【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Mathematical and physical sciences)

Title of Project : Self-Organization of Magnetospheric Plasma Confinement --- nonlinear effect of space-time distortion cause by inhomogeneous magnetic field

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Research Area : Plasma Science
Keyword : Plasma Physics, Self-organization, Vortex, Magnetosphere

【Purpose and Background of the Research】

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. We can explain the self-organization process by the nonlinear effect of "space-time distortion" represented as a "vortex" (Fig. 1); a strongly inhomogeneous magnetic field distorts the space-time metric of the magnetized particle, giving rise to various interesting phenomena. The aim of this project is to elucidate the physical mechanisms in a magnetospheric vortex and demonstrate their applications.

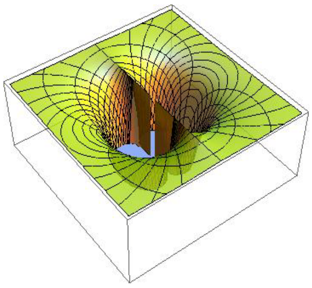

Fig. 1: The distorted metric of space-time dictating the motion of charged particles in the vicinity of a dipole magnetic field.

【Research Methods】

Recently a "laboratory magnetosphere" has been created; the RT-1 device levitates a superconducting ring magnet in a vacuum chamber and produces a magnetospheric plasma (Fig. 2). By the electron-cyclotron heating a high temperature plasma is produced proving high-beta stable confinement (simultaneous electron parameters: temperature $\gtrsim$10keV, density $\lesssim 10^{17}\,\mathrm{m}^{-3}$, beta $\gtrsim$0.7, energy confinement time $\gtrsim$0.5s).

In this project, we will explore a new regime of parameters on RT-1: (1) Developing an ion-cyclotron heating (ICH) system, we will heat ions to produce high ion beta (~0.1), and demonstrate high-performance confinement. (2) By the strong inhomogeneity of the dipole magnetic field, the nonlinear magnetic beach heating in ICH will become possible. We will study the mechanism of heating developing Pockels sensor measurement. (3) Measuring the internal structure (density and temperature distributions, flow velocity, density and electric field fluctuations), we will explore the nonlinear structure of the magnetospheric vortex. Fast rotation will emerge as the ions are heated (predicted Alfvén Mach number $\sim(\beta_{\mathrm{ion}})^{1/2}$).

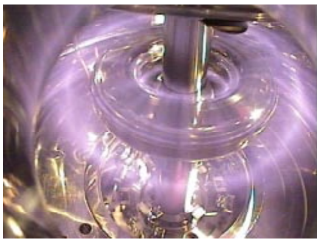

Fig. 2: RT-1plasma device; a levitated superconducting ring magnet produces a magnetospheric configuration, which confines high- temperature plasma.

【Expected Research Achievements and Scientific Significance】

The mechanism of plasma confinement in the magnetospheric system is totally different from those of tokamaks or helicals; it represents the realm of natural plasmas. The RT-1 plasma will have scaling parameters (Reynolds number, Hall parameter, etc.) comparable to space and astronomical systems, making it possible to study the mechanisms of in the Universe. The high-beta plasma in a magnetospheric system will open up the possibility of "advanced fusion" burning, for example, D-^{3}He fuel.

【Publications Relevant to the Project】

1. Z. Yoshida *et al.*; Magnetospheric vortex formation: self-organized confinement of charged particles, Phys. Rev. Lett. **104** (2010), 235004 1-4.
2. S.M. Mahajan and Z. Yoshida; Twisting space –time--Relativistic origin of seed magnetic field and vorticity, Phys. Rev. Lett. **105** (2010), 095005 1-4.

【Term of Project】 FY2011-2015

【Budget Allocation】 81,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.ppl.k.u-tokyo.ac.jp/