The X-ray view of high-redshift clusters: ICM and AGN contribution

Veronica Biffi

SISSA, Trieste (Italy)

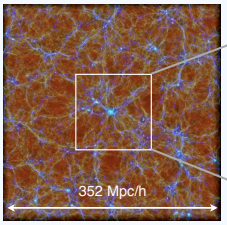
Scuola Internazionale Superiore di Studi Avanzati

ABSTRACT. X-ray observations still represent a very powerful strategy to investigate the properties of galaxy clusters through their formation history. Current and up-coming X-ray telescopes, from Chandra to eRosita and Athena, are able in fact to track the properties of the most important contributor to the cluster baryonic budget: the intra-cluster medium (ICM). ICM thermo-dynamical properties can be reconstructed from its X-ray emission and theoretical models can be evaluated against the observational evidences. Especially at high-redshift, forthcoming X-ray instruments will allow to investigate clusters at the dawn of their assembly. This will help to unveil the details of metal production and diffusion, of the interplay between cooling and feedback mechanisms and of the interaction of the ICM with member galaxies. Predictions for this can already be anticipated via state-of-the-art numerical hydro-simulations, where a vast variety of physical processes (from star formation and cooling to AGN feedback) is carefully treated. Here are presented results on the *contribution of AGN sources to the ICM X-ray properties, from cluster simulations and synthetic observations*. This will be an important issue to tackle in future observations, aiming at detecting high-redshift clusters and studying their baryonic features.

COSMOLOGICAL HYDRODYNAMICAL SIMULATIONS

MAGNETICUM simulation project (P.I. Dolag):

- simulations of cosmological volumes, from which light cones and samples of galaxy clusters are extracted;



- *various box sizes:*

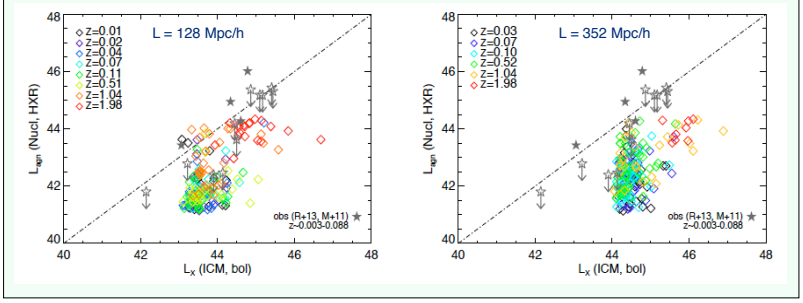
we use medium/small boxes L=128 Mpc/h (Fig.1; left) and L=352 Mpc/h (Fig.1; right) --- at high-res;

- *hydro:* metal cooling, star formation, winds, chemical enrichment according to stellar evolution, SNe-driven and AGN feedback, magnetic fields, low-viscosity scheme for turbulence;

- ***AGN X-ray luminosity:***

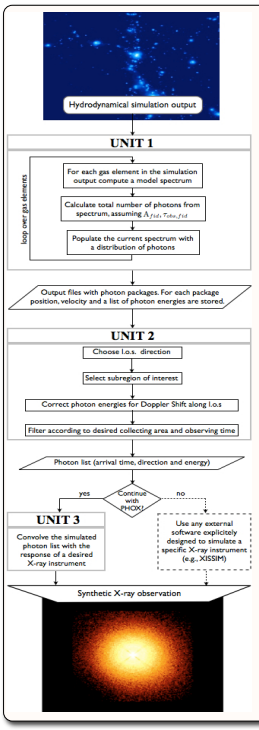
estimated from BH accretion rate, properly distinguishing between radio and quasar mode;

Fig. 1 - *Simulation data:* predicted relation between the **X-ray luminosity** (HXR band: 2-10 keV) **of** the **central AGN and** the global **ICM** X-ray (bolometric) luminosity, for clusters within two boxes at high-res. We compare with observational data --detections (filled stars) and upper limits (empty stars)-- at low redshift, taken from Russel et al. (2013) and Mittal et al. (2011), considering the clusters present in both samples. (Biffi & Dolag, *in prep.*)



Simulations show good agreement at low redshift with the available observations of the AGN (HXR) - ICM (bolometric) X-ray luminosity relation (Fig.1). Beyond the local Universe, sims allow us to explore this up to redshift $z\sim2$, where data will become available with, e.g., eRosita and Athena. Despite the scatter in both quantities, simulation data points remain close to the low-z relation. Towards $z\sim1$-2, however, we find a mild increase in the AGN contribution to total ICM luminosity (from blue to orange-red diamonds), which might compromise the detection of clusters and contaminate the determination of their global properties.

SYNTHETIC X-RAY OBSERVATIONS IN 3 STEPS: PHOX



★ UNIT 1 - Generation of the virtual cube of photons from the simulation output for:

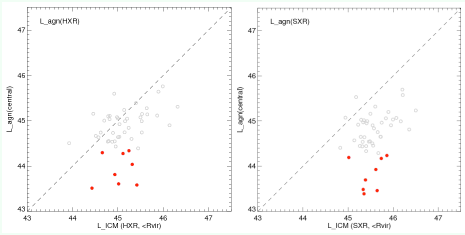
- √ X-ray emission from hot diffuse plasma - ICM
  - ➡ (model: bremsstrahlung + metal emission lines);
- √ X-ray emission from AGN-like sources
  - ➡ (model: power law);

★ UNIT 2 - Geometrical selection and projection along the line of sight (l.o.s.), accounting for l.o.s. motion of the emitting particles;

★ UNIT 3 - Convolution with the instrumental response of different X-ray instruments (e.g. Chandra, eRosita, Athena).

- Biffi, Dolag, Boehringer, Lemson (2012);
- Biffi, Dolag, Boehringer (2013);
- Biffi, Dolag (2014, *in prep*).

Fig. 2 - *Simulation data:* similar to Fig.1, but considering the possibility for each AGN to be obscured (see, e.g. Hasinger et al. 2008), depending on its intrinsic luminosity and given redshift (here: $z\sim2$).



We compare central-AGN and ICM luminosities in two energy bands: HXR (2-10 keV; left) and SXR (0.5-2 keV; right). The unobscured AGN are marked in red: at such high z, those might contaminate, unless resolved, the global X-ray luminosity of the system, by contributing up to ~10-20% of the ICM L_X.

X-RAY MOCK DATA - E.G. ATHENA

ATHENA: up-coming ESA X-ray mission optimal to achieve high spectral and spatial resolution, dedicated to the study of the hot and energetic Universe up to high redshift.

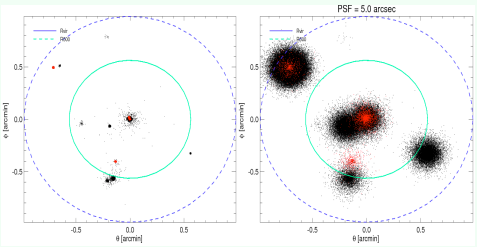


Fig. 3: Projected maps for an example cluster at $z\sim2$ of the synthetic X-ray photons from the **ICM (black)** and the (unobscured) **AGN sources (red)** obtained from PHOX adopting the Athena (WFI) response.

Left: ideal spatial distribution from the simulation gas and AGN-like particles.

Right: included a gaussian smoothing of **5"**, **mimicking Athena PSF** effect --- while resolution effects would have an even stronger impact on high-z cluster obs, for instruments with larger PSF (e.g. eRosita).

Within the projected R_{500} the contribution from AGN X-ray photons is not negligible, compared to ICM, and not easily associated to a point source.

CONCLUSIONS. Numerical hydro-simulations of clusters can include many physical processes concerning the baryonic components, but also track other sources of emission, e.g. AGN. These have been included into the PHOX code to generate more complete mock X-ray data, that account for both. Especially at high z, simulations are useful for predictions and synthetic obs. help studying the results achievable with up-coming instruments like Athena: we find that at high z ($z\sim2$) the contrbution from AGN photons to the global X-ray emission is not negligible and cannot be easily disentagled from the main ICM emission, being a significant fraction of it.