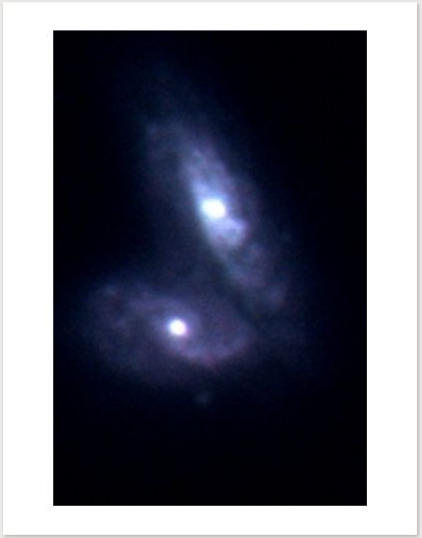
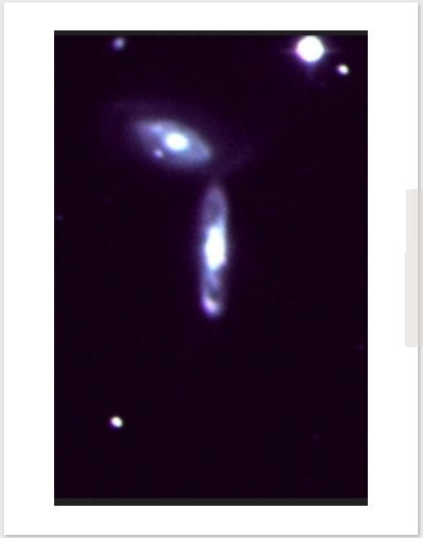
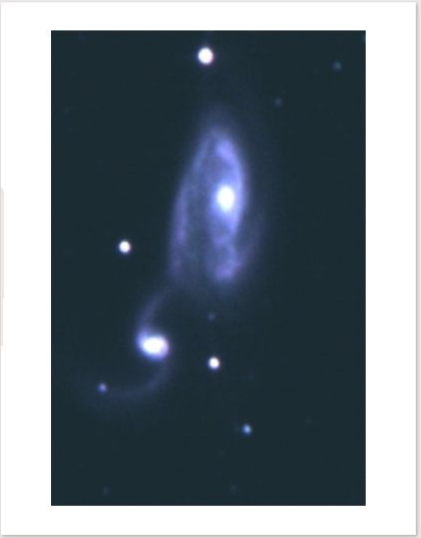





Color Ratios in Interacting Galaxies

Megan Schultze

Objectives

The objective of this project was to compare the color ratios of galaxies taken in Blue, Visible, and Red filters using the ratios B/V and V/R. These ratios were used to calculate the the average instrumental magnitude difference between different regions. The galaxies selected for this project were interacting spiral galaxies. The goal was to compare the colors of the interacting side and non-interacting side then see if there was a pattern between the difference galaxy pairs.

Data Acquisition

Imaging was done with McDonald Telescope on 3/26/23. Images of four different pairs of interacting spiral galaxies were taken:

- NGC 5394/5394
- NGC 3786/3788
- NGC 4567/4568
- NGC 5426/5427

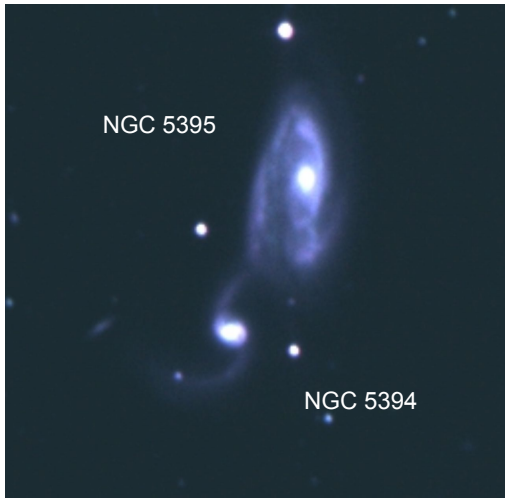
Each galaxy was imaged for three exposures of 180 seconds for each filter: B, V, and R.

Data Analysis

For each galaxy pair the following analysis was done:

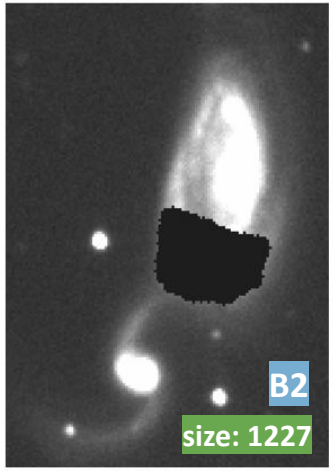
- Images for the different galaxies combined by taking the median values
- The regions were selected for each galaxy
- Probability distribution of B/V and V/R ratios were created to compare the opposite sides (interacting side vs. non-interacting side) of the same galaxy
  - KS-test done on the distributions to determine if they are different
- Graphed V-R vs. B-V color-color diagram of the mean instrumental magnitude difference of each of the regions
  - T-test completed to compare the means in the opposite sides of the galaxy
  - Unexpected results in the color-color plots indicate that there may be issue with data

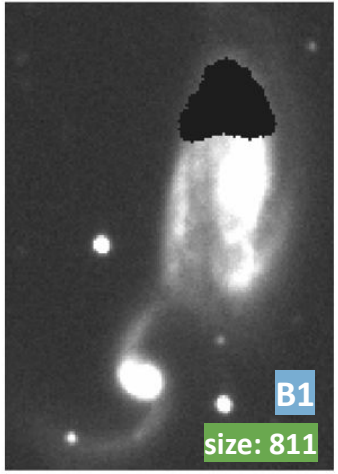
Regions of NGC 5394 & NGC 5395

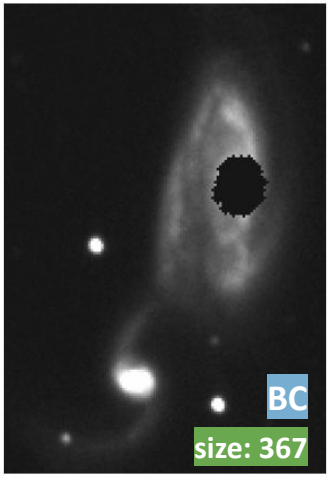


Key:
B - the larger of the two galaxies
S - the smaller of the two galaxies
2 - interacting side
1 - opposite side of galaxy
C - core region of galaxy

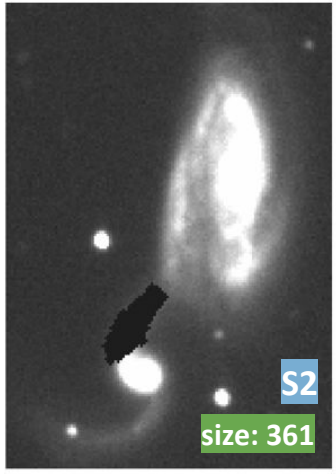
Interacting Side | Opposite Side | Core

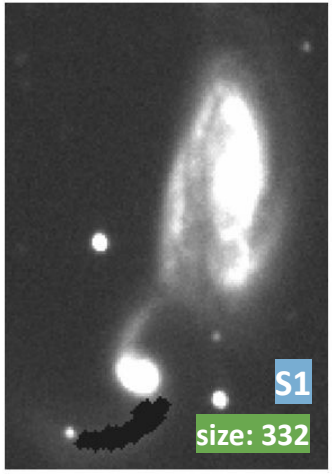


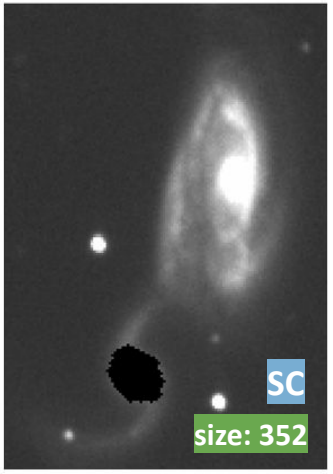




NGC 5395







NGC 5394

*selected regions are in black

Probability Distribution of Regions in NGC 5394 and NGC 5395

The probability distributions shown compare the interacting (2) and non-interacting (1) sides' color ratios distribution.

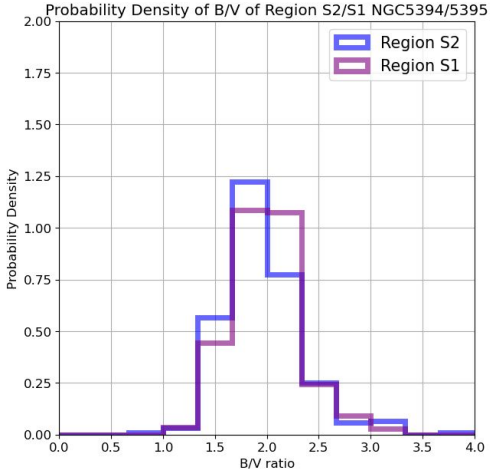
KS-test results			
Regions	Colors	Statistic	P-value
S1/S2	B/V	0.112	0.0226
S1/S2	V/R	0.0627	0.477
B1/B2	B/V	0.186	2.53e-15
B1/B2	V/R	0.0720	0.0118

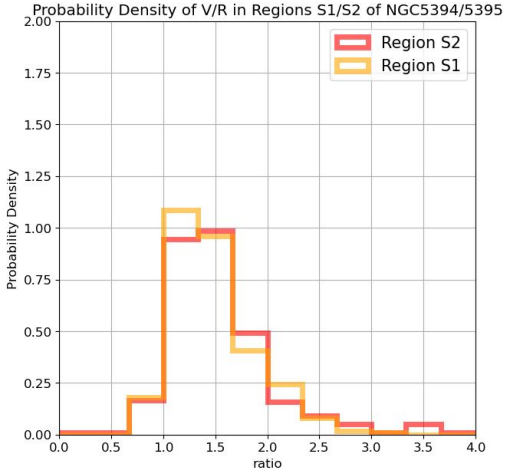
The KS-tests indicate that the regions do differ in probability distributions, expect for NGC 5394's V/R distribution.

B/V Histograms

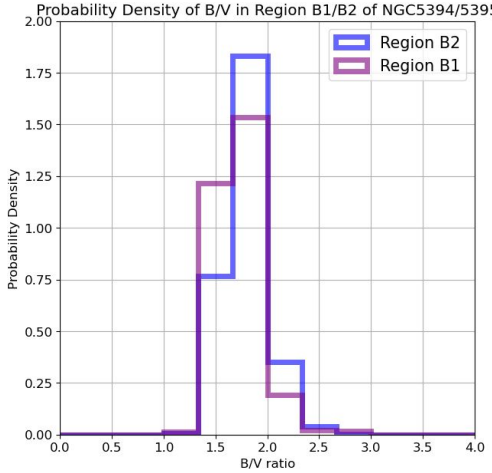
V/R Histograms

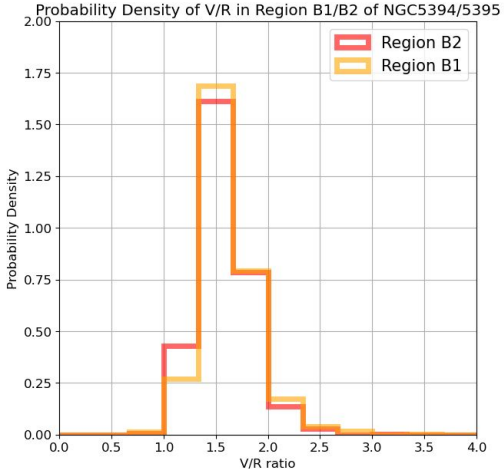
NGC 5394 (small)





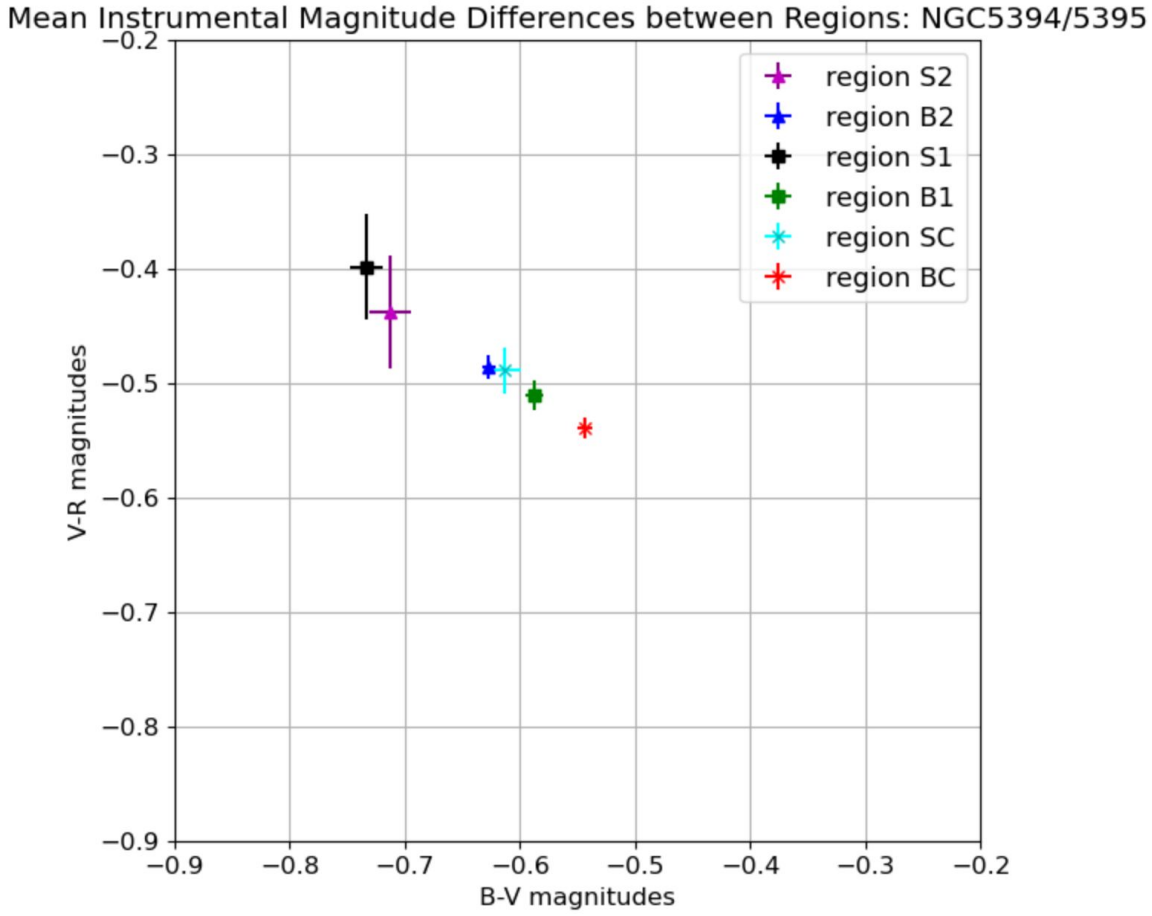
NGC 5395 (big)





Comparison of Mean Ratios and in NGC 5394/5395

A T-test was used to determine if the difference in the mean was statistically significant. This compares means in opposite sides of NGC 5395 (B) and NGC 5394 (S) for both color ratios.



T-test - Not significant difference between S1 & S2:

Regions	S1 & S2
ratio	B/V
S1 mean	-0.733
S2 mean	-0.712
T-test p	0.532

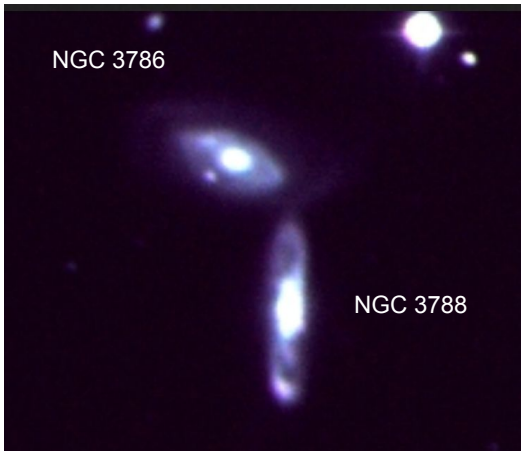
Regions	S1 & S2
Ratio	V/R
S1 mean	-0.398
S2 mean	-0.438
T-test p	0.0522

T-test -Statistically significant difference between B1 & B2 - but indicate that B2 is bluer and redder:

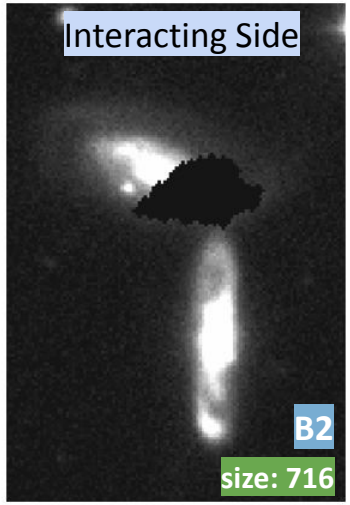
Regions	B1 & B2
ratio	B/V
B1 mean	-0.587
B2 mean	-0.627
T-test p	2.23e-12

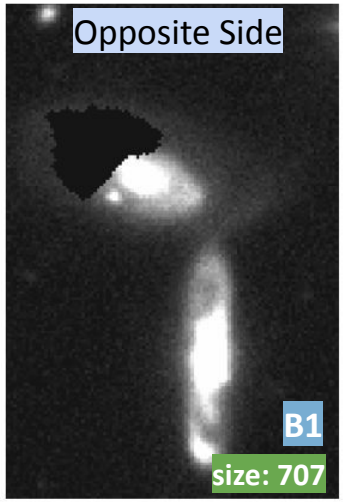
Regions	B1 & B2
ratio	V/R
B1 mean	-0.511
B2 mean	-0.486
T-test p	0.00139

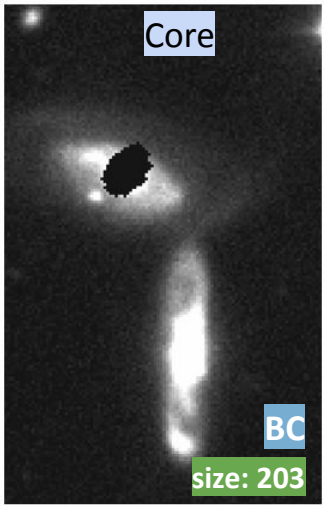
Regions of NGC 3786 & NGC 3788



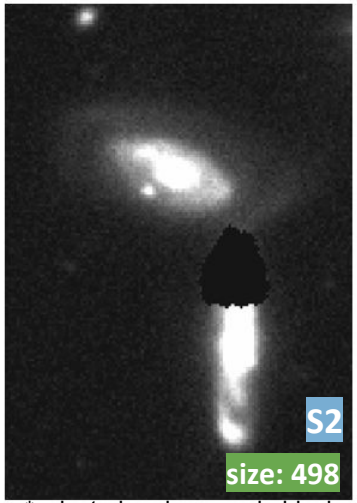
Key:
B - the larger of the two galaxies
S - the smaller of the two galaxies
2 - interacting side
1 - opposite side of galaxy
C - core region of galaxy

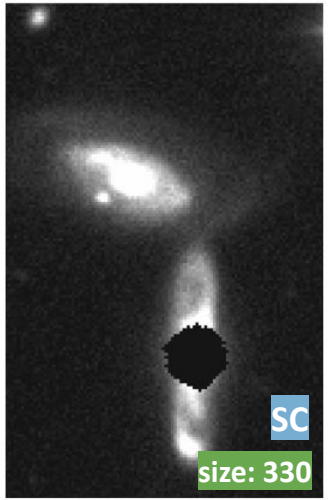






NGC 3786





NGC 3788

*selected regions are in black

Probability Distribution of Regions in NGC 3786 and NGC 3788

The probability distributions shown compare the interacting (2) and non-interacting (1) sides' color ratios distribution.

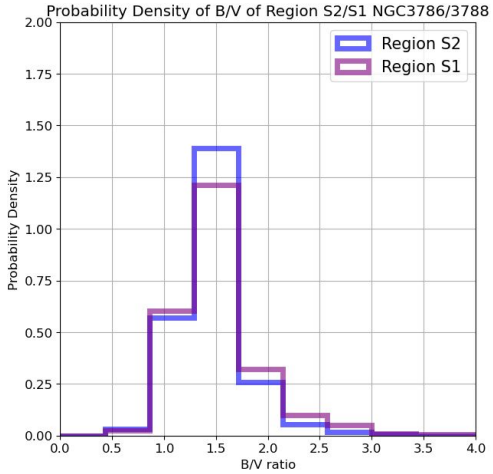
KS-test results			
Regions	Colors	Statistic	P-value
S1/S2	B/V	0.0752	0.114
S1/S2	V/R	0.0716	0.148
B1/B2	B/V	0.108	0.000475
B1/B2	V/R	0.226	2.3e-16

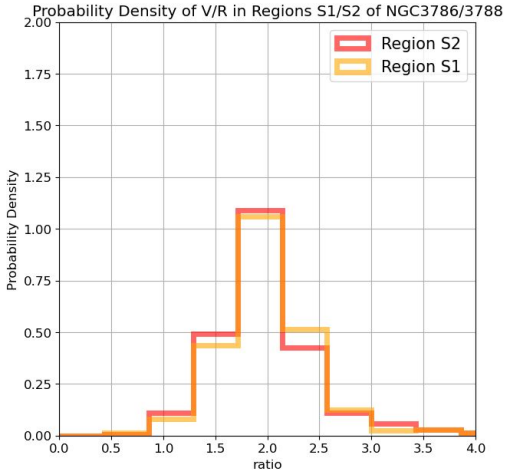
The KS-tests indicate that the regions in NGC 3786 (B) do differ, but NGC 3788's distributions are not statistically significant.

B/V Histograms

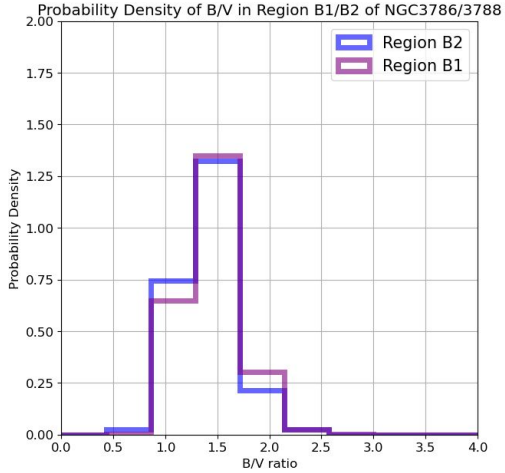
V/R Histograms

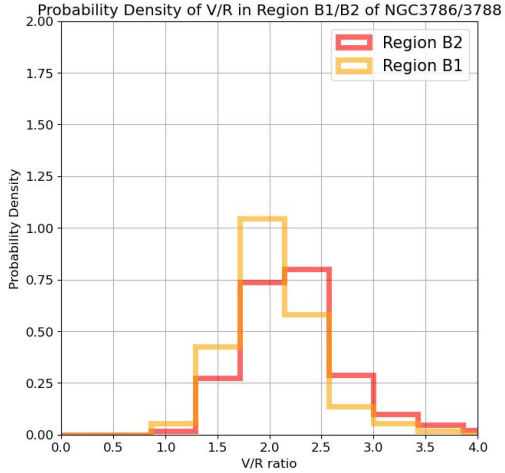
NGC 3788 (small)





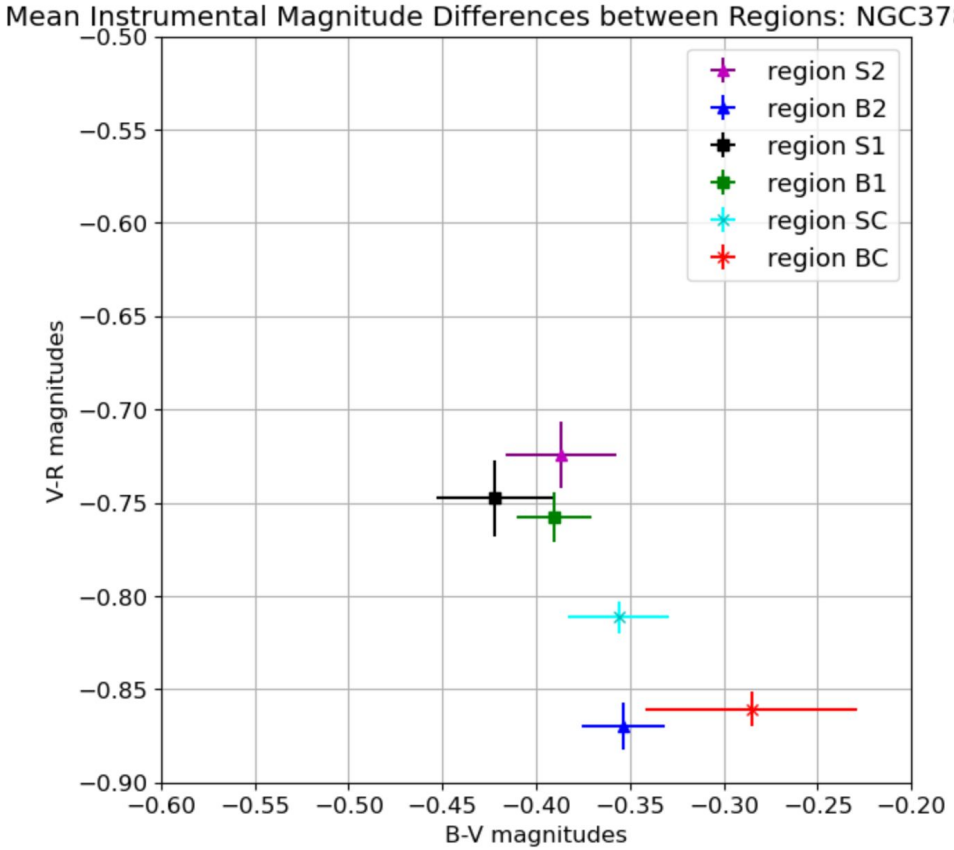
NGC 3786 (big)





Comparison of Mean Ratios in NGC 3786/3788

A T-test was used to determine if the difference in the mean was statistically significant. This compares means in opposite sides of NGC 3786 (B) and NGC 3788 (S) for both color ratios.



T-test - Statistically significant result for B/V - S1 bluer:

Regions	S1 & S2
ratio	B/V
S1 mean	-0.422
S2 mean	-0.387
T-test p	0.00806

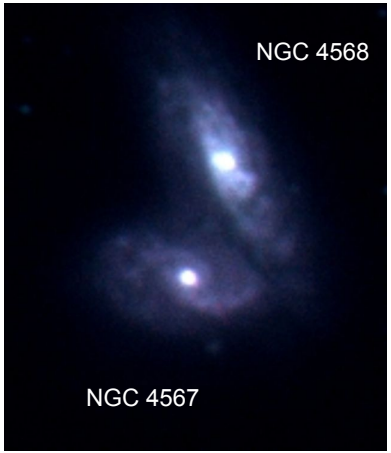
Regions	S1 & S2
Ratio	V/R
S1 mean	-0.750
S2 mean	-0.735
T-test p	0.0912

T-test - Statistically significant difference between B1 & B2 - but indicate that B1 is bluer and redder:

Regions	B1 & B2
ratio	B/V
B1 mean	-0.391
B2 mean	-0.354
T-test p	3.27e-4

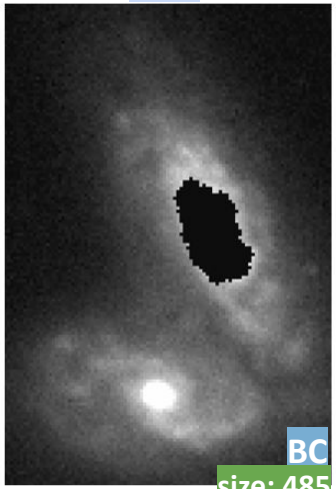
Regions	B1 & B2
ratio	V/R
B1 mean	-0.764
B2 mean	-0.870
T-test p	3.18e-13

Regions of NGC 4567 & NGC 4568

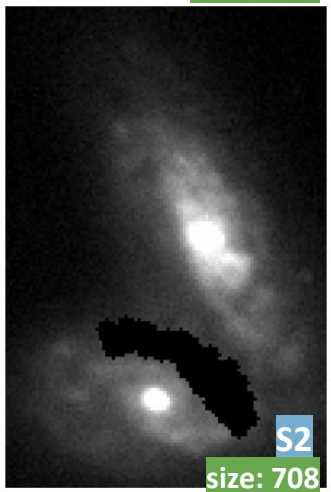


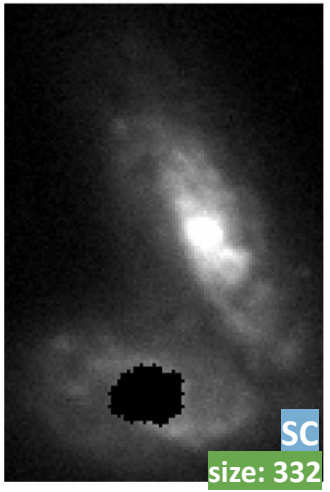
Key:
B - the larger of the two galaxies
S - the smaller of the two galaxies
2 - interacting side
1 - opposite side of galaxy
C - core region of galaxy

Interacting Side | Opposite Side | Core



NGC 4568





NGC 4567

*selected regions are in black

Probability Distribution of Regions in NGC 4567 and NGC 4568

The probability distributions shown compare the interacting (2) and non-interacting (1) sides' color ratios distribution.

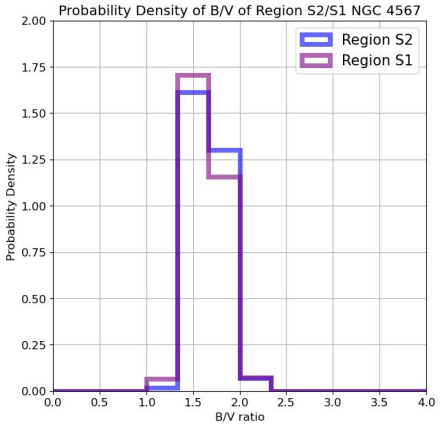
KS-test results			
Regions	Colors	Statistic	P-value
S1/S2	B/V	0.0812	0.00902
S1/S2	V/R	0.156	5.16e-9
B1/B2	B/V	0.138	9.07e-10
B1/B2	V/R	0.147	5.94e-11

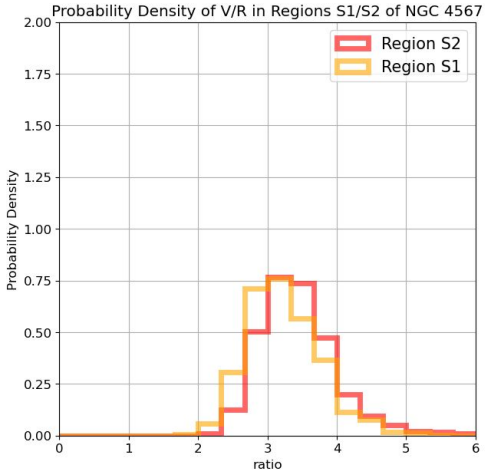
The KS-tests indicate that the regions in NGC 4568 (B) and NGC 4567 (S) do differ in their color ratios of B/V and V/R.

B/V Histograms

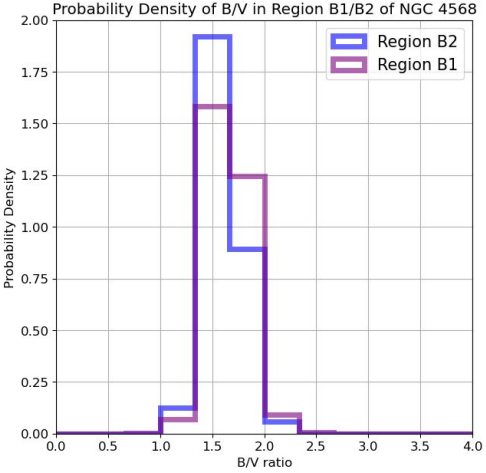
V/R Histograms

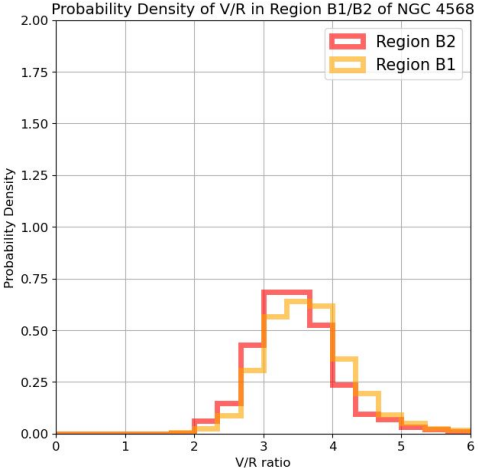
NGC 4567 (small)





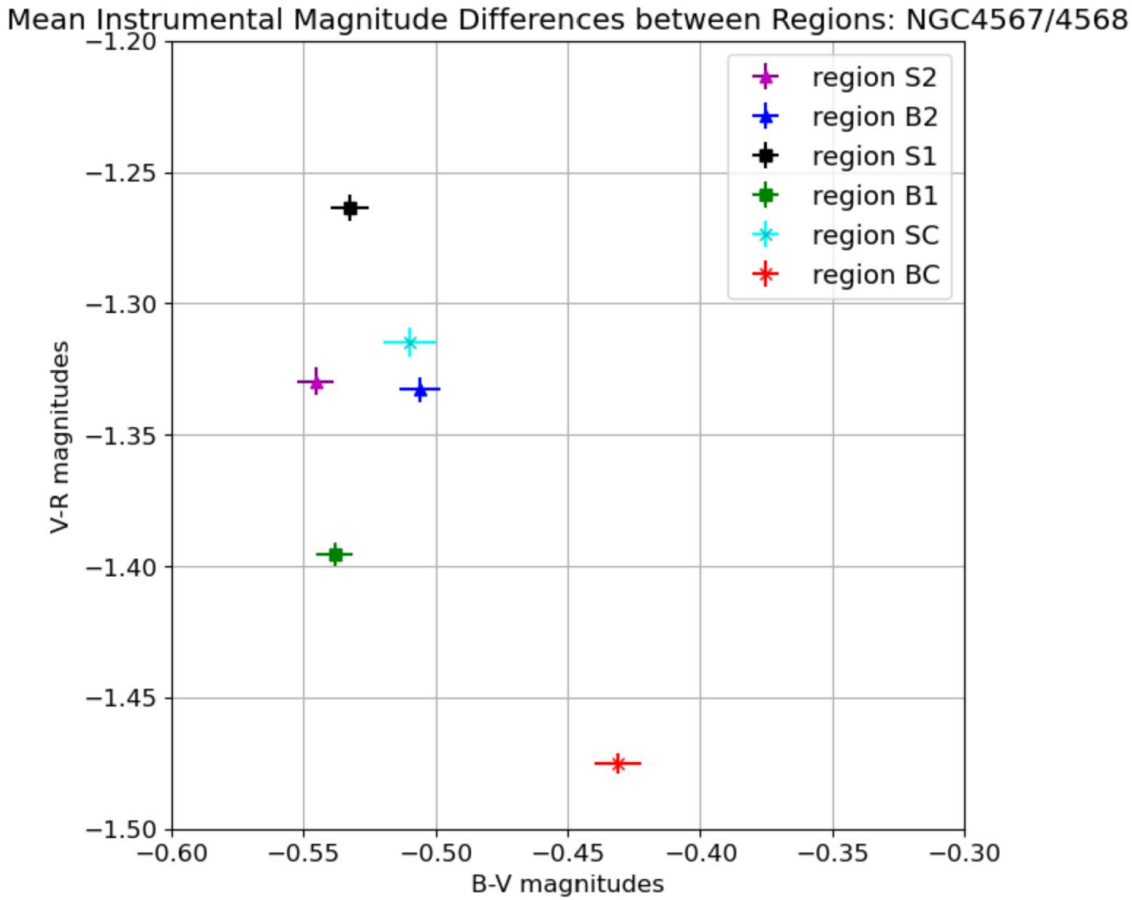
NGC 4568 (big)





Comparison of Mean Ratios for NGC 4567/4568

A T-test was used to determine if the difference in the mean was statistically significant. This compares means in opposite sides of NGC 4568 (B) and NGC 4567 (S) for both color ratios.



T-test - Statistically significant difference between
- S2 is bluer than S1

Regions	S1 & S2
ratio	B/V
S1 mean	-0.532
S2 mean	-0.545
T-test p	0.0192

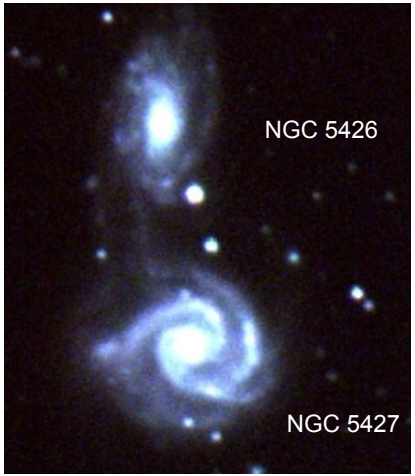
Regions	S1 & S2
Ratio	V/R
S1 mean	-1.26
S2 mean	-1.33
T-test p	2.40e-12

T-test - Statistically significant difference between B1 & B2 - indicate that B1 is bluer:

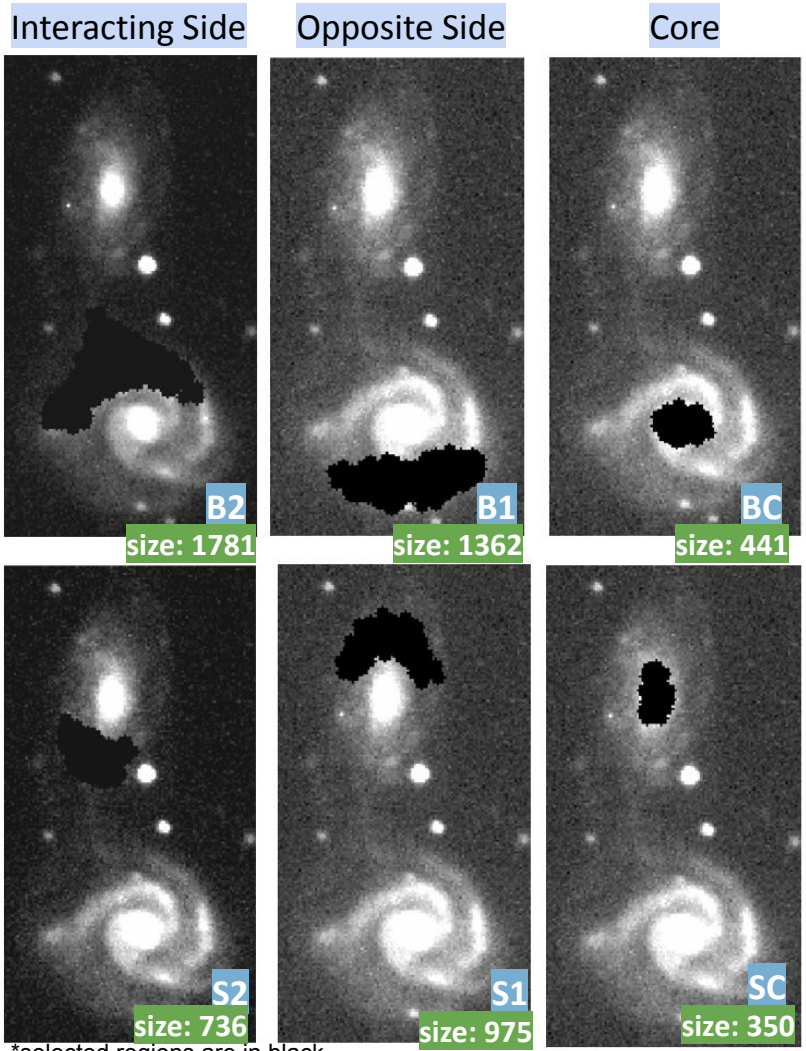
Regions	B1 & B2
ratio	B/V
B1 mean	-0.538
B2 mean	-0.506
T-test p	5.80e-11

Regions	B1 & B2
ratio	V/R
B1 mean	-1.40
B2 mean	-1.33
T-test p	7.26e-14

Regions of NGC 5426 & NGC 5427



Key:
B - the larger of the two galaxies
S - the smaller of the two galaxies
2 - interacting side
1 - opposite side of galaxy
C - core region of galaxy



NGC 5427

NGC 5426

*selected regions are in black

Probability Distribution of Regions in NGC 5426 and NGC 5427

The probability distributions shown compare the interacting (2) and non-interacting (1) sides' color ratios distribution.

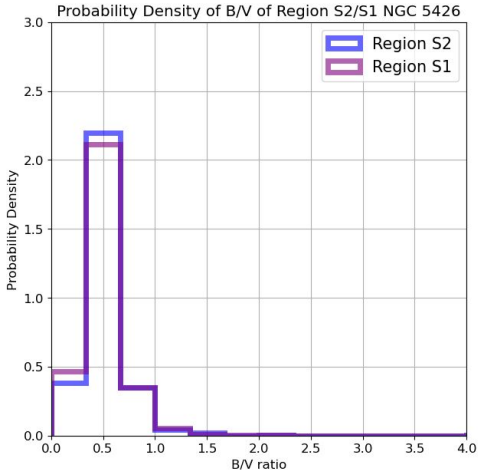
KS-test results			
Regions	Colors	Statistic	P-value
S1/S2	B/V	0.0419	0.439
S1/S2	V/R	0.101	3.50e-4
B1/B2	B/V	0.131	4.88e-12
B1/B2	V/R	0.0950	1.56e-6

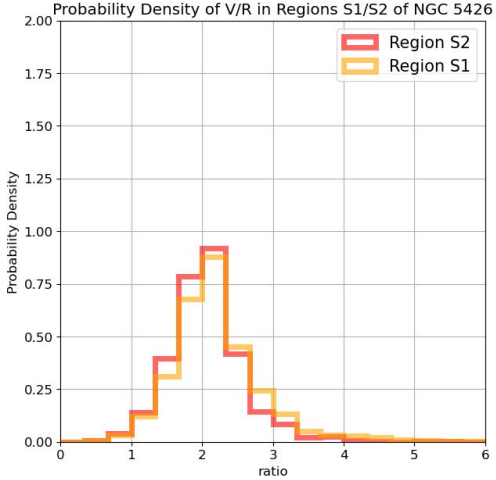
The KS-tests indicate that the regions in NGC 5426 and NGC 5427 have different distributions, except for NGC 5426's S1/S2 in B/V.

B/V Histograms

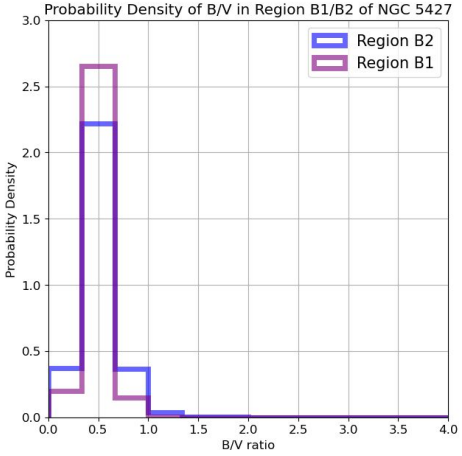
V/R Histograms

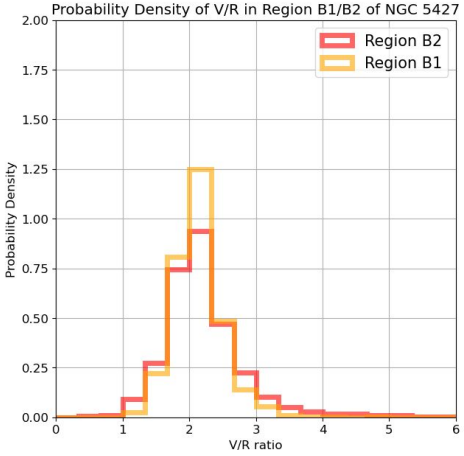
NGC 5426 (small)





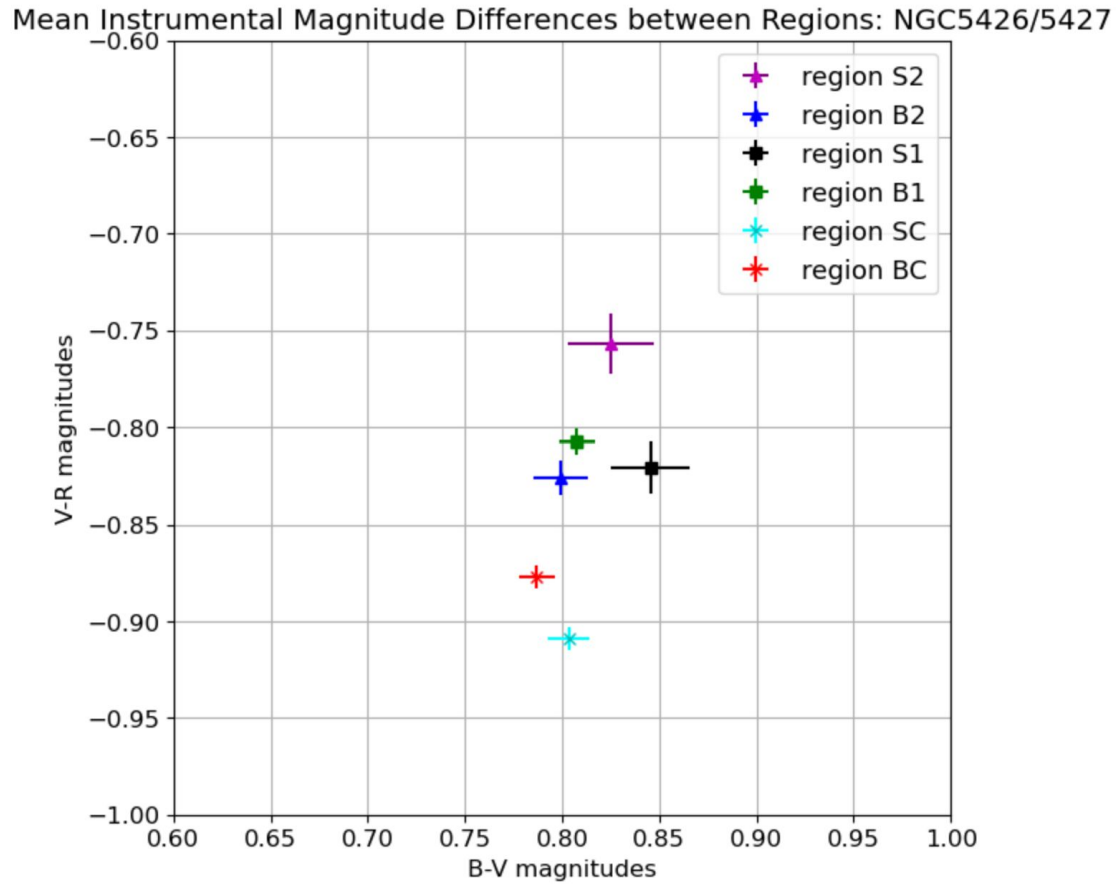
NGC 5427 (big)





Comparison of Mean Ratios in NGC 5426/5427

A T-test was used to determine if the difference in the mean was statistically significant. This compares means in opposite sides of NGC 5427 (B) and NGC 5426 (S) for both color ratios.



T-test - Statically significant difference between V/R ratios - but shows S2 is bluer and redder:

Regions	S1 & S2
ratio	B/V
S1 mean	0.845
S2 mean	0.825
T-test p	0.447

Regions	S1 & S2
Ratio	V/R
S1 mean	-0.821
S2 mean	-0.757
T-test p	7.16e-6

T-test - Statistically significant difference between B1 & B2 - indicate that B2 is bluer:

Regions	B1 & B2
ratio	B/V
B1 mean	0.810
B2 mean	0.799
T-test p	5.22e-7

Regions	B1 & B2
ratio	V/R
B1 mean	-0.808
B2 mean	-0.826
p-value	4.26e-6

Final Comparisons Using both B/V and V/R Data

The following table describes the comparison of the mean value in the V-R vs. B-V color-color diagrams. The table describes if the mean values indicate if the interacting or non-interacting side of the galaxy was more blue or more red compared to one another. The colors are only listed for the statistically significant means.

Galaxy (NGC)	5394	5395	3786	3788	4567	4568	5426	5427
Interacting Side (2)	N/A	Bluer and Redder	N/A	-	Bluer	Redder	N/A	Bluer
Non-Interacting Side (1)	N/A	-	N/A	Bluer and Redder	Redder	Bluer	N/A	Redder

*N/A indicates that there was no statistically significant difference

The table above shows that there is not a clear trend in if the interacting/non-interacting side is bluer/redder. There are also instances of the data indicating that a region is both bluer and redder than the other region. The B-V and V-R color plots shown in the pages above show a trend that is unexpected - as the B-V values increase the V-R values decrease, becoming bluer and redder at the same time. This results points to there being an error in the data.

Reasons for Unexpected Results

There is no clear explanation for why the color ratios between B-V and V-R do not have the expected relationship and indicate regions as being bluer and redder. There is the possibility that the filters were different than expected, the images were not high enough quality, or the choice of analysis was incorrect. Based on the images to the right - which display the ratio values between the colors (dark color = smaller ratio) - indicate the B/V seems to behave as expected. Small ratios can be seen (dark areas) in the core regions and in a dust lane, where we would expect the galaxy to be redder. The V/R image is opposite of what is expected. This trend was true for all of the galaxies imaged, indicating that the B/V ratios might be a better representation.

NGC 4567/4568 B/V

NGC 4567/4568 V/R

Results with only B/V data

These tables compare the mean values of the B-V instrumental magnitudes, with only the B/V data. This maybe a more accurate representation because it appears that the blue and visible ratios are a better representation of what occurs in the galaxies.

Statistically Significant Data Only:

Galaxy (NGC)	5394	5395	3786	3788	4567	4568	5426	5427
Interacting Side (2)	N/A	Bluer	N/A	Redder	Bluer	Redder	N/A	Bluer
Opposite Side (1)	N/A	Redder	N/A	Bluer	Redder	Bluer	N/A	Redder

*N/A indicates that there was no statistically significant difference

Non-Statistically Significant Data Included:

Galaxy (NGC)	5394	5395	3786	3788	4567	4568	5426	5427
Interacting Side (2)	Redder	Bluer	Redder	Redder	Bluer	Redder	Bluer	Bluer
Opposite Side (1)	Bluer	Redder	Bluer	Bluer	Redder	Bluer	Redder	Redder

Conclusions

The error in the data that caused certain regions to be consider both bluer and redder than other, makes this data inconclusive. Based on inspection of the images, it appears the the B-V magnitude differences are a more accurate representation of the galaxy. The data with just the B-V magnitude comparisons shows that the interacting and non-interacting sides are sometimes bluer or redder. There is no indication that one side is usually more or less blue/red than the other. This sample size is small and a larger sample size could help give a more accurate representation. Overall, there is a clear error with the color ratios in the data and without being able to pinpoint this issue, it is not possible to draw conclusions from the data.