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Observing plasma kinetic degrees of freedom using advanced diagnostics

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Weakly-collisional plasmas have many degrees of freedom and a non-local response function [1]. In order to describe complex plasma behaviors, such as turbulence, it is necessary to have a description which captures all of the important dynamics. For example, as collisions become weak, an increasing number of fluids is needed to accurately describe plasma behavior. If distribution functions are non-Maxwellian, then additional kinetic degrees of freedom become active [2]. In general, this is a large and unsolved problem. We will present new measurements of plasma kinetic degrees of freedom using advanced diagnostics of electrons and ions. In many situations, the full activity of a plasma is unknown for lack of appropriate measurements, so there is continued need for new measurement techniques. We present examples of new diagnostic information that provides insight on the electromechanical degrees of freedom of weakly-collisional plasma.

For ions, we discuss the detection of spontaneous fluctuations in the ion phase space [3]. Using two cross-correlated laser-induced fluorescence signals resolving velocities v and v', we obtain a matrix of spatially-localized cross-power spectra:

$$P_{ij} = P(v_i,v_j',x,w)=FFT\{<A(v_i,x,t)A(v_j',x,t-t')>_t\}_{t'}$$

(averaged over t, Fourier transform on t')

This matrix is Hermitian for a discrete array of particle velocity values v_i,v_j' which cover the same range of velocity values. We resolve the dynamics parallel to the magnetic field (which is also parallel to the two diagnostic laser beams. This local quantity is a sensitive probe for global plasma modes.

For electrons we discuss the use of wave-absorption to detect coherent fluctuations in the suprathermal tail population [4]. Wave absorption, if due to wave-particle resonance, is a phase-space resolving phenomenon which can be exploited not only to diagnose the average phase-space density of suprathermal particles in a diagnostic volume, but also small (~0.1%) fluctuations in the tail population [5]. Because the tail of the distribution is often weakly collisional, it can represent a nearly independent electro-mechanical degree of freedom in the plasma relative to low-velocity particles. The importance and prospects for expanding phase-space resolving diagnostics will also be discussed.

References

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