Complex Global Simulation Unit

Organized Session: Nov. 11th, 9:00 am - 12:00 am (JST)

The purpose of this organized session is to discuss the research plan of the Complex Global Simulation Unit and the cutting-edge research activities included in the scope of the interdisciplinary research of this unit. The Complex Global Simulation Unit aims to develop simulation methods that couple different hierarchies and physical models to realize global simulations that predict and elucidate the behavior of entire physical systems that cannot be handled by simulations based on a single system of fundamental physical equations. In this session, the research plan of the unit will be introduced by unit members Y. Todo (NIFS) and S. Goto (Osaka University), and two invited talks will be given:

- A. Spitkovsky (Princeton University) "Computational high-energy astrophysics (tentative title)"
- K. Nakajima (The University of Tokyo) "Integration of 3D simulation of strong earthquake ground motion and real-time data assimilation (tentative title)"

In order to understand the behavior of an entire system composed of multiple hierarchies, individual simulations of each hierarchy are not sufficient. Global simulations that take into account the interactions between hierarchies are required. Such complex global simulations are an important issue that is expected to be realized not only in the field of nuclear fusion research but also in many other academic fields, but their realization is not easy. The reason for this is that the temporal and spatial scales of the microscopic hierarchy and the entire system are often extremely different, and the capacity and capability of computer is not sufficient to simulate the entire range of scales based on a single system of fundamental physical equations. The purpose of this unit is to develop simulation methods to solve this problem and to promote simulation research.

This unit aims to develop 1) global simulations of the whole magnetic confinement fusion plasma including the core plasma and the peripheral plasma based on the kinetic-magnetohydrodynamic hybrid simulation [1-3], and 2) a methodology with broad applicability to achieve simulations that more closely reproduce real-world phenomena, beyond the strong limitations imposed by the capacity and capability of the supercomputer, with a special attention to modeling complex phenomena by the use of coherent structures (Fig.2), self-similarity [4] and physics-based phenomenological model [5], as well as by the use of numerical approaches including reduced-order modeling, and data science methods [6].

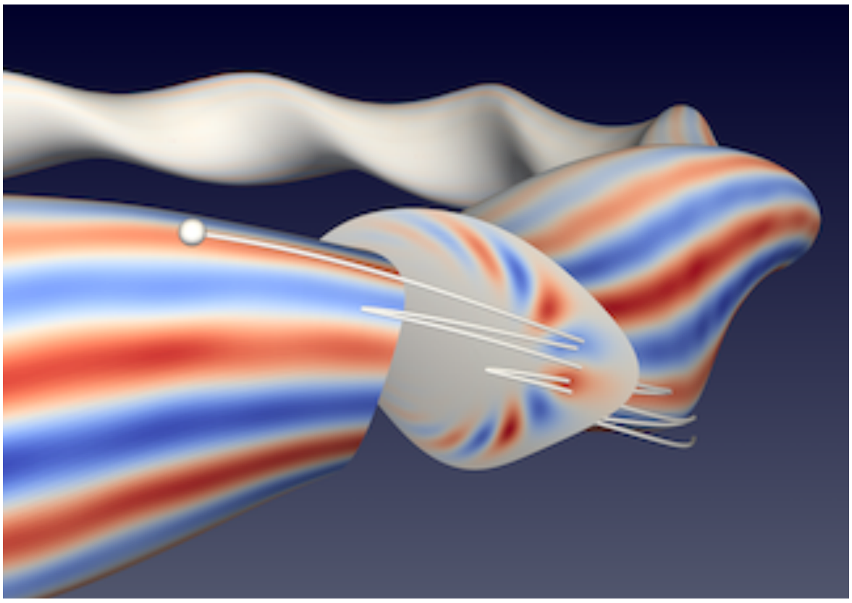

Figure 1. Pressure perturbation of a magnetohydrodynamic (MHD) instability and an orbit of trapped thermal ion in a Large Helical Device plasma simulated with kinetic-MHD hybrid simulation [2].

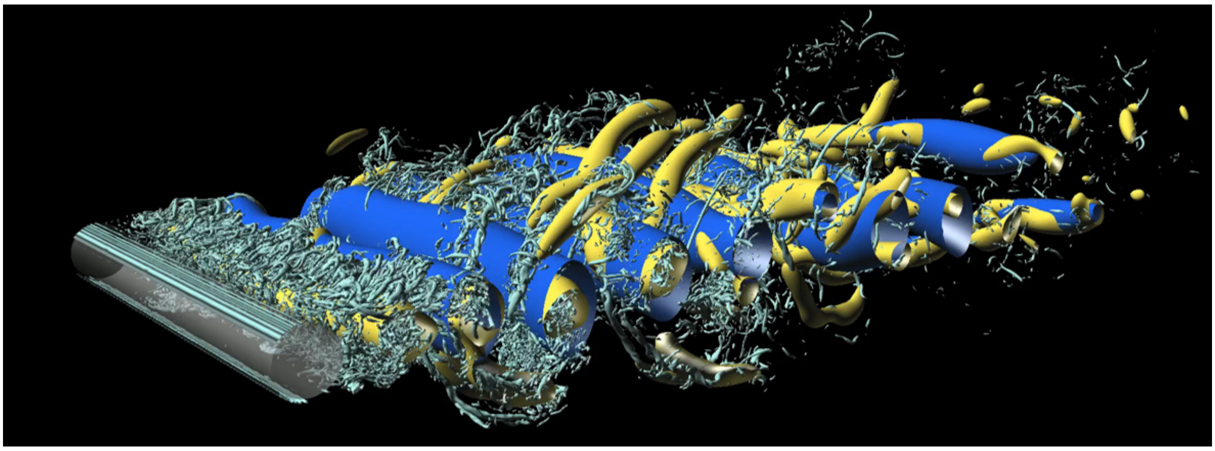

Figure 2. Hierarchy of coherent vortices in the turbulent wake behind a cylinder. Vortices at three scales (blue, yellow, and grey) are visualized by the iso-surfaces of the second invariant of the scale-decomposed velocity gradient tensor.

[1] Y. Todo, T. Sato, Phys. Plasmas. **5** (1998) 1321.
[2] M. Sato, Y. Todo, Nucl. Fusion **59** (2019) 094003.
[3] Y. Todo, M. Sato, Hao Wang, M. Idouakass, R. Seki, Plasma Phys. Control. Fusion **63** (2021) 075018.
[4] S. Goto, Y. Saito, G. Kawahara, Phys. Review Fluids **2** (2017) 064603.
[5] H. Miura, F. Hamba, J. Comput. Phys. **448** (2022) 110692.
[6] M. Inubushi, S. Goto, Phys. Review E. **102** (2020) 043301.