Variable Stars in the Fields of the Globular Clusters M10 & M12

Kaspar von Braun, Mario Mateo, Kristin Chiboucas, Alex Athey (University of Michigan) & Denise Hurley-Keller (Case Western Reserve University)

Introduction

We present the photometry results of our monitoring study of the Globular Clusters (GCs) M10 and M12. These two clusters are part of our survey of 11 Galactic GCs in which we search for eclipsing binary (EB) stars around the main sequence turnoff by means of photometrically detecting brightness variations.

The straightforward, though data-intensive, task of simply detecting EBs in GCs and confirming their cluster membership increases the presently low number of known EB systems in GCs. A statistical evaluation of this number may shed light on the influence of binaries in the dynamical evolution of GCs by returning estimates for the frequencies of binaries among main sequence stars and blue stragglers. Moreover, the simultaneous photometric and spectroscopic analysis of these systems may be used to (1) directly determine distances to the clusters, and to (2) calculate Population II main sequence masses for GC stars. The distance determination, free of intermediate steps, can provide distances out to tens of kpc and may be used to calibrate other, indirect distance determination methods (such as the L-[Fe/H] relation for RR Lyraes). Values for main sequence masses of GC stars provide a fundamental, low metallicity check of stellar models. In order to obtain zero-age mass estimates for the components in a binary system, one needs to take into account the mass transfer history between the two stars, which demonstrates the value of detecting unevolved, detached binary systems where no mass transfer has taken place. This kind of system directly returns zero-age masses for the components if no mass loss from the system as a whole has taken place.

Our observing strategy consists of repeated 1m-class telescope 600s observations of the entire cluster field. The first results of this approach are high-quality, deep color-magnitude diagrams (CMDs) of the clusters, shown in Fig. 2 and Fig. 6. We find that the main sequence of M10 changes in width and location as a function of position in the field of view (Fig. 4), but M12's main sequence appears the same regardless of location. It thus seems that, regardless of the high Galactic latitude of these two clusters and their proximity to each other, M10 suffers differential extinction across its field, whereas M12 does not.

The GCs M10 & M12 were probed for the existence of photometrically varying binary stars in the approximate magnitude range 16.5 < V < 21, using around 150 epochs (600s exp time; approx. 30000 stars/image; see Table 1 below) in V and I, taken at the LCO 1m and MDM 1.3m telescopes between 1995 and 1999. We present the results of this search for binaries in Figs. 2-3 and Figs. 6-7 in the form of the phased lightcurves of the variables as well as their locations in the field of view and the CMDs. Our variability detection is based on a simple chi-sqared algorithm with a few additional conditions (e.g., a correlated brightness variation in both bands). Periods between approximately 0.2 and 3 days for these candidates were determined using two independent methods: the minimum-string-length method as well as the analysis of variance.

While the final verdict on cluster membership of these variables can only be given by spectroscopic studies, their CMD locations seem to show that only one variable (V1 in M12) is a member binary.

Cluster Data

		M10	M12
RA (2000)		16:57:08.9	16:47:14.5
Dec (2000)		-04:05:58	-01:56:52
l		15.14 deg	15.72 deg
b		23.08 deg	26.31 deg
R (sun)		4.4 kpc	4.9 kpc
E(B-V)		0.28 mag	0.19 mag
[Fe/H]		-1.52	-1.48
Epochs used	for CMD	~ 100	~ 100
	Var. Detection	~ 150	~ 130

Table 1: Data on the GCs M10 and M12.

M10

(work in progress)

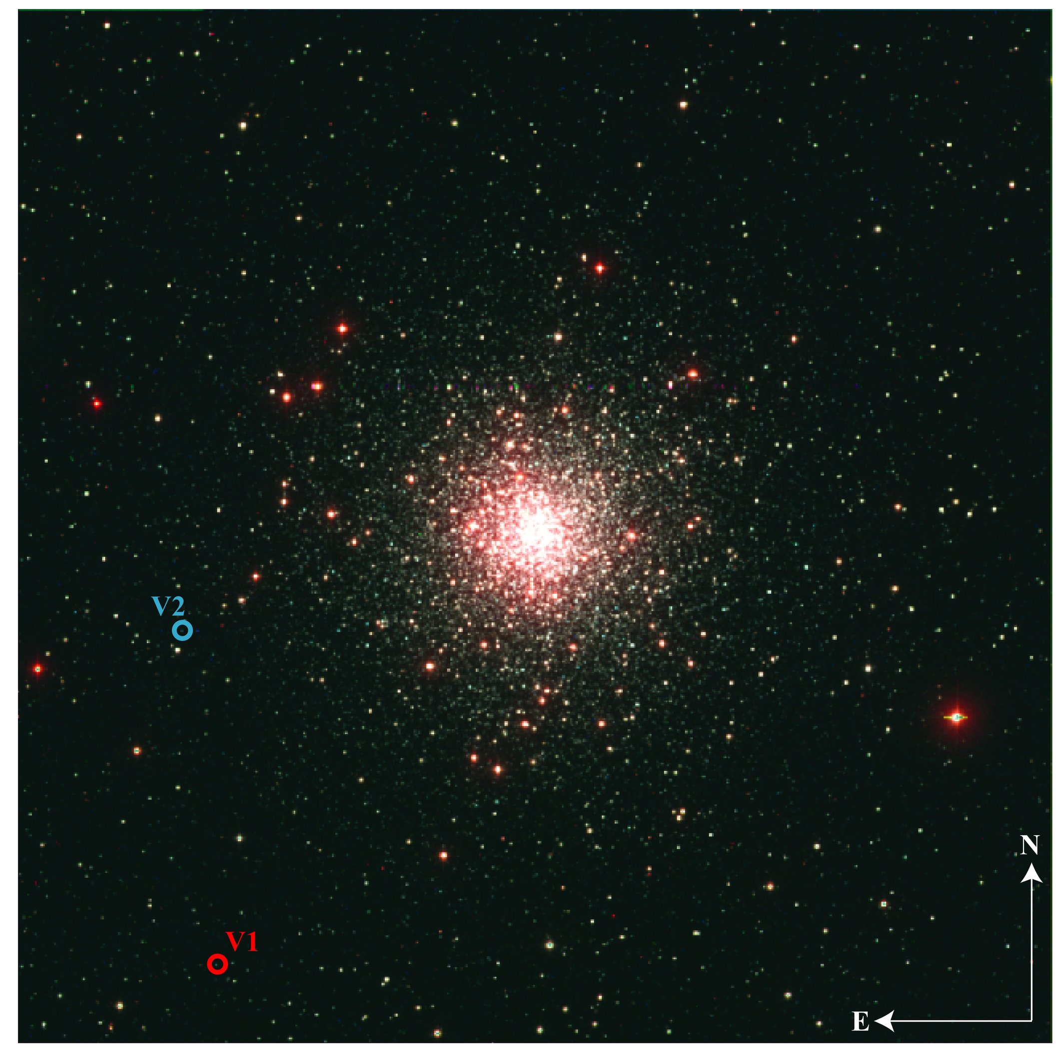

Fig. 1: Color image of M10, taken at the Las Campanas Observatory (LCO) 1m Swope Telescope. The image size is 23.5 arcmin on the side. North is up and east is to the left. The locations of the variable candidates V1 and V2 in the field are shown; their CMD locations and lightcurves are displayed in Fig. 2 and Fig. 3, respectively.

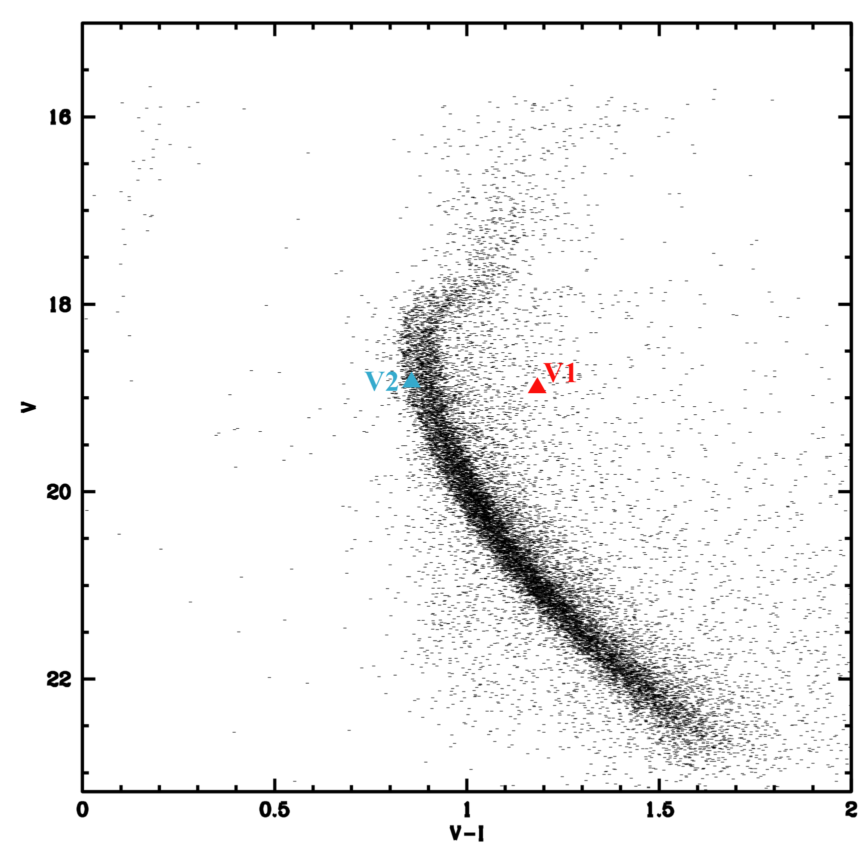

Fig. 2: Color-Magnitude Diagram (CMD) of M10 with Locations of Variables. Note the broadness of the main sequence which seems to indicate the presence of differential reddening across the field of view (Fig. 4). From their position in M10's CMD, neither V1 nor V2 appear to be cluster members. Both variables are plotted at mean brightness. The photometric results of approximately 100 VI 600s epochs were averaged and weighted by photometric error to create this CMD.

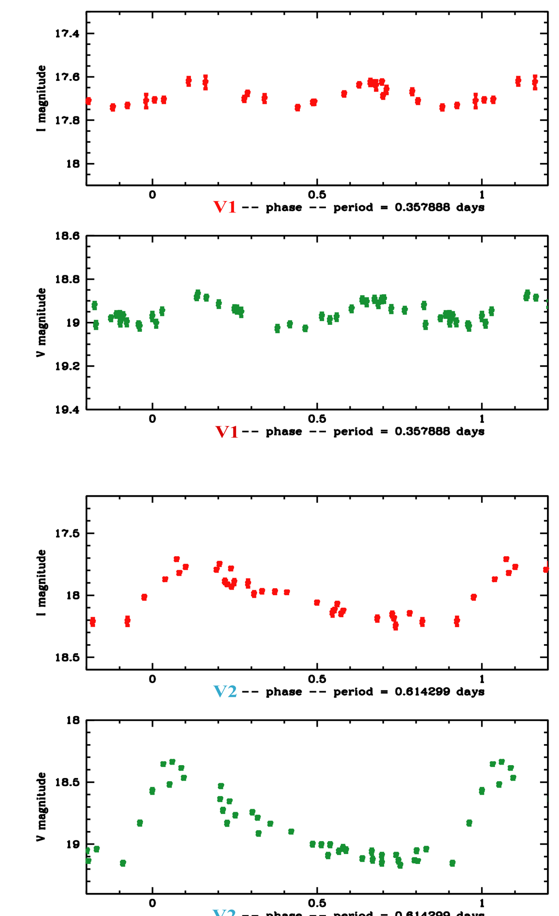

Fig. 3: Phased Lightcurves of Variable Star Candidates in the Field of M10. The upper panel is the I-band lightcurve, the lower one the V-band lightcurve. Period estimates are given below the panels. V1 appears to be a contact system whereas V2 is most likely a (background) RRLyrae star.

Differential Extinction Across the Field of M10?

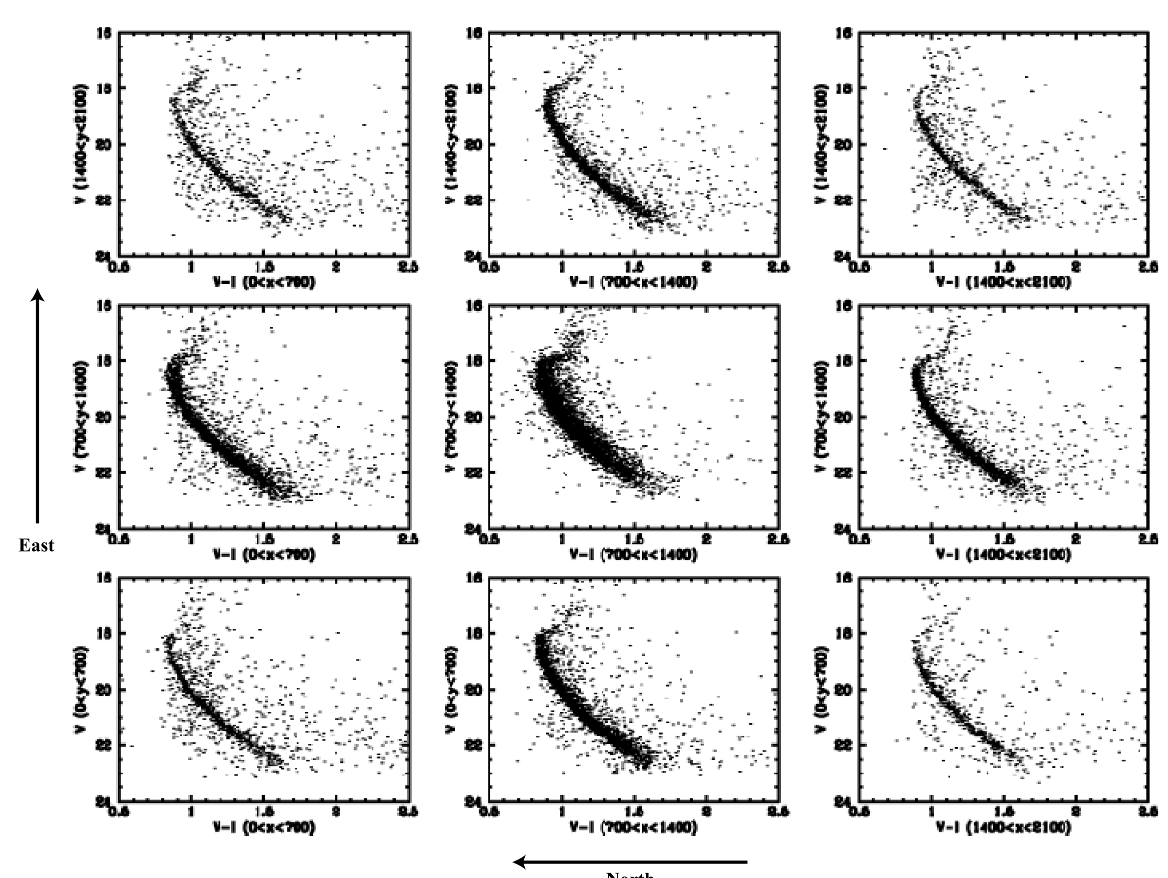

Fig. 4: Evidence of Differential Reddening across M10. For this image, the LCO field (Fig. 1) was divided into 9 subregions. The CMDs of these 9 subregions are represented in the 9 panels in this figure. Note the coordinate ranges in x and y on the bottom of each panel. The main sequence not only varies in broadness but also in location as a function of position in the field of view, possibly caused by the presence of differential extinction across the field. This result seems counterintuitive given M10's high Galactic latitude (~23 degrees). On the other hand, M12, which is located only ~4 degrees from M10, suffers significantly less extinction (E(B-V)=0.19) than M10 (E(B-V)=0.28), and its CMD does not show any dependence of main sequence broadness or location upon position in the field of M12.

M12

(work in progress)

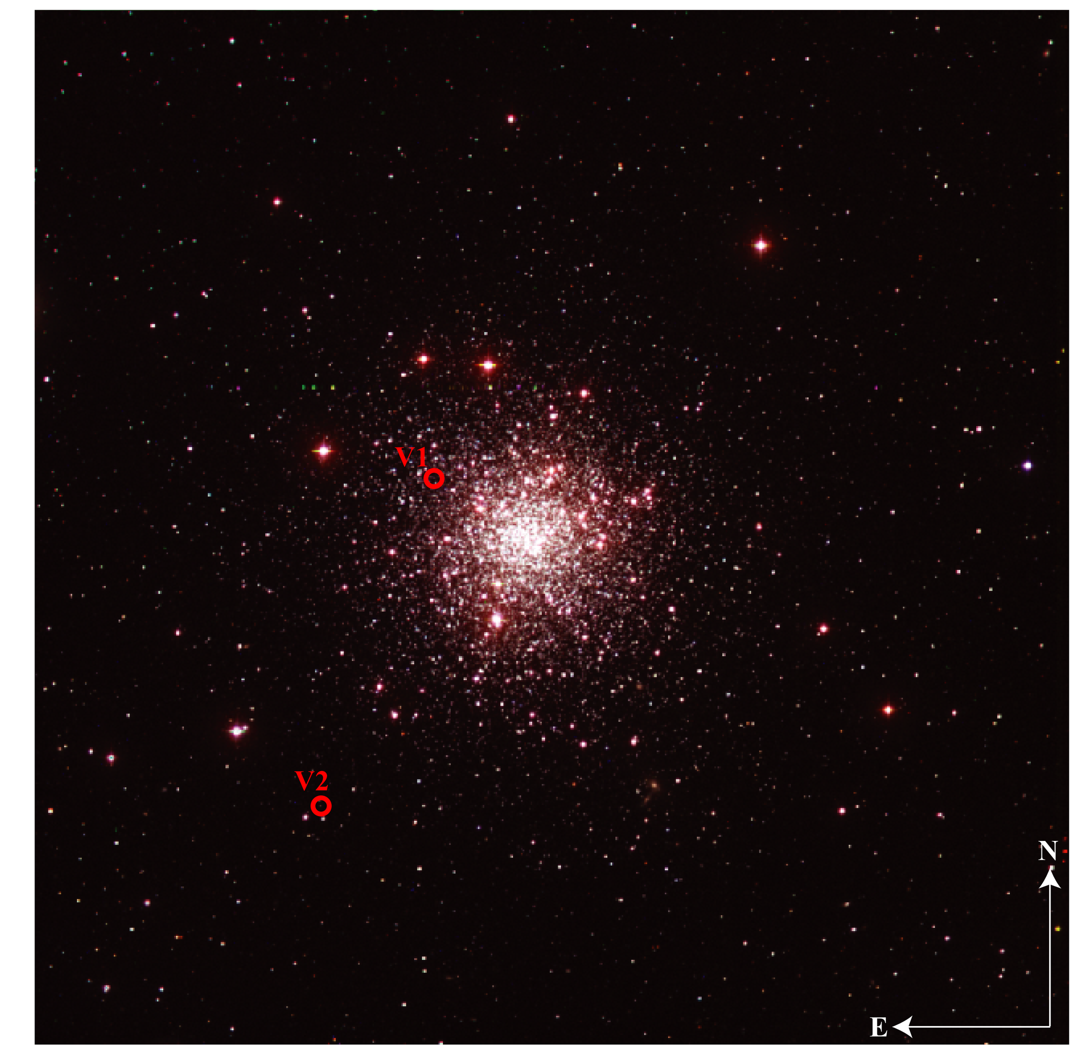

Fig. 5: Color image of M12, taken at the Las Campanas Observatory (LCO) 1m Swope Telescope. The image size is 23.5 arcmin on the side. North is up and east is to the left. The locations of the variable candidates V1 and V2 in the field are shown; their CMD locations and lightcurves are displayed in Fig. 6 and Fig. 7, respectively. V1 is most likely associated with the cluster.

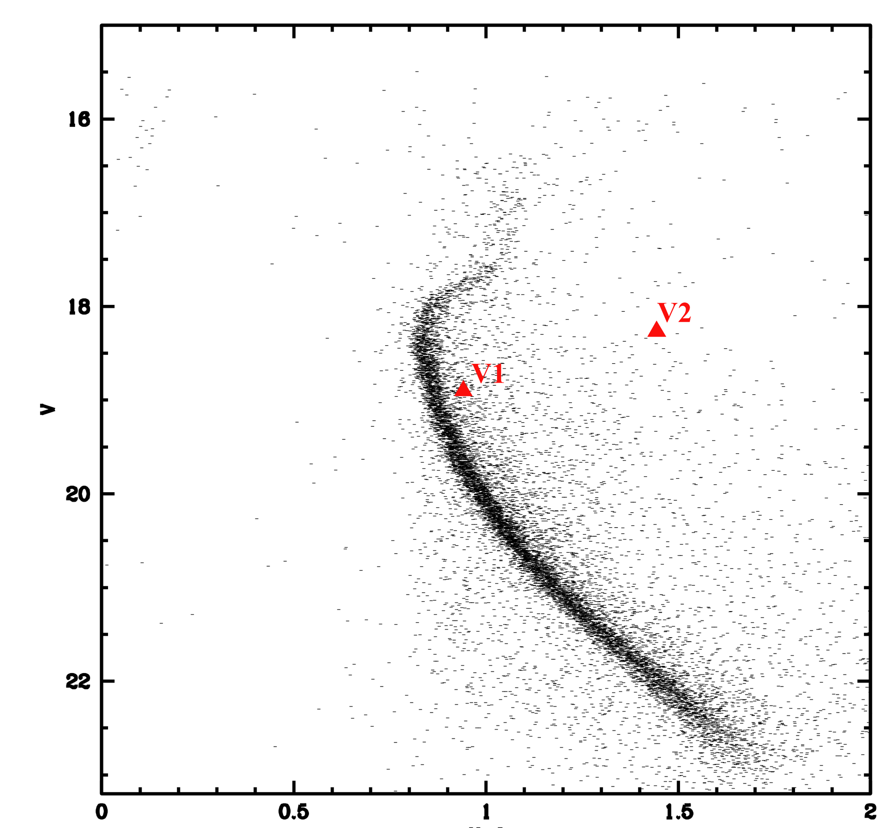

Fig. 6: CMD of M12 with Locations of Variables. Note that M12's main sequence does not display the same broadness as M10's. Variables are plotted at mean brightness. From their location in the CMD, it appears that V1 could be a cluster member, whereas V2 is unlikely to be associated with the cluster. The photometric results of approximately 100 VI epochs (600s) were averaged and weighted by photometric error to create this CMD.

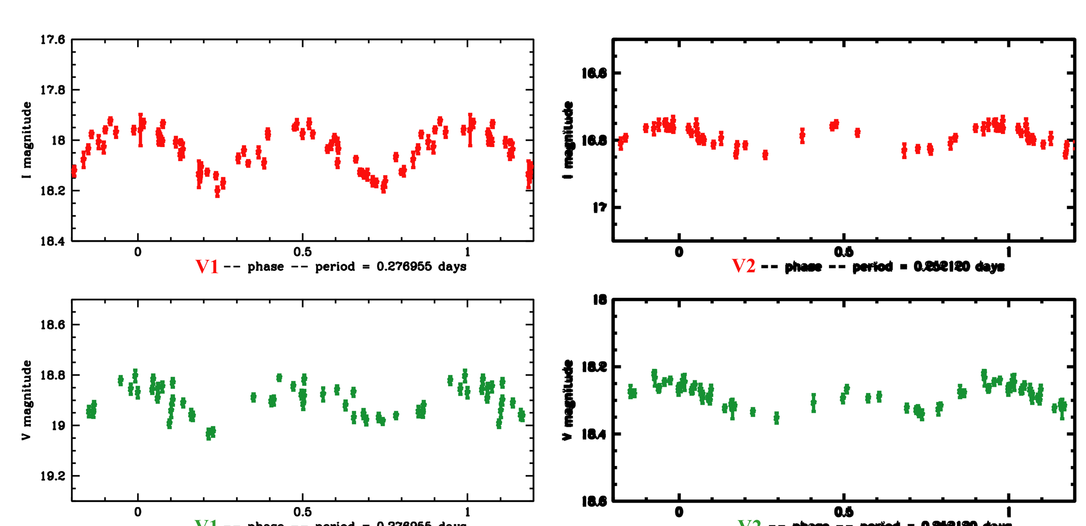

Fig. 7: Phased Lightcurves of Variable Star Candidates in the Field of M12. The upper panel is the I-band lightcurve, the lower one the V-band lightcurve. Period estimates are given below the panels. Both systems appear to be contact binaries (from the shape of the lightcurves). From its position in the CMD, V1 seems to be a cluster member.