Entropy evolution and dissipation in collisionless particle-in-cell gyrokinetic simulations

Alberto Bottino

Modern gyrokinetic particle-in-cell algorithms rely on the use of control variate methods to reduce the variance of the distribution of the markers. The δf simulation method is the most commonly used control variate procedure: the gyrocenter distribution function is split into an analytically known contribution and a perturbation part, discretized with markers. However, in this algorithm the variance of the marker weight distribution increases in time for collisionless simulations that predict nonzero turbulent fluxes. As a consequence, collisionless simulations do not reach a true steady state and are unsuited to make quantitative predictions, although low order moments may saturate. Moreover, the indefinite increase of the marker variance leads to an enhanced statistical noise that eventually limits the duration of a simulation. In this paper, it will be shown that this effect is not an exotic property of the system, but it is merely due to the lack of dissipation of the numerical scheme. When artificial dissipation is introduced, the usual properties of the system are recovered, including energetic consistency and entropy saturation.