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Very large magnetohydrodynamical simulations of structure formation with the cosmological code SWIFT

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Numerical simulations can substantially support the study of the origin and evolution of cosmic magnetic fields. Leveraging on algorithmic advances at the heart of the novel cosmological code SWIFT, and developing a suite of Modern Lagrangian Magnetohydrodynamical (MHD) Solvers - each with a different formulation of Ideal and Resistive MHD - we seek to make predictions for the large-scale structure (LSS) of magnetic fields in the late-time universe. Such a plural approach seeks to identify systematic biases introduced by the solver, so as to account for them when making forecasts.

I will discuss how we incorporated a state of the art, 'Direct Induction' formulation of Smoothed Particle MHD in SWIFT, how it yields competitive results on benchmark test cases (at a fraction of the computational cost when compared to other commonly used methods) and how it performs on a set of cosmological problems. I will compare and contrast this with a 'Vector Potential' implementation of magnetic field physics, also present in SWIFT, emphasising where the two solvers converge or diverge and commenting on what can be learned from comparing their predictions. I will finally elaborate on the coupling of our MHD prescriptions to a full galaxy formation model, which has been shown to successfully reproduce several galaxy, cluster and LSS observations in the very large cosmological hydrodynamical simulation suite FLAMINGO.

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