Shell models applied to kinetic turbulence of trapped particles in magnetized plasmas

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In fluid turbulence, shell models have been widely used for accessing wide spectral ranges at moderate numerical cost [1,2]. Indeed, the use of logarithmic discretization allows to cover large spectral intervals, and can be combined in the case of shell models to a truncation of the nonlinear interactions to the nearest neighbours. However, while standard fluid turbulence and plasma turbulence can share very similar equations, only very few applications of shell models to magnetized plasma turbulence have been made up to know [3,4,5,6]. In particular, the kinetic character of fusion relevant plasmas complicates the direct use of fluid turbulence methods.

In strongly magnetized plasmas, such as those present in tokamaks, or even some types of space plasmas, particles can be trapped in low magnetic field regions, and their motion can become periodic along two distinct angles. It is then possible to reduce the initial Vlasov-Poisson system to a two dimensional one, by making use of averages along the cyclotron motion (gyroaverage) as well as along the bounce motion (bounce-average). The resulting low dimensional system becomes a very interesting testbed for applying reduced models inspired by usual fluid turbulence techniques.

In this work, a shell model for bounced averaged gyrokinetic Vlasov-Poisson equations is presented. First, the linear growth phase of the shell model code is validated by comparisons with a standard kinetic eigenvalue solver. Then the nonlinear dynamics is studied by analyzing the wave-number spectrum of quadratic conserved quantities. The resulting spectra seems to show a cascade spectrum at high k and predator-prey like oscillations in low k. Interestingly, different behaviors between the Sabra [2] and the GOY [1] type of truncations are observed in the simulations. Comparisons will finally been made with a logarithmically discretized three dimensional version of the model [7], which is 2D in space and 1D in energy.

Références

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