MORPHOLOGY OF GALACTIC GLOBULAR CLUSTERS

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Abstract We study shapes and sizes of 110 Galactic globular clusters (GCs) with the 2MASS Point Source Catalog. In general, Galactic GCs have spherical halos, with a median flattening of 0.1. GCs closer to the bulge show more circularized shapes and have smaller physical sizes. Intrinsically more luminous clusters, hence perhaps more massive, tend to be more circularized. Six GCs are highly flattened with flattening ≥ 0.3 Arp 2 and Pal 12 are known to be associated with the streamer of the Sagittarius dwarf galaxy. Pal 5 is being cannibalized by the Milky Way, UKS 1 and NGC 6355 are bulge globular clusters suffering strong tidal distortion. NGC 2419 is a halo member with a Galactocentric distance 90 kpc. Its flattened shape can not be accounted for. It may well be the remnant core of an already dissolved dwarf galaxy.

Keywords: globular clusters : tidal distortion : morphology

1. Introduction

The destruction of globular clusters (GCs) are crucial to the evolution of the host galaxy. The initial population of GCs must be substantially higher than the current one but the clusters close to the bulge should have particularly higher mortality due to bulge shocking. Stars from disintegrated GCs were accreted to, and likely now dominate the stellar populations of, the bulge and halo of the Milky Way galaxy Gnedin & Ostriker 1997. Nordquist et al. (1999) investigated the effect of the tidal force from a bulge on the shape of a GC in a close encounter, and concluded that a typical GC passing within several hundred pc from the bulge would suffer substantial distortion. They suggested the effect to be detectable in the bulge GCs NGC 6293 and NGC 6440.

Meylan & Mayor (1986) noticed that 47 Tuc and ω Cen are flattened, likely due to their overall rotation. White & Shawl (1987) determined the axial ratios and orientations of 100 GCs with blue sensitive plates, and found a mean axial ratio of 0.93 ± 0.01, which they attributed to the rotation of the clusters

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rather than to Galactic tidal interactions. We used the Two Micron All Sky Survey (2MASS) infrared data to determine the shapes and sizes of the halos of GCs, in order to investigate how the stellar distribution changes with cluster evolution and passage through Galactic environments, e.g., by tidal interactions from the Galactic bulge or the Sagittarius dwarf. In every GC field, stars brighter than $K_s \sim 15.6$ mag, i.e., the 3-σ detection of 2MASS are selected. Without membership information, we analyze the morphology of a star cluster with a star counting method Chen et al. 2004. The clustering parameter is defined as $P_i = (N_t - N_f)/N_t = 1 - N_f/N_t$, where N_t is the total number of neighbors within a specific angular region around the *i*th star and N_f is the average field star number in the same area. The area used is a circular region which contains 50 field stars. The clustering parameter gives a measure of the local stellar density enhancement ranging from $P_i \sim 0$ in a field region to $P_i \sim 1$ in a cluster. Thus it behaves like a probability of cluster membership.

The stellar surface number density is estimated by summing up the clustering parameters of all the stars within a sky-coordinate grid. The core of a GC naturally is not resolved by 2MASS. We focus on the halo of a GC, defined as where the density drops to 5 times the background fluctuations. The boundary of the halo is then fitted with an ellipse whose flattening ($f = 1 - b/a$, where a and b are semi-major and semi-minor axes respectively) and average size ($r = (a + b)/2$) could be derived. The typical error of f is a few percent. Figure 1 shows our analysis on the bulge GC NGC 6355.

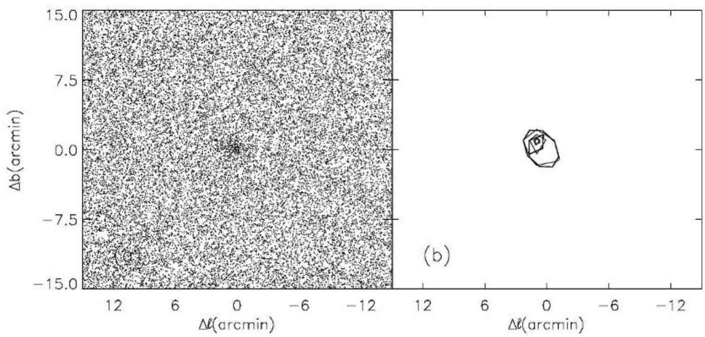

Figure 1. *Left*: The spatial distribution of 2MASS stars in the NGC 6355 field; *Right*: The computed effective stellar density contours.

2. Morphology of Globular Clusters

A total of 110 GCs selected from Harris (1996) with high enough density contrast ($\geq$ 5 times the background fluctuation) have been analyzed. The results are shown in Fig. 2. In general GC halos are circular/spherical (median f $\sim$ 0.12). The fraction of non-circular GCs is higher in our sample than in

White & Shawl (1987), who studied the cores of GCs, perhaps because the core of a GC tends to circularize by internal stellar encounters and the halo is more vulnerable to distortion by external perturbation. We also found that GCs closer to the bulge tend to be smaller and more circular. Intrinsically more luminous clusters, hence likely more massive, have more circular halos.

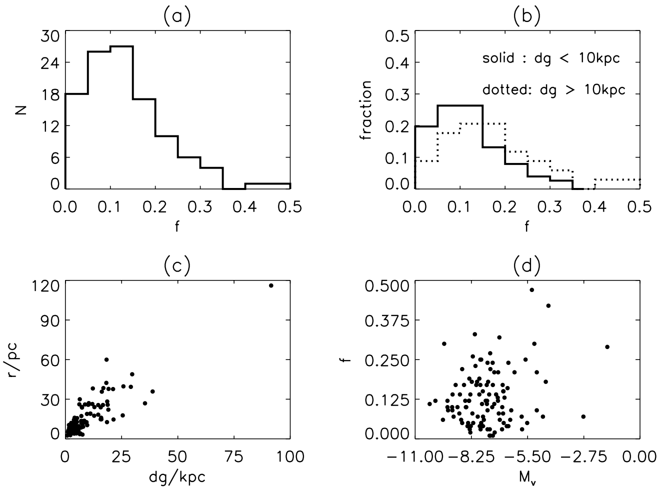

Figure 2. a) Distribution of flattening of GCs. b)Flattening for GCs close to and away from the bulge. c) The physical size vs Galactocentric distance d) Flattening vs absolute visual magnitude

None of the two bulge GCs, NGC 6293 and NGC 6440, suspected by Nordquist et al. (1999) to have distorted shapes, show detectable elongation in our analysis. We note 6 GCs with highly flattened shapes, $f \geq 0.3$. These 6 GCs, together with NGC 6293 and NGC 6440 are listed in Table 1, for which the first 5 columns give, respectively, the name of the cluster, its coordinates, heliocentric (d_s) and Galactocentric (d_g) distances, and the absolute magnitude, all taken from Harris (1996). The last 3 columns list the derived average angular radius (θ), physical size (r) and flattening (f) from our analysis.

Arp 2 and Pal 12, both known to be associated with the Sagittarius tidal stream van den Bergh & Mackey 2004 show significant elongation. Pal 12 is elongated roughly toward the direction of the tidal stream but Arp 2 points orthogonal to it. Odenkirchen et al. (2003) found a tidal tail associated with Pal 5 which extends more than 10 deg. They deduced that the cluster, being cannibalized by the Milky Way galaxy, is presently near the apocenter but has undergone several disk crossings, resulting in strong tidal shocks. Our data on Pal 5 are limited by the 1 deg field of view set by the 2MASS database interface, thus detect flattening only for the inner part of the cluster. UKS 1 and NGC 6355 are both bulge GCs, with the projected elongation in either

Table 1. Morphological Parameters of Globular Clusters

Name	(l,b) (deg,deg)	d_s (kpc)	d_g (kpc)	M_V	θ (arcmin)	r (pc)	f
NGC 6293	(357.62, +07.83)	8.8	1.4	-7.77	2.60	6.7	0.05
NGC 6440	(007.73, +03.80)	8.4	1.3	-8.75	2.54	6.2	0.06
Arp 2	(008.55, -20.78)	28.6	21.4	-5.29	1.76	14.6	0.47
Pal 12	(030.51, -47.68)	19.1	15.9	-4.48	2.88	16.0	0.42
Pal 5	(000.85, +45.86)	23.2	18.6	-5.17	4.19	28.3	0.30
UKS 1	(005.12, +00.76)	8.3	0.8	-6.88	1.02	2.3	0.32
NGC 6355	(359.58, +05.43)	9.5	1.8	-8.08	1.89	5.2	0.33
NGC 2419	(180.37, +25.24)	84.2	91.5	-9.58	4.74	116.1	0.30

case pointing to the direction of the Galactic bulge, a clear manifestation of tidal distortion. NGC 2419 is a halo member, away from the Galactic disk (35.9 kpc) and the bulge (90 kpc). It is one of the five most luminous Galactic globular clusters, and among the most metal-poor Galactic GCs, with [Fe/H] ~ -2.4 (Harris et al. 1997). There is no obvious cause for its flattened shape. It may well be in a late stage of disintegration or as the remnant core of a dissolved dwarf galaxy.

References

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