Spotted: Dual Broad Line AGNs in Two Minor Galaxy Mergers?

Ryan W. Pfeifle [1,*], Barry Rothberg [2,3], Remington O. Sexton [4], Kimberly Weaver [1], Jenna Cann [1,*], Nathan Secrest [4]

[1]NASA Goddard Space Flight Center [*]NPP Fellow [2]Large Binocular Telescope [3]George Mason University [4]US Naval Observatory

Introduction

To date, there exists no confirmed case of a kiloparsec-scale dual AGN *minor* merger in which **both** nuclei harbor broad line regions (BLRs) and are thus optically Type I AGNs. No theoretical study has closely examined whether dual AGNs in *minor* mergers should be preferentially obscured (like their major merger counterparts) during their late-stage merger phase, despite the fact that minor mergers outnumber major mergers by a factor of $\geq$3-4 at late epochs (Kaviraj et al. 2014) and *minor mergers should in fact trigger dual AGNs* (e.g., Callegari et al. 2011); these latter two points suggest that, averaged across cosmic time, dual AGNs in minor mergers could outnumber major merger dual AGNs. Furthermore, although the average duty cycle for a dual AGN in a 1:10 merger is far shorter than in gas-rich major mergers (Callegari et al. 2011, Van Wassenhove et al. 2012), the SMBH hosted in the *minor* companion should grow **8- to 10-fold in mass** during the evolution of the merger (Callegari et al. 2011, Khan et al. 2012)! This suggests that dual AGN growth in minor mergers could be an important SMBH growth channel, yet only two dual AGNs have been observed in minor mergers: Was49b and J0924+0510, which both present as optical *Type II* dual AGNs (Bothun et al. 1989, Secrest et al. 2017, Liu et al. 2018). **We have found two candidate dual Type I AGNs that reside in minor mergers with mass ratios of 1:7 and 1:29.**

Source Properties

J1421 ($z = 0.07$) and J1713 ($z = 0.1$) show clear tidal features and each consist of a primary galaxy with a bright central nucleus and an off-nuclear, dimmer secondary nucleus (Figure 1), with projected pair separations of < 8 kpc ($\lesssim 5''$) and velocity offsets of $|\Delta V| \lesssim 180$ km s^{-1}. SDSS spectroscopic fiber measurements of **both** nuclei within **both** mergers reveal broad optical emission lines, highly suggestive of dual AGNs.

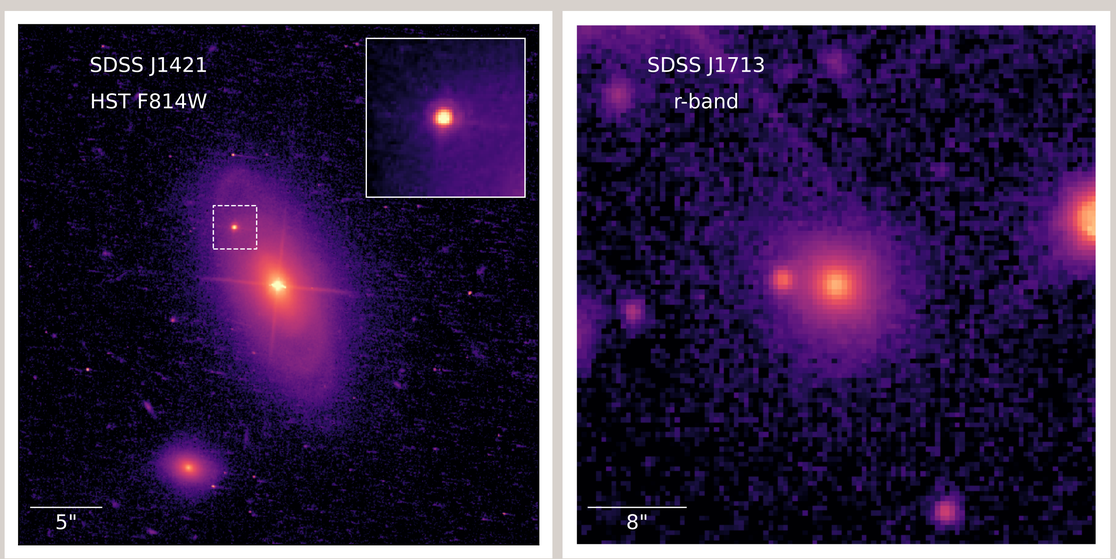

Figure 1. ***(Left)****: The SDSS and HST optical imaging of J1421. The main figure: HST F814W image. Upper right: a zoom-in view (3" x 3") of the secondary nucleus.* ***(Right):*** *SDSS r-band image of J1713. The scale bars in each panel indicate 5" (left) and 8" (right), or 6.9 kpc at $z = 0.07$ and 9.3 kpc at $z = 0.1$.*

Mass measurements from the SDSS indicate a bulge mass ratio of $\sim$ 1:7 for J1713 and $\sim$ 1:29 for J1421, **which suggests both are dual Type I AGNs hosted in *minor mergers, with J1421 having the largest mass ratio of any known candidate dual AGN*.**

Fitting the Optical Spectra

The bright, primary nuclei display prominent, broad emission lines and a few narrow emission lines. On the other hand, ***both*** of the dimmer, secondary nuclei exhibit a strong host galaxy continuum, a narrow [O III] emission line, and a very prominent and broad Hα/[N II] emission line complex.

To fit the optical spectra of both nuclei, we use the Bayesian AGN Decomposition Analysis for SDSS Spectra (BADASS) code developed in Sexton et al. 2021. This code allows us, where appropriate, to simultaneously fit for the line-of-sight velocity dispersion, broad and narrow Fe II emission features, the AGN power law continuum, broad, narrow, and absorption line features, as well as outflow features.

We iteratively fit each optical spectrum, varying the broad, narrow, and outflow emission line profile choices (gaussian, gaussian-like, or voigt) in order to find model spectra that best reproduce the observed spectra with the lowest reduced χ^2. In an effort to estimate black hole masses, we instead use only gaussian emission lines to model the narrow, broad, and outflow components in the spectra.

Tentative Results

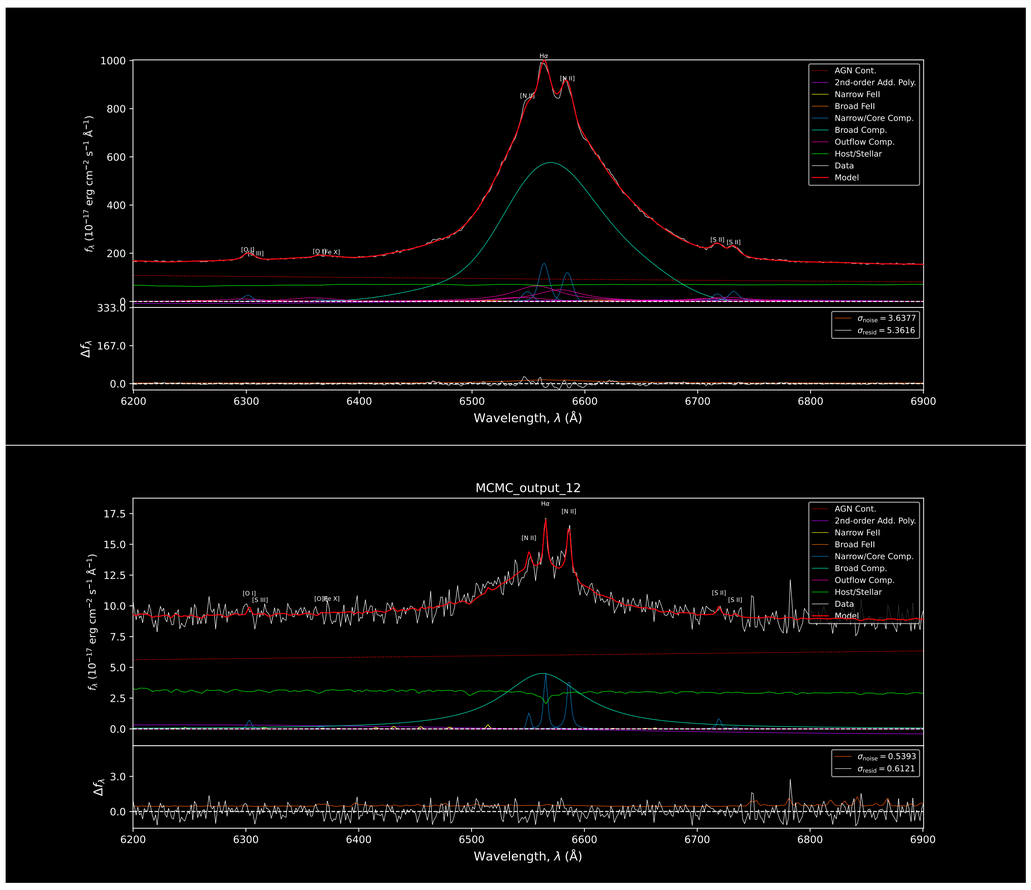

Figure 2. ***(Top)****: Tentative best fit model for the primary nucleus in J1421.* ***(Bottom)****: Tentative best fit model for the secondary nucleus in J1421. J1713 shows similar characteristics.*

Nucleus	H$\alpha_{BR,FWHM}$	log($\frac{[OIII]}{H\beta}$)	log($\frac{[NII]}{H\alpha}$)	log($\frac{[SII]}{H\alpha}$)	log($\frac{[OI]}{H\alpha}$)
J1421p	5079^{+21}_{-22}	$0.60^{+0.02}_{-0.05}$	$-0.05^{+0.03}_{-0.02}$	$-0.31^{+0.03}_{-0.02}$	$-0.73^{+0.03}_{-0.02}$
J1421s	4290^{+119}_{-118}	$0.76^{+0.24}_{-0.20}$	$0.04^{+0.13}_{-0.08}$	<-0.73	<-0.73
J1713p	4644^{+65}_{-45}	$0.90^{+0.03}_{-0.04}$	$0.05^{+0.01}_{-0.02}$	$-0.29^{+0.01}_{-0.02}$	$-1.00^{+0.03}_{-0.04}$
J1713s	3222^{+198}_{-274}	$0.99^{+0.21}_{-0.18}$	$0.15^{+0.08}_{-0.09}$	<-0.03	<-0.73

Discussion

Broad Hα emission lines are found in each nucleus within both mergers with FWHMs that are inconsistent between the primary and secondary nuclei in each system, suggesting we are observing two kinematically distinct emission regions in each merger. In addition, our analysis of the narrow emission lines suggest that each merger consists of two BPT (Baldwin et al. 1981) Seyfert nuclei.

Given the $\lesssim 5''$ separation of the nuclei in each system and the fact that the spectra were obtained using 3" or 2" diameter fibers, it is possible that the broad line and narrow lines observed in both secondary nuclei are spillover light from the central nuclei (as has been shown to be an issue for narrow line emission by Husemann et al. 2020). However, *we disfavor this scenario due to the inconsistent widths of the broad Hα emission lines*. Furthermore, if the emission in the secondary was indeed dominated by the primary, it would be unusual to see such a prominent, broad Hα/[N II] complex without the addition of other broad emission lines like Hβ that are clearly seen in the primary nuclei.

Conclusions and Ongoing Efforts

- We have identified two candidate dual Type I AGNs, each hosted in minor mergers.
- We are currently reducing deep LBT/MODS optical spectra that provide better angular resolution and higher S/N than the SDSS fibers. These observations will provide the necessary evidence to deduce whether these are true dual AGNs or further examples of fiber spillover.
- If confirmed, these mergers would be the only examples in the local Universe ($z < 0.1$) of dual Type I AGNs which also happen to be hosted in *minor* mergers.

References

Baldwin J. A.,et al. 1981, PASP, 93, 5. Bothun, G. D., et al. 1989, ApJS, 70, 271. Callegari S. et al., 2011, ApJ, 729, 85. Husemann B., et al. 2020, A&A, 639, A117. Kaviraj, Sugata, 2014, MNRAS, 440, 2944. Khan, F. M., et al. 2012, ApJ, 756. Liu, Xin, et al. 2018, ApJ, 862, 29. Secrest, Nathan J., et al. 2017, ApJ, 836, 183. Sexton R. O., et al., 2021, MNRAS, 500, 2871. Van Wassenhove, S. et al., 2012, ApJ, 748.

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Mid-IR Dual AGNs

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