DATA REDUCTION: HOMEWORK #1

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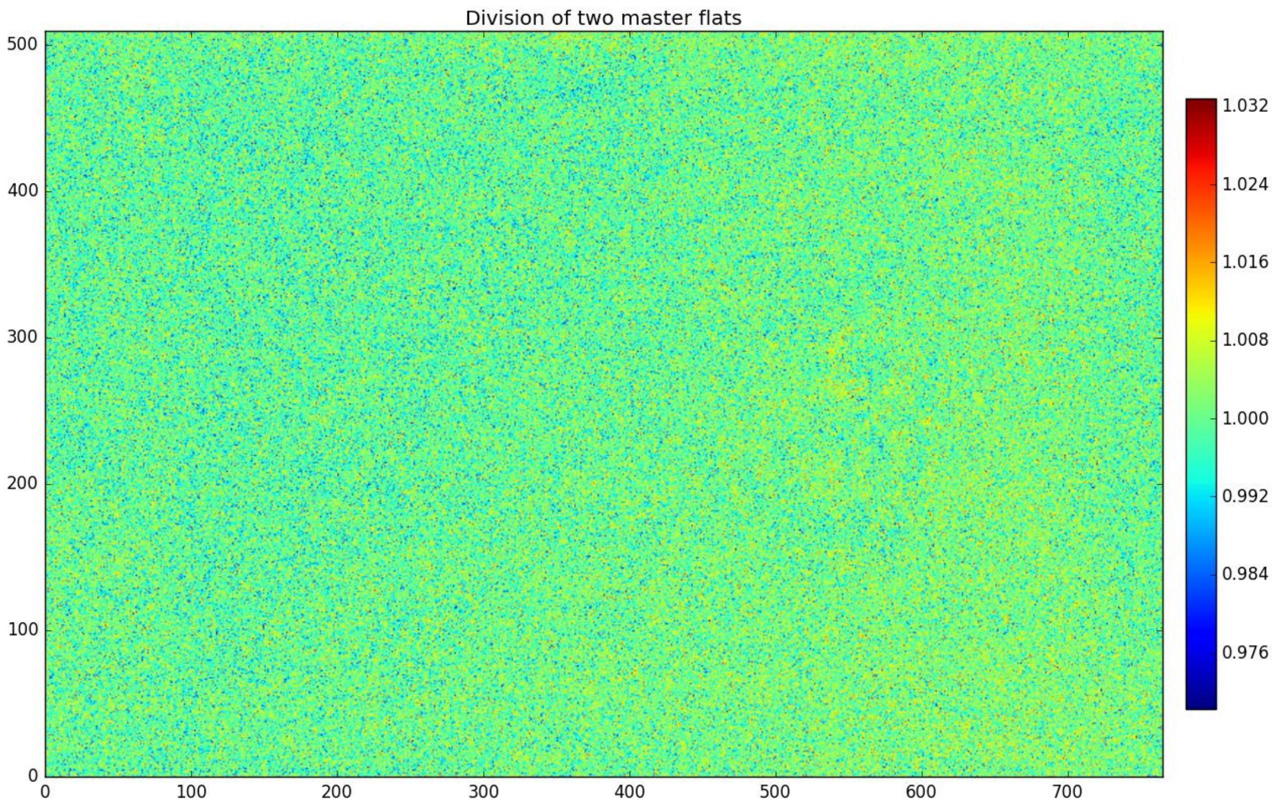
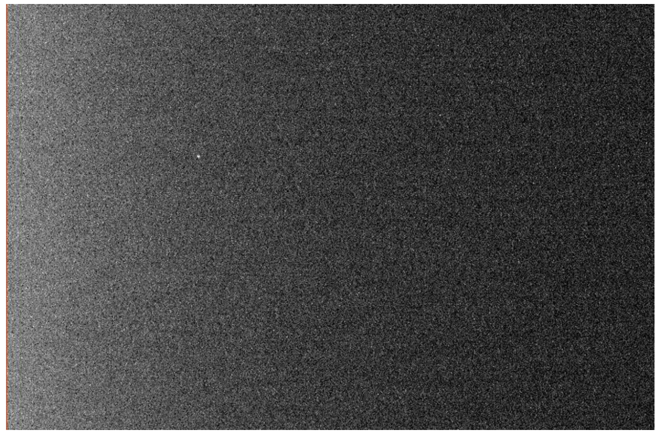
Using data reduction techniques learned both in this class and in Observational Techniques of Astronomy 1, I wrote a python program that loads flat and dark frames of the same exposure time in the same photometric filter from two different nights, October 12th, and November 2nd. It then creates two master darks, median combining the images from each night, and subtracts the master dark from the flat images from the corresponding night. Then the flat images from each night are median combined into two master flats and normalized. Another program divides these two master flats, and displays the result as both a color map and a histogram, which are included below. The telescope setup for each night was identical.

Telescope	14” Meade at CTO
Detector	SBIG 402-ME (Photometric 2)
Laptop	CTO LT-4
CCD Set point	-10º C
Filter	Johnson-Cousins R
Exposure time	2 seconds



Although the noise pictured above is relatively uniform, this map does show a noticeable systematic offset—the left side of the image is "cooler" than the right side, which is a bit "hotter". These differences show themselves in clusters of pixels that stand out from their surroundings. Since I divided the flat from Oct 12 by the flat from Nov 2 to produce this image, this means that the counts on the left side of the image were lower on Oct 12 compared with the counts obtained on Nov 2. Likewise, the counts on the right side of the image were higher on Oct 12 as compared with Nov 2.

Clearly, this image does not correspond to a uniform array of 1's, though it is close. The systematic offset described above has a clear directional preference. On Oct 12, the left side of the CCD recorded fewer counts than it did on Nov 2. The first thing that comes to mind is the direction of CCD readout, which is clearly to the left. As the potential wells clock out their electrons row by row, electrons can be misplaced and spill into other wells. These mistakes build up as the charges are shifted, and since they're being shifted to the left, the pixels along the left side of the image accumulate more of these errors, making them have higher counts. But, as long as this effect is the same night to night, it should just subtract out when the master dark is subtracted. My results here indicate that this effect was not the same between the two nights, which could be due to partly to the difference in the median values of the images. There could have also been other confounding variables that would be more difficult to isolate, such as temperature and small electronic errors.

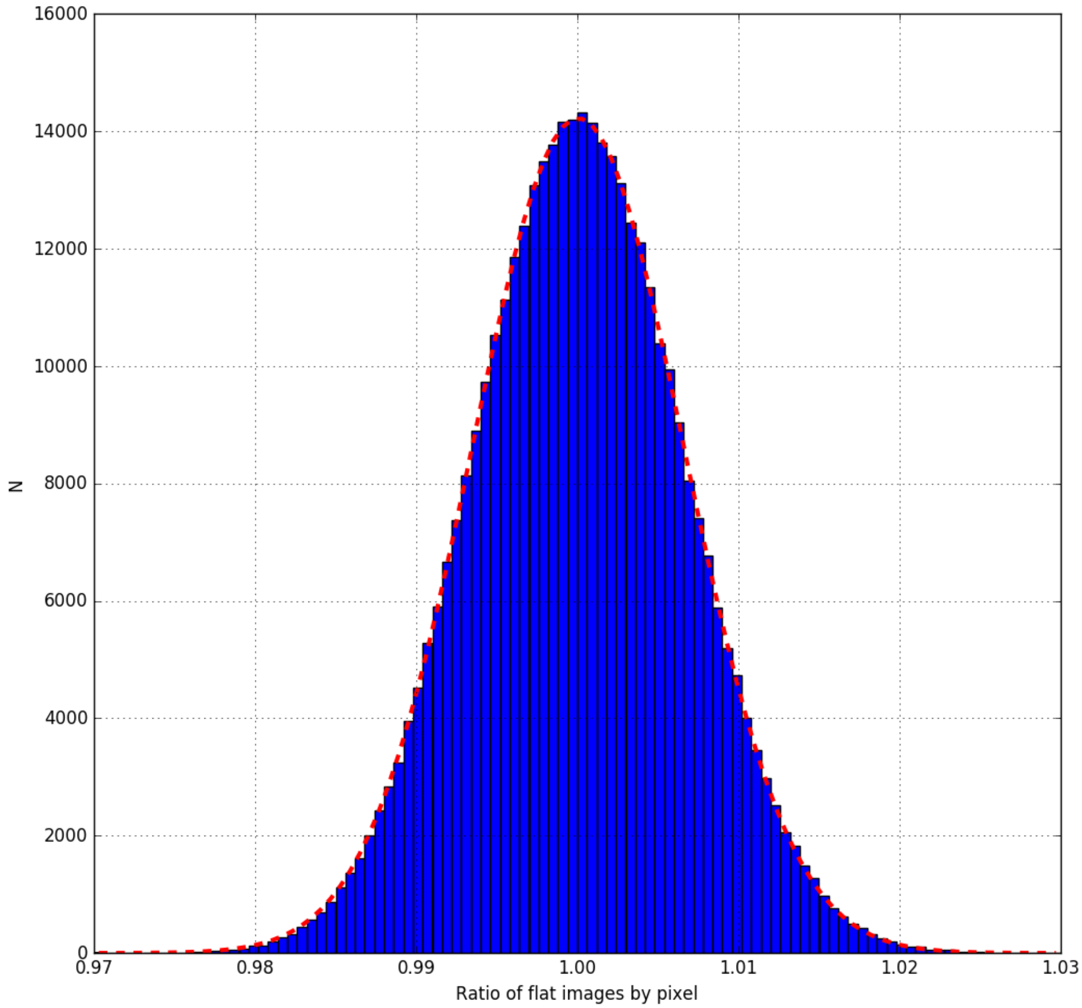


A single 2 second dark image

Thermal effects are so small in shorter exposure times that they are unlikely to cause a large systematic error, but it is indeed possible that the temperature difference in the environment could have caused some offset—a cooler outside temperature on 11/02 could mean less thermal noise on the side of the detector that houses the electronics, meaning fewer counts on due to dark current on that side of the detector. However, the opposite trend was observed; there were more counts on that side of the detector when the temperature outside was lower. So, temperature does not contribute significantly in this particular case.

The histogram below shows the pixel wise ratio of the two master flat images. The mean of the Gaussian fit to this histogram was 1.00004324, which is very close to 1. Since the data is normalized, this is to be expected. The fit has a standard deviation of 0.006567, which is acceptably minute. This further drives home the point that the variances visible in the color map are small, varying only by ±0.03 at the extremes. Though it is frustrating to not have perfect white noise in the color map, the variations are small enough that they will not dominate the error of my observations. It would be unfortunate to be limited by flat fielding error, to say the least.

Histogram of pixel values for the division of the two flat field images



		October 12	November 2	
Raw master flat frame values	Median	9648	10995	(Counts)
	Mean	9653.02	11001.37	
	Maximum	10171	11561	
	Minimum	7517	8626	
Normalized master flat frame values	Median	1.0	1.0	
	Mean	1.0005	1.0006	
	Maximum	1.0542	1.0515	
	Minimum	0.7791	0.7845	

Indeed, the non-normalized counts recorded on October 12 are clearly lower than on November 2. This means fewer electrons were clocked out in total on Oct 12, which would make readout error less likely. When the Oct 12 image was normalized and divided by the normalized Nov 2 image, the area of the field where the readout errors were larger on Nov 2 had a value slightly less than 1, explaining the “cooler” left side and “warmer” right side of the divided flats.