7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Experimental discoveries of a variety of turbulent states of magnetic fusion plasma

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Experimental discoveries of various turbulent states of magnetically confined plasmas in far non-equilibrium states for the Subrahmanyan Chandrasekhar Prize are described in this talk. The following five topics will be presented.

1. Systematizing Experimental Studies of Varieties of Turbulent States.

Systematic experimental studies of various transport state have been reviewed [1,2,3] in an ongoing effort to systematize the entire body of advanced experiments on plasma turbulent transport and many confinement modes, as seen in Figure 1. Recently, new experimental insights into the long-standing issue of the 'hydrogen isotope effect' have been found. [4].

2. Experimental discovery of intrinsic rotation due to plasma turbulence.

It was discovered experimentally that an intrinsic It was discovered experimentally that an intrinsic toroidal flow could be created [5]. The essential aspect of turbulent plasma transport that temperature gradients give rise to momentum flow was made clear. This discovery significantly contributed to the realization of fusion reactors, as plasma rotation plays an essential role in steady-state tokamak reactors and suppressing turbulence.

3. Discovery of a strong electric field in H-mode.

The realization of the H-mode was a breakthrough for fusion research. The strong radial electric field (theoretically suggested) was experimentally discovered as the mechanism for its occurrence [6]. This became the foundation for subsequent H-mode research. The elucidation of the mechanism, which followed this experimental result, provided confidence in the universality of H-mode manifestation regardless of the device and strongly supported the development of fusion reactors.

4. Experimental quantification of the relationship between topology and transport.

Plasmas can be confined by nested magnetic surfaces accompanied by magnetic islands (regions with different topologies). The nature of transport within magnetic islands was observed experimentally [7]. The difference in transport properties due to topology also affects the global properties of nested magnetic surfaces. This fundamental result improves our ability to make predictions about the global properties of nested magnetic surfaces.

5. Study of 'non-local transport' in plasmas.

Transport phenomena that diffusion models cannot explain have been observed in experiments. Phenomena in which a local gradient does not determine the transport flux are called nonlocal transport. The essential phenomena observed in various aspects, such as transport hysteresis, are formulated [8].

These discoveries have enhanced the value of plasma physics as a modern physics discipline and significantly contributed to the realization of fusion reactors.

References

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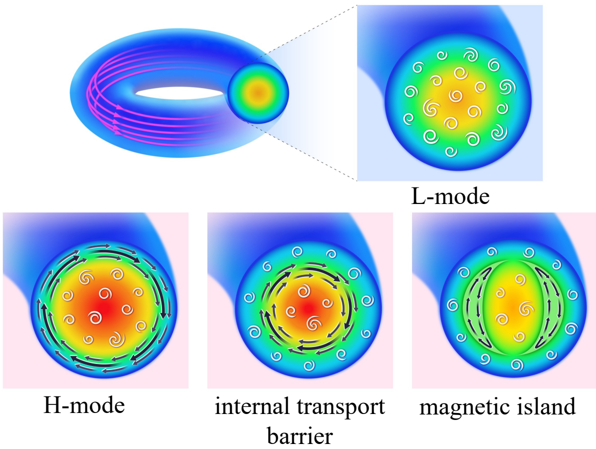

Figure 1. Various states of toroidal flow (pink lines), poloidal flow (black lines), turbulence (white lines), and temperature distribution (blue to red) generated inside the plasma. The high temperature areas are shown in red and the low temperature areas in blue. There is an L-mode with low temperature (upper right), an H-mode where the temperature rises rapidly in the periphery (lower left), an internal transport barrier mode where the temperature rises rapidly in the center (lower center), and a magnetic island state where the temperature rise is blocked in the crescent (lower right).