VARIABLE STARS, THE GALACTIC HALO
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An Update to the Web Edition of the Catalogue of Variable Stars in Galactic Globular Clusters

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Abstract. This is a report on the history and current status of the catalogue of variable stars in Galactic globular clusters.

1. Introduction

In 1939, Helen Sawyer Hogg published a catalogue of variable stars in globular clusters to enable researchers interested in the subject to get a clear picture of what work had been done. She produced subsequent editions in 1955 and 1973 and all three were published as part of the David Dunlap Observatory Publications series (Sawyer 1939, 1955; Sawyer Hogg 1973). They are all available in pdf format at `www.astro.utoronto.ca/~cclement/readhistory.html`.

In 1997, the catalogue was updated, put into electronic form and posted on the web. It was revised further in 2001 and a paper summarizing the data was published by Clement et al. (2001). Since that time, the catalogue has not been updated on a regular basis. Thus it is time for a revision.

2. Globular cluster variable stars – then and now

According to Smith (1995), the first variable to be discovered in a globular cluster was a nova that erupted in M80 in 1860. The next discovery came almost three decades later (Pickering 1889) when a bright variable star, now known to be the type II Cepheid M3-V154 (Wallerstein 1990) was detected near the centre of Messier 3. By the end of the 19th century, 508 variables had been discovered by Bailey in a systematic search of 19 globular clusters (Pickles 1998; Bailey 1902).

From the beginning, Bailey noticed that some clusters had more variables than others. More than half of the variables were in two clusters, Messier 3 and ω Centauri, which had 132 and 128 respectively. Meanwhile, Messier 13 had only two. This trend continued when Sawyer Hogg produced her catalogues. Even though more variables were discovered in more clusters, M 3 and ω Cen continued to be the most rich in variables and most of these variables were RR Lyrae type. However, Kukarkin (1973) pointed out that it is misleading to estimate the richness by merely counting the number of variable stars. One must also take into account the total number of stars in a cluster. He introduced a statistic N for estimating the frequency of variables of different types in a cluster, based on its absolute magnitude: N was the number of variable stars the cluster would have if it had an integrated $M_V = -7.5$. He derived $N_{\rm RR}$ for 46 globular clusters. When the clusters' absolute magnitudes were taken into account, ω Cen proved to be “RR Lyrae poor”, and although M3 had a high frequency of RR Lyrae variables, the $N_{\rm RR}$ statistic for NGC 3201, IC 4499 and NGC 6121 (M 4) was even higher. We now know that the frequency of RR Lyrae variables in a cluster is related to the morphology of the horizontal branch in its color-magnitude diagram. Clusters with extreme blue or red horizontal branches have few RR Lyrae or none at all, while clusters with a uniform distribution of stars from blue to red have a high frequency.

Throughout the twentieth century, RR Lyrae stars dominated the variable star population in globular clusters. In her three catalogues, published in 1939, 1955 and 1973, Sawyer Hogg summarized the data and in each case, more than 90% of the “classified” variables were of the RR Lyrae type. They were readily detected because of their high amplitudes and because they were among the brightest stars in the clusters, particularly on the blue sensitive photographic plates that were commonly used in those days. The remaining variables, mainly type II Cepheids, RV Tauri and long period or semi-regular variables, were also bright and had large amplitudes.

With the use of CCD detectors and modern image processing techniques, it is possible to detect fainter variables with small amplitudes. As a result, the frequency of SX Phe and eclipsing variables identified in globular clusters is increasing. When Clement et al. (2001) published their updated catalogue, they found that almost 10% of the variable stars were SX Phe or eclipsing and that the proportion of RR Lyrae had decreased to 83%. As more clusters are observed with modern detectors, this trend is continuing. In a catalogue of 354 “classified” variable stars in ω Cen, Kaluzny et al. (2004) found that only 55% were RR Lyrae type and more than 35% were either SX Phe or eclipsing variables.

Another cluster that has been the subject of intensive searches for variables is 47 Tucanae. It is metal rich and therefore is not expected to have many RR Lyrae variables, although a few have been detected. Sawyer Hogg’s 1973 catalogue had 52 recorded variables, most of them Miras or other red variables (Feast 1973). When the cluster was observed with CCD detectors in the 1990s, about 20 binaries were discovered by Edmonds et al. (1996) and by Kaluzny et al. (1998). In the last decade, many more variables have been identified because 47 Tuc has been the subject of two searches for planetary transits: the first was by Gilliland et al. (2000) based on Hubble Space Telescope observations and the second by Weldrake et al. (2004) who observed with a 40-inch telescope at the Siding Spring Observatory. No planets have been identified, but the data have proved useful for identifiying faint variable stars in the core of the cluster. As a result, many new variables have been anounced. Albrow et al. (2001) detected 114 new variables among the 46,422 main sequence stars surveyed by Gilliland et al. (2000). These were mainly binaries and BY Draconis variables. Weldrake et al. (2004) detected 100 variables, but most of these were associated with the SMC.

The modern detectors have made it possible to detect globular cluster variable stars at the level of the main sequence, much fainter than was previously possible. As a result, when the revised catalogue of variables in globular clusters is completed, it is expected that less than half of the variables will be RR Lyrae type. This new technology has also allowed astronomers to study RR Lyrae variables in the other galaxies of the Local Group and recent results from some of these investigations have been reported at this conference (Bernard 2010; Clementini 2010; Sarajedini & Yang 2010).

3. The revised catalogue

3.1. The format of the catalogue

The catalogue is arranged as a series of files, one for each cluster. It can be accessed at `www.astro.utoronto.ca/~cclement/read.html`. At the beginning of each file is a header containing the cluster name (with multiple designations indicated), the right ascension and declination (epoch J2000) listed by Harris (1996) and the month and year when the file was most recently revised. This information is followed by a table that lists the known variables. For each variable, we list the identification number, position, period, mean magnitude, light amplitude, filter (for the magnitude and amplitude), and the type of variable. At the end of each table, we list the original references from which all of the table entries were obtained and also include a section on the discovery of the variables.

In most clusters, the variables are numbered consecutively. This was the procedure established by Bailey (1902) and continued by Sawyer (1939) who recommended that other investgators do the same. However, in recent years, this has not always happened. For example, Kaluzny & Thompson (2001) designated new variables that they detected in Messier 22 as CASE M22-01, 02, etc. where CASE was an acronym for the "Cluster AgeS Experiment" which is a long term project for determining ages and distances of globular clusters. In this case, we have adopted a numbering system that indicates the paper in which the variables were announced. We have designated these new variables as KT-01, 02, etc. in the revised catalogue. A similar situation arises in 47 Tucanae. In their study of the HST observations, Albrow et al. (2001) set up a numbering system based on the CCD chip on which the variable was located. Lebzelter & Wood (2005) also set up their own system when they discovered 22 long period variables a few years later, designating their new variables as LW1-LW22. We adopt these numbering systems for the 47 Tuc variables because it would be confusing to change them at this stage. However, we hope that authors who discover new variables in other globular clusters will continue the practice of consecutive numbering.

In the early studies of globular clusters at Harvard, the positions of the variable stars were indicated by marking them on photographic charts and by giving their rectangular coordinates (x, y) referred to the centre of the cluster as origin (Pickering & Fleming 1897). A reticule was constructed and superimposed on an enlarged photograph of the cluster so it was a straightforward procedure to measure x and y. It was also a convenient method for deriving the coordinates of variables discovered at a later date. Sawyer Hogg followed this scheme in her three catalogues. However, Samus et al. (2009) pointed out that in the 21st century, it is more convenient to list the right ascension and declination. They recently derived accurate equatorial coordinates for 3398 globular cluster variable stars. In our revised catalogue, we list right ascension and declination for the variables if they are available. Otherwise, we continue to list x and y.

For the classification of the variable type, we use the scheme proposed by Samus in August 2006: `http://www.sai.msu.su/gcvs/future/classif.htm`

3.2. A sample file

An illustration of the format of the cluster files is shown here for Palomar 5. It is a cluster that has been discussed frequently in the literature in recent years because it has a tidal tail (Odenkirchen et al. 2009). However, its variables have not been investigated since 1962. Since it is a sparsely populated cluster, it is possible that no more variables remain to be discovered, but it would be worthwhile to check.

Table 1. Palomar 5/ Abell 5 (formerly Baade's cluster)/ C1513+000
RA: 15:16:05.3, Dec: −00:06:41 (J2000)
(Updated August 2009)

Star	Position		Units	Period	mean	amp	Filter	Type
ID	RA/X	Dec/Y		(days)	mag			
V1	15:15:57.18	−00:06:53.3	RD	0.2932	17.71	0.42	*B*	RR1
V2	15:15:57.95	−00:11:23.4	RD	0.3325	17.81	0.40	*B*	RR1
V3	15:16:12.76	−00:10:03.3	RD	0.3300	17.70	0.50	*B*	RR1
V4	15:16:05.79	−00:11:12.7	RD	0.2864	17.69	0.48	*B*	RR1
V5	15:15:58.23	−00:05:47.4	RD	0.2524	17.70	0.30	*B*	RR1

The periods, magnitudes, amplitudes and variability types listed in the above table are from a paper by Kinman & Rosino (1962). The right ascension and declination are from the catalogue of Samus et al. (2009).

V1–5 were discovered by Rosino (1951) who published their x, y coordinates (in arcseconds) and an identification chart. He also identified five additional suspected variables, but Kinman & Rosino (1962) found no evidence for their variability.

4. The current status of the catalogue

According to Harris (1996), there are 150 objects regarded as globular clusters in the Milky Way galaxy. Currently (December 2009), the files for 58 of these have been updated and posted on the variable star catalogue website. Provisional files are available for the others on request from `cclement @ astro.utoronto.ca`.

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