Global MHD galaxy simulations: feedback, non-equilibrium chemistry and the emergence of a mean-field dynamo

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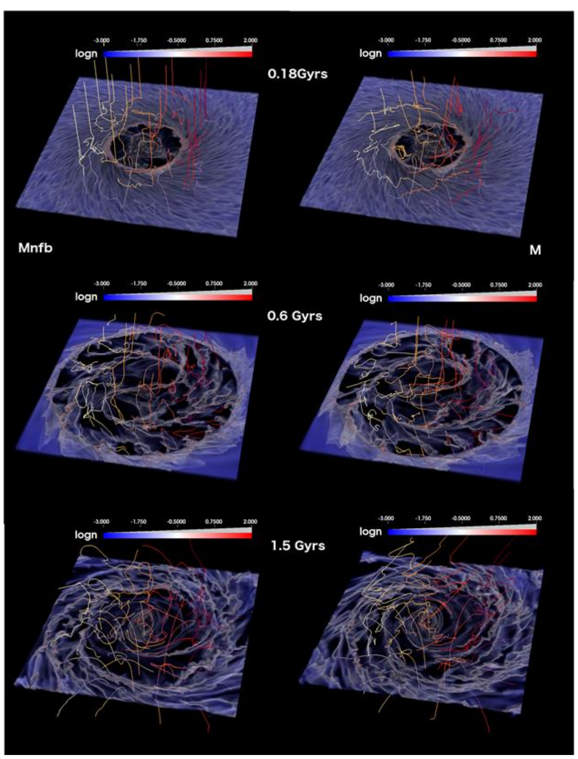
Magnetic fields are of paramount importance for understanding the evolution and dynamics of galaxies. However, even the magnetic field of our own Galaxy is still elusive, since its strength and direction are impossible to measure simultaneously. It is therefore essential that we complete our knowledge with numerical simulations of galaxy and magnetic field co-evolution. This contribution shows results from a series of high-resolution numerical models, aimed at deciphering the effect of the initial conditions and supernova feedback on the evolution of the galactic magnetic field in Milky Way-like galaxies. The models include a live potential from dark matter and stars, modeled as collisionless particles, coupled through gravity to a grid containing the magnetized gaseous disk. In models without chemistry [1,2], the gas cooling and heating is modeled based on equilibrium relations, and star formation is based on a local density criterion. Models with non-equilibrium chemistry include the physics of molecular hydrogen formation and base star formation on the molecular content of a grid cell [3]. The magnetic field of each model is either ordered on large scales, with a toroidal or poloidal geometry, or random with a power-law spectrum. Independently of these initial conditions, the galaxies quickly develop both a random and an ordered magnetic field component. An example of this evolution is shown in the accompanying figure (Figure 1), where we plot the gas number density with magnetic field lines for two models, M and Mnfb with and without supernova feedback and an initially toroidal field: both models show an increasingly complex magnetic field structure, independently of the presence of supernova feedback. This complex environment also naturally leads to a mean-field dynamo, which amplifies the magnetic field of both models by at least an order of magnitude over half a Gyr. However, the characteristics of the steady state galactic magnetic field and the magnetic-field-density relation differ for different initial conditions, indicating a possible link between observable features and initial magnetic field topology. Overall, these models highlight the importance of a systematic study of galaxy evolution including magnetisation.



References

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