Radio and Starburst Galaxies

Alexandra JW Echtenkamp, Andrew S. Bowles, Anthony J. Sinker
Chelen H. Johnson, teacher

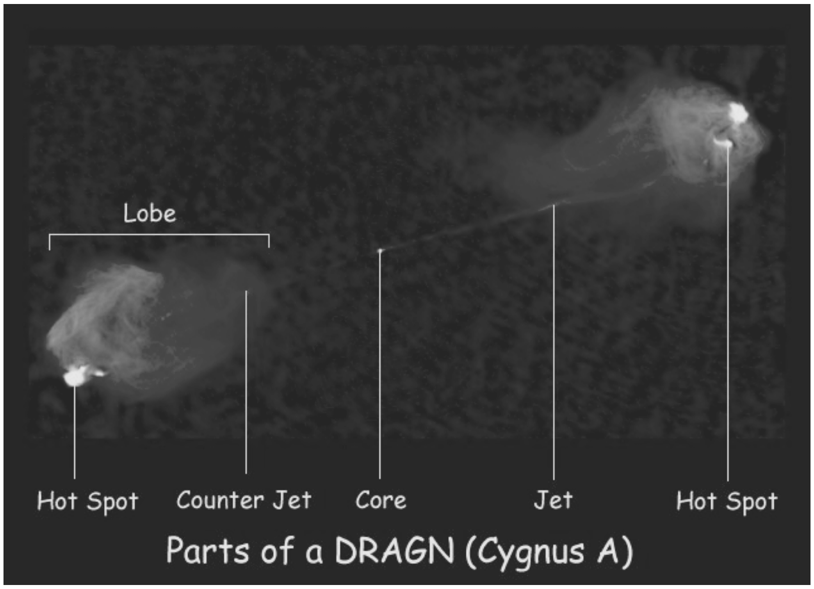
ABSTRACT

Active Galactic Nuclei (AGNs) are compact regions in the center of a galaxy that can produce more radiation than the rest of the galaxy. However, in the case of radio and starburst galaxies, AGN do not produce more radiation than the rest of the galaxy. Many different types of AGN can be formed in many different types of galaxies.*(1)* The three strongest sources are radio galaxies, quasars, and blazars. The main focus of research will be radio galaxies from Right Ascension 07h 18m to 09h 43m as part of the *FIRST Bright Quasar Survey* at the Very Large Array with the optical spectra obtained with the Kitt Peak 2.1-meter telescope. The galaxies were discovered by the Faint Images of the Radio Sky at Twenty- centimeters using a radio telescope in New Mexico.*(2)* Research will consist of looking at all the different types of galaxies within a certain area. From there the focus will turn to all the identified radio galaxies and starburst galaxies. By looking at the elements and emission lines in the graphs we were able to determine which were radio and starburst, and which were not. From there we used the lines to calculate the redshifts, velocity, and distance. Then we compared and contrasted the characteristics of the radio galaxies to the characteristics of starburst galaxies.

INTRODUCTION

Radio galaxies are for the most part found in elliptical galaxies. They were discovered in the 1940s when radio telescopes were used to scan the sky.*(3)* The radio galaxies are jet structured meaning they have jets, two lobes, counter jets, streams of electron-filled gas aimed in different directions from a black hole at the center of a galaxy*(4),* and hot spots. Between the lobes is the host galaxy, which is connected by jets. Jets are very important because they trace the path of material that is ejected from the active galactic nucleus and into the lobes. One jet is brighter and the lighter jet is the counterjet.*(5)* This structure makes the radio galaxies somewhat symmetrical.*(6)*

Figure 1. Parts of a Radio Galaxy.*(4)*



A Double Radio Source Associated with a Galactic Nucleus (DRAGN) is a radio source that is produced by jets produced by active galactic nucleus that is not in the Milky Way. This happens when an accretion disk forms around a black hole and spins, converts gravitational and rotational energy into excess perpendicular to the disk. Although DRAGNs are found in starburst galaxies, which produce radio emission lines and are mainly formed in galaxies that are larger than their host galaxies, such as elliptical galaxies.*(4)* They are comprised of lobes, jets, and a core just as other radio galaxies are, and they also have hot spots in the lobes.

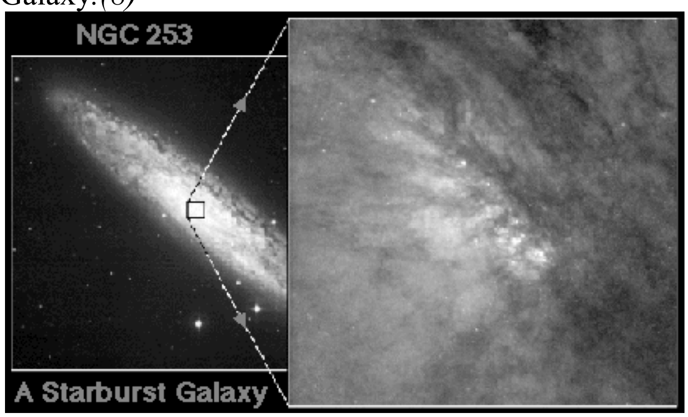
There are two types of radio galaxies, Franaroff-Riley type I (FR I) and type II (FR II). While the two groups share similar properties, such as their size, they have different UV properties, infrared properties, kinematics, and host galaxies. FR I are either old or they don't have enough material or energy to form stars. While they can no longer form new material, they are the most evolved of the radio galaxies. The FR II galaxies have higher redshifts but are less evolved; due to this they are richer groups, meaning that there are fewer things around the galaxy.*(7)*

To understand exactly what is researched, the basic knowledge of radio and starburst galaxies must be understood. A radio galaxy is formed when an AGN produces two persistent, oppositely directed plasma outflows. The outflows are what will soon to become the jets of the galaxy. While it is not known exactly what is inside the jets, they have fast moving electrons and magnetic fields, which make the high radio frequencies. The emission that occurs moves almost the velocity of sound. The jets are formed through the winding up of magnetic fields, which create a black hole in the nucleus of the galaxy. The winding of the black hole converts the energy from the magnetic field into mass. This initial winding is supersonic, meaning it is faster than the speed of sound.*(4)*

From the formation stage, the radio galaxy goes through the developmental stage. In this stage the galaxy grows as the jets stretch from the atmosphere or the AGNs, through the interstellar medium of host galaxies, lower densities and pressures of the outer halo of the galaxy, inter-galactic medium in surrounding galaxies, and finally to the low-density intergalactic medium. This growth of the galaxy and stretch of the jets extend outward and usually end up being bigger than the originating galaxy. The smallest known are only a few tens of parsecs across, while the largest are known to be up to several megaparsecs. The average radio galaxy is usually typically hundreds of kiloparsecs across. This is about twice the size of the Milky Way galaxy. The average life span of a radio galaxy is 20 million years.*(4)*

Starburst galaxies, the other type of galaxy being studied, are thought to be formed by close encounters or collisions of other galaxies. These collisions send a shock wave throughout the galaxy; pushing giant clouds of dust and gas, making them collapse and form hundreds of massive stars. These massive stars use up their fuel very quickly causing supernovas, which create more collisions, thus creating more stars. Starbursts are the most luminous galaxies and are thousands of light years in diameter.*(8)*

Figure 2. A Starburst Galaxy.*(8)*



The star formations within the galaxy that ends up creating most of the stars are known as ultra-luminous clusters. They are about 10-20 light-years across and can have luminosities up to 100 million times that of the Sun. These clusters are the densest star-forming environments known. The thing that sets starburst galaxies apart from the rest is their high, intense emission lines in the far-infrared. These lines are created by the ultraviolet that is emitted by the numerous hot stars being formed. These young stars are absorbed by the dust and remitted with higher wavelengths. These wavelengths rate second only to AGNs themselves.*(9)* While we know that starbursts last much less than the age of the universe, it is very difficult to estimate their age because new clusters are always being formed. This creates the starbursts extreme luminosity making it hard to see the older parts of the galaxy.*(10)*

OBSERVATIONS AND DATA REDUCTION

For our project, we looked at radio and starburst galaxies and then compared and contrasted them. We looked at the galaxies in the Right Ascension range of 07h 01m to 09h 59m in the *FIRST Bright Quasar Survey* at the Very Large Array with the optical spectra obtained with the Kitt Peak 2.1-meter telescope. When we recognized either a starburst or radio galaxy by its graph, we used the galaxy. Since each galaxy has its own graph, we were able to estimate whether the graph represented either a starburst or radio galaxy. We disregarded all the galaxies that were clearly not recognized as either radio or starburst galaxies. After amassing a reasonable amount of galaxies (about 70), we calculated the ratios between the prominent emission lines.

To find these ratios we divided the higher wavelength by the shorter one. We had to find the ratios of all the emission lines in order to discover which elements were responsible for the emission lines. The ratio was then compared to the ones posted on the "AGN Spectroscopy" packet on page 20. When a ratio in the packet that matched the calculated ratio was found, we knew that the elements forming the posted ratio were the elements responsible for the two emission lines that made up our calculated ratio. Based on the placement of [OIII], Hα, and Hβ lines, we were able to differentiate between starburst and radio galaxies. Radio galaxies have a small [OIII] line before a large [OII] line. Starburst galaxies have a large [OII] line preceding a small [OIII] line. These facts helped us determine which galaxies appeared to be starburst or radio galaxies and then helped us disregard the other galaxies. After the elements responsible for the emission lines were found, redshifts were calculated.

To find the redshifts, wavelengths for the elements that were commonly found in AGN were taken from a list also on page 20 of the "AGN Spectroscopy" packet. Then the wavelengths were plugged into a formula for redshifts and the redshift was found. The formula for a redshift is $1+z=\frac{\lambda obs}{\lambda rest}$ where λ_{obs} is the emission line that was found, λ_{rest} is the wavelength associated with the elements responsible for the emission line and z is the redshift. Since there were more than two emission lines found in most of the AGN, more than one redshift was calculated for each AGN. In this case, the redshifts were averaged. These averaged values, or original values if there were only two emission lines found, were the redshifts used to calculate other characteristics of the galaxies, such as velocity and distance. The formula for velocity is $v=c\frac{(1+z)^2-1}{(1-z)^2+1}$ where v is velocity, c is the speed of light (3.0×10^5 km sec^{-1}), and z is the redshift.

Distance is calculated by $d=\frac{cz}{ho}\frac{(1+.5z)}{(1+z)}$. In this equation d is the distance, c is the speed of light, z is the redshift and H_o is Hubble's constant (75km sec^{-1} Mpc^{-1}). After all the calculations were made, radio galaxies and starburst galaxies were compared to one another.

ANALYSIS AND RESULTS

For all the galaxies that we observed, both radio and starburst, the relationship between velocity and distance was linear, which Hubble's Law confirms. The vast majority of the galaxies we observed were of fairly low velocity. The galaxies of further distance/greater velocity seemed to be outliers in the data set. This is because Hubble's Law only works for low-redshift objects. Our comparison of sky location yielded less conclusive results; the data seemed to be scattered somewhat randomly. One observable pattern was that the starburst galaxies were all concentrated in the right ascension range between 8 and 9, and the radio galaxies were all located between 7 and 10. Generally speaking, however, there was a uniform lack of pattern among all observed galaxies. (Figure 4) Nearly every galaxy we observed had a redshift between 0 and 1; the only exceptions were two radio galaxies in the 2-3 range and one starburst galaxy between 4 and 5. (Figure 3)

Figure 3: Redshifts of AGN

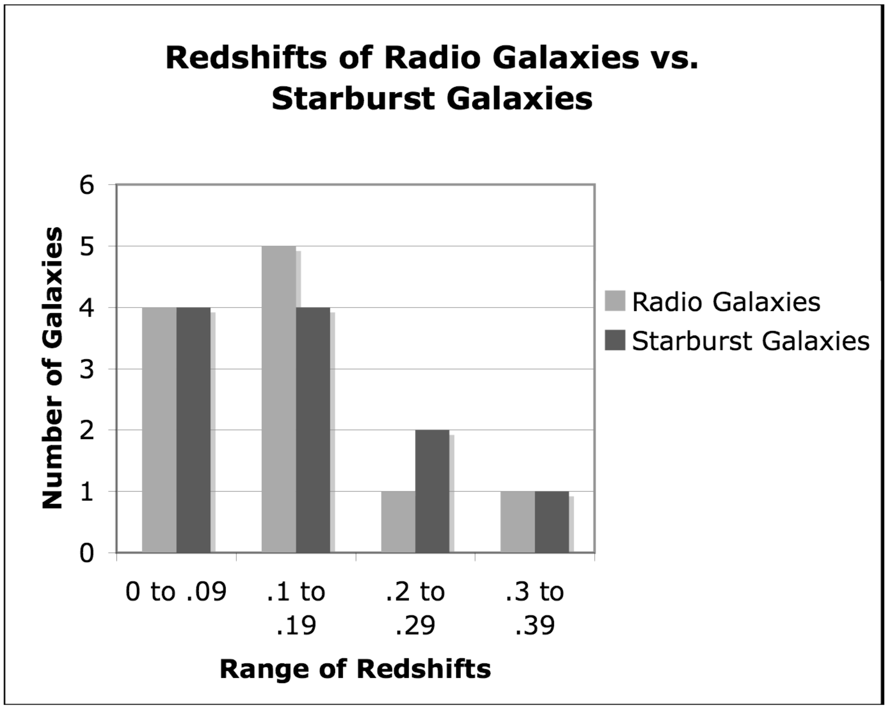


Figure 4: Location of AGN.

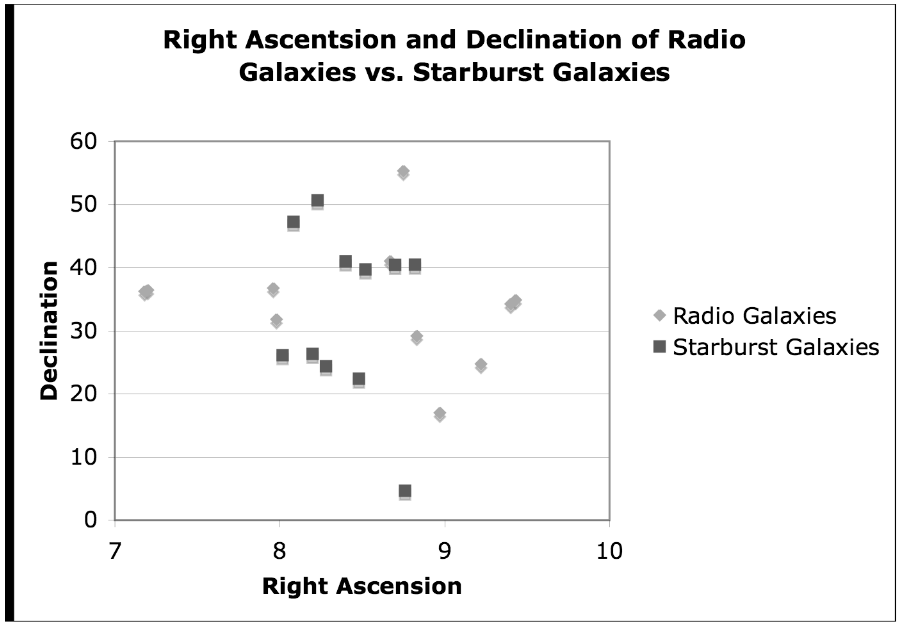


Figure 5. Velocity and Redshifts of AGN.

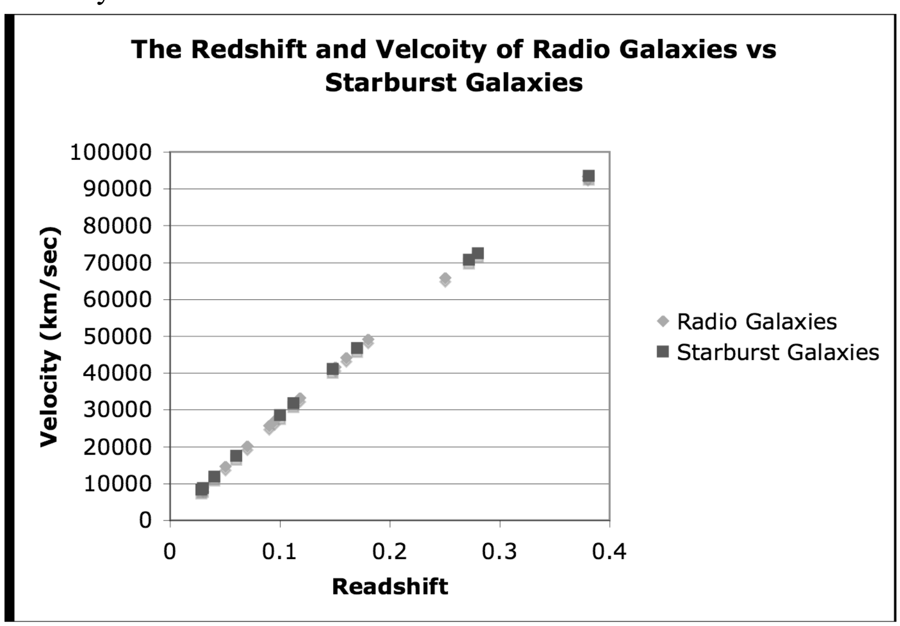
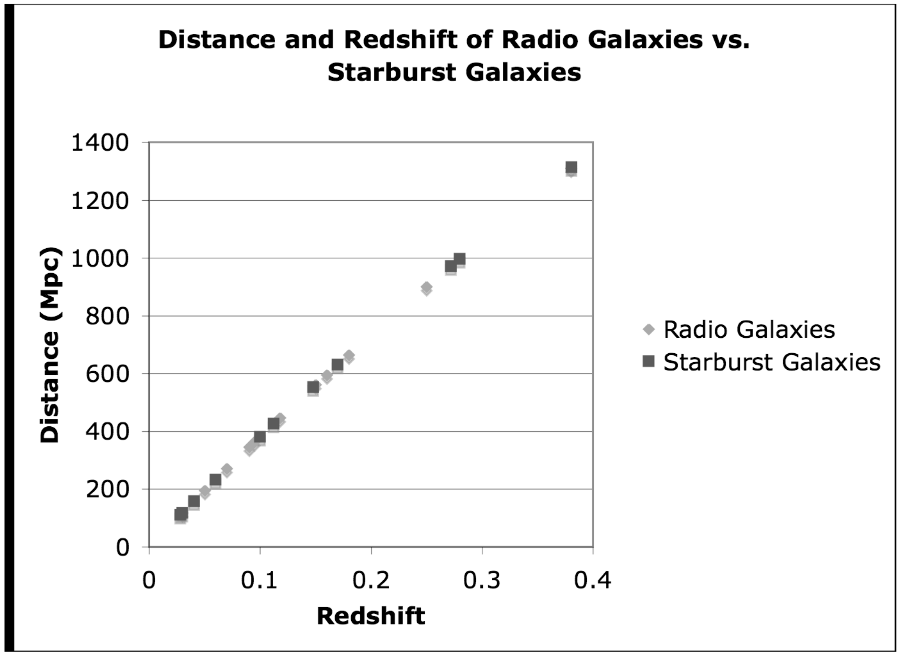


Figure 6. Distance and Redshifts of AGN.



DISCUSSION

As demonstrated by our results, radio galaxies and starbursts are similar in nearly all observable characteristics. While the elements responsible for their respective emission lines varied, the galaxies we observed had few other distinguishing characteristics.

For future projects, more characteristics for galaxies could be calculated. For example, luminosity was not found in this project. When we put checked to see if our AGN were seen with an optical telescope using the SIMBAD website, none of them were found because nobody has studied the galaxies in this research project. It would be interesting to see if there is a difference between what we found and the optical telescope. We could also use the Sloan Digital Sky Survey/ Sky Server to enter in the galaxies that were studied. From there we could find the recognized galaxies and find further characteristics as shown by the information on the survey. Another thing we could do is compare and contrast other types of galaxies besides Radio and Starburst. We could look at Quasars, BL Lacs, and Elliptical galaxies and get a further understanding of how they function compared to the already analyzed Starburst and Radio galaxies.

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