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Physics of Zonal Flows[1]

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This talk describes an overview of zonal flow physics, covering the theory, simulation and experiment. The zonal flows are excited nonlinearly by drift wave fluctuations, and suppress the turbulence and transport, so as to realize a self-regulating state for turbulence and mesoscale structure. This recognition is the central of recent paradigm shift in plasma physics, i.e., the preceding linear, local and deterministic pictures of instability and transport have been taken over by the new nonlinear, nonlocal (in real and wavenumber spaces) and statistical pictures of them. The zonal flow phenomenon, i.e., the global axial vector fields are generated by the release of global free energy in scalar fields through exciting turbulence, is a typical example of the fundamental issues in modern physics. In this review, the progresses made by theory and simulations, such as the linear damping rate, nonlinear mechanisms for growth and saturation, law of energy partition between turbulence and flow, life time of zonal flow, and so on, are explained. The transport by drift wave fluctuations, which are dressed by zonal flows, is discussed. Then experimental observations and verifications, which have been piled up rapidly in basic plasma experiments and confinement research, are explained, highlighting the integration with theory and simulation. Generalization to include magnetic field (zonal field) is addressed, in the light of the study of dynamo. Zonal flows in both laboratory and planetary-solar circumstances are discussed as well. This presentation illustrates the fast evolution of the physics of turbulence and structure formation of plasmas in the nature and laboratory. In collaboration with S.-I. Itoh, P. H. Diamond, T. S. Hahm, A. Fujisawa, G. R. Tynan and M. Yagi.

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