The XMM-LSS Survey : properties and two-point angular correlations of point-like sources

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I. Abstract

We analyse X-ray sources detected over 4.2 pseudo-contiguous sq. deg. In the 0.5-2 keV and 2-10 keV bands down to fluxes of 2 10^{-15} and 8 10^{-15} erg s^{-1}, as part of the XMM-Newton Large Scale Structure Survey. The detected sources resolve close to 30 per cent of the X-ray background in the [2-10] keV band. We study the two-point angular clustering of point sources using nearest neighbours and correlation function statistics and find a weak, positive signal for ~1130 sources, in the [2-10] keV band, but no correlation for ~400 sources in the [2-10] keV band below scales of 100 arcsec. A sub-sample of ~200 faint sources with hard X-ray count ratios, that is likely to be dominated by obscured AGN, does show a positive signal, but only at the 2-3 sigma level.

II. The XMM-LSS Survey

- 51 overlapping pointings (presently).
- 6 deg^2 contiguous.
- exposure time between 10 and 20 ks.
- Processing pipeline presented in Pacaud et al. (2006).

III. Selection of point-like sources

- Sources from the inner 10 arcmin of each pointing (PSF distortion at high off-axis angle).
- Confirmed extended X-ray sources removed from the [0.5-2] keV (soft) sample, every source considered as point-like in the [2-10] keV (hard) sample.
- Significance of source selection based upon S/N ratio.

IV. Generation of random (uncorrelated) catalogues (A)

- Significant variation in sensitivity and irregular holes ➡ crucial to simulate selection effects accurately.
- Mirror vignetting ➡ minimum detectable flux at an off-axis distance of 10 arcmin is higher by a factor of 2 as compared to optical-axis centre.
- Generation of an ensemble of random and uniform catalogues simulating the selection effects of the data points, each containing the same number of sources as the parent data catalogue.

IV. Generation of random (uncorrelated) catalogues (B)

- Randomly chosen sky positions over the inner 10 arcmin central regions of each pointing.
- Source flux randomly chosen so that they follow the logN-logS of the considered data sample.
- The source flux is compared to the limiting flux at the given position. If the limiting flux at that position is higher, the random source is discarded and another sky position is again randomly chosen.

V. Sky coverage, logN-logS and the X-ray background

Selection Criterion	Classification	0.5–2 keV	2–10 keV
S/N>3 (B+G)	Point sources	1134	413
〃	Extended sources	36	0
〃	Stars	17	0
S/N>2 (B+G)	Point sources	–	912
S/N>2 (G)	Point sources	–	473
〃	1≥HR>–0.2	–	209
〃	1>HR>–0.2	–	140

Tab. 1 Sizes of various sub-samples of X-ray sources analyzed in this work. The parentheses in the first column specify whether the sample was selected over the whole area (B+G pointings), or only over the deeper G pointings.

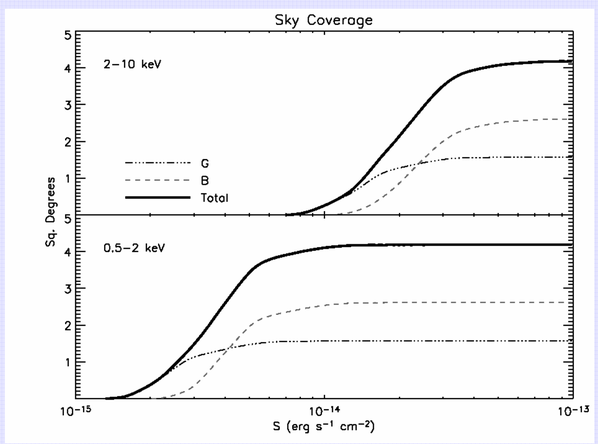

Fig. 1 The sky coverage (left) and log N-log S (right) of the XMM-LSS sample within the central 10 arcmin-radius pointing regions, for the 2-10 keV (top) and 0.5-2 keV (bottom) bands, for a threshold S/N>3 in both bands. The sky coverage is shown separately for the guaranteed time (deeper; dots-dashed; marked "G") and guest observer time (shallower; dashed; marked "B") pointings. The log N-log S is shown for all sources (clusters have a minor contribution, except at bright fluxes in the soft band; their contribution is shown as triangles; marked "extended").

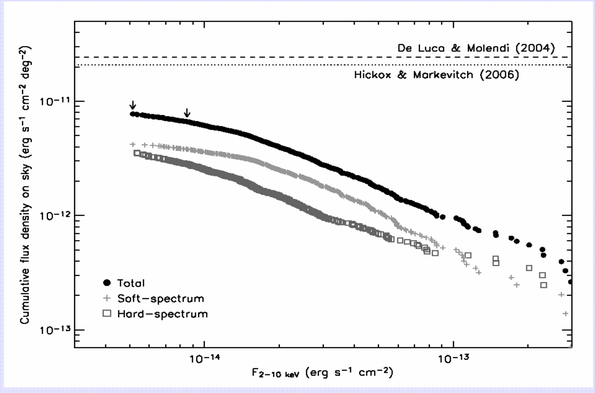

Fig. 2 Cumulative X-ray background intensities in the 2-10 keV band for the detected point sources in the full field of the XMM-LSS survey. The dashed line is the total X-ray background measurement reported by De Luca & Molendi (2004); the dotted line is the measurement of Hickox & Markevitch (2006) converted to 2-10 keV assuming a power-law with photon index equal to 1.4. The resolved source contribution is sub-divided into soft-spectrum and hard-spectrum sources.

VI. Clustering results

Selection Criteria			K-S	ACF
S/N>3 (B+G)	0.5–2 keV		0.001	$\theta_0 = 6.3'' \pm 3$; $\gamma = 2.2 \pm 0.2$
S/N>3 (B+G)	2–10 keV		0.55	–
S/N>2 (G)	〃	; 1≥HR>–0.2	0.006	$\theta_0 = 42''^{+7}_{-13}$; $\gamma = 3.1^{+1.1}_{-0.5}$
〃	〃	; 1>HR>–0.2	0.001	–

Tab. 2 Basic results of the auto-correlation analysis for various samples. "K-S" refers to the null hypothesis probability of the data and control sample being drawn from the same distribution. Power-law fits to the ACF are listed in the final column, where computed or found to be significant.

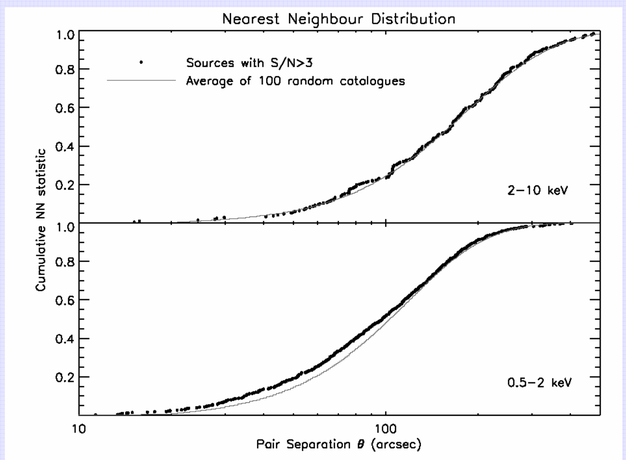

Fig. 3 Cumulative nearest-neighbour distribution function for the soft (bottom, left) and hard (top, left) bands for the point-sources with S/N>3 (filled circles) compared to the average statistic of 100 random catalogues. The soft band distribution has an excess of pairs compared to random, as opposed to the hard band sample. The ACF measured for the XMM-LSS survey in the soft (bottom, right) and hard (top, right) bands for the samples with S/N>3. The solid curve is the best-fit power-law model, while the dotted line marks w=0. Previous power-law ACFs of Basilakos et al. (2004, for the hard band) and of Vikhlinin & Forman (1995, for the soft band) are shown as the dashed and dot-dashed lines respectively.

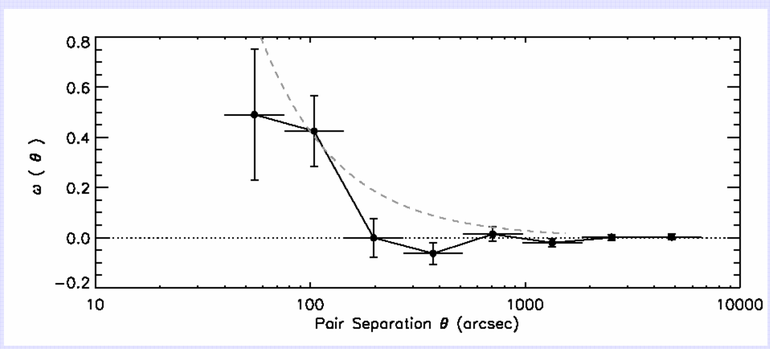

Fig. 4 ACF for the 2-10 keV sample of 209 hard-spectrum (HR>-0.2) sources with S/N>2 in the G pointings. The dashed line is the best-fit ACF of Basilakos et al. (2004).

VII. Discussion and conclusions

- ACF and NN_test both show a positive clustering signal in the [0.5-2] keV band with low significance (around 2 σ). Consistent with Basilakos et al. (2005) within the error bars.
- Results of the same analysis in the [2-10] keV band are consistent with a random and uniform distribution. This is at odds with Basilakos et al. (2004).
- Selecting hard spectrum sources over a reduced area (HR>-0.2, SN>2 on 1.6 deg^2) does reveal a rather significant clustering signal up to ~200 arcsec, consistent with Basilakos et al. (2004).

VIII. References

Baldi A., Molendi S., Comastri A., Fiore F., Matt G., Vignali C., 2002, ApJ, 564, 190
Basilakos S., Georgakakis A., Plionis M., Georgantopoulos I., 2004, ApJL, 607, L79
Basilakos S., Plionis M., Georgakakis A., Georgantopoulos I., 2005, MNRAS, 356, 183
Carrera, F.J., Ebrero, J., Mateos, S., et al., accepted to A&A (astro-ph\0703451)
Chiappetti, L., Tajer, M., Trinchieri, G., et al., 2005, A&A, 439, 413
Gandhi P., Garcet O., Disseau, L., et al., 2006, A&A, 457, 393
Pacaud F., Pierre M., Refregier A., Gueguen A., et al., 2006, MNRAS, 372, 578