MAPPING COSMIC LARGE SCALE STRUCTURES WITH XMM

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ABSTRACT

We outline the fundamental arguments in favor of Large Scale Structure investigations in the X-ray band: a new era is to be opened by XMM. We then briefly present a project specifically designed to map the X-ray universe out to redshifts of 1-2.

1. Introduction

So far, Large Scale Structure have been almost entirely investigated in the optical band, focusing on the distribution of galaxies. If the bubbly structure of the universe (CfA, Lapparent et al 1986) is now well established, present large surveys (e.g.: Las Campanas, $z_{max} \sim 0.2$, 24 000 galaxies, Landy et al 1996) suggest the existence of a characteristic scale of ~ 100 Mpc/h - a value hardly reconcilable with the present available cosmological scenarios. Large N-body simulations predict indeed that the initial density perturbations evolve toward non linear stages by forming a network of filaments and sheets where density contrasts continuously increase as time goes on. The structure evolution rate (in size and density) is therefore a key parameter for constraining the few cosmological models left open by the COBE results. This concerns primarily: the type and amount of dark matter present in the universe, the mean cosmic density and the initial perturbation spectrum. It is thus timely to study large volumes of the universe at high redshifts, combining information from different wavebands

2. The impact of XMM

Due to its very large collecting area and wide energy range, XMM is the ideal instrument for investigating cosmic structures on large scales in the X-ray band. Basically, high galactic latitude fields observed by XMM at medium depth ($\sim 10^{-14}$ erg/s/cm^2) will contain two types of objects: galaxy clusters (extended) and QSOs (pointlike). This, associated with a deep imaging and spectroscopic survey in the optical, offers numerous advantages and compelling arguments compared with traditional stand-alone optical procedures:

Clusters will be easily detectable up to $z \sim 2$ - if they exist! - (Fig. 1). For the brightest ones, the X-ray spectra will provide redshift estimates (e.g. the redshift of the Coma cluster located at $z = 1$ will be determined with an accuracy of a few hundredths). This will yield an almost instant view of the 3D topology of the deep potential wells of the universe up to an unrivalled depth. The detection of small groups of galaxies and of the tenuous gas trapped in the filaments may be also possible (Fig. 2), yielding precious informations on their physical state, on the interface filaments-clusters as well as on bias mechanisms in low density structures; so many hotly debated questions today. Very numerous and probably very distant AGNs will be detected. Their location within the structures will appear unequivocally, elucidating former questions on their correlation function - i.e., on their origin in terms of initial density perturbations. In addition, it will be most instructive to cross-correlate X-ray pixel information with weak gravitational lensing analyses in the optical as well as to combine constraints from the Sunyaev-Zeld'ovich effect on very large scales. Finally, an important "by-product" of a combined detailed X-ray/optical survey is the evolutionary study of clusters (and QSO) in both bands. For instance we could cite: the detection of "dark clusters" (extended X-ray emission without obvious optical counterpart) or conversely, the non-detection of optically rich clusters at high z.

2.1. Simulations

The two figures preented here are *colour* postscript files.

3. The XMM Medium Survey

Three XMM consortiums (SSC-Saclay, EPIC-Milan, OM-Liège) have joined efforts and pooled their Garanteed Time resources to design a large scale XMM survey at medium depth. The ultimate goal is to map a 5×5 sq. deg. area. This X-ray survey is to be coordinated with the deep MEGACAM imaging survey at the CFHT and to the VIRMOS spectroscopic survey at the VLT (more details on the whole project can be found in Pierre 1998).

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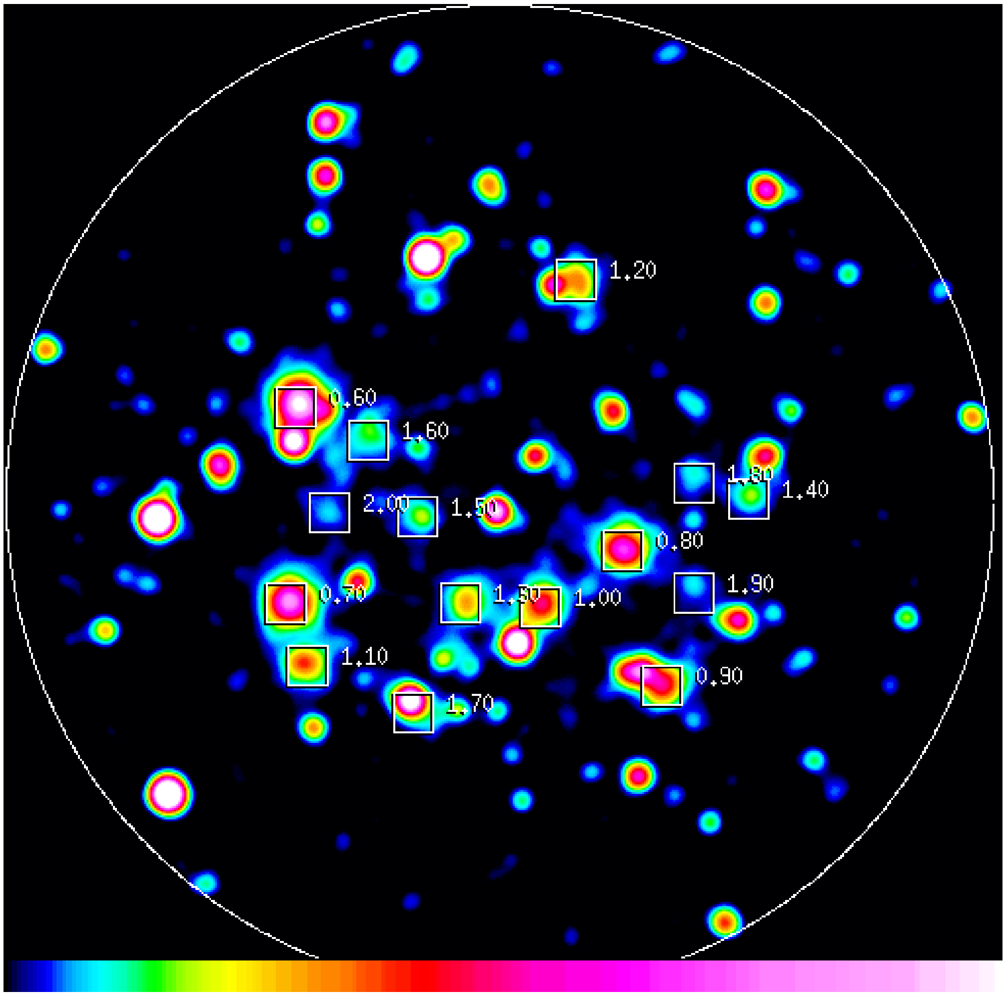

Fig. 1.— XMM/EPIC simulated field for an exposure time of 20 ks in the [0.4-4] keV band which presents the highest S/N; the field of view is 30 arcmin. The XMM spectral response, PSF off-axis and vignetting effects as well as a diffuse background contribution have been taken into account. The photon image has been filtered with a gaussian ($\sigma = 12$") and is displayed in logarithmic scale. The LogN-LogS extragalactic source distribution is reproduced assuming a photon spectral index of 2. In order to investigate the detectability of distant clusters of galaxies, 15 identical clusters ($L_{2-10keV}$ = 3 10^{14} erg/s, T = 5 keV, King luminosity profile with $\beta = 0.75$ and $R_c = 250$ kpc) have been added in the image with redshifts of 0.6, 0.7, 0.8...2. Simulated clusters are indicated by a box and redshift (some of them are occulted by a bright point-source, like the one at $z = 1.7$). In reality, only 1 or 2 clusters out to $z \sim 2$ may actually be present in such a field, assuming no evolution.

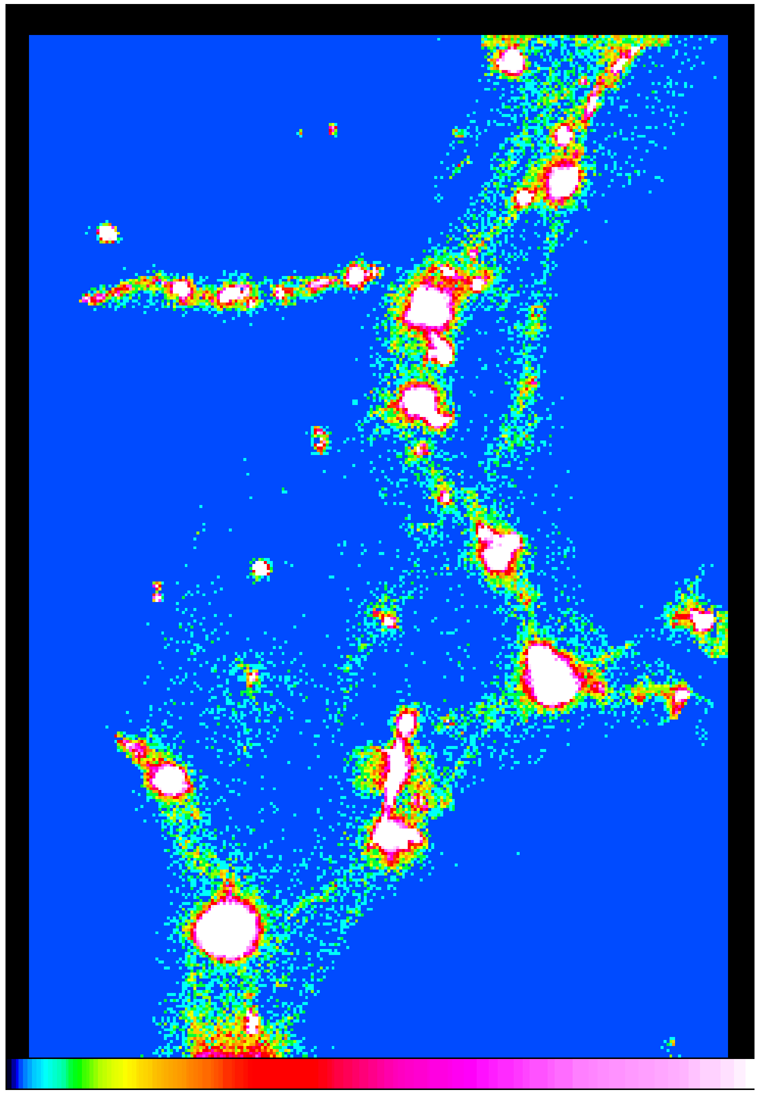

Fig. 2.— Cosmic filaments at $z = 0.5$ to be seen by XMM/EPIC in the [0.4-4] keV band. This simulated image has been produced using high resolution 3D hydrodynamical simulations by G. Bryan (1997, 1998) run for a ΛCDM model. A region ($18 \times 24 \times 35$ Mpc/h) located between two big clusters (not shown) has been extracted, the X-ray emissivity and number of photons produced by each simulation cell (100 kpc/h) were then computed, convolved by the XMM response and projected along the line of sight. This image has been calculated for an XMM integration time of 100 ks and encompasses a region of $\sim 75' \times 109'$ (Ho = 50/km/s/Mpc) but does not include the simualtion of the LogN-LogS fore/background sources. The display cuts bracket the intensity range of 0 to 30 photons per pixel. Basically, all white features are virialized; they are groups embedded in the filaments, ranging from 10^{13} to $10^{14.5}$ solar masses. Diffuse filamentary emission is also conspicuous.