Intensive Survey of X-Shaped Radio Galaxy Candidates

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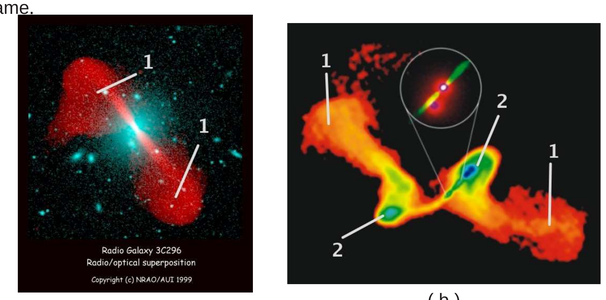
Abstract

X-Shaped Radio Galaxies are an anomalous, fascinating subset of radio galaxies due to their complex morphology. However, while there exist several explanations for the formation of these galaxies, insufficient research exists to provide a clear answer. The purpose of this project is to provide groundwork for a further study of X-shaped Radio Galaxies at radio wavelengths by studying potential X-shaped radio galaxies and creating higher resolution contour maps. These maps will help to determine the merit for the further study of the galaxies.

1. X-Shaped Radio Galaxies

X-shaped radio galaxies are an unexplained anomaly. Radio Galaxies often have jets ending in hot spots of energy. However, most radio galaxies only have one pair of jets, resulting in a line, while X-shaped radio galaxies inexplicably have two pairs of jets resulting in an X shape, giving them their name.



(a) (b)

Figure 1: *a) Typical galaxy with a single pair of jets, b) X-Shaped Radio Galaxy. Credits for a) and b), http://images.nrao.edu. Each pair of the same number in each image represents a pair of lobes from the same jet.*

Several theories exist for this phenomenon. One popular theory is that X-shaped galaxies are formed by a rotation of the ”central engine,” leaving an artifact of the original location of the jets, giving the appearance multiple jets. The other popular theory is that X-shaped radio galaxies form naturally by backflow from the hot spots, and that all X-shaped radio galaxies share a common set of initial conditions that allow for their formation. Without more information and better observations of X-shaped galaxies the theories are all merely speculation.

2. The VLA

The Very Large Array (VLA), a radio astronomy observatory, is located on the plain of San Augustin, New Mexico. It contains 27 independent antennas that are arranged in a Y-shaped configuration, each with a diameter of 25 meters.

Figure 2: *The Very Large Array in D Array.*

The telescopes are switched between four configurations with different maximum baseline separation every four months: A (36km), B (10km), C (3.6km) and D (1km) array. The VLA provides seven frequency bands (4, P, L, C, X, U, K, Q Bands); our data mainly come from L Band (1.4-1.6 GHz) and C Band (4.5-5.0 GHz).

3. Data Reducation

Working our way through Cheung’s (2007) list of 100 potential X-shaped radio galaxies, we acquired the archival VLA data for each source. We specifically searched for L band data from the times when the VLA was in A array or C band data from the times when the VLA was in B array due our desire to observe greater detail than was available to Cheung.
Once the data were acquired, they were imported into the Astronomical Image Processing System software (AIPS). Once in AIPS, each source was located within the list of sources from the imported project and was then calibrated.

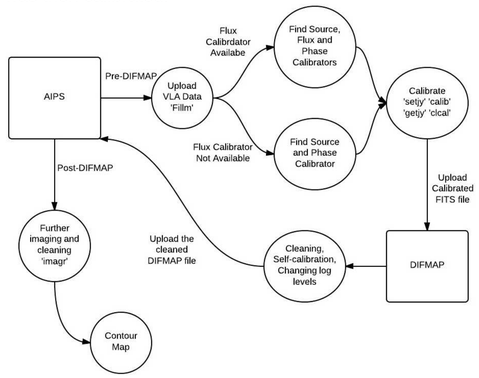


Figure 3: *A chart detailing the data reduction process.*

Once calibrated, the data were then moved into the DIFMAP software for self-calibration and CLEANing to produce an image of the source displaying the relative flux of radio emissions throughout the galaxy. Finally, self-calibrated the data were moved back into AIPS to be further processed using the task IMAGR in order to produce a final image, which is displayed as a contour map in the Results section of the poster.

4. Results

Each contour map below reflects the relative intensity of the radio waves being emitted by the source. The X (Right Ascension) and Y (Declination) axis in the figure shows the position of the source in the sky. More contours mean greater intensity of the source at that position. The contour maps below represent six of the best examples of potential X-shaped radio galaxies from the 51 galaxies that we imaged over the course of this project.

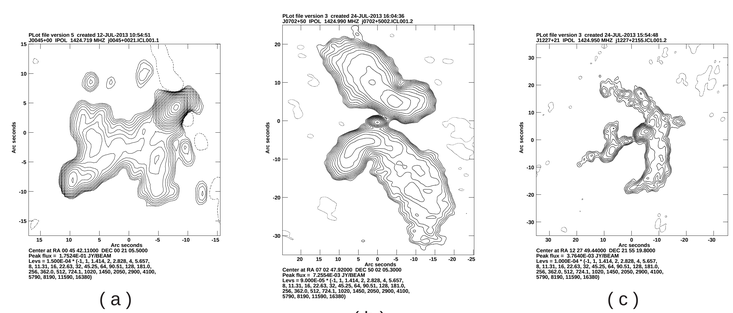
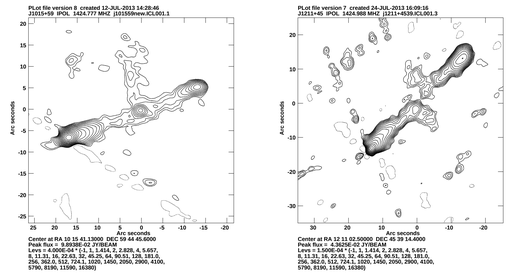
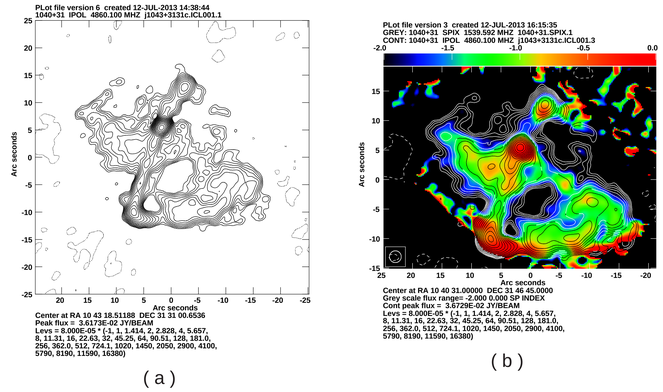


Figure 4: *Contour maps of X-shaped radio galaxy candidates a) J0045+0021, b) J0702+5002, c) J1227+2155.*



(a) (b)

Figure 5: *Contour maps of X-shaped radio galaxy candidates a) J1015+5940, b) J1211+4539.*



(a) (b)

Figure 6: *X-shaped radio galaxy candidate J1043+3131. a) Contour map, b) Spectral Index with contours.*

5. Discussion

After testing the 100 potential sources provided by Cheung’s (2007) paper, only 51 sources had the L band A array and/or the C band B array data that were necessary to produce useful images of the potential X-shaped radio galaxies. Of those 51, at least 28 are clearly worth further investigation due to their obvious X-shape. Thanks to the ground work that this project provided, it will be possible to observe the X-shaped radio galaxy candidates with the newer, more powerful Jansky VLA which should shed light on the creation of these fascinating galaxies.

6. Acknowledgments

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7. References

C. C. Cheung, ”FIRST Winged and X-Shaped Radio Sources Candidates,” 2007, Astronomical Journal, 133:2097-2121. (Cheung is an alumnus of the Brandeis Astrophysics Group, BS and PhD).