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Modeling scale coupling in space turbulence

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Modelling space, astrophysical and laboratory plasmas requires us to consider fluid and kinetic models together. Often fluid models cannot capture completely some microscopic aspects. For example, there are aspects of shocks and reconnection processes that cannot be described by fluid models completely. A striking example is the two-way coupling between particles and waves: waves energize particles and unstable particle distributions cause instabilities. Fluid models can capture some aspects but kinetic models are needed for a complete description. Conversely, kinetic models are too expensive to model large scales.
We report our efforts centered on bridging this gap. The central glue used is the implicit moment method. By introducing the moments of the distribution functions and by formulating the discretization implicitly, we allow the kinetic model to morph into a fluid model, at large scales. The latest development in our effort is to introduce a description of the first order moment (current) via a mass-matrix. The mass matrix is a mathematical construct that summarizes the plasma response.
The advantage of the new approach is to be practical at all scales: we showed one example where the same kinetic model covers nearly 20 orders of magnitude in temporal and spatial scales. Additionally, energy is conserved exactly, a feature of physical relevance and a powerful aid to avoid numerical instabilities.

[1] Lapenta, G. (2017). Exactly energy conserving semi-implicit particle in cell formulation. Journal of Computational
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[2] Lapenta, G., Gonzalez-Herrero, D., & Boella, E. (2017). Multiple-scale kinetic simulations with the energy conserving semi-implicit particle in cell method. Journal of Plasma Physics, 83(2).