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Long Period Variable Star Research

Over the past semester I have worked with Prof. Andrew Layden on Long Period Variable star research. Stars earn a classification of variable if their apparent magnitude, how bright it appears on Earth, changes over a period of hours or days to even years. The study of variable stars is important to determining the distance of the cluster that a particular variable inhabits. Studying the spectra of the stars can help us to determine what causes this periodicity.

There are many steps involved in the detection of these long period variables or LPVs for short. In fall of 2009 I helped in the gathering of images of several globular star clusters in both the Northern and Southern hemisphere not including the cluster I analyzed this past semester. I gathered these images using Bowling Green State University's professional-level 0.5 meter telescope with an attached CCD, charge coupled device, camera. In order to obtain images of a cluster from the southern hemisphere I used a remote controlled telescope in Chile through a website. After the images were gathered the rest of work was done on a computer.

I used my newly learned UNIX skills in a program called IRAF, or Image Reduction and Analysis Facility, to examine each imagine individually. Each night's worth of observation was composed of four images. The reason for having four images a night is so that they can later be combined into a single image to help eliminate any blemishes or bad pixels and to reduce the grainy "noise" of the background. We then chose a reference star for that particular cluster which was close to the cluster center. Choosing a star that is close to the cluster center ensures that the combining process can do the most accurate job of shifting the cluster center stars on top of one another. In the combining process I found the x and y coordinates of the reference star and

then ran a program in IRAF to compute the shift the other three images would need to make in order to line up the cluster center of all four images.

After combining the four images from each night's observation into a single image for that night of observation from the 2009 data set, I gathered the data from 2007 that had already been combined to give myself a bigger data pool. This is when I used a professional astronomy program called ISIS to combine all of the 2007 and 2009 images into one large image (see Figure 3). I ran various programs within ISIS that took all the images and shifted all the images to align the cluster center to one another, similar to what I did when combining each night's worth of data. This program then took everything in the images that did not vary in brightness and canceled it out. The resultant image is one that has peaks and valleys that represent the changing of brightness, either dimmer or brighter, from one night to another (see Figure 4).

The next step was to analyze these images in a tool within IRAF that displays the images. I then chose stars that appeared as big spots, see Figure 4, and looked at their star profile to see if it was truly a bump. Then I created light curves for all the stars that had this bump I was looking for. We found many of the previously known RR-Lyrae stars that have been well studied in this particular cluster. Our goal was LPVs so we focused on the brighter spots in this cluster instead of the fainter ones. During RR-Lyrae research, the cluster is observed about every thirty minutes throughout a night for up to a week. A LPV would not change much, if at all, during this time period so we looked at stars that were previously uncategorized as variable. I then used a program called super mongo to plot out these various light curves of the stars which we had picked out. The plots were shown with the 2007 and 2009 data next to each other (see Figures 1 and 2). We then compared the stars we found from out data set to a list of known variable stars already compiled to see if our telescope was sensitive enough to detect these as well as possible

new variable stars. We found our data was good enough to detect previously known RR-Lyrae stars, which only have a period of about half a day, as well as a previously unknown variable which we determined was in fact a LPV (see Figure 1). We also confirmed that a known variable star V50, see Figure 2, was an irregular LPV and we generated good light curves for previously known type-II Cepheid stars V42 and V84.

In order to work on this LPV star research project there were new skills that I had to learn. First and foremost I needed to learn how to use a professional level telescope. I learned the various components of the telescope and how to start it up in order to take pictures of star clusters. I then learned how to use the attached CCD camera in order to actually take these pictures. After the image taking process the next skill I needed to learn was how to use UNIX commands in order to navigate through the computer. Unlike a traditional computer I could not just point and click where I wanted to go and what file I wanted to open. I used various UNIX commands to move throughout directories gathering the images I needed. I then learned how to use the IRAF program and learned new commands needed to run programs through it in order to combine images together. During this step I also learned how to make scripts which runs a series of commands together in the order I choose so that the process moves along a little faster. Aside from UNIX commands and IRAF, I also learned how to use the ISIS program in order to do the shift and alignment of the entire data set into one large image with background noise eliminated. With all of these skills learned I can gather images, analyze them, eliminate background noise and find new variable stars previously undiscovered.

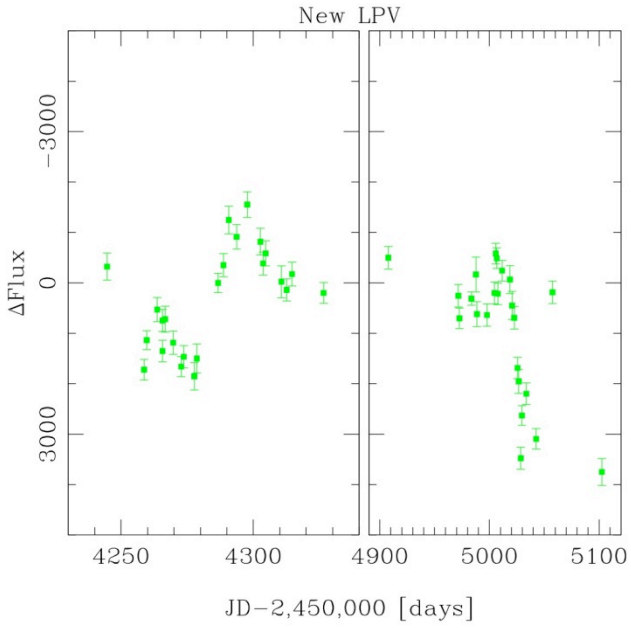

Figure 1

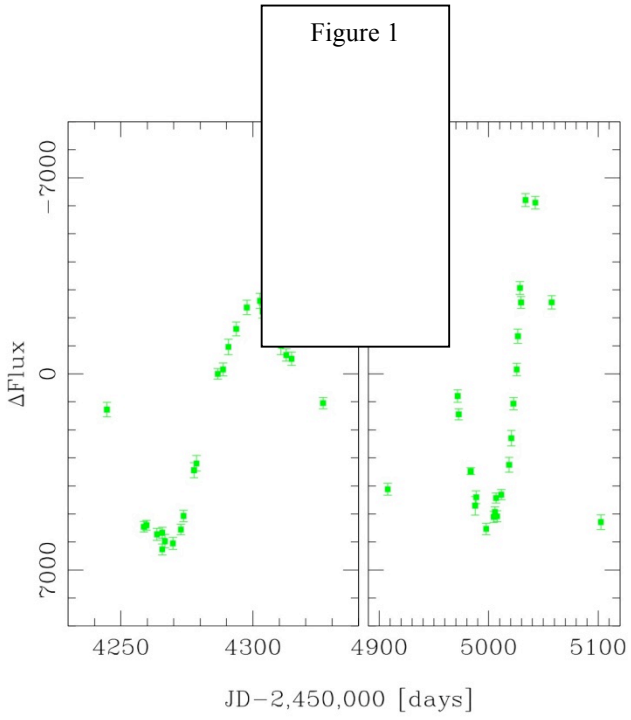

Figure 2

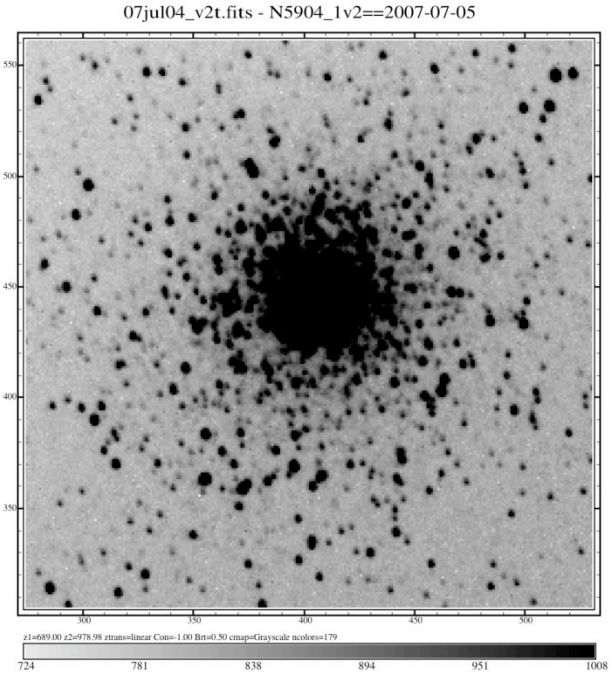

Figure 3

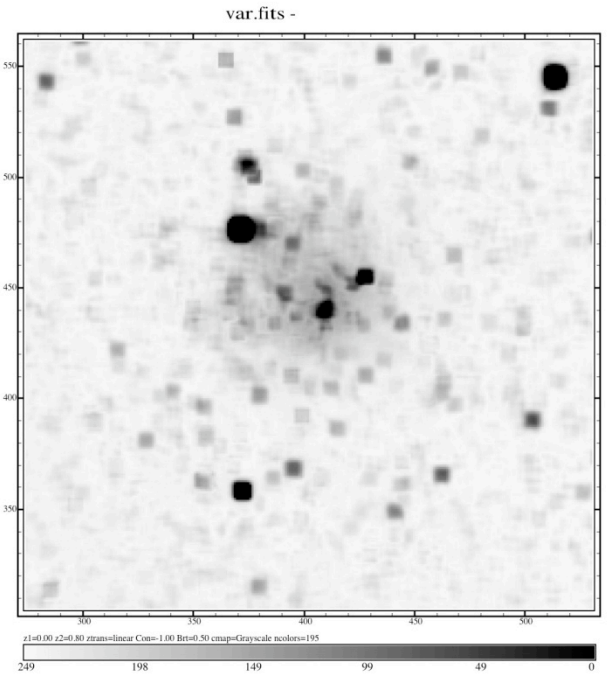

Figure 4