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SIZES OF GALACTIC GLOBULAR CLUSTERS

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ABSTRACT

A study is made of deviations from the mean power-law relationship between the Galactocentric distances and the half-light radii of Galactic globular clusters. Surprisingly, deviations from the mean R_h versus $R_{\rm gc}$ relationship do not appear to correlate with cluster luminosity, cluster metallicity, or horizontal-branch morphology. Differences in orbit shape are found to contribute to the scatter in the R_h versus $R_{\rm gc}$ relationship of Galactic globular clusters.

Key word: globular clusters: general

1. INTRODUCTION

In a recent paper, Hammer et al. (2011) presented persuasive evidence to suggest that the Milky Way is a very unusual spiral galaxy that has managed to avoid any major mergers since it originally formed. According to Hammer et al., only ∼1% of all major spirals belong to this pristine class of galaxies. It is therefore of particular interest to study the group characteristics of Galactic globular clusters, which may provide information on the earliest evolutionary phase of galactic evolution. Fortunately, we now have available from Harris (1996; 2010 edition[1]) an essentially complete catalog of data on Galactic globular clusters.

Among the properties listed in this catalog (see Table 1) are the luminosities, metallicities, Galactocentric distances, and half-light radii of individual clusters. The latter parameter is of particular interest because it is relatively insensitive to the effects of dynamical evolution (Spitzer & Thuan 1972; Lightman & Shapiro 1978; Murphy et al. 1990). It has been shown (van den Bergh 1994, 2011) that the half-light radii of Galactic globular clusters scatter widely around a relation of the form

$$R_h \alpha R_{\rm gc}^{2/3}. \quad (1)$$

It is the purpose of the present investigation to ask if this scatter correlates with the luminosity (mass), the metallicity [Fe/H], or horizontal-branch characteristics of individual clusters.

It is convenient to express the deviations of individual globular clusters from Equation (1) by a parameter that we shall call D, which is defined by the relation,

$$D = 2/3 \log R_{\rm gc} - \log R_h. \quad (2)$$

Physically, a positive value of D implies that the Galactocentric distance of a cluster is larger than expected for its size. Alternatively, one might say that clusters with positive D values are smaller than expected from their observed $R_{\rm gc}$ values.

2. DEVIATIONS CORRELATED WITH LUMINOSITY

It was first shown by van den Bergh et al. (1991) that the radii of globular clusters are uncorrelated with their luminosities. This conclusion was recently strengthened and confirmed by van den Bergh (2011) who found that the half-light radii of Galactic globular clusters are independent of their absolute magnitudes. Figure 1 shows that the parameter D is also uncorrelated with cluster luminosity. In other words, the relation between the half-light radii of clusters and their Galactocentric distances also appears to be independent of cluster luminosity, and hence presumably of cluster mass.

3. DEVIATIONS CORRELATED WITH METALLICITY

Figure 2 shows a plot of the parameter D as a function of cluster metallicity. Inspection of the figure hints at the possibility that metal-rich clusters with [Fe/H] > -1.0 might have systematically smaller D values than more metal-poor clusters. However, a Kolmogorov–Smirnov test shows that this effect falls well below any respectable level of statistical significance. In other words, D and [Fe/H] appear to be uncorrelated. Previously, it had also been found (van den Bergh 2011) that [Fe/H] of globular clusters is independent of cluster luminosity.

4. CORRELATIONS WITH HORIZONTAL-BRANCH GRADIENT

Following Lee (1990), the horizontal branches of globular clusters may be described via the parameter C defined by the relation

$$C = (B - R)/(B + V + R), \quad (3)$$

in which B, V, and R are the number of blue, variable, and red horizontal-branch stars, respectively. The individual values of C for halo clusters given in Table 1 were drawn from the compilation by MacKey & van den Bergh (2005). Inspection of the data listed in Table 1, which are plotted in Figure 3, shows not even a hint of a correlation between the parameter D and the globular cluster horizontal-branch population as described by the parameter C.

5. DISCUSSION

Using the recent compilation of data on Galactic globular clusters by Harris, it is found that the half-light radii of globular clusters scale as the ∼2/3 power of their Galactocentric distances. However, the scatter about this relationship is considerable. In the present paper, it is found that these deviations do not appear to correlate with either cluster luminosity, cluster metallicity, or population gradients along the cluster horizontal branch. However, van den Bergh (1993) was able to show that the radii of individual globular clusters depend on orbit shape,

[1] http://physwww.physics.mcmaster.ca/∼harris/mwgc.dat

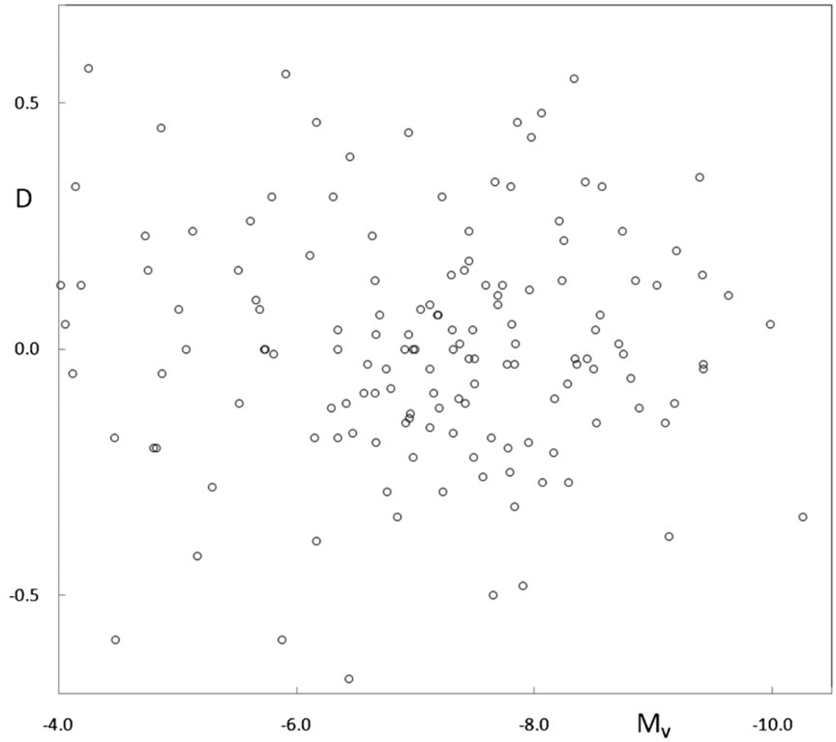

Figure 1. Parameter D, which provides a measure of deviations from the R_{gc} vs. half-light radius relation of Equation (1), appears to be independent of cluster luminosity, and hence presumably cluster mass.

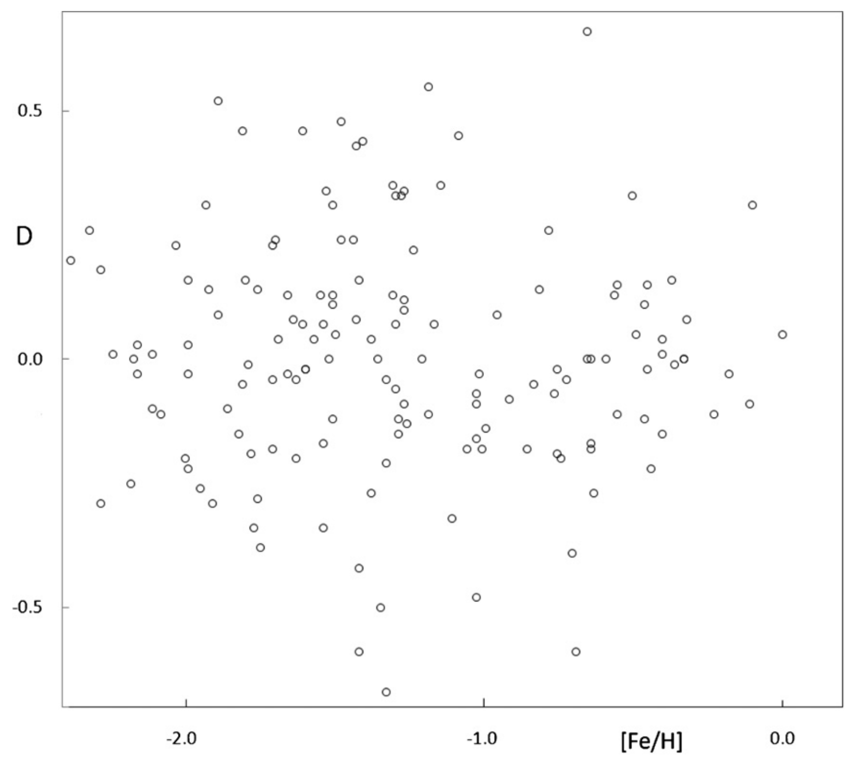

Figure 2. Parameter D appears to be independent of the cluster metallicity [Fe/H]. In other words the deviations of clusters from the half-light radius versus Galactocentric distance relationship appear to be independent of cluster metallicity.

with globulars on nearly circular orbits having above-average half-light radii. On the other hand, clusters on retrograde orbits were found to have slightly below-average radii. Some speculations about the reasons for this dependence of size on orbit shape were given in van den Bergh (1994), but no firm conclusions can yet be drawn. In any case it is clear that such a dependence of cluster radius on orbit shape will contribute to the observed scatter around Equation (1).

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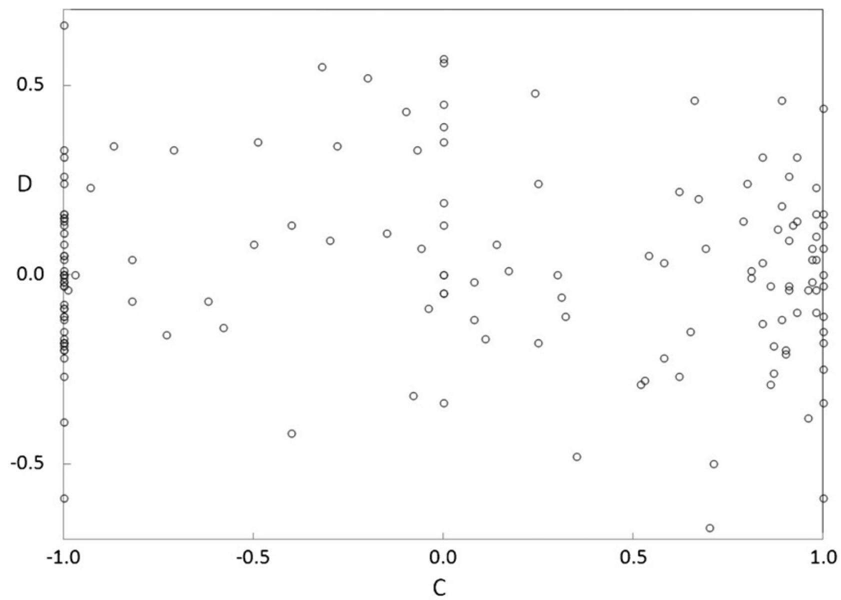

Figure 3. Plot of the parameter D, which measures deviations from the R_{gc} vs. half-light radius relation, as a function of the horizontal-branch population parameter C. The figure shows no evidence for a correlation between C and D.

Table 1
Data on Galactic Globular Clusters

ID	R_{gc}	log R_{gc}	[Fe/H]	M_v	R_h	log R_h	D	C
N 104	7.4	0.87	−0.72	−9.42	4.15	0.62	−0.04	−0.99
N 288	12.0	1.08	−1.32	−6.75	5.77	0.76	−0.04	+0.98
N 362	9.4	0.97	−1.26	−8.43	2.05	0.31	+0.34	−0.87
Whi 1	34.5	1.54	−0.70	−2.46	1.93	0.29	+0.74	...
N1261	18.1	1.26	−1.27	−7.80	3.22	0.51	+0.33	−0.71
Pal 1	17.2	1.24	−0.65	−2.52	1.49	0.17	+0.66	−1.00
AM 1	124.6	2.10	−1.70	−4.73	14.71	1.17	+0.23	−0.93
Eri	95.0	1.98	−1.43	−5.13	12.06	1.08	+0.24	−1.00
Pal 2	35.0	1.54	−1.42	−7.97	3.96	0.60	+0.43	−0.10
N1851	16.6	1.22	−1.18	−8.33	1.80	0.26	+0.55	−0.32
N1904	18.8	1.27	−1.60	−7.86	2.44	0.39	+0.46	+0.89
N2298	15.8	1.20	−1.92	−6.31	3.08	0.49	+0.31	+0.93
N2419	89.9	1.95	−2.15	−9.42	21.38	1.33	−0.03	+0.86
Ko 2	41.9	1.62	...	−0.35	2.12	0.33	+0.75	...
Pyx	41.4	1.62	−1.20	−5.73	...	...	...	−1.00
N2808	11.1	1.05	−1.14	−9.39	2.23	0.35	+0.35	−0.49
E 3	9.1	0.96	−0.83	−4.12	4.95	0.69	−0.05	...
Pal 3	95.7	1.98	−1.63	−5.69	17.49	1.24	+0.08	−0.50
N3201	8.8	0.94	−1.59	−7.45	4.42	0.65	−0.02	+0.08
Pal 4	111.2	2.05	−1.41	−3.11	16.13	1.21	+0.16	−1.00
Ko 1	49.3	1.69	...	−4.25	3.65	0.56	+0.57	...
N4147	21.4	1.33	−1.80	−6.17	2.69	0.43	+0.46	+0.66
N4372	7.1	0.85	−2.17	−7.79	6.60	0.82	−0.25	+1.00
Ru 106	18.5	1.27	−1.68	−6.35	6.48	0.81	+0.04	−0.82
N4590	10.2	1.01	−2.23	−7.37	4.52	0.66	+0.01	+0.17
N4833	7.0	0.85	−1.85	−8.17	4.63	0.67	−0.10	+0.93
N5024	18.4	1.26	−2.10	−8.71	6.82	0.83	+0.01	+0.81
N5053	17.8	1.25	−2.27	−6.76	13.21	1.12	−0.29	+0.52
N5139	6.4	0.81	−1.53	−10.26	7.56	0.88	−0.34	...
N5272	12.0	1.08	−1.50	−8.88	6.85	0.84	−0.12	+0.08
N5286	8.9	0.95	−1.69	−8.74	2.48	0.39	+0.24	+0.80
AM 4	27.8	1.44	−1.30	−1.81	4.03	0.61	+0.35	...
N5466	16.3	1.21	−1.98	−6.98	10.70	1.03	−0.22	+0.58
N5634	21.2	1.33	−1.88	−7.69	6.30	0.80	+0.09	+0.91
N5694	29.4	1.47	−1.98	−7.83	10.18	1.01	−0.03	+1.00
I4499	15.7	1.20	−1.53	−7.32	9.35	0.97	−0.17	+0.11
N5824	25.9	1.41	−1.91	−8.85	4.20	0.62	+0.14	+0.79
Pal 5	18.6	1.27	−1.41	−5.17	18.42	1.27	−0.42	−0.40
N5897	7.4	0.87	−1.90	−7.23	7.49	0.87	−0.29	+0.86

Table 1
(Continued)

ID	R_{gc}	log R_{gc}	[Fe/H]	M_v	R_h	log R_h	D	C
N5904	6.2	0.79	−1.29	−8.81	3.86	0.59	−0.06	+0.31
N5927	4.6	0.66	−0.49	−7.81	2.46	0.39	+0.05	−1.00
N5946	5.8	0.76	−1.29	−7.18	2.74	0.44	+0.07	+0.69
BH 176	12.9	1.11	0.00	−4.06	4.95	0.69	+0.05	−1.00
N5986	4.8	0.68	−1.59	−8.44	2.96	0.47	−0.02	+0.97
Lyng 7	4.3	0.63	−1.01	−6.60	2.79	0.45	−0.03	−1.00
Pal 14	71.6	1.85	−1.62	−4.80	27.15	1.43	−0.20	−1.00
N6093	3.8	0.58	−1.75	−8.23	1.77	0.25	+0.14	+0.93
N6121	5.9	0.77	−1.16	−7.19	2.77	0.44	+0.07	−0.06
N6101	11.2	1.05	−1.98	−6.94	4.70	0.67	+0.03	+0.84
N6144	2.7	0.43	−1.76	−6.85	4.22	0.63	−0.34	+1.00
N6139	3.6	0.56	−1.65	−8.36	2.50	0.40	−0.03	+0.91
Ter 3	2.5	0.40	−0.74	−4.82	2.98	0.47	−0.20	−1.00
N6171	3.3	0.52	−1.02	−7.12	3.22	0.51	−0.16	−0.73
1636-2	2.1	0.32	−1.50	−4.02	1.21	0.08	+0.13	−0.40
N6205	8.4	0.92	−1.53	−8.55	3.49	0.54	+0.07	+0.97
N6229	29.8	1.47	−1.47	−8.06	3.19	0.50	+0.48	+0.24
N6218	4.5	0.65	−1.37	−7.31	2.47	0.39	+0.04	+0.97
FRS173	3.7	0.57	...	−6.45	0.97	−0.01	+0.39	...
N6235	4.2	0.62	−1.28	−6.29	3.35	0.53	−0.12	+0.89
N6254	4.6	0.66	−1.56	−7.48	2.50	0.40	+0.04	+0.98
N6256	3.0	0.48	−1.02	−7.15	2.58	0.41	−0.09	−1.00
Pal 15	38.4	1.58	−2.07	−5.52	14.43	1.16	−0.11	+1.00
N6266	1.7	0.23	−1.18	−9.18	1.82	0.26	−0.11	+0.32
N6273	1.7	0.23	−1.74	−9.13	3.38	0.53	−0.38	+0.96
N6284	7.5	0.88	−1.26	−7.96	2.94	0.47	+0.12	+0.88
N6287	2.1	0.32	−2.10	−7.36	2.02	0.31	−0.10	+0.98
N6293	1.9	0.28	−1.99	−7.78	2.46	0.39	−0.20	+0.90
N6304	2.3	0.36	−0.45	−7.30	2.44	0.39	+0.15	−1.00
N6316	2.6	0.41	−0.45	−8.34	1.97	0.29	−0.02	−1.00
N6314	9.6	0.98	−2.31	−8.21	2.46	0.39	+0.26	+0.91
N6325	1.1	0.04	−1.25	−6.96	1.43	0.16	−0.13	+0.84
N6333	1.7	0.23	−1.77	−7.95	2.21	0.34	−0.19	+0.87
N6342	1.7	0.23	−0.55	−6.42	1.80	0.26	−0.11	−1.00
N6356	7.5	0.88	−0.40	−8.51	3.56	0.55	+0.04	−1.00
N6355	1.4	0.15	−1.37	−8.07	2.36	0.37	−0.27	+0.62
N6352	3.3	0.52	−0.64	−6.47	3.34	0.52	−0.17	−1.00
I1257	17.9	1.25	−1.70	−6.15	10.18	1.01	−0.18	+1.00
Ter 2	0.8	−0.10	−0.69	−5.88	3.32	0.52	−0.59	−1.00

Table 1
(Continued)

ID	R_{gc}	log R_{gc}	[Fe/H]	M_v	R_h	log R_h	D	C
N6366	5.0	0.70	−0.59	−5.74	2.92	0.47	0.00	−0.97
Ter 4	1.0	0.00	−1.41	−4.48	3.87	0.59	−0.59	+1.00
HP 1	0.5	−0.30	−1.00	−6.46	7.39	0.87	−1.07	+0.75
N6362	5.1	0.71	−0.99	−6.95	4.03	0.61	−0.14	−0.58
Lil 1	0.8	−0.10	−0.33	−7.32	...	...	...	−1.00
N6380	3.3	0.52	−0.75	−7.50	2.35	0.37	−0.02	−1.00
Ter 1	1.3	0.11	−1.03	−4.41	7.44	0.87	−0.80	−1.00
Ton 2	1.4	0.15	−0.70	−6.17	3.10	0.49	−0.39	−1.00
N6388	3.1	0.49	−0.55	−9.41	1.50	0.18	+0.15	−1.00
N6402	4.0	0.60	−1.28	−9.10	3.52	0.55	−0.15	+0.65
N6401	2.7	0.43	−1.02	−7.90	5.89	0.77	−0.48	+0.35
N6397	6.0	0.78	−2.02	−6.64	1.94	0.29	+0.23	+0.98
Pal 6	2.2	0.34	−0.91	−6.79	2.02	0.31	−0.08	−1.00
N6426	14.4	1.16	−2.15	−6.67	5.51	0.74	+0.03	+0.58
Djo 1	5.7	0.76	−1.51	−6.98	...	...	...	...
Ter 5	1.2	0.08	−0.23	−7.42	1.45	0.16	−0.11	−1.00
N6440	1.3	0.11	−0.36	−8.75	1.19	0.08	−0.01	−1.00
N6441	3.9	0.59	−0.46	−9.63	1.92	0.28	+0.11	−1.00
Ter 6	1.3	0.11	−0.56	−7.59	0.87	−0.06	+0.13	−1.00
N6453	3.7	0.57	−1.50	−7.22	1.48	0.07	+0.31	+0.84
UKS 1	0.7	−0.15	−0.64	−6.91	...	...	...	−1.00
N6496	4.2	0.62	−0.46	−7.20	3.35	0.53	−0.12	−1.00
Ter 9	1.1	0.04	−1.05	−3.71	1.61	0.21	−0.18	+0.25
Djo 2	1.8	0.26	−0.65	−7.00	...	...	...	−1.00
N6517	4.2	0.62	−1.23	−8.25	1.54	0.19	+0.22	+0.62
Ter 10	2.3	0.36	−1.00	−6.35	2.62	0.42	−0.18	−1.00
N6522	0.6	−0.22	−1.34	−7.65	2.24	0.35	−0.50	+0.71
N6535	3.9	0.59	−1.79	−4.75	1.68	0.23	+0.16	+1.00
N6528	0.6	−0.22	−0.11	−6.57	0.87	−0.06	−0.09	−1.00
N6539	3.0	0.48	−0.63	−8.29	3.86	0.59	−0.27	−1.00
N6540	2.8	0.45	−1.35	−6.35	...	...	...	+0.30
N6544	5.1	0.71	−1.40	−6.94	1.06	0.03	+0.44	+1.00
N6541	2.1	0.32	−1.81	−8.52	2.31	0.36	−0.15	+1.00
2MS 01	4.5	0.65	...	−6.11	1.73	0.24	+0.19	...
ESO 06	14.0	1.15	−1.80	−4.87	6.54	0.82	−0.05	...
N6553	2.2	0.34	−0.18	−7.77	1.80	0.26	−0.03	−1.00
2MS 02	3.2	0.51	−1.08	−4.86	0.78	−0.11	+0.45	...
N6558	1.0	0.00	−1.32	−6.44	4.63	0.67	−0.67	+0.70
I1276	3.7	0.57	−0.75	−6.67	3.74	0.57	−0.19	−1.00
Ter 12	3.4	0.53	−0.50	−4.14	1.05	0.02	+0.33	−1.00
N6569	3.1	0.49	−0.76	−8.28	2.54	0.40	−0.07	−0.82
BH 261	1.7	0.23	−1.30	−4.19	1.04	0.02	+0.13	...
GLI 02	3.0	0.48	−0.33	...	...	...	...	...
N6584	7.0	0.85	−1.50	−7.69	2.87	0.46	+0.11	−0.15
N6624	1.2	0.08	−0.44	−7.49	1.88	0.27	−0.22	−1.00
N6626	2.7	0.43	−1.32	−8.16	3.15	0.50	−0.21	+0.90
N6638	2.2	0.34	−0.95	−7.12	1.39	0.14	+0.09	−0.30
N6637	1.7	0.23	−0.64	−7.64	2.15	0.33	−0.18	−1.00
N6642	1.7	0.23	−1.26	−6.66	1.72	0.24	−0.09	−0.04
N6652	2.7	0.43	−0.81	−6.66	1.40	0.15	+0.14	−1.00
N6656	4.9	0.69	−1.70	−8.50	3.13	0.50	−0.04	+0.91
Pal 8	5.5	0.74	−0.37	−5.51	2.16	0.33	+0.16	−1.00
N6681	2.2	0.34	−1.62	−7.12	1.86	0.27	−0.04	+0.96
GLI 01	4.9	0.69	...	−5.91	0.79	−0.10	+0.56	...
N6712	3.5	0.54	−1.02	−7.50	2.67	0.43	−0.07	−0.62
N6715	18.9	1.28	−1.49	−9.98	6.32	0.80	+0.05	+0.54
N6717	2.4	0.38	−1.26	−5.66	1.40	0.15	+0.10	+0.98
N6723	2.6	0.41	−1.10	−7.83	3.87	0.59	−0.32	−0.08
N6749	5.0	0.70	−1.60	−6.70	2.53	0.40	+0.07	+1.00
N6752	5.2	0.72	−1.54	−7.73	2.22	0.35	+0.13	+1.00
N6760	4.8	0.68	−0.40	−7.84	2.73	0.44	+0.01	−1.00
N6779	9.2	0.96	−1.98	−7.41	3.01	0.48	+0.16	+0.98
Ter 7	15.6	1.19	−0.32	−5.01	5.11	0.71	+0.08	−1.00
Pal 10	6.4	0.81	−0.10	−5.79	1.70	0.23	+0.31	−1.00
Arp 2	21.4	1.33	−1.75	−5.29	14.73	1.17	−0.28	+0.53
N6809	3.9	0.59	−1.94	−7.57	4.45	0.65	−0.26	+0.87
Ter 8	19.4	1.29	−2.16	−5.07	7.27	0.86	0.00	+1.00
Pal 11	8.2	0.91	−0.40	−6.92	5.69	0.76	−0.15	−1.00
N6838	6.7	0.83	−0.78	−5.61	1.94	0.29	+0.26	−1.00
N6864	14.7	1.17	−1.29	−8.57	2.80	0.45	+0.33	−0.07
N6934	12.8	1.11	−1.47	−7.45	3.13	0.50	+0.24	+0.25
N6981	12.9	1.11	−1.42	−7.04	4.60	0.66	+0.08	+0.14
N7006	38.5	1.59	−1.52	−7.67	5.27	0.72	+0.34	−0.28
N7078	10.4	1.02	−2.37	−9.19	3.03	0.48	+0.20	+0.67
N7089	10.4	1.02	−1.65	−9.03	3.55	0.55	+0.13	+0.96
N7099	7.1	0.85	−2.27	−7.45	2.43	0.39	+0.18	+0.89
Pal 12	15.8	1.20	−0.85	−4.47	9.51	0.98	−0.18	−1.00
Pal 13	26.9	1.43	−1.88	−3.76	2.72	0.43	+0.52	−0.20
N7492	25.3	1.40	−1.78	−5.81	8.80	0.94	−0.01	+0.81

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