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A review of phase space turbulence: why it is important

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An interesting and important aspect of turbulent plasmas is the role of phase space. Unlike usual fluid turbulence, phase space (or in particular, the velocity space) plays important role in dynamics. A classic example is of course the wave-particle interaction, and the excitation and the damping of waves can happen via the resonance with particles in plasmas. The phase space can be a key to understand various phenomena including, but not limited to, acceleration of particles, coronal heating, etc. In more practical matters, they are a key for the success of magnetically confined plasmas.

The purpose of this talk is to present the current status of the subject and to discuss future challenges. Then, in this talk, we will start by discussing what we know, or at least we think we understand, about the subject. In this part, we will look at the simplest example of phase space turbulence in unmagnetized plasmas. This simple example is used to introduce relevant ingredients in phase space turbulence, such as phase space coherent holes[1], phase space granulations[2], etc. We will also briefly describe how these elements impact transport through dynamical frictions.

Then we discuss application to magnetically confined plasmas. In particular, we show how these phase space structures impact confinement of plasmas. A simplified drift wave is used as a typical example and characteristic structures such as drift holes, granulations, are introduced. Once formed, these phase space structures can tap free energy even when underlying drift waves cannot. This results in explosive subcritical instabilities. While driving fluctuations, phase space structures also excite meso-scale zonal flows[3]. Zonal flows set a limit on the maximum amplitude of drift holes. They also reduce transport. In addition to conventional turbulence suppression, zonal flows reduce transport by phase space structures by exerting dynamical friction on these structures.

Recent developments in experiments allow us to directly measure the distribution function[4]. While early experiments on the wave-particle interaction measured the role of phase space indirectly by observing damping length of the mode in tubes, recent experiments report the direct observation of the deformation of the distribution function. Thus now it is possible to identify turbulence activity in the distribution function. In this talk, we will discuss a possible target to identify the footprint of phase space turbulence, by using coherent drift holes as a typical example.

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