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VLBI Non-detection of a Candidate Dual AGN in a Galaxy Merger

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galaxies: individual (SDSS J085312.85+162616.0, DSS J085312.34+162619.4) ; radio continuum: galaxies

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Numerical hydrodynamical simulations (e.g., Capelo et al. 2015) show that nuclear activity is experienced in multiple episodes during major galaxy mergers. Simultaneous activity in both nuclei becomes most likely at separations $\lesssim$10 kpc. These systems where the central supermassive black holes (SMBHs) are still gravitationally unbound are called dual active galactic nuclei (AGNs). Characterizing a large sample of dual AGNs would help constraining the merger rate of galaxies and SMBHs, understanding the role of galaxy mergers in triggering AGN activity, and making predictions for SMBH coalescence producing gravitational waves. However, securely identified dual AGNs are rare. Confirmation of each case would ideally require AGN indicators at multiple wavebands. Although radio emission is associated with a minority of AGNs, the very long baseline interferometry (VLBI) technique plays a unique role in confirming emission from dual AGNs, owing to its high angular resolution (e.g., An et al. 2018).

Based on optical and X-ray imaging and spectroscopy, Lena et al. (2018) discovered a dual AGN candidate hosted in interacting galaxies. At their redshift $z = 0.064$, the 8$''$.1 angular separation between the two objects (S1: SDSS J085312.85+162616.0 and S2: SDSS J085312.34+162619.4) corresponds to 11 kpc projected linear distance. The analysis of multi-band data collected so far indicates that S1 certainly harbours an AGN. The nature of S2 is less clear, with indications that the X-ray emission comes from starburst activity.

In the radio, the catalog of the 1.4 GHz FIRST (White et al. 1997) survey contains a resolved source (R.A. = $08^h53^m12\overset{s}{.}467$, decl. = +16°26'$19\overset{''}{.}19$) with a peak brightness 2.75 mJy beam^{-1} and integrated flux density $S_{1.4}$ = 5.81 mJy. The radio source lies between the two optical/X-ray objects, closer to S2 (within 2''). Its deconvolved size is $8\overset{''}{.}1 \times 3\overset{''}{.}4$, with a major axis position angle 116° that roughly coincides with the S1–S2 position angle, suggesting that both may contribute to the radio emission.

We observed this radio source at three orders of magnitude higher angular resolution with the European VLBI Network (EVN) to check if one or both galaxies host a weak radio-emitting AGN. Both S1 and S2 fell in the undistorted field of view of our observation. The 1.7 GHz EVN experiment took place in e-VLBI mode on 2018 November 21 and lasted for 2 hr. The radio telescopes were Cambridge, Darnhall, Defford, Jodrell Bank Mk2 (UK), Medicina, Sardinia (Italy), Effelsberg (Germany), Hartebeesthoek (South Africa), Onsala (Sweden), and Tianma (China). The correlator integration time was 1 s. Eight times 32 frequency channels were used with 128 MHz total bandwidth in both left and right circular polarizations. We applied phase-referencing to a nearby ($1\overset{\circ}{.}52$) compact calibrator J0856+1739, and also observed OJ 287 as fringe-finder. The total time spent on the target was 1.6 hr. We used the Astronomical Image Processing System (Greisen 2003) to calibrate the EVN data. Imaging was attempted in the Difmap program (Shepherd et al. 1994). A more detailed description of the procedure can be found in e.g., Frey et al. (2013).

We used uniform weighting to minimize the image noise. With a resolution of ~4 mas, no compact radio features were detected, neither around the position of the FIRST source, nor at S1 and S2. The 6σ upper limit for the brightness is 0.13 mJy beam^{-1}. The radio emission detected in FIRST ($S_{1.4}$ = 5.81 mJy, power $P_{1.4} = 5.4 \times 10^{22}$ W Hz^{-1}) is apparently resolved out with VLBI and may originate from spatially extended starburst activity in the merging galaxies or resolved AGN-related structures. Assuming no AGN, the corresponding star formation rate is estimated as ~30 $M_{\odot}$ yr^{-1} (Hopkins et al. 2003) in the system, about three times higher than calculated by Lena et al. (2018) from u-band optical magnitudes.

Based on our short EVN observations, we are unable to fully exclude the presence of one or two low-luminosity AGNs in the S1/S2 system. A flux density $S \approx 0.1$ mJy in a hypothetical compact source that would have remained undetected in our EVN experiment corresponds to $P_{1.4} \approx 10^{21}$ W Hz^{-1} at $z = 0.064$. This exceeds the average power 2×10^{20} W Hz^{-1} for individual radio supernovae (Bondi et al. 2005), but is below the radio power of the weakest AGNs studied in the COSMOS field (Smolčić et al. 2008).

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