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STRUCTURAL AND DYNAMICAL PROPERTIES OF 29 GALACTIC GLOBULAR CLUSTERS[1]

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ABSTRACT

We use B band CCD images to investigate the surface brightness distributions and dynamical properties of 29 Galactic globular clusters. Model fits suggest that 22 clusters show King type surface brightness profiles, while 7 clusters are characterized by power law cusp profiles. For the King type clusters, concentration parameters ($c = log(r_t/r_c)$) range from 1.20 to 2.10, and core radii are 0.4 to 1.9 pc. The mean value of power law slopes of 7 cuspy clusters was estimated as $\alpha = 1.011 \pm 0.065$. Total masses of King type globular clusters are in the range of $1.7 \times 10^4 M_\odot$ to $1.0 \times 10^6 M_\odot$ with a mean of $1.7 \times 10^5 M_\odot$. A significant positive correlation between mass and mass-to-light ratio of King type globular clusters has been confirmed with a Pearson's correlation coefficient $r = 0.52$ and a confidence level of 99%. Our data also confirm a linear relation between total mass and absolute magnitude of King type globular clusters.

1. INTRODUCTION

It has long been known that the surface brightness profiles of Galactic globular clusters reflect their dynamical evolutionary history. Two different morphological types of globular clusters have been identified from the shape of their surface brightness distributions. Clusters of post-core-collapse are characterized by power law surface brightness profiles with a central cusp. This distinguishes them from the flat-core clusters whose profiles are well described by the King (1966) models (Djorgovski & King 1984, 1986, Djorgovski 1988). Trager *et al.* (1993) derived a range of concentration ($c = log(r_t/r_c)$) of King type clusters from 0.5 to 2.45, while Djorgovski & King (1986) found that

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$\sim$ 20% of Galactic globular clusters shows a power law cusp in their surface brightness distribution. Convincing color gradients have been reported for the post-core-collapse clusters exclusively, with centers becoming bluer (Djorgovski *et al.* 1988, Piotto *et al.* 1988, Djorgovski *et al.* 1991a, 1991b, Djorgovski & Piotto 1993). However, Sohn *et al.* (1996) have recently shown that despite of its King type surface brightness distribution, NGC 7089 possesses considerable color gradient with blue center. They also detected color gradients in the central regions of King type clusters NGC 6402 and NGC 6934, although color variations can be weaker for these clusters.

Recentely, Trager *et al.* (1995) presented a catalogue of surface brightness profiles of 125 Galactic globular clusters. However, they have used a combined data set of their own CCD and photographic observations with several other observational methods to generate their final surface brightness profiles from near the cluster center to the outer envelope. A through survey of the Galactic globular cluster system with a small telescope mounted with a large format CCD of moderate scale is still needed to produce a much more homogeneous set of surface brightness profiles and thus to derive the dynamical parameters of greater quality.

In the present paper, we use B CCD images recorded with the 1-m telescope at Siding Spring Observatory to investigate surface brightness profiles of 29 Galactic globular clusters. The observations and data reductions are described in Sec. 2. In Sec. 3, we derive surface brightness distributions and dynamical structural parameters. Correlations among properties of King type globular clusters, such as mass, mass-to-light ratio, and absolute magnitude are discussed in Sec. 4. Our results are summarized in Sec. 5.

2. OBSERVATIONS AND DATA REDUCTION

The CCD imaging observations were carried out in May and August 1991 using the Australian National University 1-m telescope at Siding Spring Observatory. Data were recorded through B band filter for 29 Galactic globular clusters. We used a EEV P8063A 576 $\times$ 380 CCD chip. At the f/8 Cassegrain focus, the image scale is $0.56''$/pixel, which gives a sky coverage of $5'.4 \times 3'.5$. The journal of the observation is given in Table 1.

The raw images were reduced using standard CCD processing techniques in IRAF. A median bias frame was subtracted from the raw exposures, and the results were divided by the twilight sky flat field image.

3. SURFACE BRIGHTNESS PROFILES AND STRUCTURAL PARAMETERS

A surface brightness profile for each cluster is extracted from the image using techniques similar to Djorgovski (1988) and Piotto *et al.* (1988). The cluster center was determined from a smoothed image processed by a boxcar median filtering with a typical width of 20 to 30 pixels. Sky level has been determined by measuring mean intensities per unit area for several circular regions of varying sizes on the sky frames, which were distant enough to be free from cluster member stars. The median value of these measurements was adopted as sky level and subtracted from the cluster image.

The cluster image is divided into eight azimuthal sectors and also divided radially into several concentric annuli of logarithmic radius increments. For each annulus, we define an effective radius

Table 1. Observational log.

Name	Exp.(sec)	X	seeing($''$)	Date	Name	Exp.(sec)	X	seeing($''$)	Date
NGC 104	100	1.357	2.04	Aug.10/11 1991	NGC6402	400	1.147	2.04	Aug.11/12 1991
NGC 362	500	1.303	2.95	Aug.13/14 1991	NGC6440	400	1.027	2.46	Aug.13/14 1991
NGC2298	400	1.574	3.12	May 15/16 1991	NGC6553	400	1.040	2.07	Aug.11/12 1991
NGC2808	350	1.359	2.78	May 15/16 1991	NGC6584	400	1.083	2.30	Aug.12/13 1991
NGC5024	400	1.539	2.98	May 16/17 1991	NGC6624	500	1.007	2.61	Aug.13/14 1991
NGC5634	250	1.251	2.36.	Aug.11/12 1991	NGC6637	400	1.008	2.95	May 16/17 1991
NGC5904	400	1.301	2.59	Aug.10/11 1991	NGC6638	400	1.087	2.71	May 16/17 1991
NGC6712	300	1.061	2.21	Aug.11/12 1991	NGC6681	300	1.070	2.43	May 15/16 1991
NGC6266	400	1.002	2.01	Aug.12/13 1991	NGC6712	400	1.089	2.95	Aug.14/15 1991
NGC6273	400	1.069	2.79	May 16/17 1991	NGC6752	400	1.179	4.21	Aug.14/15 1991
NGC6284	400	1.012	2.39	Aug.13/14 1991	NGC6838	400	1.565	2.08	Aug.12/13 1991
NGC6333	400	1.035	2.96	May 16/17 1991	NGC6934	400	1.284	2.86	Aug.13/14 1991
NGC6355	400	1.033	2.87	Aug.10/11 1991	NGC7089	400	1.376	3.85	Aug.13/14 1991
NGC6388	400	1.043	2.68	Aug.14/15 1991	NGC7099	400	1.016	2.73	Aug.12/13 1991
NGC6397	200	1.083	1.97	Aug.12/13 1991					

$r_e = [\frac{1}{2}(r_1^2 + r_2^2)]^{\frac{1}{2}}$, where r_1 and r_2 are the inner and outer radii of the annulus. The local surface brightness at an effective radius was determined by taking the median of the eight sector measurements to eliminate contamination from bright stars. Finally, their radial surface brightness distributions have been fit to the theoretical isothermal King (1966) models and power-law models. Twenty two clusters are better fit by a King type profiles, while 7 clusters have a power law cusp in the central part of their surface brightness distributions. These results are in good agreement with Chernoff & Djorgovski (1989) and Trager *et al.* (1993). Trager *et al.* (1993) pointed out that the surface brightness profiles of NGC 362 and NGC 6266 are too ambiguous for proper classification. We were able to assign convincingly a King profile with $c = 1.75$ to NGC 362 and $c = 1.80$ NGC 6266.

The resulting B band median surface brightness distributions for 22 King type clusters and for 7 post-core-collapse clusters are listed in Table 2 and Table 3, respectively. The errors correspond to the standard deviation of the eight sector values with respect to the median surface brightness for each annulus. Surface brightness profiles of 22 King type clusters are shown in Figure 1 and compare to theoretical King models with the core radius (r_c) and concentric parameter ($c = log(r_t/r_c)$). The errors for $logr_c$ and $logr_t$ are estimated to be ~ 0.1. Table 4 lists the derived dynamical structure parameters for each King type clusters. The parameters derived by Trager *et al.* (1993) and Peterson & King (1975) are also given in Table 4 for comparison. We find good agreements in most cases. The measured concentric parameters and core radii range from 1.20 to 2.10 and 0.4 to 1.9 pc for all clusters, respectively. The absolute scales were calculated using distances obtained from the mean apparent magnitudes of horizontal branch stars (Sohn 1994). Figure 2 shows the surface brightness profiles of 7 post-core-collapse clusters; α represents the slope of the power law obtained by a fit to the observed surface brightness distribution. Slopes for 7 post-core-collapse clusters are listed in Table 5, the mean value is $\alpha = 1.011 \pm 0.065$. This is in excellent agreement with Djorgovski & King (1984, 1986).

Table 2. Surface brightness distributions of 22 King type globular clusters.

$log(r''_e)$	$\Sigma(B)$	σ	$log(r''_e)$	$\Sigma(B)$	σ	$log(r''_e)$	$\Sigma(B)$	σ
	N 104			N 362			N2298	
0.541	-6.185	0.020	0.228	-6.173	0.009	0.241	-8.057	0.026
0.747	-6.215	0.018	0.434	-6.229	0.016	0.447	-8.071	0.031
0.847	-6.222	0.016	0.534	-6.290	0.027	0.547	-8.042	0.019
0.947	-6.200	0.022	0.634	-6.312	0.025	0.647	-8.101	0.030
1.047	-6.222	0.021	0.734	-6.336	0.015	0.747	-8.210	0.047
1.147	-6.287	0.026	0.834	-6.423	0.011	0.847	-8.209	0.020
1.247	-6.305	0.015	0.934	-6.488	0.016	0.947	-8.275	0.057
1.347	-6.398	0.008	1.034	-6.568	0.008	1.047	-8.244	0.086
1.447	-6.566	0.010	1.134	-6.688	0.013	1.147	-8.298	0.059
1.547	-6.688	0.016	1.234	-6.750	0.023	1.247	-8.432	0.031
1.647	-6.798	0.009	1.334	-6.973	0.030	1.347	-8.355	0.037
1.747	-6.942	0.027	1.434	-7.123	0.017	1.447	-8.716	0.047
1.847	-7.087	0.011	1.534	-7.266	0.020	1.547	-8.711	0.039
1.947	-7.271	0.011	1.634	-7.432	0.017	1.647	-8.927	0.023
			1.734	-7.669	0.022	1.747	-9.127	0.078
			1.834	-7.856	0.016	1.847	-9.464	0.105
			1.934	-8.070	0.017			
	N2808			N5024			N5634	
0.159	-6.798	0.013	0.841	-7.695	0.022	0.117	-7.273	0.007
0.365	-6.784	0.021	1.047	-7.717	0.024	0.323	-7.315	0.031
0.465	-6.827	0.024	1.147	-7.761	0.030	0.423	-7.384	0.010
0.565	-6.827	0.019	1.247	-7.797	0.020	0.523	-7.459	0.028
0.665	-6.900	0.015	1.347	-7.911	0.019	0.623	-7.445	0.022
0.765	-6.889	0.013	1.447	-8.026	0.013	0.723	-7.400	0.023
0.865	-6.924	0.008	1.547	-8.198	0.007	0.823	-7.483	0.029
0.965	-6.967	0.008	1.647	-8.261	0.018	0.923	-7.533	0.055
1.065	-7.048	0.014	1.747	-8.500	0.046	1.023	-7.617	0.049
1.165	-7.119	0.016	1.847	-8.641	0.016	1.123	-7.745	0.026
1.265	-7.204	0.009	1.947	-8.911	0.028	1.223	-7.787	0.022
1.365	-7.326	0.016				1.323	-7.995	0.018
1.465	-7.454	0.012				1.423	-8.118	0.024
1.565	-7.579	0.014				1.523	-8.320	0.024
1.665	-7.761	0.010				1.623	-8.599	0.028
1.765	-7.954	0.017						
1.865	-8.155	0.021						
	N5904			N6171			N6266	
0.715	-6.815	0.046	0.988	-8.123	0.033	0.260	-6.591	0.020
0.921	-6.780	0.028	1.194	-8.099	0.105	0.466	-6.661	0.016
1.021	-6.776	0.025	1.294	-8.027	0.052	0.566	-6.628	0.027
1.121	-6.857	0.027	1.394	-8.129	0.059	0.666	-6.709	0.017
1.221	-6.931	0.018	1.494	-8.347	0.053	0.766	-6.734	0.018
1.321	-6.937	0.024	1.594	-8.426	0.066	0.866	-6.792	0.018
1.421	-7.056	0.020	1.694	-8.502	0.013	0.966	-6.862	0.017
1.521	-7.193	0.024	1.794	-8.609	0.032	1.066	-6.989	0.030
1.621	-7.304	0.027	1.894	-8.825	0.024	1.166	-7.061	0.020
1.721	-7.434	0.044				1.266	-7.194	0.023
1.821	-7.680	0.020				1.366	-7.262	0.023
1.921	-7.809	0.018				1.466	-7.432	0.010
						1.566	-7.546	0.008
						1.666	-7.727	0.019
						1.766	-7.917	0.019
						1.866	-8.141	0.020
						1.966	-8.288	0.047

Table 2. (continued)

$log(r_e'')$	$\Sigma(B)$	σ	$log(r_e'')$	$\Sigma(B)$	σ	$log(r_e'')$	$\Sigma(B)$	σ
	N6273			N6333			N6388	
0.788	-7.603	0.011	0.495	-7.751	0.060	0.241	-6.284	0.007
0.994	-7.673	0.025	0.701	-7.666	0.048	0.447	-6.355	0.018
1.094	-7.730	0.022	0.801	-7.775	0.055	0.547	-6.376	0.018
1.194	-7.766	0.030	0.901	-7.739	0.047	0.647	-6.460	0.016
1.294	-7.834	0.012	1.001	-7.762	0.031	0.747	-6.495	0.010
1.394	-7.894	0.012	1.101	-7.911	0.027	0.847	-6.582	0.013
1.494	-7.946	0.023	1.201	-7.929	0.040	0.947	-6.642	0.007
1.594	-8.065	0.031	1.301	-7.967	0.025	1.047	-6.756	0.007
1.694	-8.172	0.028	1.401	-8.018	0.027	1.147	-6.898	0.010
1.794	-8.292	0.042	1.501	-8.178	0.025	1.247	-7.022	0.010
1.894	-8.554	0.044	1.601	-8.346	0.023	1.347	-7.223	0.014
			1.701	-8.477	0.017	1.447	-7.376	0.006
			1.801	-8.639	0.048	1.547	-7.578	0.008
						1.647	-7.805	0.009
						1.747	-7.981	0.025
						1.847	-8.202	0.034
	N6402			N6440			N6553	
0.541	-7.776	0.030	0.295	-7.634	0.008	0.344	-7.797	0.084
0.747	-7.805	0.049	0.501	-7.634	0.014	0.550	-7.920	0.166
0.847	-7.784	0.028	0.601	-7.725	0.027	0.650	-7.875	0.056
0.947	-7.855	0.030	0.701	-7.785	0.024	0.750	-7.969	0.038
1.047	-7.886	0.022	0.801	-7.857	0.026	0.850	-7.982	0.037
1.147	-7.906	0.021	0.901	-7.946	0.014	0.950	-7.989	0.010
1.247	-7.833	0.019	1.001	-8.038	0.016	1.050	-8.030	0.012
1.347	-7.931	0.021	1.101	-8.191	0.017	1.150	-8.010	0.027
1.447	-7.950	0.015	1.201	-8.320	0.010	1.250	-8.032	0.017
1.547	-8.036	0.022	1.301	-8.513	0.015	1.350	-8.116	0.024
1.647	-8.157	0.017	1.401	-8.690	0.012	1.450	-8.172	0.018
1.747	-8.250	0.014	1.501	-8.813	0.028	1.550	-8.281	0.025
1.847	-8.419	0.024	1.601	-9.030	0.014	1.650	-8.324	0.126
1.947	-8.565	0.016	1.701	-9.214	0.022	1.750	-8.443	0.137
			1.801	-9.429	0.031	1.850	-8.665	0.071
	N6584			N6637			N6638	
0.241	-7.302	0.041	0.436	-7.522	0.035	0.548	-7.767	0.006
0.447	-7.553	0.034	0.642	-7.543	0.035	0.854	-7.801	0.031
0.547	-7.689	0.063	0.742	-7.527	0.026	0.754	-7.817	0.028
0.647	-7.583	0.039	0.842	-7.538	0.026	0.954	-7.837	0.028
0.747	-7.680	0.071	0.942	-7.577	0.023	1.054	-7.962	0.030
0.847	-7.660	0.049	1.042	-7.598	0.025	1.154	-8.064	0.020
0.947	-7.713	0.050	1.142	-7.722	0.020	1.254	-8.218	0.018
1.047	-7.668	0.039	1.242	-7.784	0.024	1.354	-8.377	0.022
1.147	-7.802	0.037	1.342	-7.871	0.019	1.454	-8.548	0.025
1.247	-7.842	0.040	1.442	-8.060	0.018	1.554	-8.676	0.010
1.347	-7.988	0.049	1.542	-8.185	0.016	1.654	-8.936	0.027
1.447	-8.068	0.024	1.642	-8.314	0.021	1.754	-9.038	0.013
1.547	-8.265	0.040	1.742	-8.524	0.042	1.854	-9.266	0.040
1.647	-8.323	0.029	1.842	-8.775	0.022	1.954	-9.396	0.026
1.747	-8.428	0.021	1.942	-8.969	0.055			
1.847	-8.657	0.044						
1.947	-8.788	0.036						

Table 2. (continued)

$log(r''_e)$	$\Sigma(B)$	σ	$log(r''_e)$	$\Sigma(B)$	σ	$log(r''_e)$	$\Sigma(B)$	σ
	N6712			N6838			N6934	
0.628	-7.686	0.017	0.702	-8.171	0.123	0.228	-7.051	0.028
0.834	-7.816	0.039	0.908	-8.113	0.257	0.434	-7.189	0.052
0.934	-7.938	0.043	1.008	-7.946	0.066	0.534	-7.115	0.027
1.034	-7.998	0.055	1.108	-8.165	0.068	0.634	-7.239	0.040
1.134	-7.872	0.023	1.208	-8.215	0.080	0.734	-7.269	0.023
1.234	-7.899	0.052	1.308	-7.879	0.128	0.834	-7.267	0.024
1.334	-8.050	0.022	1.408	-8.071	0.094	0.934	-7.375	0.051
1.434	-8.033	0.096	1.508	-8.248	0.065	1.034	-7.379	0.027
1.534	-8.128	0.060	1.608	-8.280	0.055	1.134	-7.481	0.027
1.634	-8.269	0.042	1.708	-8.224	0.021	1.234	-7.627	0.030
1.734	-8.429	0.033	1.808	-8.355	0.035	1.334	-7.751	0.025
1.834	-8.482	0.055	1.908	-8.595	0.074	1.434	-7.909	0.016
1.934	-8.675	0.028				1.534	-8.100	0.026
						1.634	-8.353	0.013
						1.734	-8.556	0.061
						1.834	-8.726	0.021
						1.934	-9.017	0.049
	N7089							
0.428	-6.544	0.004						
0.634	-6.585	0.010						
0.734	-6.592	0.008						
0.834	-6.622	0.011						
0.934	-6.628	0.014						
1.034	-6.710	0.013						
1.134	-6.765	0.011						
1.234	-6.825	0.009						
1.334	-6.933	0.010						
1.434	-7.056	0.015						
1.534	-7.207	0.014						
1.634	-7.348	0.013						
1.734	-7.552	0.019						
1.834	-7.792	0.014						
1.934	-7.932	0.028						

4. DYNAMICAL PROPERTIES OF KING TYPE CLUSTERS

4.1 Masses

The total mass of each King type cluster was derived following the method of Illingworth (1976) parameterized in terms of the core radius r_c and the central velocity dispersion σ_o; *i.e.* $M(M_\odot) = 166.7 r_c(\mathrm{pc})\mu\sigma_o^2(\mathrm{kms}^{-2})$. μ is a dimensionless mass parameter, $\mu = \int_0^{R_t} 4\pi R^2(\rho/\rho_c)dR$, where $R = r/r_c$ and $R_t = r_t/r_c$.

Masses derived from a single mass King model are listed in column 6 and 7 of Table 6. These estimates are based on central velocity dispersions by Pryor & Meylan (1993) and Peterson & King (1975). The total masses of King type globular clusters are in range of $1.78 \times 10^4 M_\odot$ (NGC 6838) to $1.02 \times 10^6 M_\odot$ (NGC 6388) with a mean of $1.73 \times 10^5 M_\odot$.

Table 3. Surface brightness distributions of 7 post-core-collapse clusters.

$log(r_e'')$	$\Sigma(B)$	σ	$log(r_e'')$	$\Sigma(B)$	σ	$log(r_e'')$	$\Sigma(B)$	σ
	N6284			N6355			N6397	
0.119	-6.903	0.012	0.688	-8.163	0.031	0.641	-6.802	0.038
0.325	-7.067	0.038	0.894	-8.200	0.053	0.847	-7.041	0.052
0.425	-7.117	0.021	0.994	-8.260	0.052	0.947	-7.102	0.117
0.525	-7.257	0.019	1.094	-8.323	0.027	1.047	-7.279	0.040
0.625	-7.298	0.016	1.194	-8.435	0.043	1.147	-7.251	0.018
0.725	-7.379	0.031	1.294	-8.622	0.027	1.247	-7.226	0.091
0.825	-7.435	0.029	1.394	-8.757	0.158	1.347	-7.486	0.061
0.925	-7.540	0.011	1.494	-8.888	0.035	1.447	-7.394	0.058
1.025	-7.649	0.033	1.594	-8.981	0.020	1.547	-7.439	0.062
1.125	-7.732	0.042	1.694	-9.112	0.062	1.647	-7.339	0.038
1.225	-7.823	0.025	1.794	-9.442	0.031	1.747	-7.568	0.042
1.325	-7.986	0.021	1.894	-9.381	0.033	1.847	-7.775	0.077
1.425	-8.114	0.025				1.947	-7.895	0.054
1.525	-8.319	0.016						
1.625	-8.548	0.061						
1.725	-8.653	0.046						
	N6624			N6681			N6752	
0.174	-6.578	0.008	0.115	-6.837	0.013	0.336	-6.367	0.007
0.380	-6.741	0.011	0.321	-7.050	0.028	0.542	-6.426	0.017
0.480	-6.770	0.020	0.421	-7.093	0.023	0.642	-6.444	0.018
0.580	-6.910	0.025	0.521	-7.173	0.025	0.742	-6.492	0.021
0.680	-6.946	0.021	0.621	-7.218	0.033	0.842	-6.533	0.022
0.780	-7.056	0.022	0.721	-7.294	0.027	0.942	-6.587	0.029
0.880	-7.148	0.038	0.821	-7.404	0.025	1.042	-6.634	0.036
0.980	-7.295	0.039	0.921	-7.512	0.029	1.142	-6.794	0.035
1.080	-7.421	0.026	1.021	-7.661	0.066	1.242	-6.873	0.020
1.180	-7.455	0.016	1.121	-7.814	0.064	1.342	-6.966	0.029
1.280	-7.597	0.016	1.221	-7.852	0.021	1.442	-7.072	0.034
1.380	-7.713	0.013	1.321	-7.911	0.031	1.542	-7.190	0.026
1.480	-7.873	0.017	1.421	-8.027	0.032	1.642	-7.289	0.083
1.580	-7.982	0.011	1.521	-8.256	0.035	1.742	-7.385	0.011
1.680	-8.127	0.012	1.621	-8.465	0.022	1.842	-7.579	0.015
1.780	-8.242	0.012	1.721	-8.590	0.030	1.942	-7.671	0.021
1.880	-8.377	0.009	1.821	-8.771	0.027			
	N7099							
0.128	-6.410	0.015						
0.334	-6.525	0.046						
0.434	-6.563	0.023						
0.534	-6.629	0.021						
0.634	-6.749	0.038						
0.734	-6.800	0.026						
0.834	-6.854	0.040						
0.934	-6.977	0.030						
1.034	-7.100	0.034						
1.134	-7.131	0.031						
1.234	-7.262	0.035						
1.334	-7.382	0.026						
1.434	-7.530	0.036						
1.534	-7.678	0.040						
1.634	-7.848	0.044						
1.734	-8.124	0.071						
1.834	-8.212	0.021						
1.934	-8.412	0.025						

We note, however, that only $\sim$ 1 km s^{-1} error in central velocity dispersion can induce $\sim$ 50% error to the total mass of a cluster (cf. Meylan 1989). Therefore, high resolution spectroscopic observations of the central region of globular cluster as well as accurate deep photometry are needed to estimate accurate total masses of each globular clusters.

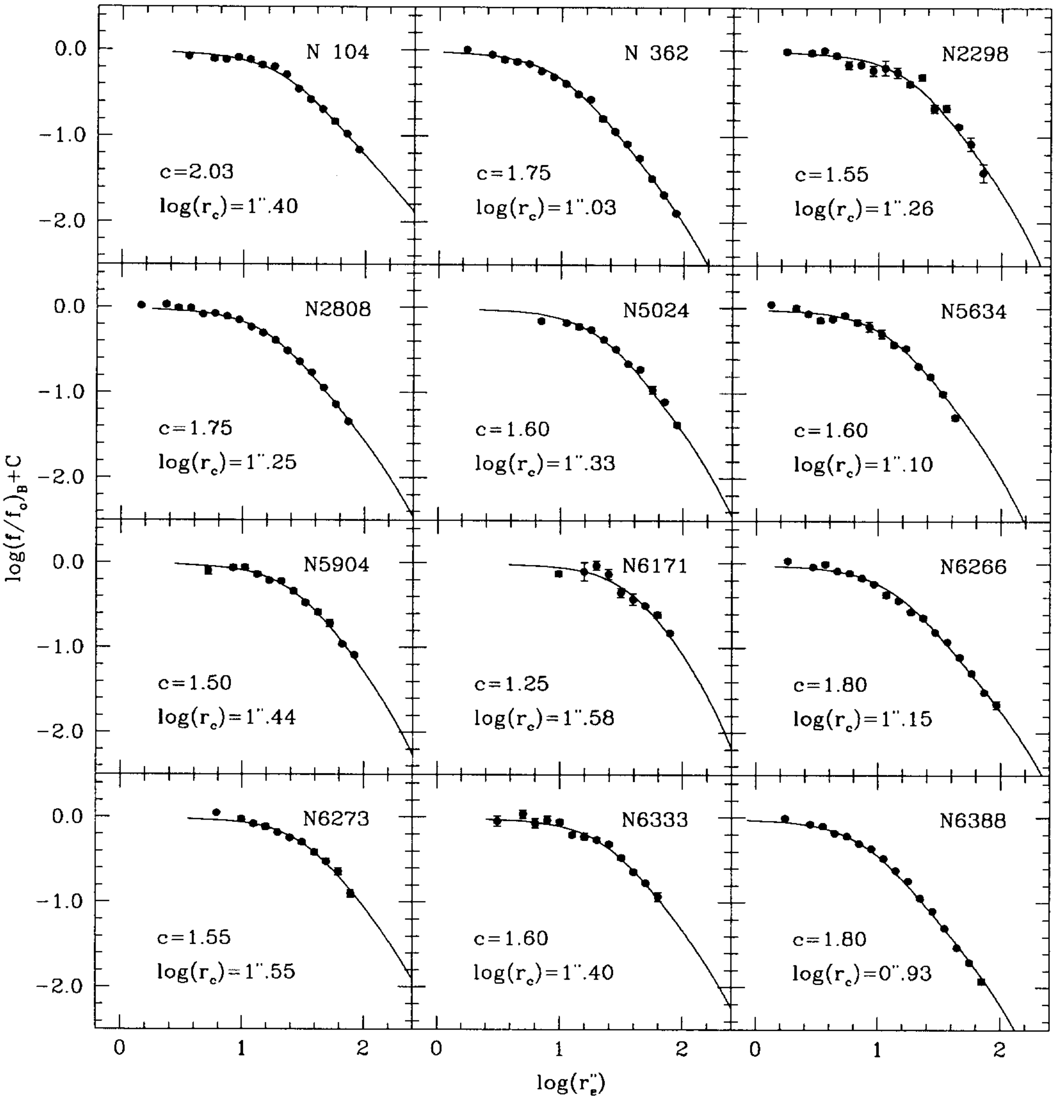

Figure 1. *B* band radial surface brightness profiles of 22 King type clusters. Single mass isotropic King model fits are also illustrated (full lines) with concentric parameter c and dynamical core radius r_c.

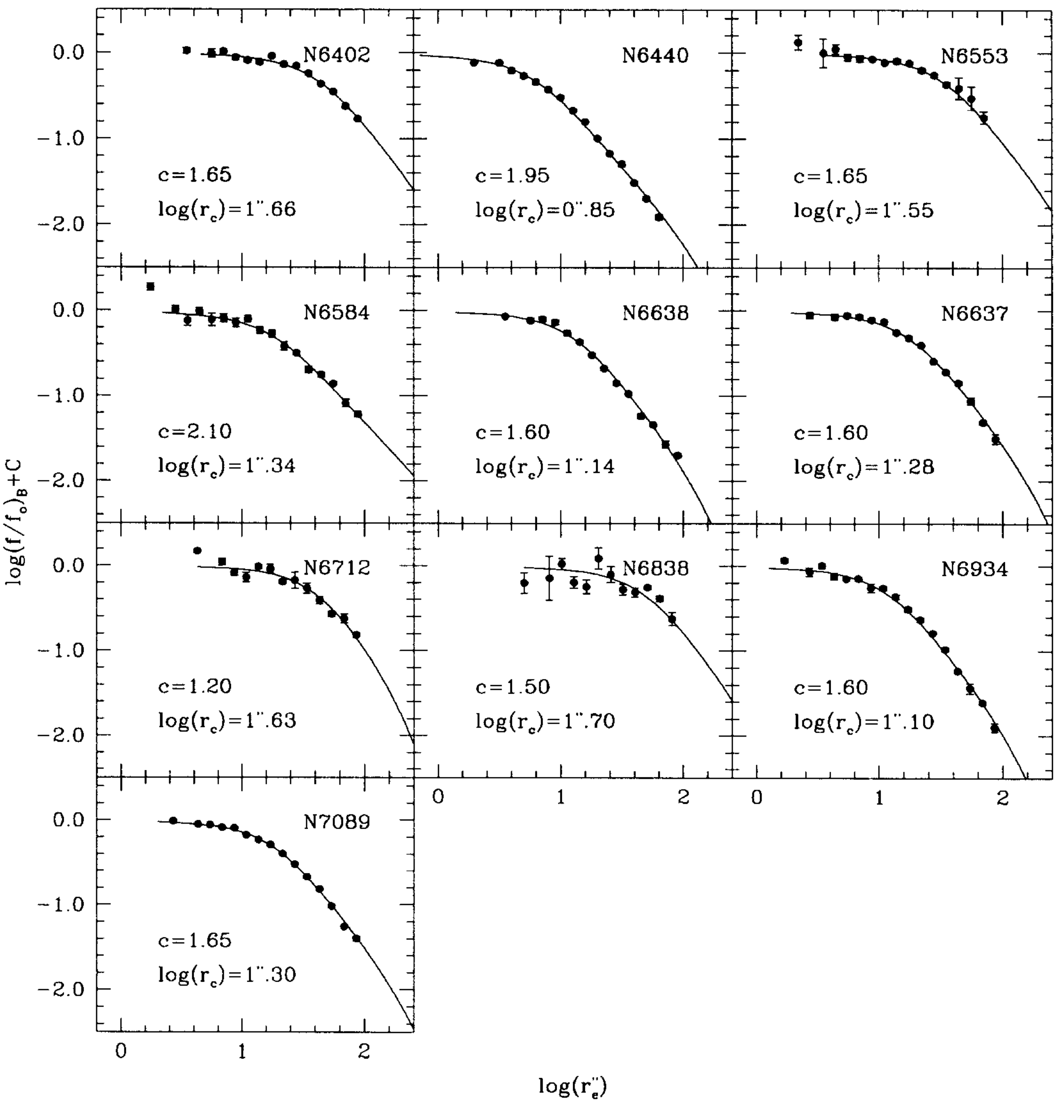

Figure 1. (continued)

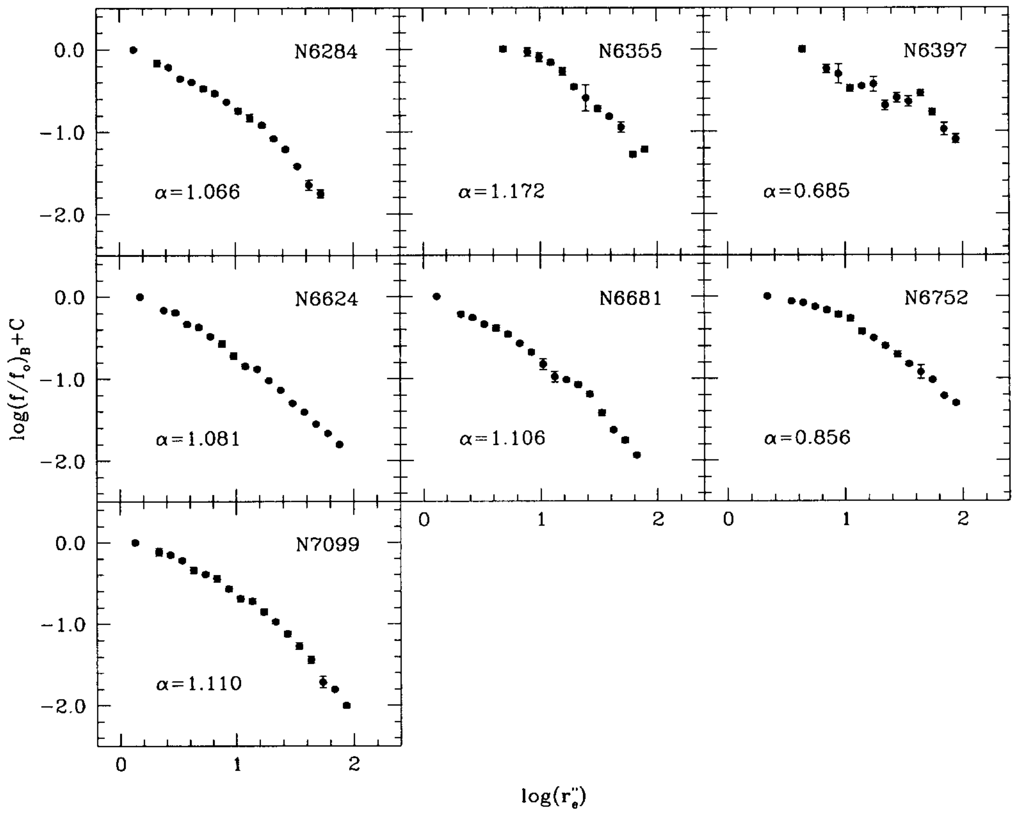

Figure 2. B band radial surface brightness profiles of 7 post-core-collapse clusters. The power law slope, α, is given for each cluster.

4.2 The Relation between Mass and Mass-to-Light Ratio

From the surface photometry of 32 Galactic globular clusters, Mandushev *et al.* (1991) derived a relation between total mass and luminosity of globular clusters. Their mass-to-light ratios are in range of 0.66 $\sim$ 2.9, and correlate linearly with the total mass of clusters. On the other hand, Pryor & Meylan (1993) estimated mass-to-light ratios of 56 globular clusters using the multi-masses King model, and found no evidence for any significant correlation of mass-to-light ratios with cluster positions, metallicities, concentrate parameters, and dynamical relaxation time scales.

Absolute V magnitudes of 22 clusters (Djorgovski 1993) are listed in column 8 of Table 6. Mass-to-light ratios of each clusters are shown in columns 9 and 10, and are also based on central velocity dispersions from Pryor & Meylan (1993) and Peterson & King (1975), respectively. We assume the absolute magnitude of sun is 4.79 mag in V. We derive a mean value of mass-to-light ratio of 1.25 ± 0.48, which is in good agreement with Mandushev *et al.* (1991).

Table 4. Dynamical parameters for 22 King type globular clusters.

Name	$log(r_t/r_c)$			$log(r_c'')$			d(kpc)		$r_c(pc)$
	SCB	TDK	PK	SCB	TDK	PK	Pet	Sohn	
N 104	2.03	2.04	2.03	1.40	1.35	1.45	4.6	3.9	0.47±0.11
N 362	1.75	1.94		1.03	1.01	1.15	8.6	8.6	0.45±0.10
N2298	1.55	1.28		1.26	1.31	1.42	10.1	10.3	0.91±0.21
N2808	1.75	1.77		1.25	1.20	1.29	9.2	9.1	0.78±0.18
N5024	1.60	1.78	1.67	1.33	1.35	1.45	18.5	19.7	2.04±0.47
N5634	1.60	1.60		1.10	1.10	1.23	25.0	25.5	1.56±0.36
N5904	1.50	1.87	1.78	1.44	1.38	1.46	7.6	7.2	0.96±0.22
N6171	1.25	1.51		1.58	1.51	1.63	6.4	5.8	1.07±0.25
N6266	1.80	1.70		1.15	1.03	1.22	5.5	5.7	0.39±0.09
N6273	1.55	1.53		1.55	1.41	1.63	10.8		1.86±0.43
N6333	1.60	1.15		1.40	1.54	1.38	7.5	7.5	0.91±0.21
N6388	1.80	1.70		0.93	0.87	1.13	11.0		0.45±0.01
N6402	1.65	1.60	1.10	1.66	1.70	1.68	10.1	8.7	1.93±0.44
N6440	1.95	1.70		0.85	0.88	0.90	7.0		0.24±0.06
N6553	1.65	1.17		1.55	1.52	1.62	3.5		0.60±0.14
N6584	2.10	1.20		1.34	1.55	1.38	9.6	11.9	1.26±0.29
N6638	1.60	1.40		1.14	1.20	1.25	8.5	8.2	0.55±0.13
N6637	1.60	1.39		1.28	1.31	1.30	10.1	7.6	0.70±0.16
N6712	1.20	0.90		1.63	1.75	1.69	6.8	6.4	1.32±0.30
N6838	1.50	1.15		1.70	1.58	1.69	3.9	3.4	0.83±0.19
N6934	1.60	1.53	1.35	1.10	1.17	1.38	14.9	14.7	0.90±0.21
N7089	1.65	1.80	1.61	1.30	1.31	1.38	11.9	11.4	1.10±0.25

SCB: This paper, TDK: Trager *et al.* (1993), PK: Peterson & King (1975), Pet: Peterson (1993), Sohn: Sohn (1994)

Table 5. Power law slopes of post-core-collapse clusters.

Name	α
N6284	1.066±0.055
N6355	1.172±0.085
N6397	0.685±0.078
N6624	1.081±0.029
N6681	1.106±0.048
N6752	0.856±0.050
N7099	1.110±0.059
Mean	1.011±0.065

Table 6. Masses and mass-to-light ratios for King type globular clusters. We assume $M_V(\odot) = 4.79$.

Name	$r_c(pc)$	$\sigma_o(km/s)$		μ	$log(M/M_\odot)$		M_V*	M/L	
		PM	PK		a	b		a	b
N 104	0.47	11.5	10.52	57.7	5.78	5.70	-9.42	1.25	1.04
N 362	0.45	6.4	9.28	34.8	5.03	5.35	-7.96	0.85	1.78
N2298	0.91			25.7			-6.16		
N2808	0.78	13.4	12.97	34.8	5.91	5.88	-9.32	1.85	1.72
N5024	2.04		5.57	27.5		5.46	-8.68		1.18
N5634	1.56			27.5			-7.66		
N5904	0.96	5.7	6.79	24.0	5.10	5.25	-8.82	0.45	0.64
N6171	1.07	4.1	3.05	16.8	4.70	4.45	-7.29	0.74	0.41
N6266	0.39	14.3	8.78	37.9	5.70	5.28	-8.90	1.67	0.64
N6273	1.86		5.62	25.7		5.40	-9.50		0.48
N6333	0.91		6.34	27.5		5.22	-7.67		1.72
N6388	0.45	18.9		37.9	6.01		-9.46	2.04	
N6402	1.93		7.98	29.6		5.78	-9.24		1.47
N6440	0.24			49.5			-8.41		
N6553	0.60		6.83	29.6		5.14	-7.56		1.58
N6584	1.26			66.9			-7.37		
N6638	0.55		5.15	27.5		4.83	-6.64		1.81
N6637	0.70		6.33	27.5		5.11	-7.86		1.12
N6712	1.32	4.3	4.67	15.6	4.80	4.88	-7.49	0.77	0.93
N6838	0.83	2.3	2.52	24.0	4.25	4.32	-5.43	1.45	1.71
N6934	0.90	5.1	5.35	27.5	5.03	5.07	-7.35	1.49	1.64
N7089	1.10	8.2	9.15	29.6	5.56	5.66	-8.88	1.24	1.56

PM: Prayor & Meylan (1993), PK: Peterson & King (1975), *: Djorgovski (1993)
[a]: results from the velocity dispersions of PM
[b]: results from the velocity dispersions of PK

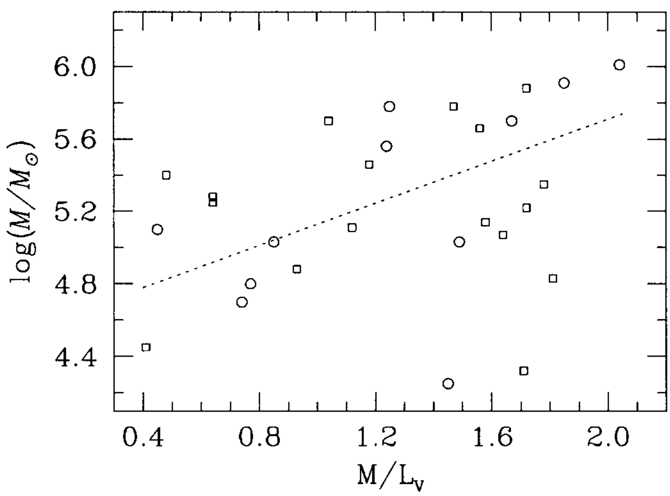

Figure 3. Correlation between mass and mass-to-light ratio for King type clusters. Open circles and open squares represent results based on velocity dispersions of Pryor & Meylan (1993) and Peterson & King (1975), respectively.

Figure 3 shows the relation between mass-to-light ratio and total mass of our program clusters. Open circles and open squares represent results from velocity dispersions of Pryor & Meylan (1993) and Peterson & King (1975), respectively. The correlation between total mass and mass-to-light ratio of globular clusters has been examined with a linear correlation Pearson's r coefficient and its confidence level which is derived from Student's t test. For 11 clusters whose masses are based on velocity dispersions of Pryor & Meylan (1993), the mass and mass-to-light ratio of clusters show a good positive correlation with a coefficient $r = 0.57$ and a confidence level of 91%. However, the correlation for 17 clusters whose masses were derived from velocity dispersions of Peterson & King (1975) is not as good with a correlation coefficient of $r = 0.11$ and a confidence level of only 33%. For all points in Figure 3, the correlation coefficient between mass and mass-to-light ratio is $r = 0.32$ with a confidence level of 90%. On the other hand, two points in lower right corner of Figure 3 represent NGC 6838, which contains the lowest mass among the program clusters. Excluding these points, we confirm a good positive correlation between mass and mass-to-light ratio of globular clusters with a correlation coefficient $r = 0.52$ and a confidence level of 99%.

4.3 The Relation Between Mass and Absolute Magnitude

Figure 4 shows a tight linear relation between masses and absolute magnitudes of King type globular clusters. Using the least square fit technique, we derived coefficients of the linear relation between $logM$ and absolute magnitude of clusters as follows:

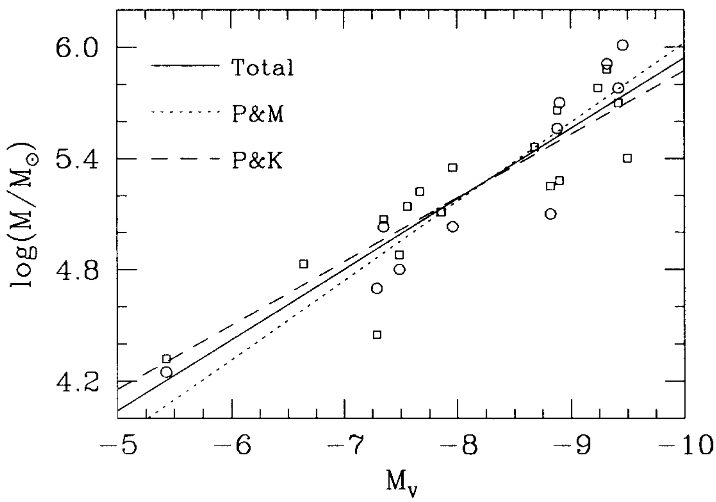

Figure 4. Correlation between mass and absolute magnitude of King type clusters. Open circles and open squares show results based on velocity dispersions of Pryor & Meylan (1993) and Peterson & King (1975), respectively. The solid line is a least square fit to all the data points, the dotted line is a fit to the open circles, and the dashed line matches open squares.

using central velocity dispersions from Pryor & Meylan (1993);
$log(M/M_{\odot}) = -0.427(\pm0.053)$ M_V $+1.751(\pm0.441)$
using central velocity dispersions from Peterson & King (1975);
$log(M/M_{\odot}) = -0.343(\pm0.047)$ M_V $+2.442(\pm0.381)$
using all data points in Figure 4;
$log(M/M_{\odot}) = -0.380(\pm0.035)$ M_V $+2.142(\pm0.285)$

For comparison, we also quote the result from Mandushev *et al.* (1991), $log(M/M_{\odot})$ = -0.456 $M_V + 1.64$, which is best matched here by our fit based on central velocity dispersions from Pryor & Meylan (1993). We note that velocity dispersions of Peterson & King (1975) were theoretically estimated values, while those of Pryor & Meylan (1993) came directly from the spectroscopic observations.

5. SUMMARY

B band CCD images have been used to investigate properties of surface brightness distributions and dynamical structures of 29 Galactic globular clusters, including 22 King type clusters and 7 post-core-collapse clusters. Model fits to the observed surface brightness distributions of flat-core clusters showed that concentration parameters range from 1.20 to 2.10, and core radii range from 0.4 to 1.9 pc. This is in good agreement with Trager *et al.* (1993) and Peterson & King (1975). The mean slope of 7 post-core-collapse clusters' surface brightness profiles has been estimated as 1.011 ± 0.065, which is in excellent agreement with Djorgovski & King (1984, 1986). Total mass of each King type cluster have been derived using core radius r_c and central velocity dispersion σ_o. They are in the range of $1.78 \times 10^4 M_{\odot}$ to $1.02 \times 10^6 M_{\odot}$ with a mean value of $1.73 \times 10^5 M_{\odot}$. The correlation between total mass and mass-to-light ratio of globular clusters has been quantified with a Pearson's correlation coefficient r. We confirmed that there is a good positive correlation between mass and mass-to-light ratio of King type globular clusters. A linear relation between mass and absolute magnitude of King type globular clusters has also been confirmed.

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REFERENCES

Chernoff, D. F. & Djorgovski, S. 1989, ApJ, 339, 904

Djorgovski, S. 1988, in IAU Symp. 126, Globular Cluster System in Galaxies, eds. J. E. Grindlay & A. G. D. Philip (Kluwer: Dordrecht), p.333

Djorgovski, S. 1993, in ASPCS vol.50, Structure and Dynamics of Globular Clusters, eds. S. Djorgovski & G. Meylan (Astronomical Society of the Pacific: San Fransisco), p.325

Djorgovski, S. & King, I. R. 1984, ApJL, 277, L49

Djorgovski, S. & King, I. R. 1986, ApJL, 305, L61

Djorgovski, S. & Piotto, G. 1993, in ASPCS vol.48, The Globular Cluster Galaxy Connection, eds. G. H. Smith & J. P. Brodie (Astronomical Society of the Pacific: San Fransisco), P.84
Djorgovski, S., Piotto, G. & King, I. R. 1988, in Dynamics of Dense Stellar Systems, ed. D. Merritt (Cambridge Univ. Press: Cambridge), p.147
Djorgovski, S., Piotto, G. & Mallen-Ornelas, G. 1991a, in ASPCS vol.13, The Formation and Evolution of Star Clusters, ed. K. Janes (Astronomical Society of the Pacific: San Fransisco), p.262
Djorgovski, S., Piotto, G., Phinney, E. S. & Chernoff, D. F. 1991b, ApJL, 372, L41
Illingworth, G. D. 1976, ApJ, 204, 73
King, I. R. 1966, AJ, 71, 276
Mandushev, G., Spassova, N. & Staneva, A. 1991, A&A, 252, 94
Meylan, G. 1989, A&A, 214, 106
Peterson, C. J. & King, I. R. 1975, AJ, 80, 427
Piotto, G., King, I. R. & Djorgovski, S. 1988, AJ, 96, 1918
Pryor, C. & Meylan, G. 1993, in ASPCS vol.50, Structure and Dynamics of Globular Clusters, eds. S. Djorgovski & G. Meylan (Astronomical Society of the Pacific: San Fransisco), p.104
Sohn, Y.-J. 1994, PhD Thesis; Yonsei University
Sohn, Y.-J., Byun, Y.-I. & Chun, M.-S. 1996, Ap&SS, 243, 379
Trager, S. C., Djorgovski, S. & King, I. R. 1993, in ASPCS vol.50, Structure and Dynamics of Globular Clusters, eds. S. Djorgovski & G. Meylan (Astronomical Society of the Pacific: San Fransisco), p.347
Trager, S. C., King, I. R. & Djorgovski, S. 1995, AJ, 109, 218