RT-1 diploe magnetic field. The figure shows the density distribution (measured by 3-cord interferometry and fitted by a Grad-Shafranov equilibrium solution) on a poloidal cross-section.

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