# “Lab” 4 – JWST Observations of Jupiter

In this lab / in-class activity you will begin to investigate the data obtained from JWST as part of its early release science observations of the planet Jupiter. The data available from the JWST public archive are the calibration level 3 data products (i.e. – with most of the JWST pipeline already applied to it).

We will be conducting image analysis on data taken from the NIRCam instrument. This will be calibrated photometric data, similar to the type of data taken for Lab 2 (Photometric Time Series). These data are taken at several broadband wavelengths across the JWST/NIRCam band, and so are in the infrared instead of the optical. Additionally, Jupiter is a resolved, extended source, unlike the stellar point sources we analyzed in Lab 2, so some aspects of the analysis will be different

If you don’t already have DS9 or something similar to view FITS images, you may want to install this on your computer, as it can make viewing much easier than in a python-only environment (although this can still work!). Part of this lab will involve changing the color scale of the data to highlight different features, which is very easy to do in DS9.

**Getting Started**

1. Download the data from the repository here on OneDrive:

   https://uflorida-my.sharepoint.com/:u:/g/personal/jasondittmann_ufl_edu/EVvf2NjUwjtMiL5NgX3Q8fABK5J2GqeOcBQHXOrG2aoPRg?e=MdA3ew

   These data are sorted into two folders, a calibration folder and a science folder, containing the calibration frames (flats and biases) and the science frames (images of WASP-10 and neighboring stars).

2. These data contain NIRCam images, separated by folders for the following filters:

   a. F150W2

   b. F212N

   c. F335M

   d. F360M

   e. F444W

   Some of these filters have data taken for multiple observations. First, load up the images for each of these filters and visually inspect them. What do you notice about the data and about Jupiter? Do the data look like the press release images or are there other things going on? If so, describe them and what their origin might be.

3. One of the important things to be aware of when inspecting images is the idea of the dynamic range of the image. Jupiter is very bright, yet it is known to possess dust rings that are very dim. There are also background galaxies as well as at least one moon in the images. Yet depending on your image display properties and the color bar, you might not be able to see anything except Jupiter. Load up one of the images, and adjust the color scale until you can see each of these objects (there is unlikely to be one color scale choice that lets you see all at the same time!). This is most easily done in DS9 which has slider bars for the z-scale, but can also be done in python.

   Record which filter image you used, and the scale parameters you used to display the image and show a cutout of each of these features: Moon, Rings, Background Galaxies, Jupiter as well as their coordinates on the image.

**Science Analysis**

In the image header, there will be diagnostic information about each of the images. Crucially, this includes the flux calibration, or how many janskys per pixel (or per unit area) is equivalent to one count. Note: The zero point calibration for JWST has been updated so the value in the image header might not be as accurate as we now know today, but it is fine for an in-class lab activity! So, let's make a broad band spectrum of Jupiter using the imaging data!

1. **Spectrum of the Integrated Disk**

   Let's first do the easy thing – pretend that Jupiter is a point source. We're going to be doing a similar thing to what you did in lab 2 – integrate all the light under Jupiter's disk as if it were the same as integrating a big blob of a star. Place a circular aperture the encloses most of the disk of Jupiter (you might miss some of the edges but this should have negligible effect). Using the information in the image header (pixel size, how to convert from counts to flux density in jansky), sum up the total integrated flux in each image. Obtain the median wavelength for each instrument setting and make a plot of Flux vs Wavelength for Jupiter. Have a horizontal error bar for each data point spanning the width of the NIRCam filter used for each image.

   For this portion, include an image of Jupiter with your chosen aperture for each of the images as well as your derived spectrum. What do you notice about this spectrum, and how do you interpret this?

2. **Spectrum of Jupiter's bands**

   One of the neat things about Jupiter is that it's not a point source! While there's other neat things about it too, we're going to exploit the fact that we can resolve its disk for this next part.

   Apparent in Jupiter's images is its banding structure. This structure is driven by the high rotation rate of the planet and compositional differences and cloud altitudes that result from this rotation. Because we can resolve Jupiter's disk, we can adjust our circular aperture from part 1 into rectangular apertures that encompass different bands.

   **Repeat part 1 above for 3 different regions on Jupiter. This can be any region you choose as long as it's visually justified. Be sure to include a plot of the spectra of your regions as well as an image showing their locations on Jupiter.**

   Do these regions have the same spectral shape? If they're different, what might be the origin of these differences?

3. **Stuff exists outside the Solar System too**

   Repeat this exercise for one of the non-Jupiter objects (likely a background galaxy but possibly a star). Galaxies are extended objects too, so similar data analysis procedures apply (although you would likely use an ellipse instead of a rectangular aperture). Show a plot of this spectrum.

**Important Considerations**

1. **Bad pixels –** When summing up the flux in a region, there may be bad pixels within your aperture. Your code should account for these in some manner. That can be either interpolating a value for those pixels from the pixels around it, or accounting for it when summing up the total flux and total emitting area in angles. Be sure to include this in your submitted code!
2. **Normalize by the size of your aperture for the regions –** If you want to compare the spectra of different regions, you'll need to account for the size of your apertures. Luckily, we know the size of the pixels of JWST/NIRCam on the sky, so you can account for this.

**THE REPORT:**

For the lab report, please submit the following:

1. Please submit all the code you used for this lab as a pdf file (Canvas can load pdf files but can't display a jupyter notebook file natively, for example).
2. Methodology: What did you do during the lab? Even though your submitted code will show your methodology, you should describe it with words as well to describe what you did.
3. Show your results and analysis. This includes images containing Jupiter and the apertures that you selected as well as your broadband spectra.
4. Conclusion: Summarize your results and what went correct and incorrect. What would you change about your analysis if you had more time or would be more thorough?