Calibrating the infrared camera Clio

Chris Bohlman

University of Arizona

Abstract:

Clio is the infrared camera of the Magellan Telescope’s Adaptive Optics instrument. The Clio detector records light levels, but as those increase, the camera response isn’t linear. I measured the nonlinear response of the Clio detector and determined how to correct this. I obtained Clio images where the exposure time was gradually increased. I read in every image’s exposure and brightness count, and devised a way to correct the images by linearization through an equation. With the coefficients generated, I calibrated other data as well. My accomplishments revolved around learning Python and seeing how coding was applied in a scientific setting. I also learned about the process of data collecting and how that relates to work beyond my undergraduate career. Since the data set is now calibrated, we can fix more data from Clio, and use that to accurately measure the brightness of other stars and exoplanets found.

Presentation Preparation:

SLIDE OUTLINE

* Slide 1: Project Name and My Name 30 sec
* Slide 2: Adaptive Optics Introduction and what I did 45 sec
* Slide 3: Picture of Magellan AO system/hands on work 30 sec
* Slide 4: What was I doing this year? 1 min
* Slide 5: Defining words 1 min
* Slide 6: explaining the coding process to audience 1 min
* Slide 7: Results of my coding, 30 sec
* Slide 8: Pictures 30 sec
* Slide 9: Impact on extrasolar planets 1 min
* Slide 10: Thank yous to my mentor and the program 15 sec
* Slide 11: Extraneous information

Presentation Slide Specific Notes:

**Slide 1:** Introductory Slide, introduce myself, my mentor, my project, sum up the presentation

Start off with: My name is, my mentor’s name is, my project is

To cover: In this presentation, I will speak about my project’s background, what I did, how I did that, and the importance of my research

Transition to next slide: After introduction, just flip to next slide

**Slide 2:** What’s the big idea? Define adaptive optics and what I generally did

Start off with: Generally speaking…

To cover: Go off slide

Transition to next slide: I wasn’t there for the image taking, as they was taken….

**Slide 3:** Picture of Las Campagnas and picture of me doing science: Where the instrument is located, and what hands on work looked like

Start off with: in Chile at the Las Campagnas Observatory

To cover: Both pictures

Transition to next slide: Still got to do hands on work, along with coding. Specifically…..

**Slide 4:** What did I do this year

Start off with: I calibrated images by….

To cover: Go off slide, expand upon points

Transition to next slide: Before I explain the calibration process, I should mention…

**Slide 5:** Define relevant terms for the project

Start off with: A few terms that are important to my project…

To cover: Slide, A linear detector will record 2x the counts with a star 2x as bright or when you integrate for 2x as long, speak about graph, speak about python packages

Transition to next slide: Now, to speak about the calibration process itself…

**Slide 6:** Explain the coding process that I took

Start off with: I had to write some very in-depth code, but for the sake of time, I will generalize it all.

To cover: Go off slide

Transition to next slide: Now, the error plots were instrumental is helping me figure out which fit to use, and they lead me to…

**Slide 7:** What did I spend 4 months doing? How did I apply those results to other pictures?

Start off with: the results of my project.

To cover: Go off slide

Transition to next slide: Now, for a visualization of my data…

**Slide 8:** Show how the data was corrected, mark that it wasn’t much of a change, so why was it necessary?

Start off with: These are some interesting graphics.

To cover: What both plots mean, why there isn’t much of a difference between the correct image and regular image

Transition to next slide: It may not look like much, but these plots were very important

**Slide 9:** Proceed to lay the smack down on why this stuff is necessary to adaptive optics as a whole

Start off with: But why exactly? Why is all of this so important?

To cover: Go off slide

Transition to next slide: Pause because it’s the end

**Slide 10:** Thank everybody everywhere, take questions

**Slide 11:** Leftover information that may be helpful with questions

Common Questions and their answers:

Other Information:

* No index cards during presentation, but have copies of my in-depth report
* Come off as personable: not condescending towards audience when talking about more scientific topics
* For presentation (business casual): Tan chinos, light blue or white shirt, dark blue tie with tie clip, maybe a grey cardigan, dark brown belt and dark brown shoes with argyle or light brown socks
* For dinner (business dress): black FITTED slacks, dark blue shirt, black tie, maybe suit jacket
* 7-8 minutes of slide time: PRACTICE
* 1-2 minutes of questions, practice fielding questions from Katie, Kara, and parents for 3 diff. levels
* Strong beginning: MAKE AN IMPRESSION- What do I want my audience to think about me/ my presentation?
* Strong ending: WHY IS THIS IMPORTANT? -Extra solar planet discovery, adaptive optics is one of the most important components for modern telescopes
* Transitions between slides: what do I want to say in order to move onto the next topic?
* **DON’T READ THE TITLE OF THE SLIDE AS YOUR INTRODUCTION TO IT**
  + **LITERALLY THE WORST THING**
* Connect dewar filling to how infrared detectors need to be kept cool: Answer why was my hands-on work (besides coding) important to the project as a whole?

Questions not covered in my main presentation slides?

If you have something technical or complicated that you feel is too detailed for the main presentation, but which might come up in questions, it is ok to have prepared an extra slide that you place after your "thank you" slide (in other words, a slide kept in reserve, just in case).

* What common questions will pop up?
* What info do I put on my extraneous slide?

The script:

Good morning, ladies and gentlemen. My name is Chris Bohlman, and on behalf of Steward Observatory, I would to present my project: Calibrating the infrared camera Clio. My mentor was Dr. Katie Morzinksi, and in this presentation, I will speak about my project’s background, what I did, how I did that, and the importance of my research.

Now, adaptive optics as a general scientific field can best be described as close-to-perfect astronomical image taking. The atmosphere actually distorts light from distant stars and planets, as the movement of hot and cool air above can cause disturbances to the light that reaches earth. Because astronomy demands highly precise data, adaptive optics have emerged as a way to correct the problem of the atmosphere. Basically, a sensor measures the distortion of the atmosphere every few milliseconds, and a mirror in the telescope deforms in order to adjust for those distortions. However, what my project concerned was what happened with the images that were taken. I wasn’t there for the image taking, as they were taken….

in Chile at the Las Campagnas Observatory. As you can see here, this observatory is in the middle of nowhere, which is good for astronomical data collection. The higher up an observatory is, the less atmosphere there is to distort images. Also, there is not major sources of light pollution, such as cities, around this observatory, since it’s in the middle of the Atacama Desert. To the right of that is a picture of me, doing some work with a dewar. Now, inside that dewar was a dummy detector that was very similar to the Clio detector, and within the dewar, we were pumping liquid nitrogen into it in order to cool the dewar to acceptable levels, since the Clio instrument, as an infrared camera, must be cooled to very low temperature. In any case, this hands-on work was important, as it allowed for me to justify the other parts of my internship and see practical applications of this program.

Now, coding was the major focus of this internship. I had to calibrate the Clio instrument through taking all the images produced, and writing code to find a suitable correction for the images. By calibrating one data set, I could obtain a set of coefficients that when applied to other data sets taken around the same time, could calibrate them as well. Therefore, it was a combination of calibrating images and coding, as well as hands on work, that really shaped this internship. Before I explain the calibration process, I should mention…

A few terms that are important to my project. First ints, or integration time, is the amount of time the Clio detector is open for an image being take. It’s the detector equivalent of exposure time of a camera. The counts are the brightness of a pixel in an image taken. For every pixel, there is a different amount of counts, so it was necessary to find the counts of every single image whenever the code called for it. Now, linearity is essential a term to describe the behavior of data. A linear detector will record 2x the counts with a star 2x as bright or when you integrate for 2x as long. However, this is not the case in the real world due to real world stipulations, so as you can see by the graph, the raw data tends to become increasingly nonlinear with time with the increase in integration time. My job was to correct for this. Now, to do that, I used the Python programming language, and utilized several packages in python, including numpy, matplotlib, and astropy. Now, to speak about the calibration process itself…

I had to write some very in-depth code, but for the sake of time, I will generalize it all. To find the calibration coefficients, I first read in every image of a set, obtained values of overall counts versus the integration time of the image. I then took the most linear section of the data, and extrapolated that portion to the whole image to view how far off from linearity I was. I then looked at second, third, and fourth order fits to the data to see how close I could get to linearity within the data. I also used error plots to devise which fit had the least amount of deviation compared to the data. In the end, it ended up being 4th order worked with the data the best, so I applied those fourth order coefficients to the images and ended up getting a very linearized data set. You know, it sounds like a fairly straightforward process, but it actually took me approximately four months to produce suitable corrections to the data.

Now, the important thing about these coefficients was the fact that I would apply them also to other data sets taken around the same time. So, after we figured fourth order was the best order, I was given another data set to apply the corrections to and see what the effects were. For a better view of what I mean…

Let’s talk about these graphics. First, the graph on the upper left illustrates the correction I could make to the data. The black dotted lines represent the corrected values for the data, so you can see that the up until around 45,000 counts, the corrected data remains linear. To the right, you can see an image subtracted to remove the background, and the that image with the correction and without the corrections. The actual difference is very sight, but the plot on the lower left shows a log plot that demonstrates how the vertical slice from the picture changed. Note the Airy disc pattern on the plot.

Now, the impact this kind of research has on modern astronomy certainly cannot be understated. Adaptive optics is certainly growing more and more advanced, and the importance of devising ways to calibrate data is integral to the success of adaptive optics. In fact, my mentor uses adaptive optics to image exoplanets, and the finding of those exoplanets in contingent on whether the data taken from telescopes is calibrated and accurate or not. With the calibrated data, beyond exoplanets, we can measure the brightness of stars and planets with a high degree of accuracy. Expanding upon brightness, we can figure luminosity, distance, and other bodies that could potentially be orbiting around the photographed body.

The presentation has concluded, and thank yous go out to Katie Morzinski, my mentor, The Magellan Adaptive Optics team at Steward Observatory, and Susan Brew and the entire Arizona Space Grant Consortium. Now, are there any questions.