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Radio relics in the MareNostrum Universe

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Abstract. We identify shocked gas in simulated galaxy clusters extracted from the MareNostrum Universe simulation (Gottloeber et al. 2006) assuming that shock waves are regions of electron acceleration. We perform flux number counts within the framework of the non–thermal emission model developed by Hoeft et al. (2008). Results are presented at two different observing frequencies, i.e. 1.4 GHz and 120 MHz, posing interesting constraints for LOFAR and upcoming radio telescopes.

Key words. Cosmology: large-scale structure of the Universe – Cosmology: diffuse radiation – Galaxies: clusters: general – Radiation mechanisms: non-thermal – Radio continuum: general – Rhock waves – Methods: numerical

1. Introduction

Radio relics are elongated structures located in the outskirts of galaxy clusters. Seemingly, these radio features are produced during cluster merger events as a result of the formation of shock waves, which are believed to be ideal sites for electron acceleration. In the presence of magnetic fields accelerated electron populations are capable of producing the observed synchrotron emission.

During the last years, the number of observed relics has dramatically increased due to the spectacular improvement in the instruments sensitivity. In particular, the system found in the galaxy cluster CIZA J2242.8+5301 is one of the most spectacular relics known to date, giving strong support to the previously mentioned astrophysical scenario (van Weeren et al. 2010).

In this work, we estimate the amount of diffuse radio emission produced in simulated relics using a synthetic galaxy cluster sample extracted from a cosmological simulation box. After identifying shocks in the simulation we apply a radio emission model based on the diffusive shock acceleration (DSA) process and count how many relics are observable as a function of redshift to assess expectations for the upcoming LOFAR radio surveys.

In Sect. 2 we give a brief overview of the method used and in Sect. 3 we close the contribution with the discussion and comment about future work.

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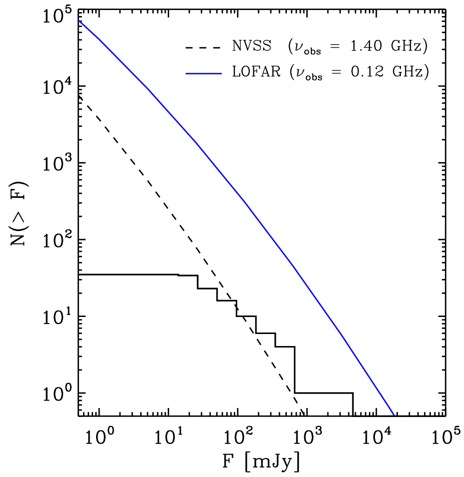

Fig. 1. Cumulative number of observed relics as a function of radio flux. The histogram shows the observed NVSS relic sample ($\delta > -40°$) as a reference. Also shown are models at 1.4 GHz (NVSS) and 120 MHz (LOFAR *Tier 1*).

2. Method

We select the 500 most massive clusters in the MareNostrum Universe simulation (Gottloeber et al. 2006), a non-radiative smoothed particle hydrodynamics cosmological run with 2×1024^3 gas and dark matter particles, at 3 different cosmic times ($z = 0, 0.5$ and 1).

Shock waves in the simulated clusters are identified in order to compute the non–thermal emission as a function of Mach number, magnetic field and thermodynamical state of the post–shock region. We assume that the magnetic field in the shocks scales with gas density simply obeying flux conservation, i.e. $B = B_0 \times (n_e/n_0)^{2/3}$, where n_e is the electron density and n_0 and B_0 are two reference values chosen to be 10^{-4} cm^{-3} and 0.1 μG respectively. In our model electrons are accelerated by means of the DSA mechanism whereas they cool down due to synchrotron looses and inverse Compton scattering with the cosmic microwave background. For more details about the shock finding technique and the radio model used see Hoeft et al. (2008).

For each simulated cluster we estimate the radio emission produced in shocks inside a sphere of size $\sim 2 \times R_{vir}$ with R_{vir} being the virial radius. In order to estimate the total non-thermal emission for less massive haloes at each redshift we construct the radio power distribution for relics in clusters with different masses and extrapolate the obtained trend. From this information we evaluate the probability of finding radio relics for a given cluster mass, radio power and cosmic time. To compute the radio relic luminosity function (RRLF) as a function of redshift we convolve this probability with the halo mass function given by Sheth & Tormen (2002). Finally, using the RRLF it is possible to perform the flux number counts.

3. Discussion

Figure 1 shows the model predictions for the observed relic cumulative number per logarithmic radio flux at 1.4 GHz (normalized to the NVSS sample at 100 mJy) and 120 MHz (corresponding to the LOFAR *Tier 1* survey). It can be seen that LOFAR will be able to observe thousands of relics. The actual number will depend on the final sensitivity of the survey and on the details of the shock magnetic field involved. We will present a comprehensive analysis using different model assumptions in a forthcoming paper (Nuza et al. 2011, in preparation).

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