Modeling drift-wave turbulence as quantumlike plasma

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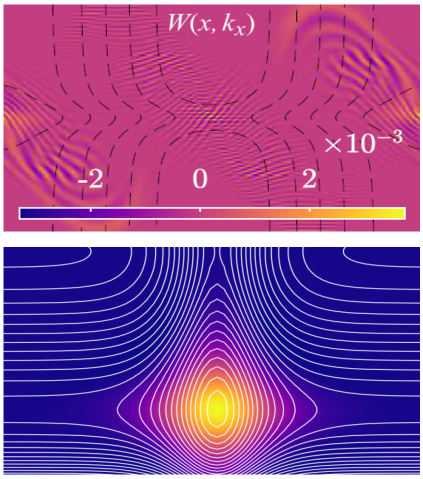

Figure 1: *Quasiprobability density (Wigner function) of DW quanta in phase space, $W(x,k_x)$, vs. isosurfaces of the DW Hamiltonian: upper – saturated ZF; lower – DW soliton.*

Inhomogeneous drift-wave turbulence with zonal flows (ZFs) can be modeled as effective quantum plasma where the ZF velocity serves as a collective field [1, 2]. This effective plasma can be described, quite intuitively, by a Wigner–Moyal kinetic equation (WMKE), which was originally introduced as phase-space description of quantum mechanics [3]. We report the first explicit application of the Wigner–Moyal formalism to analytic and numerical modeling of ZF physics [4, 5] within the generalized Hasegawa–Mima model. The corresponding WMKE is more delicate and rich in physics than that for optical turbulence, to which a similar approach was applied in the past. The WMKE is also an improvement to the traditional wave kinetic equation for DW turbulence in that it contains "full-wave" effects, i.e., those associated with the finite ratio of the ZF scales to the drift-wave wavelengths. The full-wave effects are found to be essential and can qualitatively alter the formation and stability of ZFs [4, 5, 6]. The quantumlike approach elucidates the nonlinear saturation and oscillatory dynamics of collisionless ZFs [7] and also the physics of propagating coherent structures [8], which can be viewed as drifton condensates (Fig. 1). A systematic procedure for extending the quantumlike Wigner–Moyal formulations to more general turbulent systems is also proposed.

References

[1] D. E. Ruiz, J. B. Parker, E. L. Shi, and I. Y. Dodin, Phys. Plasmas **23**, 122304 (2016).

[2] D. E. Ruiz, M. E. Glinsky, and I. Y. Dodin, J. Plasma Phys. **85**, 905850101 (2019).

[3] J. E. Moyal, Math. Proc. Cambridge Philos. Soc. **45**, 99 (1949).

[4] H. Zhu, Y. Zhou, D. E. Ruiz, and I. Y. Dodin, Phys. Rev. E **97**, 053210 (2018).

[5] H. Zhu, Y. Zhou, and I. Y. Dodin, Phys. Plasmas **25**, 072121 (2018).

[6] H. Zhu, Y. Zhou, and I. Y. Dodin, Phys. Plasmas **25**, 082121 (2018).

[7] H. Zhu, Y. Zhou, and I. Y. Dodin, arXiv:1902.04970

[8] Y. Zhou, H. Zhu, and I. Y. Dodin, arXiv:1902.06870.