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Assessing Ground Based Image Quality

This project tasked students with analyzing a set of solar data files. These files contained both rdc (reduced) and contrast image data for the Sun at various times of day. Along with the two types of information gathered, these data sets were created using two separate filters for the telescope: a 0.458[nm] wide red continuum filter centered at 607.1[nm] and a 0.273[nm] wide Ca II K filter centered at 393.4[nm]. Part of the analysis consisted of checking the image quality itself (how sharp the image is), as well as a look into the distribution of light intensity across the solar disk.

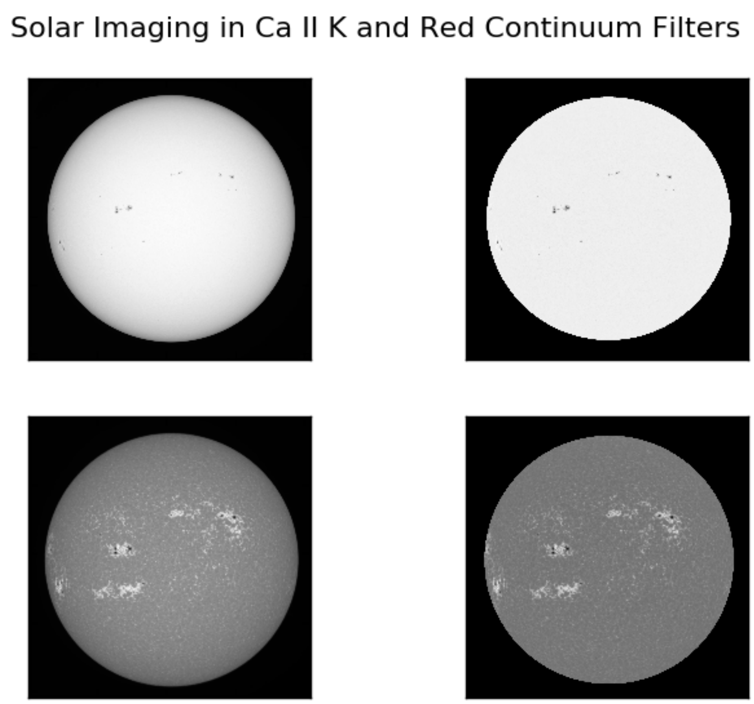

Figure 1: Grey-scale rendering of rdc (left) and contrast (right) images of both Red (top) and Ca II K (bottom) filters

By looking at the images, it may be hard to tell any obvious differences at first glance; however, it is clear after careful attention that the rdc images appear to have a more three-dimensional shape particularly close to the edge of the solar disk. In the contrast image, the Sun appears to be more flat with no sense of depth and merely showing changes in intensity. These key differences become even more apparent when a horizontal cut of the data is made and graphed for both image types.

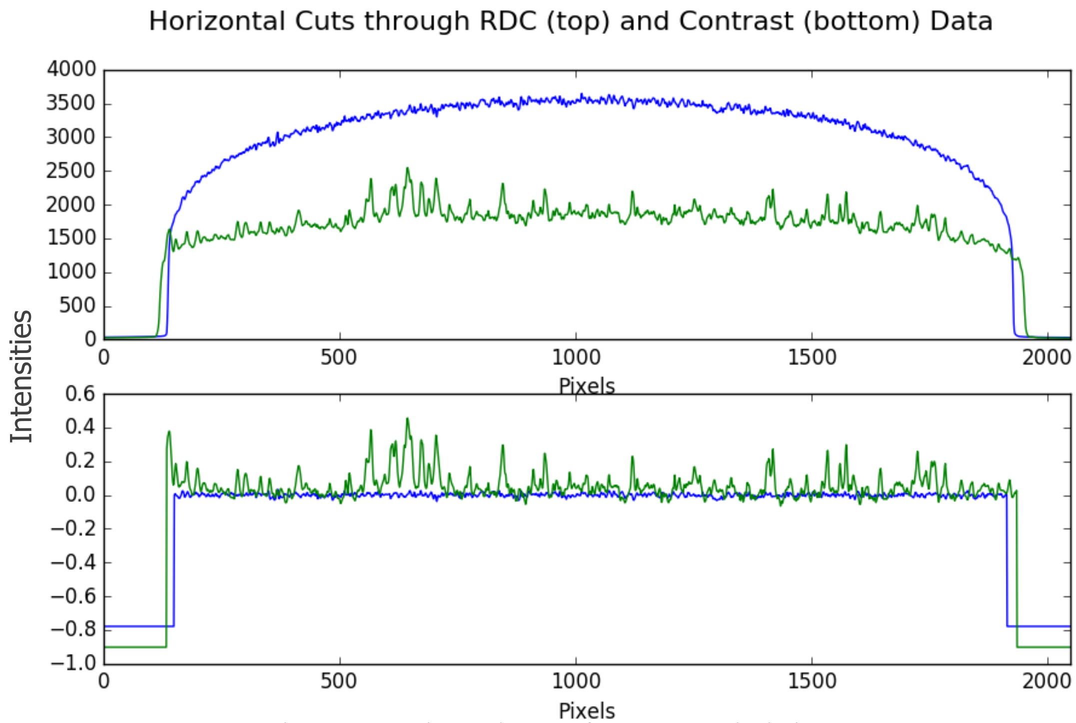

Figure 2: Horizontal cuts of contrast and rdc images
for first set of data
Red = blue Ca II K = green

After looking at both of these plots, one can see that the red continuum filter shows a more uniform distribution of light intensities across the solar disk with fairly high overall intensity values. The Ca II K filter, on the other hand, shows slightly more sporadic differences throughout the solar disk with lower overall intensities than that of the red continuum.

The header information from the rdc images was then extracted to receive more specific information that can't simply be seen from the images themselves. The values of most concern were the Julian date of the observation start time, the average width of the limbs on the gaussian distribution of the intensities across the solar disk (basically the wider the width, the less sharp the image is), and finally the root mean square average at the poles which essentially refers to the standard deviation of light intensities at the poles.

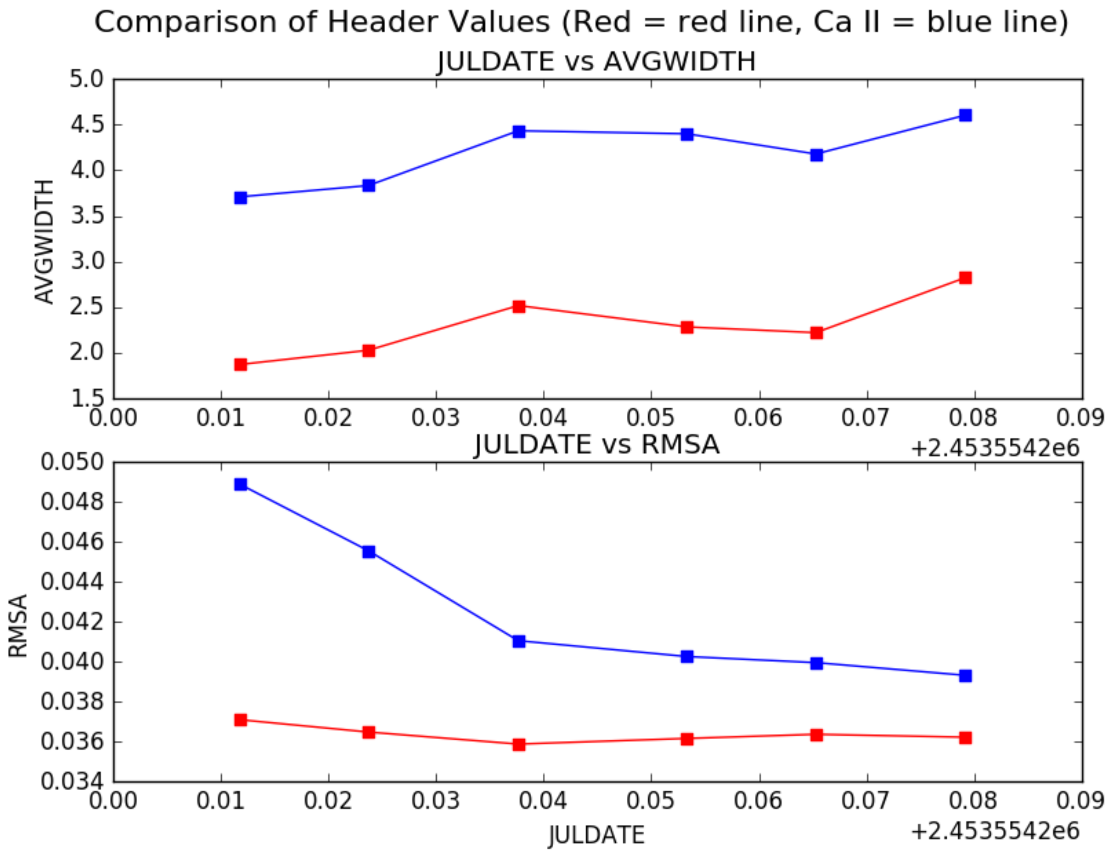

Figure 3: Plots displaying the changes of both the average width and rmsa as a function of time

In the average width plot both filters show a similar trend as time progress with the width generally increasing. This is to be expected since the sharpness of the image should decrease as the day progresses since there is more atmosphere to distort the image just above the horizon than up closer to the zenith. The rmsa shows a different trend throughout the day than the average width. The Ca II K filter appears to decrease as time progresses wheres the red continuum filter appears to remain fairly constant on the same scale.

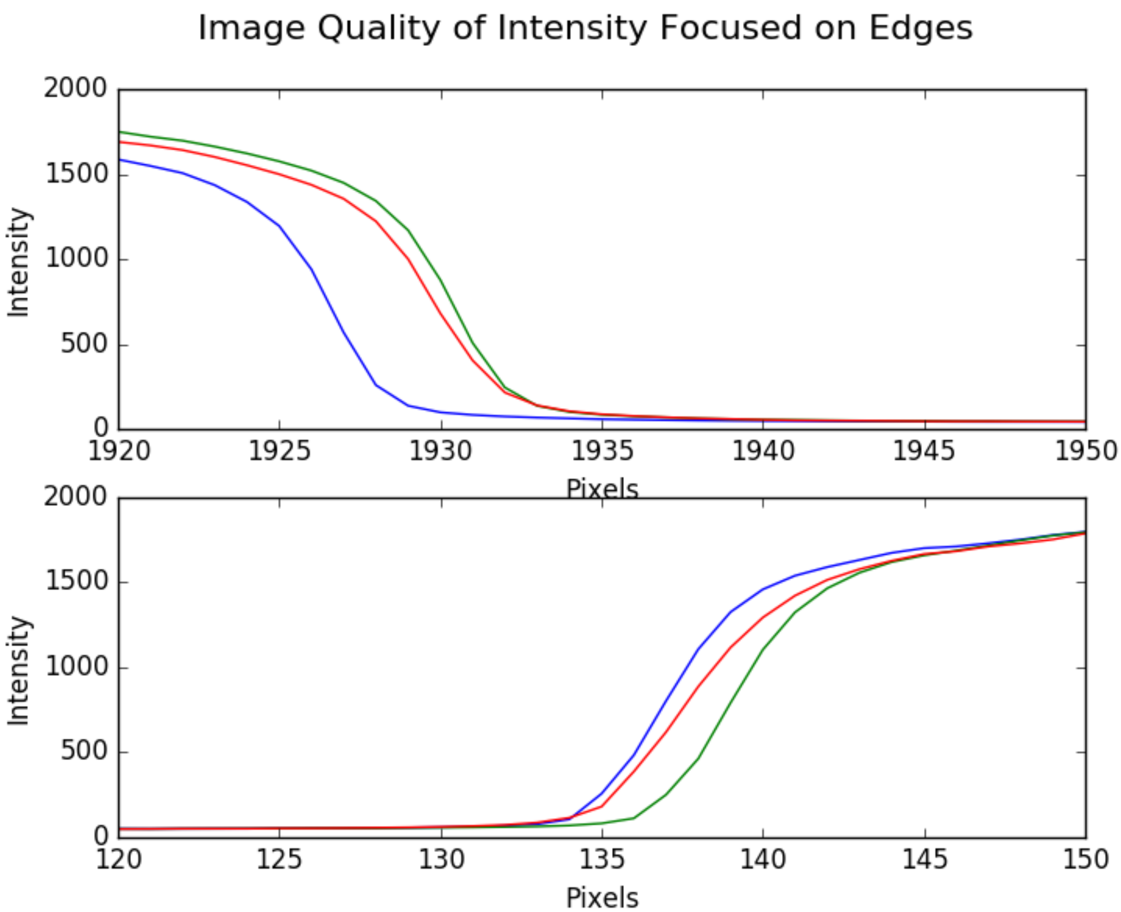

Figure 4: Plots displaying the limb of the solar disk for
the first three red rdc images
Time of Day order: Blue→Green→Red

Aside from the clear shift of the blue line from the green and red lines (which is most likely due to an inaccurate center measurement of the image), there aren't obvious differences between each line. After closer inspection, however, it seems the slope of the limb increase slightly as time increases. This makes sense because one would expect the image quality to decrease as the amount of atmosphere between the telescope and the Sun increase as the Sun sets.

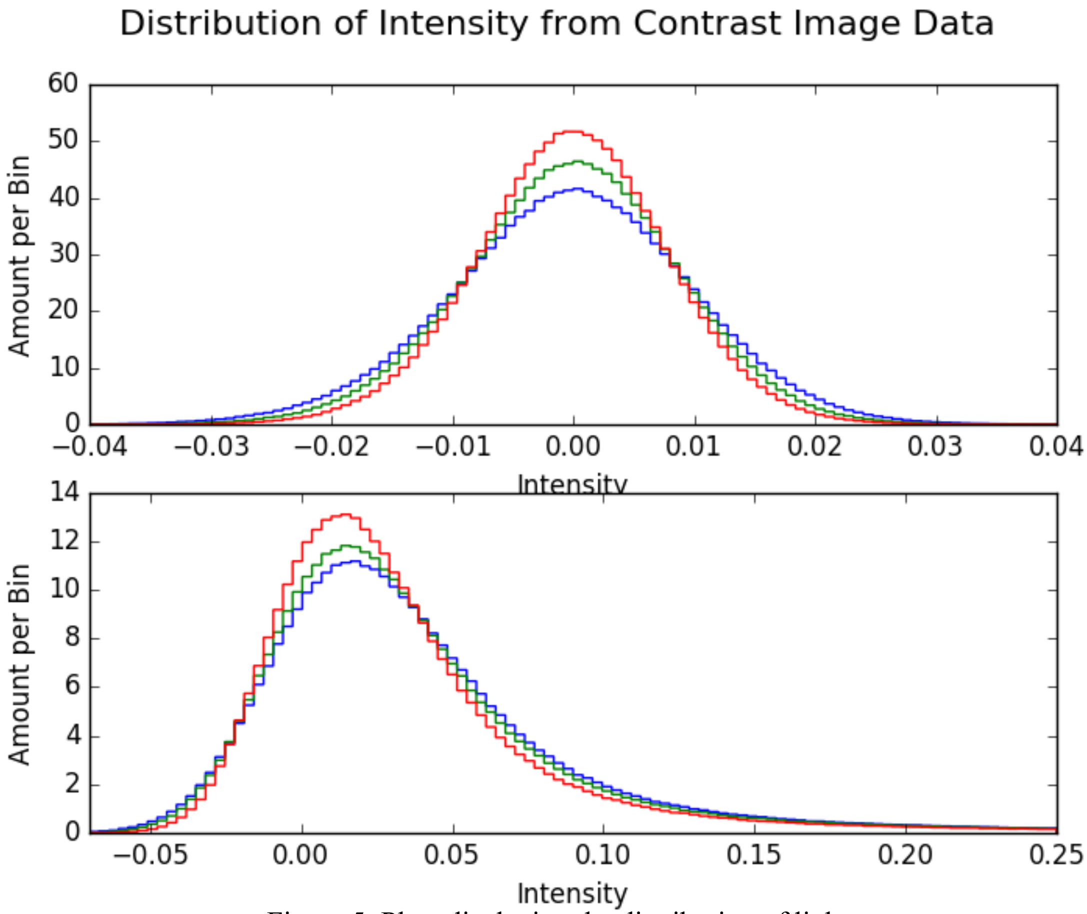

Figure 5: Plots displaying the distribution of light intensities across the solar disk with the top representing the red and bottom the Ca II K filter
Time of Day order: Blue→Green→Red

As the time of day increase it is noticeable that the peak becomes thinner and taller. This represents the distribution of the differences in the light intensity becoming less widespread and more focused and uniform across the solar disk. As the quality of the image decreases with time, the intensity distribution also smears together which would explain this more uniform distribution as the day progresses.

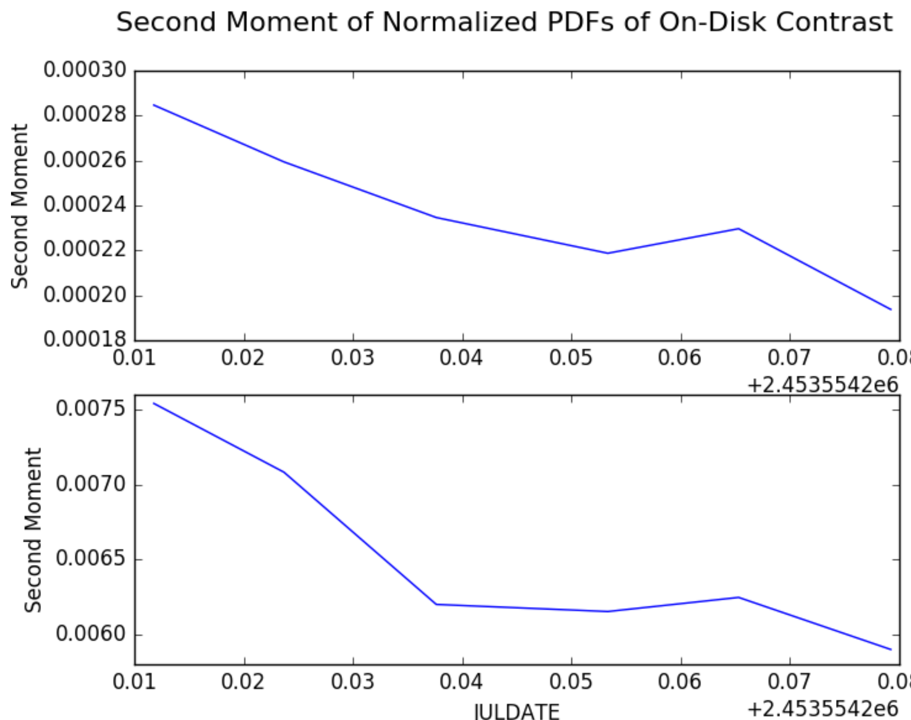

Figure 6: Plots displaying the second moment of the
on-disk contrast intensity as a function of time of day

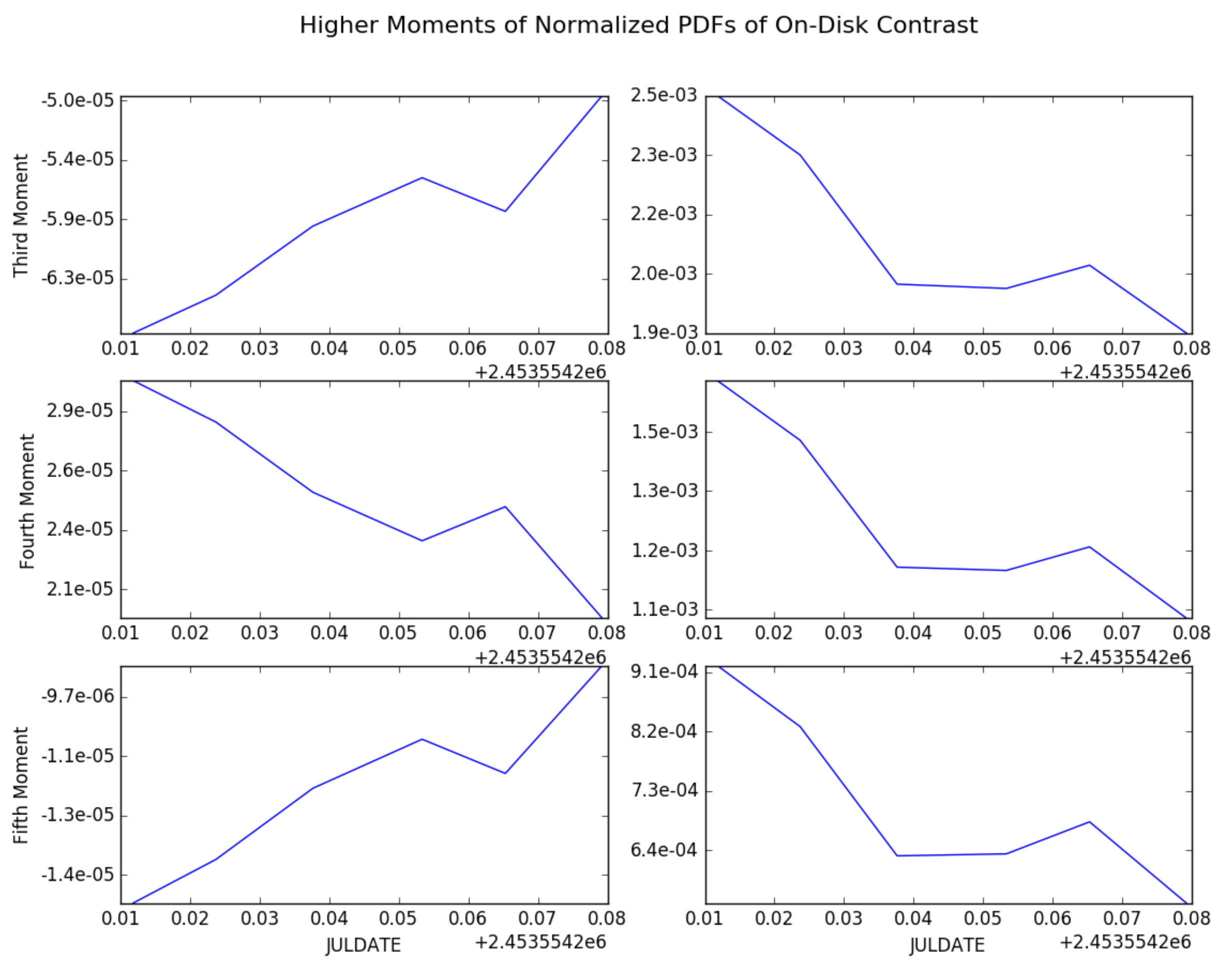

Figure 7: Plots displaying the third, fourth, and fifth
moment of the on-disk contrast intensity as a function
of time of day
(Red on right, Ca II K on left)

All of these plots show an obvious trend of approaching zero at later times of the day. Since the moments of these graph are essentially reflections of what is shown in the histograms of Figure 5 (the shrinking width), the function approaching zero makes sense as one would expect the width of histogram to continue to shrink. This same trend continues through the successive moments with the moment continuously approaching zero. The top left and bottom left plots in Figure 7 both show ascending lines, but it’s important to note that they’re axes are negative, so the ascending line still approaches zero.

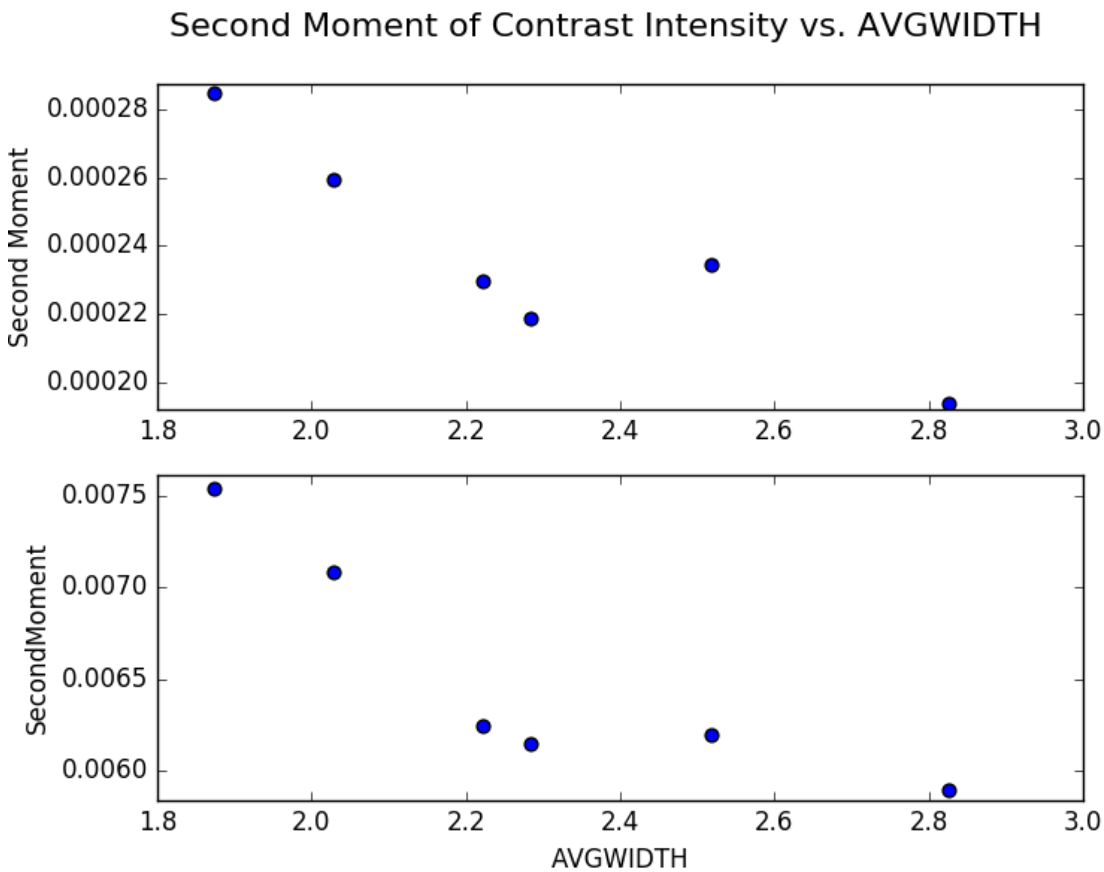

Figure 8: Plots displaying the second moment as it relates to the average widths of the gaussian distribution of light intensities

Without the aid of a line plot connecting each value, it is much easier to see a general trend of the data that is being compared. Line plots deceive the mind into think the data follows a specific pattern, but in reality the data just follows a general trend following a line of best fit. From this data specifically it can be seen with an increase in width (which represents a decrease in sharpness as mention previously, the second moment decreases since the overall intensity distribution becomes more uniform.

Thought Questions

1. By looking at the two horizontal cuts made in Figure 2, one can tell by eye that the contrast images mirror the rdc image without the slight curve that is apparent in the rdc image. The contrast image essentially just shows the change in intensity of a single pixel relative to the pixels around it. In order to change an rdc image to a contrast image by hand, one could take a horizontal slice of the data and start comparing each pixel to its neighbors and taking an average to give it a value that can be potted. This should then produce an image that would display the average differences between neighboring pixels which is really all a contrast image really is.
2. The two quality measures that were of concern in this lab assignment were denoted in the header file as JULDATE, AVGWIDTH and RMSA. The JULDATE data value represented the Julian date of when the data was actually taken. This itself wasn't a measure of quality and was simply there as a timestamp, but it was a value taken from the header data so it should be mentioned. AVGWIDTH corresponded to the average width of the gaussian distribution of intensities at the solar limb. The higher the width, the less sharp the image is. This is important information because it shows hows the edge of the solar disk became less defined as time progressed meaning a lower quality image. The RMSA stands for the Root Mean Square Average of the intensity distribution at the poles in the rdc images. This decreases with time because as the sun begins to set, it becomes more and more smeared which blends much of the intensity distribution showing a more uniform intensity everywhere on the disk. A more uniform intensity would mean a smaller and smaller standard deviation from the average. This decrease actually corresponds to a lower quality image as it shows that the image is smudging. A higher rmsa would correspond to a clearer image as there are more clear features on the solar disk.
3. Based on the data that was analyzed and the conclusions drawn from these image, the high the contrast between any two point, the higher quality the image is. It was noted that as the image begins to smudge, the contrast becomes more uniform across the solar disk, so more variation in contrast would correlate with less smudging or a higher quality image. If the object were a point source, there would be no features to distinguish (i.e distinguishing the solar limb from the solar disk). This means

that the quality of the image of a point source as it approaches portions of the sky where seeing worsens, would not see any significant changes. There would be no intensity distributions to monitor as it is a single point to analyze. The only change that could be measured would be the actual magnitude of the intensity as the increase in atmosphere might decrease it's brightness. The second moments calculated in part C essentially represent the sigma value of the histograms created in that part. A smaller moment corresponds to a thinner histogram distribution. The thinner that distribution is, the more uniform the intensity is across the solar disk, which is to be expected as stated before that the smudging created by the increase in atmosphere would cause such an effect.

4. Based on all the given data and measuring how the quality changes with time, it is safe to say that the initial image taken would be the highest quality. The quality of images then continuously decreases as the time of day meaning the final image would be the worse quality. The initial image had the highest rmsa which corresponds to clarity in the rdc images, the steepest slope along the solar limb which corresponds to a sharper edge, and the highest moment values for the intensity distributions which corresponds to a more variation in contrast images. The opposite of this was true for the final time which showed a lower rmsa, shallower slope, and lowest moment values after analysis.

Overall I found this project to be rather fun. I personally have a lot of interest in solar astrophysics so I enjoyed learning ways of analyzing solar features.