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Turbulence in laboratory and natural plasmas: Connecting the dots

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It is widely recognized that turbulence is an important and fascinating frontier topic of both basic and applied plasma physics. Numerous aspects of this paradigmatic example of self-organization in nonlinear systems far from thermodynamic equilibrium remain to be better understood. Meanwhile, for both laboratory and natural plasmas, an impressive combination of new experimental and observational data, new theoretical concepts, and new computational capabilities (on the brink of the exascale era) have become available. Thus, it seems fair to say that we are currently facing a golden age of plasma turbulence research, characterized by fundamental new insights regarding the role and nature of turbulent processes in phenomena like cross-field transport, particle acceleration and propagation, plasma heating, magnetic reconnection, or dynamo action. At the same time, there starts to emerge a more unified view of this key topic of basic plasma physics, putting it into the much broader context of complex systems research and connecting it, e.g., to condensed matter physics and biophysics. I will describe recent advances and future challenges in this vibrant area of plasma physics, highlighting novel insights into the redistribution and dissipation of energy in turbulent plasmas at kinetic scales, using gyrokinetic, hybrid, and fully kinetic approaches in a complementary fashion. In this context, I will discuss, among other things, the influence of damped eigenmodes, the importance of nonlocal interactions, the origin and nature of non-universal power law spectra, as well as the role of coherent structures. Moreover, I will outline exciting new research opportunities on the horizon, combining extreme scale simulations with basic plasma and fusion experiments as well as with observations from satellites.