Challenges in Panchromatic Modelling with Next Generation Facilities
Proceedings IAU Symposium No. 341, 2018
M. Boquien, E. Lusso, C. Gruppioni & P. Tissera, eds.

doi:10.1017/S174392131900231X

Magneto-Hydrodynamic simulations on galaxy modeling

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Abstract. Magnetic field plays an important role in star formation and galaxy evolution. Previous studies discussed about the origin of magnetic field and its effect to the environment. With the recent advancement of supercomputers, adding the magnetic field to a cosmological hydrodynamic simulations only become feasible. In this proceeding, we present the results of high-resolution magneto-hydrodynamic simulation with GIZMO and compare our simulation result with the previous literature and the observations.

Keywords. galaxies: evolution, galaxies: magnetic fields, methods: n-body simulations

1. Introduction

The existence of large-scale magnetic field has been supported by observations in recent years. Several authors have reported the findings of magnetic field of μG order of magnitude in nearby galaxies. For example, Fletcher *et al.* (2010) reported the mean field strength of 21 galaxies observed in the last decade is about 17 μG, and Adebahr *et al.* (2013) estimated the magnetic field strength to be 98 μG in the core region of M82. Beck *et al.* (2016) gave a summary table on the observations of magnetic field in various galaxy types.

The origin of magnetic field, however, is still under debate. Durrer and Neronov *et al.* (2013) reviewed the origin and the observational method of primordial magnetic field. If the magnetic field were primordial, how it amplified from extremely small $\sim 10^{-14}$ to μG level is one of the key questions in modern astrophysics. Since gas motion is directly influenced by the magnetic field thus it should affect the dynamics of galaxies. The associated star formation and supernova explosions inside galaxies are subject to change under the presence of magnetic field. Such studies can deepen our understanding of galaxy evolution. Therefore, studying the evolution of magnetic field and its impact to surroundings is of great importance.

The magnetic field amplification processes and its sustaining mechanism have already been discussed in many literatures. However, it is not until the recent advancement of supercomputer can high-resolution MHD simulations be conducted. The Auriga project (Pakmor *et al.* 2017) found that magnetic field is exponentially amplified in the center of Milky Way-like galaxies from z=7 to z=3 and linearly amplified at larger radii between z=2 and z=1. By comparing with thermal motions and turbulent kinetic energy, they showed that magnetic fields dominate galaxy evolution in latter epoch but can be neglected in high redshift universe for Milky Way-like galaxies. One shall note that even under these circumstances, magnetic fields might still play a role at earlier epoch when

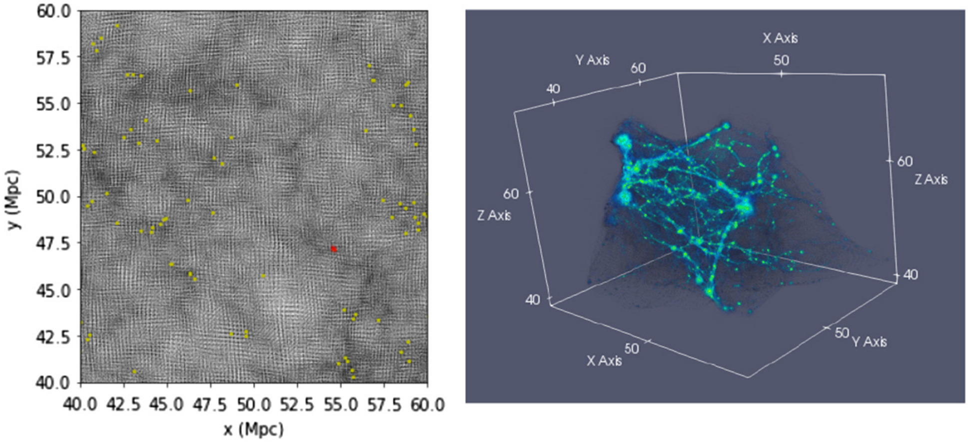

Figure 1. Left: Yellow and red dots are the high density region identified by DBSCAN algorithm. Right: Large scale structure at z=0 (without magnetic field).

anisotropic transport processes are included. The IllustrisTNG project (Pillepich *et al.* 2018) showed that magnetic field have an effect on large halos and suppressed the total star formation at low redshift.

Based on the recent simulations, we conduct a high resolution cosmological zoom-in simulation to achieve high spatial resolution while maintaining cosmological initial condition at the same time. We aim to answer open questions such as how does magnetic field effects the evolution of galaxies after anisotropic transport processes are imposed.

2. Method

In order to achieve high spatial resolution, we generated our cosmological initial condition with MUSIC (Hahn and Abel *et al.* 2011), which adopts the cosmological parameters from the WMAP data. We use a simulation box size of 100 $\mathrm{Mpc\,h^{-1}}$ at z=100 with 10^7 gas and dark matter particles each, having 10^8 solar mass per particle. However, this resolution is insufficient to resolve to the star formation process. After the universe evolves for a short period with GIZMO simulations (Hopkins *et al.* 2015), we zoom-in into a high density region with machine learning clustering algorithm DBSCAN (Ester *et al.* 1996) and apply the splitting particle method (Kitsionas and Whitworth *et al.* 2002) to increase the resolution (Figure 1). This smaller box size with split particles becomes our new initial condition for next period of simulation. By conducting this select-and-split process for ten times along with the redshift evolves from z=100 to z=15, we achieve the resolution of unit solar mass within 100 $\mathrm{kpc\,h^{-1}}$ box size. With this high resolution cosmological initial condition at z=15, we impose magnetic field of 10^{-14} G into our ongoing simulation with various processes included. We will examine our results with previous papers and compared with the observations.

Acknowledgements

This research is supported by the Ministry of Education, Taiwan, R.O.C. under Grant no. MOST 107-2112-M-001 -044 -MY3. Numerical simulations are supported by the National Energy Research Scientific Computing Center (NERSC), and the TIARA Cluster at the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA).

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https://doi.org/10.1017/S174392131900231X Published online by Cambridge University Press