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HIGH-Z X-RAY AGN CLUSTERING & COSMOLOGICAL INFERENCE

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RESUMEN

Estudiamos las propiedades del agrupamiento de los AGN seleccionados en rayos-X para diferentes muestras limitadas en flujo del CDF-N y CDF-S. Encontramos una dependencia fuerte de la amplitud del agrupamiento con el límite en flujo, un hecho que explica los diferentes resultados contradictorios de XMM y Chandra que se encuentran en la literatura. Para límites de flujo altos la amplitud de agrupamiento aumenta considerablemente; por ejemplo, si $f_{x,\rm limit} \sim 10^{-15}$ erg s^{-1} cm^{-2}, obtenemos $r_0 \simeq 17 \pm 5$ y $18 \pm 3\, h^{-1}$ Mpc, para CDF-N y CDF-S, respectivamente. Esta dependencia se transforma en una dependencia de la amplitud del agrupamiento con la luminosidad X de los AGNs. Aplicando el formalismo teórico estándar del modelo CDM en una cosmología plana (para $w = -1$ y $h = 0.72$) obtenemos: $\Omega_m \simeq 0.28 \pm 0.03$ y $\sigma_8 \simeq 0.75 \pm 0.03$. Utilizando además la relación Hubble de los SN Ia (para $\sigma_8 = 0.75$ y $h = 0.72$) obtenemos: $\Omega_m \simeq 0.26 \pm 0.04$ y $w = -0.9 \pm 0.1$.

ABSTRACT

We study the angular clustering of X-ray selected active galactic nuclei (AGN) in different flux-limited sub-samples of the *Chandra* Deep Field North (CDF-N) and South (CDF-S) surveys. We find a strong dependence of the clustering strength on the sub-sample flux-limit, a fact which explains most of the disparate clustering results of different XMM and *Chandra* surveys. At high flux-limits the clustering length increases considerably; for example, at $f_{x,\rm limit} \sim 10^{-15}$ erg s^{-1} cm^{-2}, we obtain $r_0 \simeq 17 \pm 5$ and $18 \pm 3\, h^{-1}$ Mpc, for the CDF-N and CDF-S, respectively. The flux-limit dependence translates into a luminosity dependent X-ray AGN clustering. Applying the standard formalism relating the theoretical CDM model clustering to the data in a flat cosmology (for $w = -1$ and $h = 0.72$), we find: $\Omega_m \simeq 0.28 \pm 0.03$ and $\sigma_8 \simeq 0.75 \pm 0.03$; while utilizing also the SN Ia Hubble relation (for $\sigma_8 = 0.75$ and $h = 0.72$), we find: $\Omega_m \simeq 0.26 \pm 0.04$ and $w = -0.9 \pm 0.1$.

Key Words: cosmology: observations — galaxies: active — galaxies: clusters: general

1. THE $W(\theta)$ OF HIGH-Z X-RAY AGN

The 2Ms CDF-N and 1Ms CDF-S *Chandra* data, covering an area of 448 and 391 arcmin^2, respectively, represent the deepest observations currently available at X-ray wavelengths (Alexander et al. 2003; Giaconni et al. 2001). In this work we use the source catalogues of Alexander et al. (2003) with flux limits 3×10^{-17} and 2×10^{-16} erg cm^{-2} s^{-1} for the CDF-N soft and hard band, and 6×10^{-17} and 5×10^{-16} erg cm^{-2} s^{-1} for the corresponding CDF-S, respectively. New sensitivity maps were used, produced following the prescription of Lehmer et al. (2005). In order to produce random catalogues in a consistent manner to the source selection, we discard sources which lie below our newly determined sensitivity map threshold, at their given position. We use only X-ray sources that correspond to AGN according to the Bauer et al. (2004) classification, out of which about half have spectroscopic redshift determinations.

We apply the 2-point angular correlation function analysis and we find statistically significant signals for all bands and for both CDF-N and CDF-S. We also find that in both CSF-N and CDF-S the clustering strength increases with increasing sub-sample flux-limit, in agreement with the CDF-S results of Giacconi et al. (2001).

In Figure 1 we plot the angular clustering scale, θ_0, derived from the power-law fit of $w(\theta)$, as a function of different sample flux-limits (corresponding to half their area curve) for the CDFs and a variety of other *Chandra* and XMM based results (which originally appeared to have discordant correlation lengths). Most of the different results fall within the expected, from the CDFs, flux-limit dependent clustering correlation. Their apparent disagreement can be explained as being due to the different survey flux limits.

We would like to stress that the CDFs are the only surveys, to-date, that have the large flux dynamical range which is necessary in order to clearly identify the $f_{x,\rm limit} - \theta_0$ correlation. This is probably the reason why this effect has not been detected in

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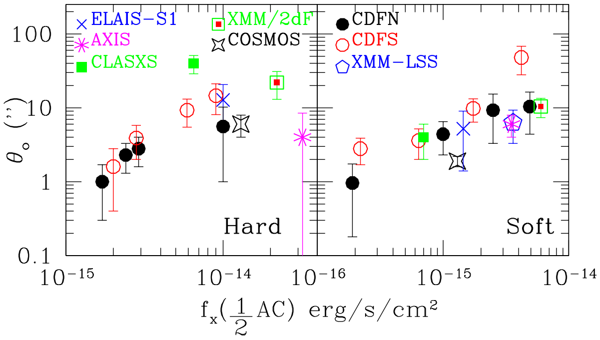

Fig. 1. The angular correlation scale, θ_0, as a function of different survey characteristic flux, defined as that corresponding to half the respective survey area-curves. Most results appear to be consistent with the clustering flux-limit dependence, found from the CDF-N and CDF-S. Errorbars correspond to 1σ Poisson uncertainties.

other surveys, although a weak such effect was found also in the CLASXS survey (Yang et al. 2006).

Using Limber's inversion in the framework of the *concordance* ΛCDM cosmological model we find, for the lowest flux-limit used, clustering lengths: $r_0 = 10.3 \pm 2\,h^{-1}$ Mpc and $r_0 = 6.4 \pm 2.5\,h^{-1}$ Mpc (fixing $\gamma = 1.8$) for the CDF-S and CDF-N respectively, in good agreement with the Gilli et al. (2005) direct 3D determination. At higher flux-limits the clustering length increases considerably; for example, at $f_{x,\rm limit} \sim 10^{-15}$ erg s^{-1} cm^{-2} we obtain $r_0 \simeq 17 \pm 5$ and $18 \pm 3\,h^{-1}$ Mpc, for the CDF-N and CDF-S, respectively.

Finally, we have derived the intrinsic luminosities, in each respective band, for those AGN that have available redshifts and find that the flux-dependent effect translates into an X-ray luminosity-clustering correlation (see Plionis et al. 2008 for details).

2. COSMOLOGICAL CONSTRAINTS

According to the linear biasing ansatz, the AGN and dark-matter correlation functions are related by: $\xi_{\rm AGN}(r,z) = b^2(z)\xi_{\rm DM}(r,z)$, where $b(z)$ is the AGN bias evolution function. We can now write the AGN spatial correlation function as the Fourier transform of the spatial power spectrum $P(k)$:

$$\xi_{\rm AGN}(r,z) = \frac{f(z)b^2(z)}{2\pi^2}\int_0^\infty k^2 P(k)\frac{\sin(kr)}{kr}{\rm d}k\,, \quad (1)$$

where $f(z) = (1+z)^{-(3+\epsilon)}$ with $\epsilon = -1.2$ (constant in comoving coordinates clustering evolution model) and $P(k) = P_0 k^n T^2(k)$ with scale-invariant ($n = 1$) primeval inflationary fluctuations. We also use the non-linear corrections introduced by Peacock & Dodds (1994) and the bias evolution model of Basilakos & Plionis (2001, 2003).

Assuming a flat cosmology with primordial adiabatic fluctuations and baryonic density of $\Omega_{\rm b}h^2 \simeq 0.022$ and utilizing a χ^2 likelihood procedure to compare the derived X-ray AGN angular correlation function (at the highest flux-limit shown in Figure 1) with the prediction of different cosmological models (see Basilakos & Plionis 2005, 2006) we find: $\Omega_{\rm m} = 0.28 \pm 0.03$, $\sigma_8 = 0.75 \pm 0.03$ and $b_0 = 2.0 \pm 0.25$ (for $\epsilon = -1.2$, $w = -1$, and $h = 0.72$). Our derived σ_8 value is in excellent agreement with the recent 3-year WMAP results (Spergel et al. 2007). Also, allowing values $w < -1$, corresponding to the so called *phantom* cosmologies (eg. Caldell 2002), we can derive a new $P(k)$ normalization given by:

$$\sigma_8 = 0.34(\pm 0.01)\ \Omega_{\rm m}^{-\gamma(\Omega_{\rm m},w)}\,, \quad (2)$$

with $\gamma(\Omega_{\rm m}, w) = 0.22(\pm 0.04) - 0.40(\pm 0.05)w - 0.052(\pm 0.040)\Omega_{\rm m}$.

The $w - \Omega_{\rm m}$ degeneracy can be broken with the additional use of the SN Ia Hubble relation (eg. Tonry et al. 2003; Riess et al. 2004). The joined likelihood analysis, performed by marginalizing over σ_8, h and b_0, gives: $\Omega_{\rm m} = 0.26 \pm 0.04$ with $w = -0.90^{+0.1}_{-0.05}$.

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