



FIRST Winged Radio Galaxies with X and Z Symmetry

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Abstract

X-shaped radio galaxies (XRGs) are a subclass of radio sources that exhibit a pair of secondary low surface brightness radio lobes oriented at an angle to the primary high surface brightness lobes. Sometimes, the secondary low brightened lobes emerge from the edges of the primary high brightened lobes and form a Z-symmetric morphology. We present a systematical search result for XRGs and Z-shaped radio galaxies (ZRGs) from the VLA Faint Images of the Radio Sky at Twenty-Centimeters (VLA FIRST) Survey at 1.4 GHz. Our search yields a total of 296 radio sources, out of which 161 are XRGs and 135 are ZRGs. We have also made optical identification of these sources from the different available literature. J1124+4325 and J1319+0502 are the farthest known XRG and ZRG, respectively. We have estimated the spectral index and radio luminosity of these radio sources and made a comparative study with previously detected XRGs and ZRGs. The average value of luminosities for XRGs is higher than that of ZRGs. With the help of a large sample size of the newly discovered XRGs and ZRGs, various statistical properties of these sources are studied. Out of 161 XRGs presented in the current paper, 70% (113) are FR II radio galaxies, and 13% (20) are FR I radio galaxies. For 28 XRGs, the morphology is complex and could not be classified. For XRGs, statistical studies are done on the angle between the major axis and minor axis and the relative size of the major and minor axes. For the ZRGs a statistical study is done on the angular size.

Introduction

A small number of subclasses are found with a nonlinear special structure. "Winged" radio galaxies is a subclass where two additional secondary lobes (wings) are found beside the primary lobes. These symmetric and low luminosity extrusion of plasma extend at an angle from the center to a distance nearly equal to or lower than the length of the active lobes. Based on the alignment of the secondary lobes with the primary lobes, two subclasses are defined, "X"-shaped radio galaxies (XRGs) and "Z/S"-shaped radio galaxies (ZRGs). For XRGs, both the sets of lobes pass symmetrically through the center of the elliptical galaxy that is the source of the lobes. In the case of ZRGs, the secondary lobes are seen from the edges of the primary jets.

The first reported radio galaxy with wings is 3C 272.1 (Riley 1972). Thereafter Leahy & Parma (1992) identified such 11 objects. A list of 100 and 290 sources are catalogued by Cheung (2007) and Yang et al. (2019) from FIRST data.

The origin of such morphology is still elusive. The proposed models are: (a) The backflow of plasma (Leahy & Williams 1984; Capetti et al. 2002), (b) A merger of two black holes (Rottmann 2001; Merritt & Ekers 2002), (c) Realignment of a central SMBH-accretion disk system (Dennett-Thorpe et al. 2002), (d) Precession of twin jets (Mack et al. 1994).

We looked for X-shaped and Z-shaped radio sources using the VLA FIRST survey database. The catalog contains a total of 946,432 radio sources. We filtered all sources in the catalog that have an angular size of $>10''$ (i.e., at least twice the convolution beam size). Our filtering gives an output of 95,243 sources.

Method

The FIRST survey (White et al. 1996) covers a radio sky of 10,575 square degrees of the north and south Galactic caps near 1400 MHz (21 cm). This survey has a typical rms of 0.15 mJy and an angular resolution of $5''$ (Becker et al. 1995). The FIRST survey area covers approximately 25% of the total sky, out of which, approximately 80% is in the north Galactic cap (8444 square degrees), and remaining 20% is in the south Galactic cap (2131 square degrees; Becker et al. 1995). The survey covers R.A 07.0h to 17.5 hr, decl. -08.0 deg to $+57.6$ deg in northern sky and R.A 20.4 hr to 4.0 hr, decl. -11.5 deg to $+15.4$ deg in southern sky.

We looked for X-shaped and Z-shaped radio sources using the VLA FIRST survey database. The catalog contains a total of 946,432 radio sources. We filtered all sources in the catalog that have an angular size of $>10''$ (i.e., at least twice the convolution beam size). Our filtering gives an output of 95,243 sources. We visually inspected fields of all the sources ($>10''$) to look for new candidate radio galaxies with wings.

Images of 'X' and 'Z' Shaped Radio Galaxies

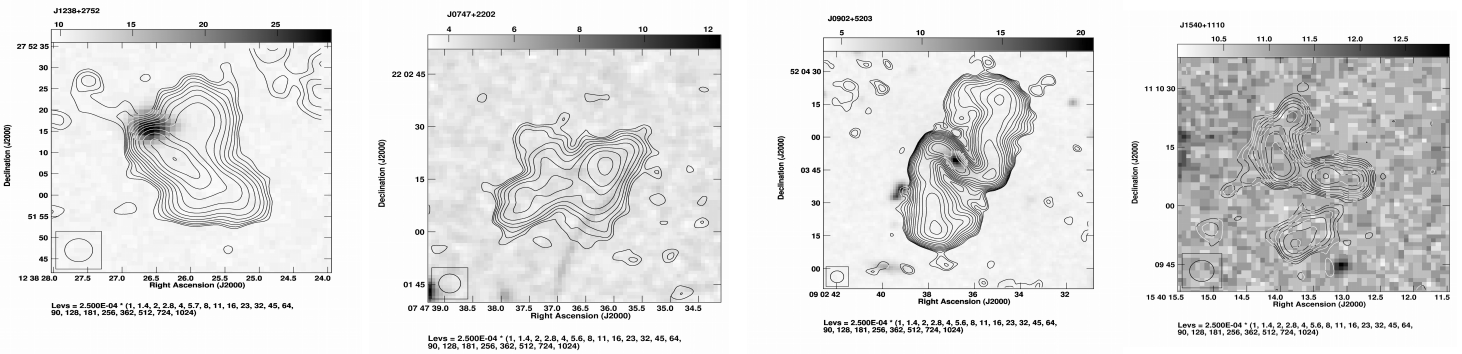


Figure: Contour images of two X-Shape (left two) and two Z-shape (right two) radio galaxies overlaid with optical SDSS.

Conclusion

We have discovered a total of 296 radio sources with wings, out of which 161 are XRGs and 135 are ZRGs. This discovery helps to increase the number of known XRGs and ZRGs significantly. Optical/IR counterparts of most of the XRGs and ZRGs are identified. As expected, most of the XRGs and ZRGs show a steep spectral index between 150 MHz and 1400 MHz. Most of the XRGs are FR II radio galaxies. The average value of luminosities for XRGs is found to be higher than that of ZRGs.

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