The Search for Variable Stars and Planets in Open Cluster NGC 6819

Antonio Talamantes, San Diego State University
Advisor: Dr. Eric Sandquist, San Diego State University

During this research period data was taken for three consecutive nights at the one-meter telescope at Mt. Laguna Observatory for the open cluster NGC 6819. Photometry was done using the ISIS image subtraction package. Ultimately, ten variable stars were located using these techniques. These variable types include a pulsating variable, five contact binaries, a near-contact binary, and two detached binaries. A previously known variable was also studied.

Variable stars often provide valuable physical information in astronomy, whether the variability is caused by the star itself, a companion star, or a planet. The main motivation of this project was the potential for discovering planets orbiting stars in this open cluster. Known extrasolar planets have all been found around stars not unlike the sun and if one were to be found in an open cluster it would be easier to determine things such as the age and chemical composition of the planet.

Data was collected on open cluster N6819 during three consecutive nights in V band. The usual steps were taken. On each night bias images were taken as well as twilight flat images. Throughout the night offsets on the telescope as well as adjustments to the focus were made. For each image the overscan regions were removed from every image. A master bias image was compiled from the individual biases and was subtracted from all of the other images in a given night. Following the bias subtraction a master twilight was created for each night. The master twilight was normalized and then divided out of each of the cluster images for that night. All of these steps were done using packages in IRAF. Following this image reduction an image was chosen from the three nights as a template to interpolate all the images to the same coordinate system using ISIS. The parameter DEGREE(which controls the polynomial fit for the interpolation) in the "process_config" file was changed from the zero to three. In this case the image that was chosen was the 50th image of the first night. After the images were all aligned, a routine was run in IRAF to determine the full width at half maximum for three stars in each image. The purpose of this was to identify the images with the best seeing of the three nights. A reference image was then compiled in ISIS using twenty of the images with the best seeing. Next, each image was transformed to the seeing of the reference image and the reference image was subtracted. For the subtraction, parameters nstamp_x and nstamp_y(which set the number of stars used for matching the seeing) were both changed to 10 in the ISIS file "process_config". In addition the parameters half_mesh_size and deg_spatial(which affect how the images are fit) were changed to 12 and 3. Following the subtraction, a routine called "detect.csh" was ran which created an image called "var.fits" which made any variable stars evident in this image. This image was examined closely to find any variable stars. By looking over this image, seven variables were initially found.

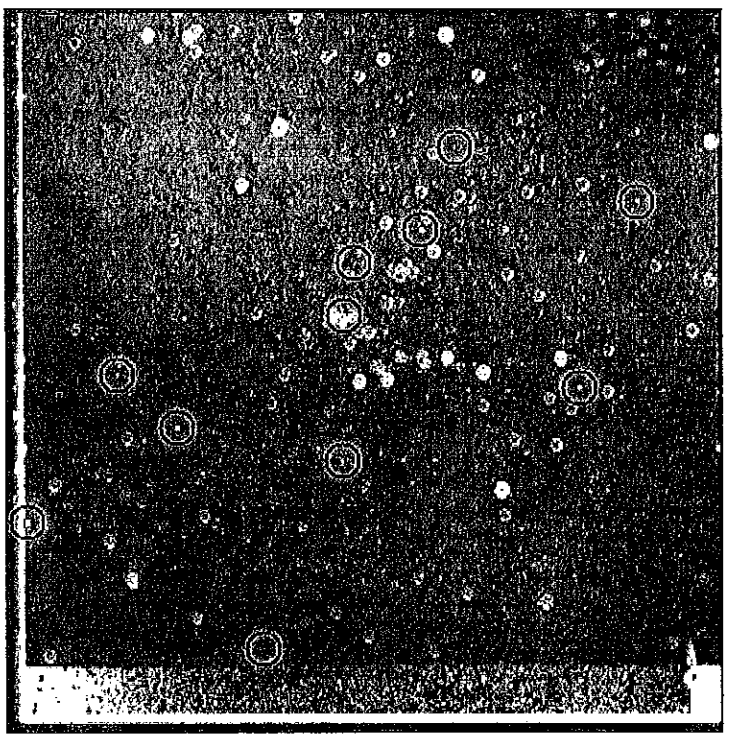

Figure 1: 'Var.fits', the variables are in the center of the circles.

Another method was used to find more variables that may not have been as obvious in the "var.fits" image. A few problems occurred when analyzing the data. Originally, there were many poor readings in the difference flux column which gave readings of zero, so these measurements were eliminated. Another problem had to do with images taken at the beginning of each night. These images were faulty because they were

much shorter exposures than the frames that were taken the rest of the night. On these images, faint stars were unmeasured and brighter stars showed large scatter. As a result these images were eliminated for our analysis. In the end, 331 images were used in the analysis. Photometry was run for the images using both IRAF and ISIS. Essential files were created from each software package containing reference magnitudes, difference fluxes, and time of observations. The information was then run through a program which was written in FORTRAN 77. The program made calculations in order to determine the julian date, the magnitude, and the error in the magnitude for each star in each image. The program also created files for each star which contained each star's mean and median magnitude for the three nights as well as the root-mean-square deviation. A plot of magnitude vs. rms deviation allowed to identify outliers in the graph

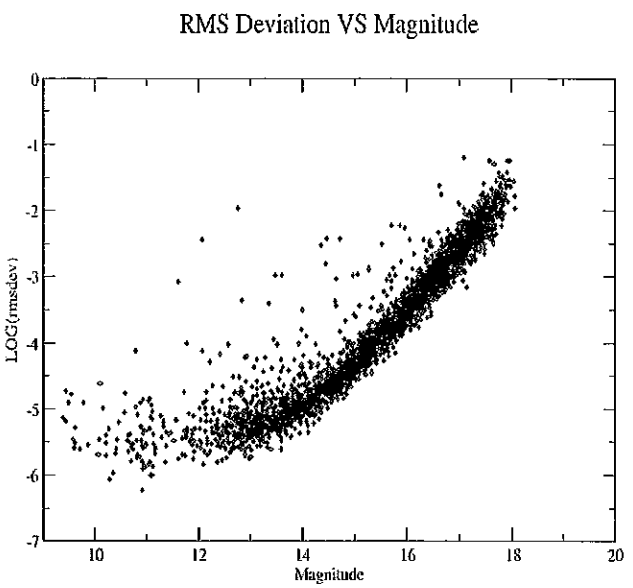

Figure 2.1: RMS Deviation VS Magnitude for each star in the cluster images.

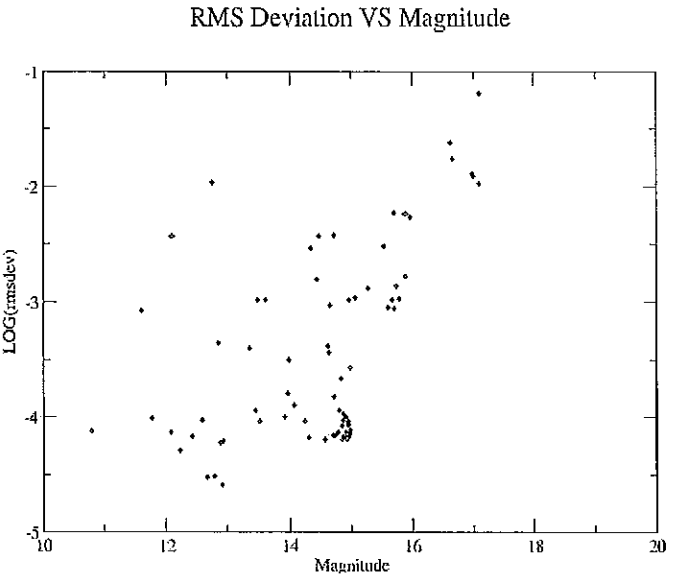

Figure 2.2: A close up of the stars whose light curves were examined by eye.

Light curves were made for these stars since a high root-mean-square deviation meant there was a possibility that the star was a variable. Using this method three additional variable stars were identified. Finally light curves were created for the identified variables. After examining these light curves, the periods for the binary stars were searched for using the Lafler-Kinman method. However this method only was applicable to the contact binaries that were identified.

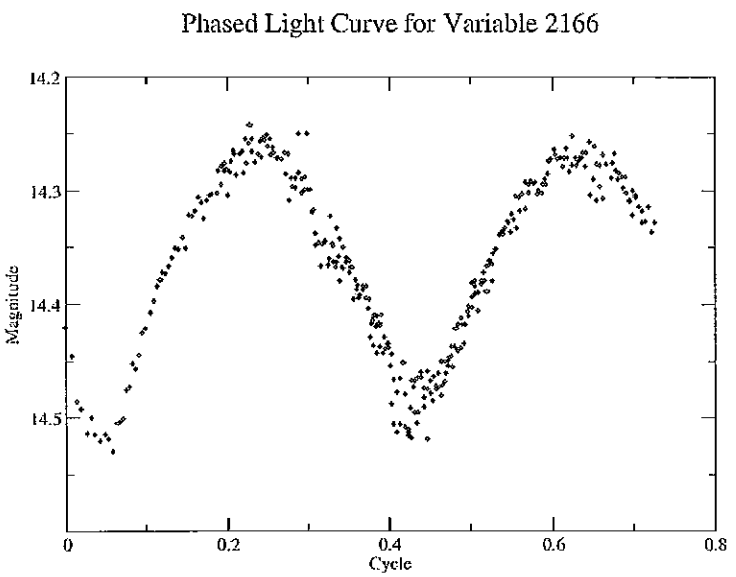

Figure 3.1: Phased light curve for a contact binary.

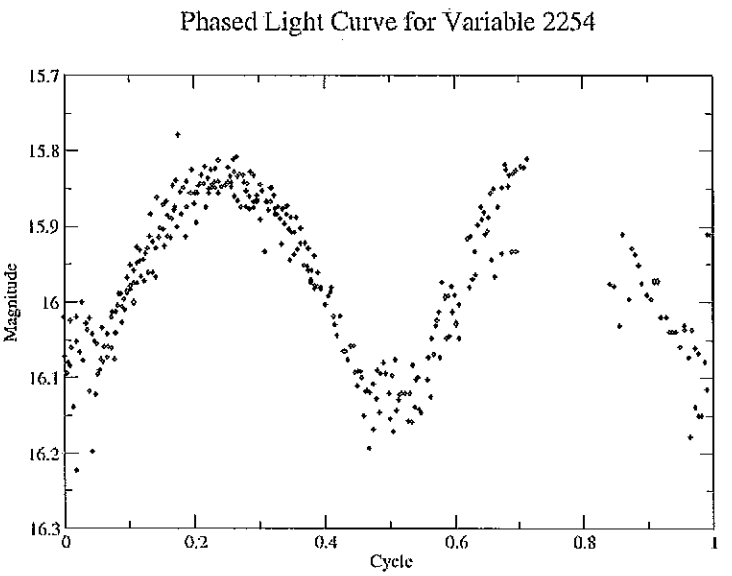

Figure 3.2: Similar to figure 2.1 with a gap in the curve due to incomplete data on the eclipse of this contact binary.

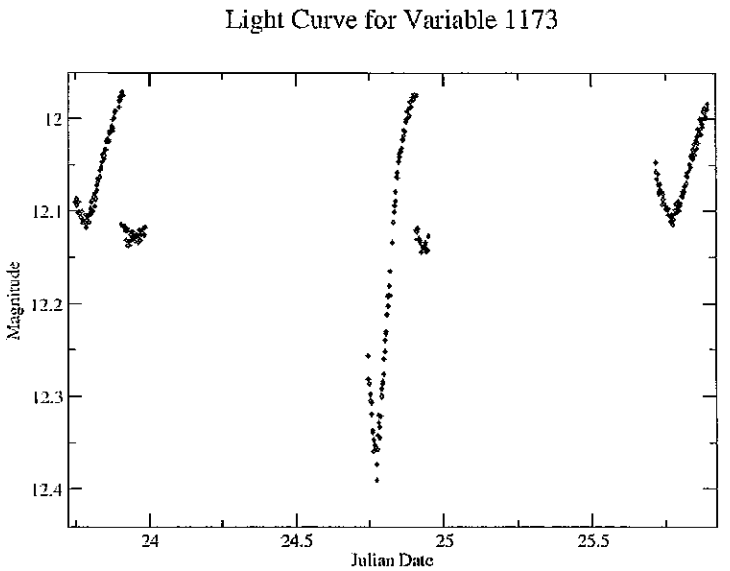

Figure 3.3: An eclipsing binary with some interesting drops in the magnitude at the end of the first and second nights.

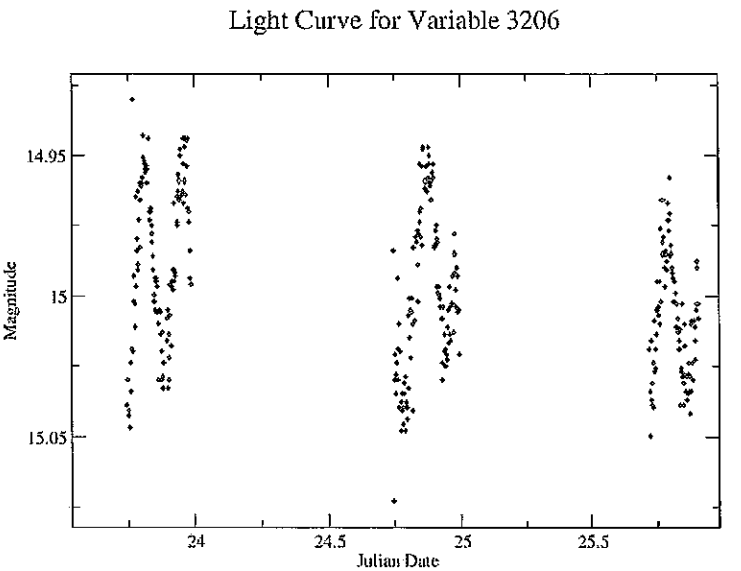

Figure 3.4: A contact binary, the scatter in the data may be because this star is near other very bright stars in the image.

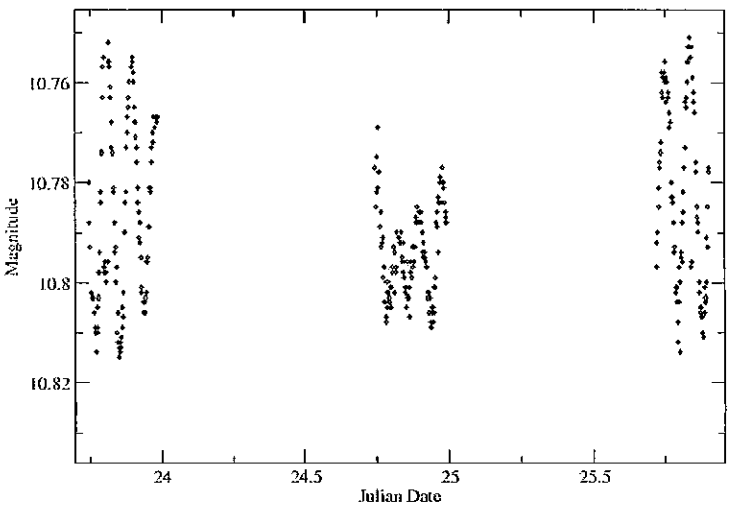

Figure 2.6: Rapid oscillations and a fairly irregular cycle show that this is a Delta Scuti variable.

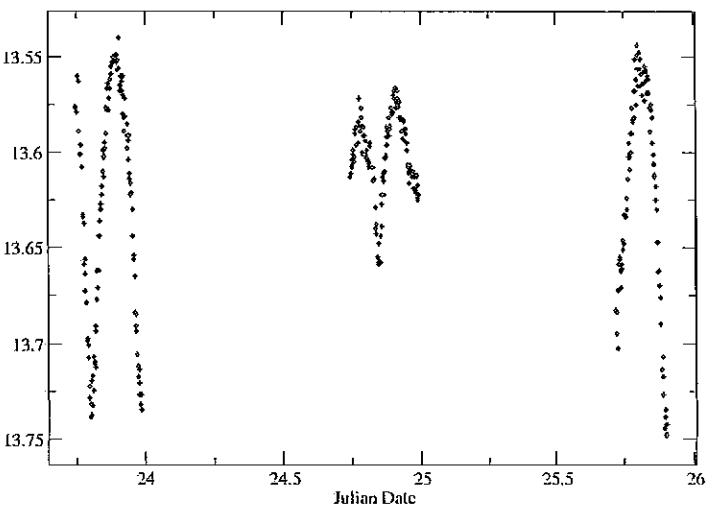

Figure 2.5: This appears to have the behavior of a contact binary, however there is a fairly noticeable change in the amplitude of the cycles.

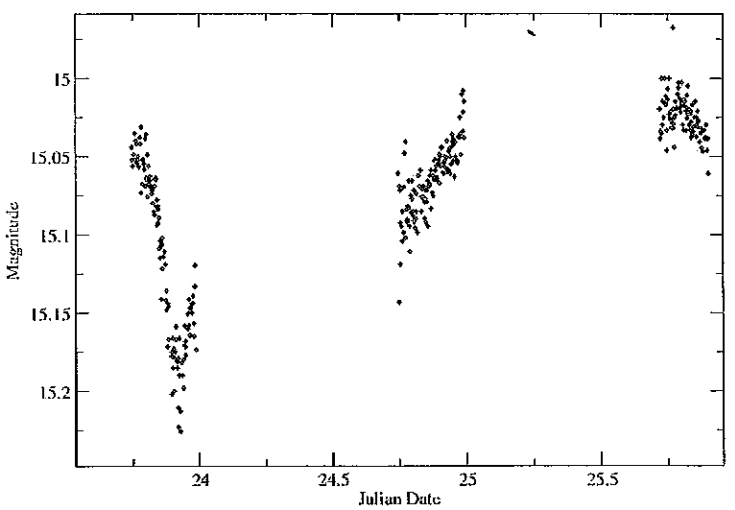

Figure 3.7 Near-contact binary

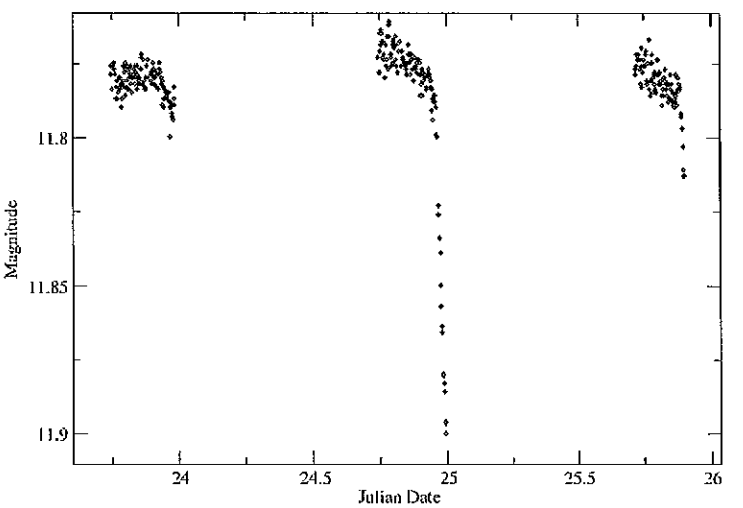

Figure 3.8: A known variable star, however these observations only caught what seems to be the beginning of an eclipse.

Star (X,Y)	350 (748,241)	1173 (77,597)	1651 (972,773)	1871 (508,861)	2166 (1638,978)	2254 (335,1014)
Julian Date at Minimum	23.921478	24.774267	24.994094	23.916282	23.901421	23.921478
Period	-	1.9910 days	1.9262 days	1.9647 days	0.4247 days	0.3378 days
Type	Near Contact Binary	Eclipsing Binary (Unusual brightness drops)	Detached Binary	Detached Binary	Contact Binary	Contact Binary

Star (X,Y)	2753 (997,1181)	3206 (1005,1329)	3460 (1194,1422)	3682 (1802,1503)	4085 (1288,1655)
Julian Date at Minimum-2454600	23.772763	23.883041	23.802762	23.864037	23.865772
Period	0.1548days	0.301 days	0.3653 days	0.2934 days	-
Type	Delta Scuti(pulsating variable)	Contact Binary	Contact Binary (amplitude variation)	Contact Binary	Detached Binary

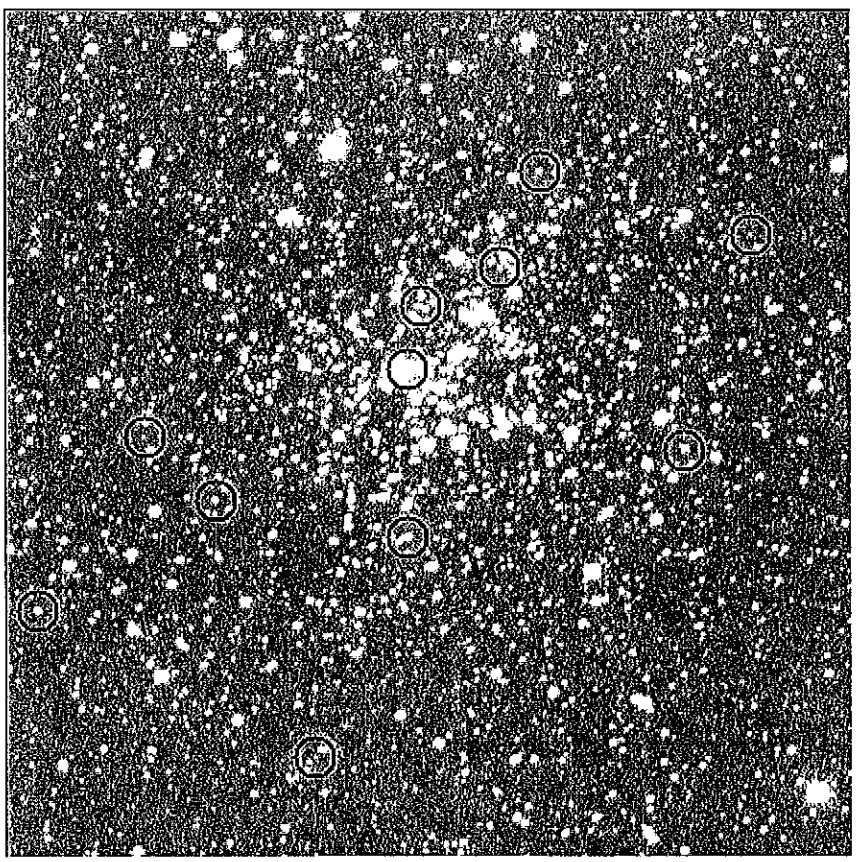

Figure 4: An image of the cluster, North is to the left, and East is to the top.

Overall, no planets were detected during this study. However, that does not rule out the possibility of planets in this cluster. This study focused on the more obvious variable stars which still leaves the opportunity to investigate the cluster further. Among the variables that were found there were a few ones that will be looked at further in the future. For example variable 1173 which demonstrated unusual activity at the end of the night, or variable 350 which shows evidence of being a near-contact binary but more observations are necessary to be able to learn the period. Additionally, a few variables showed variations in the amplitude of their oscillations. The pulsating variable 2753 and eclipsing variable 1651 are candidates for further research because of their variations can provide information about the stars mass and structure.

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Alard, C. 2000, A&AS, 114, 363
Lafler, J. & Kinman,T. 1965, ApJS, 11, 216