# THE GALACTIC DISTANCE SCALE: GLOBULAR CLUSTERS

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A new compilation of distance data for the Galactic globular clusters is used to estimate the distance to the Galactic center, $R_o$. Three different ways of using the space distribution of the clusters lead to $R_o = (8.5 \pm 1.0)$ kpc. The problem of the space distribution of the clusters in the Galactic nuclear region is briefly discussed.

The first valid estimate of the distance to the Galactic center $R_o$, and hence the scale of our Galaxy as a whole, was made by Harlow Shapley in a monumental series of papers culminating in his discussion published in 1918. The keystone of his argument, that the centroid of our globular cluster system marks the Galactic center, is one of the very few fundamental methods of calibrating $R_o$; and all treatments of this topic in the following 60 years have served only as refinements and updates of Shapley's basic breakthrough. It is worth remembering that the calibration of Shapley's cluster distances rested on an assumed luminosity for the RR Lyrae stars that was almost a magnitude brighter than that used now; that he did not take into account the effects of interstellar absorption; that his distance estimates for the individual clusters were based almost entirely on cluster diameters and 25 brightest stars; and that the sample of objects he used is now seen to have been severely incomplete and biased toward the Sun. Yet curiously these errors of detail served partly to cancel themselves out, and his resulting figure for $R_o$ was ~15 kpc, within a factor of two of the present-day estimate. (Compare the history of the Hubble constant $H_o$, whose estimates over 50 years have changed by an order of magnitude.)

The basic material one needs for this problem is simply a homogeneous list of distances for as many globular clusters as possible. As outlined in my previous discussion of this subject (Harris 1976, hereafter denoted H76), the fundamental distance indicator is the apparent magnitude $V_{HB}$ of the cluster horizontal branch, coupled with an assumed absolute magnitude for the HB (or RR Lyrae stars). A CM diagram for any cluster, if available, supersedes all other more approximate techniques, and the value of $V_{HB}$ can be taken from it without further ado.



*James E. Hesser (ed.), Star Clusters, 81–90.*


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TABLE 1

Distance Estimates for 81 Clusters from CM Studies

| NGC | Type | $V_{HB}$ | $R_{GC}$ | Primary Reference |
|---|---|---|---|---|
| 104 | G | 14.06 | 7.8 | Hesser & Hartwick 1977, Ap. J. Suppl. 33, 361; Lee 1977, Astron. Ap. Suppl. 27, 381. |
| 288 | F | 15.30 | 12.0 | Cannon 1974, MNRAS 167, 551. |
| 362 | F | 15.50 | 9.9 | Menzies 1974, Ph.D. thesis. |
| 1261 | F | 16.42 | 16.5 | Wehlau & Demers 1977, Astron. Ap. 57, 251. |
| 1851 | F | 16.10 | 16.4 | Alcaino 1976, Astron. Ap. 50, 299. |
| 1904 | F | 16.20 | 19.3 | Stetson & Harris 1977, A.J. 82, 954. |
| 2298 | F | 16.20 | 16.6 | Alcaino 1974, Astron. Ap. Suppl. 13, 55. |
| 2419 | F | 20.50 | 99.3 | Racine & Harris 1975, Ap.J. 196, 413. |
| 2808 | F | 16.20 | 11.5 | Harris 1978, PASP 90, 45. |
| Pal 3 | F | 20.6: | 99.3 | Burbidge & Sandage 1958, Ap.J. 127, 527. |
| 3201 | F | 14.75 | 9.3 | Lee 1977, Astron. Ap. Suppl. 28, 409 |
| Pal 4 | F | 20.45 | 96.1 | Burbidge & Sandage 1958, Ap.J. 127, 527. |
| 4147 | F | 16.85 | 19.8 | Sandage & Walker 1955, A.J. 60, 230. |
| 4372 | F | 15.50 | 7.4 | Hartwick & Hesser 1973, Ap.J. 186, 1171. |
| 4590 | F | 15.60 | 10.0 | Harris 1975, Ap.J. Suppl. 29, 397. |
| 4833 | F | 15.45 | 7.2 | Menzies 1972, MNRAS 156, 207. |
| 5024 | F | 16.94 | 18.0 | Cuffey 1965, A.J. 70, 232. |
| 5053 | F | 16.63 | 16.2 | Sandage, Katem, & Johnson 1977, A.J. 82, 389. |
| 5139 | F | 14.52 | 6.7 | Cannon 1974, MNRAS 167, 551. |
| 5272 | F | 15.60 | 12.1 | Sandage 1970, Ap.J. 162, 841. |
| 5286 | F | 16.20 | 7.3 | Harris, Racine, & deRoux 1976, Ap.J. Suppl. 31, 13. |
| 5466 | F | 16.56 | 15.2 | Cuffey 1961, A.J. 66, 71. |
| 5634 | F | 17.75 | 20.2 | Racine 1974, unpublished study. |
| 5694 | F | 18.4: | 26.6 | Harris & Hesser 1976, PASP 88, 377. |
| IC4499 | F | 17.65 | 15.1 | Clement, Dickens, & Bingham 1979, A.J. 84, 217. |
| 5824 | F | 18.00 | 18.4 | Harris 1975, Ap.J. Suppl. 29, 397. |
| Pal 5 | F | 17.35 | 16.7 | Sandage & Hartwick 1977, A.J. 82, 459. |
| 5897 | F | 16.25 | 7.2 | Sandage & Katem 1968, Ap.J. 153, 569. |
| 5904 | F | 15.11 | 6.5 | Arp 1962, Ap.J. 135, 311. |
| 5927 | G | 16.70 | 4.7 | Menzies 1974, MNRAS 169, 79. |
| 5986 | F | 16.50 | 4.6 | Harris, Racine, & deRoux 1976, Ap.J. Suppl. 31, 13. |
| Pal 14 | F | 19.8: | 60.0 | Hartwick & Sargent 1978, Ap.J. 221, 512. |
| 6093 | F | 15.82 | 3.0 | Harris & Racine 1974, A.J. 79, 472. |
| 6101 | F | 16.3: | 8.7 | Alcaino 1974, Astron. Ap. Suppl. 18, 9. |
| 6121 | F | 13.35 | 6.5 | Lee 1977, Astron. Ap. Suppl. 27, 367. |
| 6171 | G | 15.63 | 4.3 | Dickens & Rolland 1972, MNRAS 160, 37. |
| 6205 | F | 14.95 | 8.8 | Sandage 1970, Ap.J. 162, 841. |
| 6218 | F | 14.90 | 4.7 | Racine 1971, A.J. 76, 331. |
| 6229 | F | 18.10 | 30.5 | Searle & Zinn 1978, Ap.J. 225, 357. |
| 6254 | F | 14.65 | 5.0 | Harris, Racine & deRoux 1976, Ap.J. Suppl. 31, 13. |
| 6256 | G | 17.2: | 2.1 | Alcaino 1978, Astron. Ap. Suppl. 33, 181. |
| 6266 | F | 15.95 | 2.7 | Harris 1975, Ap.J. Suppl. 29, 397; Alcaino 1978, Astron.Ap. Suppl. 32, 379. |
| 6273 | F | 16.95: | 2.9 | Harris, Racine, & deRoux 1976, Ap.J. Suppl. 31, 13. |
| 6304 | G | 16.10 | 3.8 | Hesser & Hartwick 1976, Ap.J. 203, 113. |
| 6325 | F | 17.3: | 1.9 | Harris 1975, Ap.J. Suppl. 29, 397. |
| 6341 | F | 15.10 | 9.7 | Sandage 1970, Ap.J. 162, 841. |
| 6352 | G | 15.15 | 4.2 | Hartwick & Hesser 1972, Ap.J. 175, 77. |
| 6356 | G | 17.67 | 7.1 | Sandage & Wallerstein 1960, Ap.J. 131, 598. |
| 6362 | F | 15.30 | 5.3 | Alcaino 1972, Astron. Ap. 16, 220. |
| 6366 | G | 15.70 | 5.4 | Pike 1976, MNRAS 177, 257. |
| 6388 | G | 17.43 | 5.2 | Illingworth & Freeman 1974, Ap.J. Letters 188, L83. |
| 6397 | F | 12.90 | 6.5 | Cannon 1974, MNRAS 167, 551. |
| 6402 | F | 17.50 | 4.7 | Kogon, Wehlau, & Demers 1974, A.J. 79, 389. |
| 6441 | G | 17.10 | 1.4 | Hesser & Hartwick 1976, Ap.J. 203, 97. |
| 6517 | F | 18.0: | 3.6 | Harris 1975, Ap.J. Suppl. 29, 397. |
| 6522 | F | 16.25 | 2.0 | Arp 1965, Ap.J. 141, 43. |
| 6528 | G | 16.75 | 2.7 | van den Bergh & Younger 1979, in press. |
| 6541 | F | 15.20 | 2.6 | Alcaino 1979, Astron.Ap. Suppl. 35, 233. |
| 6553 | G | 16.95 | 3.3 | Hartwick 1975, PASP 87, 77. |
| 6624 | G | 16.05 | 1.5 | Liller & Carney 1978, Ap.J. 224, 383. |
| 6637 | G | 16.20 | 1.7 | Harris 1977, PASP 89, 482. |
| 6656 | F | 14.20 | 5.4 | Alcaino 1977, Astron. Ap. Suppl. 29, 383. |

TABLE 1 (continued)

| NGC | Type | $V_{HB}$ | $R_{GC}$ | Primary Reference |
|---|---|---|---|---|
| 6681 | F | 16.00 | 3.2 | Harris 1975, Ap.J. Suppl. 29, 397. |
| 6712 | G | 16.11 | 3.8 | Sandage & Smith 1966, Ap.J. 144, 886. |
| 6715 | F | 17.71 | 13.6 | Harris 1975, Ap.J. Suppl. 29, 397. |
| 6723 | G | 15.48 | 2.5 | Menzies 1974, MNRAS 168, 177. |
| 6752 | F | 13.80 | 5.6 | Cannon & Stobie 1973, MNRAS 162, 227. |
| 6779 | F | 16.20 | 9.5 | Barbon 1965, Asiago Contrib. No. 175. |
| 6809 | F | 14.40 | 4.4 | Lee 1977, Astron. Ap. Suppl. 29, 1. |
| Pal 11 | G | 17.0: | 5.8 | Canterna & Schommer 1978, Ap.J. Letters 219, L119. |
| 6838 | G | 14.45 | 7.2 | Arp & Hartwick 1971, Ap.J. 167, 499. |
| 6864 | F | 17.45 | 12.1 | Harris 1975, Ap.J. Suppl. 29, 397. |
| 6934 | F | 16.80 | 11.9 | Harris & Racine 1973, A.J. 78, 242. |
| 6981 | F | 16.85 | 12.8 | Dickens 1972, MNRAS 157, 281. |
| 7006 | F | 18.72 | 32.3 | Sandage & Wildey 1967, Ap.J. 150, 469. |
| 7078 | F | 15.86 | 10.1 | Sandage 1970, Ap.J. 162, 841. |
| 7089 | F | 16.05 | 10.3 | Harris 1975, Ap.J. Suppl. 29, 397. |
| 7099 | F | 15.20 | 7.4 | Dickens 1972, MNRAS 157, 299. |
| Pal 12 | G | 17.10 | 13.8 | Harris & Canterna 1979, preprint. |
| Pal 13 | F | 17.70 | 25.6 | Ciatti, Rosino, & Sussi 1965, Padova Comm. No. 44. |
| 7492 | F | 17.00 | 18.7 | Barnes 1968, A.J. 73, 579. |

TABLE 2

Distance Estimates for 33 Clusters from Secondary Methods

| NGC | Type | $V_{HB}$ | Weight | $R_{GC}$ | Methods |
|---|---|---|---|---|---|
| Pal 1 | F | 19.3 | 2 | 51.9 | BG |
| 5946 | F | 17.2 | 5 | 5.1 | BG, IR |
| 6139 | F | 17.5 | 4 | 2.9 | BG, IR |
| 6144 | G | 16.18 | 11 | 2.9 | BG, RR, IR |
| 6235 | F | 16.60 | 9 | 2.2 | BG, RR, IR |
| 6284 | F | 16.55 | 11 | 2.6 | BG, RR, IR |
| 6287 | G | 16.52 | 10 | 1.7 | BG, RR, IR |
| 6293 | F | 16.14 | 11 | 1.3 | BG, RR, IR |
| 6316 | G | 17.8 | 4 | 3.8 | BG, IR |
| 6333 | F | 16.09 | 8 | 2.0 | BG, RR, IR |
| 6342 | G | 18.0 | 2 | 5.0 | BG, IR |
| 6355 | F | 17.2 | 4 | 1.6 | BG, IR |
| 6401 | G | 17.3 | 3 | 2.4 | BG |
| Pal 6 | F | 19.1 | 3 | 4.7 | BG |
| 6426 | F | 18.0 | 1 | 10.9 | IR |
| 6440 | G | 17.4 | 2 | 4.5 | BG, IR |
| 6453 | F | 17.7 | 3 | 1.9 | BG, IR |
| 6496 | G | 14.9 | 3 | 3.4 | BG, IR |
| 6535 | F | 16.50 | 9 | 4.4 | BG, RR, IR |
| 6539 | F | 16.6 | 1 | 6.0 | IR |
| 6544 | F | 15.8 | 5 | 4.1 | BG, IR |
| 6558 | G | 16.7 | 4 | 0.9 | BG, RR |
| IC1276 | G | 18.5 | 4 | 3.4 | BG, RR |
| 6569 | G | 17.1 | 6 | 1.7 | BG, RR, IR |
| 6584 | F | 16.8 | 5 | 7.9 | BG, IR |
| 6626 | F | 15.61 | 9 | 2.5 | BG, RR, IR |
| 6638 | G | 16.2 | 8 | 2.2 | BG, RR, IR |
| 6642 | G | 15.5 | 6 | 3.8 | BG, RR |
| 6652 | G | 16.7 | 6 | 4.4 | BG |
| Pal 8 | G | 19.5 | 1 | 26.1 | BG |
| 6717 | G | 17.0 | 4 | 5.3 | BG |
| 6760 | F | 16.5 | 6 | 5.7 | BG, RR, IR |
| Pal 10 | F | 19.2 | 1 | 8.0 | BG |

Currently 81 clusters now fall into this category: I have listed them in Table 1 along with my $V_{HB}$ estimates and the adopted primary reference sources for the CM diagrams.

Going beyond the primary list of Table 1, there are 33 more clusters for which rougher distance estimates can be gauged through a variety of secondary methods (cf. H76). I have recalibrated all of these (see Appendix) in terms of the primary clusters, to yield the $V_{HB}$ estimates listed in Table 2 (BG = brightest giants, RR = RR Lyrae variables, IR = integrated cluster magnitudes). Although all the $V_{HB}$ figures are systematically homogeneous, they have a wide range of relative qualities and I have tried to indicate this by the weights assigned in column 3. By contrast, any value obtained from a well defined CM diagram would have a weight of about 20 (corresponding to $\pm 0.05$ mag) on this scale. In assembling Tables 1 and 2 I have tried to go back to all the original source material and re-evaluate the data for every cluster anew: the final values here therefore constitute a completely new listing and not just an update of previous ones.

To convert $V_{HB}$ into distance modulus I used the assumption $M_V(HB) = 0.6$ for the "metal-poor" clusters (F-type integrated spectra, $[m/H] < -1$) and 0.9 for the "metal-rich" clusters (G-type spectra, $[m/H] > -1$). During the last few years, important observational evidence has accumulated to favor the view that $M_V(HB)$ is indeed fainter for the higher-abundance clusters: the main-sequence fitting analyses of 47 Tuc by Hartwick and Hesser (1974), Demarque and McClure (1977), and Carney (1979), and an interesting infrared photometric study of several G-type clusters by Lloyd Evans and Menzies (1977), all strongly support the adoption of $M_V(HB) = 0.9$ uniformly for such clusters. On the other hand, the calibration of $M_V(HB) = 0.6$ for the more metal-poor group still seems as valid as before (H76). If a smooth relation exists between $[m/H]$ and $M_V(HB)$, we still have insufficient data to establish it with any confidence, and for the present I have adopted the simple two-step scale given above. Column 2 of the tables indicates which of the two abundance groups (F or G) each cluster has been assigned to (H76; Harris and Racine 1979; Harris and Canterna 1979). The resulting apparent distance moduli are finally converted into true distances by inserting E(B-V) values taken from the catalog of Harris and Racine (1979) and the ratio $R = A_V/E(B-V) = 3.1$ (Turner 1976). The projected space distribution of the clusters in the XZ plane -- the most relevant one for determining $R_o$ -- is shown in Figure 1. In all, we now have a sample of 114 clusters with useful distance information; Shapley used just 69.

Starting from the basic distance list, several approaches can be employed to calculate $R_o$, but all give much the same result. The method I adopted previously (H76), which relies heavily on the distribution of clusters at large Z (and therefore mostly metal-poor objects with low reddenings), is summarized graphically in Figure 2. Here $\langle X \rangle$ is the mean X-coordinate of all clusters farther above or below the Galactic plane than $|Z| = Z_{lim}$ (excluding 5 objects more distant than $\sim 40$ kpc). Since the clusters near the plane with small Z-values are heavily biased toward the Sun (see Fig. 1), ideally <X> should approach the true value of $R_o$ as $Z_{lim}$ increases from zero and as the low-latitude objects drop out of the sample. This has to be balanced off against the large increase in the internal statistical error of <X> (error bars in Fig. 2) as $Z_{lim}$ increases and the cluster sample shrinks. The best estimate from Fig. 2 seems to be $R_o$ = (8.0 ± 1.4) kpc, but my belief is that this is still a slight underestimate because our knowledge of clusters at low or intermediate latitudes and large X-values is probably not yet complete.

A second approach which I have tried here is, in a sense, the reverse of the first one. Rather than relying on the clusters far from the disk, we can instead look more carefully at the distribution of the G-type clusters by themselves (which have mostly low Z and high reddenings). The G-types are, after all, the ones which concentrate most closely around the Galactic center and they would in principle mark its position most sharply if we could only pinpoint their locations completely and accurately. But let us assume (as seems quite plausi-

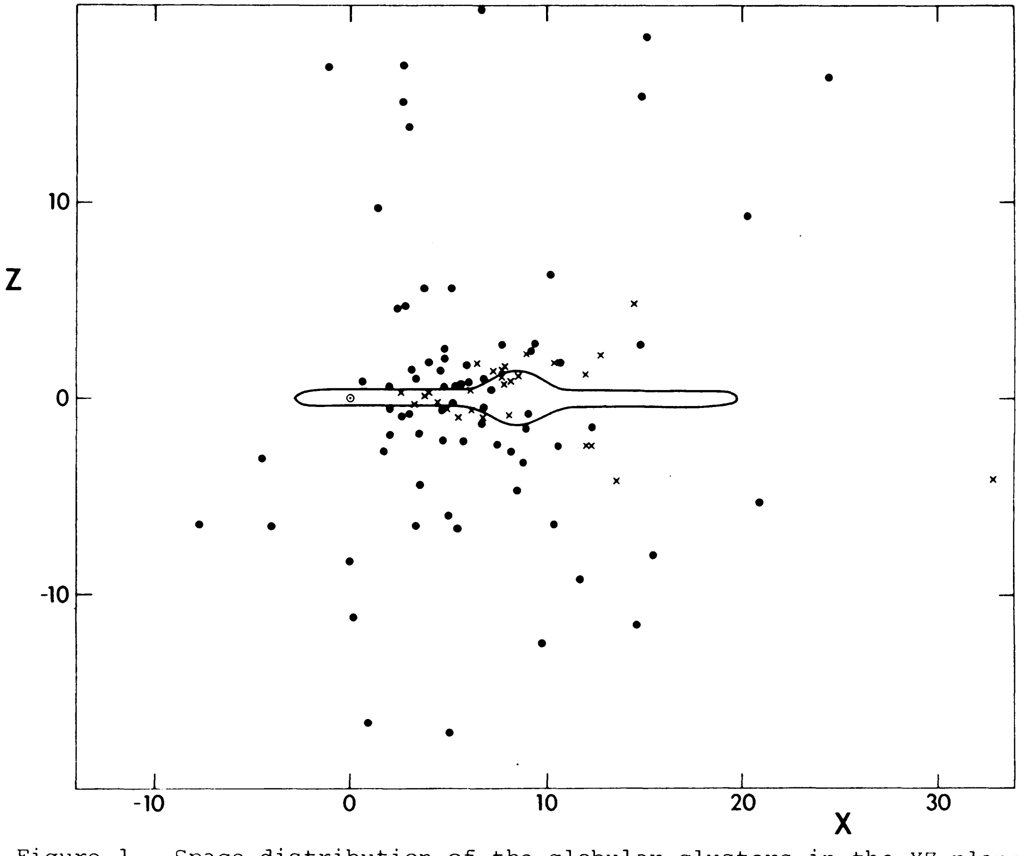


Figure 1. Space distribution of the globular clusters in the XZ plane. The Sun is the circled dot, clusters from Table 1 are solid dots, and clusters from Table 2 are crosses. Both scales are in kpc.

ble; see Fig. 1 again and H76) that the great majority of the G-type clusters in Tables 1 and 2 are on the near side of the Galactic center to us and that those on the far side ($X > R_o$) have mostly been blocked from our view by increasingly heavy visual extinction. Then we can simply inspect the distribution of the known G-type clusters along the X-axis, and look for a sudden cutoff in their numbers as the Galactic center is approached. The XZ diagram for them is shown in Figure 3; and an obvious drop in their numbers does indeed appear between 8 and 9 kpc as we move along the X-axis. From this method I would therefore estimate $R_o = (8.5 \pm 1.5)$ kpc.

A third approach is an ingenious one discussed recently by Sasaki and Ishizawa (1978). By investigating what happens to typical globular-cluster orbits in a conventional mass model of the Galaxy over the course of $\sim 10^{10}$ y, they find that a "cone of avoidance" develops directly above and below the Galactic center in which few clusters now exist. They can then estimate $R_o$ from the observed space distribution of the actual globular clusters by moving the vertex of this cone along the X-axis until the maximum cone size (or minimum number of clusters in the cone) is achieved. Starting from my earlier list of distances (H76) they obtain $R_o = (9.4 \pm 1.2)$ kpc; with the distance scale revisions used here this figure would likely be decreased by $\sim 0.5$ kpc or so.

Within their own internal errors, the various methods agree well, and I have adopted a final estimate of $R_o = (8.5 \pm 1.0)$ kpc. This figure has been used to calculate the galactocentric distances $R_{GC}$ in Tables 1 and 2. The mutual agreement is perhaps to be expected, since all approaches must use the same initial data, and they differ only in their respective devices for sidestepping the seriously asymmetric distribution of low-latitude clusters along the X-axis. It is difficult to see how the internal error of the globular-cluster method can be pushed any lower than $\sim 1$ kpc; to obtain a sharper measurement of $R_o$ it seems essential to add in other independent methods.

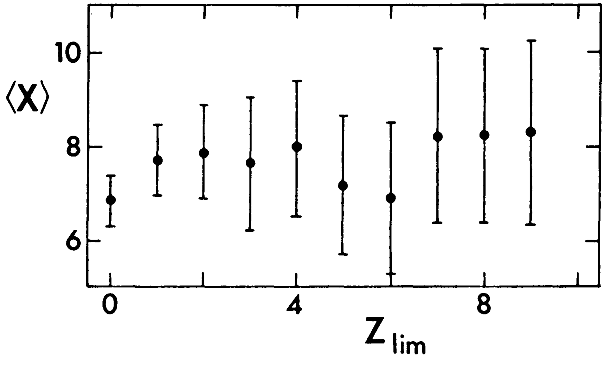


Figure 2. The mean X-coordinate over all clusters with $|Z| > Z_{lim}$, plotted as a function of $Z_{lim}$. Error bars are the statistical internal standard errors of each average.

A final topic of interest here concerns the true distribution of the "nuclear" G-type clusters in three dimensions: do they occupy a spherical region of space around the Galactic center, like the F-type subsystem, or are they flattened toward the disk? The former viewpoint was supported by Woltjer (1975) and H76, by inspection of the actual distribution of the central clusters in the YZ plane, which is nearly free of the effects of random distance errors that tend to spread the points out along the X-axis. However, two more recent papers have renewed the controversy as to whether a true "disk" globular cluster population exists, as was first suggested (though on incorrect grounds) by Baade (1958). First, van den Bergh (1979), using a simple model of the cluster system, has stressed the importance of heavy low-latitude reddening on the observed distribution in the YZ plane. Since adding a uniform absorbing layer into the disk will preferentially block the lowest-latitude objects from our view, the apparently spherical distribution of the real clusters in YZ would mean that their true distribution in the central regions is actually flattened toward the plane. Second, Keenan (1979) has investigated theoretically what happens to the orbits of "disk" globular clusters. He finds that the effects of dynamical friction on clusters that do spend most of their time in the disk are severe enough near the nucleus to cause these orbits to decay within $10^{10}$ y, so that such clusters are eventually absorbed into the nucleus. Taken at face value, these results indicate that nature has effectively frustrated our attempts to find out anything much about the hypothetical "disk" globular clusters: if any existed to begin with, they have long since been digested by the nucleus, and any that remain are tremendously obscured by many magnitudes of visual extinction.

The actual projected locations of all known clusters within 10° of the Galactic center are shown in Figure 4. Each cluster is plotted by its estimated value of E(B-V) (Harris and Racine 1979) where available, in units of 0.01 mag; clusters with unknown extinctions (mostly

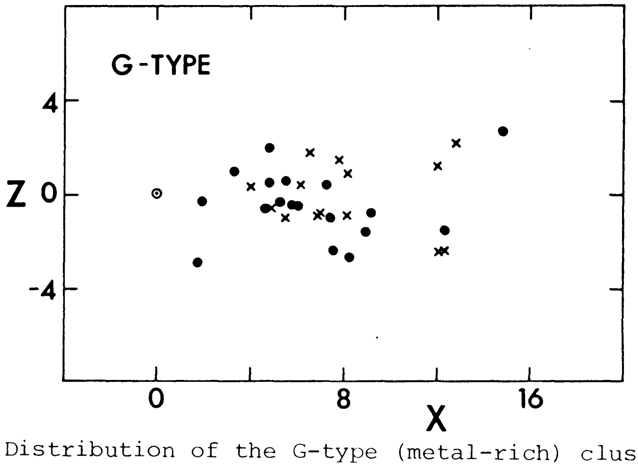


Figure 3. Distribution of the G-type (metal-rich) clusters in the XZ plane; symbols are as in Fig.1.

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Terzan objects) are indicated by dots, though it is likely that their reddenings must be ~ 1 mag or more. For any given angular distance from the center, even in this small region the reddenings decrease somewhat more rapidly away from the center if we go along the Z-axis ($l = 0^{\circ}$) than if we move in directions closer to the plane, in agreement with the picture of van den Bergh (1979). The actual absorbing layer is also noticeably thicker just above the plane than just below. However, it must be stated that the scatter of points in Fig. 4 is wide enough to permit agreement with model spheroidal distributions covering a significant range of ellipticities (horizontal to vertical axial ratios of ~ 0.6 to 1.4). Thus without a more complete sample of clusters in the Galactic center region, it seems risky to form any strong conclusions about the intrinsic structure of the cluster system there. The rough first-order assumption that the globular cluster system has spherical symmetry throughout is still quite workable for most purposes.

## APPENDIX

For the clusters in Table 2, the secondary distance measurement techniques used to calculate $V_{HB}$ include: (a) classical photographic measurements of the 25 brightest stars, as collected by Arp (1965); (b) mean $m_{pg}$ values for RR Lyrae stars as cataloged by Sawyer Hogg (1973) and others; (c) visual estimates of the brightest red giants by van den Bergh (1967); correlation of the Kukarkin (1974) richness index IR with the integrated absolute magnitude of the cluster; and (e) recent photo-

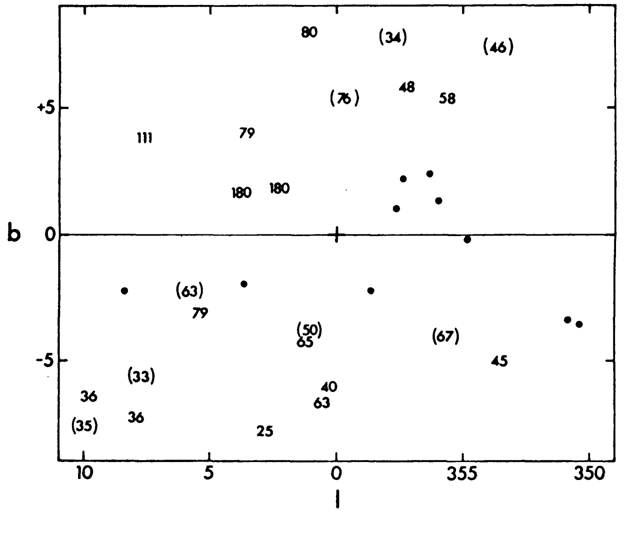


Figure 4. Locations of the clusters near the Galactic center as projected on the sky (latitude b vs. longitude l). Parentheses mark F-type clusters.

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metry of the V-magnitude level of the brightest red giants in several southern clusters, by Alcaino (1977) and Diamond (1976). The procedures for calibrating these indicators by the primary clusters in Table 1 are described in H76. All the relations involved were recalibrated here using the new $M_V$(HB) distance scale and the updated list of primary clusters (Table 1). The revised key numerical relations for each technique are as follows, where the notation and symbol definition follow H76:

(a) 25 brightest stars: $\delta B_{25} = -0.79 - 0.35\, M_{Vt} - 1.04\, (B-V)_0$
(b) RR Lyrae stars: $B_{HB} = \langle m_{pg} \rangle(RR) = V_{HB} + E(B-V) + 0.3$
(c) Brightest giants: $\delta V = 3.60 - 0.11\, M_{Vt} - 2.62\, (B-V)_0$
(d) Richness index: $M_{Vt} = -5.59\, IR - 4.67$

For the Alcaino and Diamond photometry, a mean difference of $\Delta V$(HB-BG) = 2.7 ± 0.3 was added to their mean magnitudes for the brightest giants, without dependence on cluster luminosity or color. The integrated colors $(B-V)_0$ and magnitudes $V_t$ of the clusters were taken where necessary from the catalog of Harris and Racine (1979). In general, weights of 2 were assigned to methods (a), (b), (c), and (e), and 1 to method (d) when forming the final averages given in Table 2.

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DISCUSSION

*KING:* With regard to the distance of the galactic center, there is one statistical test that you could make that I don't know that you or anyone else ever has made. When you think that you have a complete sample along the X-direction you ought to fold it around your center and see if you have the same distribution on one side of the center as on the other side of the center, which you should if there isn't incompleteness on the far side. I would suggest that that might be a very useful thing to do.

*HARRIS:* Yes.

*KRAFT:* When you discussed other methods, I noticed you left out any discussion of the work of a number of people who have tried to use the RR Lyraes in Baade's window directly to get the distance to the center.

*HARRIS:* Yes.

*KRAFT:* Since that is based exactly on the same distance scale as the cluster distance scale is based on, I'm a little confused as to why you didn't mention it. Do you have something against it?

*HARRIS:* Nothing at all; in fact the internal error in that method is a little lower than the globular cluster method.

*KRAFT:* So you have no objection to the method?

*HARRIS:* Oh, none at all. It's obviously a very valuable addition. It's just that globular clusters were the topic here.

*KRAFT:* That's what I thought, but you mentioned the word "other" and you sort of didn't say that at all, so I thought that, perhaps you were . . .

*HARRIS:* But this is not entirely independent, because it is still the Population II distance scale.