UNDERSTANDING DUAL ACTIVE GALACTIC NUCLEUS ACTIVATION IN THE NEARBY UNIVERSE

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ABSTRACT

We study the fraction of dual active galactic nuclei (AGNs) in a sample of 167 nearby (z < 0.05), moderate-luminosity, ultra-hard X-ray-selected AGNs from the all-sky Swift Burst Alert Telescope (BAT) survey. Combining new Chandra and Gemini observations together with optical and X-ray observations, we find that the dual AGN frequency at scales <100 kpc is ≈10% (16/167). Of the 16 dual AGNs, only 3 (19%) were detected using X-ray spectroscopy and were not detected using emission line diagnostics. Close dual AGNs (<30 kpc) tend to be more common among the most X-ray luminous systems. In dual AGNs, the X-ray luminosity of both AGNs increases strongly with decreasing galaxy separation, suggesting that the merging event is key in powering both AGNs. Fifty percent of the AGNs with a very close companion (<15 kpc) are dual AGNs. We also find that dual AGNs are more likely to occur in major mergers and tend to avoid absorption line galaxies with elliptical morphologies. Finally, we find that SDSS Seyferts are much less likely than BAT AGNs (0.25% versus 7.8%) to be found in dual AGNs at scales <30 kpc because of a smaller number of companion galaxies, fiber collision limits, a tendency for AGNs at small separations to be detected only in X-rays, and a higher fraction of dual AGN companions with increasing AGN luminosity.

Key words: galaxies: active – galaxies: interactions – X-rays: galaxies

Online-only material: color figures, machine-readable table

1. INTRODUCTION

The detection and frequency of dual active galactic nuclei (AGNs) on kiloparsec scales is an important test of the merger-driven AGN model. Understanding the types of galaxies and specific merger stages where dual AGNs occur provides important clues about the peak black hole (BH) growth during the merging process. Over the last decade, several nearby dual AGNs on kiloparsec scales have been found serendipitously in interacting galaxies (Komossa et al. 2003; Koss et al. 2011a). In addition, higher redshift dual AGN systems have been discovered using high-resolution integral field spectroscopy or radio observations (Fu et al. 2011b). Finding these duals is an important step, but a systematic study of dual AGNs offers the best chance of understanding their frequency and the types of galaxies and interactions involved in their triggering.

Early studies of the dual AGN frequency at higher redshift (z > 0.15) focused on quasar pairs but suffered from severe observational difficulties detecting close pairs. Djorgovski (1991) found a 2× quasar overabundance on <100 kpc scales based on normal galaxy clustering. Other early observations found a small fraction (0.1%) of quasar pairs with typical separations of 50–100 kpc suggesting that at least one AGN shuts off on scales <30 kpc (Mortlock et al. 1999). Recent studies using the Sloan Digital Sky Survey (SDSS) suggested dual quasars peak at small <50 kpc scales with a small excess extending to hundreds of kpc (Hennawi et al. 2006; Foreman et al. 2009). Other recent studies found the opposite result with only a small excess at <35 kpc (Myers et al. 2007). However, on close scales <30 kpc, these observations are complicated by gravitational lenses (Narayan & White 1988; Kochanek et al. 1999) as well as an inability to easily resolve each AGN in optical and X-ray observations.

Nearby galaxies are better suited for dual AGN studies since both the nuclear engine and the host galaxies can be resolved and studied down to separations of a few kpc. A large study of optical AGN pairs at z < 0.16 using SDSS spectroscopy found that their fraction was ≈1.5% within 30 kpc (Liu et al. 2011) while their cumulative fraction increases linearly with separation. However, because of fiber collision limits, this technique suffers from incompleteness at close scales. Furthermore, optical surveys are incomplete since X-ray- and IR-selected AGNs are not always detected optically (Hickox et al. 2009; Koss et al. 2011a). Therefore, a study of nearby AGNs using emission line diagnostics and X-ray observations provides the best chance of accurately measuring the dual AGN frequency.

In this Letter, we determine the incidence of dual AGNs in the local universe by searching for multiple active nuclei from the Koss et al. (2011b) sample of ultra-hard X-ray-selected AGNs. This sample is ideal since archival X-ray data from SWIFT X-ray Telescope (XRT), XMM, or Chandra exist for the entire set of objects. The ultra-hard X-rays also offer a reliable tracer of the bolometric luminosity of AGNs since it is nearly unaffected by host galaxy contamination or obscuration, which strongly affects other selection techniques such as optical emission lines, infrared spectral analysis, or optical colors.

2. DATA AND ANALYSIS

We adopt Ωm = 0.3, ΩΛ = 0.7, and H0 = 70 km s⁻¹ Mpc⁻¹ to determine distances.

2.1. Samples

The Burst Alert Telescope (BAT) AGN sample consists of 167 nearby (z < 0.05) ultra-hard X-ray BAT-detected AGNs from Koss et al. (2011b) catalog in the Northern sky (>-25°),
with low Galactic extinction \((E(B-V) < 0.5)\). For each BAT AGN, we search the SDSS, 6DF, 2DF, and NED for apparent companions within 100 kpc with small radial velocity differences \((-300 \text{ km s}^{-1})\). For comparison, we use a sample of emission-line-selected type 2 Seyferts in the SDSS taken from the Garching catalog, which we refer to as SDSS Seyferts. We use the emission line diagnostics of Veilleux & Osterbrock (1987), revised by Kewley et al. (2006). We require each optical AGN to be classified as Seyfert using the \([O\text{ iii}]\) \(\lambda5007/\text{H}\beta\) versus \([\text{N}\text{ ii}]\) \(\lambda6583/\text{H}\alpha, [\text{S}\text{ ii}]\) \(\lambda\lambda6717, 6731/\text{H}\alpha, \) and \([\text{O}\text{ i}]\) \(\lambda\lambda6300/\text{H}\alpha\) diagnostics, as well as having a signal-to-noise ratio > 10 in all lines. We restricted our SDSS Seyferts to \(z < 0.07\) totaling 1988 Seyferts.

### 2.2. X-Ray Data

To determine the AGN nature of the galaxy companions, we use X-ray data from *Chandra*, XRT, or *XMM*. Because of the difficulty identifying dual X-ray point sources at separations <20" with *XMM* or XRT, we obtained *Chandra* observations (PI: Mushotzky, 12700910) for 11 BAT AGNs with close companions (<20"). The *Chandra* exposure times ensured >10 photons for a source with \(10^{41}\text{ erg s}^{-1}\) and a column density of \(5 \times 10^{23} \text{ cm}^{-2}\); objects with lower column densities will have more counts.

To fit X-ray spectra we assumed a fixed Galactic photoelectric absorption (Kalberla et al. 2005), a floating photoelectric absorption component, and a power law \((F \propto E^{-\Gamma})\). For source counts we use a 1.5 (3 pixel) radius aperture in *Chandra*, 6" (1.5 pixel) radius in *XMM*, and 7.1 (3 pixel) radius in XRT. We apply aperture corrections based on the point-spread function at 1.5 keV. For sources with <50 counts, we use a fixed power law of \(\Gamma = 1.8\). For sources without detections, we calculate 95\% confidence limit Poisson statistics assuming \(\Gamma = 1.8\) and \(N_{\text{H}} = 10^{22} \text{ cm}^{-2}\).

### 2.3. Emission Line Diagnostics and Optical Data

We use optical spectroscopy from the SDSS DR8 to search for dual AGNs within 100 kpc. Because of the 55" fiber collision limits in the SDSS, we observed 11 BAT AGN galaxies with Gemini. We observed both galaxy nuclei simultaneously using the B600-G5307 grating with a 1" slit in the 4300–7300 Å wavelength range, for 37 minutes each. We follow Winter et al. (2010) for correcting Milky Way reddening, starlight continuum subtraction, and fitting AGN diagnostic lines. To correct our line ratios for extinction, we use the narrow Balmer line ratio \((\text{H}\alpha/\text{H}\beta)\) assuming an intrinsic ratio of 3.1 and the Cardelli et al. (1989) reddening curve.

To compute the ratio of stellar masses of the AGN host galaxy and its companion, we use *ugriz* photometry and follow Koss et al. (2011b). If the galaxy nuclei were too close to accurately measure stellar masses in multiple filters, we use the ratio of \(i\)-band luminosity to determine stellar mass ratios or if unavailable, ratios of \(K\)-band luminosity from Two Micron All Sky Survey.

### 2.4. Dual AGN Classification

We classify a source as a dual AGN when the companion galaxy’s optical emission line diagnostics or X-ray data indicate an AGN. We require that at least two of three emission line diagnostics indicate a Seyfert or LINER. For the companions of BAT-detected AGNs, we also use X-ray data for companion classification. Since X-rays can be produced from star formation, a galaxy is an AGN only if \(L_{2-10\text{keV}} > 10^{42} \text{ erg s}^{-1}\) or X-ray spectroscopy indicates a hard power law \((\Gamma < 2)\), an Fe K line, or rapid time variability indicative of an AGN. At \(L_{2-10\text{keV}} > 10^{42} \text{ erg s}^{-1}\), a very high star formation rate \((\text{SFR} > 200 M_\odot \text{ yr}^{-1})\) would be required to generate the observed hard X-ray luminosity (Ranalli et al. 2003). For AGNs with multiple companions within 100 kpc, we test each galaxy pair separately and only compare the three nearest companions to ensure that the sample is not dominated by galaxy groups. We note that this AGN classification excludes some lower luminosity AGNs with lower X-ray luminosities or composite optical spectra.

### 3. RESULTS

#### 3.1. Companion Sample Study

We identify 81/167 (49\%) of BAT AGNs having at least one companion within 100 kpc. Additionally, 16 BAT AGN galaxies have two companions within 100 kpc and have three or more companions within 100 kpc. The total number of companions in the sample is 106. A list of the BAT AGNs and their companions can be found in Table 1. In the SDSS Seyfert sample, 358/1988 (18\%) have at least one companion within 100 kpc. Additionally, 17 SDSS Seyferts have two companions within 100 kpc and have three or more within 100 kpc, for a total of 385 companions.

We find that major mergers \((M_1/M_2 < 3)\) are more frequent at close separations for BAT and SDSS Seyferts. At <15 kpc, 78\% (14/18) of BAT AGN galaxy companions have \(M_1/M_2 < 3\), while at 60–100 kpc separations, only 30\% (10/33) have \(M_1/M_2 < 3\). Both the SDSS and BAT AGN sample show similar distributions of average stellar mass ratio with host galaxy separation. We also find that BAT AGNs are more likely than SDSS Seyferts or inactive galaxies to have companions at small separations. Namely, at separations <15 kpc, 10% (16/167) of BAT AGNs have companions, while for the SDSS Seyferts this fraction is only 1% (20/1988), and only 2% (4/167) among inactive galaxies matched in stellar mass and redshift to the BAT AGNs consistent with Koss et al. (2010).

#### 3.2. Dual AGN Frequency with Projected Separation

Among the entire sample of BAT AGNs and SDSS Seyferts, we find a lower limit of the dual AGN frequency between 1 and 100 kpc of 9.6\% (16/167) for BAT AGNs and 0.5\% (10/1988) for SDSS Seyferts. These are lower limits because we exclude sources classified as composites by their optical emission line properties, and because both samples have incomplete X-ray and optical spectroscopy.

Sample images of the BAT-detected dual AGNs can be found in Figure 1. The majority of these dual AGNs (75\%, 12/16) are found on scales <30 kpc. NGC 835 is a triple AGN system with 50\% (8/16) of their companions are 24 kpc, and 50\% (8/16) are duals.

Dual AGNs in the BAT and SDSS have, on average, smaller separations than the AGNs with inactive companions. The mean and \(1\sigma\) values of the separations among BAT AGNs and their companions are 28 ± 24 kpc, and 50 ± 26 kpc for the dual AGNs and the AGN-inactive galaxy systems, respectively. A Kolmogorov–Smirnov (K-S) test indicates a negligible \((<2 \times 10^{-5})\) chance that the distribution of separations for the dual AGNs and AGN-inactive systems are from the same
Table 1
Dual AGN Study of BAT Sample

| BAT Source Name | Galaxy Comp. | Sep. (kpc) | $M_1/M_2$ | X-Ray 2\(\alpha\) 2–10 (keV) | Opt. 2\(\alpha\) | Refs. | Refs. |
|-----------------|--------------|------------|-----------|-------------------------------|-----------------|-------|-------|
| NGC 6240S       | NGC 6240N    | 1.5        | 1.6       | 0.51                         | ?               | CXO   | G     |
| Mk 739E         | Mrk 739W     | 3.4        | 0.5       | 1                            | C/SF/SF         | CXO   | G     |
| Mk 463E         | Mrk 463W     | 3.9        | 1.2       | 3.8                          | AGN/Sy/Sy2      | CXO   | S     |
| IRAS 05589+2828 | 2MASX J06021107+2828382 | 8 | 5.7 | 0.07 | AGN/Sy/Sy2 | CXO | G |
| ESO 509-IG 066 NOD | ESO 509-IG066E | 10.5 | 1.6 | 0.95 | AGN/Sy/Sy2 | XMM | 6DF |
| IRAS 02219+4031 | 2MASX J03251221+402021 | 10.8 | 2.6 | 1.3 | AGN/Sy/Sy2 | XMM | 4 |
| NGC 3277        | NGC 3226     | 12.3       | 1.7       | 0.02                         | AGN/L/L         | CXO   | 1     |
| NGC 835         | NGC 833      | 14.8       | 1.5       | 0.7                          | SF/L/SF         | XMM   | S     |
| UGC 11185 NED02 | UGC 11185 NED01 | 22.6 | 1.3 | <0.9 | AGN/Sy/Sy2 | XRT | G |
| MCG +04-48-002  | NGC 6921     | 25.2       | 0.4       | 0.87                         | Sy2             | XMM   | N     |
| NGC 2992        | NGC 2993     | 25.8       | 2.7       | 0.0089                       | SF/SF/SF        | XMM   | 6DF   |
| UGC 8327 NED02  | UGC 08327 NED01 | 26.1 | 2.8 | 0.014 | AGN/Sy/Sy2 | XMM | S |
| Mrk 268         | MRK 268SE    | 44         | 5.5       | <0.23                        | AGN/Sy/Sy2      | XMM   | S     |
| NGC 7679        | NGC 7682     | 77.6       | 2.3       | 0.11                         | Sy2             | XMM   | S     |
| NGC 1052        | NGC 1042     | 83.7       | 3.3       | <0.0004                      | C/SF/Sy2        | CXO   | S     |
| M106            | NGC 4220     | 85.7       | 12        | ?                            | AGN/Sy/Sy2      | XMM   | 1     |
| NGC 835         | NGC 839      | 87         | 2.1       | 0.03                         | AGN/Sy/Sy2?     | XMM   | 6     |

Notes.

* Projected separation.
* Host galaxy stellar mass ratio between BAT AGNs and companion.
* Galaxy companion $L_{2–10\text{keV}}$ in units of $10^{42}$ erg s$^{-1}$.
* AGN diagnostics from $\text{[O} iii\text{]} \lambda 5007/\text{H}$ and $\text{[N} ii\text{]} \lambda 6583/\text{H}$, $\text{[S} ii\text{]} \lambda 6717, 6731/\text{H}$, and $\text{[O} i\text{]} \lambda 6300/\text{H}$ ratios.
* $\text{CXO} = \text{Chandra}, \text{XRT} = \text{Swift}$.
* Optical spectroscopy where $S = \text{SDSS}, G = \text{Gemini}, N = \text{NED}, 1 = \text{Ho et al. (1997)}, 2 = \text{Winter et al. (2010)}, 3 = \text{Veilleux & Osterbrock (1987)}, 4 = \text{M. Trippe 2012, in preparation}, 5 = \text{Veilleux et al. (1995)},$ and $6 = \text{de Carvalho & Coziol (1999)}$.
* Symbol ‘?’ indicates no available X-ray or optical spectroscopy for the companion.

(The table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)

Distribution. A similar result is found for SDSS Seyferts with separations of 41 ± 30 kpc, and 64 ± 24 kpc for the dual AGN and single AGN systems, respectively, with a <5% chance from a K-S test. The BAT AGNs in duals are at smaller separations than SDSS Seyferts in duals with a <0.01% chance of being from the same distribution.

3.3. Host Properties of Dual AGNs

We studied the galaxy morphologies and merger types of systems hosting dual AGNs. We limited this study to projected separations <30 kpc because of the low frequency of duals found at larger separations and the higher chance of projection effects causing the galaxies to appear to be at artificially small separations. We find that the frequency of dual AGNs is strongly dependent on galaxy mass ratio (Figure 2), suggesting a minor merger is insufficient to trigger dual AGNs. The mean stellar mass ratio and 1σ are 2.1 ± 1.3. The highest fraction of duals occurs in galaxy pairs with small stellar mass ratios ($M_1/M_2 < 3$) where 65% (11/17) of these pairs are in dual. No dual AGNs are found in galaxy pairs with $M_1/M_2 > 6$.

We also investigated the types of galaxies that are single AGN systems even though they have a close companion (<30 kpc) and a small stellar mass ratio (<0.6). This includes a total of 11 systems (Figure 3). In optical spectroscopy, five of these companion galaxies are red elliptical absorption line galaxies, two are star-forming emission line galaxies, and four have no available optical spectroscopy. In the X-rays, 4/11 are at separations <20′, where a faint dual AGN may be missed and have no Chandra observations. The two star-forming emission line galaxies not classified as duals are UGC 4727 and SDSS J112648.65+351454.2. UGC 4727 is at stellar mass 5.9 times lower than the BAT source and a separation of 26 kpc. UGC 4727 is also a bulgeless galaxy. The other galaxy with star-forming...
Figure 1. Nine composite gri images selected at random from 16 BAT-detected dual AGNs in Table 1. A red circle indicates X-ray and optical AGN detection. A green circle indicates X-ray AGN detection, but no optical detection. A blue circle indicates optical emission line diagnostics detect the AGN, but there are too few X-ray counts to detect an AGN.

(A color version of this figure is available in the online journal.)

Figure 2. Left: frequency of dual AGNs for galaxies with companions as a function of apparent separation. Error bars assume binomial statistics. We find that the dual AGN frequency increases at smaller separations in BAT AGNs and SDSS Seyferts. Right: frequency of dual AGNs as a function of the ratio of galaxy stellar masses. We limited this study to projected separations <30 kpc because of the low frequency of duals found at larger separations. The dual AGN frequency increases in major mergers for both BAT AGNs and SDSS Seyferts.

(A color version of this figure is available in the online journal.)
Figure 3. Composite gri filter images of nine BAT AGN hosts with inactive companions within 30 kpc. A red circle indicates a BAT AGN. We find the majority of inactive companions are elliptical absorption line galaxies or minor mergers. (A color version of this figure is available in the online journal.)

emission line diagnostics is SDSS J112648.65+351454.2 with a stellar mass 3.6 times lower than the BAT AGN, Mrk 423. These results suggest that dual AGNs tend to avoid elliptical/absorption line galaxies.

3.4. X-Ray Properties of BAT AGNs in Duals

We detect 12/16 of the dual AGNs using X-rays. Four of the secondary AGNs are detected using optical spectroscopy, but have no X-ray detection. One of these, UGC 11185, has a large upper limit because of its close proximity (28") to a bright BAT AGN. The remaining dual AGNs with X-ray nondetections are at large separations (>40 kpc) and have a lower stellar mass than the BAT AGNs (M1/M2 > 3). The median value of the L_{2-10 keV} ratio between the dual AGNs is 11, but varies dramatically, with the smallest ratio being 1.1 between NGC 6240S and NGC 6240N, and some dual pairs having X-ray ratios greater than 1000 (IRAS 05589+2828 and UGC 8327).

We find that the X-ray luminosity of both AGNs increases with decreasing separation, suggesting that the merging event is key to powering both AGNs (Figure 4). For example, the six most luminous companion AGNs are found at small separations (<15 kpc). A Spearman correlation test indicates a >99.998% probability that the L_{2-10 keV} of the AGN companion and separation are inversely correlated. Similarly, a Spearman test indicates a >90% that the primary AGNs 2-10 keV luminosity and separation are inversely correlated. Finally, a Spearman test indicates a >98.8% chance the ultra-hard X-ray luminosity is inversely correlated with separation; however, this low spatial resolution measure may be biased toward small separations because it includes emission from both AGNs.

Finally, we investigated the close (<30 kpc) dual AGN fraction with bolometric luminosity assuming a conversion factor of L_{bol} = 15 \times L_{14-195 keV} based on Vasudevan et al. (2010). For systems with L_{bol} > 10^{45} erg s^{-1}, the mean bolometric luminosity is (2.2 \pm 1.1) \times 10^{45} erg s^{-1} and 17.1% (6/35) are close (<30 kpc) dual AGNs. Among less luminous systems, the mean bolometric luminosity is (4.4 \pm 2.9) \times 10^{44} erg s^{-1} and dual fraction is 4.5% (6/132). This suggests that close dual AGNs may be more common among luminous systems.

4. SUMMARY AND DISCUSSION

We study the frequency of dual AGNs in nearby ultra-hard X-ray-selected BAT AGNs using archival optical and X-ray imaging spectroscopy along with new observations from Gemini and Chandra. We find the following.

1. Dual AGNs are much more likely to occur in systems with a close companion within <30 kpc among BAT AGNs and SDSS Seyferts. Among BAT AGNs with a companion at small separations (<15 kpc), a high fraction (50%, 8/16) are duals.

2. In 19% (3/16) of the dual AGNs in the BAT sample, X-ray spectroscopy reveals the presence of a dual AGN that is not detected with emission line diagnostics (NGC 6240, Mrk 739, NGC 833).

3. The hard X-ray luminosities of both AGNs increase as the separation between the galaxies decreases suggesting...
that the merging event is key in powering the AGNs. Additionally, close dual AGNs (<30 kpc) tend to be more common among the most X-ray luminous systems with $L_{\text{bol}} > 10^{45}$ erg s$^{-1}$. This is in agreement with recent simulations suggesting that peak accretion and BH luminosity appear at small scales, while relatively lower luminosity dual AGNs are found at wider separations (Van Waasen et al. 2011).

4. Dual AGNs are more prominent among major mergers ($M_1/M_2 < 3$) and avoid absorption line galaxies with elliptical morphologies. However, AGN activity is more difficult to detect in dwarf companions because of the likely lower mass BHs.

5. We find that SDSS Seyferts are much less likely than BAT AGNs (0.25% versus 7.8%) to be found in dual AGNs at scales <30 kpc.

These results suggest that in systems already hosting a single AGN, nuclear activity in companions is triggered in the majority of close-separation major mergers. Indeed, our sample finds that all 11 BAT AGNs with non-absorption line companions in major mergers ($M_1/M_2 < 3$) and close separations (<30 kpc) are dual AGNs. Our sample also suggests that early-type gas-poor (red/elliptical) companions are unlikely to host AGNs, possibly because it may not be able to capture enough gas during the merging process. From these results, one might expect a high dual AGN fraction in luminous infrared galaxies (LIRGs) which are associated with gas-rich mergers. However, only a few dual AGNs in this sample are LIRGs (e.g., NGC 6420, Mrk 463) which is consistent with the overall fraction of LIRGs in the rest of the BAT sample (18%; Koss et al. 2010). Therefore, it seems that the particular type of merger triggering the luminous BAT AGNs also triggers the secondary AGNs.

Dual AGN systems are more common in ultra-hard X-ray-selected AGNs than SDSS Seyferts since they have more close companions (Koss et al. 2010). Since there are more dual AGNs among BAT AGNs than SDSS Seyferts by more than a factor of 10, the much higher fraction is most likely mainly because of the higher AGN luminosities of BAT AGNs, not the lack of X-ray observations of SDSS Seyferts.

We also find a higher total fraction of dual AGNs compared to dual AGN studies using the double-peaked method (Comerford et al. 2009). At scales <15 kpc, we find 5% (8/167) are dual AGNs, ≈10× higher than that estimated from double peak sources (0.3%–0.5%, at $z \approx 0.4$, Rosario et al. 2011; <3%, at $z \approx 0.1–0.6$, Fu et al. 2011a). This is likely because:

1. double peak sources are at higher redshifts, ≈10 times that of this sample ($z = 0.02$ versus $z = 0.3$) so they are more difficult to detect as dual AGNs;
2. the SDSS fiber is 3′′, so it is sensitive to different, typically smaller physical scales (at $z = 0.4$, 3′′ ≈ 15 kpc);
3. the double peak method is biased toward selecting certain types of single AGNs such as radio bright AGNs (Smith et al. 2010), which is different from BAT AGNs where only 0.5% are radio loud (Teng et al. 2011); and
4. the double peak method has difficulty detecting dual AGNs with small velocity offsets, weak lines, or those dual AGNs that are detected only in the X-rays like NGC 6240. Finally, because of the fixed SDSS fiber size, the double peak method is sensitive to AGNs with different physical separations and different luminosities depending on the redshift range studied making a comparison difficult, but our results suggest that the fraction of dual AGNs is much higher than the double peak method suggests among luminous AGNs.

This type of extensive study is impossible to do at higher redshifts because of surface brightness dimming and the limitations in resolution and exposure time, particularly in X-rays since the secondary AGNs are typically 10×–100× fainter. However, the pair fraction and frequency of gas-rich “wet” galaxy mergers increases with redshift. This suggests that dual AGN activation may be much more common at higher redshifts.

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