Studying solar limb darkening in H-Alpha with a Coronado PST

Jessica N. Farrell, Dr. Jennifer Birriel, Mentor

Department of Mathematics and Physics, College of Science

Abstract

Solar limb-darkening refers the optical effect observed in the Sun (and other stars) in which the brightness of the disk is greatest at the center and decreases moving outward to the limb of the disk. We use a Coronado Personal Telescope (PST) to image the disk of the Sun to study this effect. We take photographs of the sun using a cell-phone camera, with both a JPEG and RAW outputs, and the images are analyzed used free online software. We measure the brightness as a function of position on the solar disk and compare results to the known wavelength dependent relationship. We conclude with a brief discussion of how this can be used as an excellent advanced physics lab experiment that can be done during the day: it allows students to learn the basics of astronomical imaging and image processing using their own cellular devices and software.

Methods

Coronado Personal Solar Telescope

The Coronado PST is a dedicated solar telescope - meaning that it can only be used for viewing the Sun. Its filtering allows for viewing in a very narrow wavelength range 656.2 to 656.4 nm (in the hydrogen-alpha bandpass. This narrow range of light gives the image a reddish hue and allows one to observe great surface detail including prominences and filaments at the edge of the Sun, sunspots and other surface details in incredible detail. It has a street price of $595 without a tripod. We acquired images using a cell-phone camera placed at the eyepiece of the telescope.

Solarscope

The SolarScope is a white light projection telescope that allows safe observations of a projected image of the Sun on a white surface. The telescope aperture is 40 mm, but because it is a projection telescope, the image of the sun is much larger. This telescope costs around $225.

Procedures

The camera was used in manual mode to allow us to change ISO and exposure time settings. Because the PST telescope does not have a uniform illumination across the lens, we placed a white, translucent plastic over the lens, which allows us to remove the effects of uneven illumination. Using the SolarScope, we took images of the solar projection using the same cellphone camera, also in manual mode. This instrument does have even illumination across the lens.

In order to analyze the images that we received from the telescopes, we used the free software SalsaJ:
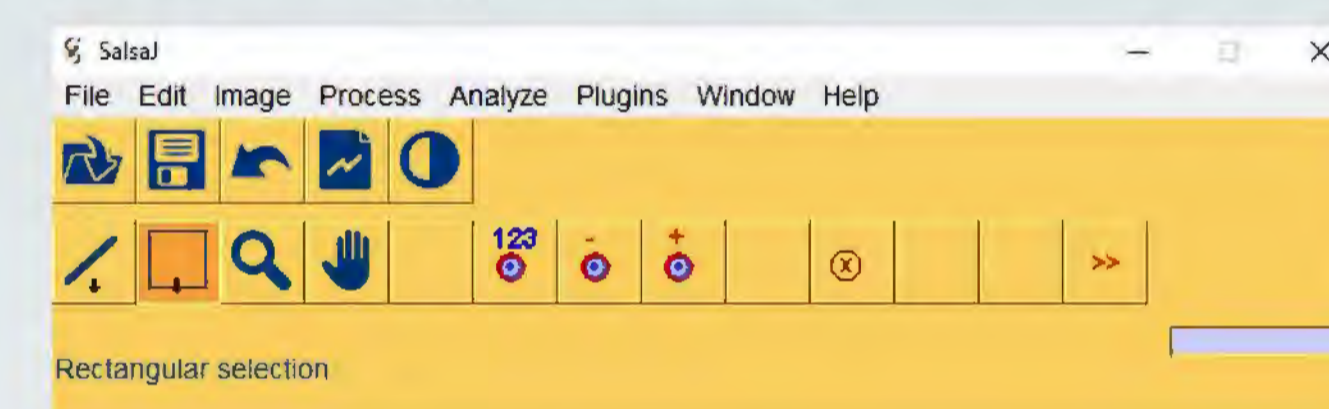
This software allows one to subtract the background brightness from the image, measure specific areas of the image, and plots the brightness of the image. The software was designed for high school and undergraduate students for learning the basics of image analysis.
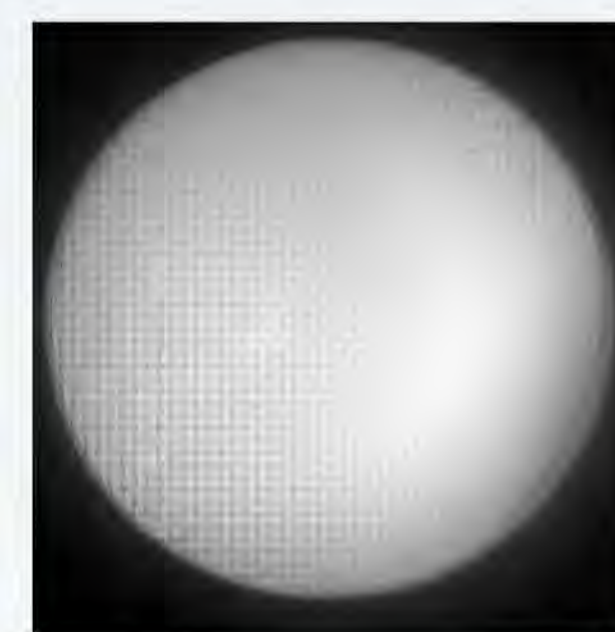
Image taken with Coronado PST:
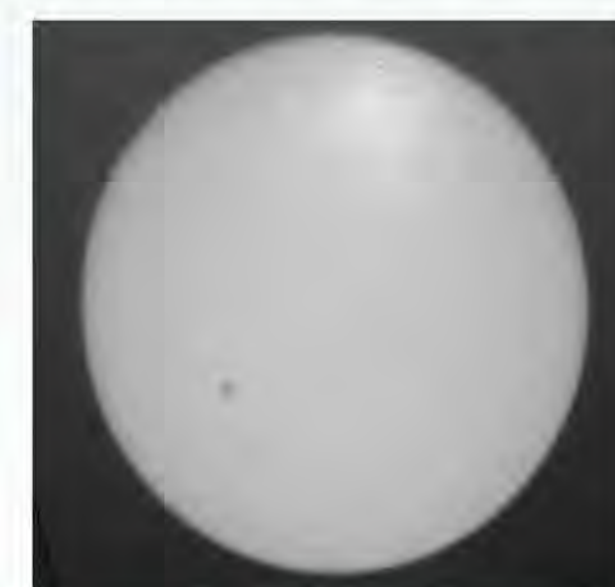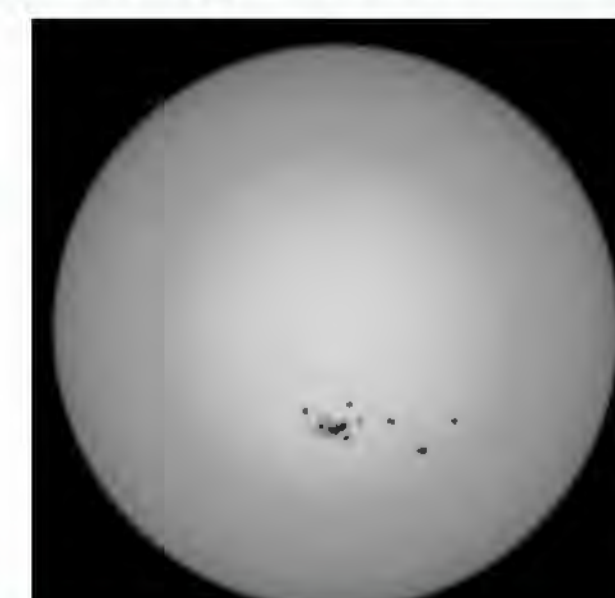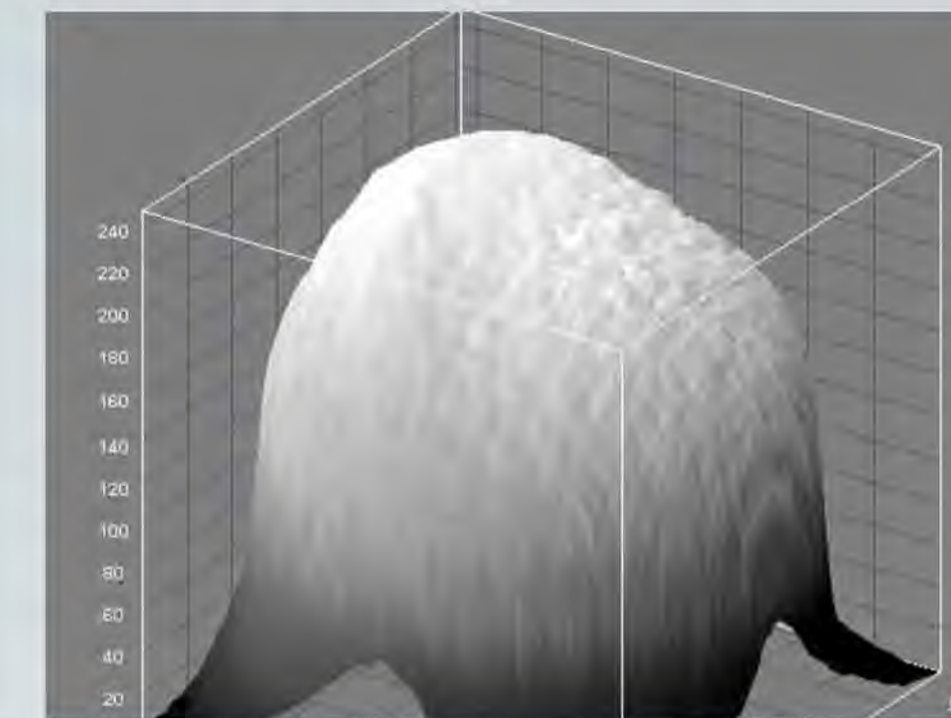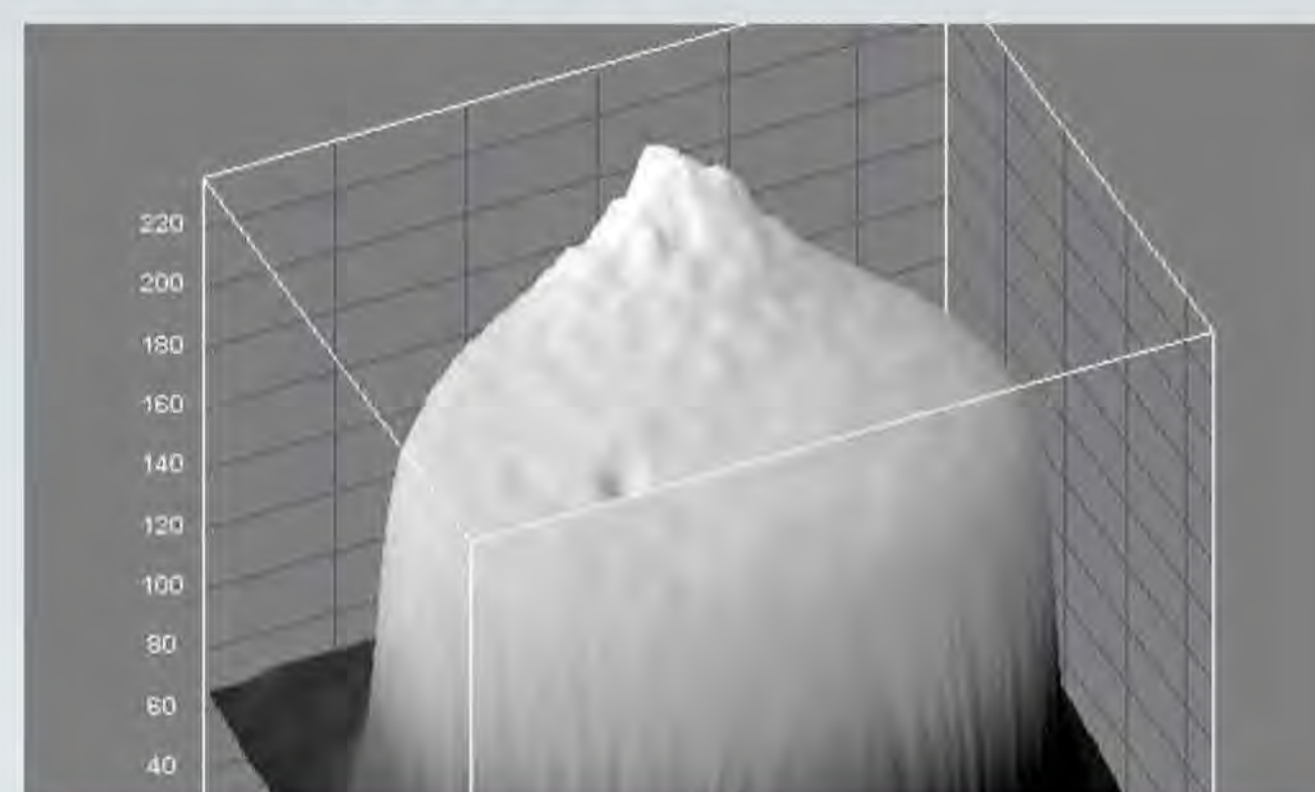

Image taken with Solarscope:

Image taken by NASA:
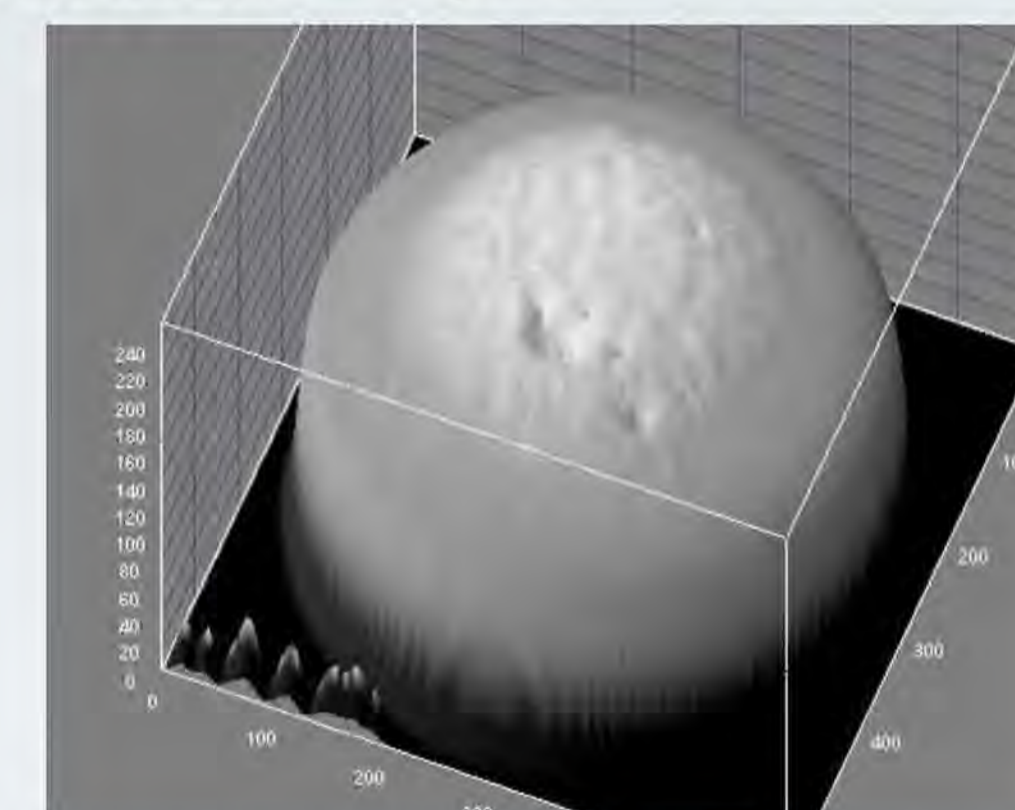

Results

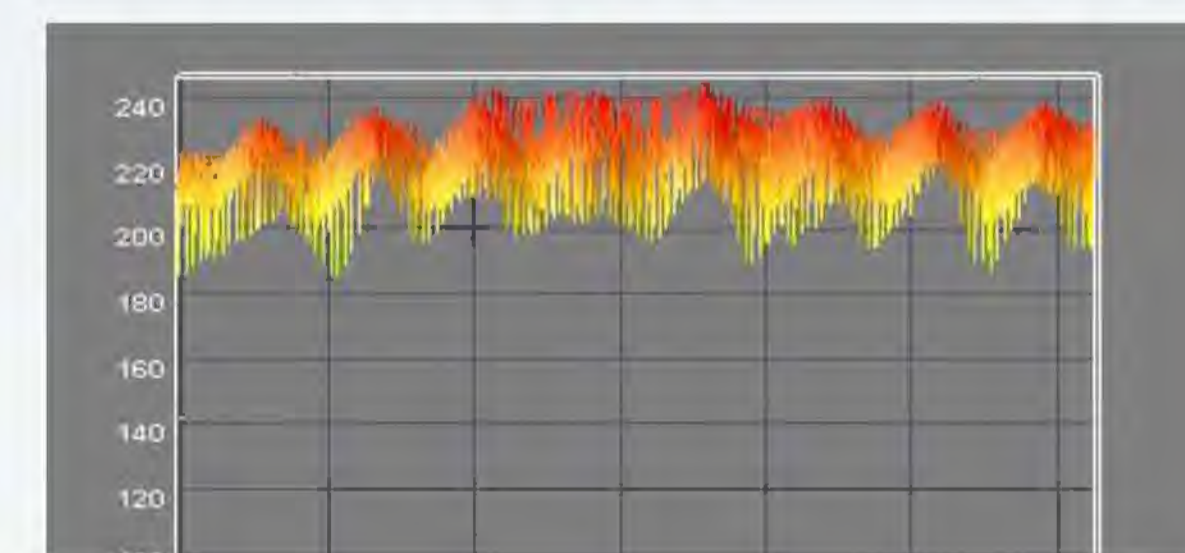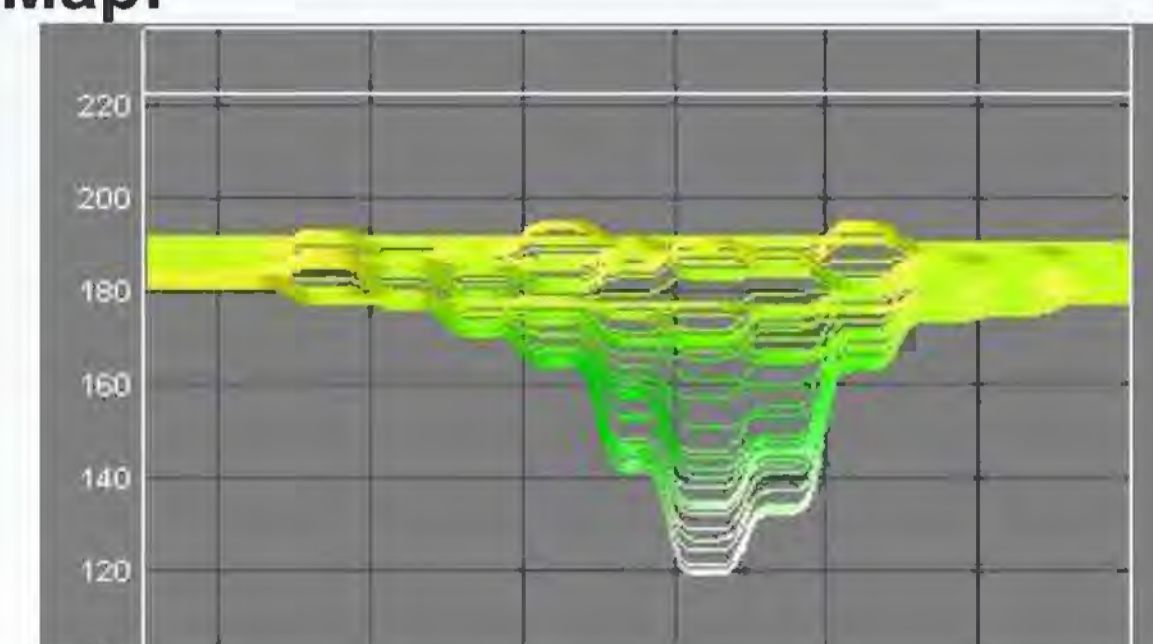**Coronado PST Sun Analysis:**

Solarscope Sun Analysis:

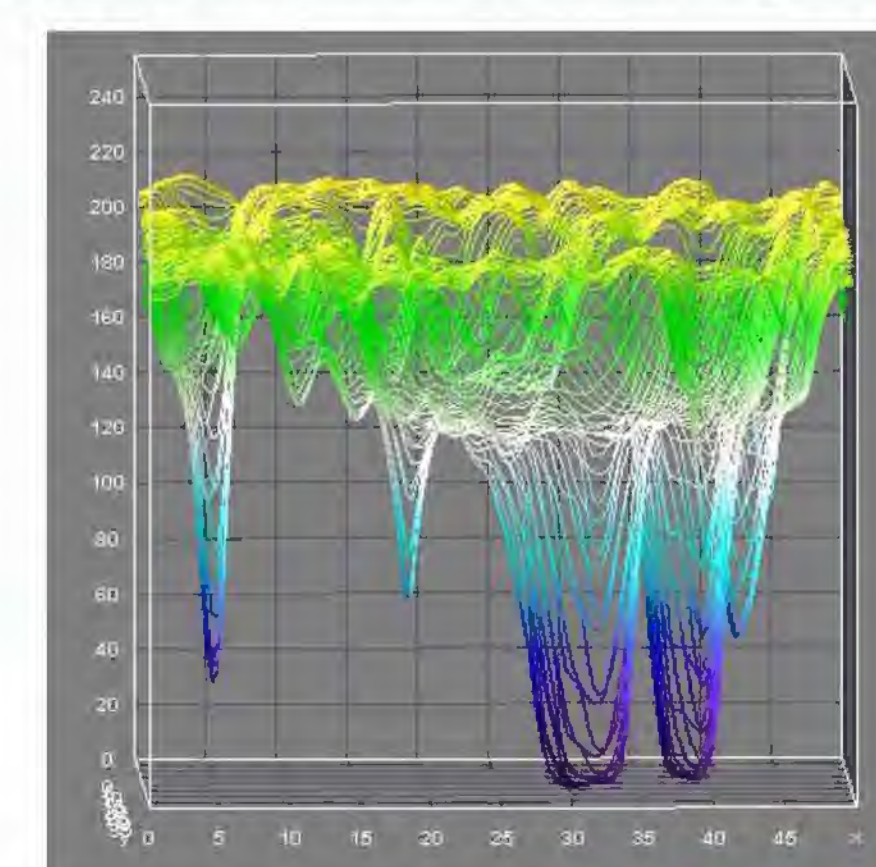

NASA Sun Analysis:

Coronado PST Sun Spot Topography:


Solarscope Sun Spot Topography Map:

NASA Sun Spot Topography Map:

Conclusion

Based on this analysis, it appears that the cheaper, more accessible Solarscope provides students the best images to analyze, as it provides the highest quality analysis compared to images taken by NASA. Because of its affordability, ease of use, and ability to provide high-quality images of the sun and of sun-spots, the Solarscope would be ideal for an advanced physics laboratory.
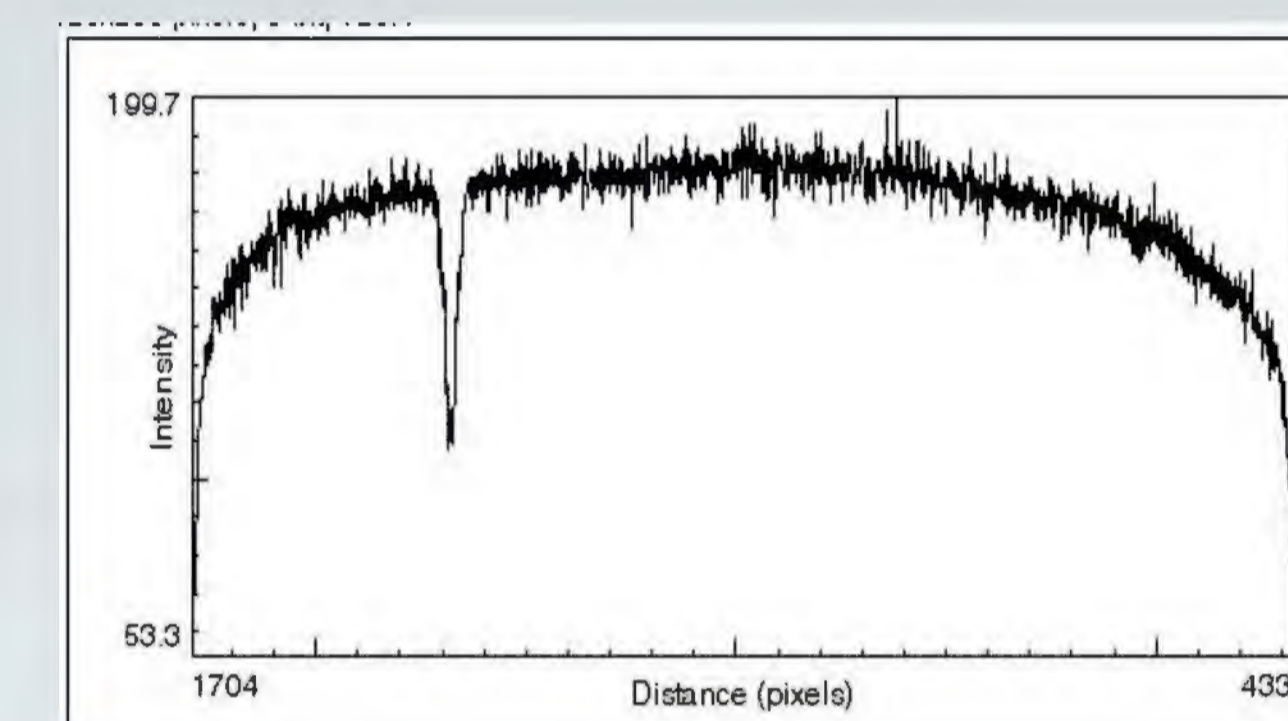
The graphs obtained from the sun's surfaces match the above graph, with the brightest parts of the sun being towards the center and the darkest parts being around the edges. In addition, the sunspots were clearly visible in the analysis. In future work, the graphs obtained of the intensities as a function of the Sun's radius will be compared to the following intensity equation:

$$\frac{I(\theta)}{I(\theta = 0)} = A + B\cos(\theta)$$

References

Astrosurf. (2010). *IRIS Software*. Retrieved from Image Processing: http://www.astrosurf.com/audine

Britannica. (2003, October 28). Photosphere of the Sun. UK. Retrieved from http://media-3.web.britannica.com/eb-media/91/118391-004-BAA3318E.jpg

Meade Instuments. (2014). *Coronado Personal Solar Telescope*. Retrieved from Products: http://www.meade.com/products/coronado/coronado-personal-solar-telescope-pst-0-5-angstrom.html

Nave, R. (2014). *Wien's Displacement Law*. Retrieved from Star Temperatures: http://hyperphysics.phy-astr.gsu.edu/hbase/wien.html

Richmond, M. (2014, February 11). *Limb Darkening Lecture*. Retrieved from Observational Astronomy: http://spiff.rit.edu/classes/phys440/lectures/limb/limb.html

University of Georgia. (2011, February 11). Optical Depth .