§21. Theoretical Analysis and Discussion of Two-fluid Plasma Experiments

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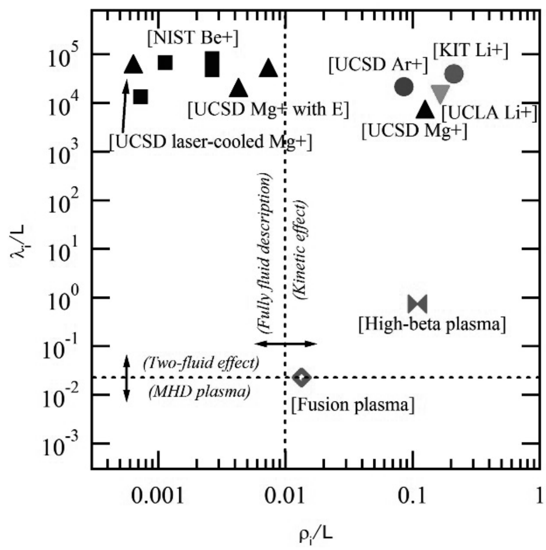
The extended magnetohydrodynamics (MHD) model, especially the two-fluid plasma is a challenging subject in experimental plasma physics. Unlike an MHD plasma, two-fluid plasma allows ion and e^- fluids to move independently. This plasma model have been proposed in both theoretical and computational plasma physics to explain observations such as high-β equilibrium and magnetic reconnections. However, no direct experiments focusing on the two-fluid plasma state have been conducted, although some researchers have discussed it.

This lack of study is mainly due to the experimental difficulty of probing the short-scale length of the ion skin depth λ_i where the two-fluid plasma state or the two-fluid effect is expected to appear. However, λ_i can be far longer in non-neutral plasmas, because of the relatively low ion density. The ion and the electron fluids in non-neutral plasmas can be separately produced and simultaneously confined in the BX-U machine, wherein they rotate around the trap axis in opposite directions owing to the reverse-polarity of their charges. Such an anti-rotation may be ideal for exploring the two-fluid plasma state, because we could then produce both the ion and e^- fluids with different initial velocities perpendicular to the magnetic field (B) before superposing them to creating the two-fluid plasma state. This is apparently difficult to accomplish with ordinary plasmas produced via gas discharge.

The two-fluid plasma state has commonly been discussed in terms of fully ionized plasmas composed of light-element ions such as H^+. In addition, the relative weakness of B results in longer gyro radii (ρ_i) of ions in the vicinity. This increases the ratio of ρ_i to the characteristic length (L) of the ion plasma. This phenomenon is remarkable in the field-reversed configuration (a high-β plasma) and the domain of magnetic reconnection, in which $\rho_i/L \sim 0.1$ and weak B are typical. This is sometimes referred to as a kinetic effect. In these plasmas, L extends to lengths of at least several centimeters, so the ion and e^- numbers contained in the domain are accordingly seldom small. Such an intricate situation may be also created in experiments using weakly magnetized lithium ion (Li^+) plasmas with ion density (n_i) near the Brillouin density limit (n_B). The figure below shows the values of λ_i/L and ρ_i/L attained in typical ion plasmas, including high-β and fusion plasmas. As we observe, the unexplored plasmas when $\lambda_i/L > 1$ and $\rho_i/L < 1$ are easily produced using weakly magnetized ion plasmas. The condition $\lambda_i/L > 1$ can be understood in light of the fact that electrostatic effects dominate in non-neutral plasmas, and electromagnetic effects can therefore be neglected. Because of this and other benefits of using non-neutral plasmas, we proposed a new experiment on the BX-U.



To evaluate experimental observations in the merging experiment, we decided to build a simulation code in the 2016 academic year.

Publication List

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