Astron 98 Final Project: Enhancing Astronomical Image Clarity Through Data Reduction Techniques for Ideal Image Cohesion for Observation

By: Natalia Nikkhoo and Madelyn Rahimi

Introduction:

Images initially quantified through CCD devices linked to telescopes must go through a series of reductions to produce a clear picture resonant with post-production imaging. There are multiple degrees of noise complacent in raw telescopic images that must be considered, and we have chosen to focus on the two main sources of distortion for this project: sensor and atmospheric disruption and faulty CCD data acquisition. As such, three types of files are required for the aforementioned data reduction to occur. Raw telescopic files that are overridden with both the science image and background interference, flat frame images that essentially photograph a uniformly illuminated background to account for dust and atmospheric interference, and a dark frame that is taken with the lens cap on to denote imperfect pixel sensors within the CCD. the raw image has the relationship denoted in equation one with each degree of interference, and thus the reduced image can be solved and is denoted by the second equation. Furthermore, although data reduction may account for some of the error associated with image acquisition, a small percentage of noise is random, and thus cannot be separated from the reduced image as included in the equations below.

(1) raw image = dark frame + flat (reduced image + noise)

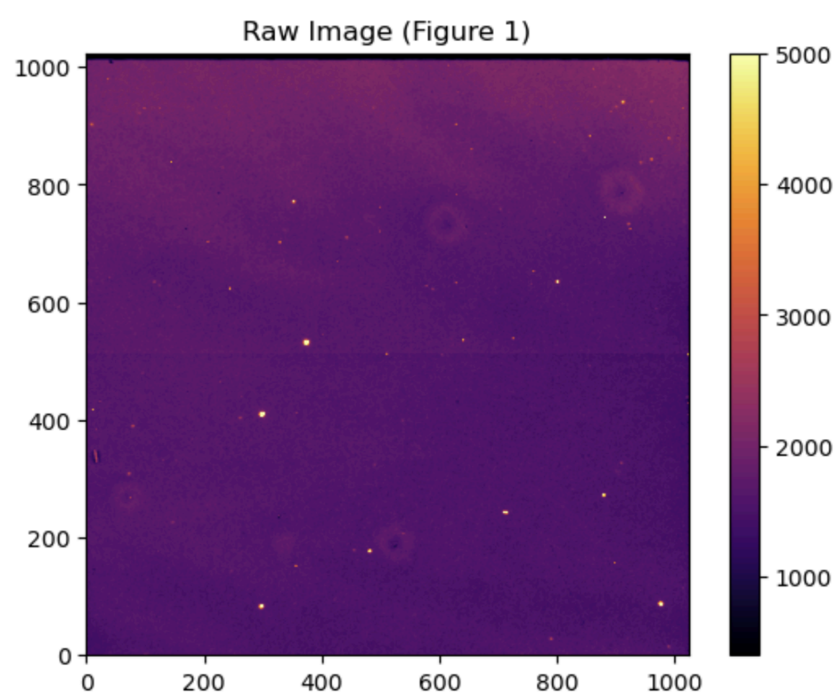
(2) reduced image + noise = (raw image - dark frame) / flat

Sourcing Data:

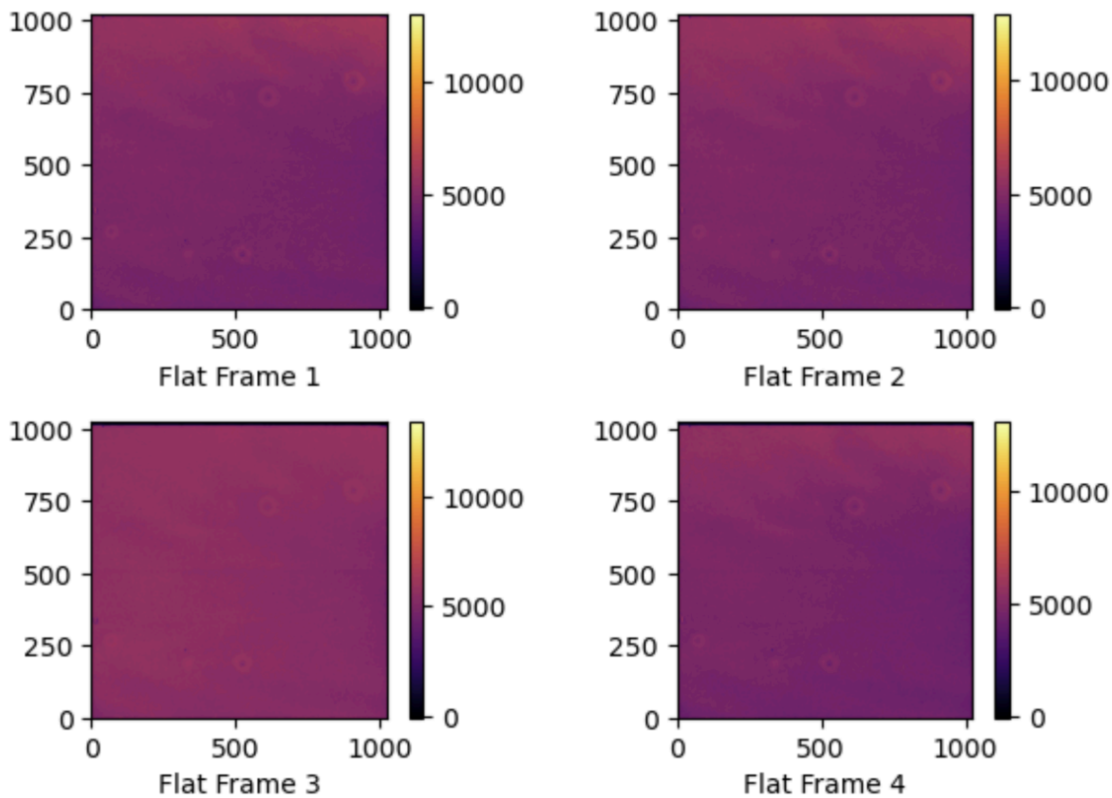
Data was sourced from the ESO (European Southern Observatory) science archive facility. We selected the date March 6th, 2020 to source our images as there were available images of the flat field and dark field from that day along with astronomical objects pictured. The telescope used to capture the images is the SOFI instrument on the New Technology Telescope telescope at LaSilla. We were able to gather the flat and dark frame images and standard astronomical object images from this date from the public archive as fits files and thus specific packages from astropy.io were imported to run the data.

Data Reduction Process:

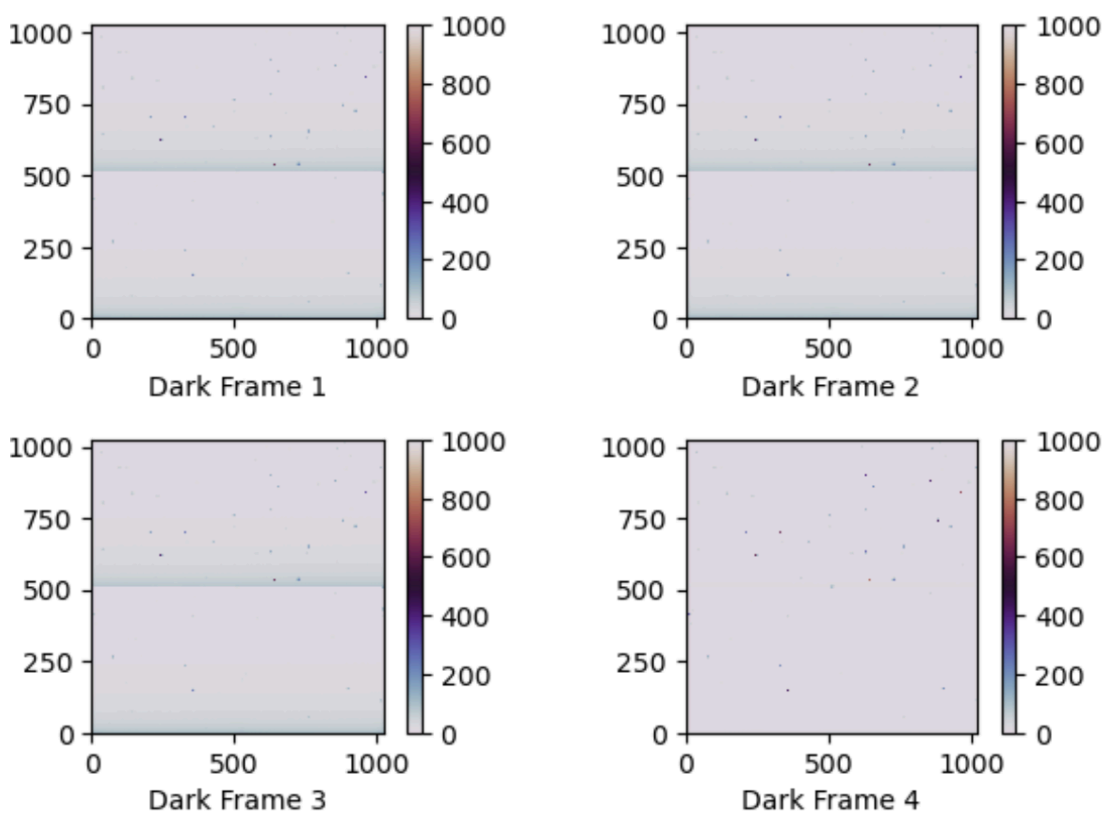
The required packages for fits file processing, array manipulation, and respective plotting including numpy, matplotlib,pyplot and functionalities from astropy.io were first imported to allow for the processing of data gathered online. Next, the raw file was opened and transformed into a format that would allow plotting using the plt.imshow functionality for multidimensional data. The result of such processing and honing in on the color profile using vmin and vmax customization is denoted in Figure 1. Highly visible in this picture are rings associated with telescopic dust formation and bad pixels dispersed throughout the image. Next, using the subplot functionality, four flat frame images were also transformed into a graphable format and plotted side by side as denoted in Figure 2. The same process was repeated for dark frame images as denoted in Figure 3. The four flat frame images and dark frame images were then averaged separately and graphed as denoted in Figures 4 and 5. Finally, in accordance with equation 2 listed in the introduction, the averaged flat and dark frames were transformed into numpy arrays such that the raw image array could be subtracted from the dark frame and divided out by the flat frame (dark frame subtraction and flat fielding in data reduction terminology). The final image was then graphed and is denoted as Figure 6.



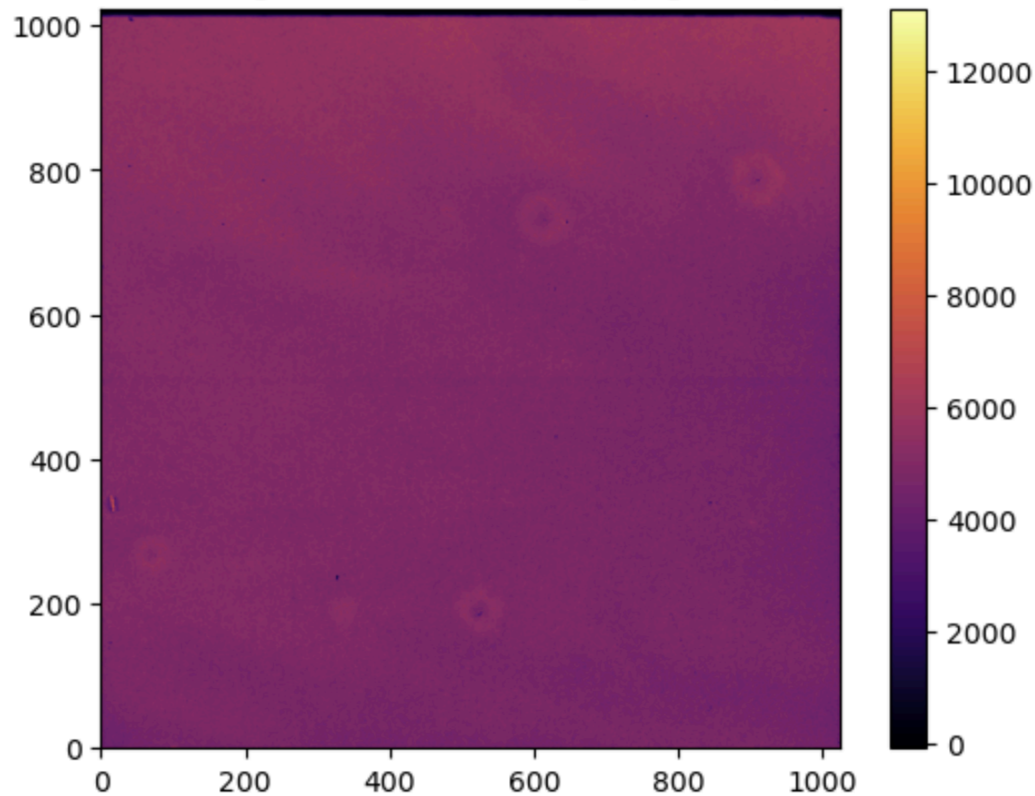
Flat Frame Images (Figure 2)



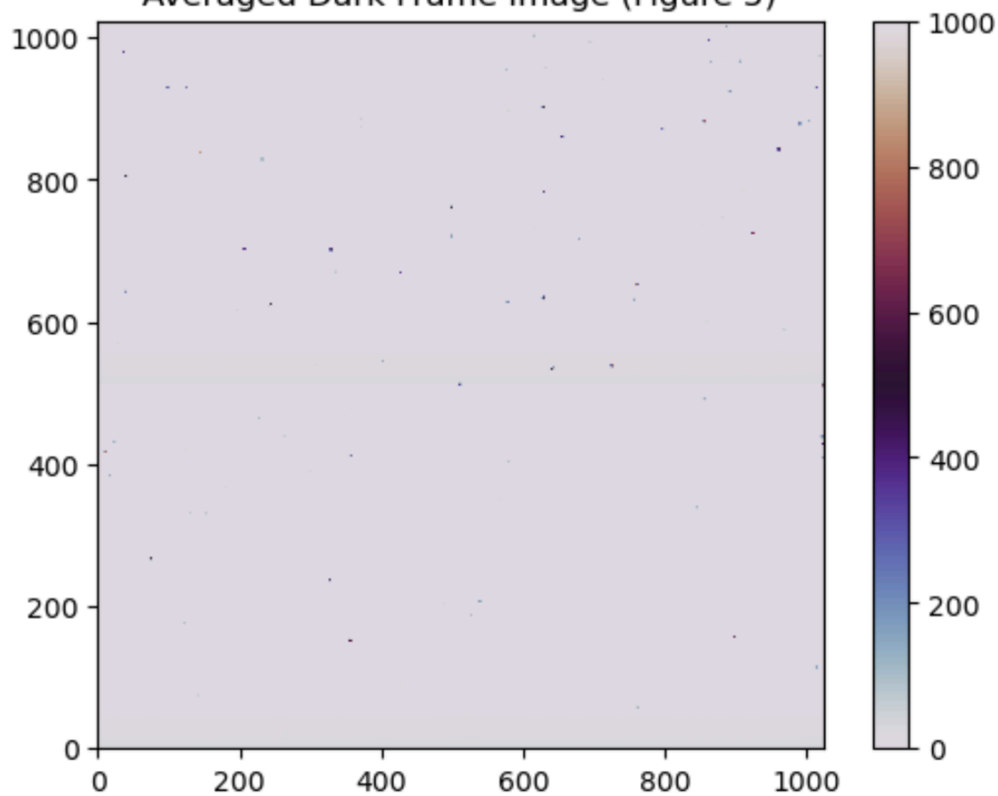
Dark Frame Images (Figure 3)

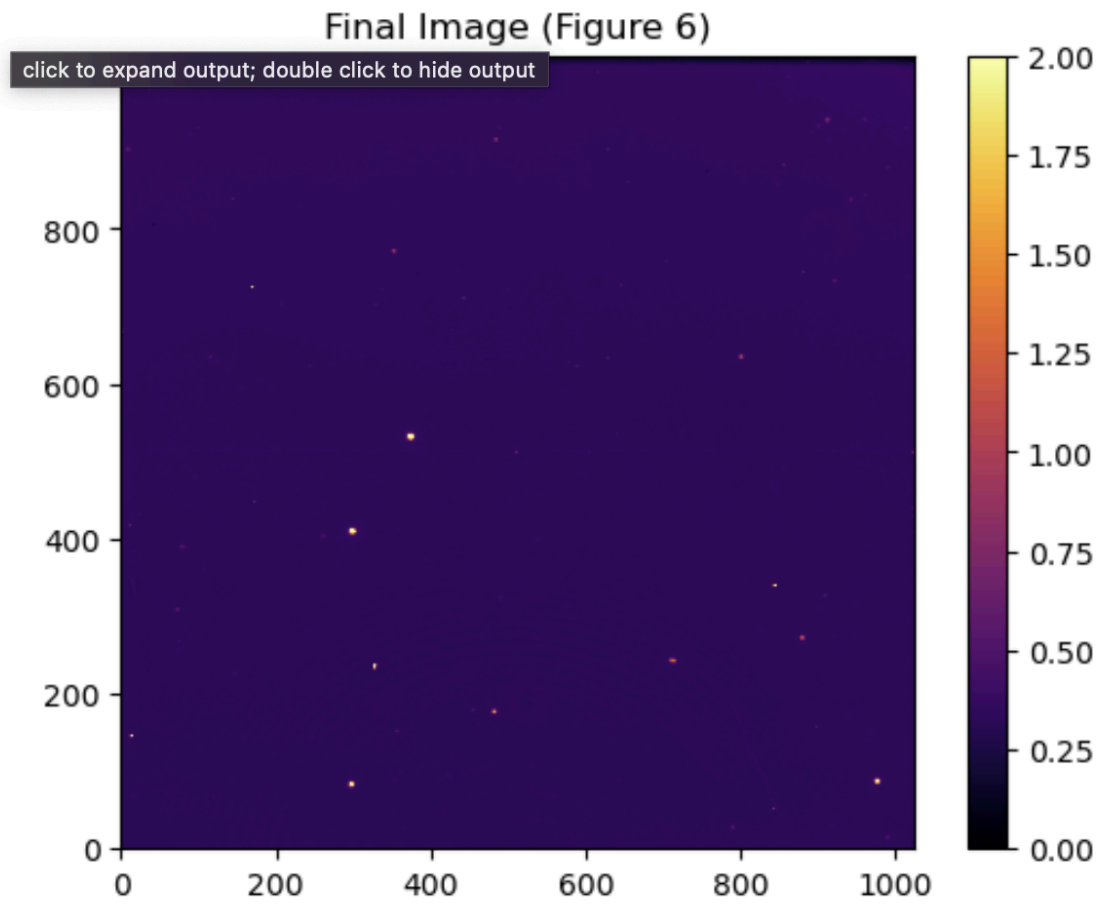


Averaged Flat Frame Image (Figure 4)



Averaged Dark Frame Image (Figure 5)





<u>Conclusion:</u>

The final image denoted above as Figure 6 is an image developed after subtracted data removed imperfections resulting from dust or discrepancies in the telescope and equipment used. There is a significant enhancement in both the clarity and the quality of the images, initially sourced from the ESO (European Southern Observatory) science archive facility. By using both the raw images in comparison with flat field and dark field images from that day, we could deduce what imperfections in the ESO captured image were the result of dust or equipment discrepancies.

We corrected these flaws through dark frame subtraction and flat fielding. By distinguishing the intrinsic imperfections in the image, we subtracted these from the original and divided the result through flat fielding to compose the final image displayed. The composite image developed exemplifies the efficiency of this method with a clearer, free-of-imperfections image shown post data reduction.

This project demonstrated the necessity of data reduction in working with raw astronomical data captured through telescopes to allow for a clearer, composite image without external interference of dust and technical imperfections. The rigorous data reduction methods following initial image capture supports the integrity and reliability of astronomical observations captured through telescopic imagery.

European Southern Observatory Science Archive Facility:
https://archive.eso.org/eso/eso_archive_main.html