NuSTAR and XMM-Newton Observations of Dual AGN Candidates

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Introduction

Since the vast majority of galaxies contain supermassive black holes (SMBHs) and galaxy interactions trigger nuclear gas accretion, a direct consequence of the hierarchical model of galaxy formation would be the existence of dual active galactic nuclei (AGNs). Both theory and observations suggest that merger-triggered SMBH growth plays a vital role in driving the coordinated evolution of SMBHs and galaxies. *Dual* AGNs with separations < 10 kpc in particular provide unambiguous confirmation of an ongoing merger and are found in late stage mergers when the black holes experience their most rapid growth.

Motivated by the possibility that AGNs are most likely to be obscured by the inflowing material during peak black hole growth, where dual AGNs are expected to be found (Blecha et al. 2018), we used the *WISE* survey to identify a population of almost 200 strongly interacting galaxies that display extreme red mid-infrared colors ($W1-W2>0.8$) highly suggestive of powerful AGNs. The vast majority of these galaxies are optically quiescent suggesting that they represent an obscured population of AGNs that cannot be found through optical studies. Our Chandra campaign revealed dual AGN sources in 8/15 mergers, and at least a single AGN in all of the mergers (Satyapal et al. 2017, Pfeifle et al. 2019). Further, our X-ray analysis suggested that the vast majority of our sample of mergers hosted heavily obscured AGNs with column densities $>10^{23}-10^{24}$ cm^{-2}.

Selection Methodology

In our original studies, Satyapal et al. 2017 and Pfeifle et al. 2019, we drew a sample of mid-IR selected galaxy mergers in a search for dual AGNs. Briefly, this selection technique required the following:

- Drawn from Galaxy Zoo (667,000 galaxies), (Lintott et al. 2011)
- Required high probability of merger (40%; ∼12,000)
- Required $W1-W2>0.8$ and nuclear separations $\lesssim$ 10 kpc
- 15 mergers were follow-up with the Chandra X-ray Observatory

Motivated by our findings with Chandra, we observed a subset of these mergers with XMM-Newton and NuSTAR in an effort to gather higher signal-to-noise spectra in the 0.3-10 keV band (with XMM-Newton), and access the hard energy 10-24 keV band (with NuSTAR), which is an important energy band to study when examining obscured AGNs.

Sample Properties

- J0122+0100: a dual AGN candidate, exhibiting two nuclear X-ray point sources. A [Si VI] coronal line was detected in one nucleus.
- J0841+0101: a dual AGN candidate, exhibiting two X-ray point sources (though Foord et al. 2019 find this system more consistent with being a single point source). The Chandra spectroscopic analysis suggested a column density $N_{\rm H}=$.
- J0849+1114: a confirmed triple AGN (Pfeifle et al. 2019b, Liu et al. 2019), with the NuSTAR data published in Pfeifle et al. 2019b. The joint Chandra and NuSTAR spectroscopic analysis suggests a column density $N_{\rm H}=$.
- J1221+1137: a dual AGN candidate hosting two X-ray point sources. The implied NH from the Chandra data is $N_{\rm H}=$.
- J1306+0735: a dual or triple AGN candidate, hosting two, possibly three X-ray point sources in a train-wreck system. The implied NH from the Chandra data is $N_{\rm H}=$.

NuSTAR Imaging

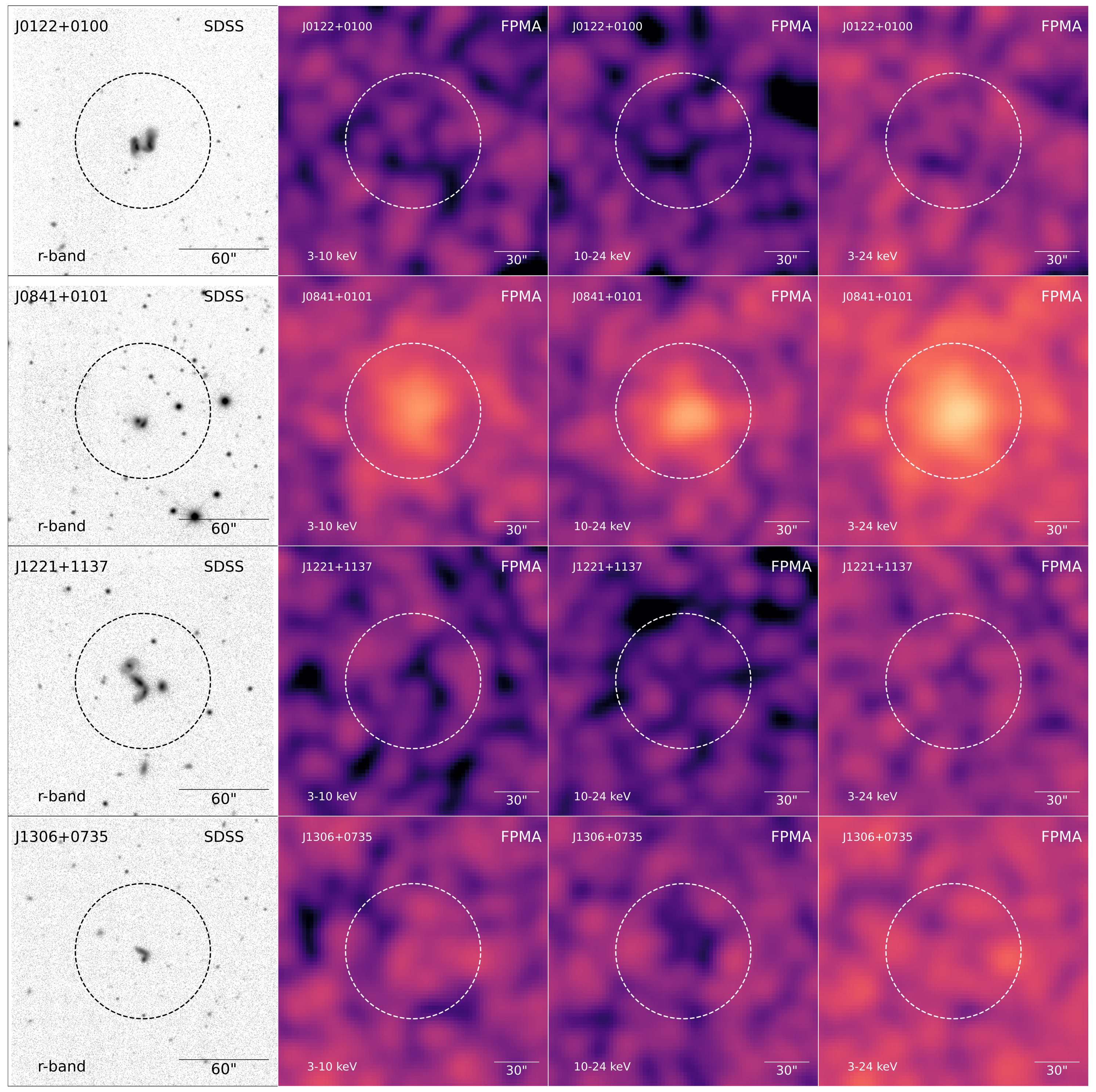

Figure 1. Another figure caption.

NuSTAR Photometric Results

System	Observed Flux (10^{-13} erg cm^{-2} s^{-1}) 3-24 keV	3-10 keV	10-24 keV	2-10 keV	$\log(N_{\rm H}/{\rm cm}^{-2})$
J0122+0100	<0.895	<0.434	<1.19	<0.558	24.7 (24.9)
J0841+0101	12.61 ± 0.68	4.67 ± 0.35	11.42 ± 0.95	5.99 ± 0.45	...
J1221+1137	<1.81	<1.07	<2.36	<1.37	24.4 (24.6)
J1306+0735	<1.13	<0.80	<1.23	<1.03	24.1 (24.3)

Table 1. NuSTAR Upper Limit Fluxes for the AGNs.

- Of the four newly observed mid-IR selected dual AGN candidates, three were not detected by *NuSTAR*: J0122+0100, J1221+1137, and J1306+0735. J0841+0101, however, is strongly detected by both *XMM-Newton* and *NuSTAR*.
- There are no hard X-ray emitting AGNs in the 10-24 keV band in excess of 1.2×10^{-13}, 2.36×10^{-13}, and 1.23×10^{-13} erg s^{-1} cm^{-2} in J0122+0100, J1221+1137, and J1306+0735, respectively.
- The upper limits for J0122+0100, J1221+1137, and J1306+0735 imply column densities in excess of log()=24.7, 24.4, and 24.1, if we attribute the non-detections to obscuration alone.

XMM-Newton Imaging and Spectroscopy

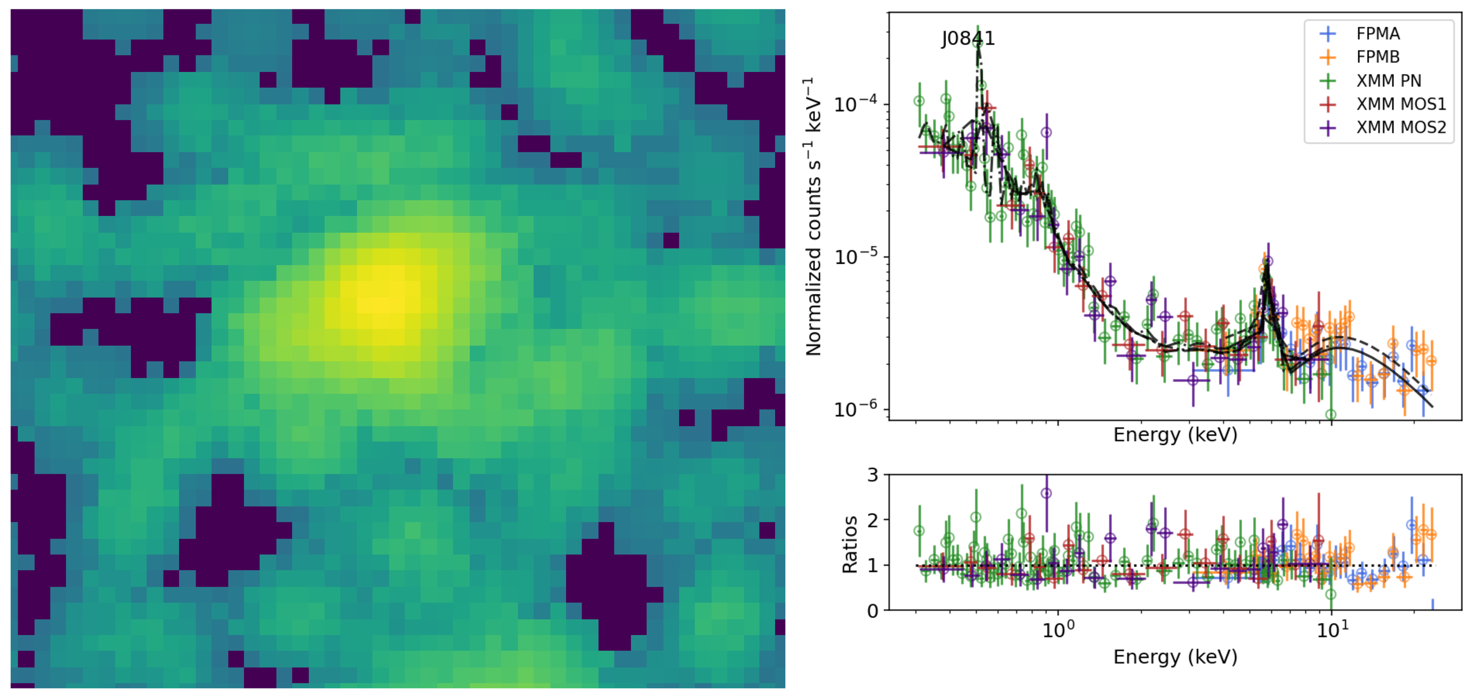

Figure 2. XMM-Newton Imaging and joint X-ray spectroscopic fitting for J0841+0101.

The XMM-Newton and NuSTAR spectra reveal a number of clear X-ray emission properties that were not possible to ascertain with the quality of the Chandra observations. Our spectroscopic analysis is nearly complete, and our two best fitting models both consist of an absorbed, intrinsic power law, a scattered power law, two thermal components in the soft X-rays, and a component for processing of the X-ray emission by an obscuring torus. The difference between these two models is how we implement reprocessing from the torus: in one model, we use borus (Balokovic et al. 2018), which X, while in the second model we use pexrav to model reflection. Both models satisfactorily reproduce the observed spectra from XMM-Newton and NuSTAR, and are consistent with J0841+0101 hosting a heavily obscured AGN with column density 8×10^{23} cm^{-2}.

Conclusions

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References

Satyapal S., Secrest N. J., Ricci C., Ellison S. L., Rothberg B., Blecha L., Constantin A., et al., 2017, ApJ, 848, 126. Pfeifle R. W., Satyapal S., Secrest N. J., Gliozzi M., Ricci C., Ellison S. L., Rothberg B., et al., 2019, ApJ, 875, 117. Pfeifle R. W., Satyapal S., Manzano-King C., Cann J., Sexton R. O., Rothberg B., Canalizo G., et al., 2019, ApJ, 883, 167. Foord A., Gültekin K., Nevin R., Comerford J. M., Hodges-Kluck E., Barrows R. S., Goulding A. D., et al., 2020, ApJ, 892, 29.

My Other Work

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Pfeifle et al. 2019a | Pfeifle et al. 2019b | Pfeifle et al. 2022 | Dual Type I AGNs | Bulgeless Galaxies