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Coupling Fluid and Kineitc Effects in Space Weather: an interdisciplinary task

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Two agents are key to space weather: electromagentic fields and energetic particles. Magnetic fields carried by plasmas in the solar wind interact with the Earth magnetosphere and solar energetic particles produced by solar events or in cosmic rays affect the space environment. Describing both is challenging. Magnetized plasmas are most effectively described by magneto-hydrodynamics, MHD, a fluid theory based on describing some fields defined in space: electromagnetic fields, density, velocity and temperature of the plasma. High energy particles, instead need a more detailed approach , kinetic theory, where statistical distributions of particles are governed by the Boltzmann equation. While fluid models are based on the ordinary space and time, kinetic models require a six dimensional space, called phase space, besides time. The two methods are not separated, the processes leading to the production of energetic particles are the same that involve space plasamas and fields. Arriving at a single self-consistent model has been the goal of the Swiff project funded by the EC in FP7 and it is now a key goal of the ongoing DEEP-ER project.
We present a new approach developed with the goal of extending the reach of kinetic models to the fluid scales. Kinetic models are a higher order description and all fluid effects are included in them. However, the cost in terms of computing power is much higher and it has been so far prohibitively expensive to treat space weather events fully kinetically. We have now designed a new method capable of reducing that cost by several orders of magnitude making it possible for kinetic models to study space weather events [1,2]. We will report the new methodology and show its application to space weather mdeling.

[1] Giovanni Lapenta,Exactly Energy Conserving Semi-Implicit Particle in Cell Formulation, to appear, JCP, arXiv:1602.06326
[2] Giovanni Lapenta, Diego Gonzalez-Herrero, Elisabetta Boella, Multiple scale kinetic simulations with the energy conserving semi implicit particle in cell (PIC) method, submitted JPP, arXiv:1612.08289