Processing an AstroImage from the James Webb Space Telescope data observations utilizing the Mikulski Archive for Space Telescopes, *Siril* astronomical image processing tool, and *GIMP* Image Manipulation Program.

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- Downloading software that we will utilize.
  - *Siril*
    - *Siril* is a free, and fully capable software application often used in astrophotography. It allows preprocessing and processing of images utilizing a variety of algorithms built into the program.
      - Download the software here:
        - https://siril.org/download/
  - *GIMP*
    - *GIMP* is an acronym for GNU Image Manipulation Program. It is a freely distributed program for image handling.
      - Download the software here:
        - https://www.gimp.org/downloads/

- Finding and Downloading "Image" Files:
  - For this project, we need to access the public telescope observation data made available through the Mikulski Archive for Space Telescopes (MAST).
- Go to MAST data archives: https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html
  - Search for a celestial object name in the top search bar (ex. M 74) - **(Figure 1.0)**
    - Messier (M) 74 is the large spiral galaxy in the equatorial constellation Pisces
    - When searching for a celestial object, keep in mind that there are only a limited number of celestial objects with observations available so far. However, new data sets are being added to the MAST Archive all the time

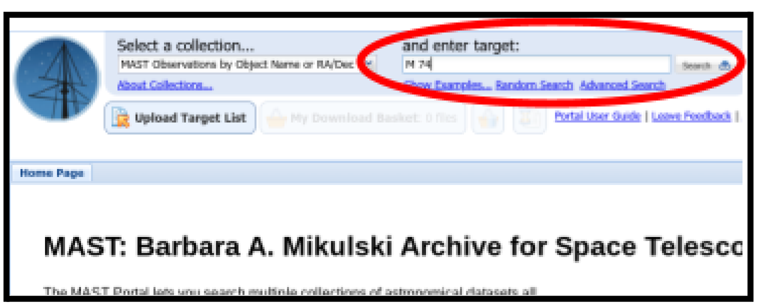


Figure 1.0

- After searching for a specific celestial object, a new screen should pop up with rows of data observations for your specific object.
  - Now we need to reduce the amount of observations shown using the filter boxes on the left side of the screen
    - On the left panel, check boxes for:
      - Mission: JWST
        - This selects the specific telescope that we want to access the data from. We chose JWST… The James Webb Space Telescope. **(Figure 1.1)**

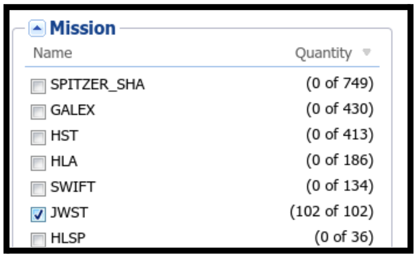


Figure 1.1

      - Instrument: NIRCAM or NIRCAM/IMAGE
        - If both options are available, select both. However, if not just select one of these options. **(Figure 1.2)**
        - This selects the specific instrument on the telescope that we want to access data from. NIRCAM and NIRCAM/IMAGE are the instruments on the James Webb that detect our desired ranges of Infrared radiation.

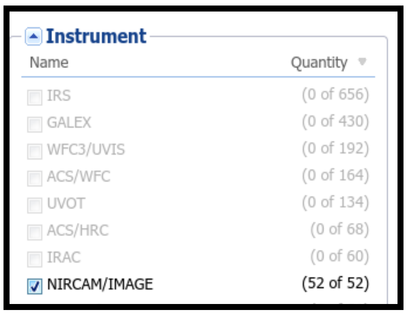


Figure 1.2

      - Calibration Level
        - This option can be used if you are still left with a bunch of data sets and still need to reduce the results. Calibration level 3 is optimal, and anything under 2 is not worth using. The higher the number, the better. **(Figure 1.3)**

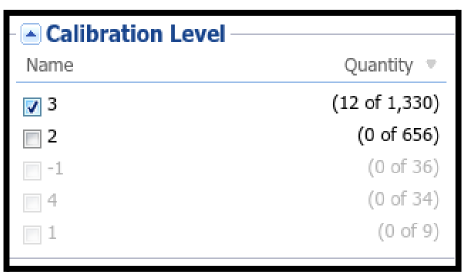


Figure 1.3

      - Data Rights: Public **(Figure 1.4)**
        - Sometimes this box does not appear after searches. If this is the case that's fine.
        - We use this to remove data that hasn't been made available to the public yet. Public accessible data sets should appear white. If data sets are yellow or orange, they have not yet been made publicly available quite yet. **(Figure 1.5)**

←Figure 1.4

Figure 1.5

- Now that we've greatly reduced the data results for our celestial object, we want to select the specific filters of the infrared spectrum to get the data from. Some filters only detect and record data from certain values of the infrared spectrum. Example filters are… (fw444, fw277, fw150, etc)
    - Go to the horizontal scroll bar on the middle of the screen and scroll over until we see the "Filter" category, and click on it to sort the filters in ascending order. **(Figure 1.6)**

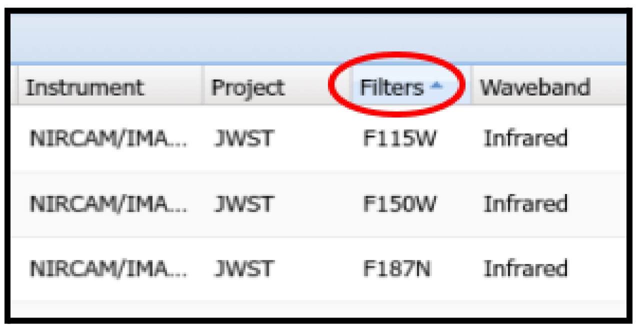


Figure 1.6

- We now need to determine which filters we want to download. Press the floppy disk icon for the desired filter data sets to download a specific filter's data set. **(Figure 1.7)**

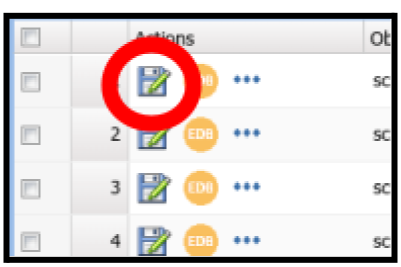


Figure 1.7

        - My advice is to select as many filters as possible within the F090W - F444W range for your celestial object.
            - However, do not select duplicate filters, you only need one observation of a filter. It is better to start with more and greater variety rather than less. 5-6 is probably sufficient.
            - Some downloads take up to 4 or 5 GB of storage per data set. So it is advised that you clear some storage before downloading your files.
    - When you download the files from a filter, each package of files should be compressed into its own .zip folder.
        - You need to extract each filter's zip folder.
            - Make sure you extract the contents to a location that you know. You will need to have easy access to individual files in these folders in the next set of steps.

        - Create a new folder in the same location. Name the folder "i2d-Fits".
            - After creating the new folder, go back to the extracted folders.
                - You now need to locate the correct file in each extracted folder. It should have a suffix something like "*filter*_i2d.fits"
                    - Go into each of the extracted folders and copy these i2d.fits files to your new "i2d-fits" folder.
                    - After moving these files to the new folder, you need to change the file extensions of each individual file from .fits to .fit This will allow Siril to properly read the file without an error later on.

- Open *GIMP* Image Manipulation Program
- We now need to create single frame .fit files for each filter. The i2d files typically have more than one frame in them.
        - Go to file -> open. Then open a singular i2d.fit file
            - A file may look completely black. This is totally fine.
                - There are multiple layers shown at the top of the GIMP interface. (**Figure 1.8**)
                - We need to delete all layers, EXCEPT for the layer with a long specific name relevant to that specific filter. The layers in which the name does not match the file name. (stuff like Background, etc) can be deleted. (**Figure 1.9)** Simply click the little x on the layer tile in the top left.

Figure 1.8

            - After deleting the correct layers, we need to take note of the dimensions of the image we have open.
                - Go to image -> scale
                    - Take note of the filter number (ex f444w) and its dimensions. You will need this information again later.
            - Now, we need to go to file -> export.
                - You want to overwrite the original i2d.fit file with the new, single layer i2d.fit file. Make sure you overwrite the correct file!
            - Repeat this process for all of the multi layer i2d.fit files until they're all overwritten with a file that has just one layer.

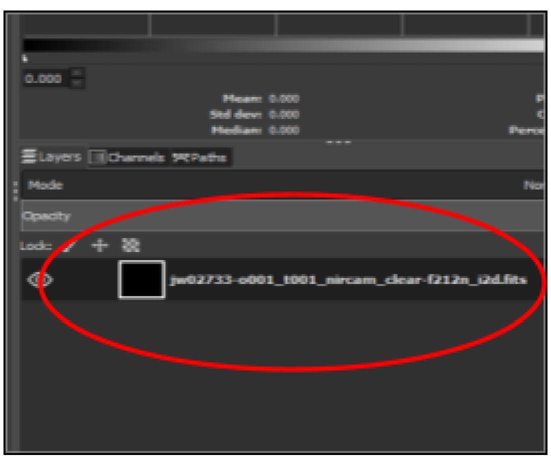


Figure 1.9

- Open *Siril*
  - Now that we have single layer “image” files, we need to go into *Siril* and make some changes to our images in *Siril*.
  - Since you recorded all of the dimensions of the single layer filter images, determine the 3 most similar in size filters, and delete the rest from your computer.
    - In the *Siril* interface, at the top left, press open. Start by opening your **smallest** dimension image. This is important. It will most likely appear black.
      - At the top of the Siril interface, go to Image Processing -> Histogram Transformation. A new window should open. Select auto stretch **(Figure 2.0)** Apply -> Close.
      - We now want to crop the image. Use the selection tool to select an area on the image. Click and drag the mouse to select the main portion of the image. You are going to want to crop out the rough edges and blank spots . Once you have selected an area, you can zoom in on the edges (the green lines) to precisely crop the image to the EXACT size you want in pixels. Make sure to note the dimensions that you crop it to **(Figure 2.1)**.
      - Next, go to Image Processing -> Background extraction.
        - A new window should open. Select “add dither” -> generate -> compute background - > Apply -> Close
        - Now go to save at the top right, and overwrite the previous file.
      - After saving, close *Siril* and reopen it. Repeat this process for all of the i2d.fit files until they’re all overwritten. **ALL** 3 images should also be cropped to the same size.

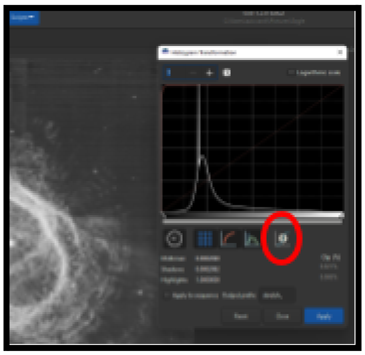


Figure 2.0

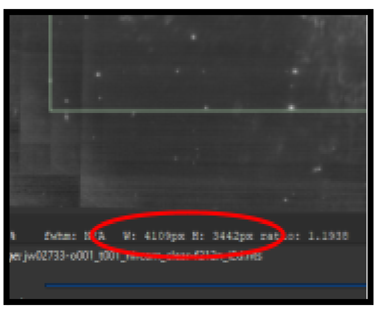


Figure 2.1

- After all files are cropped to the same size and the files are overwritten, re-open *Siril*. At the top of the Siril interface, go to Image Processing -> RGB Compositing. A new window should open.
  - We now need to open our different files under the correct RGB values.
    - If you want to get more complicated, you can map the observed value of the infrared of each filter to a value of visible light. Otherwise, skip to the next section.

(Advanced Mapping Method) NOTE: If your filters are close in number, ex your 187 and 200, this method may not give you the best results possible. It may be better to use the more simple method; skip ahead.

- Otherwise, locate the NIRCam Filter map shown. (**Figure 2.2**)
  - Access the map here;
    - https://jwst-docs.stsci.edu/jwst-near-infrared-camera/nircam-instrumentation/nircam-filters

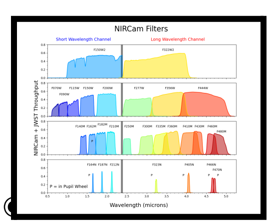
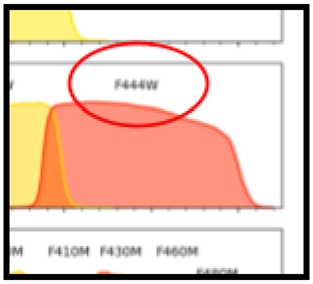


Figure 2.2



←**Figure 2.3**

- After you locate the chart, you need to calculate the RGB value for each color.
    - Looking at the chart, find the filter number. For example, we are going to use F444W. **(Figure 2.3)**
    - We need to determine the median of wavelength for the filter
        - Take your filter numerical value (444 in this case) and divide by 100.
            - Ex. 444 ÷ 100 = 4.44
                - This resulting number is your median wavelength value in Microns.
    - We now need to map this micron value to a Nanometer wavelength value on the visible light spectrum.
    - Use this formula:
        - Nanometer value = 380 + 81.6*X
            - X equals the micron value of the filter from before.
    - The resulting number is a value of visible light in Nanometers.
        - For the "444 filter", we used the value of 4.44 microns.
            - Nanometer value = 380 + 81.6*(4.44)
            - We then got the value, 742.304 Nanometers.
- Do this same Nanometer mapping process for all of the filters you cropped and stretched. Then, write down the filter numbers and their respective Nanometer-mapped value.

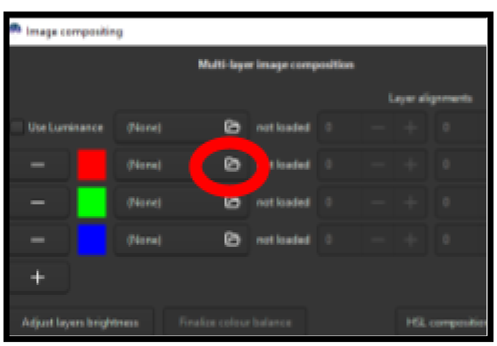


Figure 2.4

- We now want to create a layered image composed of the single layer files that we have.
    - First, go to Image Processing -> RGB Compositing. A new window should open.
    - Each Red, Green, and Blue layer needs an image assigned to it for stacking and registering.
        - Stacking is basically piling all the image/.fit files into one image.
        - Registering is lining up the image features like swirls and stars so they're aligned on top of each other.
    - First, select the red channel folder icon. **(Figure 2.4)** (Leave luminance unchecked and unused). Now, assign the largest number filter file to the red. (Ex. 444 assigned to red, b/c the

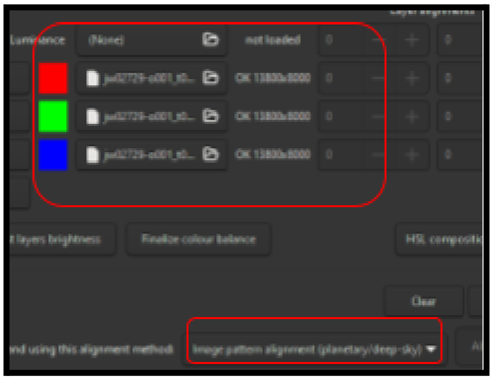


Figure 2.5

other filters are 335 and 200). With this information, select your desired file for the red channel.

- Next, we assigned the medium number filter number to the green channel and the lowest number to the blue channel.
- Note that *Siril* will say "OK" or "not loaded" if it was successful or not **(Figure 2.5).** Size of the file (in pixels) matters here. Mismatched sizes are no good. They need to be exactly the same.
- For the alignment tool, choose "Image Pattern Alignment (planetary/deep-sky)" **(Figure 2.5)**.

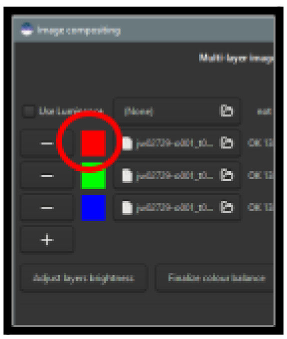


Figure 2.6

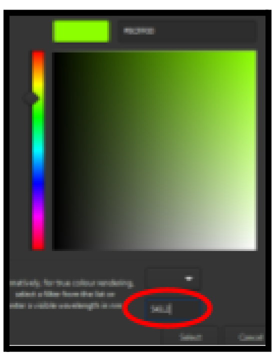


Figure 2.7

- Next, we need to assign the proper color to each channel.
  - To do this, click on the colored square **(Figure 2.6)** -> New Custom. A new window will appear **(Figure 2.7)**.
  - Now you want to take the Nanometer value for the respective filter that you calculated before, and enter it into the box **(Figure 2.8)**
  - Repeat these last few steps for each color channel.
  - You now need to register and align the image layers.
    - To do this, select the green channel at the top left of *Siril*. **(Figure 2.8)**
    - Now, click and drag on the image area to highlight a rectangle. If you can see your image, include a feature like a swirl or a cluster of stars. If not, it's recommended to select a larger portion of the image.
    - Next, go back to the RGB compositing window. Select "Align"
      - This step has caused my computer to freeze up many times. I've found that even when it freezes, don't close the program. If you leave it alone for a while, it will finish.
    - After alignment has finished, we selected the RGB channel at the top left of *Siril*. Now you need to export the file as a .tiff extension.
    - Continue the instructions following the simplified version

Figure 2.8

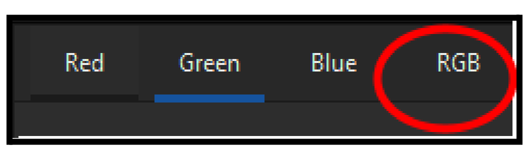


Figure 2.9

(Simplified Method)

- We now want to create a layered image composed of the single layer files that we have.
  - First, go to Image Processing -> RGB Compositing. A new window should open.
  - Each Red, Green, and Blue layer needs an image assigned to it for stacking and registering.
    - Stacking is basically piling all the image/.fit files into one image.
    - Registering is lining up the image features like swirls and stars so they're aligned on top of each other.
  - First, select the red channel folder icon. **(Figure 3.0)** (Leave luminance unchecked and unused). Now, assign the desired image file to the red.
    - We assigned the highest numerical value filter to the red channel (Ex. 444 assigned to red, b/c the other filters are 335 and 200). With this information, select your desired file for the red channel.
  - Next, we assigned the medium filter number to the green channel and the lowest number to the blue channel.
  - Note that *Siril* will say "OK" or "not loaded" if it was successful or not **(Figure 3.1).** Size of the file (in pixels) matters here. Mismatched sizes are no good. They need to be exactly the same.
  - For the alignment tool, choose "Image Pattern Alignment (planetary/deep-sky)" **(Figure 3.1**). Keep the RGB compositing window open.
  - Keep in mind that an image may or may not appear. It's okay if there is a blank picture.

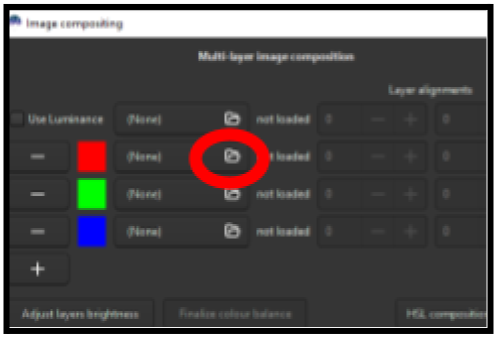


Figure 3.0

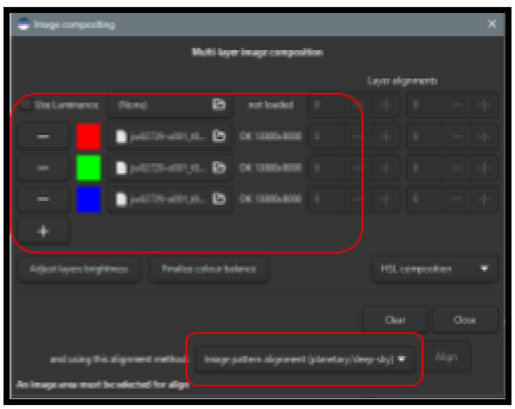


Figure 3.1

Figure 3.2

  - You now need to register and align the image layers.
    - To do this, select the green channel at the top left of *Siril*. **(Figure 3.2)**
    - Now, click and drag on the image area to highlight a rectangle. If you can see your image, include a feature like a swirl or a cluster of stars. If not, it's recommended to select a larger portion of the image.
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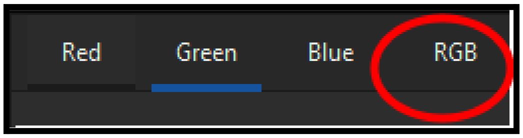


Figure 3.2

close the program. If you leave it alone for a while, it will finish.

- After alignment has finished, we selected the RGB channel at the top left of *Siril* (**Figure 3.2**). Now you need to export the file as a .tiff extension.

- Open *GIMP* Image Manipulation Program
  - Now that you have a stacked image, we are going to use *Gimp* to edit the color curves.
- When in *GIMP*, open your .tiff file.
  - To edit your color curves, go to, Colors -> Curves
    - Change the color channel to edit, using the drop down menu **(Figure 3.2)**
    - Play around with the color curves of each channel and see what you think looks best.
      - Once you find the curves that you like, you are almost done!
    - Now go to File -> Export As, and export the final file to the location you choose.
  - Change the file extension to .JPG instead of .tiff

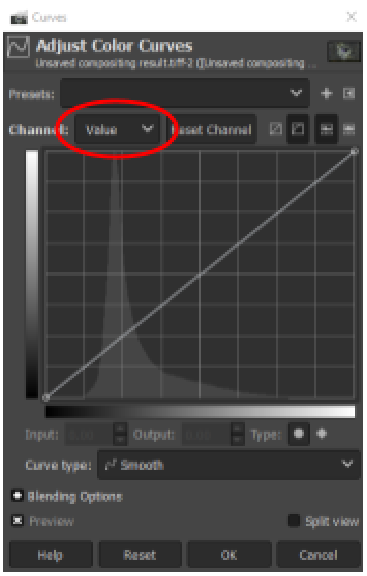
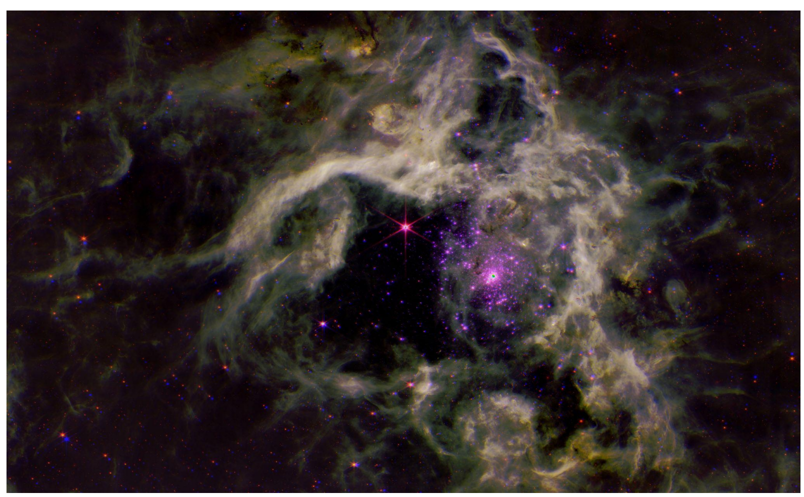


Figure 3.2



Credits: NASA, ESA, CSA, STScI and Gavin Rauh

Please take a few moments to answer these 5 questions to help improve the quality of these instructions: https://www.surveymonkey.com/r/DMZXVWK