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IRAF Tutorial
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IRAF is the Image Reduction and Analysis Facility, a software system for the reduction and analysis of scientific data. The purpose of this tutorial is to familiarize yourself with the basic process of calibrating astronomical images. It is assumed that you are using a Unix-based system, preferably a stable Linux distribution, with IRAF already installed.

Along with this tutorial, you will have been provided with a data file that contains a combination of object and calibration frames. The goal of this tutorial is to become familiar with basic Unix terminal commands, how to prepare astronomical calibration frames, and how to calibrate an object frame. At the end, you will have a raw and calibrated object frame to compare with each other.

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ACQUIRE CALIBRATION FRAMES
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You'll want to acquire the frames that will be used in the calibration process. I typically collect all frames into a single directory, and then sort the calibration frames and object frames into separate subdirectories. Make sure to move your working directory into a place that you can access easily, like Documents or Downloads.

During your observing run, you should acquire the following: bias, dark, flat, and object frames.

First, you'll want to acquire bias frames. Recall that bias frames are showing the pixel-to-pixel variation of the chip given an integration time of zero seconds. You will be subtracting this frame from the object frame, which will effectively remove the bias offset of the chip.

Next, you should take your flats. Flat frames are time-dependent if using the evening sky. You're aiming for an integration time that returns an average pixel value that is somewhere between 35-50% of the saturation value for the CCD chip. Flats demonstrate the optical discrepancies in the setup you are using. Dust, vignetting, and other unwanted effects are removed when normalizing with a flat frame. You want the flats to be taken with the same properties as your object frames, so take them with the same settings such as filter, binning, and chip temperature. Try to get several flats if you can, since averaging them will reflect a more accurate flat than just using one.

Then, you will probably begin your observing run, so take exposures of the object you planned to observe. Remember you're ultimately trying to maximize the signal-to-noise ratio of the object in the frame. You don't want to oversaturate the camera, but you also want a significant signal above the noise floor of the background. You also don't want unwanted effects like cosmic rays or tracking errors, but sometimes these are unavoidable.

Finally, given an opportunity either between objects or after your observing run, you will need to take darks. Some observers take darks for both their object and flat frames, and other observers take darks just for their object frames and then use what is called a "scalable dark" frame. This latter process is what we'll be adopting here.

In this instance, you have been provided with a single directory called "Data" which contains the following:

1. 15 bias frames (**bias-001.fit**, **bias-002.fit**, etc.)
2. 15 dark frames (**dark_obj-001.fit**, **dark_obj-002.fit**, etc.)
3. 10 flat frames (**flat-011.fit**, **flat-012.fit**, etc.)

4. 1 object frame (**hatp27-001.fit**)

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INITIATE IRAF
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In the IRAF directory (should have **login.cl** listed in the directory), run IRAF by using the terminal command **cl**. A message should begin by welcoming you to IRAF, listing the available commands that can be run, and the command prompt should be **vocl>**. Now that you're running IRAF, navigate to the directory that contains your object and calibration frames to work there. The appendix at the end of this tutorial contains useful terminal navigation commands if you forget.

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PREPARE CALIBRATION FRAMES
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Here is an outline of the steps you'll be taking:

1. Average the bias frames. This is your AVERAGE BIAS.
2. Average the dark frames (of a single integration time – in this case all your dark frames are of the same integration time, so no worries there).
3. Subtract the average bias frame from the average dark frame.
4. Divide the previous bias-subtracted dark frame by the integration time of the dark frame. This is called a DARK CURRENT frame.
5. Average the flat frames.
6. Subtract the average bias from the average flat.
7. Multiply the dark current by the integration time of the flat.
8. Subtract the previous scaled dark current from the flat.
9. Divide the resulting flat by the mean pixel value of the flat. This is your FLATFIELD.

When doing these steps, be very careful in keeping track of the steps you are taking. I find it helpful to first understand conceptually what is going on in each step. Then, I figure out the command I need to use (see the end of this tutorial for an appendix of commands). Finally, I write down a useful and descriptive file output name. At the end, I wind up with a flowchart of filenames that help me remember what steps I have done so far.

For example, step one above is to average the bias frames. I would do the following:

imcombine bias-* bias-avg.fit combine=median

What I've done here is to use **imcombine** on all frames with **bias-** in the name (in this case, all the bias frames, and the * is used to basically say "fill in the blank"). The input is a list of all bias frames. The output will be a mean bias frame called **bias-avg.fit**. The method of combine is **median** combine. I recommend using median combine for all averaging steps, since that will be better at removing transient effects such as cosmic rays.

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CALIBRATE OBJECT FRAMES
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In this tutorial, you have been provided with a single object frame (**hatp27-001.fit**). The process of calibrating your object frame is much simpler than the previous steps of preparing the calibration frames.

The outline is:

1. Subtract AVERAGE BIAS from object frame.
2. Subtract DARK CURRENT from object frame.
3. Divide object frame by FLATFIELD.

And finally you have a calibrated frame! Now you can begin to do science on the frame, like measure flux, and calculate useful stuff like magnitude or surface brightness. Try loading up ds9 and placing the raw and calibrated object frames next to each other to compare. Also, try running **imstat** on the raw and calibrated object frames to see the properties such as reduction in standard deviation.

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TERMINAL STUFF
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ls – list the subdirectories in your current working directory

cd <directory> – change your current directory to the specified directory

cd .. – moves your one directory up

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IRAF STUFF
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? - list tasks

?? - list detailed tasks

imhead <frame> l+ - display the FITS header

imstat <frame> - report statistics of frame or multiple frames

imarith - do image arithmetic on chosen frames (follow the prompts)

imcombine <input> <output> combine=(average|median|sum) – use image combine on specified input frame, output frame, and combine method

If you want to list several frames when using **imstat** or **imcombine** then type them like: **frame1.fit,frame2.fit,frame3.fit** (no spaces, since IRAF will interpret a space between two frames as indicating the first as the input and the second as the output))