Diffuse InterGalactic Magnetic Fields and Constraints for the CTA and ASTRI MINI-ARRAY Observations

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Introduction

- The InterGalactic Medium (IGM) is observed to contain diffuse Magnetic Field
- Primordial magnetic fields in galaxies are amplified by turbulent dynamo effects, and dragged out of the ISM by powerful galactic outflows generated by various processes:
  - Stars, stellar evolution
  - SuperNovae (SN) explosion,
  - Active Galactic Nuclei (AGN) feedback
  - Mergers and tidal interactions between galaxies.
- These above processes enrich the IGM with Magnetic Fields.
- The aim of this project is to investigate the origin of the IGMF, explore the evolution of IGMFs through cosmic epochs and constrain the strength and the filling factor of the cosmic magnetic fields.

Numerical Methods

- Hydrodynamic simulations of cosmological volumes with periodic boundary conditions (Barai et al, 2013), of boxsize $(2Mpc)^3$.
- The simulations were performed using the code GADGET-3, which is a Lagrangian SPH numerical method.
- The GADGET simulation gives as output these quantities about the gas particle: position, velocity, radius ($R_{comoving}$), density (ρ_{gas}), mass ($M_{gaspart}$), specific internal energy (U_{int}).

Analysis

- We perform post-processing analyses for gas flows around simulated galaxies.
- Thus we compute the diffuse IGMFs in different cosmological boxes.
- Cosmic time is measured using the Redshift (z).
- Comoving distance:

$$R_{physical} = \frac{R_{comoving}}{1+z} \quad (1)$$

$R_{physical}$ = Physical distance = Actual distance at an earlier cosmic epoch, $R_{comoving}$ = Comoving distance (or, the distance at $z = 0$), which the simulation gives as output.
- Overdensity:

$$\delta = \frac{\rho_{gas}}{<\rho_B>} \quad (2)$$

where ρ_{gas} is gas density and $<\rho_B>$ is mean density of the universe. We have that $<\rho_B>$ is theoretical model of the flat universe, therefore:

$$<\rho_B> = \frac{\Omega_{B,0} 3 H_0^2}{8\pi G} \quad (3)$$

Simulation Results

Using the analysis methods, the following figures were obtained for the magnetic field in the $(2Mpc)^3$ cosmological volume at the cosmic epoch $z = 6.5$:

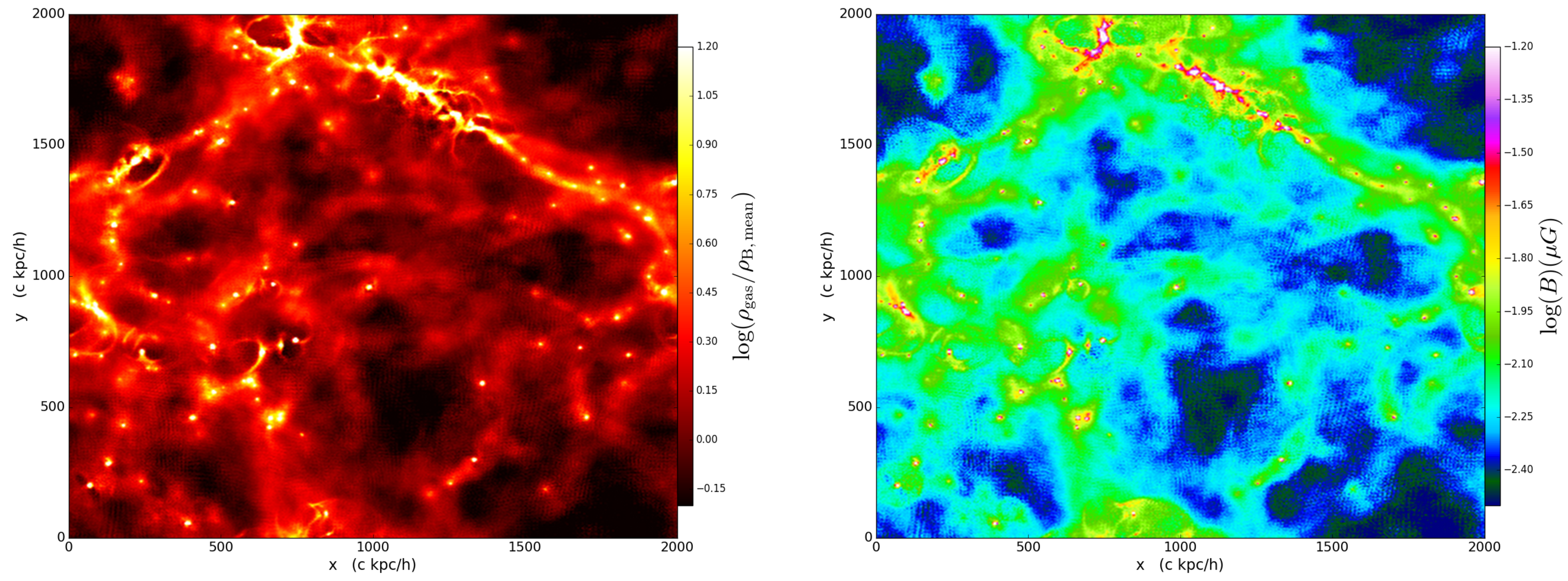

Fig. 1: Projected 2D maps of the gas overdensity and the magnetic field, respectively.

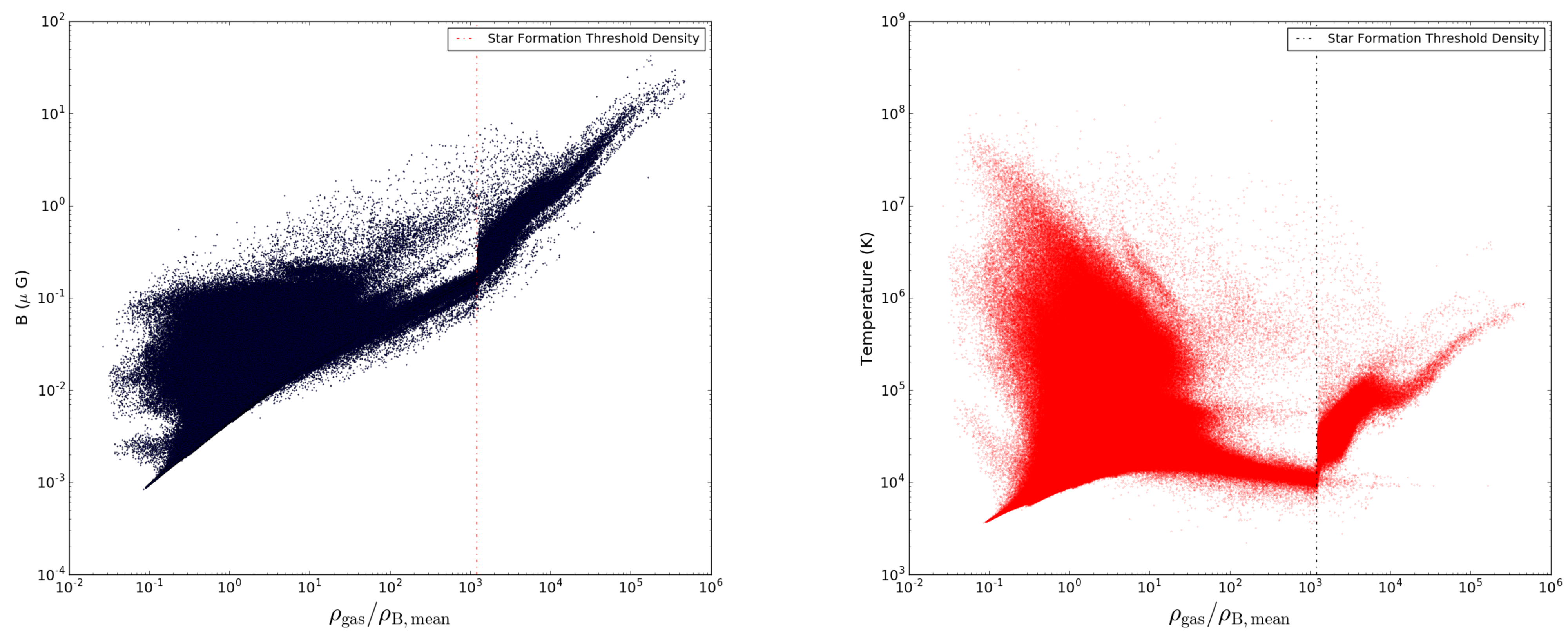

Fig. 2: Diagrams of correlation of magnetic field with overdensity, and temperature with overdensity, respectively.

Analysis

- The methodology used for computing the magnetic field B_c will be following Barai (2008). This assumes equipartition of energy between the gas and magnetic field:

$$u_B = \frac{u_E}{2} = \frac{B_c^2}{8\pi} \quad (4)$$

where u_B is the energy density of magnetic field, u_E is the energy density of the particles and B_C is the magnetic field.

$$u_B = \frac{U_{int} \times M_{gaspart}}{volume} \quad (5)$$

$$volume = \frac{4\pi R_{physical}^3}{3} \quad (6)$$

- Star Formation Threshold Density

$$\rho_{SFTD} = \frac{n_{SF} \times M_{hydrogen}}{<\rho_B> (1+z)^3} \quad (7)$$

where ρ_{SFTD} is the star formation threshold density and n_{SF} is the number density $0,13 cm^{-3}$

$$\rho_{SFTD} = 1.200298 \times 10^3 \quad (8)$$

Discussion and Conclusion

- From the partial results, we conclude that the Magnetic field has a positive correlation with the overdensity in the IGM (Figure 2 on the left side) and inside the galaxies.
- On the right side of figure 2, a positive correlation is noted in the temperature inside the galaxies. Outside, it is possible to note that most of the distribution has low temperatures.
- Around overdensities of 10^3, it is possible to notice two regions with different behaviors regarding their particle distribution.

References

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