# CS 6635/5635 Project Report

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## Project Title

James Webb Space Telescope Astronomical Visualization: False-Color Imaging and Analysis

GitHub link: https://github.com/ArtyNar/AstroVis

## Project Overview

Our project consisted of taking raw data obtained by one of the many instruments present on the James Webb Space Telescope, and visualizing it. We specifically used data from the Near Infrared Camera (NIRCam for short). The NIRCam is used to capture electromagnetic emissions in the wavelength range of 0.6-5 microns. This spectrum of light is useful for detecting the formation of stars, as well as to observe exoplanets that are near stars.[9]

The goal of our project was to take raw data from this instrument, and to use it and a technique known as false-color mapping in order to create visualizations of certain astral bodies, and to then annotate said visualizations with calculated distances between Earth and those astral bodies.

## Project Background and Relevant Work

The data source for our project is the The Mikulski Archive for Space Telescopes (**MAST**) archive, which allows searching multiple collections of astronomical datasets all in one place.

We learned about and utilized a community-built "Astropy" Python library to complete the project, which contains functionality aimed at professional astronomers and astrophysicists.

The paper "Preparing Red-Green-Blue Images from CCD Data" by Lupton et al. (2004) [7] describes an "optimal" algorithm for producing red-green-blue composite images from three separate high-dynamic range arrays.

# Project implementation

Before the astronomical data can be visualized, the data from the JWST requires preprocessing, such as reprojection, normalization, and stretching, which this section describes in detail.

## Reprojection

Astrographical images from the different JWST instruments and filters come in different orientations, scales, and resolutions. Because of this, images have to be aligned before a composite is created. To help with that, JWST `.fits` files contain World Coordinate System information, which is a coordinate system for celestial objects. A sample of how the coordinates are mapped can be seen below.

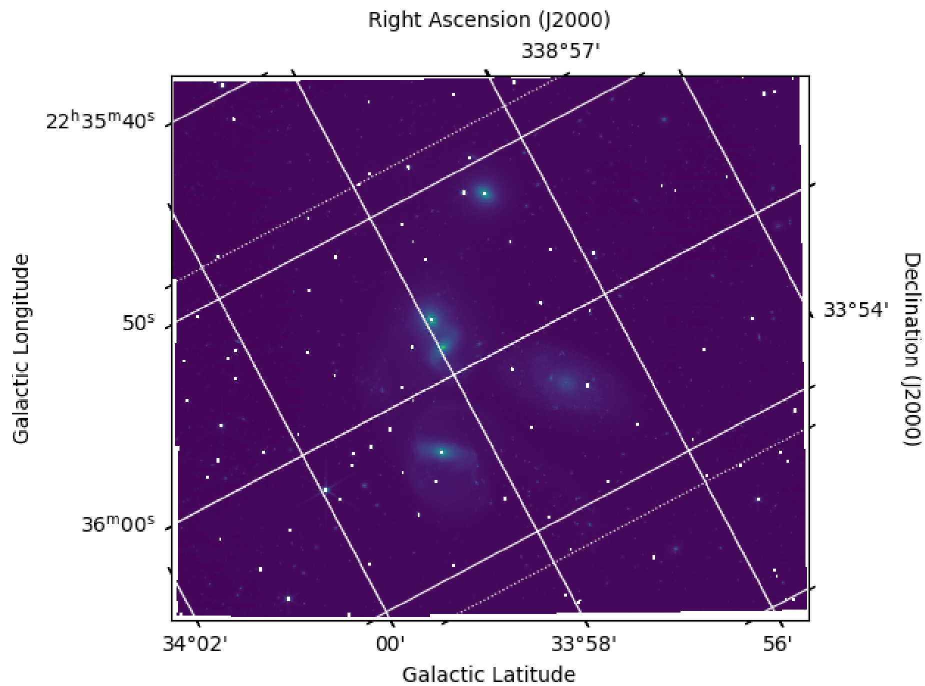


Figure 1: Example of the World Coordinate System

## Normalization

Initially, data from the telescope is not clean: it contains null and negative values and possible noise that needs to be removed. Additionally, it helps to normalize the data to the [0:1] range using lower and upper limits, where $x$ represents the values in the original image:

$$y = \frac{x - v_{\min}}{v_{\max} - v_{\min}} \tag{1}$$

## Stretching

A common data distribution in a JWST image can be seen below.

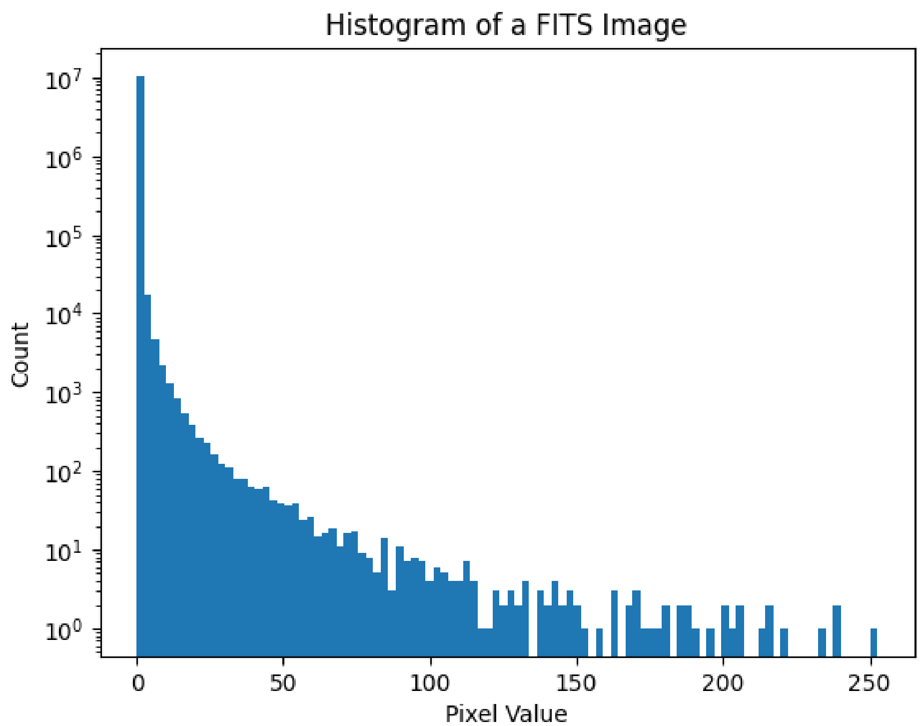


Figure 2: Pixel value distribution

If the values are plotted as is, certain areas will dominate the image while the rest will be too dim to see, resulting in visually underwhelming images. In order to get a more detailed and interesting result, numerous stretching functions can be applied to the data. We have tested the following stretching functions:

- Log stretching:
$$y = \frac{\log{(ax+1)}}{\log{(a+1)}} \tag{2}$$

- Asinh stretching:
$$y = \frac{\operatorname{asinh}(x/a)}{\operatorname{asinh}(1/a)} \tag{3}$$

# Results

## Saturn

Image below is the first that we produced, and required a single image from the NIRCam instrument. Also, a custom color map was made to match typical Saturn colors.

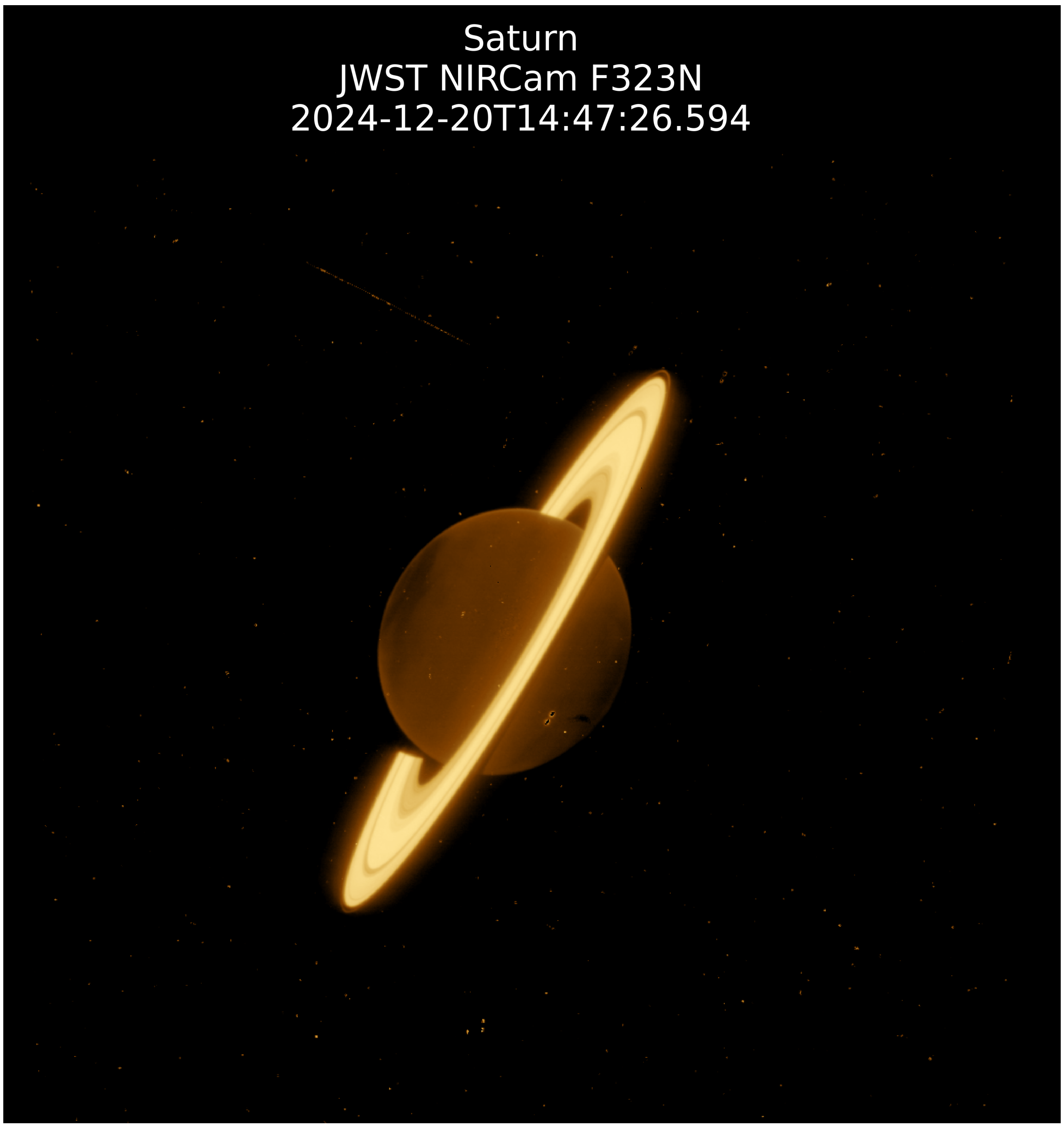


Figure 3: Saturn resulting image

## Neptune

For our dataset covering Neptune, it required merging four images from the NIRCam together, all of which used different filters, meaning that they captured different wavelengths of light. These images were not taken from the exact same angle, so it was necessary to reproject them onto each other.

The first image is the result obtained when using the Log stretching function mentioned above, while the second image is the result when using the Asinh function.


Figure 4: Neptune resulting image (log stretching)

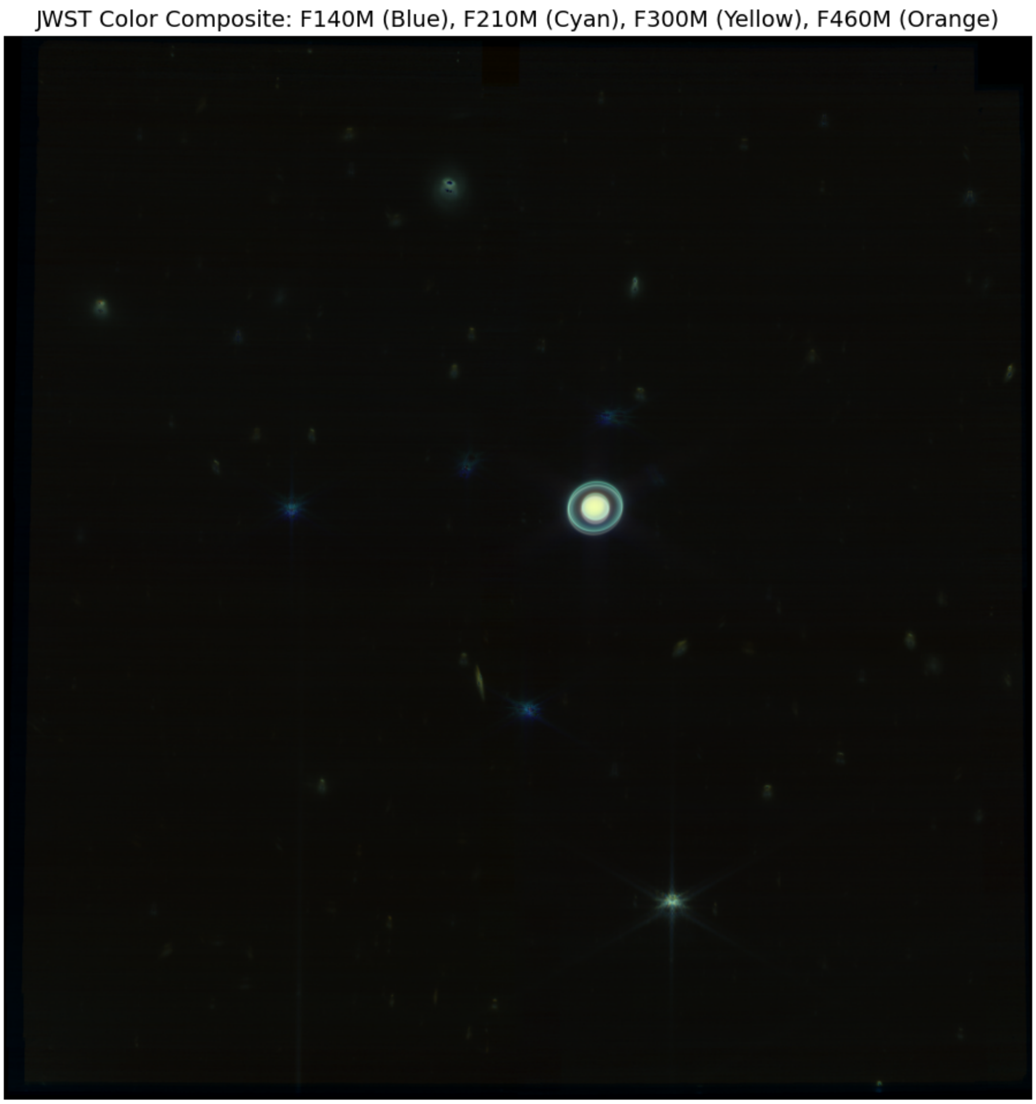


Figure 5: Neptune resulting image (asinh stretching)

## Stephan's Quintet

Stephan's Quintet is a grouping of 5 galaxies, the first grouping of galaxies ever discovered by humankind.[8] To properly visualize it, the dataset used was around 30GB in size, encompassing data captured with 6 different filters present on the NIRCam.

For the following visualizations, we made use of the algorithm created by Lupton [7]. Through experimenting with parameters on this algorithm, we were able to achieve a stunning visualization, akin to those created by professionals in the field.

The image below is what the data looks like when processed with ranges of different stretching parameters (i.e. 'Q' affects how much the asinh stretching function is softened and 'stretch' affects how much the values are linearly stretched).

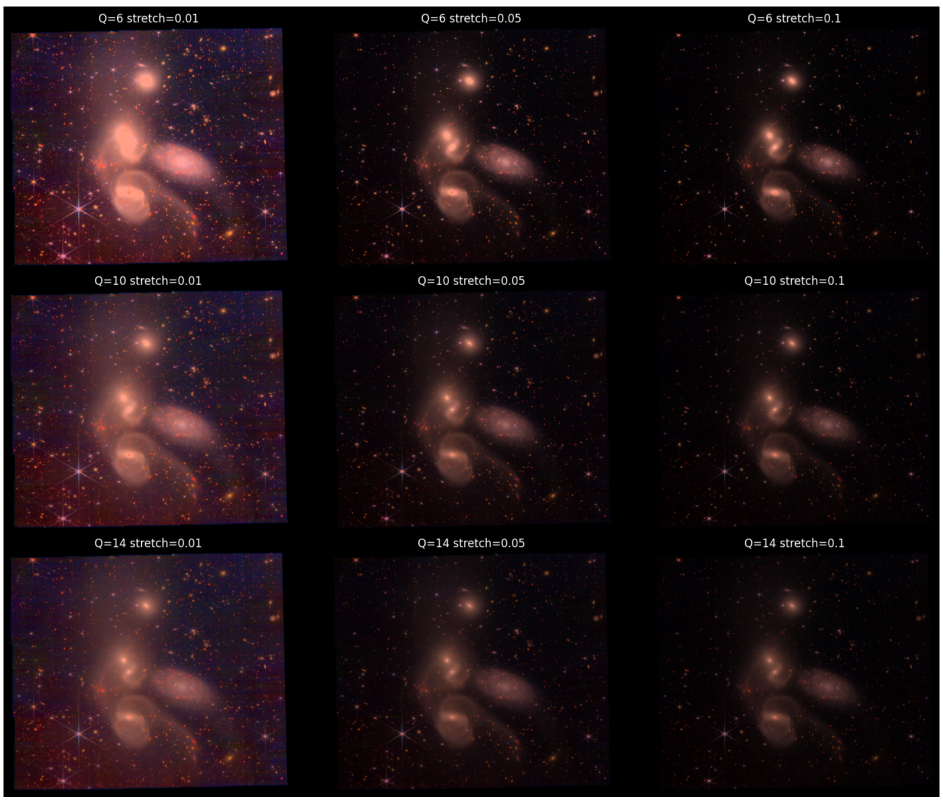


Figure 6: How processing parameters affect the result

This final image is the crowning piece of our project, obtained by tuning the parameters with the aforementioned algorithm.

Figure 7: Stephan's Quintet Visualization

Full-resolution file is available HERE.

# What we learned

We initially set out with the goal of making these visualizations as well as using the underlying data to annotate astral bodies with their distance from Earth. Unfortunately, we were unable to achieve those annotations. The data necessary to perform those distance calculations were not present within our chosen datasets. However, the effort to simply produce these visualizations was educational in itself. The process of obtaining the raw data, normalizing and reprojecting, and finally false-color mapping an image showed us just how much effort goes into creating visualizations from JWST data. It helped us learn a new perspective on just how much effort goes into the very common space visualizations we see in our daily lives.

# Project Evaluation

Although we did not achieve everything we set out to achieve at the beginning, overall, this project felt very much like a success. We were able to take our raw data, and produce very impressive imagery, despite the hurdles inherent to the task. If we were to repeat this project, we would take care in the future to choose datasets for which we could easily obtain the necessary specular data to properly annotate our visualizations.

These datasets vary largely in size and require much more pre-processing than we thought at the beginning of this project. It was through this project that we were able to gain a better appreciation for the work that goes on behind the scenes in astrophysics visualizations.

# References

[1] Astropy Collaboration. "Astropy documentation." (2025), [Online]. Available: https://docs.astropy.org/en/latest/index.html.

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[9] NASA. "Near infrared camera (nircam)." (2024), [Online]. Available: https://science.nasa.gov/mission/webb/nircam/.