ED42B-0566

Supermassive Black Holes:

An Exploration of Galactic Nuclei and Jets via Radio Emissions

Rishika Porandla • Ambika Grover • Sarah Pinto • Siddhi Raut • Malithi Sella Kapu • Dr. Judit Ries

Project Overview

We are searching for supermassive black holes that emit radio jets using citizen science data in addition to measuring the comparative ratios of active galactic nucleus radii to their corresponding jet length. We find that the major problem with the existing study of supermassive black holes is that the relationship between the size of both the galactic center and jets is not often explicitly analyzed and described. This issue remains prevalent because many radio images that are available to the public contain these imaging inconsistencies that can affect future conclusions. We aim to counter this issue by investigating galaxies using the Radio Galaxy Zoo: LOFAR software, the basis of citizen science, and use the collected data and images to see if there is any such relationship

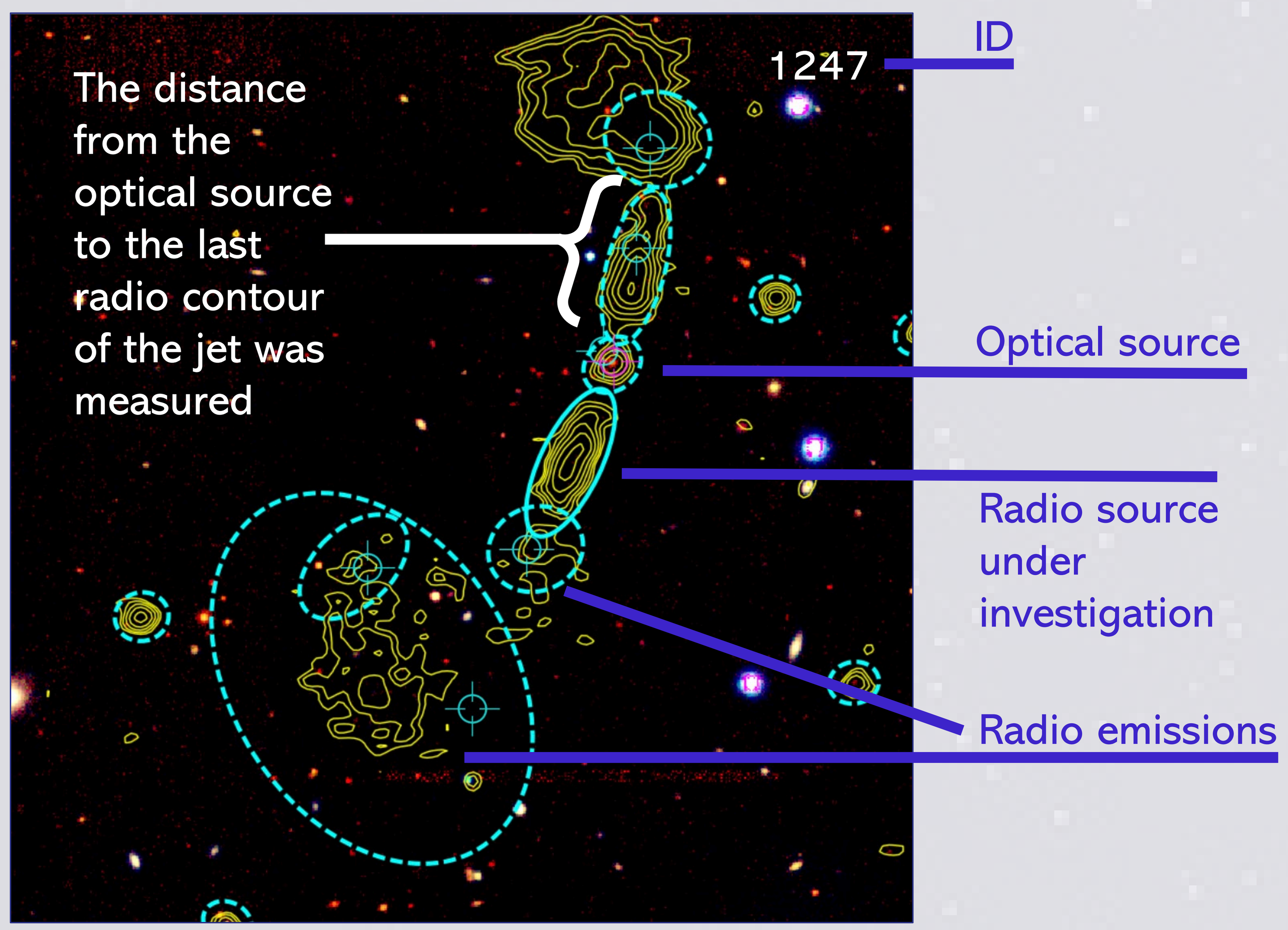


Image: LOFAR Radio Galaxy Zoo: Citizen Science Project

Citizen Science: Our Task

With citizen science we looked at pictures showing the radio sources and their locations overlaid on the image of the sky. We would then identify the optical source of the radio emission and any radio emission we believe is also belonging to the optical source through ellipses in the image. Our group completed this task on 1000 images. We also sorted the images in categories if they were a special case. However, the rest of our research is independent of the tasks assigned by our citizen science project

Methodology

In our research, we cross examined data from telescopic archives such as the Sloan Digital Sky Survey, LOFAR, and SIMBAD.

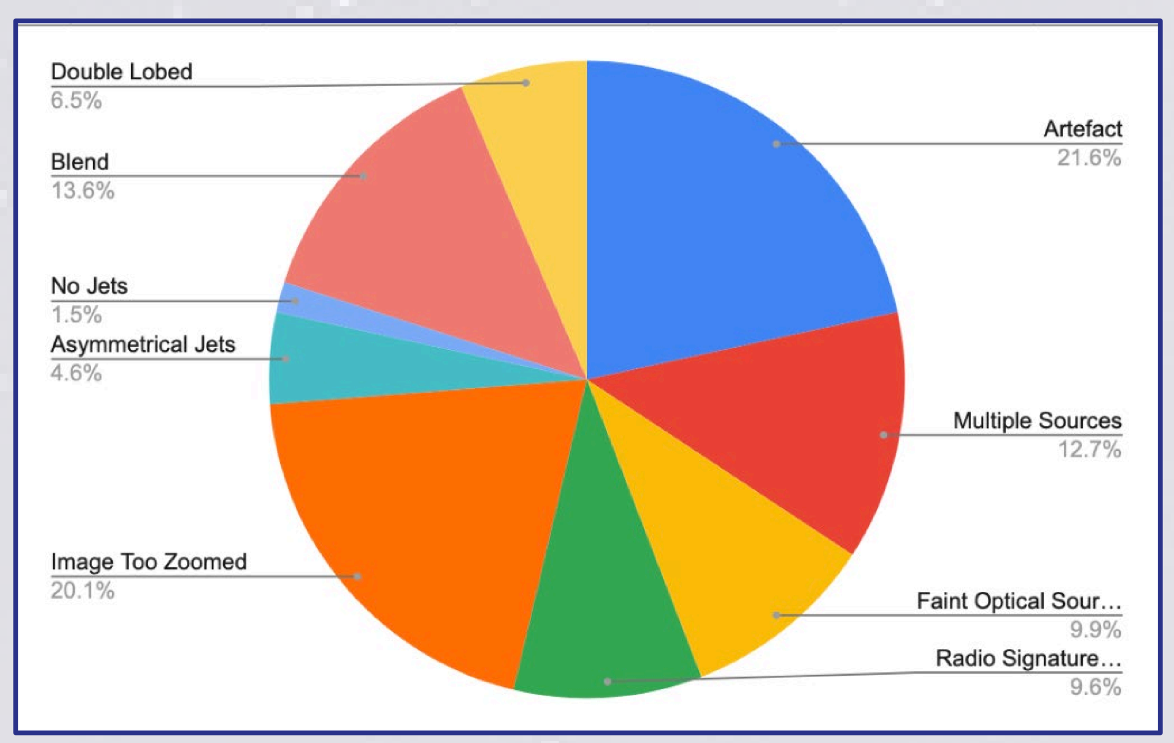
1. Read instructions/project information
2. Analyze galaxies in Citizen's Science and save photos
3. Sort images by visibility of source and definition of the jets
4. Continue grouping until we ended with images with visible optical points of origin
5. Use Adobe illustrator pinpoint location of galaxy
6. Convert redshift value to distance using a cosmological calculator
7. Measure and calculate ratio of linear distance of the jet to the radius of the source
8. Analyze findings and reflect

Special Cases

We analyzed about 1000 images by noting which radio contours are emissions of the source (via placing a mark in a certain dashed ellipse), and which optical object is the source of the radio jets. We also come across situations where the ellipses aren't related to the optical source in any way, or the image itself could have an error or a special case where it is hard to make any conclusion.

The most notable were:

- **Artefact:** where the radio sources are distorted due to calibration problems. This happens when a bright radio source is close by, therefore possessing an "explosion" like nature.
- **Too zoomed in:** where radio regions go far beyond the borders of the image–i.e., we cannot tell what we are really seeing.
- **Blends:** where the blue ellipse views two or more separate sources.
- **Diffuse radio source:** where the image does not map any radio structures.



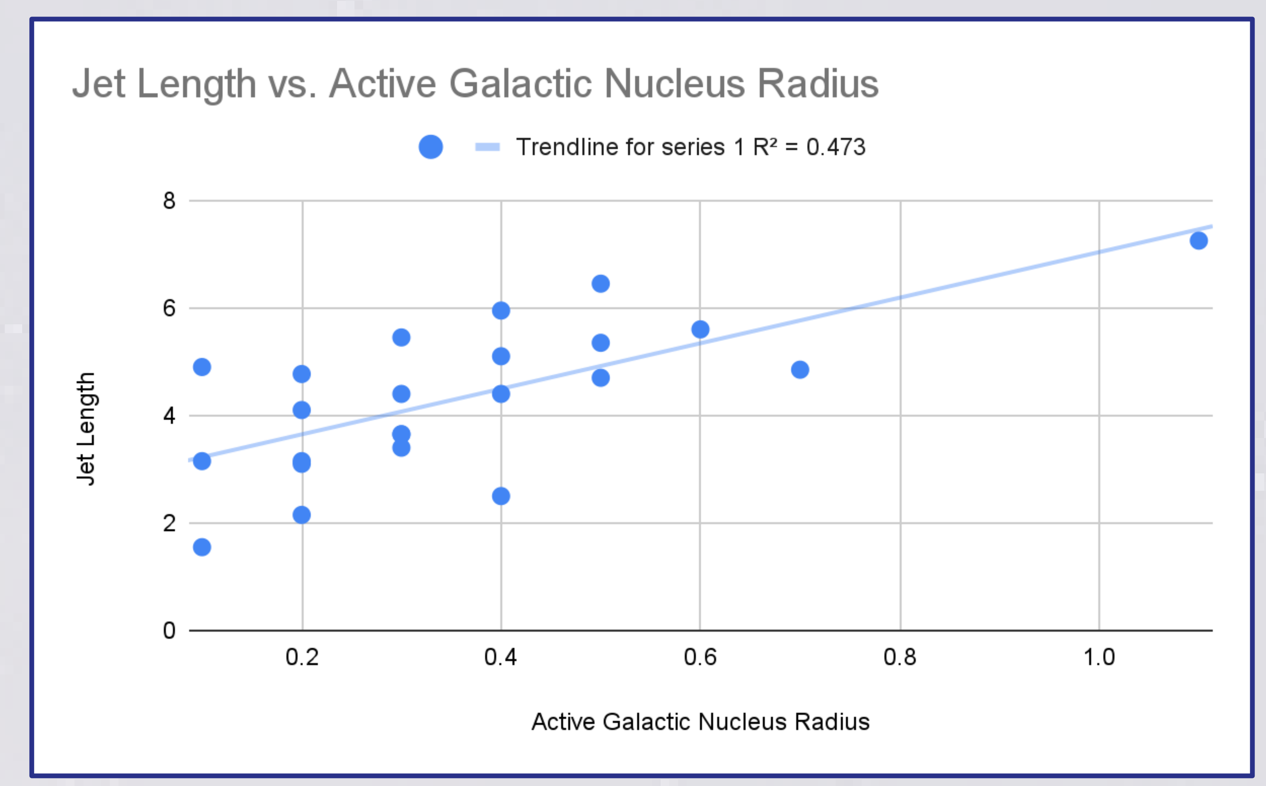
Only about *11%* of the total galaxies classified yielded genuine supermassive blackholes with clear optical sources.

Consistency

Although everyone in our group was working independently to classify the citizen's science images, there were 44 that were classified by more than one of our group members. We took these data points and analytically determined our **success rate of 90.7%**, showing the high reliability of our classifications. This made our group's collective accuracy nearly 15 times more accurate than the standard machine learning tool, showing how useful human input is for the scientists running the citizens science project.

Our Research: Ratios

Our team completed nearly 1000 classifications on the citizens science website however this is not the extent of our research. After we made these classifications, we sorted the images based on criteria such as having a bright source and having a double or single lobbed jet, which are optimal for further research. We then took these optimal images and measured the length from the source to the furthest end of the innermost radio source. If there was more than one jet, we would take the average distances to compare to the radius. We also measured the radius of the optical source. Both data points were measured in centimeters. From this data we divided the linear distance of the jet by the radius of the optical source to get the ratio comparing these two pieces of information.



Research Analysis and Results

We can see that there is a positive, linear relationship between the radius of the source and the linear distance from the source to each of the jets which we expected from the start of the project something. As the radius increases, the length of the jets also increases. A Larger AGN radius corresponds to a brighter AGN, and a brighter AGN indicates that a greater amount of energy is emitted from the jets.