The Probability of Galaxy Merging Given Redshift, Morphology and Galactic Mass

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Abstract

In order to gain insight into how galaxies evolve we must understand more about how the galaxies merge. Galaxy merging is the process of two galaxies combining into one which in result helps move along galaxy evolution. Merging can be studied in two ways, though image analysis and via n-body simulation. However, images often don't provide enough detail regarding a merge and therefore simulations are more useful as they can provide data on an entire merge. Simulations, while better then images, they still have limitations as they are only predictions by scientists to which galaxies will most likely merge and can be incorrect. In order to improve on the accuracy of simulations, research was done to find the probability of merging. This was done by finding the probability of merging given redshift, morphology and galactic mass, which in future research can be applied to simulations. Overall, it was found that merging in galaxies was most probable if the galaxy had a high redshift range and was an elliptical galaxy. This suggests that if a galaxy has an elliptical morphology and is merging at a redshift above .079, it has the highest likelihood of merging with other galaxies opposed to galaxies with different properties. The probability of merging given a high redshift and elliptical morphology was 9.6%. In the future, this research can be applied to improving the accuracy of galaxy merging simulations which will help scientists gain clearer knowledge on how galaxies evolve.

Introduction

Galaxy merging is when two galaxies pass through each other until they finally become one. Not only does galaxy merging enable galaxies to continue through their lifespan by resulting in a change of morphologies, stimulate star production and change the galactic mass, studying galaxy merging is a crucial factor in the measurement of galaxy evolution. Therefore, studying these events is critical to learning about our universe. The two most common methods include using images of galaxies that are merging at the time of the photo to study the merge and running simulations of a merger between two galaxies that scientists predict will merge in the future. However, using images cannot gather enough data, and simulations have limitations. In order to increase the accuracy, the probability of galaxy merging given specific galactic mass, redshift, and morphology must be analyzed.

Review of Literature

Faults in Galactic Merging Research

Past research has looked at galaxy merging by studying a database known as the Galaxy Zoo and the images of merging galaxies taken from the Sloan digital sky survey. Galaxy properties such as stellar mass, morphology and redshift and their correlation to star production and active galactic nuclei of galaxies were analyzed (Figure 1) (Darg G, 2010). As in this study, numerous research projects typically use images of galaxies rather as an opposed to simulation, which in other research has shown to be more useful as more information can be provided. This is best shown in four similar studies done where galaxy merging is again studied however, with the use

Figure 1 sample of images from the Sloan Digital Sky Survey used in the research, an example of three different merging spiral galaxies (Darg 2010) of various simulations rather than images, also showing a larger gain of information of the merger history.(Nevin R, 2019/, Makino J,1996, Neistien E, 2007/ Lacey C, 1994) However, through the use of simulations, researchers are not limited to exactly one image of a certain galaxy.

Improving the Accuracy of Simulations

Using n-body simulations (simulation of a dynamical system of particles) to study galaxy merging, exemplifies how using simulations to study galaxies is preferred, as shown in figure 2 where each stage of the merger can be observed. (White S.D,1978,1982). However, very few, if any, studies have focused on the reliability of simulations since 1980 and the true reliability of simulations used today is put into question (Schruben L.W., 1980). To combat this issue, research has been done to model how simulations can be more reliable. (Resat H., 2001) A way to improve reliability is to find merging probability in order to know if the galaxies merging being simulated is plausible. While studying galaxy merging probability, three very important facts must be examined, morphology, redshift, and stellar mass. Galactic mass specifically is one of the most important aspects to consider while studying galaxy merging. Past research looks at the mass ratios of different galaxies in merging pairs and found that the galactic mass was key when studying galaxy merging (Lotz J, 2010). Using galaxy merging probability research, simulations of merging could become a strong tool to use in the study of galactic evolution.

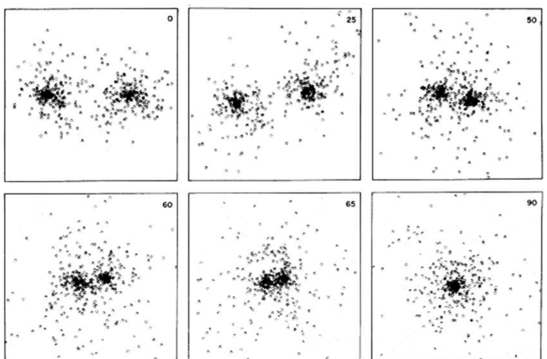

Figure 2 The projections of possible merging galaxies as they orbit each other, studied through simulation (White S.D. 1983)

Problem Statements Phase 1

- Correlations between average redshift and redshift of all the merging galaxies, their masses, and their morphologies of the different galaxies and merging stages is still unknown. Were there any connections between the average
- Little is known on how each type of redshift (photometric and spectroscopic) effect the circumstances of merging.
- If redshift affects what types of galaxies are merging more often at particular redshifts of each kind has yet to be further understood.
- How mass of galaxies take part into merging and how different morphologies effect merging is still a very little-known subject.
- Not much is known on if galaxy properties effect how long a galaxy merger goes through a certain stage.

Problem Statements Phase 2

- Images do not provide enough information needed to fully study galaxy merging, and the accuracy of simulations has not been tested for decades.
- If probability is used to find likelihood of merging in different scenarios, simulations could be far more accurate.

Objectives Phase 1

- Find how the different properties of galaxies effect galaxy merging so that understanding can be found on how galaxies gain certain properties not previously there before merging

  <u>O1 a</u>

    - Understand the effect of a galaxies properties on length of time in stage in order to understand how a galaxies property will further effect not only merging but longevity of merge.

- How often different galaxies will merge together in order to better understand and add characteristics to galaxy morphologies
- Compare the redshifts of the different galaxies in each merger pair to find if redshift is a property that will also effect merging.

  <u>O3 b</u>

    - Find if certain merging galaxies with different morphologies will become more common at different redshifts to learn reasons for certain merger pairs of different morphologies.

Objective Phase 2

- Find the probability of galaxy merging given a specific redshift therefore it is known at what redshifts is worth studying merging to get more accurate information on merging.
- Find the probability of galaxy merging given different galaxy morphologies therefore it is known what morphologies are worth studying the merging of to get more accurate information on merging.
- Find the probability of galaxy merging given different galactic masses therefore it is known what masses are worth studying the merging of to get more accurate information on merging.

Hypotheses Phase 1

- It was hypothesized that galaxy properties such as redshift and morphology will affect galaxy merging because past research shows that galaxies of certain morphologies tend to merger more than others.
    - It was further hypothesized that galaxy properties will affect how long a galaxy is in a stage but not significantly.
- It was hypothesized that there would be a correlation between redshifts in both galaxies of a merging pair as past research also shows possible correlation.
    - It was further hypothesized that certain galaxy pairs with different or similar morphologies will not be more likely at certain redshifts due to redshift and morphology having little to nothing to do with each other.
- It was hypothesized that there would be similar trends when studying the different redshifts due to past research suggesting correlations.

Hypotheses Phase 2

- If a galaxy has a high redshift range, the galaxy will have a higher probability of merging as past research has shown that higher redshifts have more galaxies present, therefore facilitation more merging due to galaxies in a closer proximity to each other.
- Galaxy merging will have a higher probability with a spiral morphology or galaxies with a similar morphology as past research has shown that the spiral morphology is one of the most common galaxy types and therefore should merge more often.
- Galaxies with higher masses will have a higher probability in the higher galactic mass range as past research shows objects with a higher mass have a stronger gravitational pull, therefore facilitating a galactic merge.

Methodology Phase 1

Role of Student and Mentor

At the beginning this research, my mentor assisted me in finding the database (Galaxy Zoo) and taught me how to sort through the data accurately. Over the course of 16 weeks, over two summers, I was responsible for sorting through the data taken from Galaxy Zoo, obtaining information from Galaxy Zoo on the properties of galaxies to aid the research and finding correlations between morphology, galactic mass and redshift. Lastly, I was responsible for analyzing the data in order to find potential trends in finding the probability of merging given different morphologies, galactic masses and redshifts.

Database

To achieve the objectives, the data was downloaded from the open source database, Galaxy Zoo. While the full data list included 900,000 galaxies, the data used was the from the 6008 merging galaxies. Data in Galaxy Zoo was originally collected from the Sloan Digital Sky Survey (SDSS).

Collecting Data

Through Galaxy Zoo program, each of the galaxy properties such as spectroscopic redshift, photometric redshift, morphology, merger stage, (if the galaxy is merging) and its galactic mass were identified.

Sorting Data

In order to conduct the research, all the data needed to be sorted based upon morphology, galactic mass, and redshift. A key on full meanings of abbreviations provided by Galaxy Zoo was used in order to facilitate sorting (see Figure 3). Morphology was the first characteristic studied. This is needed as morphology is one of the defining features of merging and therefore needed to be accounted for when assessing probability. Morphology was separately observed in the first and second galaxies in a merger pair then ordered alphabetically (A to Z). This was done in order to correlate one morphology to other morphologies, redshift or stage correctly so the probabilities could be found separately. Next, redshift was studied. Redshift was studied in photometric and spectroscopic for both galaxy pairs. Ranges of redshifts where found in this way in order to find the most frequent redshift for each morphology of merging galaxies for the first and second pair. This was done to find at what redshifts it would me most probable for a galaxy to merge. Lastly the average galactic mass was found for both elliptical and spiral galaxies in order to account for galactic mass into the probability of merging.

OBJECT1	-	SDSS DR7 objID for the first galaxy in the merging pair
OBJECT2	-	SDSS DR7 objID for the second galaxy in the merging pair
MORPH1	-	morphology of the first galaxy in the pair (S = spiral, E = elliptical, SU = spiral (unsure), EU = elliptical (unsure
MORPH2	-	morphology of the second galaxy in the pair (S = spiral, E = elliptical, SU = spiral (unsure), EU = elliptical (unsur
COMMENTS	-	additional comments from D. Darg or S. Kaviraj on the merging pair
STAGE	-	visually-classified stage of the merger (1 = "separated", 2 = "interacting", 3 = "approaching post-merger")
U_APP_1	-	apparent u-band magnitude of the first galaxy in the pair
G_APP_1	-	apparent g-band magnitude of the first galaxy in the pair
R_APP_1	-	apparent r-band magnitude of the first galaxy in the pair
I_APP_1	-	apparent i-band magnitude of the first galaxy in the pair
Z_APP_1	-	apparent z-band magnitude of the first galaxy in the pair
U_APP_2	-	apparent u-band magnitude of the second galaxy in the pair
G_APP_2	-	apparent g-band magnitude of the second galaxy in the pair
R_APP_2	-	apparent r-band magnitude of the second galaxy in the pair
I_APP_2	-	apparent i-band magnitude of the second galaxy in the pair
Z_APP_2	-	apparent z-band magnitude of the second galaxy in the pair
U_APP_ERR_1	-	measured uncertainty in apparent u-band magnitude of the first galaxy in the pair
G_APP_ERR_1	-	measured uncertainty in apparent g-band magnitude of the first galaxy in the pair
R_APP_ERR_1	-	measured uncertainty in apparent r-band magnitude of the first galaxy in the pair
I_APP_ERR_1	-	measured uncertainty in apparent i-band magnitude of the first galaxy in the pair
Z_APP_ERR_1	-	measured uncertainty in apparent z-band magnitude of the first galaxy in the pair
U_APP_ERR_2	-	measured uncertainty in apparent u-band magnitude of the second galaxy in the pair
G_APP_ERR_2	-	measured uncertainty in apparent g-band magnitude of the second galaxy in the pair
R_APP_ERR_2	-	measured uncertainty in apparent r-band magnitude of the second galaxy in the pair
I_APP_ERR_2	-	measured uncertainty in apparent i-band magnitude of the second galaxy in the pair
Z_APP_ERR_2	-	measured uncertainty in apparent z-band magnitude of the second galaxy in the pair
U_ABS_1	-	absolute u-band magnitude of the first galaxy in the pair, based on spectroscopic redshift
G_ABS_1	-	absolute g-band magnitude of the first galaxy in the pair, based on spectroscopic redshift
R_ABS_1	-	absolute r-band magnitude of the first galaxy in the pair, based on spectroscopic redshift
I_ABS_1	-	absolute i-band magnitude of the first galaxy in the pair, based on spectroscopic redshift
Z_ABS_1	-	absolute z-band magnitude of the first galaxy in the pair, based on spectroscopic redshift
U_ABS_2	-	absolute u-band magnitude of the second galaxy in the pair, based on spectroscopic redshift
G_ABS_2	-	absolute g-band magnitude of the second galaxy in the pair, based on spectroscopic redshift
R_ABS_2	-	absolute r-band magnitude of the second galaxy in the pair, based on spectroscopic redshift
I_ABS_2	-	absolute i-band magnitude of the second galaxy in the pair, based on spectroscopic redshift
Z_ABS_2	-	absolute z-band magnitude of the second galaxy in the pair, based on spectroscopic redshift
PLATE1	-	SDSS plate number for the observation of the first galaxy in the pair
MJD1	-	SDSS Modified Julian Date for the observation of the first galaxy in the pair
FIBERID1	-	SDSS fiber ID for the spectrosopic observation of the first galaxy in the pair
PLATE2	-	SDSS plate number for the observation of the second galaxy in the pair

Darg et al. (2010a) and Darg et al. (2010b)

Figure 3: an example of the key used to decipher abbreviations used in the data base. (exapmle; MORPH1, STAG)

Analyzing Data

After all information was gathered, it was analyzed to determine if there were statistically significant correlations using percent error. Redshift was compared to morphology and both pairs in all galaxy mergers in order to find average redshift and the most common redshift that galaxies tended to merge at. Morphology was compared to stage in order to find what stage a galaxy spent the most extended time merging in. Morphologies' impact on merging was studied in order to find the frequency at which galaxies with different or similar morphologies merged as well as how common galaxies of specific morphology's merged. Lastly, galactic mass was compared with morphology and redshift, and the mode was found for the mass of elliptical and spiral galaxies.

Methodology Phase 2

Probability

$$P(A|B) = \frac{P(A \cap B)}{P(B)} \tag{1}$$

Equation 1 is a given that probability formula where P stands for probability, A stands for first value and B stands for the second value. Once the statistics need for research were ready for use, based upon what probability circumstance was being found, they were placed into the equation as shown in equation 1. Probabilities were found by splitting the research into three stages. Probabilities of galaxies with lower galactic masses in the first galaxy pair given different redshifts, stellar masses, and morphologies which was then repeated for galaxies first in the merging pair with average and larger stellar masses. Each probability equation was run three times to account for when galaxies of different morphologies merged. (spiral-spiral pair, elliptical-spiral pair, elliptical-elliptical pair) Further, three redshift ranges used were to be run three times as well to account for every possible redshift.

Results Phase 1

General Galaxy Merging

Before any specific objectives could be achieved, an overall understanding of how the galaxies were merging (with similar morphologies or not) and quantities how many of each type galaxy that merged had to be found (as shown in figure 5). A comparison of quantity of galaxy merging between different and similar morphologies also had to be found (as shown in figure 6) This was needed in order to separate data that was really due to a property or if it was just due to more of one galaxy then the others. Overall 6004 galaxies mergers were studied, of which included spiral galaxies, elliptical Galaxies, unsure spiral galaxies and, unsure elliptical galaxies. These four galaxies were studied as they were the four different galaxies observed by the Sloan Digital Sky Survey (SDSS) Out of these, the biggest quantities of galaxies pulled from the Sloan Digital Sky Survey (SDSS) were Spiral galaxies.

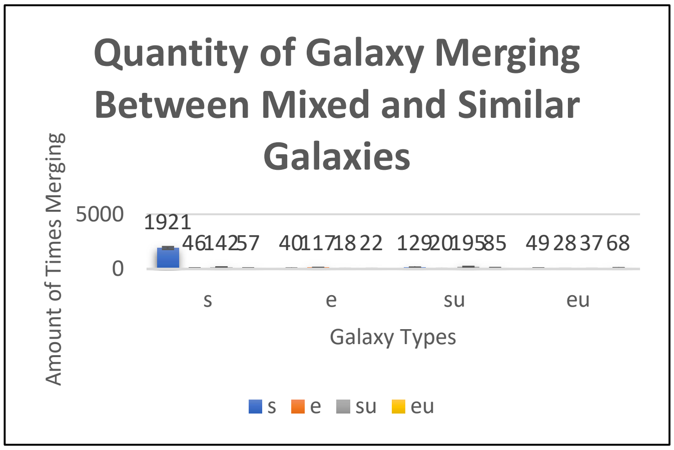

Figure 5 How many galaxies are merging between different morphologies. S stands for spiral galaxies, e stands for elliptical galaxies, su stands for unsure spiral and eu stands for unsure

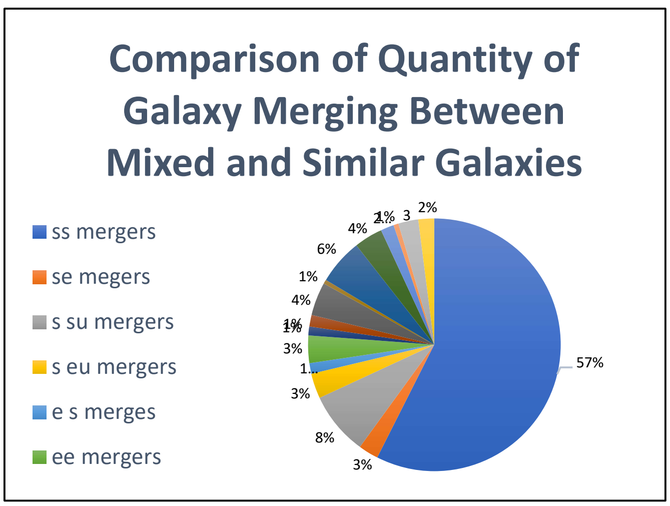

Figure 6 A comarison of how many merger pairs are merging. S standing for spiral, e standing for elliptical, and u standing for

A comparison of all galaxies to merging galaxies Merging galaxies and their morphologies

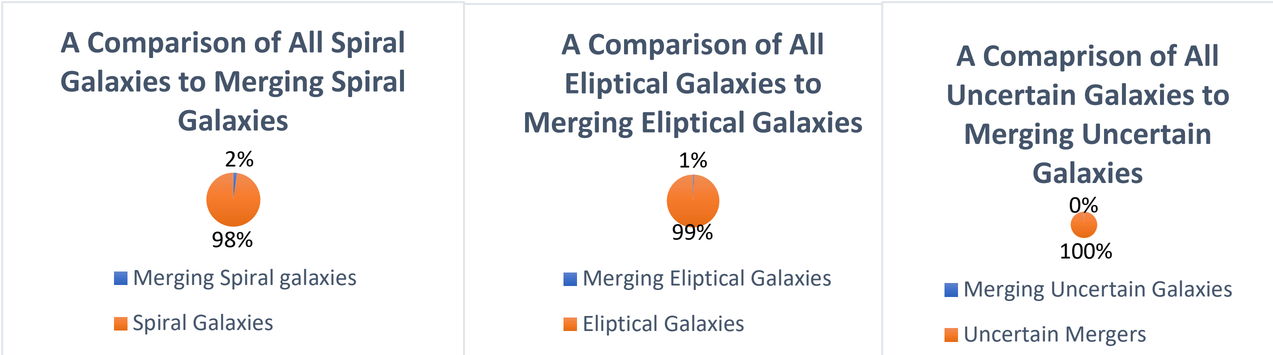

Figure 7 Here, all galaxies taken by the SDSS are compared to the amount of merging galaxies taken by the SDSS

were also compared to all merging galaxies and their morphologies (as shown in figure 7). Figure 7 shows what part of all the galaxies observed by SDSS where merging. As comparison for figure 7, how many total galaxies that were observed merging or not had to be compared to total galaxies merging. A total of 900,000 galaxies were observed by SDSS and only 6,004 of those were merging galaxies.

Redshift

Ranges of redshifts (z) of merging galaxies Before most redshift (z) calculations could be done, a general range of what the galaxies redshifts where had to be found as a comparison (as shown in figure 8). Figure 8 shows a gradual decrease in the number of galaxies that are merging as the range becomes lower and lower.

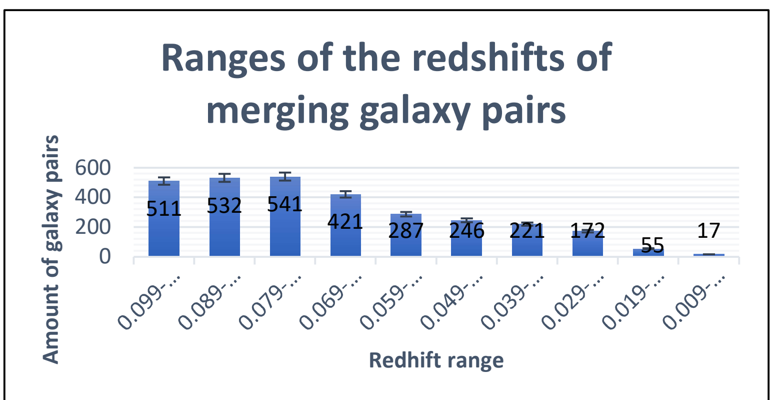

Figure 8 The ranges of all the redshifts of what galaxies were studied by the SDSS compared to how many galaxies merged in each rage

Out of the 3,002 galaxy merger pairs studied, 2,292 of them merged when z was 0.05 or greater.

Average spectroscopic and photometric \ redshift of galaxies For all types of galaxies, in the first and second pair of the merger, the average spectroscopic and photometric redshift was found. (as shown in figure 9 and 10) Spectroscopic redshift is the interaction between an object and electromagnetic radiation. Figure 9 shows the average spectroscopic redshift for each galaxy and its morphology. All the galaxies were spread out on a large redshift range and in past research using the same galaxies from SDSS, this is shown. (Darg, 2010) The average spectroscopic and photometric redshift is higher on the scale as the smallest redshift looked at was less than 0.0.

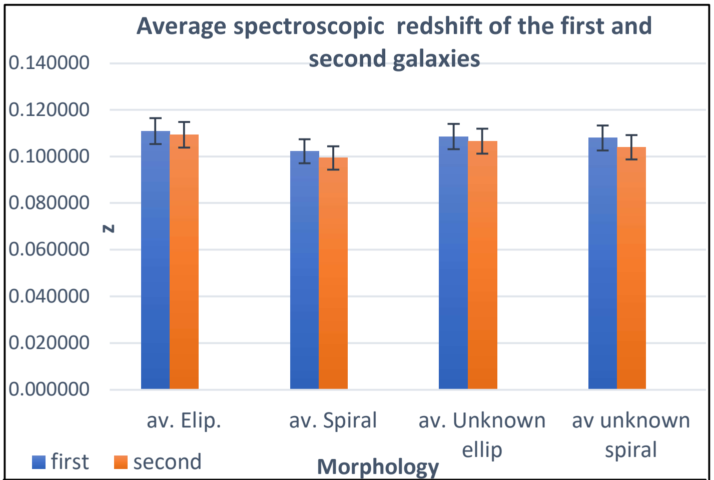

Figure 9 the average spectroscopic redshift for different morphologies from galaxy pairs The first galaxy is shown in blue and the second galaxy is shown in orange

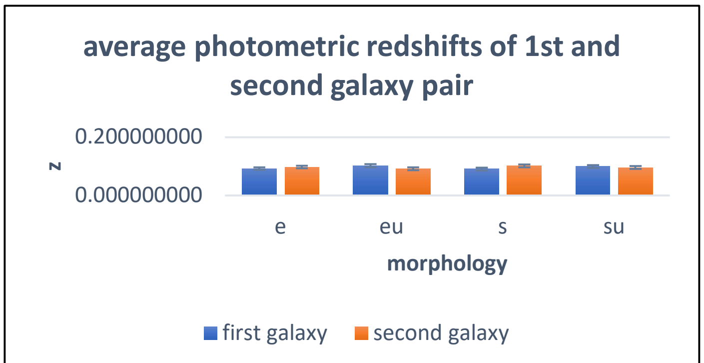

Figure 10 Average photometric (photoz) redshift (z) when looking at the second galaxy in the galaxy pair. The first galaxy is shown in blue and the second galaxy is shown in orange

Average redshift of galaxies with different and similar

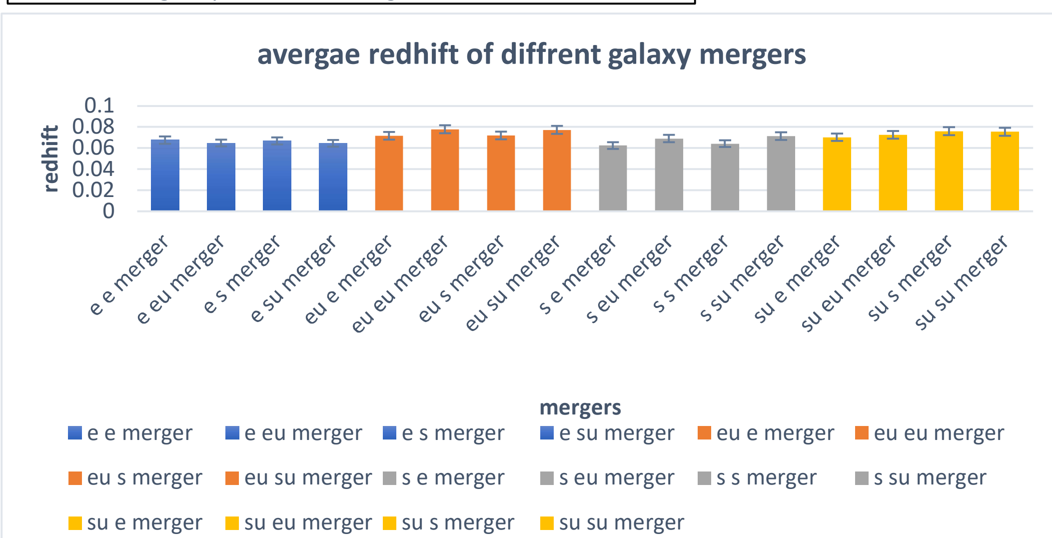

Figure 12 Average redshift for galaxy pairs of different morphologies, s stands for spiral e stands for elliptical u stands for unsure. Elliptical mergers are shown in blue, unsure elliptical galaxies are shown in orange. Spiral galaxies are shown in grey, and unsure spiral are shown in yellow.

morphologies was also found. This was done in order to learn if there is a correlation between galaxy pairs and their morphologies and redshift.

Modes of Redshifts Mode of redshift had to be calculated for all galaxy morphologies to find a

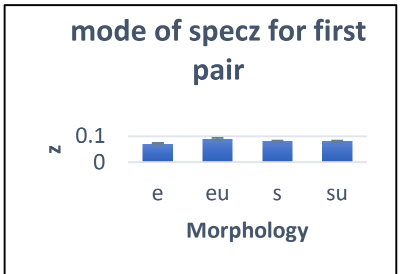

Figure 12 The mode of spectroscopic (specz) redshift for the first galaxy pair. Z is redshift

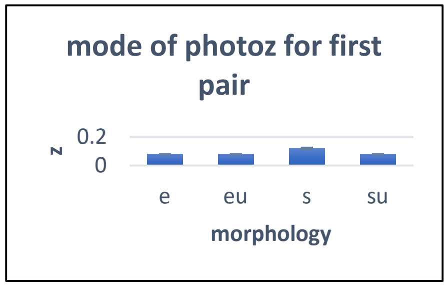

Figure 13 The mode of photometric (photoz) redshift for the first galaxy pair. Z is redshift

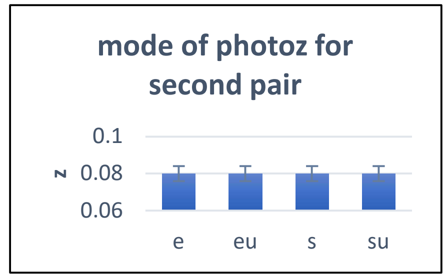

Figure 14 The mode of photometric (photoz) redshift for the second galaxy pair

correlation (as shown in figure 12,13, and 14). Figures 12, 13 and 14 all show the redshift most commonly found for each morphology. When looking at both types of redshift in both galaxy pairs at all morphologies, there was a similar redshift amongst a majority of them (0.08). Spectroscopic and photometric redshift were both looked at and both still show a similar mode of redshift for most morphology which shows that at that similar redshift there must have been an abundance of galaxies merging.

Galaxy Merging Stages

Merger pairs were sorted according to what stage they were in. There are three stages in merging. Stage one is the initial gravitational pull between two galaxies. Stage two is when the galaxies will pass through each other. Finally Stage three is when the galaxies will eventually come together as one. The number of galaxies in each

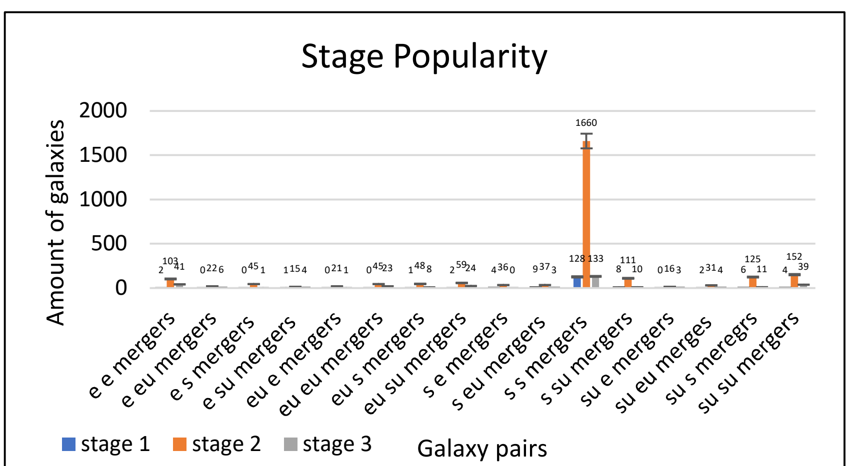

Figure 3 This shows how many of each galaxy pair of different and similar morphologys there are at diffent stages. Stage one is shown in blue, stage two is hsown in orange and stage three is shown in grey.

stage was looked at with every type of galaxy morphology pair. This was done to find if morphology had an effect on how long a galaxy stayed in a stage.

Results Phase 2

Redshift Probability

To begin finding the probability section of the research, the probability two galaxies will merge given various redshifts was studied. Redshift was split in to three ranges, z=0.000-0.039, 0.040-0.069, and 0.070-.099. this was done to efficiently find the probability rather than unnecessary study them individually. When a galaxy is in an interval of z=0.000-0.039, it has a probability to merge at 8.25%. When a galaxy is in an interval of z=.040-.069 it had the smallest probability to merge at 7.25%. When a galaxy is merging between z=.079-.099 it had the largest probability to merge at 9.50%.

Morphology Probability

Next, the probability of merging given different morphologies was studied. Given that a galaxy is spiral, it had the highest probability of merging if the nearest galaxy was also spiral. The probability that two spiral galaxies would merge was 22%. Given that a galaxy was spiral, and the nearest galaxy is an elliptical, the probability of merging was 1.5%. Given that a galaxy is elliptical and the nearest galaxy in the is also elliptical, the chances of merging are the lowest at 1.25%.

Galactic Mass Probability

The probability of merging with respect to galactic mass was looked at. Galactic masses were broken into two groups based on whether they were more or less than 1 trillion stellar masses. Galaxies that had smaller galactic masses had the smaller probability of merging at 5.25%. Galaxies that were higher in mass had a larger probability of merging at 6.25%.

Overall Merging Probability

Due to the fact that the galactic masses were so close, all galaxies studied were approximately the same mass, therefore exclude as a factor of overall probability. Given that a galaxy is in the lowest redshift range and spiral the probability for it to merge with the nearest galaxy is .4%, and given the galaxy is elliptical the probability of merging is 8%. Given a galaxy is in the middle redshift range and the galaxy was spiral, the probability of merging is 7.27%, and given the galaxy is elliptical, the probability of merging is 8%. Lastly, given a galaxy merging in the highest redshift range and spiral, the probability of merging is 9.5%, and given the galaxy is elliptical, the probability of merging is 9.6%. All data on probability including spiral galaxies can be found in table 1 while all data on probability including elliptical galaxies can be found in table 2.

Table 1: Includes the probability of redshift and spiral galaxies merging with other galaxies, shows probability of low range redshift, spiral probability and probability of merging given low range redshift and spiral morphology.

redshift (z=0.000-0.039) and spiral probability	**redshift probability (z=0.000-0.039)**	**spiral probability**	**Probability given redshift (z=0.000-0.039) and spiral morphology**
1.82%	8.25%.	22%	0.40%
redshift (z=0.040-0.069) and spiral probability	**redshift probability (z= 0.040-0.069)**	**spiral probability**	**Probability given redshift (z=0.040-0.069) and spiral morphology**
1.60%	7.25%.	22%	7.27%
Redshift (z=0.070-.099) and spiral probability	**redshift probability (z=0.070-.099)**	**spiral probability**	**Probability given redshift (z=0.070-.099) and spiral morphology**
2.10%	9.50%.	22%	9.50%

redshift (z= 0.000-0.039) and elliptical probability	**redshift probability (z=0.000-0.039)**	**elliptical probability**	**Probability given redshift (z= 0.000-**

			0.039) and elliptical morphology
0.10%	8.25%	1.25%.	8%
Redshift (z=0.040-0.069) and elliptical probability	**redshift probability (z=0.040-0.069)**	**elliptical probability**	**Probability given redshift (z=0.040-0.069) and elliptical morphology**
0.10%	7.25%.	1.25%	8%
Redshift (z=0.070-.099) and elliptical probability	**redshift probability (z=0.070-.099)**	**elliptical probability**	**Probability given redshift (z=0.070-.099) and elliptical morphology**
0.12%	9.50%.	1%	9.60%

Table 2: Includes the probability of redshift and elliptical galaxies merging with other galaxies, shows probability of low range redshift, elliptical probability and probability of merging given low range redshift and elliptical morphology.

Discussion

General Galaxy Merging

While considering general galaxy merging, morphology was studied first. When looking at what galaxy pairs were merging the most, spiral, spiral mergers were the most common merger group. A reason for this may be that a majority of the galaxies observed from SDSS were spiral galaxies, although it is notable that spiral galaxies tended to merge most with other spirals as opposed to any other galaxies. When redshift ranges and number of galaxies within those ranges was observed, it was observed that the higher the redshift (therefore longer ago in the history of the universe) the more mergers. Next, when studying average of spectroscopic redshift, there was a consistency with the first and second galaxy in each merger pair for every morphology traveling at very similar redshifts. While studying average of photometric redshift, there was no similarities between morphologies, however they all had a similar average redshift. When looking at average redshift for different merger morphology pairs there was no correlation besides that they all have a redshift in the same range. While studying mode of spectroscopic and photometric redshift average for each galaxies type, 0.08 was the most common redshift for a majority of morphologies. It can be concluded that galaxies that are classified as spiral are more likely to merge because spiral galaxies had the highest number of mergers merged. Further, it can be concluded that galaxies will be more likely to merge if they are merging with a galaxy of the same morphology as shown by each galaxy morphology having the highest quantity of mergers when paired with a galaxy of a similar morphology. It is also suggested that a majority of the merging galaxies looked at in this study merged at a redshift of .08, which is a high redshift. Because the data shows that galaxies merge more at higher redshifts, it is implied that there were more galaxies traveling at higher redshifts making merging more likely as the gravitational pull between galaxies would be strong as result of less space between them.

Probability

While studying the probability of galaxy merging given different galaxy properties such as redshift, morphology and stellar mass each property had to studied meticulously. While studying redshifts, it was found that galaxies had a higher probability given the redshift was in the highest range. This suggests that galaxies with higher redshifts have higher probabilities of merging. This is most likely due to the fact that there are more galaxies at higher redshifts therefore facilitating merging as when there are a larger number of galaxies in one area, there is stronger gravitational pull. Studying the probability of merging given different morphologies showed that galaxies will have the highest chance to merge if at least one galaxy in the pair is spiral. Lastly, when studying the probability of galaxy merging given different stellar masses, it was found that galaxies with higher stellar masses have the highest probability of merging. This is most likely due to galaxies with higher stellar masses having a stronger gravitational pull.

Overall it was found that a galaxy had the highest probability of merging if it is traveling at a high redshift, is a spiral galaxy and has a larger galactic mass.

Future Research

There are many factors that impact if a galaxy merges or does not merge, while redshift, morphology and stellar mass all play important roles, there are many other smaller properties a galaxy can have that can impact merging just as important to larger properties. Therefore, in the future this study should be repeated while studying every property known to impact merging in some way. Further, repetition of this research done with an even larger data sample could lead to future improvements on simulations to enhance the accuracy and allow scientists to more accurately study galaxies and re-visit the work done by researchers such as Schruben L.W in1980 on accuracy of simulations and apply it to a more modern setting.

Conclusion

The overall objective of this research was to find how properties (stellar mass, redshift and morphologies) of galaxies affected galaxy merging and to find the probability of merging given different redshifts, morphologies and stellar masses. This was done by finding a database (Galaxy Zoo) that had information on galaxies, specifically merging galaxies, to collect data using the SDSS galaxies, sorting all of the necessary data to find patterns and correlations within what information is found when looking at each property and merging, and finally analyzing said data it to make conclusions based on past research and other observations made. Then the data from phase one was used and put into probability formulas to find the probability of galaxy merging under different circumstances. There were three hypotheses made during stage two, all of which were supported. The probability of merging will be the highest given merging at high redshift. Next, the probability of merging will be the greatest if tone of the merging galaxies is spiral. Lastly the probability of merging will be the highest when a galaxy has a high stellar mass. This research is necessary in taking steps to further understanding galaxy interaction. Using the methodology created, more research can be done on galaxy interaction. Studying is extremely vital to the understanding of galactic evolution which is very important to understanding galaxy creation and the beginnings of the universe. In the distant future, a deeper knowledge of how galaxies work will facilitate intergalactic travel, as researchers will know more of what to expect when designing space crafts.

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