

Search for Other Worlds:

A Learning Experience in the Basics of Photometric Data Reduction

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This summer, I worked on detecting extrasolar planets by way of the transit method and differential photometry. The goal was to learn the basics of photometric data reduction. Another task was to compare the results to the work already done on the same set of data using different algorithms. I was able to gain valuable experience in the scientific field by learning and using programs like IRAF, Linux, and FORTRAN for the first time. This was also the first time I had been exposed to CCD astronomy and the actual process of data reduction.

Introduction

The data I was designated to photometrically reduce came from the Vulcan Project. The team utilizes a fully-robotic four-inch telescope with the sole purpose of surveying the sky for extrasolar planets. Information about a variety of extrasolar planetary systems is necessary to better comprehend the formation of planetary systems and their final configurations. The ground-based Vulcan telescope is sensitive enough to detect giant Jupiter-sized planets in close orbits around sun-like stars.

These planetary systems are quite different from the one we reside in. The identification of transiting planet systems allows us to directly measure the size, mass, density, and orbital parameters of the inner orbit of giant planets. "Current theories predict that the size of the atmospheres of the short-period planets will vary with the mass of the planet and the size of the orbital semi-major axis because of the intense stellar insolation." Detection of short-period transiting planets allows us to test these theories. Other types of planetary systems, such as binary star systems with orbiting planets, need to be studied in order to understand the differences from our own planetary system.

Observations and Reduction

The first step in the data reduction process was to bias correct and flat-field all the images. I was able to closely follow Dr. Welsh's guide to doing this except when it came to the steps requiring the use of "ccdproc" in IRAF. The tasks "zerocombine" and "flatcombine" gave me an output in the .imh format where the resolution information in the headers was inconsistent with the rest of the data. I had to convert these .imh files back to .fits files, which fixed the header, but made the images incompatible with "ccdproc". Instead, I used the task "imarith" to calibrate the data. Also, the set of data I was working with had no overscan region so trimming at this juncture was not necessary.

Next, I carried out the actual photometric reduction. Here, I used Dr. Orosz's handout as a guide through IRAF and the "daophot" task. Many differences arose in these data reduction steps. The first noticeable inconsistency was that the airmass (and information such as right ascension, declination, sidereal time, and epoch, which can be used to obtain the airmass) was not present in the headers. I had to add this information to each image and use it to compute the airmass for each image.

An important step in the data reduction process was determining the instrumental magnitudes for each star. I used "daophot.phot" which gave me a list of the magnitudes for each aperture of each star entered. The output contained "coordinates of the peak, the aperture radii, and the instrumental mags⁵" of every star measured. This step was not especially different from what Dr. Orosz instructed. I used 14 apertures, ranging in radius sizes from 5 pixels to 18 pixels. Other steps, such as aligning the images, performing the curve of growth analysis, and running a time series analysis did not translate well to the Vulcan set of data.

One difference that repeatedly caused me to diverge from what Dr. Orosz demonstrated at the beginning of the summer was that my images contained tens of thousands of stars while the Tr-ES1

data that was used to demonstrate the photometry contained about a dozen prominent stars. Once I had all the peculiarities of my sets of data figured out, I was able to develop a method better suited to reduce the Vulcan data.

Analysis

My analysis is of the data reduction process itself. I did fulfill a goal of gaining an understanding of basic data reduction. The following are what I felt were the more important aspects of the data reduction and how they differed from what was demonstrated at the beginning of the summer.

I mentioned before how the Vulcan data contained many more stars per image than the Tr-ES1 data. I believe the large number of stars combined with not setting a threshold led to the unexpected read out of over 300,000 stars when I ran “daofind” on an image. In Dr. Orosz’s handout, setting the sigma of the sky in the “daophot.datapars” parameter list was not explicitly specified. However, “to find stars, one always must set a threshold in units of sky sigma.” I found that piece of information using the task “fitsky” in the “apphot” package, and using it, received a star coordinate list from “daofind” of a little over 30,000 stars—a result that made much more sense.

To the right is a typical image from the Vulcan Camera Project. This is a 7x7 degree field of the sky. A full moon occupies half a degree of the sky. It can be seen in Image 1 that the sample of stars is astronomical (pardon the pun). It was necessary to decrease the number of stars to be analyzed to keep the required CPU time manageable while learning and testing algorithms and also to remove the saturated stars. Such steps were a non-issue with the example of the Tres1 data since those images contained an easily manageable number of stars. Also, with this large number of stars, the maglim parameter in the task “mkapfile” had to be lowered past the default of .1. The maglim parameter is the maximum permitted magnitude error. Lowering the magnitude limit cuts down on the amount of stars on which the curve of growth analysis takes place. I had to lower it to as low as .0019 to get the curve of growth analysis to converge.

Monitoring such a large area of the sky requires the use of wide angle, or wide field of view (f.o.v.), lens. Using such a lens adds its own distortions that must be considered during the data reduction process. Displayed below are examples of the effect that a wide f.o.v. lens can have on the data. Image 2 shows the difference in the amount of light reaching the ccd plate from the center to the edges. Image 1 does not look the same since the flats (such as Image 3) were divided into all of the data. But, this distortion takes center stage when differential photometry is carried out. Differential photometry requires a target star, and comparison stars. In the Tr-ES1 data, choosing comparison stars for a target star was simple since the f.o.v. was very small and the selection of stars was also limited. They would all have similar airmasses and conditions no matter from where on the image the comparison stars were selected. In the Vulcan images, because of their size, the distortion of the wide f.o.v. lens, and varying atmospheric conditions over the entire image, only stars nearest to the target star can be used

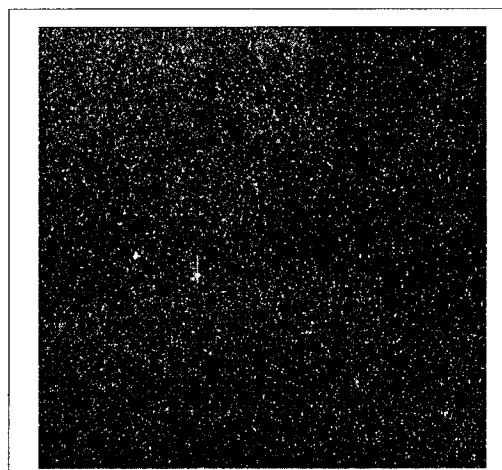


Image 1: FBCygIII48489_07Aug03, biased and normalized image from Cygnus III star field

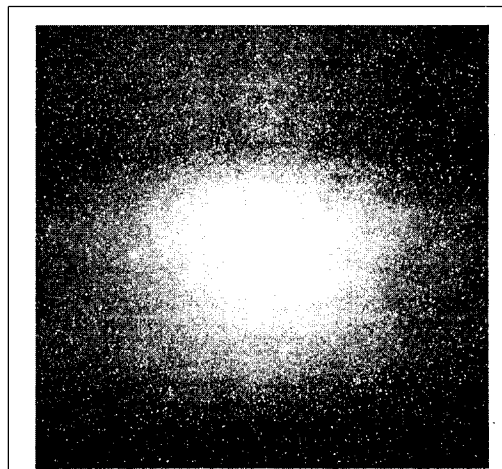


Image 2: CygIII48489_07Aug03, raw data image from Cygnus III star field

as comparison stars. This required me to add a radial search to the FORTRAN program that had been written by Dr. Orosz to do the actual differential photometry. I used the Pythagorean Theorem with the coordinates to make sure possible comparison stars were near enough, but not too near the target star.

Conclusions

This summer, I was mainly given the task of learning the basics of photometric data reduction and obtaining a light curve for comparison with previous work. I was not able to get a light curve but learned rather detailed intricacies of the data reduction process. I also came to the realization of how the method and tools used to collect data can add to the uniqueness of the process in which the data is reduced. I have gained valuable experience in photometric data reduction and feel confident in continuing the work.

Acknowledgements

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References:

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