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CLUSTERING OF INTERMEDIATE LUMINOSITY X-RAY SELECTED AGN AT $Z \sim 3$

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RESUMEN

Presentamos los primeros resultados en propiedades de acumulación de AGN seleccionados en rayos-X a $z \sim 3$. Usando imágenes en rayos-X y colores ópticos UVR de la fotometría del survey MUSYC, seleccionamos una muestra de 58 candidatos a AGN a $z \sim 3$. Además, a partir de los datos ópticos, seleccionamos 1385 LBG a $2.8 < z < 3.8$, con magnitudes R < 25.5. Realizamos análisis de auto- y cross-correlación, y en este trabajo presentamos las amplitudes de correlación y las masas de los halos de materia oscura calculados para cada muestra. Para los LBG encontramos un largo de correlación de $r_{0,LBG} = 6.7 \pm 0.5$ Mpc, de lo cual deducimos un factor de bias de 3.5±0.3 y masas de los halos de materia oscura (DM) de $\log(M_{\rm min}/M_\odot) = 11.8 \pm 0.1$. La cross-correlación entre AGN y LBG entrega $r_{0,AGN-LBG} = 8.7 \pm 1.9$ Mpc, lo cual implica un factor de bias de 5.5±2.0, y masas de los halos de materia oscura de $\log(M_{\rm min}/M_\odot) = 12.6^{+0.5}_{-0.8}$, para AGN a $2.8 < z < 3.8$. La evolución de estos halos en una cosmología Lambda CDM implica que estos AGN a $z \sim 3$ se encontrarían hoy en día preferentemente en galaxias masivas, con una luminosidad típica de $7^{+4}_{-2}\ L^*$.

ABSTRACT

We present the first clustering results of X-ray selected AGN at $z \sim 3$. Using Chandra X-ray imaging and UVR optical colors from MUSYC photometry in the ECDF-S field, we selected a sample of 58 $z \sim 3$ AGN candidates. From the optical data we also selected 1385 LBG at $2.8 < z < 3.8$ with R < 25.5. We performed auto-correlation and cross-correlation analyses, and here we present results for the clustering amplitudes and dark matter halo masses of each sample. For the LBG we find a correlation length of $r_{0,LBG} = 6.7 \pm 0.5$ Mpc, implying a bias value of 3.5±0.3 and dark matter (DM) halo masses of $\log(M_{\rm min}/M_\odot) = 11.8 \pm 0.1$. The AGN-LBG cross-correlation yields $r_{0,AGN-LBG} = 8.7 \pm 1.9$ Mpc, implying for AGN at $2.8 < z < 3.8$ a bias value of 5.5±2.0 and DM halo masses of $\log(M_{\rm min}/M_\odot) = 12.6^{+0.5}_{-0.8}$. Evolution of dark matter halos in the Lambda CDM cosmology implies that today these $z \sim 3$ AGN are found in high mass galaxies with a typical luminosity $7^{+4}_{-2}\ L^*$.

Key Words: galaxies: active — galaxies: high-redshift — large-scale structure of universe

1. INTRODUCTION

One of the basic properties of galaxy populations is their clustering strength, but there are few constraints on this quantity for fainter, high-redshift AGN. Furthermore, there are important disagreements in the literature: e.g. galaxy-AGN cross-correlation measurements at $z \sim 3$ by Adelberger & Steidel (2005b), imply a bias factor of 3.9 ± 3.0 for luminous AGN (UV luminosities between $-30 < M_{1350} < -25$), while recent work by Shen et al. (2007) suggests a value of 9.1 ± 0.9 for sources with similar luminosities at the same redshift. For galaxies, e.g., measurements indicate a strong luminosity dependence in the clustering length (Giavalisco & Dickinson 2001). On the other hand, for AGN there are a handful of claims that this is not the case (Croom et al. 2005; Myers et al. 2006; Adelberger & Steidel 2005a). Determining the bias with accuracy puts important constraints on models of AGN formation and evolution, (e.g., Lidz et al. 2006; Hopkins et al. 2007) but requires spanning a broad range in luminosity and obscuration level. There have been

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several measurements of the spatial correlation function of X-ray selected AGN at $z < 1$, with samples ranging from 200–500 sources. At higher redshifts, the statistics are much poorer, and consist of purely optically selected AGN. In this work, we constrain the clustering strength of an AGN sample at $z \sim 3$ jointly selected by optical and X-ray photometry. We determine whether these sources cluster more or less than non-active galaxies at this redshift, and discuss their present-day descendants.

2. OBSERVATIONS

The MUSYC survey was optimized to study galaxies at $z \sim 3$, with imaging depths down to the spectroscopic limit, U, B, V, $R \sim 26$ (Gawiser et al. 2006b). The main MUSYC catalog is based on the sources detected on the combined BVR image, and aperture photometry is performed on each filter in those positions (see Gawiser et al. 2006a).

The deep Chandra observations of this field have produced four X-ray catalogs: Giacconi et al. (2002); Alexander et al. (2003); Lehmer et al. (2005); Virani et al. (2006). The first two comprise 1 Ms of exposures inside the central region (CDF-S proper), covering an area of $\approx$0.1 deg^2 (PI R. Giacconi). The last two catalogs come from the four $\approx$250 ks pointings that cover an area of $\approx$0.3 deg^2 around the E-CDFS field (PI N.Brandt). Our full set of unique X-ray counterparts is constructed joining the former catalogs using a maximum likelihood procedure to match sources between the X-ray and optical catalogs (Cardamone et al. 2008).

The MUSYC spectroscopic follow-up program carried out with Magellan/Baade+IMACS has yielded 280 successful identifications of $z > 2$ galaxies, from which 131 correspond to LBG and 30 to $z \sim 3$ AGN (P. Lira et al., in preparation).

3. RESULTS AND DISCUSSION

We have measured the autocorrelation strength of $z = 3$ LBG and the cross-correlation between these galaxies and AGN selected using both X-ray and optical data. For the LBG sample, we obtained a bias factor of 3.5$\pm$0.3. This is somewhat higher than the value 2.8$\pm$0.3 found by Adelberger et al. (2005) at $z = 3$. Hildebrandt et al. (2007) obtained a bias value of 3.2$\pm$0.2 for an equivalent LBG population, consistent with ours. From the AGN-LBG cross-correlation and the bias calculated for the LBG, we have deduced a bias factor of 5.5$\pm$2 for our AGN sample. The active galaxies targeted in this study appear to cluster more than star-forming galaxies with similar restframe-UV colors. This is consistent with cosmic downsizing of AGN, implying that typical SMBH tend to sit in more massive galaxies than the "normal" galaxy population. We need greater statistics to confirm this result, since the values are consistent within the uncertainties.

To estimate the dark matter halo mass of the typical descendant of the halos that host these $z \sim 3$ galaxy sets at the present time, we calculated the mode and width of the conditional probability distribution of the expected mass $z = 0$ (see Hamana et al. 2006, and references therein). For the LBG bias of 3.5 at $z = 3.2$, we obtain a bias of $1.3^{+0.3}_{-0.1}$ at $z = 0$. In the nearby universe (Zehavi et al. 2005), this corresponds to the clustering of a somewhat massive galaxy, with $L = 2.7^{+1.9}_{-0.6}\ L^*$. On the other hand, our AGN sample, with a bias of 5.5 at $z = 3.2$ would have a typical halo with a bias factor of $2.0^{+0.6}_{-0.3}$ at present. Extrapolating from Zehavi et al. (2005), this corresponds to the clustering of galaxies having $7^{+4}_{-2}\ L^*$, which at the present time are most likely located in groups and galaxy clusters.

This work shows that targeting high-redshift AGN for clustering analyses can be done very efficiently by means of deep optical and X-ray imaging, and for that reason, future surveys with deep X-ray coverage will be ideal for obtaining large samples of active galaxies in restricted redshift ranges, suitable for clustering studies. For more details on the methodology and target selection on this work, see Francke et al. (2008).

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