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Observation, Simulation and Machine Learning: analysing vast particle data sets to extract physics insight into turbulence and reconnection

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Particle in cell simulations of 3D reconnection and turbulence can highlight the fundamental physics and lead to true discovery. But they are a virtual experiment. There is a need to understand the information present in the output in terms of fields and particle distributions. Field data is more manageable but particle data currently can easily reach the size of several TB produced by each time step. Similarly, space missions in bursts mode can produce a large number of time series for fields and moments but analysing the particle distribution functions is a tremendous challenge.

We think two new developments can transform the way we analyse the data. The first is ML that provides techniques to treat this large data sets and discover within them features and properties that would escape traditional approaches [1,2]. But the second profoundly transforming development is the rise of heterogeneous computers where GPUs and CPUs have to be used together. These twi developments allow us to design PIC simulations and their methods of analysis using ML that make the best use of these new resources.

[1] Dupuis, R., Goldman, M. V., Newman, D. L., Amaya, J., & Lapenta, G. (2020). Characterizing magnetic reconnection regions using Gaussian mixture models on particle velocity distributions. *The Astrophysical Journal*, 889(1), 22.
[2] Goldman, M. V., Newman, D. L., Eastwood, J. P., & Lapenta, G. (2020). Multibeam Energy Moments of Multibeam Particle Velocity Distributions. *Journal of Geophysical Research: Space Physics*, 125(12), e2020JA028340.