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Completing the census of (bright) variable stars in galactic globular clusters

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Abstract. We present a long-term project aimed at completing the census of (bright) variable stars in Galactic globular clusters. While our main aim is to obtain a reliable assessment of the populations of RR Lyrae and type II Cepheid stars in the Galactic globular cluster system, due attention is also being paid to other types of variables, including SX Phoenicis stars, long-period variables, and eclipsing binaries.

Key words. Stars: Population II – Galaxy: globular clusters – stars: variables: RR Lyr

1. Introduction

Variable stars remain one of the most important types of object in astronomy. They are widely used in a variety of different areas, from tests of stellar structure and evolution theory to the determination of the extragalactic distance scale. Globular star clusters present a particularly interesting "astrophysical laboratory" for

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the study of variable stars, since in these environments one is offered the chance of studying statistically significant samples of variable stars in different evolutionary stages, all at the same distance from us, with a common age, and (nearly) the same chemical composition.

By the early-1990's, it was widely perceived that "most variables that are in [globular] clusters have by now become discovered" (Suntzeff et al. 1991). In the Suntzeff et al. compilation, only a few "notable exceptions" were mentioned. More specifically, Suntzeff et al. (1991) estimate that "only 6% of the cluster [RR Lyrae] variables remain to be discovered." Has this assessment withstood the test of time?

Unfortunately, not quite: some 15 years later, it is now clear that not only do several of the "notable exceptions" mentioned by Suntzeff et al. (1991) remain poorly studied in terms of variability, but also, and importantly, many—if not all—globular clusters whose variable star populations were considered exhaustively known by the early 1990's are now known to be affected by severe incompleteness in their reported numbers of even the brighter variable stars (such as the RR Lyrae).

Consider, as an example, the case of M3 (NGC 5272), first studied by Bailey (1913), and subsequently investigated in detail by Carretta et al. (1998), Kaluzny et al. (1998), Corwin & Carney (2001), and Strader et al. (2002), among others. According to the compilation of variable stars in globular clusters by Clement et al. (2001), by the end of the 1990's M3 had a total of 182 catalogued RR Lyrae variables. By the year 2004, about 230 RR Lyrae variables were already known in the cluster (Bakos et al. 2000; Clementini et al. 2004)—thus representing an increment of 26% with respect to the Clement et al. compilation.

There are two main reasons for the somewhat unexpected increase in the numbers of (bright) variable stars in globular clusters. First, the pre-1990's studies were primarily based on photographic photometry, which in many cases appears not to have been precise enough to tell small-amplitude variables from noise. Second, it was only very recently that an image-subtraction technique was developed which is capable of quickly, efficiently and automatically subtracting out the constant information from one CCD frame of a cluster to the next, also matching the differences in seeing between the frames in the process. This remarkable achievement is due primarily to tools created by Alard & Lupton (1998) and Alard (2000), which have become accessible to the astronomical community in the form of the ISIS image-subtraction program.

While very efficient in *detecting* variable stars in crowded fields, ISIS presents the drawback of providing light curves in flux values relative to a reference image only. For this reason, ISIS does not provide light curves in standard magnitudes, and the reference image has to be processed independently for this purpose. While DAOPHOT/ALLFRAME (Stetson 1994) offer excellent tools to perform absolute photometry in the crowded regions found in globular clusters, it is still often the case that the variable stars cannot have their absolute fluxes reliably measured in the ISIS reference image, making it very difficult to convert the ISIS relative-flux light curves into calibrated ones without additional images obtained with higher spatial resolution.

In the present paper, we present our long-term project to complete the census of (bright) variable stars in Galactic globular clusters. The tools adopted to analyze our time-series photometry are ISIS (detection, light curves in relative fluxes for period and variability type determination) and DAOPHOT/ALLFRAME (light curves in standard magnitudes, positioning of the variables in the color-magnitude diagram, determination of variability types, and determination of physical properties on the basis of the Fourier decomposition parameters).

2. Observational Data

The data upon which this project is based comes primarily from small (i.e., 2m class or less) telescopes, such as the Danish 1.54m, the CTIO 0.9m and 1.3m, the LCO Warsaw 1.3m, and the Rozhen 2m telescopes. Data available in public archives are also being used. The observational data, generally consisting of sets of B, V, and (less often) I images, are usually collected during observing runs split in

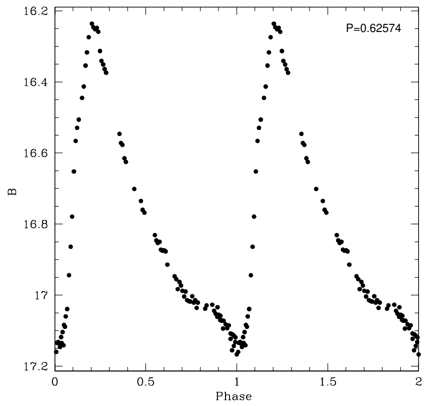

Fig. 1. Light curve in *B* for a newly discovered RRab Lyrae variable in M69.

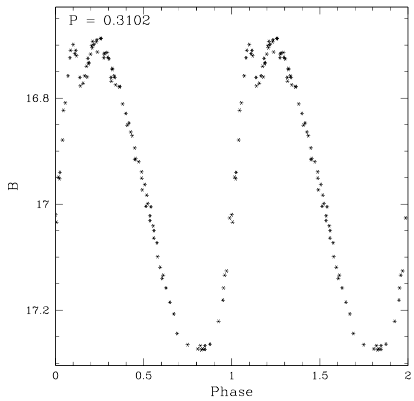

Fig. 2. Light curve in *B* for a newly discovered RRc Lyrae variable in NGC 5286.

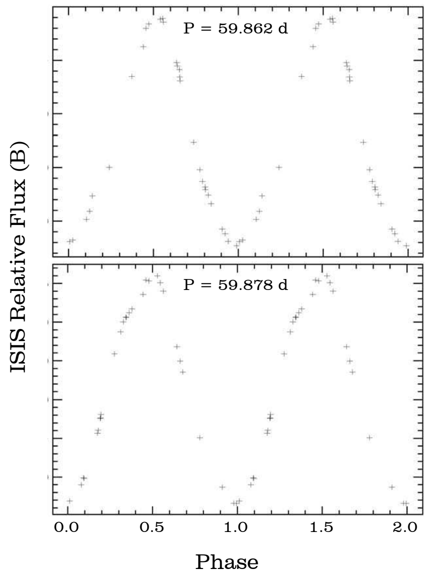

Fig. 3. Light curves for two newly discovered type II Cepheids in M28.

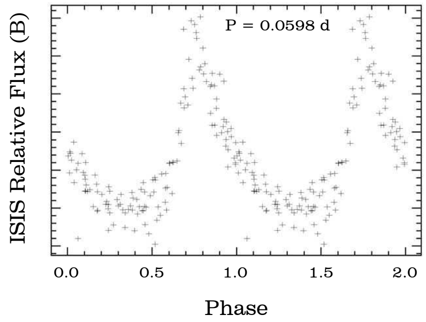

Fig. 4. Light curves for a newly discovered SX Phe candidate in NGC 2808.

blocks of several days, spread over several months, which helps ensure proper coverage of the periods of both RR Lyrae stars and type II Cepheids. In the case of the CTIO data, most of our data has been obtained in service mode, with one or more datapoints being collected per night over a period of several months.

In what follows, we describe some of the latest results of this project, which have not yet appeared in the refereed literature.

3. Some Recent Results

3.1. The Metal-Rich Globular Cluster M69 (NGC 6637)

This project is based on data collected at LCO with the Warsaw 1.3m telescope. In Figure 1 is shown a light curve of an RR Lyrae star that was discovered in the field of the cluster in the course of our study. Its period is relatively long for a metal-rich globular cluster, thus bringing to mind the cases of V9 in 47 Tucanae and the many long-period RR Lyrae variables in

NGC 6388 and NGC 6441. While membership status is unclear at present, the star does appear to lie sufficiently close to the cluster's horizontal branch (HB) in the color-magnitude diagram as to merit further analysis of this possibility. De Lee et al. (these proceedings) discuss the possibility that NGC 6304 may provide yet another example of a metal-rich globular cluster with long-period RR Lyrae variables.

3.2. *NGC 5286: an RR Lyrae-Rich Globular in the Canis Major Dwarf Spheroidal Galaxy (CMa dSph)?*

This project is also based on data collected at the LCO with the Warsaw 1.3m telescope. NGC 5286 is a particularly interesting cluster due to its suggested association with the CMa dSph (Frinchaboy et al. 2004; Martin et al. 2004). We have found a rich harvest of RR Lyrae stars in this cluster, increasing quite substantially the number of known variables. Figure 2 shows a light curve for a newly discovered RRc star.

3.3. *Type II Cepheids in the Blue HB Globular Cluster M28 (NGC 6626)*

The data used in this project were collected using the CTIO 1.3m telescope in service mode. A fairly large number of variable stars was discovered, including short-period ($P < 0.3$ d) RRc variables; long-period ($P > 0.7$ d) RRab variables; type II Cepheids (Fig. 3), including four stars with periods very close to 60 d; and long-period or semi-regular variables with periods longer than 50 d.

3.4. *SX Phoenicis Variables in NGC 2808*

Until recently, NGC 2808 had been though to be essentially devoid of RR Lyrae variables. In the course of the present project, however, we were able to discover a sizeable number of RR Lyrae stars in the cluster, as described in Corwin et al. (2004). Recently, we have also found that the cluster contains a significant number of SX Phe variables, and a sample light curve is provided in Figure 4.

4. Conclusions

This project is still in its beginning, and it is already clear that there is a long road before we can consider the variable star populations in globular clusters as well known. In addition, while our attention (and observing strategies) have mainly focused on the brighter RR Lyrae and type II Cepheid variables, it is becoming increasingly clear that there is also a rich harvest of SX Phe and eclipsing variable stars in globular clusters waiting to be found. It is our hope that the astronomical community will continue to support the operation of 1m-class telescopes throughout the world, so that the study of variable stars—upon which so much of modern astrophysics relies—can truly become a well-established enterprise.

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