Typical AGN at intermediate redshifts

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Abstract. We study the host galaxies and black holes of typical X-ray selected AGN at intermediate redshifts ($z \sim 0.5 - 1.4$). The AGN are selected such that their spectral energy distributions are dominated by stellar emission, i.e., they show a prominent $1.6 \mu m$ bump thus minimizing the AGN emission contamination. This AGN population comprises approximately 50% of the X-ray selected AGN at these redshifts. AGN reside in the most massive galaxies at the redshifts probed here, with characteristic stellar masses that are intermediate between those of local type 2 AGN and high redshift ($z \sim 2$) AGN. The inferred black hole masses of typical AGN are similar to those of optically identified quasars at similar redshifts. Since the AGN in our sample are much less luminous than quasars, typical AGN have low Eddington ratios. This suggests that, at least at intermediate redshifts, the cosmic AGN ‘downsizing’ is due to both a decrease in the characteristic stellar mass of the host galaxies, and less efficient accretion. Finally there is no strong evidence in AGN host galaxies for either highly suppressed star formation, expected if AGN played a role in quenching star formation, or elevated star formation when compared to mass selected galaxies of similar stellar masses and redshifts.

Keywords: galaxies: active — galaxies: evolution — galaxies: high-redshift — galaxies: stellar content — infrared: galaxies

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INTRODUCTION

One of the challenges faced by galaxy formation models is to explain the population of today’s red massive quiescent elliptical galaxies. AGN feedback has been proposed as an efficient process for suppressing any further star formation in the late stages of galaxy evolution, while still allowing for continuing black hole (BH) growth. The location of intermediate-$z$ X-ray selected AGN ([1]) in the transition between the ‘red sequence’ and the top of the ‘blue cloud’ may indicate that AGN play a role in causing or maintaining the quenching of star formation. However, in the local universe AGN with strongly accreting BH tend to be hosted in massive galaxies with blue (i.e., star-forming) disks and young bulges ([2,3]) implying a close link between the growth of BH and bulges.

About half of AGN with $L_X > 10^{44} \text{erg s}^{-1}$ at intermediate-$z$ do not show broad lines or high excitation lines characteristic of AGN in their optical spectra ([4]). Since the AGN emission does not dominate their rest-frame UV to near-infrared (NIR) emission ([5]), they are the ideal targets to study their host galaxies and investigate the role of AGN in galaxy evolution. In this paper we study the host galaxies of X-ray selected AGN with stellar dominated spectral energy distributions (SEDs) at intermediate redshifts ($0.5 < z < 1.4$) in the Chandra Deep Field South (CDF-S). The AGN host galaxy properties are then compared with a sample of stellar-mass selected galaxies ([6]). Full details of the study are discussed by [7]. We assumed: $H_0 = 70 \text{km s}^{-1} \text{Mpc}^{-1}$, $\Omega_M = 0.3$ and $\Omega_\Lambda = 0.7$. 
SAMPLE, OBSERVATIONS AND MODELLING OF SEDS

We started with all the CDF-S X-ray sources with redshifts in the range of $0.5 < z < 1.4$. Then we restricted ourselves to the GOODS CDF-S field. We cross-correlated the positions of the X-ray sources with the IRAC (simultaneous detections at 3.6 and 4.5 $\mu$m)-selected galaxies of [6]. We constructed the SEDs using the photometric catalogs of [6] which include the two other IRAC bands, UV, optical, NIR, and Spitzer/MIPS 24 $\mu$m data. For this study we selected AGN with stellar-dominated UV through NIR SEDs, and in particular with a strong 1.6 $\mu$m bump resulting in a sample of 58 AGN. This selection minimized the AGN contamination which is essential for studying the properties of their host galaxies. Our selection thus excluded X-ray sources with AGN-dominated SEDs such as IR power-law galaxies ([8, 9]) or IRAC color-color selected AGN ([10, 11]). More importantly AGN with stellar dominated SEDs comprise approximately 50% of the population of X-ray selected AGN. 52 AGN in the sample are optically-dull, that is, they do not broad or high excitation emission line characteristic of AGN. The remaining 6 AGN are optically-active, that is, they have high excitation emission line. We fitted their rest-frame UV through MIR SEDs using stellar and dust models to derive the stellar masses ($M_*$) as well as the total (UV+IR) star formation rates (SFRs). The stellar masses were calculated for a Salpeter IMF between 0.1 and 100 $M_\odot$. The SED modelling also allowed us to obtain photo-$z$ for the 6 AGN in our sample without spectroscopic redshifts. [6, 7] give full details of the modelling.

PROPERTIES OF TYPICAL AGN AT INTERMEDIATE-Z

Stellar masses of the host galaxies

Fig. 1 shows the redshift evolution of the stellar mass of AGN compared with that of the IRAC-selected sample of galaxies of [6]. At the redshifts probed here the IRAC-selected comparison sample is essentially a stellar mass selected sample. Clearly (X-ray identified) AGN reside in galaxies with a range of about an order of magnitude in mass, including some among the most massive at these intermediate redshifts. The characteristic stellar masses are $7.8 \times 10^{10} M_\odot$ at $0.5 < z < 0.8$ (median $z = 0.67$) and $1.2 \times 10^{11} M_\odot$ at $0.8 < z < 1.4$ (median $z = 1.07$). These masses are intermediate between those of local type 2 AGN ([2]) and $z \sim 2$ AGN ([12]). The evolution of the quenching mass (mass above which, star formation should be mostly suppressed) inferred by [13] is also shown in Fig. 1. The fraction of AGN above the line is small perhaps indicating that star formation has not been fully suppressed yet in these galaxies. It is important to stress that the AGN studied here comprise $\sim 50\%$ of the X-ray selected AGN population at $0.5 < z < 1.4$. Ideally we would like to estimate the stellar masses for all optically-active AGN at intermediate redshifts, but this becomes increasingly more uncertain, as for more luminous X-ray sources the AGN emission in the optical-NIR becomes more dominant ([9]). The masses of the six optically-active AGN in our sample do not appear to be fundamentally different from optically-dull AGN, although we note that the number statistics is small.
Star formation activity

In this section we quantify the star formation activity of AGN with stellar-dominated SEDs in relation to IRAC-selected galaxies of similar stellar masses and at similar redshifts. We use the specific SFR (= SFR/\(M_\ast\)) as an indicator of the star formation activity rather than the absolute SFRs, as the specific SFR measures the rate at which new stars add to the assembled mass of the galaxy. Fig. 2 (left panel) compares the median specific SFRs for intermediate-\(z\) AGN with those of the IRAC-selected sample of [6]. The AGN specific SFRs do not appear to be fundamentally different from those of IRAC-selected galaxies. In contrast, [12] found evidence for a relation between the suppression of star formation and the AGN phase for \(K\)-band selected galaxies. In the local universe AGN tend to be hosted in massive galaxies with younger stellar ages than non-AGN of similar morphological types (early-type) and stellar masses ([2,3]). This was interpreted as evidence that enhanced star formation is a requisite for feeding the AGN. At \(z \sim 1\) galaxies (presumably both AGN and non-AGN) with \(M_\ast \sim 10^{10} - 5 \times 10^{11} \, M_\odot\) are still being assembled (see [6]), so perhaps it is not surprising that the SFR of AGN and non-AGN are not significantly different.

Black holes masses and Eddington ratios

Using the local relation between \(M_{\text{bulge}}\) and \(M_{\text{BH}}\) of [14] the inferred BH masses have a median value of \(M_{\text{BH}} \sim 2 \times 10^8 \, M_\odot\). These BH masses are similar to those of broad-line AGN although with lower Eddington ratios (\(\eta \sim 0.01 - 0.001\), see Fig. 2, right panel) than luminous quasars. One possibility to explain the low Eddington ratios is that we were overestimating significantly the BH masses. This does not seem to be the case as the host galaxies appear to be bulge-dominated ([15]), so the assumption \(M_{\text{bulge}} \simeq M_\ast\) is probably correct. The low Eddington ratios together with the characteristic stellar
masses of the host galaxies of AGN suggest that, at least at intermediate-$z$, the cosmic AGN `downsizing’ is probably due not only to a decrease in the characteristic stellar mass of the host galaxy ([16]), but also to less efficient accretion (see also [17]).

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