A New Catalog of Globular Clusters in the Milky Way

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ABSTRACT

A new revision of the McMaster catalog of Milky Way globular clusters is available. This is the first update since 2003 and the biggest single revision since the original version of the catalog published in 1996. The list now contains a total of 157 objects classified as globular clusters. Major upgrades have been made especially to the cluster coordinates, metallicities, and structural profile parameters, and the list of parameters now also includes central velocity dispersion.

NB: This paper is a stand-alone publication available only on the astro-ph archive; it will not be published separately in a journal.

Subject headings: catalogs; Galaxy: globular clusters: general

1. Introduction

In 1996 the author published a catalog of parameters for globular clusters in the Milky Way (Harris 1996). This critical list has been frequently used since then, over four different updates that have been made available through the Web. The last of these, however, was eight years ago, and since then a huge amount of observational work on individual clusters and on large collections of clusters has been carried out. A new edition at this stage is well justified to take advantage of this rich new vein of material.

The 2010 edition can be found at physwww.mcmaster.ca/~harris/Databases.html

As before, the publication includes two files: the compiled database, and a much longer separate file giving the complete bibliography and explanation of how each quantity is derived. In total, for this edition material from almost 300 published papers since 2002 has been added.

2. New Clusters, Coordinates, and Distances

Seven new objects classified as globular clusters have been added to the previous list, bringing the total to 157. The new additions are Whiting 1, Koposov 1 and 2, FSR1735, BH261, and GLIMPSE-01 and 02. Several other candidates have been proposed in the literature over the past decade, but as yet the evidence for those is less convincing. Many are equally likely to be ultra-faint satellites of the Milky Way, or old open clusters in the Galactic disk.

The fundamental list of coordinates has been completely reconstructed for this edition of the catalog, thanks to numerous papers over the past decade that provide distinct improvements over older work. At present the center coordinates for the clusters are now uncertain to typically 1-2 arcseconds, and better than 1″ in a few cases that have attracted especially intensive study.

The working definition of the cluster center that I use here is the center of the overall light distribution, as defined for example by concentric-aperture photometry, ellipse contour fitting, or light profile fitting. In a few special cases now in the literature alternate definitions have arisen, such as the “center of gravity” from starcounts or the point around which the velocity dispersion would be maximized at zero radius. At the level of 1″ or so, these different definitions may disagree.

The primary distance indicator for each cluster continues to be the empirically observed horizontal branch level $V(HB)$. Wherever possible, $V(HB)$ denotes the mean $V$ magnitude of the RR Lyrae.
stars; for blue-HB clusters, it denotes the magnitude of the HB at the blue edge of the RR Lyrae region, while for red-HB clusters it denotes the mean magnitude of the red HB stars themselves.

The absolute calibration of $V(HB)$ adopted here is

$$M_V(HB) = 0.16[Fe/H] + 0.84$$  \hspace{1cm} (1)

which is slightly fainter (though at most 0.05 mag) than in previous editions of the catalog. This calibration is constructed from the most direct currently available distance measurements, including

(a) main-sequence fitting to metal-poor field subdwarfs (Harris 2000; Grundahl et al. 2002; Gratton 2003; Layden et al. 2005; Bergbusch & Stetson 2009); (b) trigonometric parallax for field RR Lyrae stars (Gratton 1998; Feast et al. 2008); (c) dynamical parallax from combined solutions to radial velocity and proper motion dispersions (Rees 1996; McLaughlin et al. 2006; van de Ven et al. 2006; van den Bosch et al. 2006); (d) eclipsing binary solutions (Thompson et al. 2001, 2010); and (e) Fourier analysis of light curves or Baade-Wesselink method for RR Lyraes (Olech et al. 2001; Cacciari et al. 2005; Dekany & Kovacs 2009; Arellano Ferro et al. 2010; Zorotovic et al. 2010).

The results for these methods are shown in Figure 1. A weighted fit gives

$$M_V(HB) = (0.165\pm0.045)[Fe/H] + (0.863\pm0.071).$$  \hspace{1cm} (2)

A useful supplement to these Milky Way results can be obtained from the observed HB levels in M31 globular clusters if we adopt a fiducial distance for M31. Rich et al. (2005) provide a set of homogeneous, HST-based photometry and metallicities for 19 such clusters. These are also shown in Figure 1, for an adopted distance modulus $(m - M)_0 = 24.47$ from a combination of several standard candles including Cepheids, RR Lyraes, Mira variables, and planetary nebulae. A weighted fit for all 39 results, both M31 and Milky Way, gives

$$M_V(HB) = (0.160\pm0.033)[Fe/H] + (0.844\pm0.049)$$  \hspace{1cm} (3)

which is highly consistent with the trend from the Milky Way alone. This second version is essentially the calibration adopted for the catalog.
rms scatter around these best-fit relations is ±0.11 magnitude.

3. Metallicities and Velocities

Considerable new work on abundances particularly from high dispersion spectroscopy has been accomplished for individual clusters in the past decade. The new heavy-element abundance scale adopted for the catalog is the one established by Carretta et al. (2009). This represents a fundamental shift from the older Zinn & West (1984) metallicity scale used in previous editions of the catalog and by most other writers before the past decade. The arguments for making this change of base are well detailed by Carretta et al. (2009 and earlier papers), but essentially reduce to the fact that the traditional Zinn/West scale was calibrated against only a handful of high-dispersion spectroscopic \([\text{Fe/H}]\) values available at that time. In the subsequent ∼30 years, far more high-dispersion, high signal-to-noise spectroscopic measures for vastly more clusters have been produced, along with superior abundance analysis methods based on more advanced model atmospheres.

Carretta et al. (2009) publish mean \([\text{Fe/H}]\) values for 95 clusters derived from a weighted average of (a) their own high-dispersion spectra in that paper and in earlier papers from their group, (b) the Kraft & Ivans (2003) spectroscopic metallicities transformed to their \([\text{Fe/H}]\) scale, (c) the Zinn & West (1984) Q39 photometric metallicity index transformed to their \([\text{Fe/H}]\) scale, and (d) the Rutledge et al. (1997) \(W'\) calcium index transformed to their \([\text{Fe/H}]\) scale.

These 95 transformed and averaged values are used as the homogenous, modern basis for the present catalog listing. In addition to this basic list, dozens of additional spectroscopic values of \([\text{Fe/H}]\) for many individual clusters are averaged in from all other studies not already included in the sources listed above. Lastly, metallicities based on photometry (rather than spectroscopy) are used for several clusters in which no other estimates can be found. These are mostly the clusters in the Galactic center region that are very heavily reddened and where every kind of observation is more difficult. The photometric metallicities are in most cases constructed from recent color-magnitude analyses and use parameters such as the slope and color of the red-giant branch in various optical and near-infrared bandpasses.

Similarly many new measurements of cluster radial velocities have been incorporated, though these have not required any fundamental shift of basis. Almost all the clusters in the Milky Way now have useful, contemporary measurements of both metallicity and velocity.

An entirely new addition for this edition is the internal velocity dispersion \(\sigma(v_r)\), a critically important quantity for independent calibration of cluster mass as well as all dynamical studies. The major starting point for this parameter continues to be the work of Pryor & Meylan (1993), who collected and analyzed the available measurements up to that point. Numerous additional papers are now to be found with useful \(\sigma(v_r)\) data, though in most cases these are only new measurements for the same clusters as in the Pryor/Meylan compilations. Thus unfortunately more than half the clusters do not yet have a direct measurement of their internal velocity dispersion. The velocity dispersion as quoted in the catalog is the estimated central value (at or near \(r = 0\)), sometimes relying on small model extrapolations from velocity or proper motion data within the cluster core, or in the best cases from the complete velocity dispersion profile.

4. Structural Parameters

Structural parameters for globular clusters continue to be useful for a wide range of purposes such as discussions of dynamical relaxation, core collapse, formation of exotic objects (black holes, degenerate binaries, blue stragglers and so forth), or evolution of clusters in the tidal field of the galaxy. The basic measureables include core radius \(r_c\), half-light or effective radius \(r_h\), central concentration \(c\) as defined in the King-model sense as the ratio of tidal to core radius, and central surface brightness at zero radius \(\mu_V(0)\).

The starting points for the present list of structural parameters are the major compilations of McLaughlin & van der Marel (2005) and Trager et al. (1993, 1995). MV05 use the same raw data as TKD95, and direct comparison of their derived values from King (1966) dynamical profile models shows good internal agreement except for a few cases where the profiles are unusually complex or
Fig. 2.— Correlations of King-model structural parameters from two recent studies, McLaughlin & van der Marel (2005) and Trager, King & Djorgovski (1995). Successive panels show Trager et al. vs. McLaughlin & van der Marel for the central concentration $c$, core radius $r_c$, half-light radius $r_h$, and central surface brightness $\mu_V(0)$.

low signal-to-noise. The direct comparisons are shown graphically in Figure 2. In addition to these studies, however, almost two dozen other recent sources are used for individual clusters.

The “tidal” or limiting radius commonly labelled $r_t$ is, however, no longer listed specifically in the catalog. Recent work (see particularly McLaughlin & van der Marel) has made it clear that $r_t$ is a much more model-dependent number than the other parameters, because it requires an extrapolation of the observed starcounts versus radius to the point at which the stellar density drops to the (unmeasureable) level of zero. It can also be affected by the existence of tidal tails or envelopes of gradually escaping stars outside the nominal tidal boundary, which are problematic for the simple structural models.

5. Summary

The raw census of Milky Way globular clusters continues to increase, albeit slowly. Objects discovered and identified fairly convincingly as globular clusters over the past $\sim 20$ years have almost invariably been small, faint systems either deep in the heavily reddened bulge region or in the remote halo. A few more discoveries of such objects can be expected from deep, wide-field surveys covering the halo particularly.

Some of the more commonly used distribution functions drawn from the new catalog are shown in Figures 4 and 5: metallicity $[\text{Fe/H}]$, luminosity $M_V$, half-light radius $r_h$, and median relaxation time $t(r_h)$. The basic features of these distributions have not changed in any major way, but they are now more confidently filled out and include almost every known cluster.

More than anything else, this new edition of the catalog is a testament to the rate of intensive observational work on a variety of fronts during the past decade. It is a pleasure to acknowledge the ever-increasing quality and depth of such work on which any compilation such as this is built.

This work was supported by the Natural Sciences and Engineering Research Council of Canada through research grants to the author. I am grateful for the hospitality at ESO (Garching) and at Mount Stromlo Observatory where most of this work was done.
Fig. 3.— *Left panel:* Distribution of metallicities [Fe/H] for all Milky Way globular clusters. *Right panel:* Distribution of luminosities $M_V$.

Fig. 4.— *Left panel:* Distribution of effective (half-light) radii for all Milky Way globular clusters. *Right panel:* Distribution of median internal relaxation times $t(\tau_h)$.

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