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Decoding DDRG growth and environment with the largest sample from LoTSS

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Double-double radio galaxies (DDRGs) are key evidence of recurrent AGN activity, featuring two pairs of radio lobes, typically along a similar axis. These DDRGs, often displaying FR-II morphology, exhibit differences between their outer, diffuse lobes from earlier activity cycles and their more recent, hotspot-rich lobes. Variations in the restarting timescale or environmental inhomogeneities often result in offsets between these lobe pairs. DDRGs provide insights into the AGN duty cycle, with their morphology and radio spectra shedding light on episodic activity histories. They raise crucial questions about AGN triggering and fueling mechanisms, activity cycles, radio galaxy evolution, and AGN feedback processes. Understanding these aspects, particularly through studies of remnant and restarted galaxies like DDRGs, is vital. Here, low-frequency telescopes such as LOFAR play a key role, offering sensitivity to the diffuse and steep-spectrum plasma common in these sources.
As of 2016, only around 300 giant radio sources (size > 0.7 Mpc) were known, considered rare. Now, there are approximately 3300, with about 2500 identified via LoTSS. In contrast, DDRG numbers haven't significantly risen since 2017's count of 70, largely due to insufficient systematic searches in deep radio surveys.
To advance the above-mentioned studies, it's crucial to compile a large statistical sample of DDRGs and examine them alongside other radio galaxy phases, like remnants. DDRG identification relies primarily on radio morphology; while automating this process through machine learning is developing, it remains challenging. Therefore, manual visual inspection, despite being laborious, is currently the most reliable method.
However, covering the vast 5700 sq deg of LoTSS DR2 sky manually is challenging. Notably, many known DDRGs are giants (>0.7 Mpc). To streamline our DDRG search, we utilized LoTSS DR2's list of nearly 2500 giant radio sources, identifying 84 new DDRGs exceeding 0.7 Mpc. Interestingly, a significant number of these DDRGs were not detected in high-frequency surveys like NVSS, underscoring their steep spectral characteristics and the critical role of LoTSS surveys. Interestingly, we also, found two radio sources with three episodes of jet activity (triple-double radio galaxy or TDRG), making it only the 4th and 5th such known so far. The unprecedented sensitivities achieved by the LoTSS survey at 150 MHz, unveiled many peculiar morphological traits associated with these sources, which we have attempted to characterise and explain. Hence, for the first time, we can characterise the low-frequency radio properties of a large sample of DDRGs.
Employing ancillary data from high-frequency radio surveys such as NVSS and APERTIF-WSRT, we estimated their integrated spectral indices in conjunction with LoTSS data. Furthermore, through higher resolution surveys like FIRST and VLASS, we determined the radio core properties and core dominance factors, crucial for investigating Doppler boosting and related asymmetries.
The high resolution and sensitivity of the LoTSS maps have been instrumental in estimating the arm-length and flux ratios of both inner and outer doubles. This analysis enables us to infer details about both the local and broader environments surrounding DDRGs by scrutinizing radio morphological asymmetries. Consequently, this serves as an effective probe for environmental conditions and their impact on source growth. Notably, in several instances, we observed a 'flipping of symmetry'—where the inner double is symmetric and the outer double asymmetric, or vice versa. This phenomenon offers unparalleled insights into the cocoons surrounding newer or inner doubles. Additionally, it allows us to comprehend how a restarted source propagates in such environments, its effects on the source itself, and subsequently on the duty cycle. Our systematic approach to this analysis, a first for such an extensive sample, proves to be exceptionally effective in advancing our understanding of DDRGs. We also uncovered numerous Gigahertz-Peaked Spectrum (GPS) candidates within our sample, along with several DDRGs being hosted by Brightest Cluster Galaxies (BCGs). Lastly, we correlated the radio morphological asymmetries with the optical morphology of the host galaxies to identify signs of mergers. In several cases, we observed a direct correlation, further enhancing our understanding of these phenomena. We aim to explain our methods and results via an oral contribution at the SPARCS meeting (2024).

keywords

AGN, Restarted AGN, large sample study. environment

In-person or online?

in-person

Career level

ECR

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