Interactions of Waves and Turbulent Eddies: "Truth and Consequences" for transport and dissipation

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ABSTRACT

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Turbulence and nonlinear phenomena are central to our elucidating and modeling the dynamics of fluids and plasmas, and yet they still resist analytical resolutions in many instances. However, our understanding has progressed in recent years in specific cases, displaying a richness of phenomena which, to a large degree, was somewhat unexpected a few years back.

I will specifically briefly discuss four examples:
(i) The existence of non-Gaussian wings of Probability Distribution Functions of the *velocity, temperature and magnetic fields themselves* (in addition to their gradients), and the link to strong intermittent large-scale fluctuations, as observed in turbulence, *e.g.* for plasmas, the Solar Wind, or the atmosphere and ocean, and possibly leading to localized disruptive events.
(ii) The link of *(i)* with linear scaling of dissipation in terms of the control parameter (ratio of wave period to eddy turn-over time) in the regime where strong interactions between nonlinear eddies and waves are present, *e.g.* in the case of reduced MHD, or for rotating/stratified flows.
(iii) The possibility of direct measurements of the magnitude of dissipation in a turbulent plasma, using the so-called exact laws stemming from invariance principles (under some restrictive conditions), as found for the total energy together with the cross-correlation between the velocity and magnetic fields (the magnetic-helicity case being more complex). And finally:
(iv) The *constant-flux, simultaneous and bi-directional* cascades to small *and* to large scales, as for energy in MHD with a strong guiding magnetic field, or in rotating stratified turbulence, with implications for small-scale transport properties.

I will illustrate these points with scaling laws, together with data analysis stemming from laboratory experiments, space observations and direct numerical simulations.
If time permits, I will briefly explore the possible implications for several modeling strategies, and I will end with a specific example of modifying in Hall MHD the inverse cascades of magnetic and generalized helicities to large scales, through changes in the ratio of the ion inertial scale to the characteristic forcing scale. Open problems might also be evoked.