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Applications of the wave-kinetic approach: from wakefield accelerators to space plasmas[1]

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The theory of wave-kinetics is a new approach to the study of the propagation of broadband, incoherent waves in dispersive media. The wave-kinetic approach is centered around the propagation of individual wave modes, and both monochromatic and incoherent waves can be described easily through the wave mode distribution function. Where the classical approach to wave-driven processes restricts itself mainly to monochromatic waves coupling to other monochromatic waves, the wave-kinetic approach allows one to study the coupling of random and/or broadband pump waves coupling to monochromatic or coherent structures in the medium. The list of phenomena that can be studied through this approach is very long, reaching from laser-wakefield studies to lower-hybrid drift wave studies, turbulence in planetary atmospheres, and even neutrino-driven shock waves in collapsing stars. We have employed the wave-kinetic approach to study photon acceleration (changing the frequency of laser light using a spatially and temporally changing index of refraction) in ultrafast, ultra-intense laser-plasma interaction experiments. Photon acceleration can be used both as a means to prove the existence of laser-driven wakefields and as a tool to determine their properties. In addition, we have used the wave-kinetic approach to model drift wave turbulence interacting with zonal flows in a magnetized plasma. We have discovered a mechanism for spontaneous generation of soliton-like structures, which has applications ranging from turbulence at the magnetopause boundary layer to edge localized modes in tokamaks. For both laser-plasma interaction and drift mode turbulence, we will compare wave-kinetic simulations against the results of recent experiments.

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