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ASTR499 Final Project

Our group's final project was to investigate the effects that adaptive optics had on imaging bright and dim stars. We did this by calibrating the AO, choosing objects in the night sky to view, then imaging them with and without AO enabled. We looked at Alnath, Capella, two stars in M45, and one star in NGC869.

Many papers on ADS reference adaptive optics, but they all simply use it to view distant, faint objects rather than conduct comparisons with images without AO. While not an academic paper, Brad Wallis' work on the subject was an important basis for our project[1].

I wrote a Python program to perform data analysis and calculations. Namely, it calculated the FWHM of the star, generated an isophote image, and graphed the flux versus sample radius about the star's center[2]. These were sufficient to give us a good objective measurement of AO's effects on images. We took the images over three nights, using one-second exposure times for Alnath, Capella, and the second capture of M45, 1.5 second exposure times for the first capture of M45, and 2 seconds for NGC869. The AO was calibrated each night using Capella, and the AO speeds were set to 0 in CCDOps for the non-AO images. The AO and non-AO images of each star were taken one right after another and the telescope was not touched from the beginning of the first exposure until the end of the second. The CCD temperature varied from night to night from 0C to -6C, but was constant for each pair of images. We verified that the sky tracking feature of the telescope was working at all times, so no smudging is due to that feature not working correctly.

The brighter stars, Alnath and Capella, gave us some very good results. The FWHM of Alnath with AO was 9.4 pixels, while it was 14.7 pixels with AO disabled. Additionally, it had about the same amount of flux inside a 13 pixel radius of the center with AO on as the non-AO image did inside of 18 pixels. The result is a more well-defined star with a bright peak and smaller visual radius with AO on. The FWHM of Capella was about the same on both images, but the peak flux with AO on was slightly higher than without, the isophote plot shows that the AO image is closer to being circular, and the image without AO appears visibly smudged. Both of these images were taken with an exposure time of one second; a longer exposure may have shown AO in a more positive light because AO is best at counteracting atmospheric distortions over a longer period of time.

The dimmer stars had more mixed results. The images we took of NGC869 were extremely noisy for some reason, and despite my best attempts to clean them up and compensate for it in my algorithms, I couldn't get any usable data from them. The M45 images were cleaner, but gave some puzzling results. The first image had a FWHM of 7 pixels without AO, but 9 pixels with. The image with AO also looked more oblong than without, which is the opposite of what one would expect. The second image of M45 is more in line with expectations. The AO image had a FWHM of 3.4 pixels, and while the algorithm wasn't able to correctly calculate the FWHM for the non-AO image, it appears to be around 10 pixels. The counts

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[1] http://www.frazmtn.com/~bwallis/AO_COMP.HTM
[2] See info.txt for usage and notes on the program.

versus sample radius plot shows that the flux was slightly more concentrated around the center with AO on, showing 140 000 counts within 20 pixels of the center versus around 130 000.

In summary, AO tends to improve image quality more often than not. It can reduce the visual radius of stars and keep the starlight more concentrated in one spot. This would be especially important when observing objects that have more complex shape than a simple point source, such as galaxies or nebulae, as imaging them without AO would cause some of their shape to be obscured.