

Clustering of X-ray sources in the XMM-Newton COSMOS field

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Abstract: A strong spatial clustering signal ($\sim 8\sigma$) is detected for a sample of 378 X-ray sources with spectroscopic redshift in the XMM-COSMOS field. The best fit parameters of the spatial correlation function (SCF) are found to be $r_0 \sim 8 h^{-1}$ Mpc and $\gamma \sim 1.6-1.8$ at a median redshift of $z \sim 1$. Because of the low spectroscopic completeness (30%), these results are preliminary and await for more identifications to be confirmed. A positive clustering signal is also detected for the angular correlation function (ACF) measured on the sample of ~ 1300 X-ray sources detected so far. When converting the ACF into SCF using Limber's equation, the best fit correlation length and slope are consistent with those measured directly from spatial clustering.

Rationale: Spatial clustering analysis is a powerful tool to address the co-evolution between galaxies and Active Galactic Nuclei, i.e. the link between the formation and evolution of galaxies and of supermassive black holes at their centers. Robust AGN clustering measurements have become recently possible based on extensive optical surveys like the 2dF and the SDSS, which however miss obscured QSO known to represent the majority of the AGN population. X-rays are able to sample the obscured AGN population, however the clustering measurements obtained so far for X-ray selected AGN suffer from significant variance due to the small sky areas sampled and/or the limited number of identified sources. The sample of ~ 2000 X-ray sources with the high degree of spectroscopic completeness, expected at the end of the 2deg² XMM-COSMOS survey, will produce a major step forward in the knowledge of X-ray source clustering, allowing for the first time to determine the clustering of obscured AGN as a function of cosmic time.

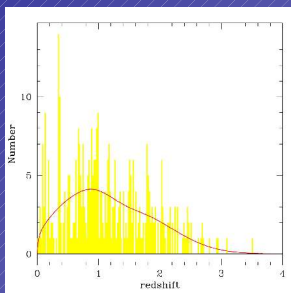


Fig.1: Redshift distribution of the 378 spectroscopically identified X-ray sources (e.g. Brusa et al. 2006). Redshifts have been collected both through a dedicated program (Impey et al. 2006, Trump et al. 2006) and cross-correlation with z-COSMOS sources (Lilly et al. in 2006). The red curve is the smoothed distribution used to generate the redshift catalog for the control random sample.

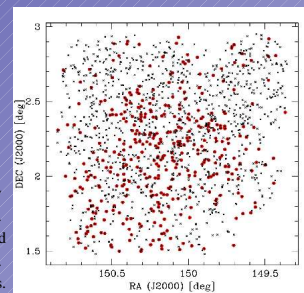


Fig.2: The (α, δ) distribution of the ~ 1300 X-ray sources detected so far in the XMM-COSMOS field. Details of the X-ray observations and sample are presented by Hasinger et al. 2006 and Cappelluti et al. 2006. Sources with spectroscopic redshift are shown as red circles.

Analysis techniques: to avoid distortions in redshift space we computed the projected correlation function defined as in Davis & Peebles (1983, ApJ, 267, 465):

$$w(r_p) = \int_{-r_{v0}}^{r_{v0}} \xi(r_p, r_v) dr_v$$

where ξ is the two point correlation function expressed in terms of the separations parallel (r_p) and perpendicular (r_v) to the line of sight.

If the spatial correlation function can be approximated by a powerlaw $\xi(r) = (r/r_0)^{-\gamma}$

the best fit parameters r_0 and γ can be estimated by fitting $w(r_p)$, since the following relation holds: $w(r_p) = A(\gamma)r_0^\gamma r_p^{1-\gamma}$

To estimate ξ we used the Landy & Szalay (1993, ApJ, 412, 64) estimator: $\xi(r_p, r_p) = (DD - 2DR + RR) / RR$, where DD, DR and RR are the normalized data-data, data-random and random-random pairs in a given r_p bin. In the generation of the random control sample, redshifts have been extracted from the smoothed distribution shown in Fig.1. To account for the uneven distribution of the real sources on the sky plane (e.g. because of the criteria adopted in the selection of candidates for optical spectroscopy observations, or because of the varying X-ray sensitivity across the field) random sources are placed at the same coordinates of the real sources with z-spec (see Fig.2). About 10000 sources have been considered in the random sample.

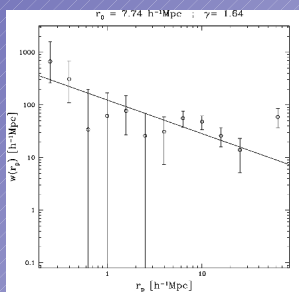
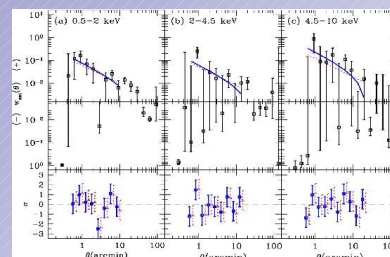


Fig.3. The projected correlation function measured for the 378 XMM-COSMOS sources with z-spec.

Fig.4. The angular correlation function for the XMM-COSMOS sources detected in different X-ray bands (from Miyaji et al. 2006, in preparation)



Results: the projected correlation function $w(r_p)$ for the sample of 378 XMM-COSMOS sources with spectroscopic redshift is shown in Fig.3. We also measured $w(r_p)$ separately for the 362 X-ray sources detected in the soft band and the 261 sources detected in the hard band, without finding significant differences. The measured spatial correlation length is intermediate between the values measured in the two 0.1 deg² Chandra Msec Fields (Gilli et al. 2005, A&A, 430, 811) and in line with that measured for X-ray sources in the 0.4 deg² CLASXS field (Yang et al. 2006, ApJ in press; astro-ph/0601634). We also measured the angular correlation function for the ~ 1300 X-ray sources detected so far in the COSMOS field (see Fig.4; Miyaji et al. 2006) and inverted the angular correlation function through Limber's equation to get the spatial correlation length. Assuming a slope of 1.8, a comoving correlation length of 9-11 h¹Mpc was found, with $\sim 30\%$ uncertainties, which makes this result consistent with that obtained from the preliminary spatial analysis.