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STUDIES OF THE VARIABLES IN THE GLOBULAR CLUSTER NGC 6171

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By Christine M. Coutts* and Helen Sawyer Hogg

Abstract

The purpose of this investigation is to study periods of the variables in NGC 6171 over a long time interval and to look for period changes in the RR Lyrae stars. The study is based on a collection of 47 photographs taken at the David Dunlap Observatory between 1946 and 1969 and 24 photographs at Cerro Tololo in 1970 combined with published observations of other investigators dating back to 1935.

Twenty-three variable stars have been studied. Twenty-two of these are RR Lyrae stars, 10 of which show period changes. One of the variables is a long period variable with a period of 332 days. All the variables inside the cluster radius are RR Lyraes.

Introduction

NGC 6171 (Messier 107, R.A. $16^h29^m.7$, Dec. $-12°57'$, 1950) is a globular cluster with a relatively high metal content. There are 24 variables which Oosterhoff (1938) discovered on fifteen plates taken with the Mt. Wilson 60-inch reflector in 1935. He published magnitudes for 23 of the stars and photometer readings for variable 22, which was much fainter than the others and below his magnitude sequence. His material was not adequate for period determination and the periods for these stars were not found until much later.

Mannino (1961) at Bologna and Kukarkin (1961) at Sternberg both investigated the periods of the variables. Mannino's work was based on 199 photographs taken with the Loiano 60-cm. reflector during 1959 and 1960. He made visual estimates of the apparent magnitudes for 15 of the variables and determined periods for 10. Kukarkin took 67 photographs of the cluster with the 40-cm. reflector at Sternberg, also during 1959 and 1960; he determined periods for 19 of the stars from visual estimates.

Thirty-one variables beyond the visible boundaries of the cluster have been announced. Kurochkin (1962, 1964) found 29, of which 14 are RR Lyrae and Kukarkin (1962) found 2, for one of which he determined an RR Lyrae period.

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The periods of the variables in the cluster given by Kukarkin and by Mannino agree fairly well for all except three, numbers 2, 3, and 8. Mannino considered all of these stars to be RR Lyrae variables of type *c*, while Kukarkin's results definitely show them all to be of type *a*, and in all three cases,

$$\frac{1}{P_K} = \frac{1}{P_M} - 1$$

where P_K, P_M are the periods by Kukarkin and Mannino respectively.

Variables 1, 11, 20, 22, and 24 were not measured by either Kukarkin or Mannino. Variables 1 and 22 were too far from the centre of the cluster to appear on their plates, and variables 11, 20, and 24 were too close to the centre to be resolved.

Since we began work on this cluster, Dickens (1970) has published an extensive paper on it, making use of some of our unpublished data. He studied all the variables except nos. 1, 22, and 24. His work is based on 25 U, 48 B, and 45 V plates of the cluster, all taken with the Mt. Wilson 100-inch telescope in 1966 and 1967.

Investigations at the David Dunlap Observatory

The observing program on NGC 6171 was begun by one of us (Sawyer Hogg) in 1946 with the 74-inch reflector. The David Dunlap Observatory collection includes 46 photographs taken with this telescope in 10 different years between 1946 and 1969 and one photograph (D250) taken with the 16-inch reflector on the campus of the University of Toronto in 1969. This material has been supplemented by 24 plates taken by Coutts with the Curtis 24-inch Schmidt of the University of Michigan on Cerro Tololo in 1970.

Twenty-three stars have been measured on the David Dunlap plates. Variables 6, 7, 8, 9, 11, 20, and 24 were measured visually, the others with an iris photometer. Variable 22, probably not a cluster member, was again too far from the centre of the cluster to appear on the David Dunlap plates and it was not studied. All measures of the variables on the Cerro Tololo plates were made with an iris photometer, but variables 9, 11, and 24 were too crowded for measurement. The photographic magnitudes and heliocentric Julian Days are in Table I. Variable 1 is considered separately later. All the observations up to and including Julian Day 2440393 are from David Dunlap plates; all later observations are from Cerro Tololo.

The adopted periods are listed in Table II, which also gives the photographic magnitudes at maximum and minimum light, the ampli-

TABLE I

Photographic Magnitudes

TABLE I. PHOTOGRAPHIC MAGNITUDES

Dunlap	Julian Day	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
12068	31970.762					15.65	15.95		16.20		16.05
12116	76.729	15.67	15.92	15.91	15.93	15.70	15.95	15.95	15.80	16.23	16.05
12121	.767	15.84	16.00	15.63	15.98	15.70	16.05	16.00	16.00	16.22	16.05
12140	77.709	16.41	15.54	15.74	16.17	15.70	15.75	15.40	15.85	15.41	15.65
12261	99.720					16.10	16.10	16.00	15.70		15.85
12280	2000.695					15.85	16.10	15.50	15.70		16.25
12326	04.682	15.53	16.09	15.56	15.66	16.25	15.85	15.55	16.25	16.32	16.20
13400	354.693	15.50	16.10		16.03	16.05	16.50	15.95	15.80	16.06	15.70
13426	55.712	16.36	16.09	15.55	16.24	16.00	16.40	15.40	16.05	16.22	16.05
13446	56.674	16.28	15.82	16.06	15.86	15.70	16.45	16.35	16.00	15.38	16.00
13447	.697	16.30	15.75	16.09	15.96	15.75	16.40	16.40	16.30	15.39	16.00
13462	57.675	15.89	15.62	15.52	16.19	16.00	16.40	16.35	16.15	16.23	15.70
14512	733.679	16.38	16.12	15.96	15.85	16.30	16.25	15.60	16.00	16.21	16.00
14517	.722	16.34	15.70	15.68	15.71	16.00	16.20	15.85	16.05	16.29	16.00
14536	34.661	16.22	16.12	15.77	16.08	16.05	16.15	16.35	16.10	16.33	16.05
14542	.732	16.32	16.18	16.15	16.21	16.20	16.30	15.40	16.20	16.43	15.65
20077	4538.691	16.34	15.62	16.04	16.19	15.80	16.25	16.40	16.00	16.08	15.60
20229	72.634	16.02	15.82	15.85	15.93	16.35	16.50	16.30	16.00	16.35	16.05
20241	73.647	15.91	16.26	16.05	16.24	16.20	16.20	15.95	16.05	16.03	15.80
20275	75.612	16.23	15.80	16.11	16.20	15.80	16.30	16.35	16.10	15.67	16.05
21416	930.630							16.45	15.70		15.95
21424	31.636							16.35	15.75		
22472	5307.634	15.94	16.23	15.66	16.22	16.25	16.35	15.50	15.70	16.38	15.85
22475	.673	16.25	16.28	15.67	16.25	16.15	16.45	15.65	15.65	16.52	16.15
26830	8198.715	16.09	16.01	15.76	16.26	15.95	16.25	16.40	16.15	15.41	15.70
26833	.744	16.19	16.06	16.00	16.47	16.10	15.95	16.15	16.25	15.66	15.70
26850	99.679	15.75	15.53	16.22	15.86	15.75	16.05				16.05
26852	.702	15.69	15.84	15.96	15.80	15.75	16.10	15.90	16.10	16.08	
26856	.740	15.73	16.03	15.63	15.93	16.00	16.05	16.00	16.15	16.36	16.10
27541	583.724	16.46	16.24	15.82	16.09	16.00	15.65	15.54	16.10	16.38	16.05
27545	84.638	16.14	15.88	15.88	16.12	15.60	16.00	16.23	15.70	16.36	15.60
27561	87.712	16.18	15.96	15.70	16.30	15.60	15.60	15.73	15.90	15.72	15.70
29101	9265.794	16.00	16.33	16.13	15.95	16.10	16.25	15.95	15.60	16.20	15.95
29105	.837	16.05	16.45	16.18	15.39	16.25	16.25	16.10	15.60	15.27	16.10
29144	70.834	15.70	16.32	15.81	15.58	15.85	16.25	15.85		15.41	16.10
29160	71.738		15.75	16.16	16.12	15.85	15.80	16.15	16.05	15.78	16.05
29166	39271.787	16.40	15.97	15.91	16.14	15.95	16.10	15.45	16.05	15.87	16.15
29171	.834	16.25	15.98	15.87	16.05	16.15	16.05	15.20	15.95	16.20	16.25
29557	357.580		16.13	15.77	16.35	15.65	15.60	15.90	15.65	16.20	15.80
32128	40354.772	15.75	16.02	16.05	16.10	16.05	16.10	15.65	16.20	16.10	
32142	56.807	16.50	15.61	16.02	16.00	16.10	16.00	16.15	15.85	16.20	
D250	82.735	16.05	16.06		15.92	15.70	15.60	15.35		16.22	
32203	89.690	16.05	15.80	15.70	15.95	15.75	15.70	16.15	16.10	16.10	15.80
32206	.733	16.30	16.10	15.98	16.05	15.60	15.60	16.40	16.05	16.31	16.05
32210	.777	16.15	16.11	16.05	16.10	15.75	15.85	16.25	15.95	16.20	16.05
32228	93.703	16.25	15.95	15.95	16.40	15.90	15.55	16.25	15.60	15.65	
32231	.745								15.55	15.95	
C.T.I.O											
6408	691.892	16.54	16.34	16.00	16.15	16.18	15.94	15.50		15.70	
6417	92.681	16.15	15.92	15.96	16.23	15.71	15.88	16.06		15.86	
6428	.889	16.06	16.21	16.12	16.27	15.92	15.96	15.04		15.16	
6438	93.681	16.72	15.98	16.18	16.25	15.67	15.90	15.86		15.25	
6443	.801	16.53	16.10	15.84	16.06	16.00	15.90	15.98		15.82	
6447	.874	15.88	15.98	15.83	16.13	16.43	16.03	15.85		15.93	
6477	94.912	16.69	15.88	15.88	16.40	16.24	15.90	16.09		15.20	
6491	95.878	16.42	16.27	16.21	16.11	15.63	15.86	15.59		15.67	
6650	708.793	16.01	16.23	15.84	16.17	16.00	16.07	15.92		15.84	
6927	45.631	16.53	16.35	16.23	16.20	16.32	15.98	15.55		15.06	
6931	47.669	16.18	16.19	16.02	16.35	16.16	15.92	15.92		15.03	
6945	49.679	16.46	16.27	15.72	16.27	15.76	16.29	16.00		15.83	
7031	801.476	16.45	16.00	16.41	16.23	15.98	15.47	15.69		15.47	
7043	.606	16.64	16.39	15.90	16.43	16.16	15.88	15.61		15.54	
7065	02.586	16.35	16.04	16.19	16.00	16.17	15.80	15.61		15.18	
7077	03.486	16.00	16.39	16.22	16.20	16.30	15.45	15.88		15.37	
7087	.632	16.20	15.90	15.94	16.16	16.06	15.96	15.73		15.59	
7107	05.663	16.47	16.17	16.21	16.25	15.81	16.09	15.72		16.00	
7115	06.493	16.21	15.98	16.12	16.41	16.10	15.59	16.15		15.82	
7119	.560	16.19	16.04	16.35	16.41	16.19	15.92	15.37		15.81	
7145	08.469	16.68	16.17	16.43	16.37	15.53	15.52	15.94		15.80	
7155	.613	15.86	16.20	15.73	16.17	16.00	15.84	15.81		15.86	
7166	09.536	16.35	16.29	15.84	16.19	15.65		15.65		16.10	
7172	.634	16.54	16.15	16.23	15.92	15.78	15.96	15.59		15.24	

No.12	No.13	No.14	No.15	No.16	No.17	No.18	No.19	No.20	No.21	No.23	No.24
		16.10						15.75			15.25
16.18	16.43	16.20	15.63	16.43	16.29	15.75	15.92	15.75	16.29	16.05	15.85
16.23	16.43	16.30	15.80	16.38	16.31	15.74	15.88	15.65	16.28	16.14	15.75
16.40	16.52	16.20	16.12	16.26	16.17	16.31	16.12	15.45	16.66	16.08	15.95
		16.10						16.00			15.95
		16.15						15.30			15.90
16.40	16.20	16.15	15.71	15.60	16.16	16.38	15.89	15.35	16.53	15.90	15.20
16.54	15.67	16.15	16.03	16.26	15.87	16.53	16.10	15.60	16.38	15.88	15.45
16.44	16.20	16.60	16.10	16.52	15.44	16.38	16.28	15.55	16.55	16.04	15.35
16.48	16.30	16.35	16.19	15.97	16.45	16.00	15.81	16.00	16.56	16.23	15.95
16.55	16.52	16.20	16.21	16.12	16.37	16.10	15.76	15.80	16.49	16.24	16.05
16.58	16.56	16.40	15.60	15.82	16.21	15.79	16.25	15.80	16.79	16.17	15.85
	15.30	16.15	15.69	16.12	16.28	16.07	16.12	15.55	16.56	16.08	16.05
16.45	15.75	16.15	15.82	16.25	16.26	16.27	16.36	15.40	16.78	16.22	16.00
16.67	15.60	16.05	16.09	15.89	16.12	16.01	15.88	15.85	16.41	16.11	15.80
15.25	16.32	16.35	16.29	16.13	16.24	15.77	15.92	15.95	16.65	16.28	15.85
15.66	16.57	15.65	16.27	16.35	15.88	16.38	16.18	15.65	16.38	16.19	15.80
16.41	16.58	16.15	15.93	16.29	16.30	16.53	16.01	15.45	16.78	16.18	15.65
15.46	16.50	16.15	16.16	16.33	16.23	16.36	16.20	15.70	16.68	16.13	15.45
15.80	16.72	16.60	16.19	15.88	15.40	16.51	15.90	15.50	16.44	15.83	16.05
		15.45						15.55			15.95
		15.50									
16.30	15.79	16.45	15.85	15.88	16.26	16.57	16.15	15.65	16.49	16.02	15.20
15.65	15.98	16.50	15.89	15.96	16.38	16.07	15.96	15.75	16.46	15.90	15.30
16.09	16.45	16.25	15.83	16.00	16.12	16.39	16.03	15.60	16.38	15.78	15.85
16.40		16.20	15.83	15.95	16.28	16.44	15.82	15.65	16.37	15.70	15.70
		16.50									15.55
16.37	16.56	16.20	16.17	15.78	15.88	16.05	16.38	15.45	16.68	15.65	16.00
16.44	16.55	16.15	16.17	15.90	16.05	16.30	16.28	15.25	16.59	15.84	16.15
16.44	16.33	15.60	15.98	16.48	16.44	16.40	15.97	15.85	16.66	16.39	15.95
16.43	16.14	15.40	16.19	16.22	16.03	16.30	16.14	15.90	16.36	16.35	15.70
15.76	16.26	16.20	15.66	16.07	16.16	16.37	16.26	15.40	16.33	15.86	15.65
16.01	16.15	15.65	16.17	15.97	15.49	16.08	15.83	15.55	16.35	16.04	15.55
15.70	16.40	16.00	15.99	16.17	15.75	16.05	15.49	15.55	16.45	16.11	15.70
16.15	15.85	16.15	15.62	16.42	15.45	15.75	15.74	15.70	16.55	16.15	15.95
16.05	15.95	16.10	15.90	16.40	16.24	16.48	15.94	15.85	16.30	16.20	15.55
16.30	16.23	16.15	16.15	16.46	16.28	16.45	16.38	15.85	16.50	16.30	16.15
16.25	16.41	16.15	16.11	16.53	16.53	16.31	16.39	15.75	16.55	15.95	16.00
15.88	15.62	16.15	16.15	16.50	16.31	16.16	15.80	15.70	16.55	16.05	15.70
16.05	16.10	16.00	15.71	15.96	16.14	16.51	16.15	15.70	16.50	15.95	16.10
		16.15	15.89	16.43	16.02	16.54	16.10	15.75	16.65	15.93	15.70
16.40	16.05	16.10	15.82	16.08	16.17	16.34	16.54	15.55	16.35	16.28	15.30
16.12	15.89	16.25	15.89	16.59	16.19	16.68	16.00	15.45	16.30	15.85	15.90
16.23	16.16	15.55	15.95	16.70	16.05	16.26	16.19	15.65	16.45	16.00	16.10
16.34	16.37	15.20	16.07	16.21	15.43	16.32	16.08	15.70		15.99	16.10
16.05	16.50	15.55	15.82	16.24	15.30	16.30	15.70	15.45	16.60	16.03	15.65
16.07					15.44					16.23	
15.66	16.13	16.22	15.95	16.36	15.79	16.02	16.39	15.15	16.46	16.30	
15.69	15.88	15.24	15.86	15.90	16.18	16.46	16.35	15.38	16.51	16.12	
15.68	16.25	16.22	16.03	16.37	15.52	16.56	16.07	15.30	16.60	16.12	
15.60	16.10	15.32	16.17	16.01	16.09	16.28	16.17	15.10	16.48	15.90	
15.60	16.46	16.20	16.10	16.30	16.24	16.39	16.50	15.15	16.47	16.33	
15.90	16.34	16.32	15.85	16.13	15.93	16.40	16.18	15.34	16.63	16.18	
16.13	15.28	16.40	16.27	16.38	16.26	16.60	16.46	15.20	16.80	16.03	
15.97	15.49	16.30	15.84	16.27	16.11	15.97	16.03	15.38	16.46	16.11	
15.70	16.30	16.15	16.23	15.76	16.05	16.13	16.19	15.20	16.36	16.14	
15.71	16.23	16.32	16.25	16.39	15.59	16.31	16.37	15.18	16.53	16.23	
15.41	15.45	15.69	16.20	16.33	16.20	16.60	16.39	15.24	16.60	16.02	
15.86	16.08	16.14	16.25	16.16	15.96	16.31	15.96	15.18	16.70	16.14	
15.44	15.96	16.23	15.88	16.25	16.08	16.02	16.20	15.20	16.35	16.35	
15.59	16.23	15.67	16.04	16.31	16.12	16.56	16.27	15.40	16.70	16.06	
15.65	16.26	15.71	16.10	16.22	15.96	16.12	16.37	15.13	16.44	16.12	
15.54	16.25	15.24	15.88	16.10	15.71	16.70	16.08	14.94	16.52	16.37	
	16.15	15.86	16.12	16.29	15.88	15.84	16.45	15.14	16.49	15.92	
15.82	16.00	16.15	16.17	16.27	15.55	16.58	16.20	15.22	16.43	16.19	
16.08	15.45	16.16	16.08	16.17	16.15	15.92	16.33	15.06	16.74	15.92	
15.94	15.86	16.29	16.16	15.79	16.22	16.17	16.00	15.26	16.76	15.94	
16.20	16.35	15.96	15.94	16.58	15.76	16.62	16.09	15.32	16.35	16.10	
15.42	16.18	16.17	16.06	15.90	15.94	16.80	16.27	15.28	16.80	16.14	
15.49	15.98	16.15	16.00	16.51	15.45	16.45	16.29	15.13	16.31	16.32	
15.84	16.12	16.02	15.74	16.29	15.88	16.37	16.00	15.12	16.88	16.22	

TABLE II

ELEMENTS OF TWENTY-THREE VARIABLES

Variable	Photographic Magnitudes Max.	Min.	Amp.	Epoch of Max	Period days	β days/10^6yr.
1	14.0	17.0	3.0	40504.	332.	
2	15.6	16.4	0.8	40389.502	0.5710205	
3	15.55	16.25	0.7	40389.595	0.566343	
4	15.5	16.15	0.65	40389.628	0.2821317	
5	15.7	16.25	0.55	40389.709	0.70238	0.9
6	15.7	16.25	0.55	40389.740	0.2602558	
7	15.6	16.55	0.95	40389.696	0.49959	−0.15
8	15.4	16.45	1.05	40389.957	0.559921	−0.25
9	15.95	16.35	0.4	40389.583	0.3206025	0.15?
10	15.4	16.6	1.2	40389.532	0.4155329	1.1
11	15.8	16.45	0.65	40389.611	0.592808	−0.21
12	15.25	16.5	1.25	40389.593	0.472956	2.2 to −1.1
13	15.35	16.6	1.25	40389.596	0.466797	
14	15.4	16.5	1.1	40389.763	0.4816129	0.5
15	15.6	16.25	0.65	40389.687	0.2885895	
16	15.65	16.5	0.85	40389.853	0.5228709	−1.6
17	15.4	16.45	1.05	40389.761	0.561154	
18	15.75	16.5	0.75	40389.898	0.564378	
19	15.75	16.3	0.55	40389.822?	0.2787622	
20	15.65	16.4	0.75	40389.653	0.5781113	
21	16.3	16.6	0.3	40389.704	0.258125	
23	15.5	16.2	0.6	40389.725	0.3233436	
24	15.65	16.45	0.8	40389.615	0.3462153	−0.35?

REMARKS TO TABLE II

Variables for which no β is given here are considered as having constant periods and their light curves are shown in Figure II. Values of β have been determined on the assumption of linear period change, as represented in the phase shift diagrams in Figure I.

V7 Period derived from Kukarkin's alternate period 0.4996. His favoured period 0.3332065 did not fit the David Dunlap observations. Period decrease seems indicated but a constant period is not ruled out.

V9 Period increase seems indicated, but a constant period is not ruled out.

V11 Adopted period derived from that of Dickens (0.59280). The value of β is uncertain. The phase-shift diagram is better represented by an abrupt change of period than by a linear change (i.e. two intersecting straight lines rather than a parabola).

V12 The assumed period indicates both an increase and decrease of period over the 35 year interval. If instead, the phase-shift diagram was constructed with P = 0.472972, a period decrease of 1.6 days per million years would be indicated. The adopted period is that which gives the smaller dispersion of points in the phase-shift diagram over the 35 year interval.

V20 Period derived by us and confirmed by Dickens.

V21 Probably not a cluster member.

V24 Period derived by us, but uncertain because there were no observations by Kukarkin, Mannino or Dickens. An alternate period, P = 0.529586 is possible.

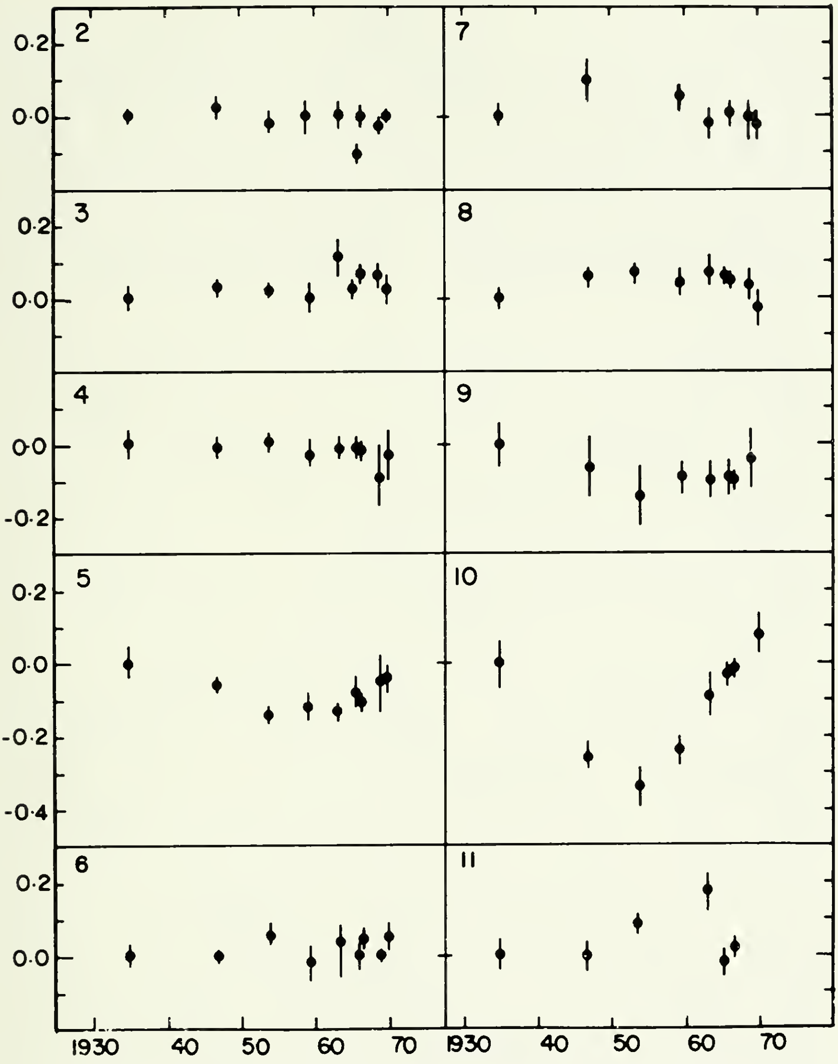

FIG. 1—Phase-shift diagrams (phase-shift vs. year). The marks along the vertical axis are one tenth of a cycle apart. Vertical bars represent probable errors.

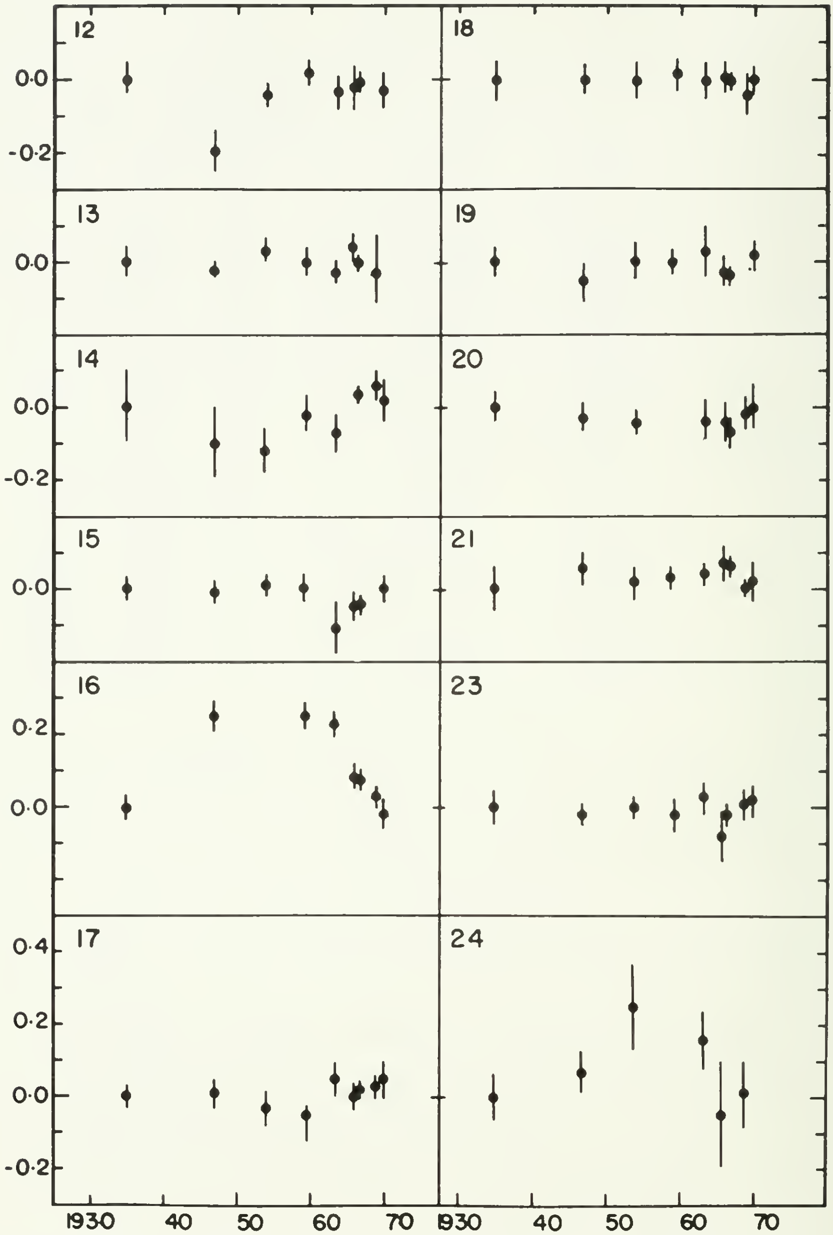

FIG. 1, cont'd—Phase-shift diagrams (phase-shift vs. year). The marks along the vertical axis are one tenth of a cycle apart. Vertical bars represent probable errors.

tudes, the epochs of maximum light and β, the rate of period change in days per million years. The periods were derived from those of Kukarkin (1961) except for variable 7, where we chose his alternate period, and variables 1, 11, 20, and 24. Dickens (1970) has studied variables 11 and 20; he confirmed a value of the period for variable 20 which we communicated to him (Coutts 1964), but ruled out our period for variable 11 so the period we have adopted for this star is based on his value. We are not certain about our value for the period of variable 24 and have suggested an alternative, but it does not fit the observations as well.

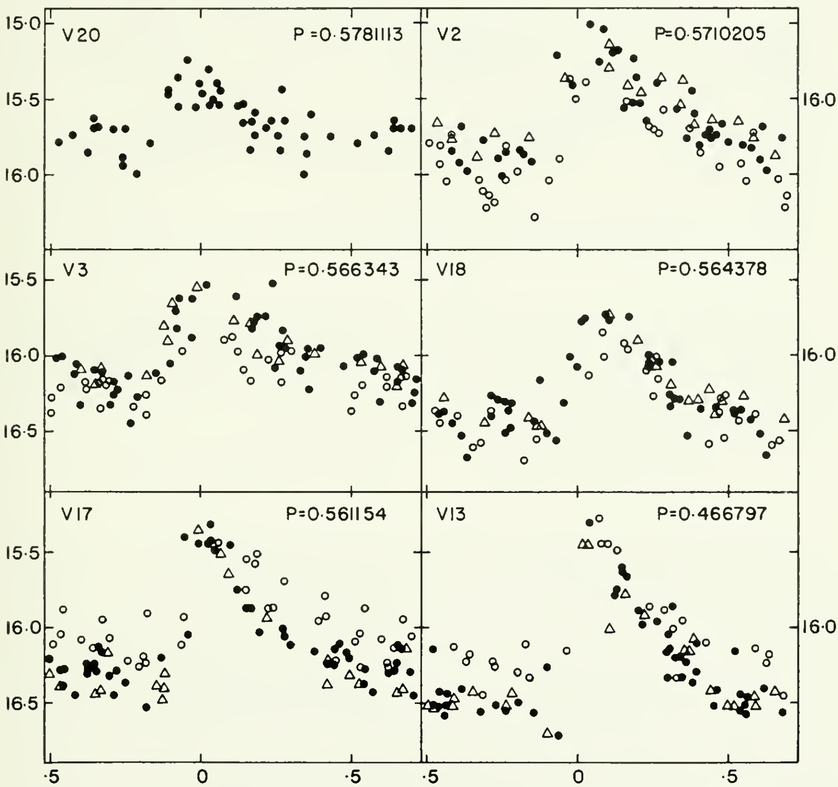

FIG. 2—Light curves for stars with constant periods. The phase is in fractions of a period. Triangles represent the observations from Mt. Wilson (1935), closed circles from the David Dunlap Observatory, and open circles from Cerro Tololo. For variable 20, only the David Dunlap observations are plotted because there are large systematic differences in magnitudes between the observations from different observatories.

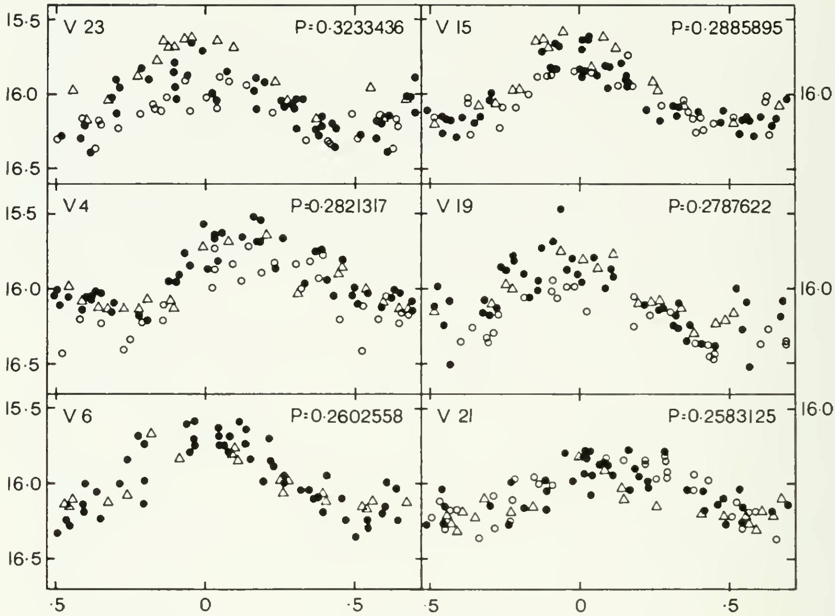

FIG. 2, cont'd—Light curves for stars with constant periods. Triangles represent the observations from Mt. Wilson (1935), closed circles from the David Dunlap Observatory, and open circles from Cerro Tololo. For variable 6, only the Mt. Wilson and David Dunlap observations are plotted because the star is not resolved on the Cerro Tololo plates and the magnitudes are brighter.

We have investigated the variables for period changes by the method described by Belserene (1964). Using the periods of Table II, light curves for the Mt. Wilson 1935 observations were drawn on tracing paper and fitted to the curves for other years to determine the phase shifts. The phase shift data are shown in Table III and the diagrams in figure 1. For twelve of the stars, no period change is indicated over the time interval 1935–1970. Light curves for these stars are shown in figure 2. For the stars which have period changes, β has been calculated as for Messier 5 by Coutts and Sawyer Hogg (1969). Standard parabolas for different values of β/P^2 were fitted visually to the phase shift diagrams and the best value of β calculated. These values of β are listed in Table II and the relationship between β and period is shown in figure 3.

TABLE III

PHASE SHIFTS (in fractions of a period)

Year	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
1935	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1946–48	.02	.03	−.01	−.06	.00	−.10	.06	−.06	−.26	.00	−.20
1953–55	−.02	.02	.01	−.14	.06		.07	−.14	−.34	.09	−.04
1959–60	.00	.00	−.03	−.12	−.02	.05	.04	−.09	−.24		.02
1963–64	.00	.11	−.01	−.13	.04	−.02	.07	−.10	−.09	.18	−.03
1966	−.10	.02	−.01	−.08	.00		.06	−.09	−.03	−.02	−.02
1966–67	.00	.07	−.02	−.11	.05	.01	.05	−.10	−.02	.02	.00
1969	−.02	.06	−.09	−.05	.00	.00	.03	−.04			
1970	.00	.02	−.03	−.04	.05	−.02	−.03		.08		−.02

Year	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18	No. 19	No. 20	No. 21	No. 23	No. 24
1935	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1946–48	−.02	−.10	−.01	.25	.01	.00	−.05	−.03	.06	−.02	.07
1953–55	.03	−.12	.01		−.03	.00	.00	−.04	.02	.00	.25
1959–60	.00	−.02	.00	.25	−.05	.02	.00		.03	−.02	
1963–64	−.03	−.07	−.13	.23	.05	.00	.03	−.04	.04	.03	.16
1966	.04		−.05	.08	.00	.01	−.03	−.04	.07	−.08	−.05
1966–67	.00	.03	−.04	.07	.02	.00	−.04	−.07	.06	−.02	
1969	−.03	.06		.03	.03	−.04		−.02	.00	.01	.01
1970		.02	.00	−.02	.05	.00	.02	.00	.02	.02	

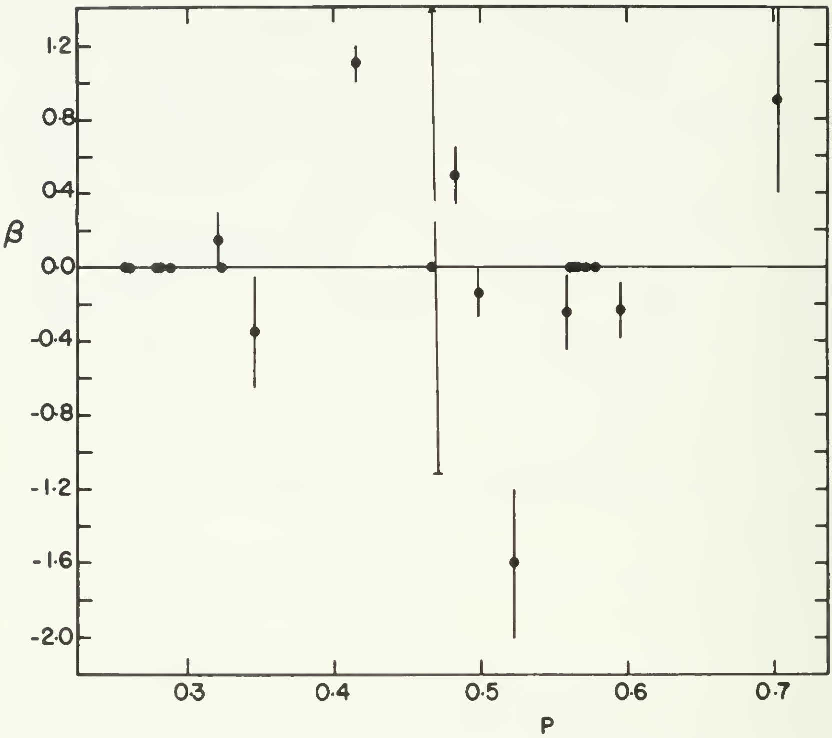

FIG. 3—The rate of change of period β (in days per million years) vs. period (in days). Vertical bars represent the probable errors in β for stars with changing periods.

Variable 1

Variable 1 (V720 Oph) is a long period variable. It is located 8′.9 from the centre of the cluster. The cluster radius is given as 6′.4 by Kron and Mayall (1960). Owing to the distance of this variable from the centre of our plates and the fact that it is brighter than the standard sequence of Oosterhoff at maximum and fainter at minimum it is difficult to determine the magnitudes accurately. In Table IV, we give mean photographic magnitudes and mean Julian Days for all observations separated by less than a week. The period of this variable appears to be very long, 332 days. Its light curve is shown in figure 4. According to Feast (1965), no Mira variables with periods greater than 220 days have been found to be members of globular clusters. He is currently working on the important problem of the membership of this star.

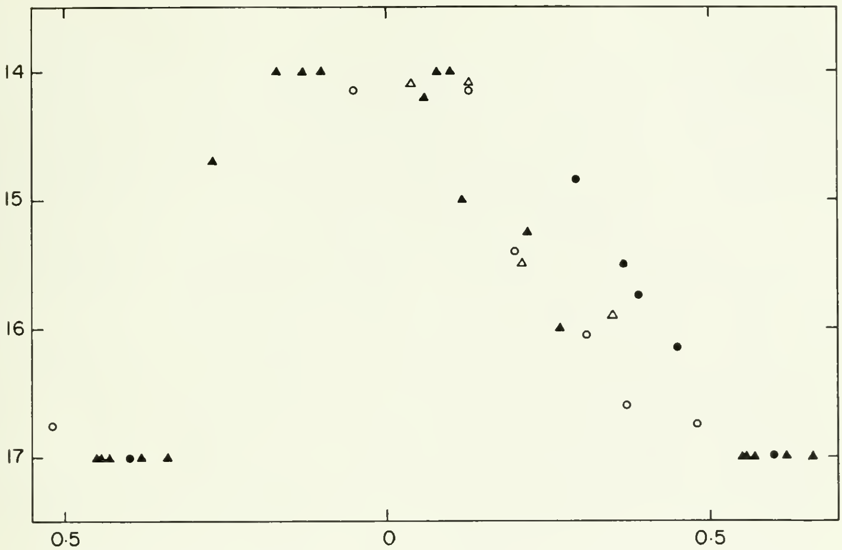

FIG. 4—Light curve for variable 1. The phase is in fractions of a period. Open circles represent the observations of 1935, closed circles 1946–48, open triangles 1953–55 and closed triangles 1963–70.

TABLE IV

MEAN POINTS FOR LIGHT CURVE OF VARIABLE 1

Julian Day	Magnitude
31970	14.85
32000	15.75
32328	15.5
32355	16.15
32734	17.0
34540	14.1
34570	14.1
34930	15.5
35308	15.9
38199	14.2
38585	15.25
39265	16.0
39357	17.0
40355	17.0
40390	17.0
40449	14.0
40692	17.0
40708	17.0
40747	14.7
40801	14.0
40809	14.0
40862	14.0
40870	14.0
40880	15.0

Discussion

There are twenty-two RR Lyrae variables in NGC 6171. Of these, fourteen are of Bailey type *a*, *b* and eight type *c*. One of the type *c* variables, no. 21, is fainter than the others and is probably not a cluster member. Dickens (1970) excludes this variable from his discussion of the properties of RR Lyrae variables in NGC 6171. The number of RR Lyrae type *c* variables is therefore seven. The mean period of the *a*, *b* stars is 0.54 days, and of the type *c* stars 0.29 days. These periods are short for their types, a feature which is characteristic of relatively high metal content. This is expected because the Morgan class of the spectrum is V (Sandage and Katem 1964) and in the colour-magnitude diagram, the horizontal branch is heavily populated on the red side of the RR Lyrae gap (van Agt 1961, Sandage and Katem 1964). The period-amplitude relation is shown in figure 5 and the period-frequency distribution in figure 6. These diagrams indicate that NGC 6171 is a cluster of the Oosterhoff type I, or, as Dickens (1970) notes, it might even represent a somewhat shorter period group.

We have found that almost half of the variables show period changes during the 35 year interval of observations. Four have increasing periods (median rate 0.7 days per million years) and five decreasing (median rate 0.25 days per million years). One variable, no. 12 appears to have had an increase and a decrease in its period over the 35 year interval. Behaviour like this raises doubt that observed changes are caused by evolutionary effects in the stars. Also it can be seen from figure 1 that the observations for both variables 10 and 11 would be better represented by two intersecting straight lines (indicating an abrupt period change) than by a parabola (indicating a uniform change). This problem of the interpretation for phase-shift diagrams was discussed for six stars in M5 by Coutts (1969) who concluded that the hypothesis of abrupt period change was usually better than that of the uniform change.

The period changes for these variables in NGC 6171 are large compared with those in M5 where 20 stars have increasing periods (median 0.05 days per million years) and 12 have decreasing periods (0.075 days per million years). However, we must keep in mind the fact that with observations over a time interval of only 35 years in NGC 6171, the minimum value of β that can be detected when $P = 0.5$ is 0.15 days per million years.

The period changes of the RR Lyrae variables in M3 are of about the same order of magnitude as those we observe in NGC 6171 and in both clusters there are about the same number increasing as decreasing. On the other hand, almost all the RR Lyrae stars investigated in ω

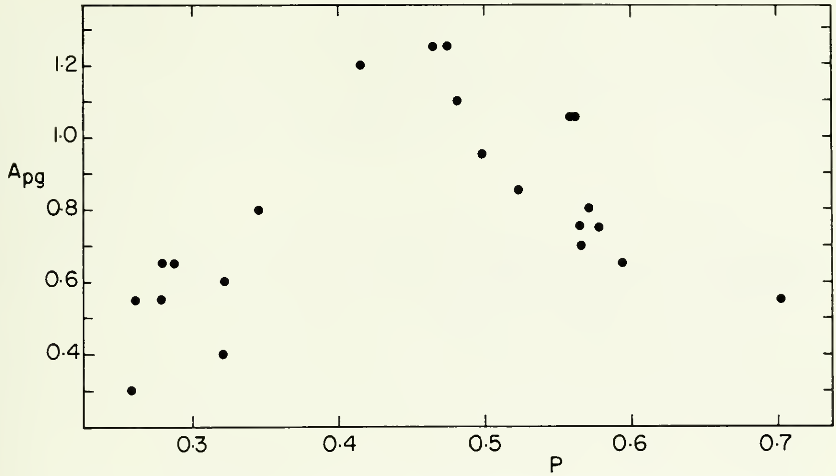

FIG. 5—Period-amplitude relation. The amplitude in photographic magnitudes was calculated from the David Dunlap observations.

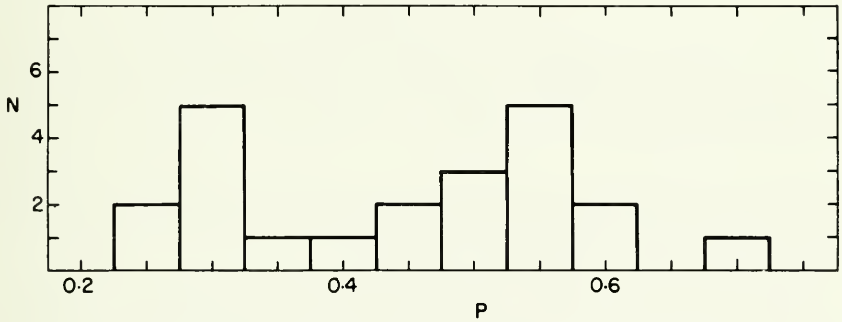

FIG. 6—Period-frequency distribution of the RR Lyrae stars.

Centauri show increases in period. If the observed dispersion in period changes is due to some random noise as Iben and Rood (1970) commented, it would appear that the RR Lyrae periods are increasing at a rate of 0.1 days per million years. These authors pointed out that one of their models for horizontal branch stars ($Y = .30, Z = 10^{-4}$) gave a reasonable fit to the observed period changes of the RR Lyrae stars in ω Centauri. They found that a model with $Y = 0.30, Z = 10^{-3}$ gave an approximate fit to the observations in M3. It appears that the period changes found for the variables in M5 and NGC 6171 are similar to those in M3 and give a reasonable fit for Iben and Rood's models. However, if the observed increases and decreases are both caused by evolutionary effects, most theories indicate that increases and decreases

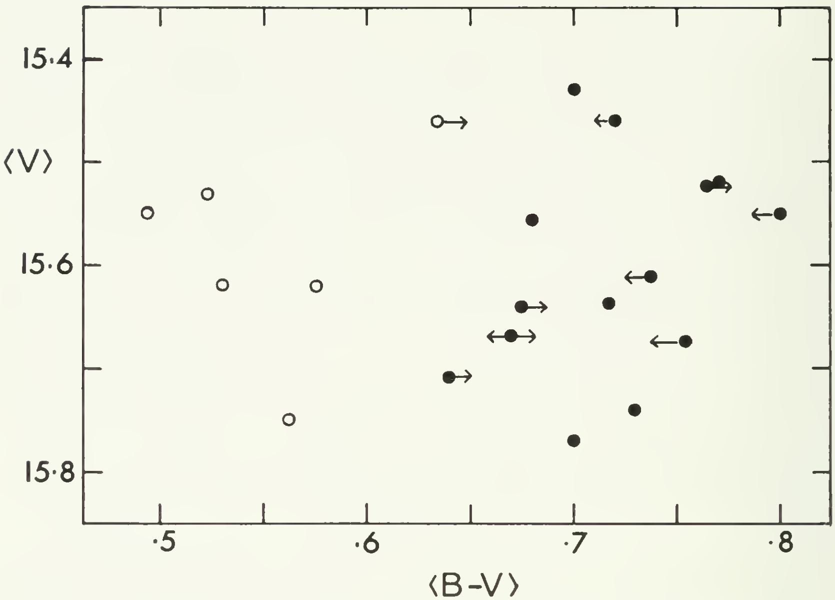

FIG. 7—Colour-magnitude plot of the RR Lyrae variables in NGC 6171. The data are taken from Dickens (1970). Arrows pointing to the right indicate period increases; and those to the left, period decreases.

should be at different rates and consequently we should find more periods changing in the direction in which the evolution is slower. This is not the case in any of these clusters.

Figure 7 shows the positions of the RR Lyrae variables in a colour-magnitude plot. The data have been taken from Dickens (1970). Arrows indicate the direction of the period change (if any). The most noticeable feature of this diagram is the absence of period change among the type *c* variables with $\langle B - V \rangle < 0.60$. It is possible that these stars have constant periods because they are changing the direction of their evolutionary path in the HR diagram.

At the present time, it seems doubtful that the observed period changes are caused by evolution of the stars. It is interesting to note, however, that the period changes indicate a difference between ω Centauri and M3, M5 and NGC 6171. These latter clusters are of the Oosterhoff type I while ω Centauri belongs to the longer period type II group. Belserene (1956) pointed out that ω Centauri appears to be a cluster relatively poor in RR Lyrae variables when their numbers are compared with all the other horizontal branch stars. On the other hand, according to her investigation M3 and M5 are richer and NGC 6171 is one of the richest clusters. The reality of the separation of the clusters into two groups according to the period changes of their RR Lyrae stars can be better established when the variable rich and metal poor cluster M15 is reinvestigated.

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