A TRIO OF MASSIVE BLACK HOLES CAUGHT IN THE ACT OF MERGING

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1. INTRODUCTION

Black holes pairs and triples are natural out comes of the hierarchical galaxy and black hole assembly process. Studies based on the SDSS galaxies show that 2% of (major) merging systems involve three galaxies (e.g., Darg et al. 2010) and only three kpc-scale triple AGN candidates are known. The galaxy SDSS J084905.51+111447.2 at redshift z = 0.078 contains three optical stellar nuclei within a projected ~5 kpc radius with disturbed morphology, representing the first known case of a triple type-2 Seyfert nucleus. We present a comprehensive follow-up campaign including APO 3.5m/DIS spectroscopy, HST/WFC3 imaging, Chandra ACIS-S X-ray imaging spectroscopy and VLA radio imaging to confirm the AGN nature of triple nuclei.

2. OPTICAL AND UVIS/IR

![Fig1. SDSS color composite image and HST/WFC3 IR/F105W (Y) and UVIS/IR/F336W (U) band](image)

We extracted 1D spectra and fitted the narrow emission lines. BPT diagram classifies all three nuclei as type-2 Seyferts.

3. X-RAY AND RADIO

![Fig2. VLA radio image and Chandra 0.5-2, 2-8 keV band images](image)

We reprocessed the Chandra data and measure the intrinsic X-ray luminosity for each nuclei. Nucleus A is detected in both soft and hard bands, whereas B and C are only detected in the soft band. Only nucleus A has sufficient counts to perform spectral analysis.

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<table>
<thead>
<tr>
<th>nucleus</th>
<th>intrinsic X-ray luminosity [10^44 erg s^-1]</th>
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<tbody>
<tr>
<td>A</td>
<td>~2x10^44</td>
</tr>
<tr>
<td>B</td>
<td>~1x10^44</td>
</tr>
<tr>
<td>C</td>
<td>~5x10^43</td>
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With VLA A-configuration observation at 9.0 GHz, we have detected nucleus A and C and set a 3σ upper limit for nucleus B. We extrapolate our VLA 9.0 GHz measurements to 1.4 GHz to estimate lower radio-based SFR.

4. NATURE OF NUCLEAR IONIZING SOURCES

- Nucleus A is detected as a compact point source in both soft and hard X-ray bands. The high hard X-ray luminosity, particularly when compared to its moderate SFR, unambiguously confirms A as an AGN.
- Nucleus C is detected as a compact radio source by VLA in 9.0 GHz, while it is undetected in the hard X-ray. The expected soft X-ray luminosity from pure star formation related processes is an order of magnitude smaller than the total soft X-ray luminosity. Thus it confirms C as an AGN
- While Nucleus B is neither detected in the hard X-rays nor in the radio, its soft X-ray luminosity exceeds that would be expected from pure star formation related processes driven from both HST U-band and radio luminosity. In addition, photoionization in favor of an additional AGN in B, rather than being solely ionized by A and/or C.

5. DISCUSSIONS

- By modeling host galaxy photometry and internal dust extinction of SDSS J0849+1114, we have estimated the stellar masses of the three merging components to be ~10^{11}M_☉, 10^{10.0}M_☉, and 10^{9.5}M_☉ for A, B, and C. Assuming the empirical correlation between black hole mass and host total stellar mass observed in local broad-line AGN (Reines &Volonteri 2015), the inferred black hole masses are ~10^{5}M_☉, 10^{4.5}M_☉, and 10^{3}M_☉, consistent with independent estimates based on host galaxy stellar velocity dispersion within uncertainties.
- Using a simple stellar dynamical friction argument, we have estimated that the trio in SDSS J0849+1114 may form a bound MBH triple in ~2 Gyr.

6. SUMMARY

By conducting new, spatially resolved optical spectroscopy, we have classified all three nuclei as type-2 Seyferts based on the classical BPT diagram.

Our comprehensive observations, including Chandra X-ray imaging spectroscopy, HST U- and Y-band imaging and VLA radio imaging, strongly suggest that all three nuclei are AGN, making SDSS J0849+1114 the first most unambiguous case known to host a kpc-scale trio of massive black holes.

Similar systems may be more common in the early universe when galaxy mergers are thought to be more frequent.

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