THE TIDAL RADII OF GLOBULAR CLUSTERS IN M31

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ABSTRACT We have determined tidal radii for 30 globular clusters in the halo of M31 from deep direct images. Although the uncertainty of each individual measurement is large, in the mean the tidal radii suggest that the M31 globular clusters have orbital eccentricities and mass-to-light ratios that are very similar to those of Galactic globular clusters.

OBSERVATIONS

Deep images taken with the 4-Shooter at the Cassegrain focus of the 200-inch telescope at Palomar Mountain were used to obtain spatial profiles of a sample of globular clusters in M31 beginning at the nucleus and extending out along the minor axis.

Mean radial surface brightness profiles were determined for each image. There are typically 3 images of each cluster. The seeing was usually about 1.0 arc-sec FWHM.

ANALYSIS

King profiles were used to fit the surface brightness profiles. They were convolved in 2 dimensions with the observed point spread function as determined by averaging the results for 4 bright, isolated stars in each image. The core and tidal radii were measured. As the measured r_c are very uncertain, Table I lists the effective radius instead, where r_e is the radius containing half the light, and is computed from the King profiles using the measured values of r_c and r_t.

TABLE I Properties of the M31 Globular Clusters

ID	r (mag)	g - r (mag)	R_{gc} (kpc)	r_t (pc)	r_e (pc)
M31					
vdB5			0.5	23	4.7
K25	18.71	0.91	10.7	48	6.0
K108	15.62	0.44	4.3	63	5.5
K109	17.56	0.43	6.5	15	3.5
K111	17.21	0.40	5.7	19	5.8
K122			16.0	39	4.3
K124	15.23	0.71	3.1	21	4.0
K132	18.30	0.02	2.5	20	7.8
K135	16.56	0.38	5.7	23	6.0
K143	16.62	0.44	11.8	15	3.9
K146	16.90	0.42	6.0	21	8.5
K151	17.99	0.00	1.5	38	5.4
K155	16.49	0.51	1.4	28	5.6
K159	16.48	0.53	2.0	18	4.0
K165			0.7	20	4.0
K169			0.9	18	3.9
K174			0.6	31	5.0
K177			0.5	11	2.9
K180			9.3	19	5.6
K184	16.79	0.39	0.6	15	4.3
K185			0.2	20	5.6
K189			0.3	13	4.0
K194	16.68	0.30	0.8	23	4.1
K198	15.76	0.39	0.9	18	3.1
K200			0.8	12	3.1
K202	17.37	0.35	9.3	27	7.8
K207	15.86	0.40	1.1	20	4.1
K208	16.62	0.50	1.1	22	5.4
K308	17.30	0.61	10.3	41	7.6
K312	15.95	0.69	0.9	34	3.8

The tidal radius represents the radius of the cluster as it is truncated by the tidal field of the galaxy. N-body simulations by Seitzer (1985) have demonstrated that a suitable approximation for r_t is the radius of the inner Lagrangian point at the perigalactic distance of the cluster's orbit around the galaxy, where the tidal field is at a maximum. In a spherical logarithmic potential, the tidal radius is then given by

$$\frac{r_t}{M_{cl}^{\frac{1}{3}}} = \left[\frac{Rp}{V}\right]^{\frac{2}{3}} \left[\frac{G}{2g(e)}\right]^{\frac{1}{3}}, \tag{1}$$

where V is the amplitude of the flat galactic rotation curve, M_{cl} is the cluster mass, and $g(e)$ is a slowly varying function of the orbital eccentricity, $e = (R_a - R_p)/(R_a + R_p)$: R_a is the orbital apogalactic radius and $g(0) = 1$.

To remove the dependence of r_t on the cluster mass, we assume that $M/L_V = 2.0$, and use the observed integrated luminosities to calculate average values of $P = r_t/M_{cl}^{\frac{1}{3}}$ for our sample of globular clusters in M31. These values are given in Table 2.

Assuming that in the Galaxy the spatial density of globular clusters follows $\rho \propto r^{-3}$ we calculate the corresponding ranges of *true* galactocentric distances r_{GC} for the galactic sample, omitting clusters fainter than $M_V = -7.1$ mag.

The average values of r_t for the galactic sample thus defined are also given in Table 2. However, M31 is more luminous and rotates more rapidly than the Galaxy, so a further scaling is required before we can directly compare the values of P for M31 and the Galaxy. From equation (1), we must adjust the galactic globular cluster value of $< P >$ by the ratio $(V_{Gal}/V_{M31})^{\frac{2}{3}}$. For $V_{Gal} =$ 220 km s^{-1} and $V_{M31} = 265$ km s^{-1}, this factor is 0.88. The adjusted values $< P_c >$ are given in the fourth column of Table II.

TABLE II Mean Tidal Radii Corrected for Cluster Mass (and Galactic Rotation)

	The Galaxy			M31		
r_{GC} (kpc)	No.	$< r_t/M_{cl}^{1/3} >$ ($pc/M_{\odot}^{0.33}$)	$< r_t/M_{cl}^{1/3} > c$ ($pc/M_{\odot}^{0.33}$)	R_{GC} (kpc)	No.	$< r_t/M_{cl}^{1/3} >$ ($pc/M_{\odot}^{0.33}$)
<5.5	33	0.47	0.41	<4	19	0.37
5.5<21.9	35	0.76	0.67	4<16	11	0.60

The similarity between the $< P_c >$ values for the brighter galactic globular clusters and $< P >$ for our sample of globulars in M31 is impressive. From equation (1), this implies that the average values of $< \frac{r_p^2(M/L)}{G(e)} >$ for M31 and galactic clusters in each radial interval of Table II are approximately equal. The mean values of M/L for clusters in M31 and the Galaxy are about the same (Peterson and Lupton, unpublished, see Peterson 1989). It then follows that the orbital eccentricity distributions for clusters in M31 and the Galaxy are similar, to within the limits of our measurements.

Full details can be found in the paper which has been submitted for publication in the Astronomical Journal.

REFERENCES

Peterson, R. C. 1989, in *Dynamics of Dense Stellar Systems*, ed. D. Merritt, p. 161.

Seitzer, P. 1985, in *Dynamics of Star Clusters*, ed. J. Goodman and P. Hut, p. 343.