HIGH-ENERGY ASTROPHYSICS OF GALAXIES AND AGN IN THE COSMOLOGICAL CONTEXT BY CONNECTING NUMERICAL SIMULATIONS AND OBSERVATIONS WITH THE CTA AND ASTRI MINI-ARRAY

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This project aims to explore high-energy astrophysical processes: star-formation, feedback from supernovae (SN) and active galactic nuclei (AGN) accretion, in the cosmological context. Using an approach going beyond the state-of-the-art, we will perform numerical magneto-hydrodynamical simulations and predict observables for next-generation observations. One main aim is to make predictions for the upcoming gamma-ray telescopes: Cherenkov Telescope Array (CTA), and its precursor – the ASTRI MINI-ARRAY. The scientific objectives are grouped into 4 broad topics.

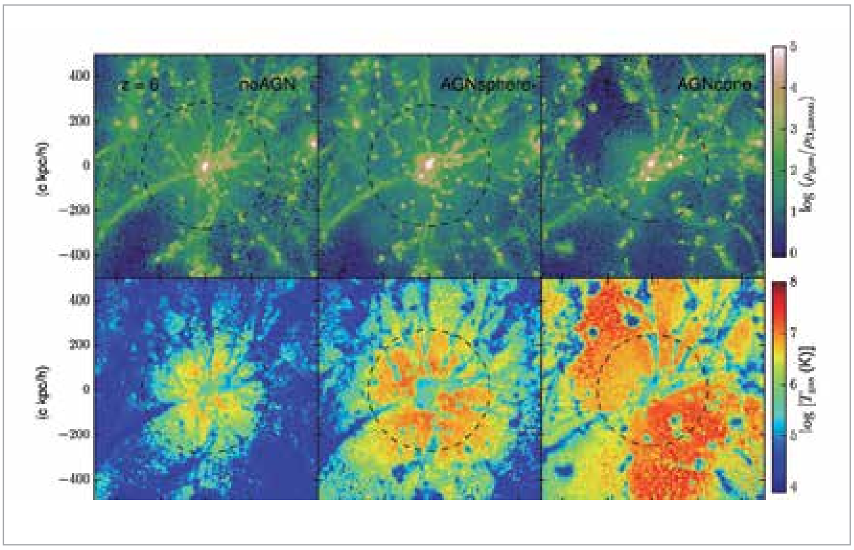

Figure 1. Source: http://adsabs.harvard.edu/abs/2016MNRAS.461.1548B (Barai et al. 2016. MNRAS, 461, 1548)

(1) Feedback from Star-Formation and SN Explosion in Galaxies: Magnetic fields produced in galaxies are dragged to the intergalactic medium by SN-driven galactic winds. We will study the history of gas outflows in different galaxies, and explore the origin of diffuse intergalactic magnetic fields (IGMFs); especially constrain the strength and the filling factor of the cosmic IGMFs.

(2) Central Black Hole Accretion, Outflows, and Jets from AGN: We will perform cosmological simulations, and compute the flux of high-energy diffuse emission coming from AGN, to set predicted constraints on the extragalactic background light, the production and propagation of very high-energy cosmic-rays and gamma-rays, that can be observed with the CTA.

(3) Dark Matter (DM) Annihilation Signatures From gamma-ray Detection: Efforts for detection of cold DM particles has so far been unsuccessful. We will:
- Explore the cross section threshold for DM self-annihilation.
- Consider two types of sources as the primary: (i) center of our Milky Way Galaxy, (ii) DM halos of nearby dwarf spheroidal galaxies.

(4) Support the science case development of CTA and ASTRI Mini-Array to Observe High-Energy Phenomena: Evaluate the performance of the MINI-ARRAY configuration and additional configurations consisting of medium-size-telescopes, to obtain the best array configuration.

The proposed investigation of high-energy astrophysical phenomena, by confronting numerical simulations with observations uniquely lies at the forefront of cutting-edge research in Astrophysics, bridges the gap between theory and observations, and expects high-impact results.

Many more energetic events would start to be detected in gamma-ray observations using the precursor ASTRI MINI-ARRAY and full CTA later, which has not been widely simulated; therefore it is important and timely to explore these phenomena, especially at earlier epochs. Currently this project is at a beginning phase. We have performed a dark-matter only simulation (using the SPH code GADGET-3) of a cubic cosmological volume of side 20 Mpc comoving, starting from redshift z=100 to z=0. We selected a massive halo from the box of total mass M_halo = 1e+12 Msun. We are currently preparing the zoom-in initial conditions to add baryons and perform hydrodynamical simulations. This will allow us to study simulated galaxies and their outflows. An example is shown in the *Figure 1* (showing gas density in the top row and gas temperature in the bottom row of 3 galaxies taken from 3 simulations) from a previous study (Barai et al. 2016) where AGN outflows were investigated.

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