

Long Period Variables in Galactic Globular Clusters: First Results

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NGC 5904 (M5)

M5 is a moderate metallicity ([Fe/H] = -1.27) cluster located well out of the Galactic plane with a correspondingly low interstellar reddening of $E(B-V) = 0.03$ mag (Harris 1996). It has a large and well-studied variable star content (Clement et al. 2000) including two type II Cepheids, numerous RR Lyrae, and one LPV.

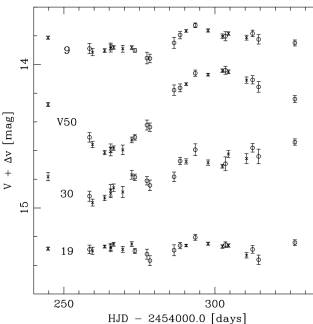
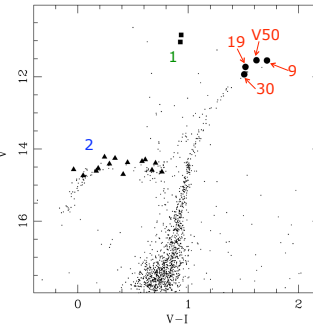
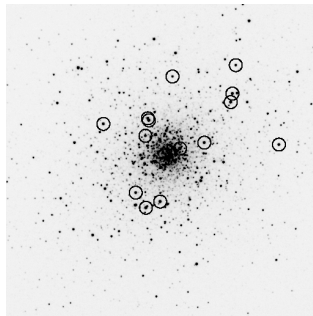
We acquired images of M5 on 28 nights from May to August 2007 using the 0.5-m telescope by DFM, Inc., and an Apogee Ap6e CCD. The observatory is located on the BGSU campus so is convenient to our student observers, but suffers moderate light pollution.

We processed, combined, and ran DAOPHOT on the V and I images as described in the Methods section. One of our images is shown at right with high-variability stars circled.

The color magnitude diagram shows stars more than 4 arcmin from the cluster center. The photometry is calibrated to Johnson & Bolte (1998). We recovered the two known Cepheids (1) and many RR Lyrae (2), along with the known LPV V50. We also discovered three additional LPV stars.

The V-band light curves of these four LPVs are shown with small vertical offsets to avoid overlap. V50 varied over one cycle during the 80-day window with a V amplitude of 0.6 mag. The stars #9 and #30 certainly vary; the former is likely an Irregular, while the latter may have a period longer than 80 days. Star #19 is near our variability detection threshold.

To confirm and refine the variation behavior of these LPVs, we have acquired ~30 new observations of M5 between March and September 2009, and intend to observe it further during 2010.



Abstract

Variable stars provide important constraints on models of stellar structure, evolution, and pulsation. Variable stars in globular clusters are particularly valuable, since these systems have little internal spread in composition, age, or line-of-sight distance, thereby controlling many important parameters. Long period variable stars (LPVs) are an understudied type of variable found in globular clusters. We report progress on searches for LPVs in the clusters NGC 1851, NGC 5904 (M5), and NGC 5927, and present some light curves. Regular access over months or years to imaging telescopes is essential to this project; we discuss how we accomplish this using the 0.5-m telescope at BGSU (Ohio) and the 0.4-m PROMPT telescopes at CTIO.

NGC 1851



Soon after the PROMPT telescopes came on line, we performed a pilot study to search for bright variables in NGC 1851. This cluster was chosen as it is typical of the diameter, distance and crowding expected from our program clusters.

We gathered B, V, R, I images on 12 nights between October 2006 and May 2007 using the PROMPT 3 and 5 telescopes. The time coverage and consistency of the data were not ideal for a scientific study, but we learned:

- exposure times of 80 sec or less limit trailing on these unguided images;
- quality images can be taken at airmasses up to ~2.5;
- though LPV amplitudes tend to be largest in B, the stars are very faint and contrast poorly with the other cluster stars, limiting the utility of this filter;
- long-term access to single-instrument telescopes aids in building a consistent set of images.

Methods

The PROMPT Observatory is a set of five robotic 0.4-m telescopes located on Cerro Tololo in Chile. Observations are requested and retrieved via a web-based interface. For both PROMPT and BGSU data, we typically acquire V, I images at four dither positions. Students perform standard CCD image processing and combine the images to remove cosmic rays and warm pixels, and to improve signal-to-noise. Stellar photometry is performed using the DAOPHOT (Stetson 1994) suite of PSF-fitting programs, including MONTAGE and ALLFRAME to generate and employ a consistent object list for all images. Likely variable stars are flagged based on high values of the Variability Index provided by DAOPHOT separately on the V and I image sets. Photometric calibration is done using secondary standards from studies in the literature.



References

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Conclusions and Future

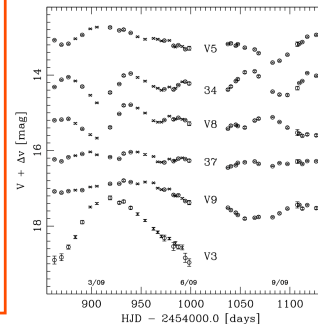
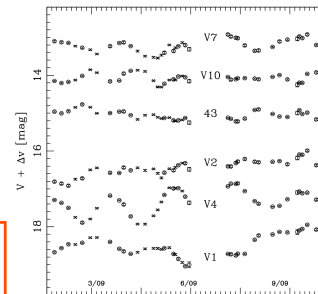
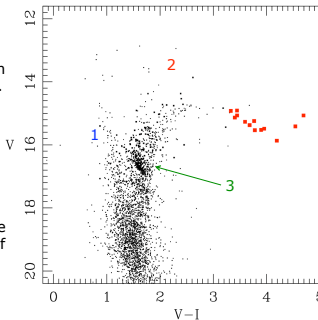
Our pilot study on NGC 1851 showed that the PROMPT Observatory is well-suited to studying LPV light curve behavior. Results on NGC 5927 include recovery of the eleven known LPVs plus discovery of at least six more. Our light curves add to and improve upon the photographic data of Lloyd Evans & Menzies (1977), the previous best work on the LPVs in this cluster. Our work on M5 shows that well-studied northern clusters can yield new LPVs, even when observed from light-polluted sites. We recovered the known LPV in M5 and discovered 2-3 new, lower-amplitude LPVs.

We will continue to monitor these clusters to better-characterize the amplitudes, periods, and light curve shapes and regularity of their LPVs. We have also begun to use ISIS image-subtraction software (Alard 2000) to detect low-amplitude LPVs near the cluster centers, so our population statistics will be as complete as possible. We have been observing other clusters with the PROMPT and BGSU Observatories with the aim of making a comprehensive study of LPV pulsation properties, evolutionary state, and specific frequency across a wide range of metallicity.

NGC 5927

NGC 5927 is a metal-rich ([Fe/H] = -0.37) cluster located toward the Galactic center at $(l, b) = (327^\circ, +5^\circ)$ in a field with a moderate reddening of $E(B-V) = 0.45$ mag. Clement et al. (2001) listed 11 known variables. Lloyd Evans & Menzies (1977) indicated they are all LPVs, and provided amplitudes and periods for some, including the Mira variable V3 (Osborn 1968), though light curves are not provided in the literature.

We obtained images in V and I using the PROMPT 5 telescope ~1-2 times per week between January and October 2009. Images were processed, combined, and photometered with DAOPHOT as described in the Methods section. We used a preliminary calibration based on Samus et al. (1996) to produce the following color-magnitude diagram.



A strong field star component is evident from the plume of blue stars (1) and their red giants (2). Differential reddening elongates the cluster red horizontal branch (3) and giant branches. Stars with high values of the Variability Index are marked with red squares; clearly they are all LPV stars in the cluster or field.

Light curves of the variable stars near the cluster center are shown, shifted vertically for clarity. Crosses and circles indicate images with better and worse than median seeing.

Some of the variables, such as V4, V7 and V10, have Semi-Regular periods. Our periods roughly agree with those of Lloyd Evans & Menzies (1977). Many of the variables seem to be Irregular type LPVs. The Mira V3 ($P = 312$ days) is located near the center of the cluster and dropped out of our star list for part of its cycle; we are experimenting with ways of recovering it. We will continue to monitor NGC 5927 at ~14 day intervals over the next 1-2 years to complete V3's light curve.

