# Reducing Imaging Data

This lab takes you through first the basic data reduction process (removing as many "intervening" sources of signal and noise as you can), and then on to do photometry on some objects (measuring their flux). It is useful to think of these as two pieces, although in almost all astronomical data you'll need to do both of these steps (data reduction, and data analysis).

A useful note - Keep a copy of the raw data somewhere. This way, if you have an issue it is easy to revert to unreduced data.

For this exercise, the python CCDproc manual is very useful. It can be found here: https://ccdproc.readthedocs.io/en/latest/

Please answer all bolded questions in the area below. Turn in your responses, as well as your code and appropriate plots, in a single PDF uploaded to Canvas.

PLAN YOUR NAMING CONVENTION NOW. What will your images be named after they have bias removed? What about after flats are removed? What about after the sky is removed? Have a plan, and make a note. Otherwise you get stuck with images and you're not always sure how processed they are.

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## Data Reduction

*Use your project data for this section.*

*Step 1: Put a copy of your data in a working directory.*

### Bias & Overscan

The first step in reducing imaging data is removing the bias.

The data you downloaded hopefully has many bias frames, rather than just one.

**Q1: Define the bias. Include both a description of what it looks like physically, why it occurs, and how we take it into account (how do we remove its effect on our data images?)**

**Q2: Why would we use more than one bias frame?**

*Step 2: Combine your bias frames to make a master bias. Use the technique of your choice to combine and median the bias frames you have available.*

*Step 3: Then use the master bias to remove the bias through subtraction.*

**Q3: List the average value of each of your bias frames, as well as your final master bias.**

We don't always take bias frames. Sometimes we can just use the overscan regions on the CCD. If you are using ARCSAT - there is no overscan region. Answer Q4, but skip Q5 (just answer - ARCSAT has no overscan)

**Q4: Define “overscan”.**

*Step 4: Trim the overscan regions. If you have overscan in all your images, this is a good place to develop a framework of code to perform an action on a list of images. You might also find tools in CCDproc that do similar operations.*

**Q5: List your overscan parameters. (Where is the overscan on your images?)**

### Flat fields

We’ve removed the bias, now it is time to do flat field corrections.

**Q6: Which filters do you have flat fields for? List the flat field file names for each filter that you need. Do you have more flats than you need? Confirm that your flat fields have the same binning as your data.**

**Q7: Why do we need flat fields for each filter we have used for observations?**

*Step 5: Collect and combine the flats for each filter. Then normalize them and correct each science frame. Remember - this has to be done separately for each filter you’re going to use.*

*BIAS SUBTRACTION AND FLAT FIELD NORMALIZATION SHOULD BE DONE ON EACH OF YOUR OBJECT IMAGE FILES. It is a good place to take a little time and develop a loop, or a small pseudo pipeline.*

*It is worth visually inspecting files at each step to make sure both the files you’re using (like median images) AND the resulting images (with biases subtracted, for example) look as expected.*

### Darks

If your science images here are short, the dark current is extremely low and so we ignore it here. If you are taking longer images, or on instruments with lots of dark current, you can’t neglect this term of the noise in reduction. Make sure to take into account darks.

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## Data Analysis (Photometry)

You now have images that are as close as we can get to what was emitted from our source. You can either use one of the broadband images from your project data or download the image from Canvas to use for this portion of the lab. It will provide an example for the different approaches to photometry you can then use for your project. (The next portion looks for point sources - if you use an image that has a diffuse image, like the nebulas, it might do some weird things for some of the options like DAOStarFinder. If you’re having trouble navigating that - just grab the image on canvas.)

We are going to use the “photutils” python package to measure the signal. It can be found here.: https://photutils.readthedocs.io/en/stable/

### The Sky

We've gotten rid of instrumental effects, and optical effects. But the sky glows, and our images carry that signal across the whole image (even where we have objects). If you display one of the reduced images and put your cursor into "blank" areas, you should still see counts. That's the sky.

We are going to be subtracting the sky on the fly as we use aperture photometry to calculate the flux of the stars in our field. If your primary science object is diffuse or extended just choose a stars in your field that aren't overexposed/saturated as your object.

**Q8: What drawbacks could exist from this method of sky subtraction?**

**Q9: Why does sky subtraction matter?**

*Step 6: Identify the sources to perform photometry on in your image. DAOStarFinder is one method provided within phototils. Plot the stars found on top of your image. Adjust your parameters to select a smaller set of stars (Between 10-100ish. Depending on your image). Replot. Remove any "bad" stars from the sources array by hand (hot spots, stars on the edge, stars on the overscan).*

**Q10: How many objects did you identify with DAOStarFinder? Look at your image. Do you think that's a reasonable number? What did you change to adjust the number of stars detected? How many stars did you end up with?**

Photutils provides many different kinds of apertures. We will use two here, but other cases (such as galaxies) might require apertures that aren't round.

*Step 8: First, use the "circular aperture" Choose your method and execute your aperture photometry. Review the output.*

*Step 9: Plot your apertures on top of your image.*

**Q11: Are you happy with your apertures? Why or why not? Save the list of sources for comparison.**

*Step 10: Now we're going to do the same thing, but instead of using just a circular aperture, we're going to use annuli. This means you can specify a region for the star, and a nearby region for the sky. This allows us to use the sky that is close to the individual objects to subtract.*

**Pick your object aperture and note it in your Q12 answers.**
**Pick your sky annulus minimum and maximum note it in your Q12 answers.**

*Step 11: Now, run as above, except using the "CircularAnnulus" command. Use these two measurements of flux to remove the background from the originally measured flux, and print those results.*

**Q12: Make a plot comparing the measurements of the two different methods.**

Aperture photometry can be useful, but as you might see setting a single aperture for a field of stars might not be ideal. We can also use PSF fitting, which will individually identify the point spread function of each object.

*Step 12: Use PSF fitting to calculate the flux of the same set of sources you found with DAOstarfinder. Make sure to sky subtract.*

**Q13: Make a plot comparing the PSF fitting output to the aperture output. Are they the same? Why or why not?**

**Q14: What do you need to do differently for your science image? (For example - are you studying one point source, many point sources, or a diffuse object? What does that change?)**

**Q15: Did you prefer PSF fitting or aperture photometry? Think of one situation that you think would be best for each method.**