Contribution ID: 714

# Inward diffusion driven by low frequency fluctuations in self-organizing magnetospheric plasma

Friday 14 May 2021 18:25 (20 minutes)

The new findings for dynamic process of inward diffusion in the magnetospheric plasma are reported on the RT-1 experiment: (i) The evolution of local density profile in the self-organized process has been analyzed by the newly developed tomographic reconstruction applying a deep learning method [1] . (ii) The impact of gas injection excites low frequency density fluctuation, which continues until the peaked density profile recovers. The fluctuation has magnetic components (suggesting the high-beta effect) which have two different frequencies and propagation directions. The phase velocities are of the order of magnetization drifts and increase in proportion to the plasma pressure. The self-regulating mechanism of density profile works most apparently in the naturally made confinement system, magnetosphere, which teaches the basic physics of long-lived structures underling every stationary confinement scheme.

The spontaneous confinement of high-beta plasma in the magnetospheric configuration results from the inward (or uphill) diffusion driven by "low-frequency" fluctuation; the relevant frequency must be in the ion drift frequency range so that the constancy of the angular momentum is broken, while the actions of the bounce and gyro motions are conserved. The topological constraints due to these adiabatic invariants explain the inward diffusion [2]. The Ring Trap 1 (RT-1) device confines a high-beta plasma (local electron beta  $\sim$  1) in a dipole magnetic field generated by a levitated superconducting magnet. The density has a strongly peaked profile that is explained as the homogenization of particle number among different magnetic flux tubes. In the high-density regime of RT-1, interferometers and a reflectometer detect edge localized fluctuations in the electron density in the frequency range less than 1 kHz. The fluctuation level increases obviously near the cut-off density, suggesting the density dependence of the fluctuations.

Perturbing the density profile by neutral-gas injection, we demonstrate the excitation of low-frequency fluctuations which persist until the inward diffusion reproduces the self-organized density profile [3]. A tomographic reconstruction method using a deep learning technique has been developed to obtain local-intensity profiles from imaging-diagnostic data [1]. We applied this method to obtain local electron density profiles. Fig. 1 (a) and (b) show the local density profiles before and after the inward diffusion obtained by this method, respectively. Using a pair of emission lines of neutral helium with wavelengths of 388 nm and 447 nm, each line-of-sight integrated image measured by a high-speed camera is reconstructed to a local-intensity profile by the tomographic method. The local value of the electron density is obtained by line ratio spectroscopy by taking the ratio of these two local-intensity profiles. The local density profile shows that a peak density profile is formed in the high magnetic field side near the levitation coil as the result of inward diffusion.

#### Indico rendering error

Could not include image: Problem downloading image (https://workshop.nifs.ac.jp/fec2020/image/30-Kenmo

Simultaneous excitation of low-frequency fluctuations during the inward diffusion are observed in electrostatic potential, density, and magnetic field (B<sub>||</sub> direction) measured by a floating potential probe, interferometers, and magnetic probes, respectively. Figure 2 (a) shows the time evolution of phase difference for each frequency between two magnetic probes toroidally separated by  $\Delta \varphi = 45$  degrees. A neutral gas is injected at t = 1.1 sec and the inward diffusion occurs until t = 1.8 sec. The fluctuations of two frequency fluctuation in toroidal and z-direction are 30 km/s ( $k_{\perp} = 0.003 \text{ cm}^{-1}$ ,  $k_{\perp}\rho_i \sim 0.02$ ) and 2 km/s ( $k_{||} = 0.03 \text{ cm}^{-1}$ ,  $k_{||}\rho_i \sim$ 0.2), respectively. Here, the  $k_{\perp}$  and  $k_{||}$  are wave number in the perpendicular and parallel direction to the magnetic field, respectively, and the  $\rho_i$  is on gyroradius. The phase velocity of the fluctuation during the inward diffusion is of the order of diamagnetic drift velocity of  $10^4$  m/s and it increases from 20 km/s to 40 km/s as the increase of electron beta ( $\beta_e$ ) (Fig. 2 (b)). The phase velocity in the z-direction also increases from 1.5 km/s to 2.5 km/s as the increase of  $\beta_e$  (Fig. 2 (c)). During the inward diffusion from t = 1.1 sec to t = 1.8 sec, the fluctuation of  $\sim 1$  kHz propagates toroidally in the electron diamagnetic direction. After the inward diffusion, on the other hand, the fluctuation of  $\sim 1$  kHz disappeared and the fluctuation of  $\sim 0.7$  kHz which propagates in the ion diamagnetic direction is gradually excited. The propagation direction depends on the density profiles, suggests that the drift wave instability is a possible candidate for the low-frequency fluctuation.

Indico rendering error

Could not include image: Problem downloading image (https://workshop.nifs.ac.jp/fec2020/image/30-Kenmo

The results are summarized as follows: (i) The self-organized peak density profile after the inward diffusion has been visualized by the tomography with deep learning technique. (ii) The existence of low frequency fluctuation which drives inward diffusion has been experimentally proved and its physical characteristics have been revealed. These results advance our understanding of transport and self-organization not only in dipole plasmas, but also in general magnetic confinement systems relevant to fusion plasmas.

### References

 $\Delta \varphi$  N. Kenmochi *et al.*, Plasma Fusion Res. **14** (2019) 1202117.  $\beta_e$  N. Sato and Z. Yoshida, Phys. Rev. E **97** (2018) 022145. [1] M. Nishiura *et al.*, Nucl. Fusion **59** (2019) 096005.

## Affiliation

Graduate School of Frontier Sciences, The University of Tokyo

## **Country or International Organization**

Japan

**Authors:** Dr KENMOCHI, Naoki (Graduate School of Frontier Sciences, The University of Tokyo); Mr YOKOTA, Yuuki (Graduate School of Frontier Sciences, The University of Tokyo); Dr NISHIURA, Masaki (National Institute for Fusion Science); Dr SAITOH, Haruhiko (Graduate School of Frontier Sciences, The University of Tokyo); Dr SATO, Naoki (Research Institute for Mathematical Sciences, Kyoto University); Ms NAKAMURA, Kaori (Graduate School of Frontier Sciences, The University of Tokyo); Mr UEDA, Kenji (Graduate School of Frontier Sciences, The University of Tokyo); Prof. YOSHIDA, Zensho (Graduate School of Frontier Sciences, The University of Tokyo)

Presenter: Dr KENMOCHI, Naoki (Graduate School of Frontier Sciences, The University of Tokyo)

Session Classification: P8 Posters 8

Track Classification: Magnetic Fusion Experiments