AGN feedback in overdense environments at z=2.23

Adrian B. Lucy[12], B.D. Lehmer[13], D.M. Alexander[4], P.N. Best[5], J.E. Geach[6], C.M. Harrison[4], A.E. Hornschemeier[13], Y. Matsuda[7], J.R. Mullaney[4], I. Smail[4], D. Sobral[8]
[1]NASA GSFC [2]Uni. of Oklahoma [3]Johns Hopkins Uni. [4]Durham Uni. [5]IfA Edinburgh [6]McGill Uni. [7]Chile Observatory NAOJ [8]Leiden Observatory
alpha@ou.edu (A.B.L)

I. Introduction

We aim to observe the evolutionary history of the massive elliptical galaxies in local clusters, and thereby observe the emergence of the local M_{BH}-M_* relation.

M_{BH}-M_* gives the ratio of a supermassive black hole's (SMBH) mass to its host galaxy's stellar mass. Scatter in M_{BH}-M_* is low due to feedback processes linking active galactic nuclei (AGN), their host galaxies, and the media in which these reside (e.g., Scannapieco & Oh 2004; Croton et al. 2006).

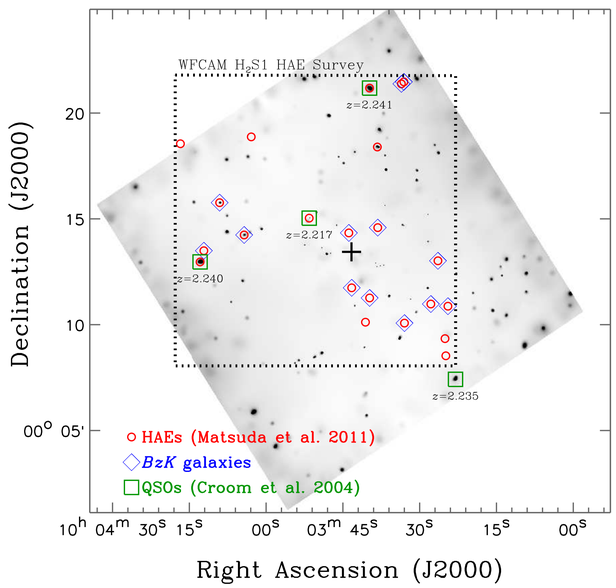
Massive ellipticals are dormant in the local universe; models predict that they and their SMBHs grew in high-density protocluster environments at $z \gtrsim 2$-3 (e.g., Kauffmann et al. 1996). Observations at z≈2-3 have found AGN fractions in protoclusters to be higher than those in lower-density fields (e.g., Lehmer et al. 2009a,b; Digby-North et al. 2010).

We present new results from a ≈100 ks *Chandra* X-ray observation of the z=2.23 2QZ Cluster 1004+00 (2QZ Clus) structure of Hα-emitting galaxies (HAEs), and compare these results to a new analysis of 210 HAEs in the *Chandra*-COSMOS (C-COSMOS) field.

Hα is a tracer of star formation, so both samples select for high star formation rates (SFRs). 2QZ Clus was initially identified as an overdensity of four optically-selected QSOs; only later were these found to overlap with 22 HAEs (Matsuda et al. 2011). C-COSMOS, in contrast, is free of QSO selection bias.

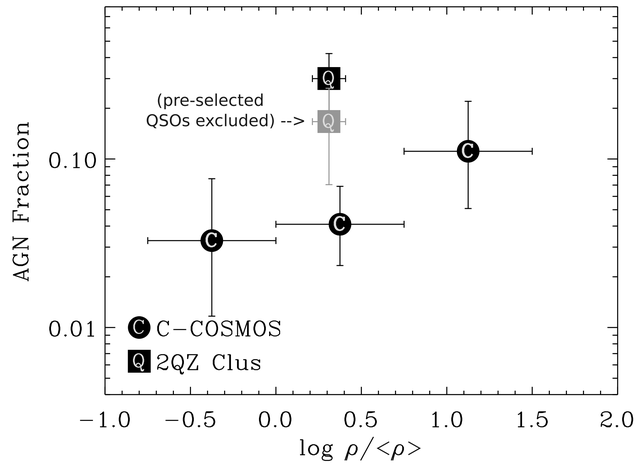
II. Data products

Fig. 1 - A 0.5-7 keV illustration of our *Chandra* exposure of 2QZ Clus, with relevant properties and the HAE survey region denoted. A catalog of all source detections with photometry is available in Lehmer et al. (2013, submitted).



III. AGN fractions

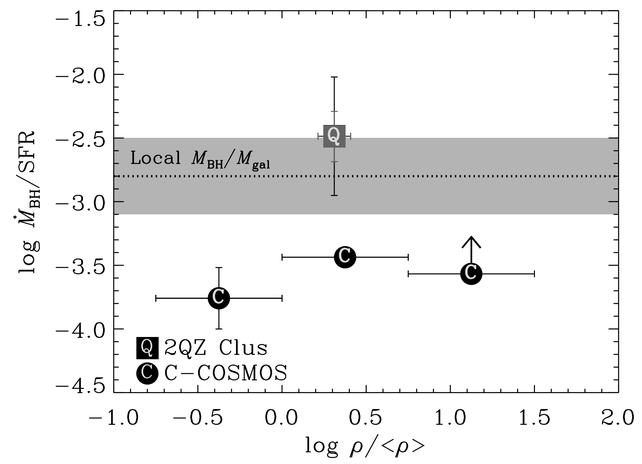
Fig. 2 - The fraction of HAEs that are AGN hosts, as a function of local HAE density ρ normalized to the average density ⟨ρ⟩ of the HiZELS COSMOS field. Note $\rho \approx 4/(\pi r_4^2)$, where r_4 is the separation between a given source and its fourth nearest neighbor. **As expected, AGN fraction increases with HAE density in C-COSMOS. But we also see that AGN fraction is significantly higher in 2QZ Clus than in C-COSMOS at comparable HAE densities.**



In fact, if we assume that AGN fraction is a function of HAE density only and that C-COSMOS HAEs are representative of all HAEs at z=2.23, then the binomial probability of this AGN fraction enhancement in 2QZ Clus HAEs, with the pre-selected QSOs excluded, is only ≈4.1%. **Some undetermined physical mechanism, or environmental property unrepresented by HAE density, is likely responsible for elevating nuclear activity in 2QZ Clus.**

IV. $\dot{M}_{BH}$/SFR

Fig. 3 - The ratio of SMBH growth rate ($\dot{M}_{BH}$) to star formation rate (SFR) as a function of local HAE density. **$\dot{M}_{BH}$/SFR in C-COSMOS HAEs is lower than we would naively—i.e., under conditions of concurrent galaxy and SMBH growth, and assuming that HAEs are representative of the general population—expect from the local M_{BH}-M_* relation.**



V. $\dot{M}_{BH}$/SFR trends

To determine whether the low C-COSMOS $\dot{M}_{BH}$/SFR is a real effect, rather than a result of the SFR bias inherent in selecting HAEs, it helps to place our results in a broader context.

Fig. 4 - Plotting $\dot{M}_{BH}$/SFR as a function of X-ray 2-10 keV luminosity, we compare our samples to AGN-biased samples from Harrison et al. (2012; H12) at z≈2 and Mullaney et al. (2012a) at z≈1–3. Our 2QZ Clus and C-COSMOS results are both consistent with the trend exhibited by AGN-selected sources.

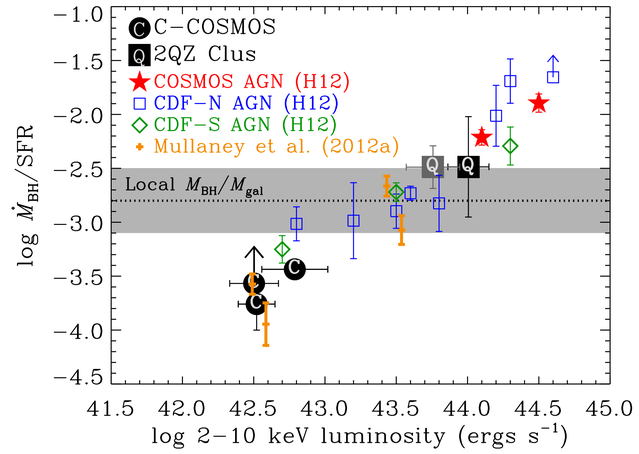
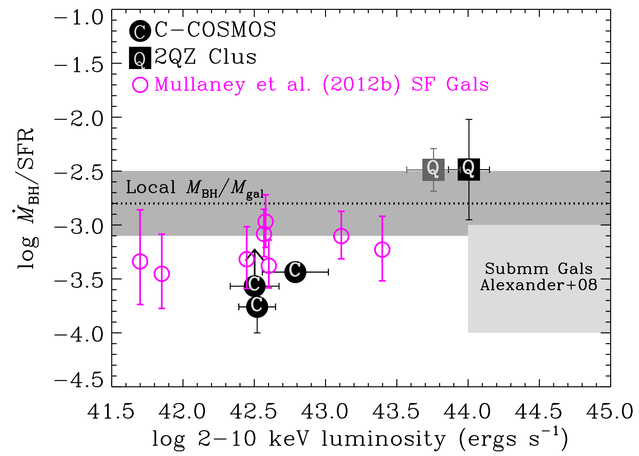


Fig. 5 - We compare our samples to SFR-biased samples from Mullaney et al. (2012b) at z≈1–2 and the parameter range of submillimeter galaxies from Alexander et al. (2008) at z≈2. Our C-COSMOS results are consistent with SF-selected sources.



These trends suggest the low $\dot{M}_{BH}$/SFR in C-COSMOS HAEs may indeed be the norm, a scenario wherein the local M_{BH}-M_* relation arises via relatively brief phases of elevated $\dot{M}_{BH}$/SFR rarely observed in surveys that do not specifically select for nuclear activity.

VI. Ref.

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