Search for Long-Period Variables on the Edges of the Hercules Globular Cluster, M13

Keith McBride & Andrew Layden

Dept. of Physics & Astronomy, BGSU (Independent Study)

Abstract

In order to discover and confirm Long-Period Variable (LPV) stars in the M13 Globular Cluster, we analyzed V- and i-band images taken over a timeframe of 5 years (2006-2011). Analysis of these images was conducted in a LINUX environment utilizing IRAF, ISIS, and SM. The results include 35 variable stars detected, and as many as 6 new LPV’s discovered. The type of variability was deduced from light curves and plotting on the color-magnitude diagram (from DAOPHOT). Many of the detected variables and their periods are consistent with previous research. However, our data suggest different periods or even no variability at all for a few stars. This research presents the results of those variables on the edges of the cluster, >25 arcmin from the center. For the new suspected LPV’s, Right Ascension (RA) and Declination (DEC) coordinates were determined through 2MASS image files. Overall, this research helps provide information for theoretical modeling of pulsation instability.

ISIS

A reference image (Figure B) was created by combining the best six V and i images. The combined images (ISIS result) were subtracted using ISIS from the reference image and then used to produce the variable image in V and i (see Figure A) separately. This displays those stars that have had variability over the timeframe of observation, eliminating the majority of stars not obviously variable. The subtraction process makes it possible to find variable stars in the crowded cluster center, but the process requires the outer edges of the images be trimmed off, eliminating distant variables.

DAOPHOT

After IRAF, another process to find variable stars was used with the software DAOPHOT. The same reference image made using ISIS was used in DAOPHOT. In this package, the magnitude is calculated for every individual star in every image. A significant change in the magnitude of a star makes it as variable. Overlapping stars near the crowded cluster center are difficult to measure reliably.

ISIS and DAOPHOT comparison

The flux vs. time and phase plots produced through the process in ISIS were compared to the magnitude vs. time and phase plots produced from DAOPHOT. One difference is that the star’s brightness (y-axis) is in magnitudes for DAOPHOT, in contrast to flux values for ISIS (Figures H and I). magnitudes are often easier to interpret for stars near the cluster center, DAOPHOT data tend to have more scatter than ISIS data. However, DAOPHOT can measure the outer variables that ISIS misses. Thus, there are advantages and disadvantages for both the Image subtraction (ISIS) method and measuring magnitudes using DAOPHOT. The innermost variables were studied using ISIS and are presented in a different poster.

Conclusion

Comparison of the plots produced by DAOPHOT and ISIS shows advantages and disadvantages for both. The analysis here shows that certain stars are not variable that were thought to be in previous studies. In addition, some of the old period variable stars were discovered. However, the periods for these new stars could not be deduced due to two complications; either they were too short in period for the time interval here to determine or not enough change (‘signal’) was collected to show confidence in a period. We list these as suspected variables (W1, N3, etc). Finally, RA and DEC for each variable star on the edges of the cluster were determined.

References

- DSS image: http://archive.stsci.edu/cgi-bin/dss_form

Images were taken using the BGSU 0.5m telescope with Apogee Ap6e CCD camera in both the V and i bands for a total of 8 images taken per observation epoch. In addition, each of these 8 images is offset slightly compared to the others so that when they are combined and referenced, any consistently bad pixels are removed, increasing the signal to noise ratio for each night. This process was done in IRAF.

SuperMongo

Finally, the light curves produced from ISIS and DAOPHOT, a macro file for each variable star was made for the graphing program SuperMongo. These output the flux vs. time plots (e.g., Figure C) of the magnitude vs time plots (Figure C-I). For those variables with known periods, a flux vs mag. vs. phase plot (Figure D) was also made illustrating the star’s change in brightness if its pulsation is consistent (regular) and not erratic.

IRAF

D) Those are the flux and magnitude versus time plots for the Cepheid variable V6. The short period of 2.112918 days (used in the phase-plot to normalize (p=2.112918) and not apparent on these time plots because of the scale of the time axis. In I, the flux seems consistent, however, in the magnitude there was an abnormally high magnitude spike (varied) around 5000 days. This is not an error by DAOPHOT, but rather a high sky background on that image.

Finally, using the light curves produced from ISIS or DAOPHOT can measure the outer variables that ISIS misses. Thus, there are advantages and disadvantages for both the Image subtraction (ISIS) method and measuring magnitudes using DAOPHOT. The innermost variables were studied using ISIS and are presented in a different poster.