A Multi-Frequency Galaxy Cluster Catalog from the MultiDark Cosmological Simulation

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ABSTRACT Using the observed X-ray properties of galaxy clusters we have implemented a phenomenological model to assign to each cluster in the MultiDark N-body cosmological simulation (www.multidark.org) a gas density profile using only its mass. In this way we have created a large galaxy cluster mock catalog, with more than 10,000 clusters above $1\times10^{14}\ h^{-1}\ M_\odot$, that display the basic observed X-ray properties, such as the luminosity-mass relation and the luminosity function. This mock catalog can be used in making predictions for eROSITA and, generally, in synergy with cluster samples for various purposes. In particular, we will compute the radio and gamma-ray non-thermal emission resulting from hadronic cosmic rays interactions with the ambient gas in order to compare predictions with expectations from LOFAR and gamma-ray experiments. We will further investigate the X-ray properties of our sample and finally make it available on-line [1].

METHODOLOGY Our final goal is to predict the diffuse synchrotron radio and gamma-ray emission of galaxy clusters, assuming that it is mainly due to hadronic cosmic rays (CR) interactions with the ambient gas [2], for a cosmological complete sample. The two fundamental ingredients are the cosmological simulation from which we construct our cluster sample, and the intra-cluster medium gas density profile needed to calculate the emission.

We use the MultiDark N-body cosmological simulation which consists of 2048^3 particles within a $(1000\ h^{-1}\ \mathrm{Mpc})^3$ cube done with the ART code [3]. Creating our complete cluster sample, we impose a mass cut of $M_{200} \geq 1\times10^{14}\ h^{-1}\ M_\odot$ and we select only distinct halos, i.e. those halos which are not sub-halos of any other halo. In this way, we obtain a final cluster sample of about 10,000 objects for redshift $z \leq 0.1$.

In order to assign a gas density profile to each dark matter halo of our sample, we fit the REXCESS clusters gas data [4] with a generalized Navarro-Frenk-White profile (GNFW). We obtain two general profiles for non-cool core (NCC) and cool core (CC) clusters, respectively, as can be seen in Figure 1. We then use the f_{gas} - M relation [5] in order to introduce a mass-scaling. We separate our cluster sample in two equally numerous NCC and CC populations. Finally, we additionally introduce a random scatter and the self-similar evolution in the gas densities. In this way we construct a *phenomenological* model with which we can assign a gas profile to each cluster given only its mass.

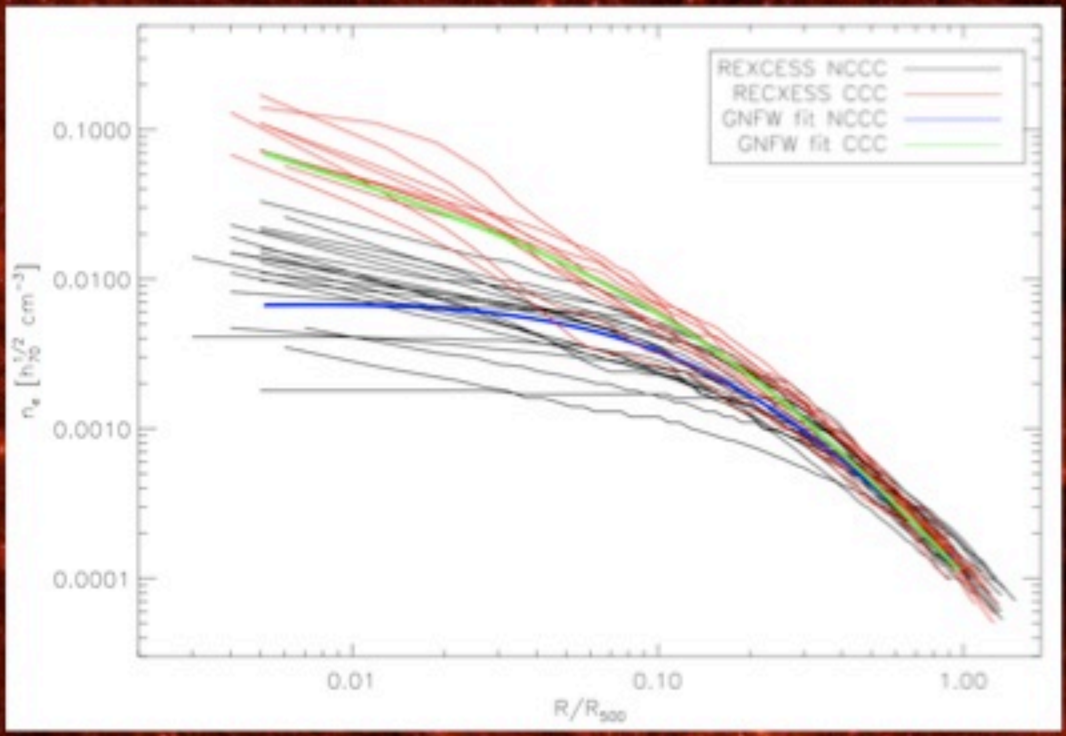

Figure 1. Electron density profiles of the REXCESS cluster sample [4] and the NCC and CC GNFW profiles obtained from them.

RESULTS In order to check whether our approach is correctly reproducing the observations, we calculate the bolometric X-ray thermal bremsstrahlung luminosity for the clusters in our catalog and compare the predicted L_{BOL} - M relation and luminosity function (XLF) with observations. In doing this we additionally need the clusters temperature for which we adopt a M-T relation [6].

In Figure 2, we show how our L_{BOL} - M predictions compare with observations [6] and find that we can reproduce them very well. We also find that the scatter of our sample at different redshifts are in all cases distributed as a Gaussian with $\sigma_{LM} \approx 0.18$ well reproducing observational results.

In Figure 3, we compare the BCS XLF [7] with our XLF at z = 0.1. Note that the BCS sample redshift is z < 0.3 but with most objects at $z \leq 0.1$. We over-produce the observed XLF at low luminosities, which might be due to low-luminosity incompleteness of the BCS sample, while we are compatible with it at high luminosities.

Concluding, our *phenomenological* model works very well in obtaining gas density profiles which well reproduce the basic observed X-ray cluster properties and therefore can be used to obtain realistic predictions [1].

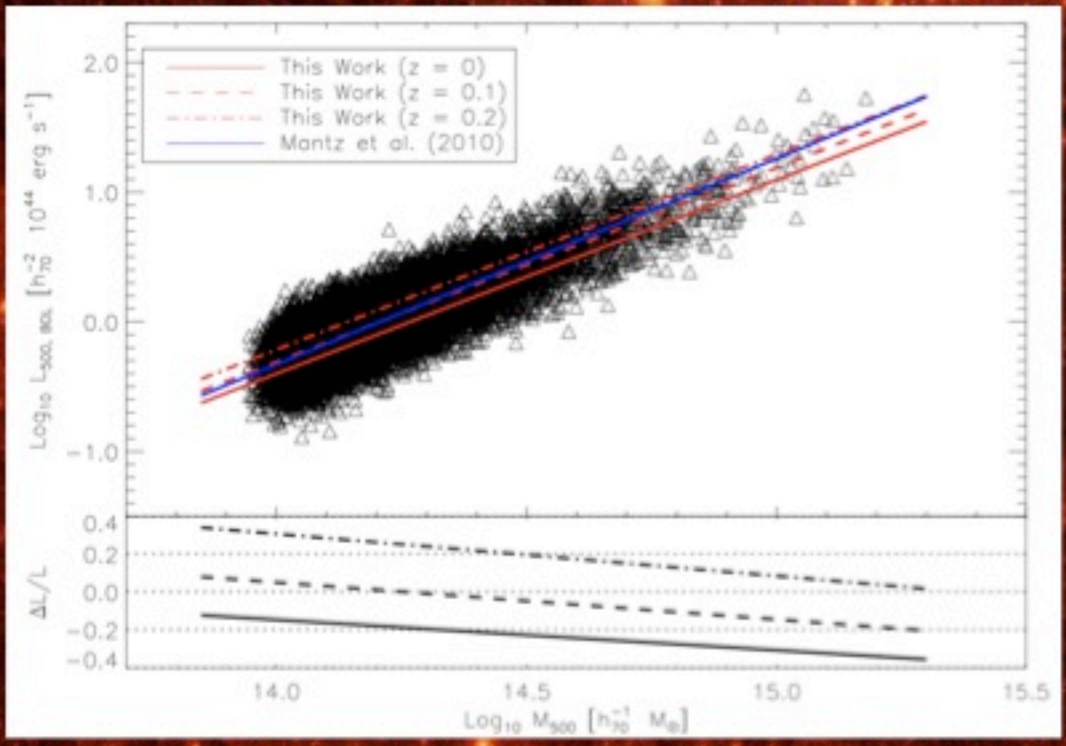

Figure 2. L_{BOL} - M relation. Black triangles show our z = 0.1 sample case. Red lines show our results for different redshifts. The blue line is the observational result obtained with a sample of clusters at 0.02 < z < 0.46 but most of them at z < 0.3 [6]. The bottom panel shows the difference of this work with respect to observations.

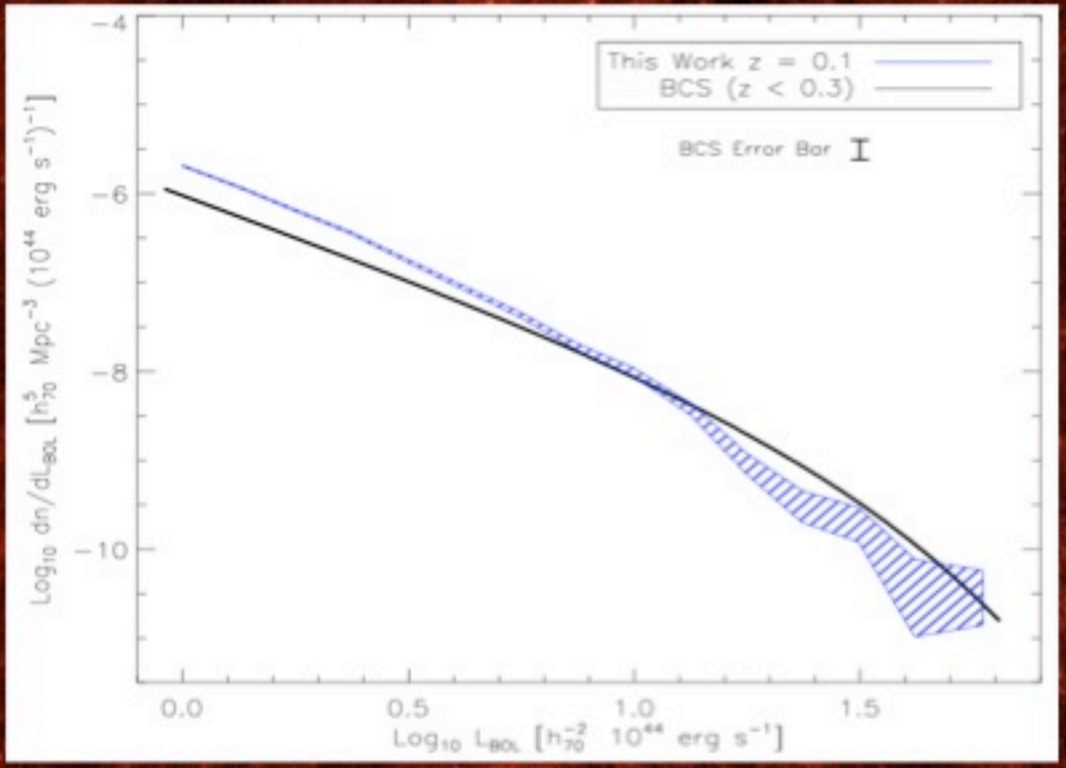

Figure 3. Bolometric luminosity function obtained in this work for redshift z = 0.1 (in blue, where the shaded region corresponds to 1σ Poissonian errors) compared to the BCS [7] XLF (black line).

REFERENCES: [1] Zandanel, Pfrommer & Prada 2011, in preparation; [2] Enβlin et al. 2011, A&A 527, 99; [3] Prada et al. 2011, ArXiv 1104.5130; [4] Croston et al. 2008, A&A 487, 431; [5] Sun et al. 2009, APJ 693, 1142; [6] Mantz et al. 2010, MNRAS 406, 1773; [7] Ebeling et al. 1997, APJ 479, 101