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THE VARIABLE STARS IN THE FIELD OF THE GLOBULAR CLUSTER NGC 6544

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ABSTRACT

A search for variable stars in the neighborhood of the galactic globular cluster NGC 6544 has located two variables within the tidal radius of the cluster and two outside. A star of large proper motion was also detected. One of the variables within the tidal radius is possibly an eclipsing binary; the other is a RR Lyrae type ab star that may be a cluster member. The two field variables are RR Lyrae type ab stars.

1. INTRODUCTION

The globular cluster NGC 6544 (C1804−250) lies at $\alpha = 18^h04^m15^s$, $\delta = -25°00'.3$ (1950); $l = 5°.8$, $b = -2°.2$. Webbink's (1985) listing indicates that it is a cluster of moderate central concentration, with a low metallicity, [Fe/H] = −2.15, and a tidal radius of approximately 12 arcmin. He gives the foreground reddening as $E_{(B-V)} = 0.73$ mag.

Alcaino (1983) has measured standards near NGC 6544 and derived a color–magnitude diagram for the cluster that, although the scatter is large, appears to show a very blue horizontal branch. He places the horizontal branch at $V \sim 15.0$ mag. Sawyer Hogg (1973) lists no searches of this cluster for variable stars, and the SIMBAD data base lists no searches since that time.

2. OBSERVATIONS AND REDUCTIONS

The photographic material for this study is comprised of 29 plates exposed in the B passband (103a-O+GG385 filter) with the 1 m Yale reflector at CTIO. The years (number of plates) are: 1977 (4), 1978 (1), 1979 (2), 1980 (4), 1983 (3), and 1985 (15). Blinking of 9 independent pairs of plates (18 plates) revealed two new variables, V1 and V2, within the tidal radius of NGC 6544, and two, F1 and F2, outside. These four variables are identified in Figs. 1 and 2 (Plates 48 and 49). In addition, a star of large proper motion was identified near the cluster; this is labeled "LPM" on Fig. 1.

Calibration of the plates involved use of Alcaino's (1983) photometric standard stars A–N, P–R, T, and U, giving a sequence to $B = 17.46$ mag. In addition, two stars near the cluster, labeled HA and HB on Fig. 1 were measured photoelectrically, once each, by the author in 1980 June (see Hazen-Liller 1984 for details of the observations and reductions), giving values for HA: $V = 12.25$ mag, $B - V = +0.52$ mag; HB: $V = 14.06$ mag, $B - V = +0.60$ mag. These stars are in good agreement with the calibration curves from Alcaino's standards.

In order to extend the sequence about a magnitude, four of the 1985 plates were exposed with a Pickering–Racine sub-beam prism in place. On these plates, with an iris photometer, measurements were made of the primary images of Alcaino's sequence, the secondary images of A–H, S, T, HA, and HB, and nine faint secondary standards, labeled b–f and i–l on Fig. 1. The calibration curve of the eight secondary images brighter than $B = 17.46$ mag, when compared with the curve from the primary images, gave Δmag for each plate individually (values from 3.36 to 3.58). After application of the Δmag to derive B for the secondary images, one calibration curve was drawn for each of the four plates using the Alcaino sequence plus all the measurable secondary images. From this curve, photographic B were derived for Alcaino's standards I–N, P–R, T, and U, and also for the secondary standards b–f and i–l. Means from the four plates were taken, and the resulting photographic sequence is presented in Table 1, where the first

TABLE 1. Photographic B magnitudes for photometric standards.

Alcaino Desig.	B (mag)	Sec. Std. Desig.	B (mag)
I	14.70	b	18.35
J	14.67	c	17.72
K	15.41	d	18.11
L	15.90	e	16.39
M	16.48	f	16.32
N	16.63	i	18.02
P	17.09	j	17.51
Q	17.30	k	16.68
R	17.36	l	15.64
T	14.52		
U	15.42		

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TABLE 2. *B* magnitudes of the variables.

Hel. J.D 2,440,000+	V1	V2 (mag)	F1	F2	Hel. J.D. 2,440,000+	V1	V2 (mag)	F1	F2
3330.768	18.27	16.32	16.64	17.64	6208.655	18.05	16.43	16.36	17.89
3332.783	18.33	15.58	16.51	17.59	6208.826	18.5:	15.34	15.46	16.76
3341.677	>18.4	16.46	16.67	17.46	6209.651	18.21	16.39	15.79	17.35
3348.714	17.89	16.66	16.27	17.86	6209.832	18.10	16.50	16.02	17.60
					6210.705	18.15	16.15	16.39	18.01
3698.786	>18.4	16.29	16.75	17.23	6211.691	18.21	15.42	16.14	17.18
					6211.900	18.25	16.31	16.01	17.69
4016.853	>>18.4	16.03	16.90	17.48	6212.671	18.30	16.46	16.15	17.83
4017.831	>>18.4	15.13	16.49	17.88	6212.889	18.18	15.68	16.37	16.57
					6213.625	18.14	16.28	16.42	16.54
4397.684	>17.5	16.51	15.99	>17.5	6213.823	18.15	16.49	16.33	17.43
4399.863	>18.4	16.53	15.74	17.85	6214.608	18.37	15.76	16.34	17.59
4401.574	17.99	16.59	16.45	17.32	6214.801	18.19	16.43	15.71	17.87
4401.691	18.25	16.47	16.48	17.71	6215.665	18.37	15.22	16.33	16.59
					6215.880	18.24	16.31	16.43	17.48
5519.695	18.29	16.44	16.71	18.06					
5520.578	18.33	16.06	15.60	16.93					
5520.705	18.35	16.46	15.91	17.38					

column is the Alcaino standard designation, and the second the photographic magnitude adopted. Columns 3 and 4 give the secondary standard designation and the magnitude. The average standard deviation of the values from the four plates was ± 0.06 mag, and appeared to be independent of *B*.

With the photographic standards in Table 1, *B* magnitudes were determined for the four variables on each of the 29 plates with an iris photometer. V1 lies in a crowded region of the cluster and is quite faint; its magnitudes are undoubtedly somewhat less reliable than those for the other variables. The measured *B* for the variables are given in Table 2, where the first column gives the heliocentric Julian Date of midexposure of the plate, and the remaining four columns the magnitudes.

The agreement among the standards discussed above suggests that the individual magnitudes for the variables are accurate to ± 0.06 mag. However, the problems arising from use of the Pickering–Racine prism have been well documented (see, for example, Blanco 1982). Thus, the derived *B* lying fainter than the faint end of the photoelectric sequence ($B > 17.46$ mag) may have systematic errors in addition to the error quoted above.

3. THE VARIABLE STARS

Period searches for V2, F1, and F2 were conducted on the magnitudes derived from the 15 plates from 1985. The results are presented in Tables 3 and 4, where column 1 gives the variable designation, and columns 2 and 3 the position of the variable. In Table 3, this is first the distance in arcsec east (positive) or west (negative), and south (negative) of the cluster center; and beneath these figures for each star, the R.A. and Dec., epoch 1950. For F1 and F2, only the R.A. and Dec., epoch 1950, are given in these columns. The fourth and fifth columns of Tables 3 and 4 contain the maximum (brightest) and minimum (faintest) *B*, and the sixth column a "mean" magnitude $\langle B \rangle = (B_{\max} + B_{\min})/2$. Column 7 gives the period for the stars V2, F1, and F2; column 8 the epoch of maximum light; and column 9 the probable variable type. Light curves for V2, F1, and F2 from the 1985 data appear in Fig. 3. For V1, no period was determined, because crowding and faintness render the *B* for this variable rather uncertain. However, from the run of *B* as shown in Table 2, it seems possible that V1 may be an eclipsing binary. This is noted in the final column of Table 3.

TABLE 3. Characteristics of the cluster variables.

Var. No.	x(arcsec) R.A.(1950)	y(arcsec) Dec.(1950)	B_{max} (mag)	B_{min}	<B> (mag)	P (days)	Epoch 2,440,000+	Prob. Type
V1	- 55	- 55	17.9	>>18.4	-----	----	-------	ecl??
	$18^h04^m11^s.2$	$-25^\circ01'13''$						
V2	+111	-119	15.1	16.6	15.85	0.57	4017.831	RRab
	18 04 23.4	-25 02 18						

TABLE 4. Characteristics of the field variables.

Var. No.	R.A. (1950)	Dec.	B_{max} (mag)	B_{min} (mag)	<B> (mag)	P (days)	Epoch 2,440,000+	Prob. Type
F1	$18^h03^m50^s.1$	-25°22′11″	15.5	16.9	16.2	0.74	6208.826	RRab
F2	18 03 28.7	-24 54 11	16.5	18.1	17.3	0.69	6213.625	RRab

4. THE PROPER MOTION STAR

The star labeled "LPM" in Fig. 1 was observed in the blinking process to have moved significantly between 1977 and 1985. Table 5 presents data for two observations of this star, where the first column gives the heliocentric Julian Date, and the second and third columns the observed right ascension and declination. The difference in position gives a yearly proper motion of 0.22 arcsec yr^{-1} in a position angle of 197°. The B of this star is approximately 14.1 mag. No star of large proper motion is listed in the SIMBAD data base at or near the position of this star.

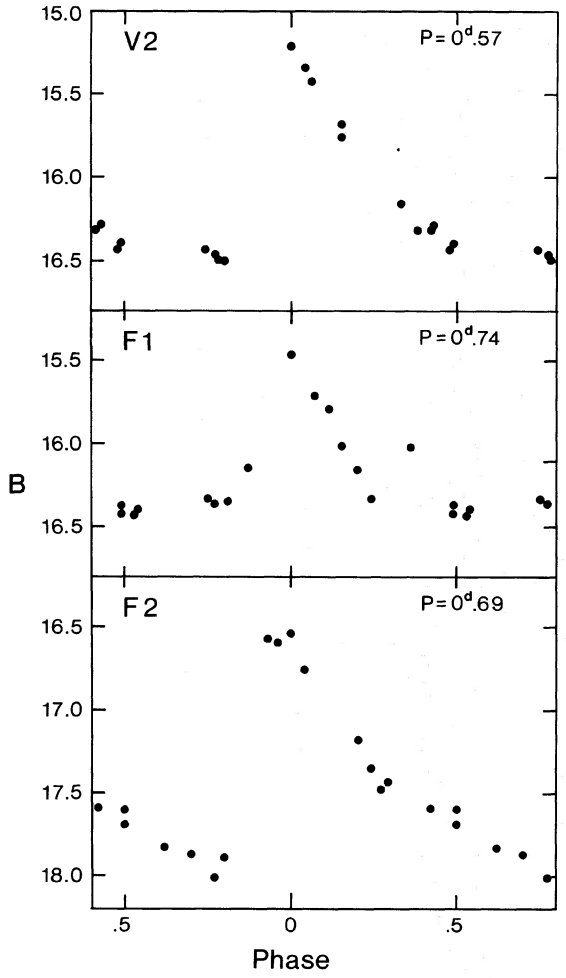

FIG. 3. Light curves for the RR Lyrae variables V2, F1, and F2.

5. DISCUSSION

The only possibility for an RR Lyrae star as a true member of NGC 6544 is V2, a type RRab variable with a period of 0.57 days, a blue amplitude from Table 3 of 1.5 mag, and a $\langle B \rangle$ of 15.85 mag. If we use V of the horizontal branch and $E_{(B-V)}$ as given in Sec. 1 of 15.0 and 0.73 mag, respectively, and if $(B-V)_{RR} \sim 0.35$ mag, the $\langle B \rangle$ expected for an RR Lyrae star in NGC 6544 is 16.1 mag. This value is somewhat fainter than the $\langle B \rangle$ derived for V2, apparently ruling out membership in the cluster. But the uncertainties in Alcaino's horizontal branch V and in the present photometry make it impossible to draw such a firm conclusion.

A second piece of data, however, which would appear to support cluster membership for V2, is its period in relation to its amplitude. A plot of amplitude against period given by Sandage *et al.* (1981) shows mean relations between these two quantities for clusters of two different metallicities: M3, [Fe/H] = −1.69, and M15, [Fe/H] = −2.15, with the latter showing longer periods at a given amplitude. V2 in NGC 6544, with the data given in Table 3, falls very close to the mean line for M15, a cluster of similar metallicity to NGC 6544. Therefore, on the basis of the period–amplitude relation, V2 would seem a possible member of NGC 6544.

The resolution of the status of V2 must await a study of other criteria for membership, such as proper motion or radial velocity.

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TABLE 5. Data for the large proper motion star.

Hel. J.D. 2,440,000+	R.A. (1950)	Dec.
3332.783	$18^h04^m11^s.92$	-25°04′15″.5
6213.823	18 04 11.88	-25 04 17.1

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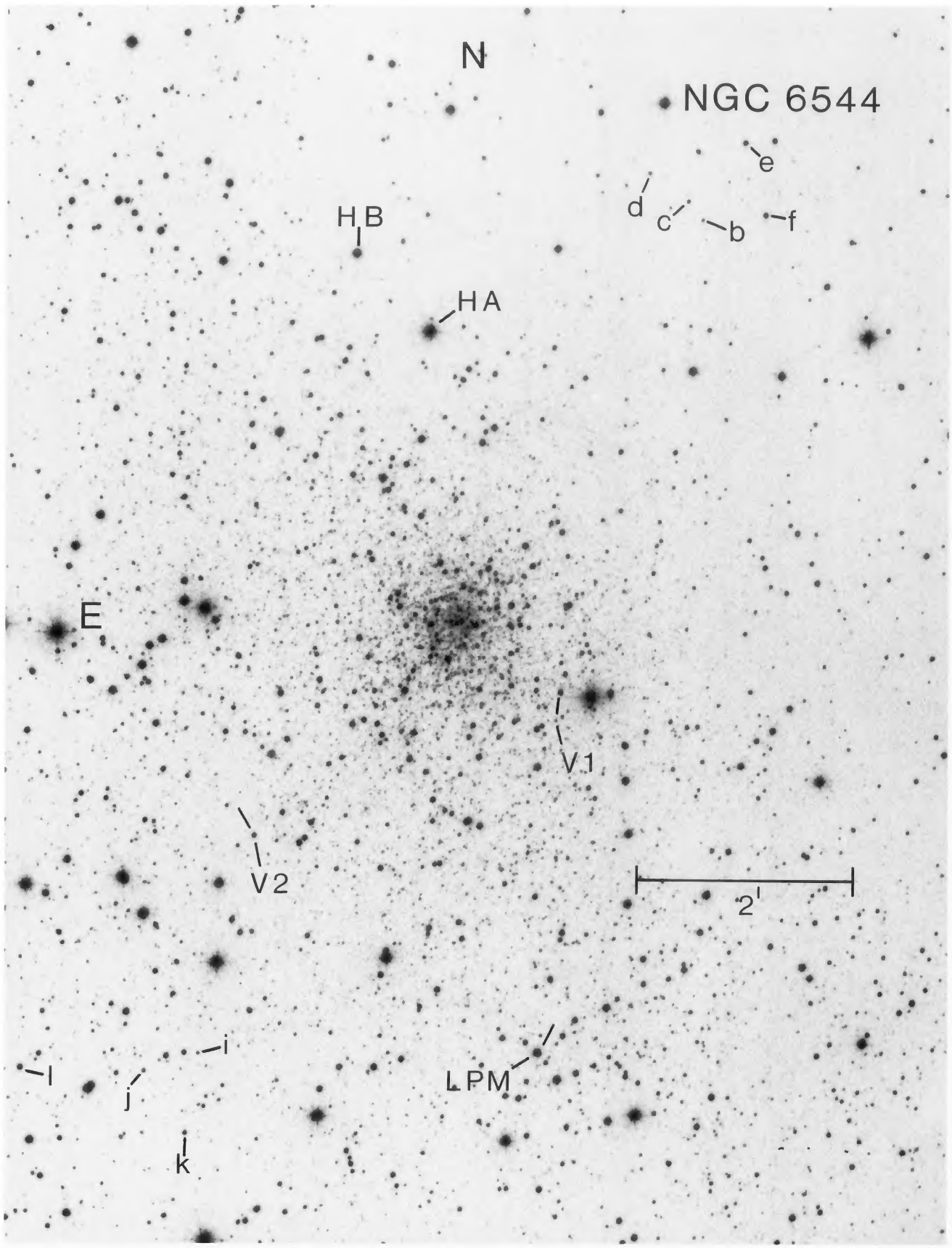

FIG. 1. Chart of NGC 6544 showing cluster variables V1 and V2, photoelectric standards HA and HB, secondary standards b–f and i–l, and the large proper motion (LPM) star. Pickering–Racine prism secondary images appear ~0'.5 SW of the brighter stars. Exposed with the 1.0 m Yale reflector at CTIO for 15 min on baked Kodak 103a-O emulsion behind a Schott GG385 filter.

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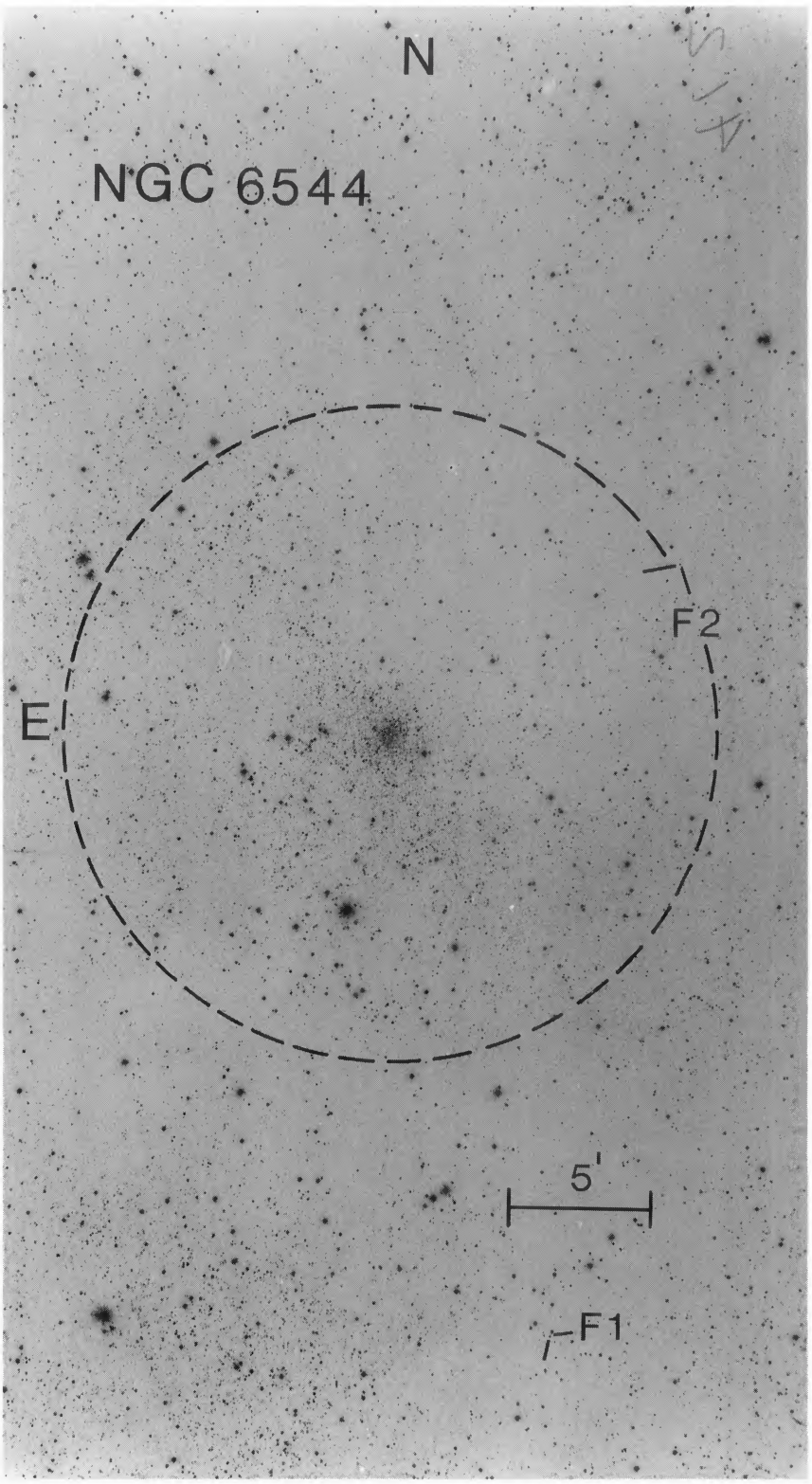

FIG. 2. Chart of the field around NGC 6544 showing field variables F1 and F2. The radius of the dashed circle is the approximate tidal radius of the cluster (12 arcmin). Original plate data as for Fig. 1.

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