Abstract

We report results of $V I$ time series photometry for the bright globular cluster M5 taken between 2007-2011 using the 0.5-m telescope at Bowling Green State Univ. and the PROMPT #4 telescope at Cerro Tololo. We used DAOPHOT to obtain photometry to a limiting magnitude of $V \approx 19$ mag. A search for variable stars using the DAOMASTER variability index enabled us to recover the three known bright variables (two Cepheids and one red, long period variable, or LPV) and many known RR Lyrae stars, and to discover as many as thirteen new, low-amplitude LPVs. We present light curves of several stars and analyze periods and amplitudes where applicable.

1. Introduction

The globular cluster M5 (NGC 5904) is a bright, well-studied cluster of moderate metallicity. In addition to its abundant RR Lyrae stars, M5 has two well-studied type II Cepheids, V42 and V84, which are the subject of recent CCD photometry by Rabidoux et al. (2010). The irregular LPV star V50 has been known since Bailey (1917) but has never been the subject of CCD photometry. No other bright variables are known in M5.

The goals of our CCD study are to seek new long period variables and obtain their light curves (LCs), amplitudes, and periods; to compare them with metal-rich LPVs in clusters and the LMC; and to test the hypothesis that period and amplitude increase as stars evolve up the giant branch.

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2. Data and Analysis

Images were obtained in \( V I \) using the BGSU 0.5-m and Apogee Ap6e CCD during the summers of 2007, 2009, and 2010, and using the PROMPT #4 0.4-m and Apogee Alta CCD at CTIO in the fall of 2010 and throughout 2011 via the robotic SKYNET client. Standard image processing was performed on each image. We ran the images through the DAOPHOT and ALLFRAME point-spread function fitting photometry packages (Stetson 1987, 1994), and used Stetson’s DAOMASTER program to combine data across images and search for variable stars. Photometric calibration was performed using in-field standards from Stetson (2000). To obtain a more complete census of bright variables in the cluster center, we employed the ISIS image subtraction program (Alard 2000).

Figure 1 shows color-magnitude diagrams of stars in the BGSU data located more than 1 arcmin from the center of M5, along with magnitude as a function of variability index, \( \Lambda \). The two stars with large \( \Lambda \) are the known Cepheids V42 and V84. RR Lyrae stars at the level of the horizontal branch also show large \( \Lambda \) but these stars have been studied well by other observers, so we do not consider them further. Some stars at the tip of the giant branch have large \( \Lambda \) and are candidate LPV stars.

3. Variable Stars

Figure 2 shows the light curves of type-II Cepheids V42 and V84. We folded V42 using the period from Rabidoux et al. (2010), suggesting little period change since their 2003-6 observations. The scatter at \( \phi \approx 0.25 \) is real. It was more difficult to characterize the light curve of V84. We folded the PROMPT data using the Rabidoux period of 26.93 d, but a shorter period near 26.74 d was needed to fold the earlier BGSU data. We are collaborating with Horace Smith to use these and new MSU data to extend the period change analysis from Rabidoux et al. (2010).

In Figure 3, we show the light curves of two irregular LPV stars, the known variable V50 and the newly detected variable ID#4. Notice how the amplitude of both stars waxes and wanes, as if two oscillations with similar periods were beating against each other. From his photographic data, Bailey (1917) estimated the period of V50 to be 106 days. We reanalyzed his data using the phase dispersion minimization (PDM) method, and found a period of 105 ± 2 days. Using PDM on our CCD data, we obtained a period of 102 ± 1 days. However, the photographic data of Coutts Clement & Sawyer Hogg (1977), taken from 1946-1957, shows no coherent period in the light curve or via PDM. More observations over decades may be required to establish whether the underlying periodicity is fundamentally stable.

We estimated periods and photometric ranges \( (V_{\text{min}} - V_{\text{max}}) \) for each of the thirteen LPV stars. Several of the stars seem to show very short period variations (< 30 day cycles) on a long, secondary period, seen in ~30% of irregular LPVs (Kiss et al. 1999).
Figure 4 shows the LPVs’ $V - I$ color, magnitude range, and period plotted against $V$ magnitude. The red giant stars in M5 show no sign of variability at $V \approx 1$ mag below the giant branch tip, but some stars show $= 0.1$ to $0.2$ mag variations on $< 30$ d timescales as much as $V \approx 0.5$ mag below the tip. By $V \approx 0.2$ mag below the tip, variations become more prominent, culminating with V50. Star #18 is a notable exception to this pattern.
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4. Conclusions

We present the first time series CCD photometry of the LPVs in M5. We recovered the known irregular variable V50 and discovered thirteen new, low-amplitude, irregular LPVs. The pulsation characteristics, period and magnitude range, increase with position up the giant branch, suggesting that stars become increasingly unstable to pulsation as they evolve toward cooler surface temperatures and lower surface gravities. We will investigate the exception to this rule, ID#18, checking whether it is a
Figure 4.— (Left) The CMD zoomed in on the red giant stars; variable stars are marked with red squares. (Center) Periods, and (right) magnitude ranges of the variables are shown. Error bars show the variation in amplitude from cycle to cycle, while blue triangles mark stars with possible long secondary periods.

cluster member using existing proper motion and radial velocity surveys. Compared to LPVs in more metal-rich systems, the M5 LPVs tend to have lower amplitudes, shorter periods, and less regular cycles, no doubt because the bluer giant branch of M5 reaches less far into the Mira instability domain.

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