

A Statistical Investigation into Galaxy Cluster Radiative Process Correlations

by

Ben Fredebo Rasmussen

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of

BACHELOR OF SCIENCE (HONOURS)

in the Department of Physics and Astronomy

© Ben Fredebo Rasmussen, 2024
University of Victoria

All rights reserved. This thesis may not be reproduced in whole or in part, by photocopying or other means, without the permission of the author.

A Statistical Investigation into Galaxy Cluster Radiative Process Correlations

by

Ben Fredebo Rasmussen

Supervisory Committee

Dr. J. Willis, Supervisor
(Department of Physics and Astronomy)

Dr. G. Steeves, Departmental Member
(Department of Physics and Astronomy)

ABSTRACT

This is where the abstract will go.

Contents

Supervisory Committee	ii
Abstract	iii
Table of Contents	iv
List of Tables	vi
List of Figures	vii
Acknowledgements	ix
Dedication	x
1 Introduction	1
1.1 Introduction Introduction	1
1.2 Background	1
1.3 The Data (This Could Potentially be Chapter 2)	2
1.3.1 Meet the Members	2
1.3.2 What about the Xrays	5
1.4 Motivation of the Work	6
1.4.1 Importance of Claims in Context	6
1.5 Agenda	6
2 What is the Problem? (Could also be the setup to the project, about the data, fluxes etc.)	7
3 Linear Correlation Techniques	14
4 Radial Correlation Techniques	21

5 Spatial Correlation Techniques	24
6 Analysis	29
7 Conclusions	30
A Additional Information	31
A.1 Plots to Further Understand the Spatial Densities	32
A.2 Images that Didn't Make it in	36
Bibliography	39

List of Tables

List of Figures

Figure 1.1 Image of the Cluster with Highlighted Members	2
Figure 1.2 Redshift Histogram	3
Figure 1.3 Colour Magnitude Diagram (Insert More Here)	4
Figure 1.4 Image of the Raw Xray Image	5
Figure 1.5 Image of Adaptively Smoothed Xray Image	6
Figure 2.1 Segmentation Map of Image (Will likely not include)	8
Figure 2.2 Segmentation Map of Members (Will likely not include)	9
Figure 2.3 Manual Flux Determination example for object 451	10
Figure 2.4 BCG Galaxy projected to xray image frame	11
Figure 2.5 Plot of flux vs. mass for the four methods of obtaining flux values	12
Figure 2.6 Comparison of important selected flux methods (and smooth vs. raw)	13
Figure 3.1 Pearson r for each subsample (so far) and the four major methods used. USeful to compare statistical behaviour for each method and choosing one.	14
Figure 3.2 Linear Relation established from mass and magnitude for known masses (Trudeau et al)	15
Figure 3.3 Colour magnitude diagram showing sample that will be examined for possible member extensions	16
Figure 3.4 Bootstrap Pearson-r for each of the possible candidates as a func- tion of redshift. Lines for $z=1.98$ and $r=0.329$ which is 68.5th percentile.	17
Figure 3.5 Xray flux as a function of galactic mass for all 6 sub samples . .	18
Figure 3.6 Pearson r coefficient for all 6 of the final samples.	19
Figure 3.7 Pearson r coefficient <i>p-value</i> for all 6 of the final samples. Plotted logarithmically.	20

Figure 4.1 Cumulative radial mass distributions for each of the samples. Yellow is x-ray flux radial profile normalized to the red extension sample.	21
Figure 4.2 KS-Test D-statistic from the distributions in 4.1.	22
Figure 4.3 KS-Test p-value from the distributions in 4.1 corresponding to the critical values of the D-statistics from 4.3.	23
Figure 5.1 Spatial mass densities generated using a circular aperture with varying radii (in kpc). Sample shown here is the 26 member galaxies.	24
Figure 5.2 2D Pearson r coefficient as a function of aperture size using a circular aperture with all 6 previously defined samples.	25
Figure 5.3 2D Pearson r coefficient for a circular aperture of radius $a=250$ kpc. Corresponds to \approx the maximum values from 5.2. Doesn't really add much here so will likely remove. For completeness it would be nice to have another 6 bar bar chart somewhere in this chapter.	26
Figure 5.4 Spatial mass densities generated using a Gaussian aperture with varying a parameter (in kpc). Sample shown here is the 26 mem- ber galaxies.	27
Figure 5.5 2D Pearson r coefficient as a function of aperture size using a Gaussian aperture with all 6 previously defined samples.	28
Figure A.1 Density maps for the 6 samples with a Gaussian aperture with a parameter $a=50\text{kpc}$	32
Figure A.2 Density maps for the 6 samples with a Gaussian aperture with a parameter $a=100\text{kpc}$	33
Figure A.3 Spatial mass densities generated using a circular aperture with varying radii (in kpc). Sample shown here is the red extended sample.	34
Figure A.4 Spatial mass densities generated using a Gaussian aperture with varying radii (in kpc). Sample shown here is the red extended sample.	35
Figure A.5 Image of the Cluster	36
Figure A.6 Xray Image of the Cluster and Surrounding Region	37
Figure A.7 Smoothed Xray Image of the Cluster and Surrounding Region . .	38

ACKNOWLEDGEMENTS

DEDICATION

My cat... for now.

Chapter 1

Introduction

Room for introduction here.

1.1 Introduction Introduction

This is where the introduction to chapter one will go.

1.2 Background

This is where the background will go.

1.3 The Data (This Could Potentially be Chapter 2)

1.3.1 Meet the Members

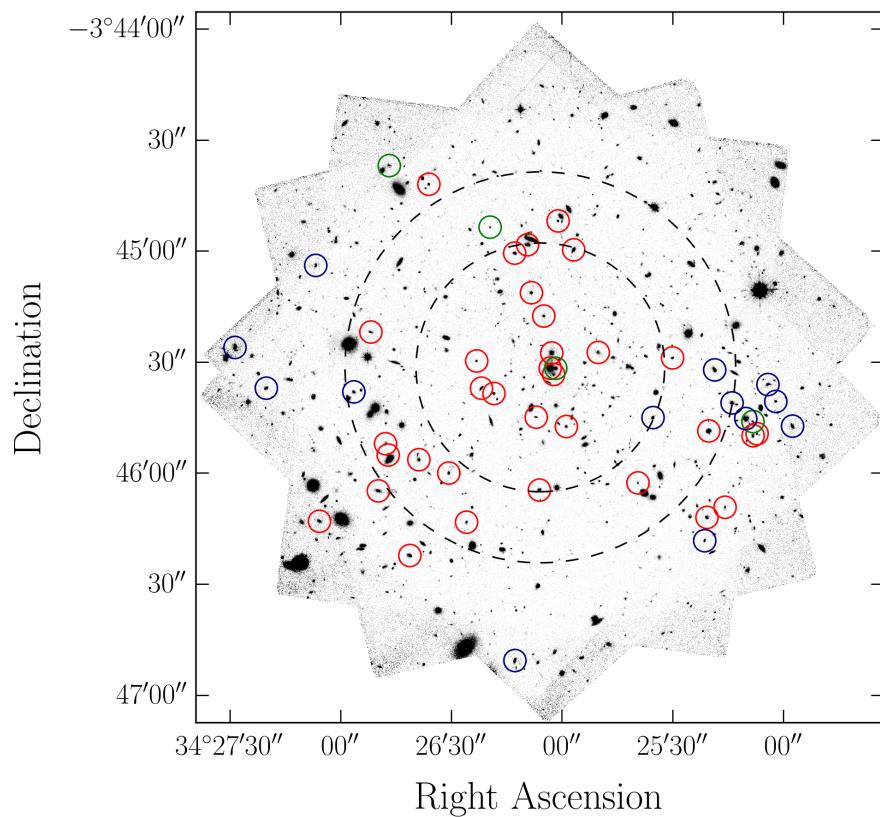


Figure 1.1: Image of the Cluster with Highlighted Members

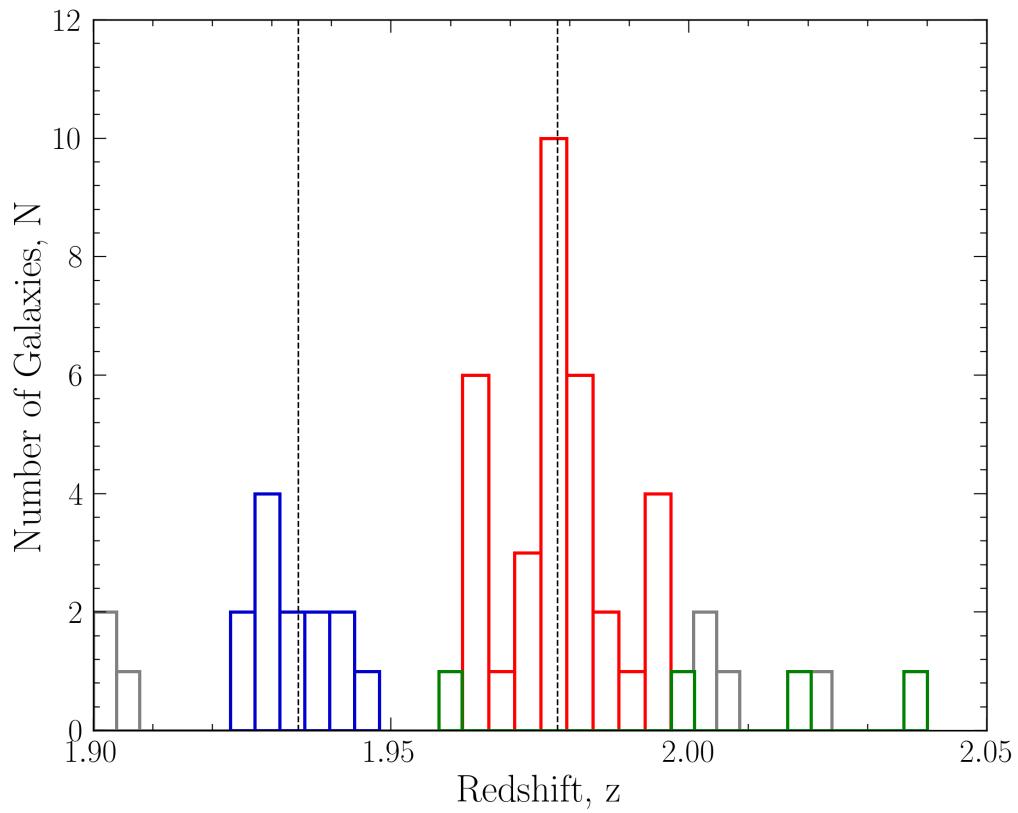


Figure 1.2: Redshift Histogram

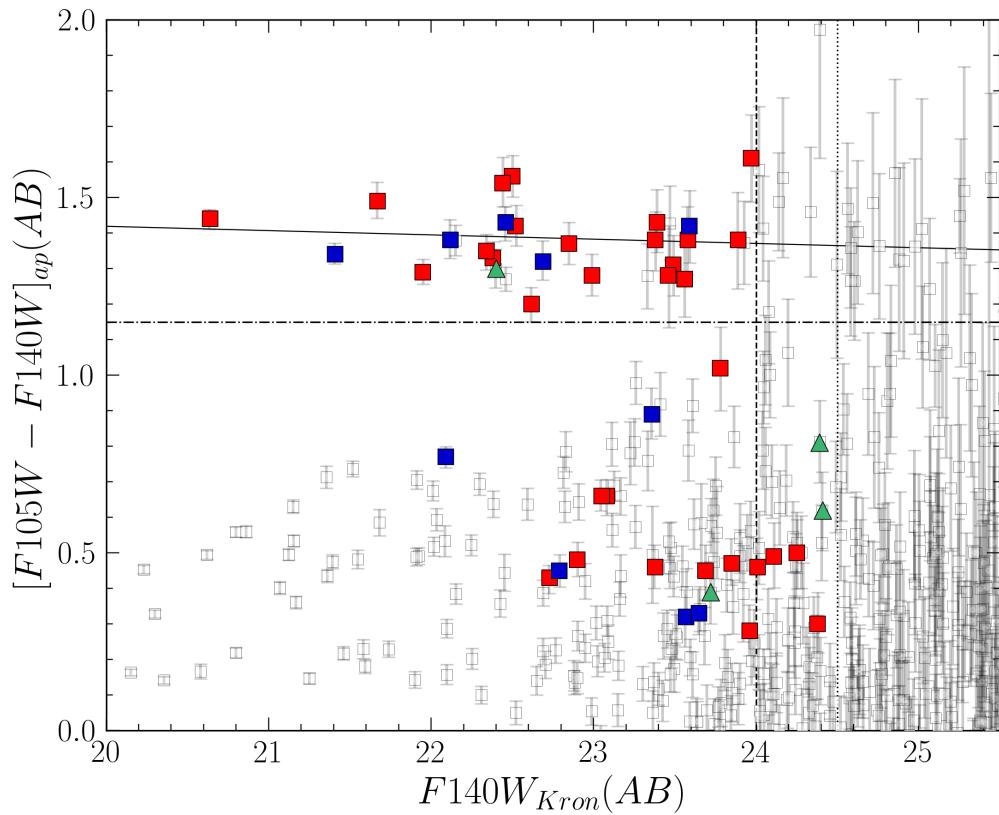


Figure 1.3: Colour Magnitude Diagram (Insert More Here)

1.3.2 What about the Xrays

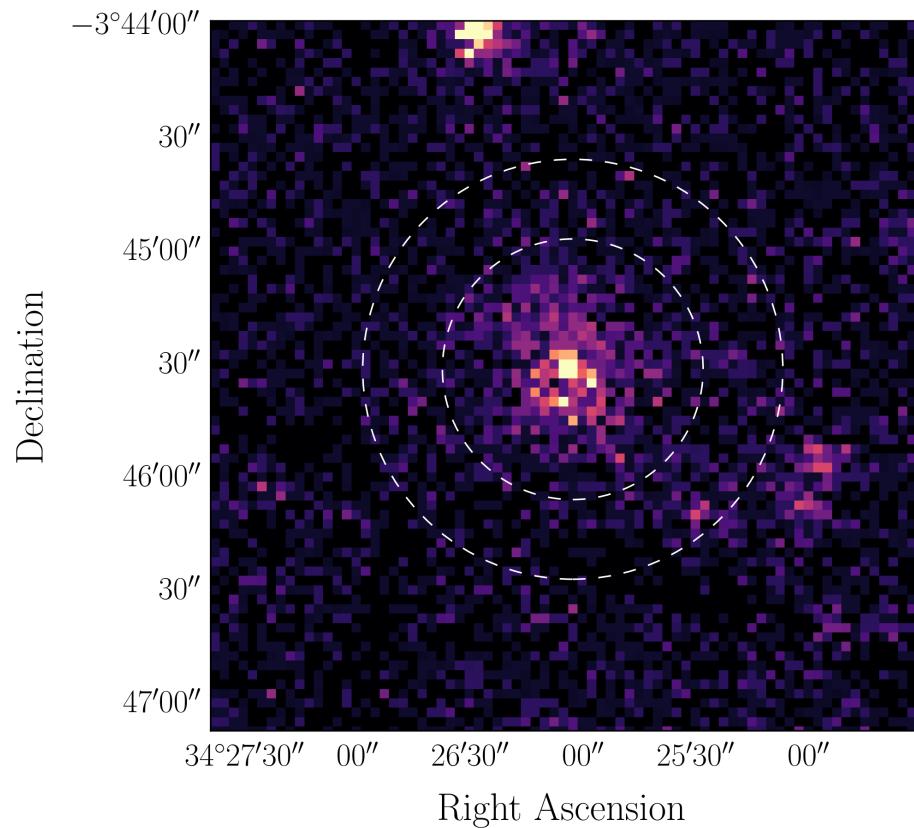


Figure 1.4: Image of the Raw Xray Image

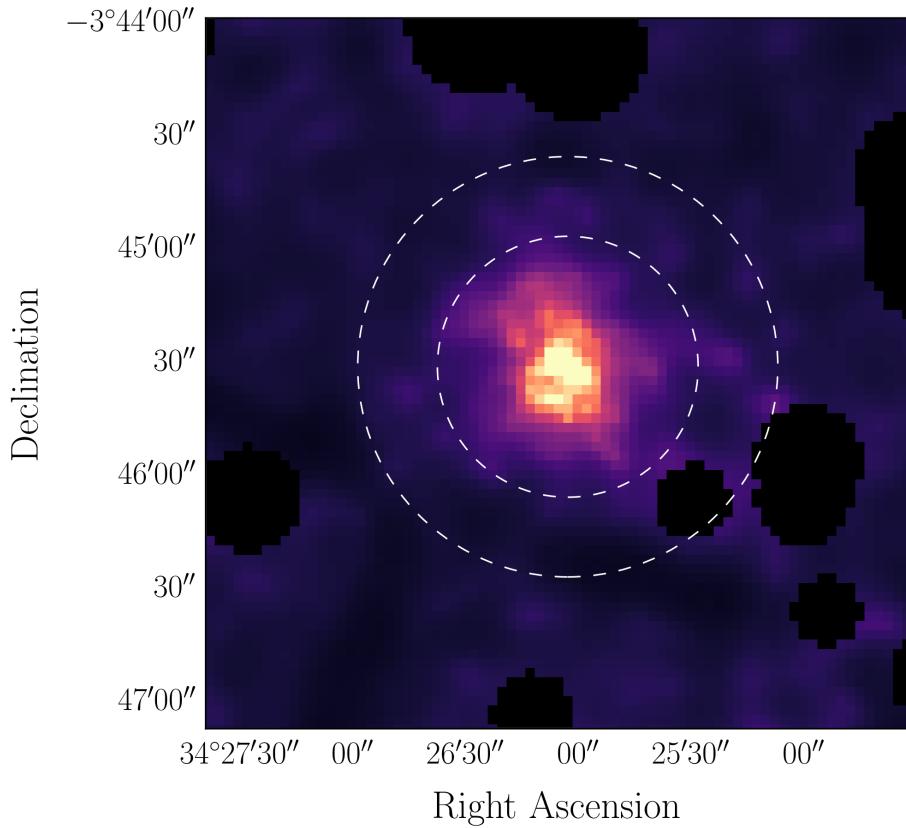


Figure 1.5: Image of Adaptively Smoothed X-ray Image

1.4 Motivation of the Work

Highlight problem to be solved and any claims made by the author (me).

1.4.1 Importance of Claims in Context

Implications of contributions etc.

1.5 Agenda

Highlight the narrative structure of the document here.

Chapter 2

What is the Problem? (Could also be the setup to the project, about the data, fluxes etc.)

In-depth motivation for the work here. Background of the problem/project.

Could push the above into the intro chapter and leave this for the preliminary work.

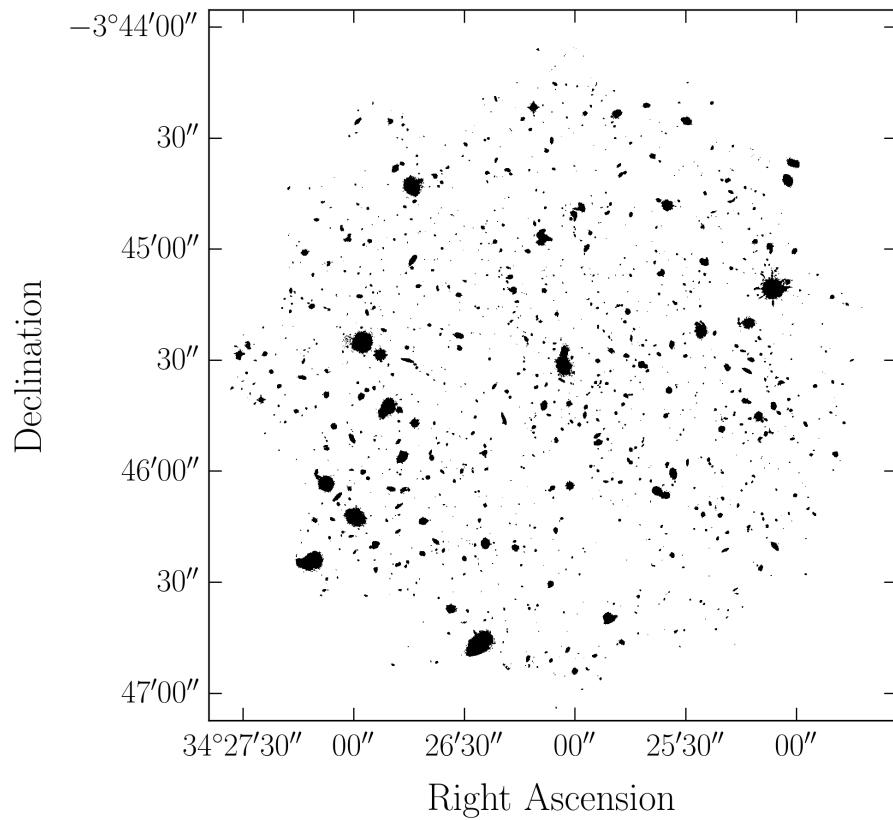


Figure 2.1: Segmentation Map of Image (Will likely not include)

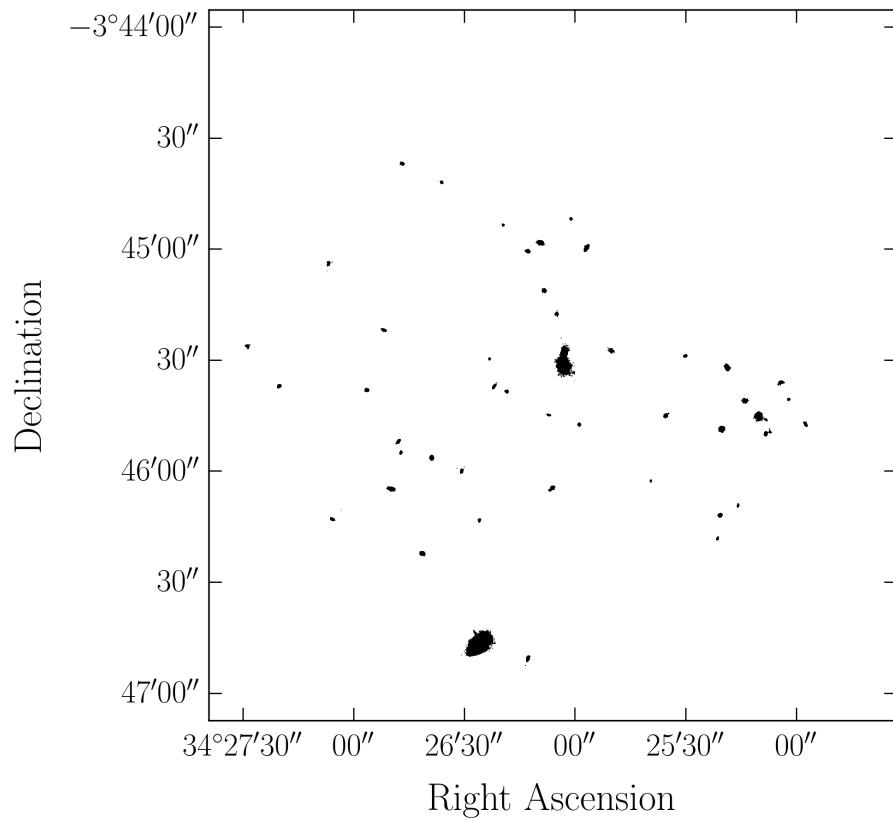


Figure 2.2: Segmentation Map of Members (Will likely not include)

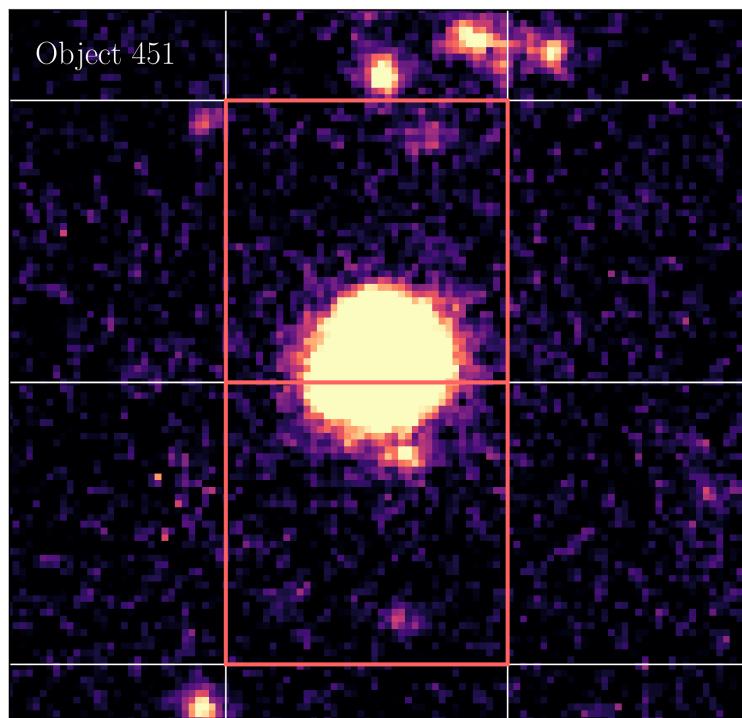


Figure 2.3: Manual Flux Determination example for object 451

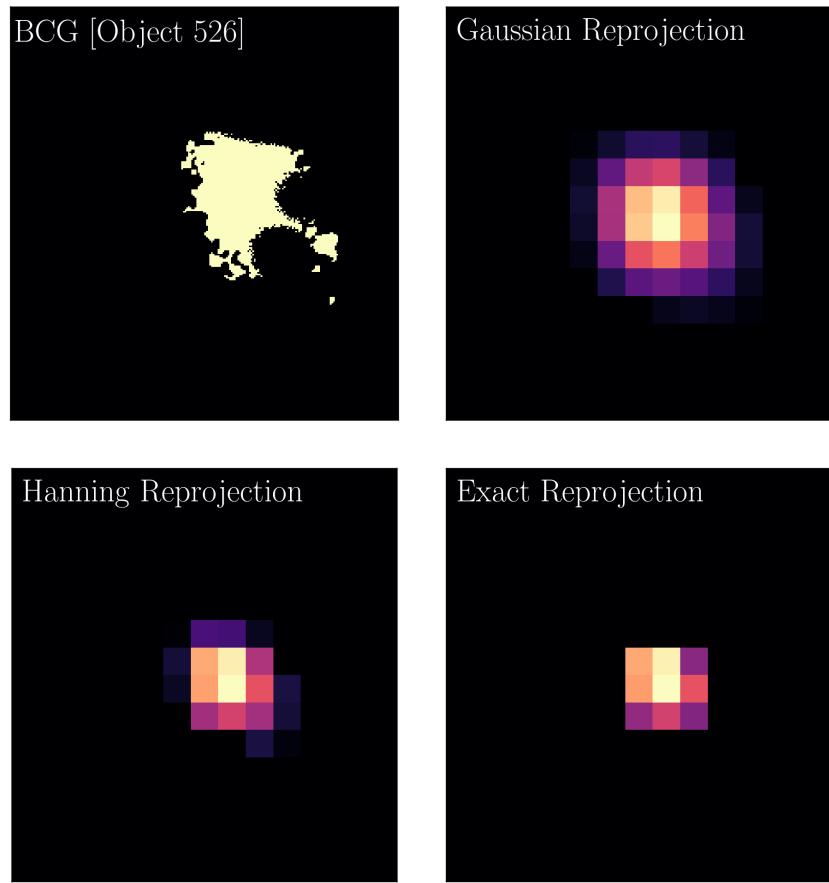


Figure 2.4: BCG Galaxy projected to xray image frame

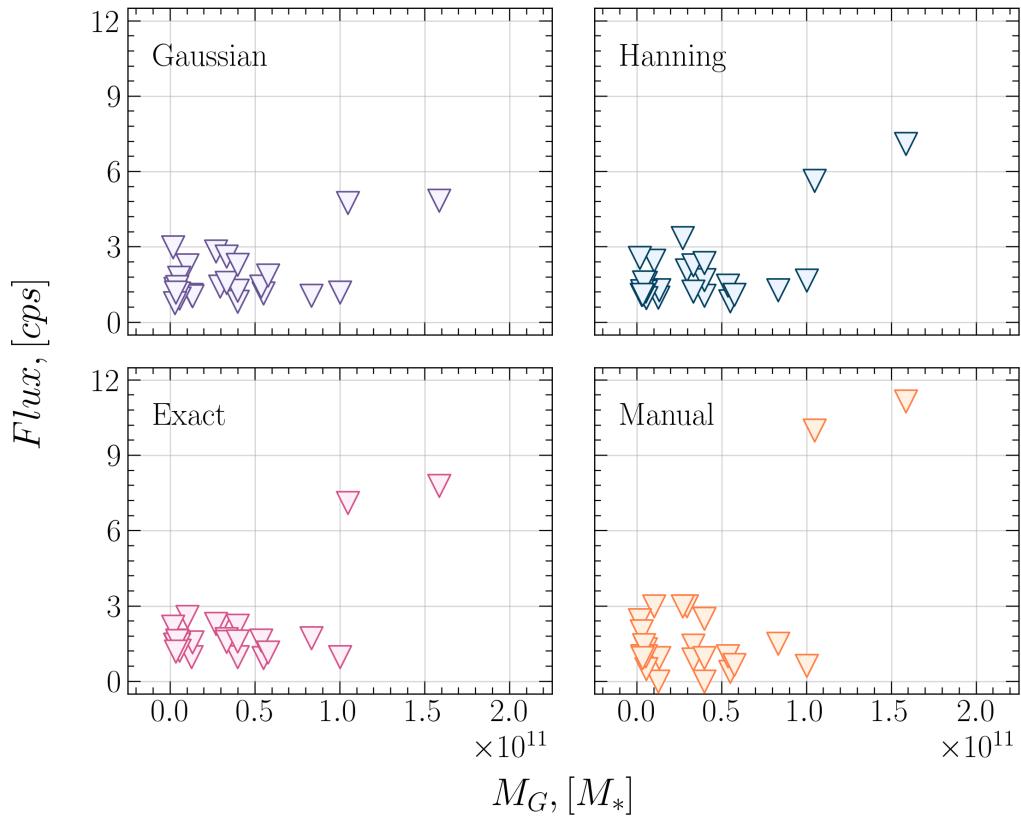


Figure 2.5: Plot of flux vs. mass for the four methods of obtaining flux values

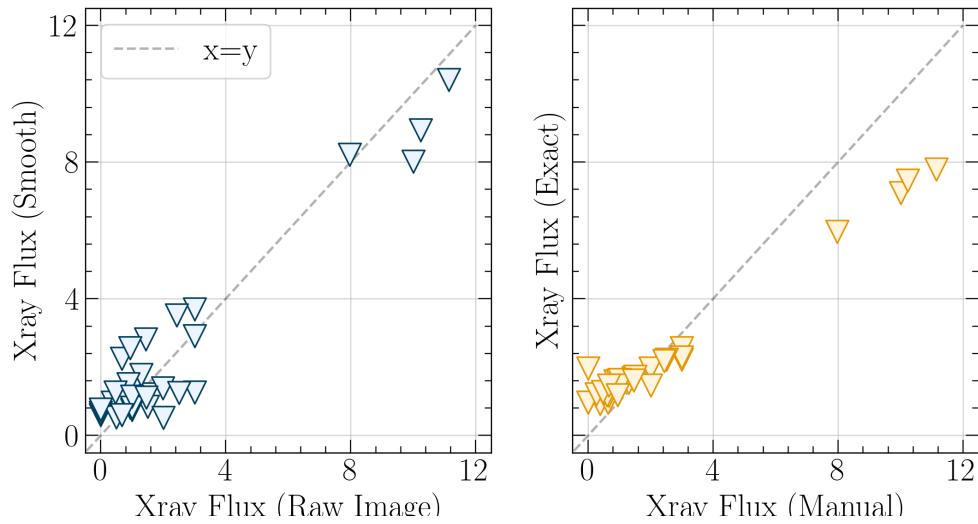


Figure 2.6: Comparison of important selected flux methods (and smooth vs. raw)

Chapter 3

Linear Correlation Techniques

Stuff about the first few weeks of the project.

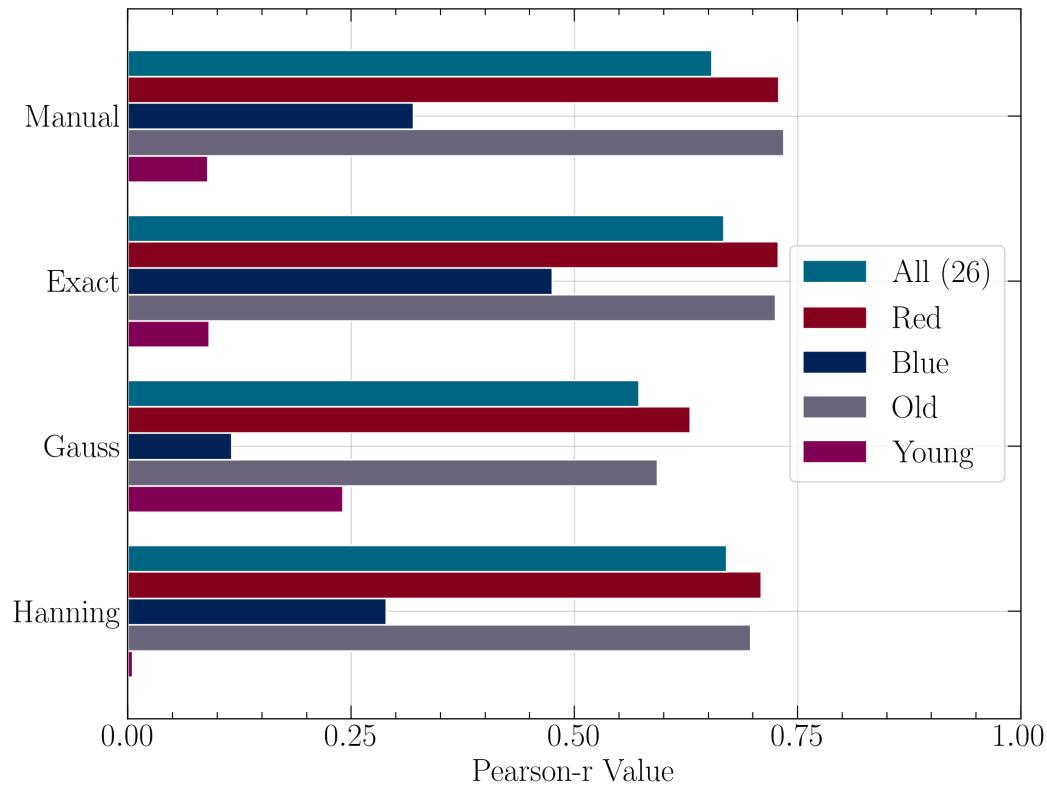


Figure 3.1: Pearson r for each subsample (so far) and the four major methods used.
Useful to compare statistical behaviour for each method and choosing one.

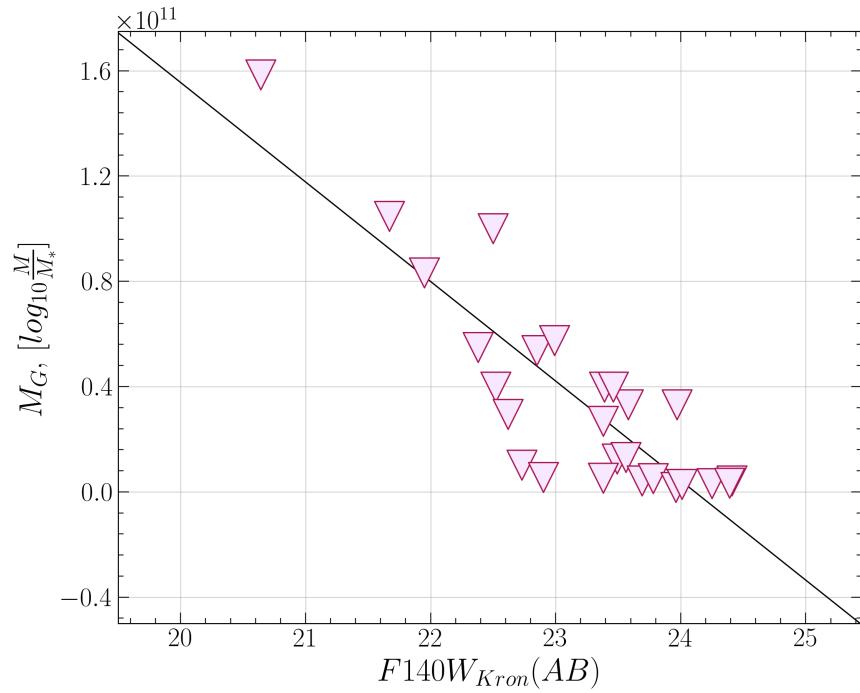


Figure 3.2: Linear Relation established from mass and magnitude for known masses (Trudeau et al)

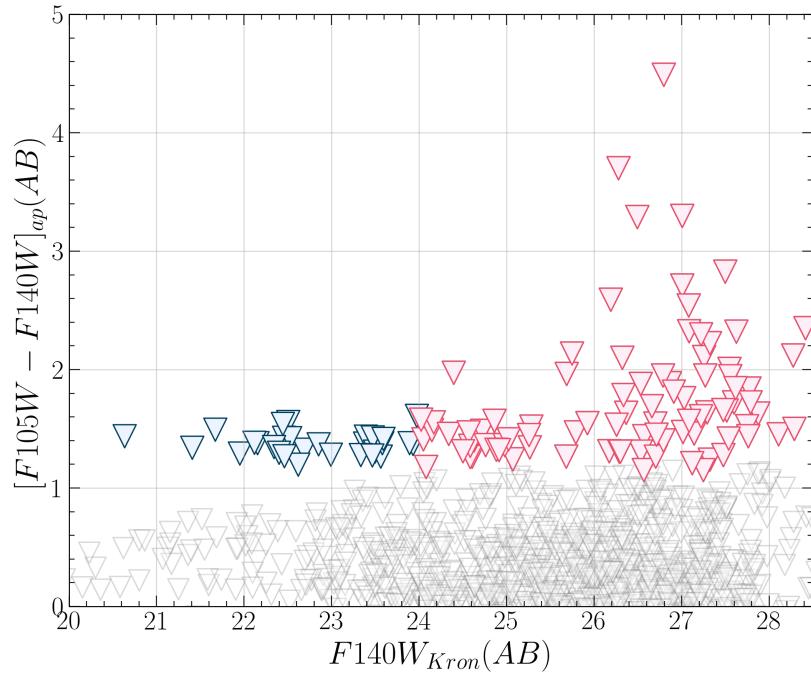


Figure 3.3: Colour magnitude diagram showing sample that will be examined for possible member extensions

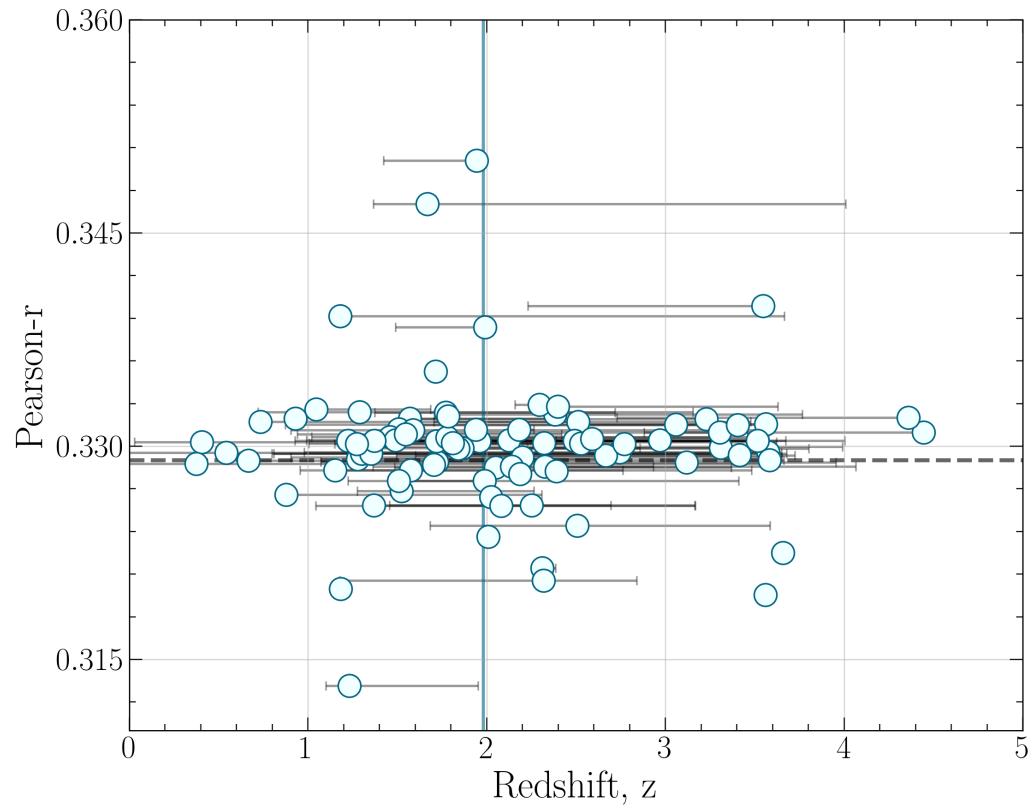


Figure 3.4: Bootstrap Pearson-r for each of the possible candidates as a function of redshift. Lines for $z=1.98$ and $r=0.329$ which is 68.5th percentile.

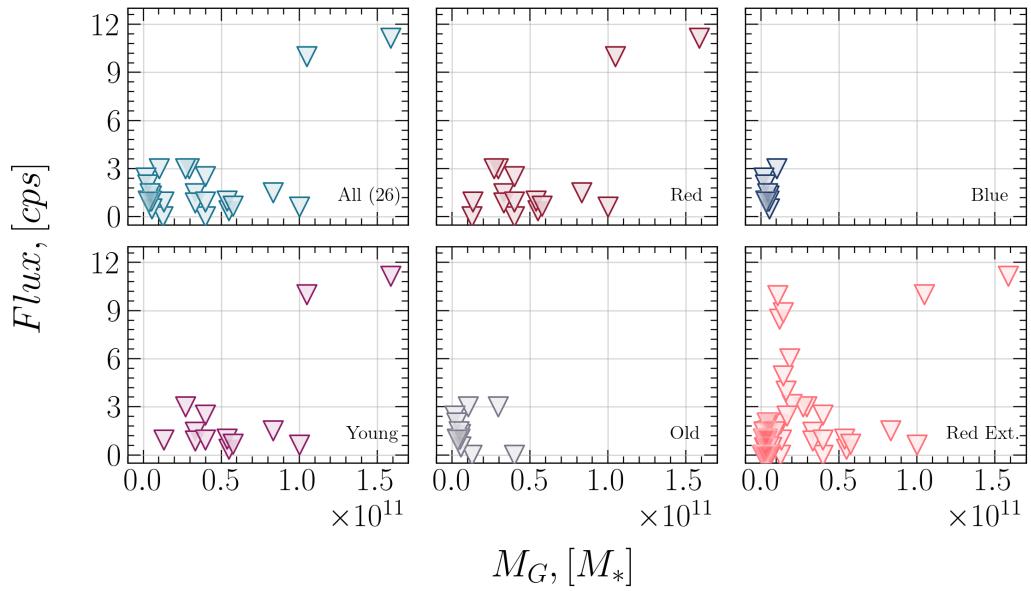


Figure 3.5: Xray flux as a function of galactic mass for all 6 sub samples

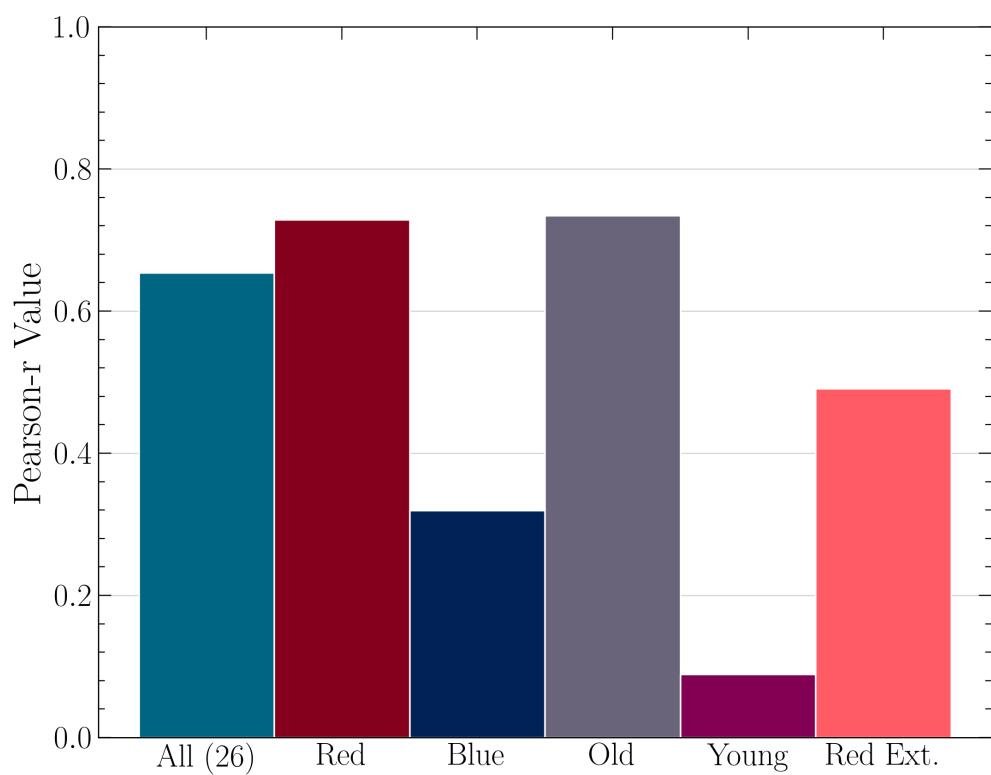


Figure 3.6: Pearson r coefficient for all 6 of the final samples.

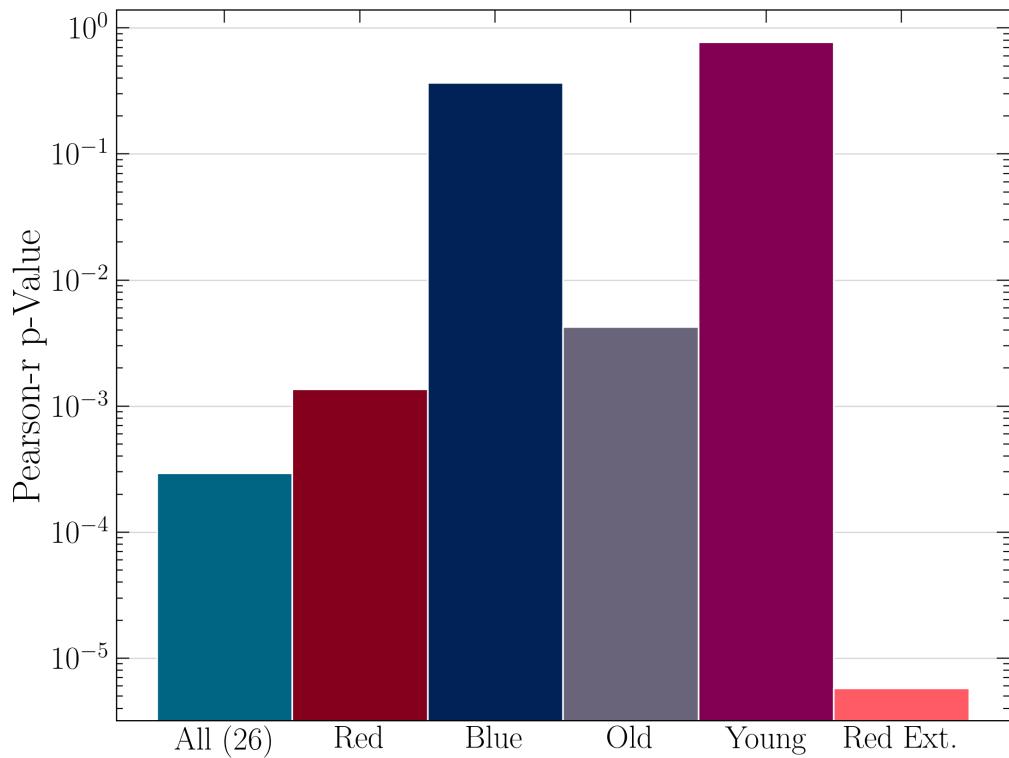


Figure 3.7: Pearson r coefficient *p-value* for all 6 of the final samples. Plotted logarithmically.

Chapter 4

Radial Correlation Techniques

All of the work from the second stage of the project.

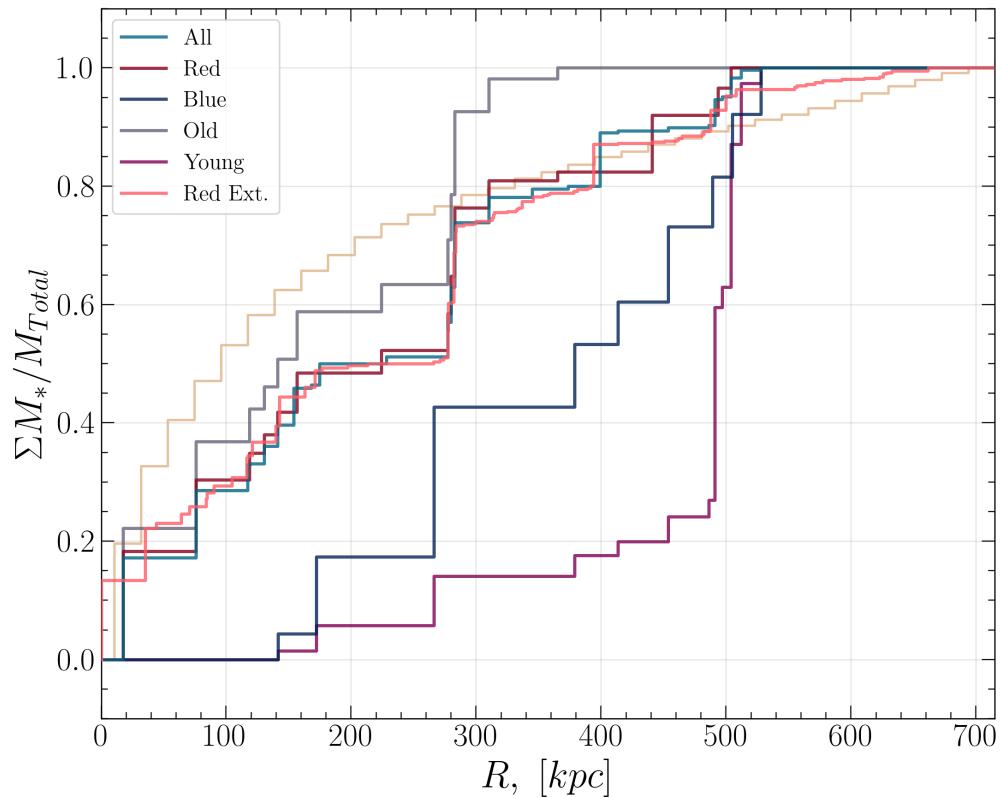


Figure 4.1: Cumulative radial mass distributions for each of the samples. Yellow is x-ray flux radial profile normalized to the red extension sample.

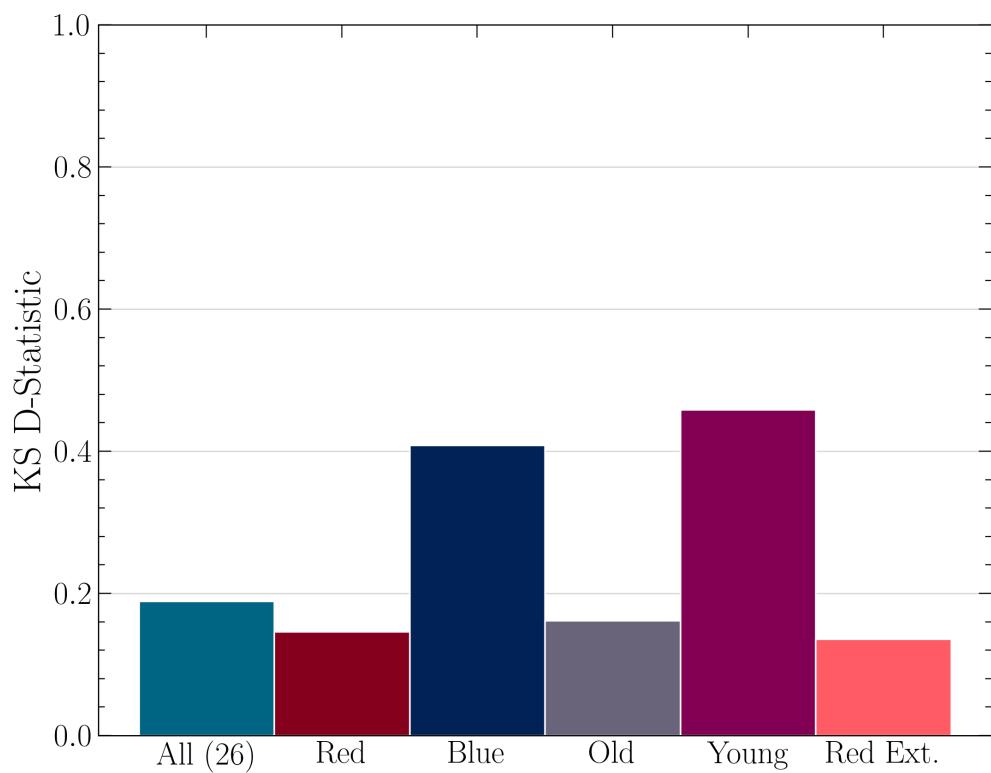


Figure 4.2: KS-Test D-statistic from the distributions in 4.1.

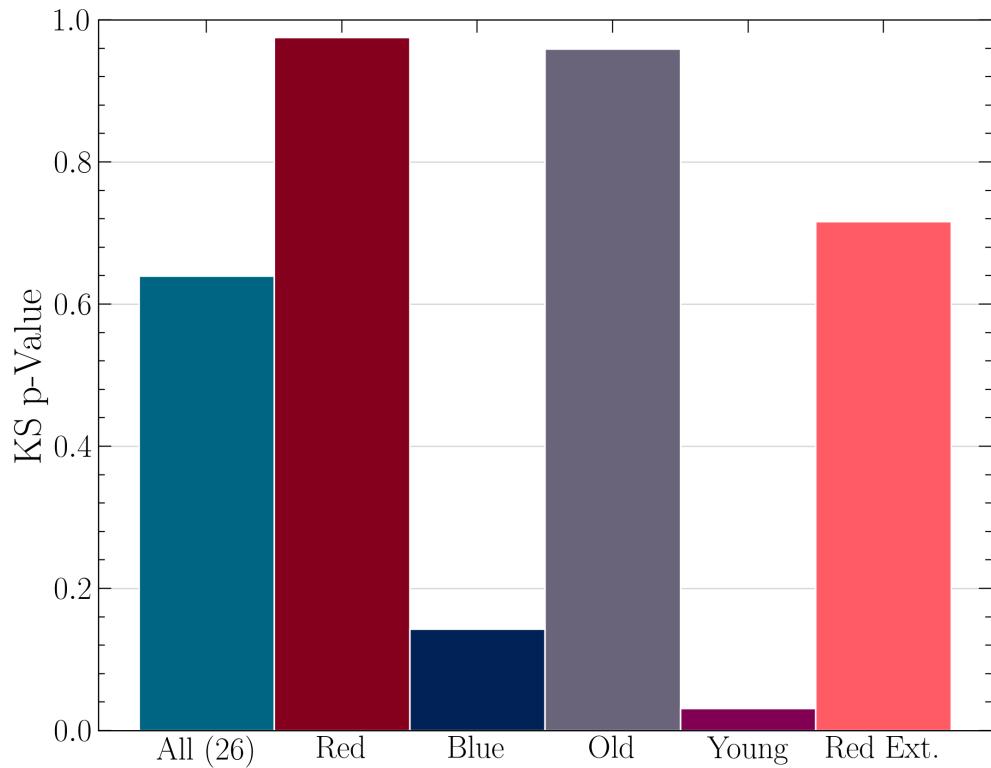


Figure 4.3: KS-Test p-value from the distributions in 4.1 corresponding to the critical values of the D-statistics from 4.3.

Chapter 5

Spatial Correlation Techniques

This is where the third part of the project will go.

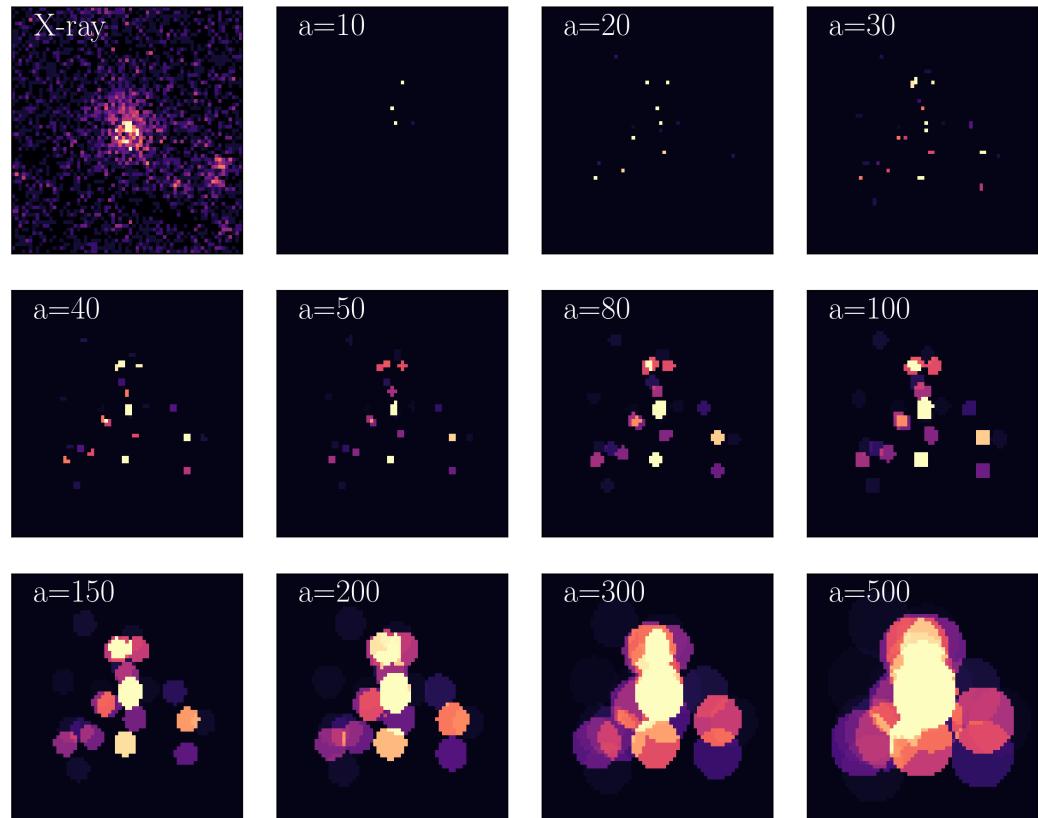


Figure 5.1: Spatial mass densities generated using a circular aperture with varying radii (in kpc). Sample shown here is the 26 member galaxies.

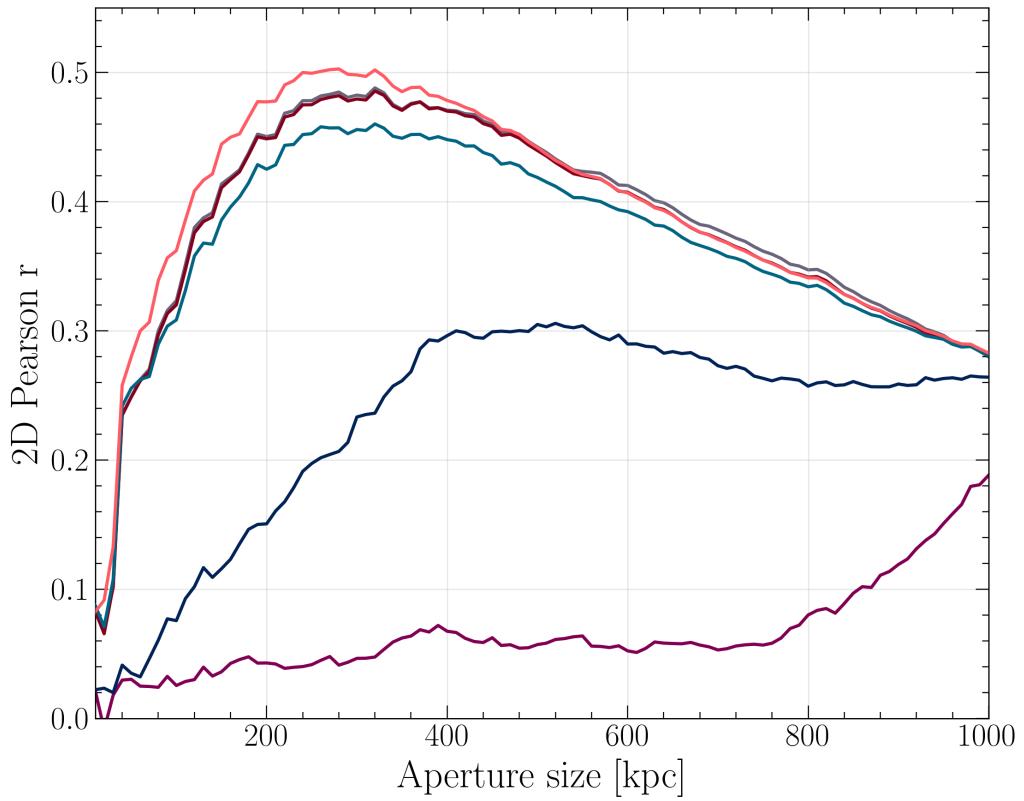


Figure 5.2: 2D Pearson r coefficient as a function of aperture size using a circular aperture with all 6 previously defined samples.

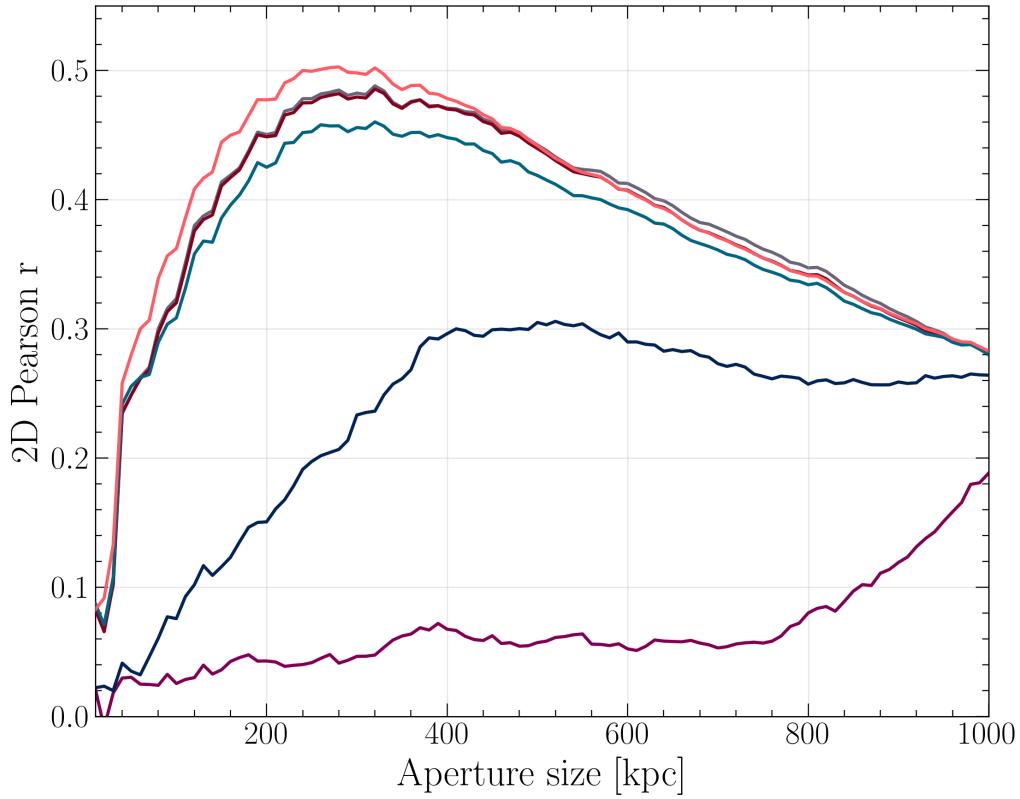


Figure 5.3: 2D Pearson r coefficient for a circular aperture of radius $a=250$ kpc. Corresponds to \approx the maximum values from 5.2. Doesn't really add much here so will likely remove. For completeness it would be nice to have another 6 bar bar chart somewhere in this chapter.

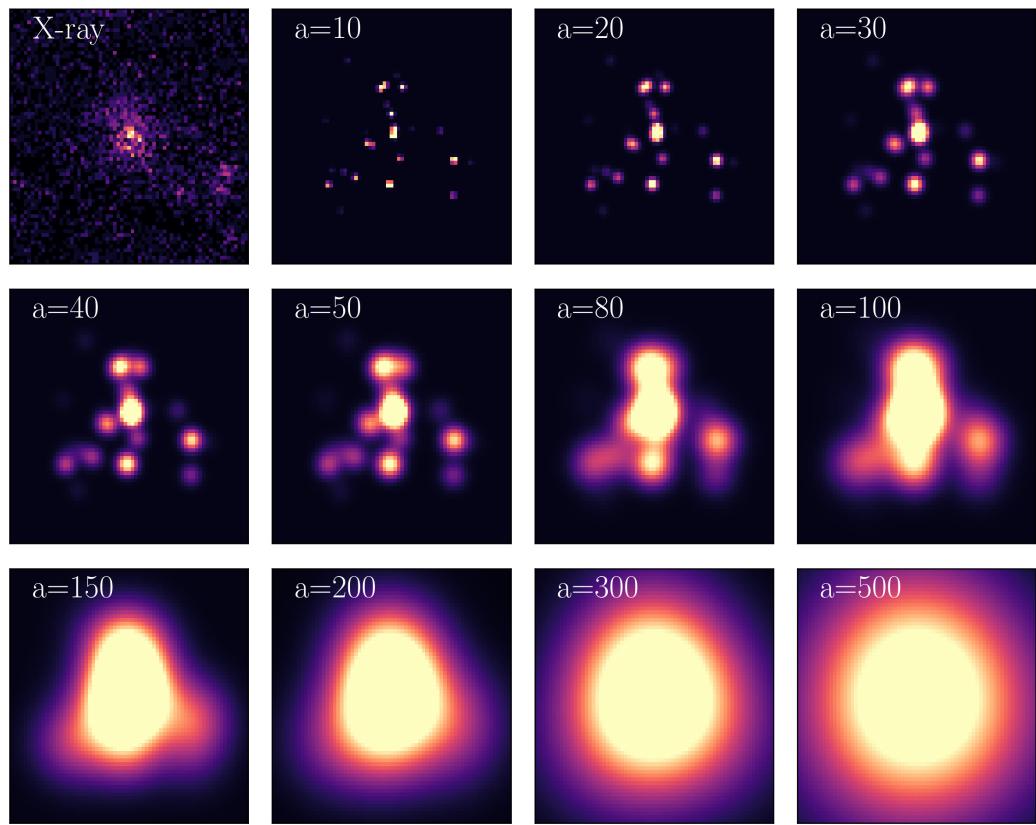


Figure 5.4: Spatial mass densities generated using a Gaussian aperture with varying a parameter (in kpc). Sample shown here is the 26 member galaxies.

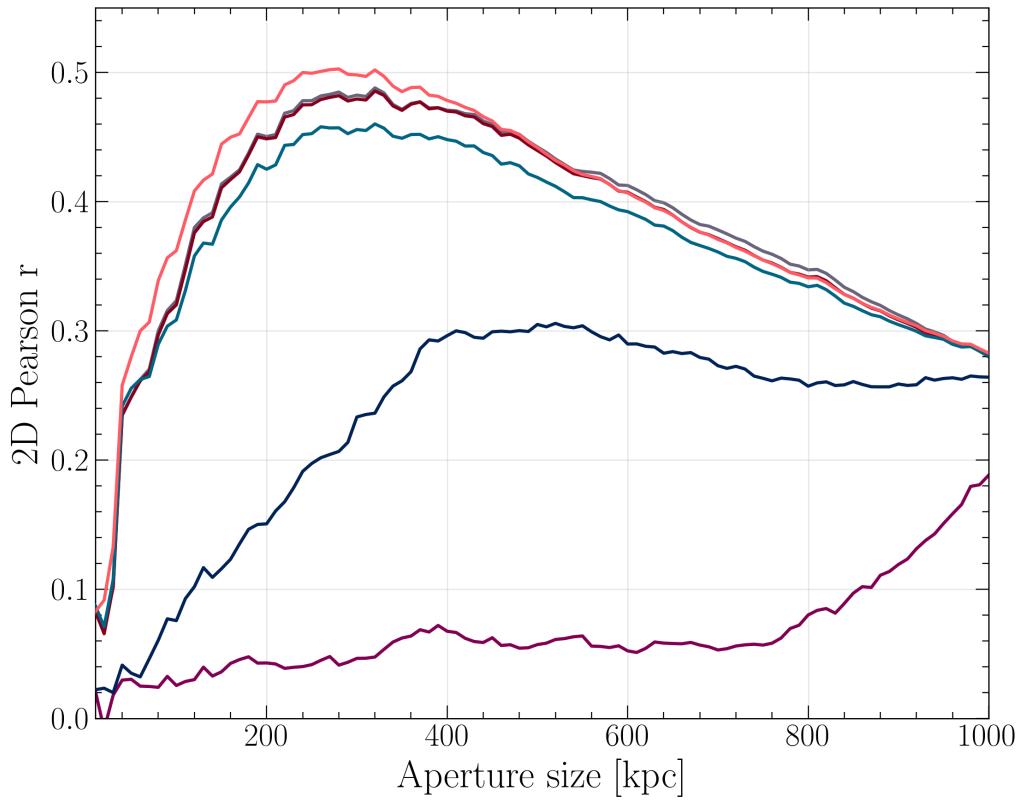


Figure 5.5: 2D Pearson r coefficient as a function of aperture size using a Gaussian aperture with all 6 previously defined samples.

Chapter 6

Analysis

This is where the big picture will hopefully become clear.

Chapter 7

Conclusions

This is where the conclusions from the work will go.

Appendix A

Additional Information

Additional info here like the data (especially the flux values from each technique). Tables, figures, etc that don't tell the narrative smoothly.

A.1 Plots to Further Understand the Spatial Densities

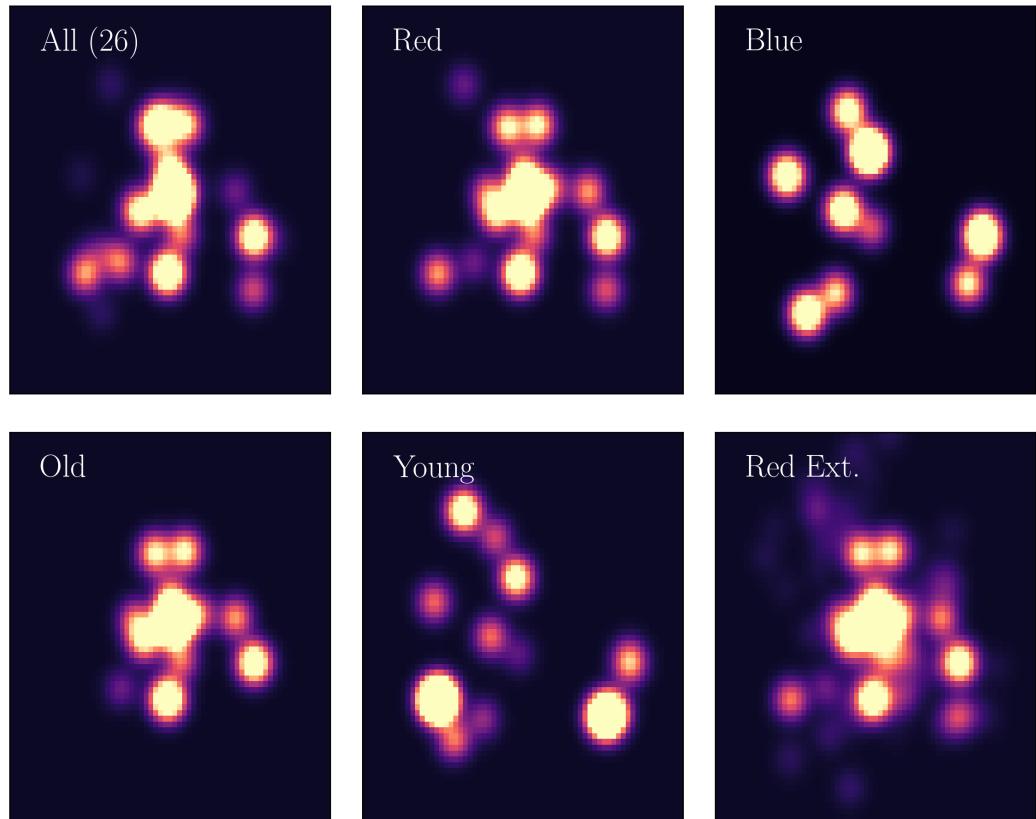


Figure A.1: Density maps for the 6 samples with a Gaussian aperture with a parameter $a=50\text{kpc}$.

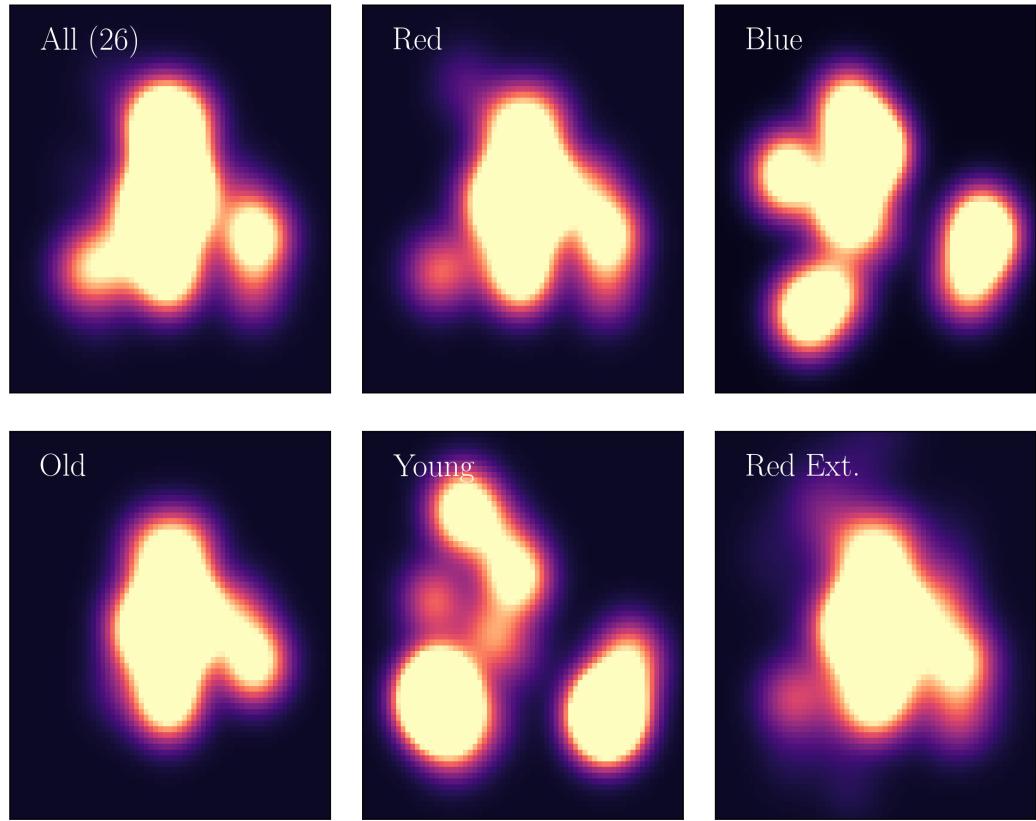


Figure A.2: Density maps for the 6 samples with a Gaussian aperture with a parameter $a=100\text{kpc}$.

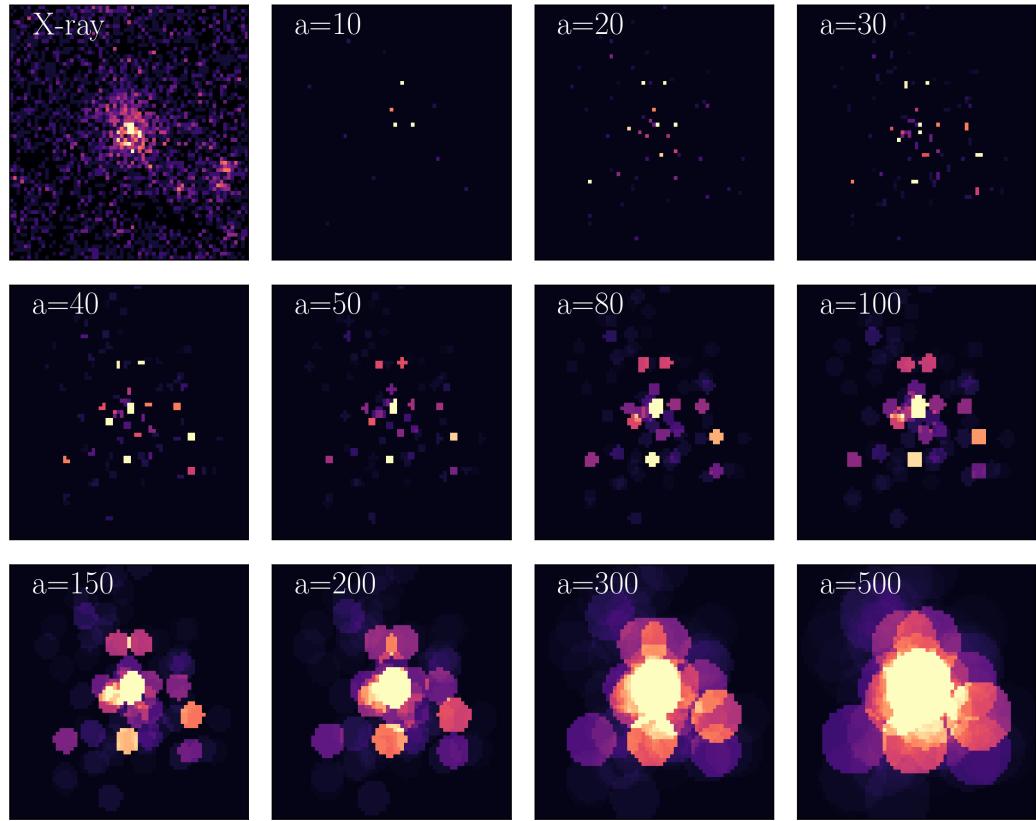


Figure A.3: Spatial mass densities generated using a circular aperture with varying radii (in kpc). Sample shown here is the red extended sample.

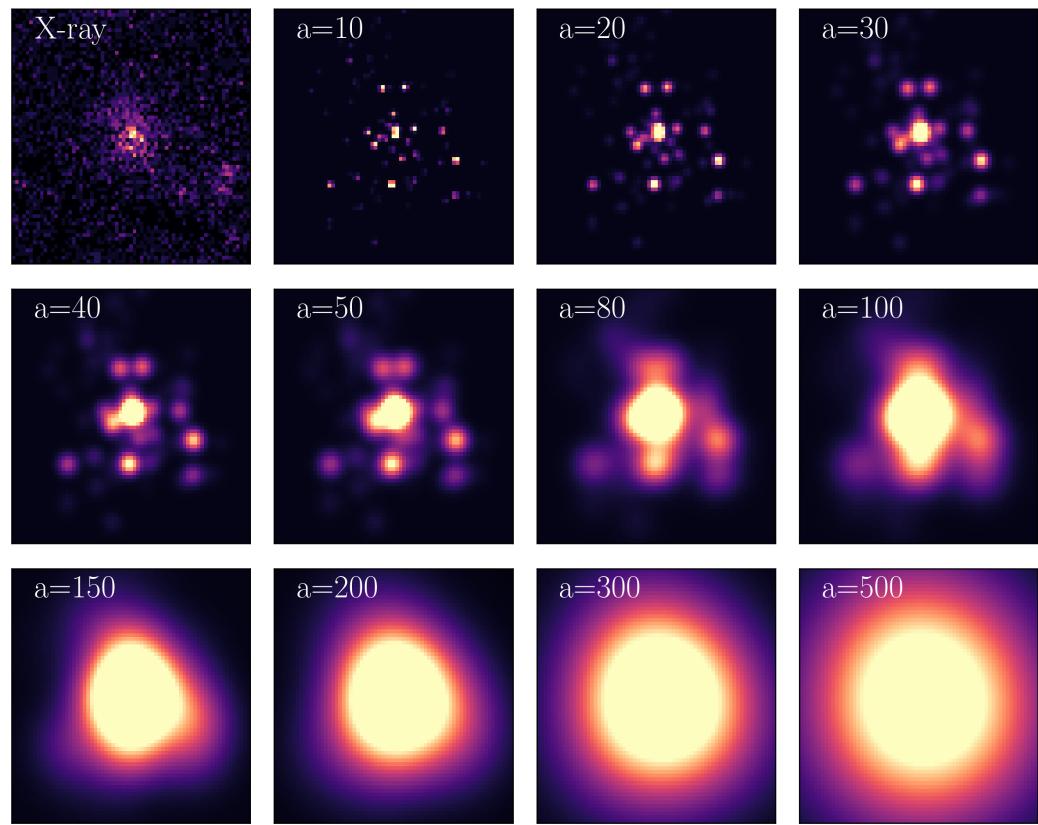


Figure A.4: Spatial mass densities generated using a Gaussian aperture with varying radii (in kpc). Sample shown here is the red extended sample.

A.2 Images that Didn't Make it in

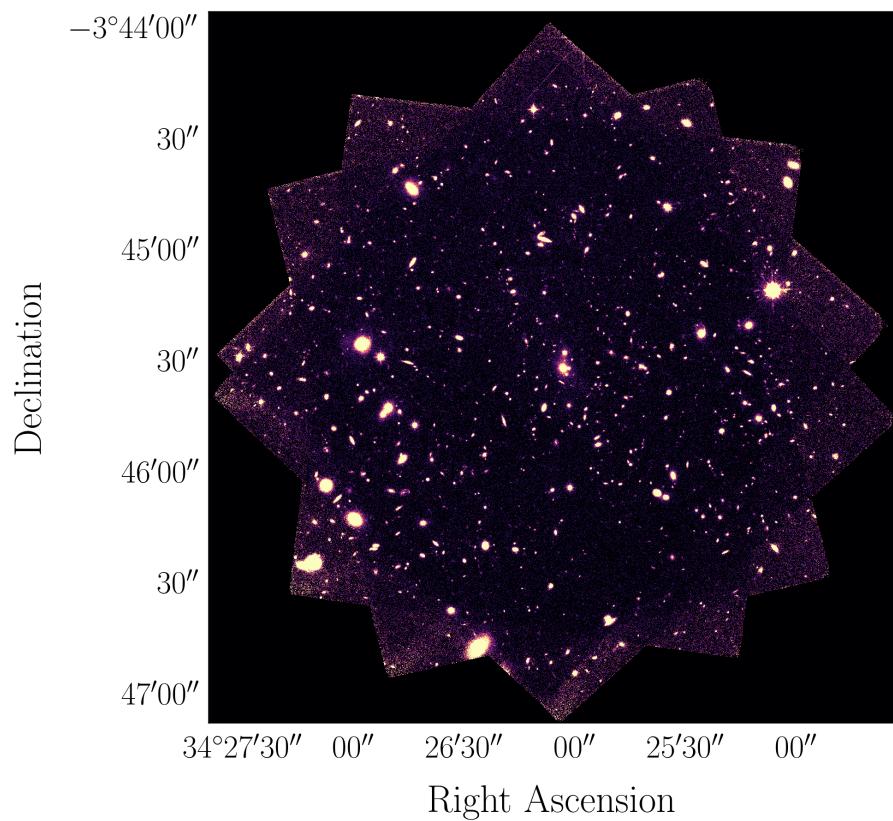


Figure A.5: Image of the Cluster

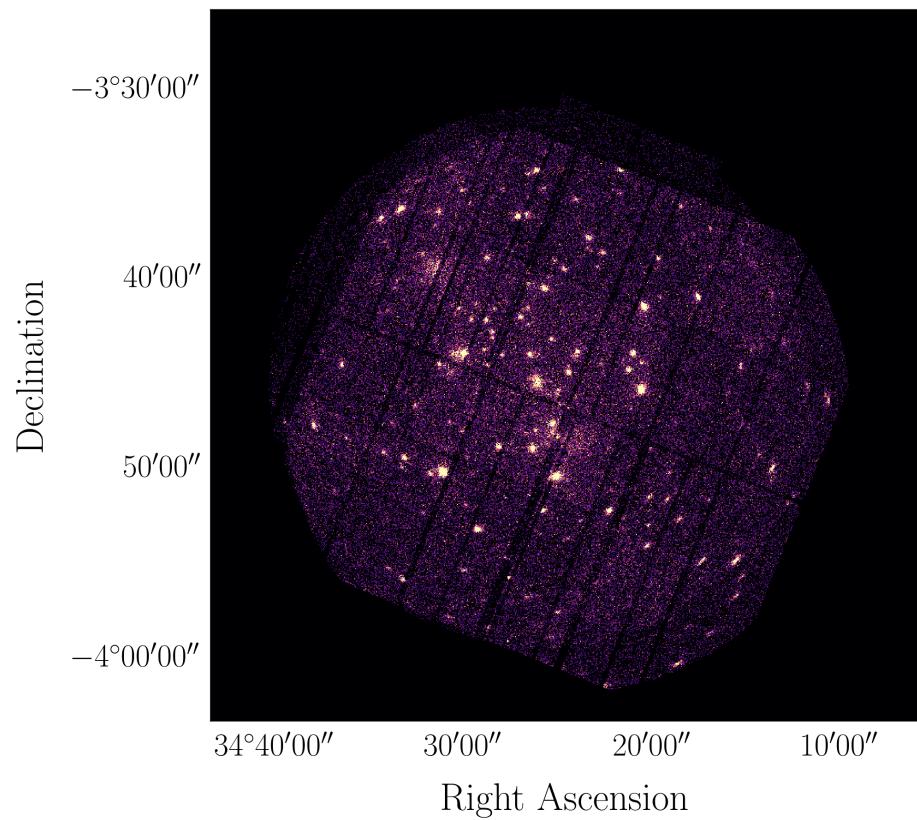


Figure A.6: Xray Image of the Cluster and Surrounding Region

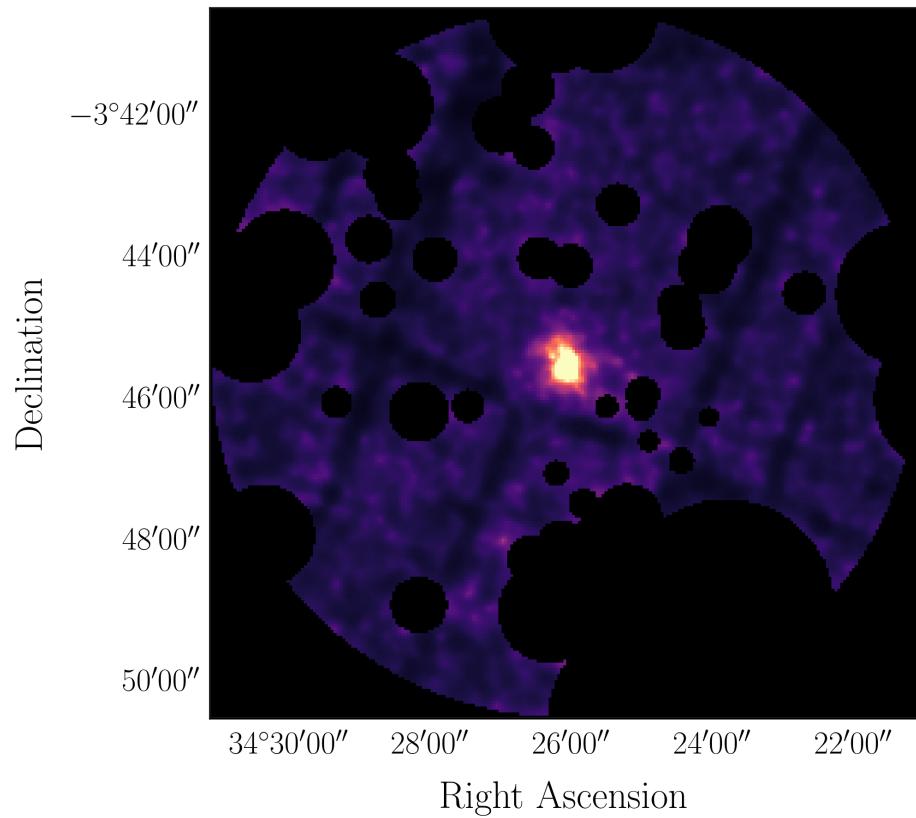


Figure A.7: Smoothed Xray Image of the Cluster and Surrounding Region

Bibliography