Creating Reddening Maps in M31 and M33 with Hubble and James Webb Space Telescope Data

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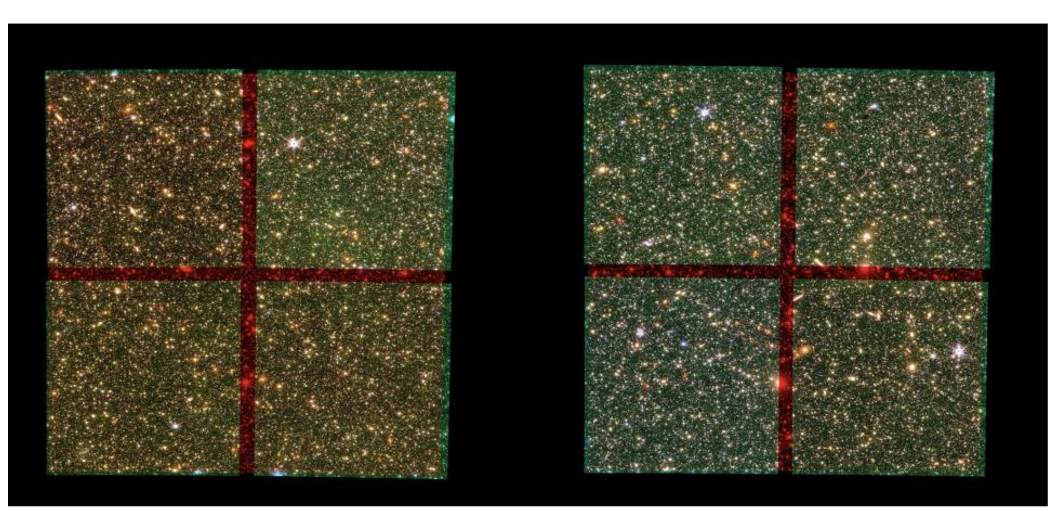
Introduction

The Andromeda galaxy is the Milky Way's nearest galactic neighbor, and the largest spiral galaxy in Local Group. It's satellite, the Triangulum galaxy, is the third largest spiral in Local Group located at a similar distance from the Milky Way as Andromeda. Due to their proximity, we are able to obtain high resolution images of them using Hubble and James Webb Space Telescope data, making them primary targets for creating reddening maps.

To make reddening maps, we are primarily interested in red clump and red giant branch bump stars, which act as standard candles. Our goal is to create reddening maps of regions in Andromeda and Triangulum to determine the difference in observed reddening between maps made with only Hubble data and maps made with both Hubble and Webb data.

A combination of Hubble and Webb data is used in this study, including the F475W and F814W bands from Hubble and the F090W, F162M, F200W, F300M, F356W, and F460M bands from James Webb. Subsets of data were made based on RA and Dec to ensure the stars in each subset are in same area of sky. The image below shows the area of Andromeda outer taken by NIRCam (Domenico Nardiello).

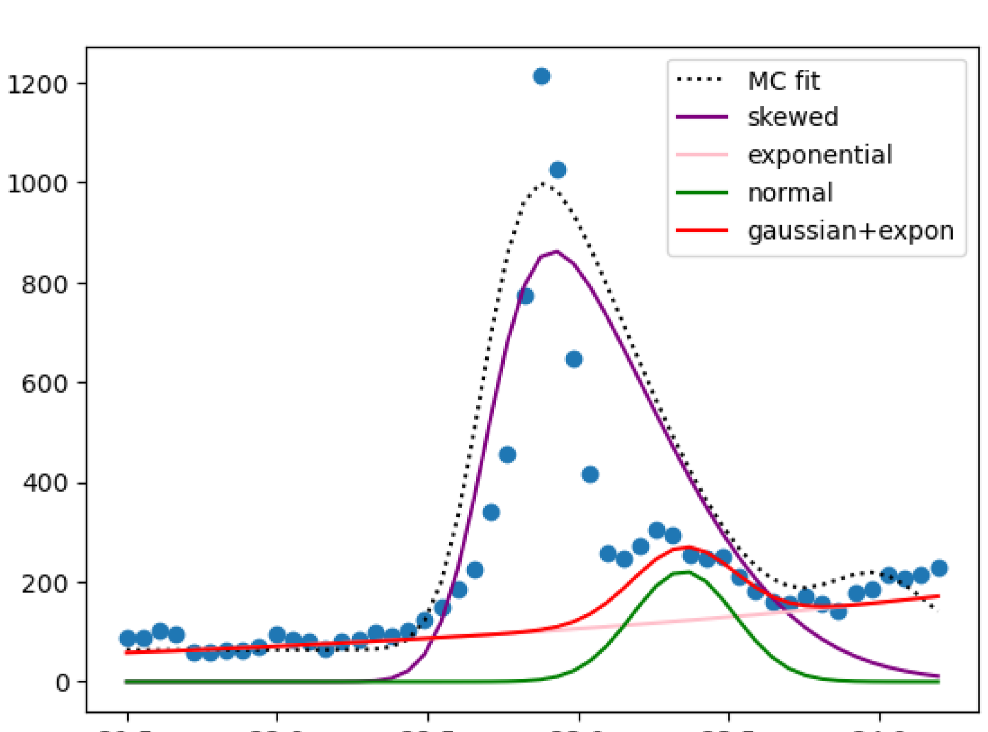


Methods

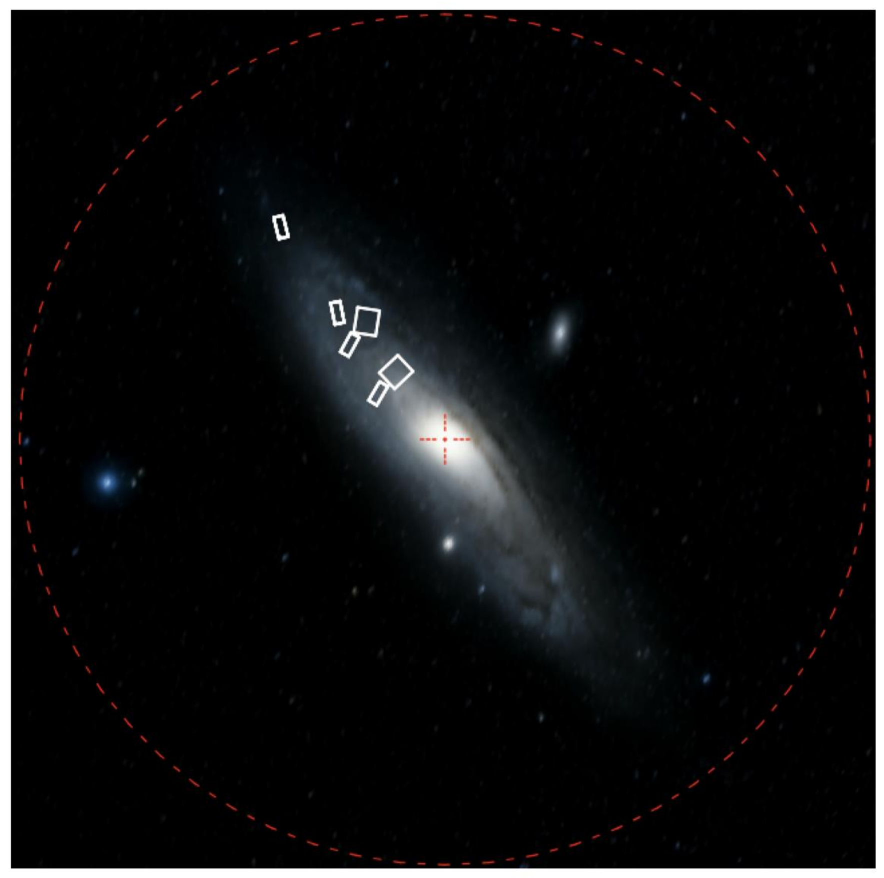
In order to fit for the red clump and red giant branch bump, color and magnitude cuts are made. These cuts for the F090W and F162M bands are listed in the table below.

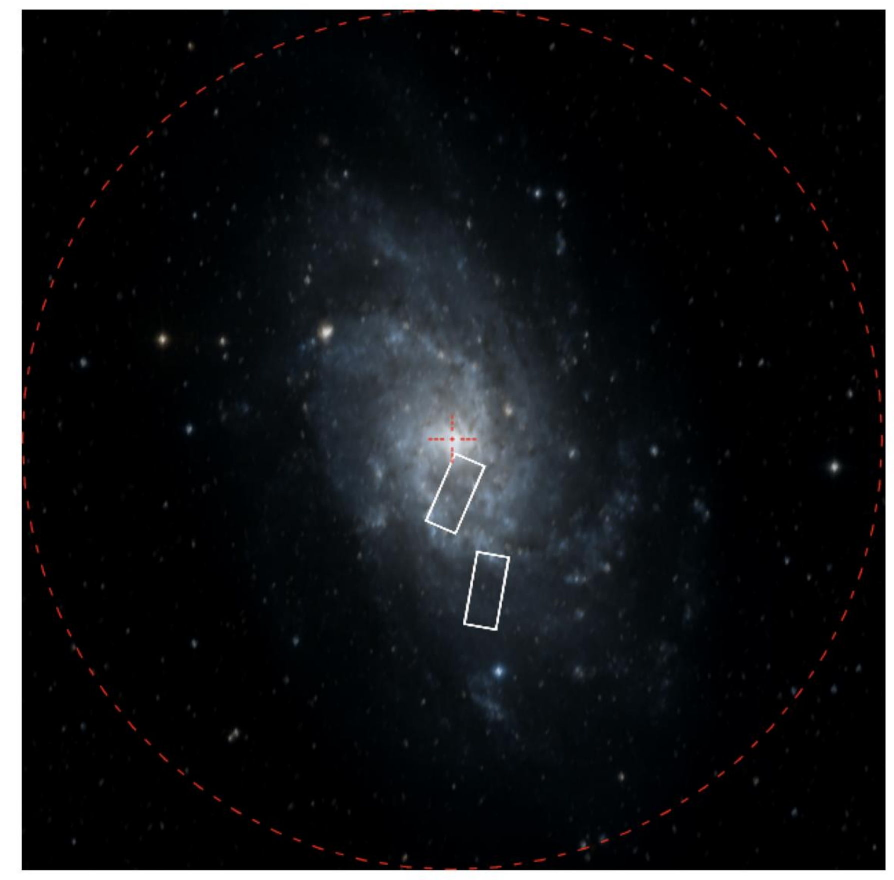
		RC+RGB	
CMD	Region	Magnitude	Color
F090W−F162M	Inner	22.75 − 25.25	0.75 − 2.0
F090W−F162M	Outer	23.0 − 25.0	1.0 − 1.5

Various models are shown below, starting with simpler versions and increasing complexity. The final model is a skewed gaussian + exponential + gaussian, which is used to calculate the red clump average magnitude in each subset for the F090W band.



$$N(m)dm \propto \sum EW_{RC}2\phi(x)\Phi(\alpha x) + e^{\beta(x-\mu_{RC})} + \frac{fEW_{RC}}{\sqrt{2\pi\sigma^2_{RGBB}}}e^{\frac{-(x-(\mu_{RC}+\Delta))^2}{2\sigma^2_{RGBB}}}$$





The images above show the Andromeda (left) and Triangulum (right) galaxies, created by Rachel Pauline using Astroview on MAST. Bands used to observe all 8 of these regions are listed below.

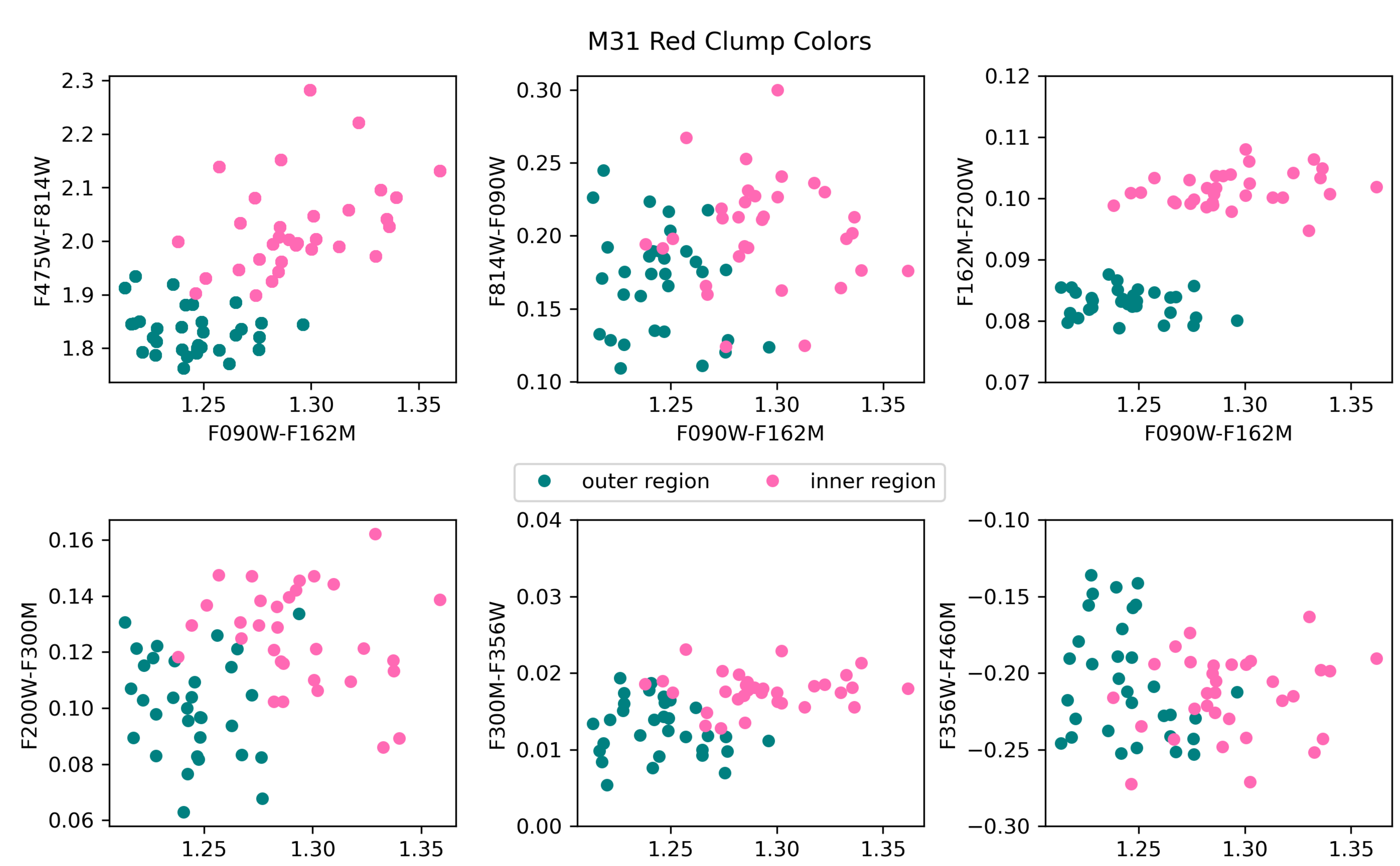
	M31	M33
HST	F475W	F475W
	F814W	F814W
JWST	F090W	F090W
	F150W	F150W
	F162M	F200W
	F200W	F300M
	F277W	F356W
	F300M	F460M
	F356W	
	F444W	
	F460M	

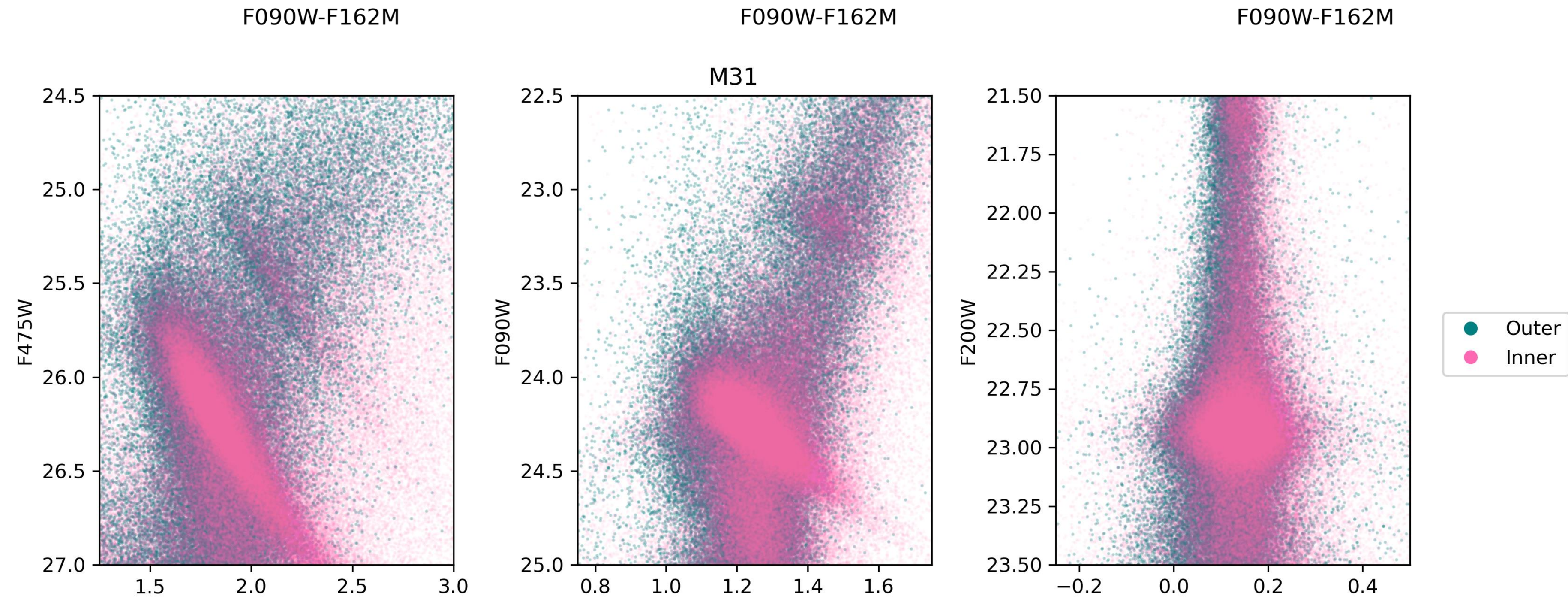
A skewed gaussian has rarely been used to fit for the red clump and this combination accounts for the red giant branch slope, and the red clump and red giant branch bump populations added together. Data is normalized when plotting, not when running the maximum likelihood estimation or Markov Chain Monte Carlo sampler.

With the average magnitude, we weight stars based on their distance from the red clump, and determine the average color associated with the average magnitude. These average colors are then used to create color-color plots (see Results), which show the shift in each color for each subset.

Results

As of now, we have 8 large subsets and 32 smaller subsets of data for each of the two outermost regions of Andromeda referred to as Andromeda outer and inner. The color-color plots for each of the 7 colors available in this data set are shown below. Teal represents the color-color points for 32 outermost subsets, and the dark pink represents the 32 subsets for the second outermost region.





This plot depicts three color-magnitude diagrams for both the inner and outer regions of Andromeda, focusing on the red clump and red giant branch bump.

Discussion

With the color-color plots made, we will be able to calculate a reddening vector for each color combination across these 2 outermost regions with respect to wavelength. These 2 regions have the least amount of reddening, so we expect the shift towards redder colors to increase with the 4 additional fields, as the regions get closer to the galaxy's center.

We expect noise due to PSF variations across the detector to shrink as the study progresses since these will be better modeled with the addition of the higher reddening fields. Additional data reductions will be implemented to improve the underlying data and reduce the presence of NIRCam artifacts.

The asymptotic giant branch bump may also be visible for many of the subsets in the F090W band. We are working on accounting for this by adding a fixed gaussian to our model, potentially changing our current results.

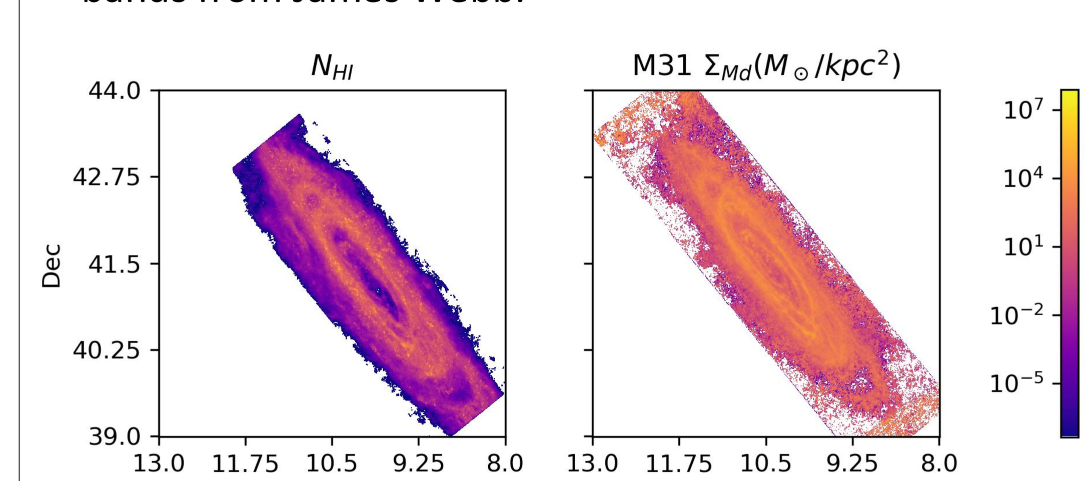
Conclusions

For the Andromeda outer region, we have tested several models to find the best fit for the data and run several samplers on the data. Our best fits so far provide us with an avenue to calculate the reddening vectors for these two regions using the average color and magnitude points. Our working model and methodology can be easily adapted to work with the remaining regions in both galaxies.

Future Work

We plan to use my code for the remining Andromeda sightlines, adapting it based on color and magnitude cutoffs in each region, creating reddening maps for each field. Once we have reddening vectors for all of our subsets and fields, we will determine the wavelength dependence of the reddening vector for Andromeda. This study may also indicate the best sightline for observing Andromeda based on the amount of reddening in each region.

Following the creation of our reddening maps, we plan to compare our maps with preexisting reddening maps such as those shown below from Dalcanton et al. (2015) and Draine et al. (2013). In doing this, we hope to see how the distribution of dust across several sightlines and varying amounts of reddening changes with the added photometric bands from James Webb.



The above diagram shows my recreation of an HI column density map (left, Braun et al. 2009) and a map of dust mass (right, Draine et al. 2013). Note that the color bar for the left plot is unknown.

Since dust is highly correlated with the presence of neutral atomic hydrogen (HI), we plan to compare our findings to maps of HI, such as the HI column density map shown above on the left.

After concluding this work on Andromeda, we aim to apply the same methodology to the 2 fields in Triangulum.