Strong Plasma Turbulence, Localized Wave Packets, and Radiation

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Sufficiently intense high-frequency plasma waves undergo modulational instabilities to form intense localized wave packets that self-focus and collapse once they exceed a threshold, dissipating energy at short scales, typically through coherent transit-time particle acceleration. The ponderomotive force of the localized waves drives low-frequency density perturbations, excavating deep wells that relax and radiate low-frequency waves after collapsed packets dissipate. In strong plasma turbulence, extended plasmas support an ensemble of such packets amid lower-level waves, typically involving high-frequency electrostatic Langmuir, upper-hybrid, or lower-hybrid waves interacting with ion-acoustic or magnetosonic modes. Electromagnetic (EM) waves can also interact with localized wave packets, with emission being enhanced by the intensity of the localized fields. Similar emission effects exist for waves localized by other mechanisms including stochastic wave growth and wave trapping.

Localized wave packets, some of which undergo collapse, have been found to exist in a wide range of laboratory, space, and astrophysical situations, including beam-plasma, laser-plasma, and ionospheric modification experiments, and in solar, planetary, and interplanetary radio sources. Other likely applications include pulsar emissions and laser-fusion devices.

Theories have been developed for the dynamics of individual localized and/or collapsing wave packets and their emission of radiation. Statistical theories of strong plasma turbulence and other ensembles of localized wave packets also exist, into which these emission rates can be incorporated to calculate mean

emissivities for extended sources. Strong turbulence and wave collapse theories agree with the results of extensive numerical simulations, mostly carried out using the electrostatic or electromagnetic Zakharov equations.

Here, key aspects of strong plasma turbulence, wave collapse, and associated emission mechanisms are reviewed, particularly highlighting recent discoveries, underexploited areas, potential applications, and links to radiation from other types of wave packet.

Keywords: plasma turbulence, Langmuir turbulence, waves, radiation, wave-wave processes, wave-particle interactions, wave collapse, self-focusing, transit-time interactions, simulations.