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Non-MHD effects in the nonlinear development of the MHD-scale Rayleigh-Taylor instability

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Nonlinear development of the Rayleigh-Taylor instability (RTI) is studied by means of the full kinetic Vlasov simulation with two spatial and two velocity dimensions. The RTI is one of interchange instabilities that take place in various situations in natural plasma. There is a number of theoretical works on the nonlinear development of the RTI via fluid simulations. However, non-MHD and kinetic effects on the RTI are unknown. In the present study, we change the ratio of the plasma pressure to the magnetic pressure (so-called plasma beta) as 1/4 for Run1, 1/64 for Run 2, and 4 for Run 3.

In Run 1, the wavelength of the RT mode is set as $\lambda_{RT} = d_i/12 = r_i/48$, where d_i and r_i represent the ion inertial length and the ion gyro radius. Hence, it is expected that both of the Hall and finite Larmor radius (FLR) effects are small in Run 1. It is confirmed that the primary RTI in the MHD regime develops symmetrically in a coordinate axis parallel to gravity as seen in the previous MHD simulations [Huba, 1996]. However, small-scale secondary instabilities are driven due to secondary velocity shear layers formed by the nonlinear development of the primary RTI. The secondary instabilities take place asymmetrically in the coordinate axis parallel to gravity [Umeda and Wada, 2016].

to see how “non-MHD” effects play roles in the nonlinear development of the primary RTI. In Run 2, the wavelength of the RT mode is set as $\lambda_{RT} = d_i/3 = r_i/48$. It is expected that the ion inertial (Hall) effect is large in the “nonlinear” development of the RTI in Run 2. In Run 3, the wavelength of the RT mode is set as $\lambda_{RT} = d_i/12 = r_i/12$. It is expected that the FLR effect is large in the nonlinear development of the RTI in Run 3. It is shown that the Hall term in Run 2 plays a role in the asymmetric development of the primary RTI in a coordinate axis parallel to gravity. The electron stress terms in Run 3 play a role in driving small-scale (electron-scale) secondary RTIs by coupling with Hall electric fields. On the other hand, the ion stress terms in Run 3 are small, which is quite different from the general understanding on the FLR effect. The ion heat flux terms also play a role in the asymmetric development of the RT finger/bubble structures in all the simulation runs [Umeda and Wada, 2017].

References

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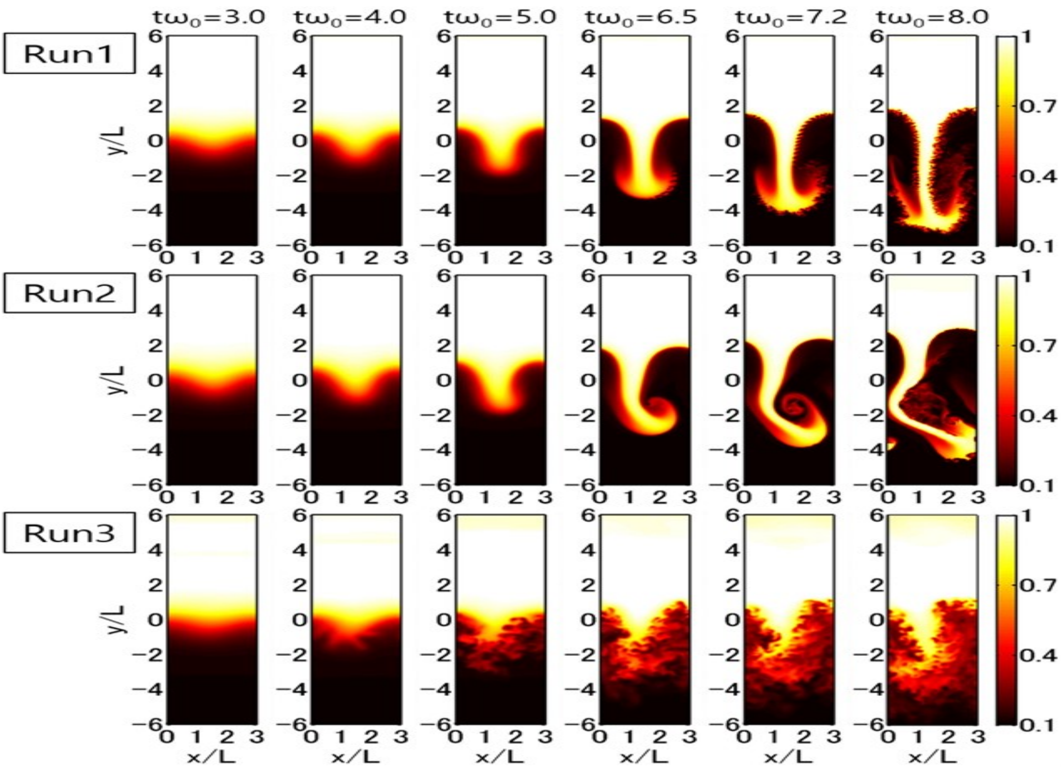

Figure 1. Temporal development of the ion density due to the Rayleigh-Taylor instability with different plasma beta (1/4 for Run1, 1/64 for Run 2, and 4 for Run 3).