PhD Prize Talk

Large eddy simulations of compressible magnetohydrodynamic turbulence

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Compressible magnetohydrodynamic (MHD) turbulence is thought to play an important role in many astrophysical processes. In absence of detailed three-dimensional observations, simulations can partially fill the observational gap in order to help to understand these processes. Unfortunately direct simulations with realistic parameters are often not feasible. Consequently, large eddy simulations (LES) have emerged as a viable alternative. In LES the overall complexity is reduced by simulating only large and intermediate scales directly. The smallest scales, usually referred to as subgrid-scales (SGS), are introduced to the simulation by means of an SGS model.

In this talk, I will present a new nonlinear MHD SGS model that explicitly takes compressibility effects into account. The model includes closures for all SGS terms in MHD: the turbulent Reynolds and Maxwell stresses, and the turbulent electromotive force (EMF). The model is systematically validated both in *a priori* and *a posteriori* tests, and compared to traditional models such as eddy-viscosity and scale-similarity type models.

In the *a priori* tests, we use high-resolution reference data of stationary, homogeneous, isotropic MHD turbulence ranging from the subsonic ($\mathrm{Ms} = 0.2$) the supersonic ($\mathrm{Ms} = 20$) regime. We compare exact SGS quantities against predictions by the closures. We find that the new nonlinear model outperforms the traditional ones in all tests conducted including the representation of the energy flux along the turbulent cascade.

In the *a posteriori* tests, we perform LES of decaying, supersonic MHD turbulence with all models and evaluate their performance in comparison to simulations without a model (and at higher resolution). We find that the models need to be calculated on a scale larger than the grid scale, e.g. by an explicit filter, to have an influence on the dynamics at all. Furthermore, we show that only the proposed nonlinear closure improves higher-order statistics such as distributions of vorticity and current density, or structure functions.