

UBV r SEQUENCES AND OBSERVATIONS OF OPTICALLY IDENTIFIED RADIO SOURCES

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Photoelectric observations of eight optically identified radio sources and comparison stars in nearby fields are presented. Six of these objects have continuous spectra and may belong to the BL Lac class of variables. The reported observations indicate possible short-term, small-amplitude variations in some of the optical counterparts of the radio sources.

Key words: radio sources — UBV r photometry — sequences

I. Introduction

Recent spectroscopic surveys of optically identified radio sources have shown that a significant number of these objects possess continuous spectra. The characteristics of many of these objects are similar to those of the class prototype BL Lacertae which is varying at both optical and radio frequencies. The possibility of faint underlying galactic structure for this class of objects implies that spectroscopy may be fruitful if undertaken during brightness minima, when the nuclear regions are not competing so effectively in luminosity with the hypothesized underlying galaxy. Some of these objects are bright enough to be photographically monitored on a regular basis by observers with access to telescopes of moderate aperture. In order to encourage this type of observation we have obtained broadband magnitudes and color indices of comparison sequences for six candidates. Two other radio sources which exhibit one or more emission lines, but which are also bright enough for photographic monitoring, have been included in this program. It should be emphasized that for monitoring programs to be of greatest value, times of brightness minima must be communicated immediately to groups engaged in spectroscopic observations of radio sources.

Table I contains a list of objects for which sequences and observations have been obtained to date, along with 1950 positions, number of comparison stars in the sequence (n), spectral character, and a partial list of references which yield pertinent data on each object.

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II. The Observations

The observations were obtained during the nights of 1974 August 8, 9, 10, 11, 19, and 20 using a computer-controlled photometer now in use with the 90-inch (2.29 m) reflector of Steward Observatory. The sensitivities of our ultraviolet, blue, and visual bands reproduce the UBV standard bands. The red band is centered at 7000 Å with a half bandwidth of 1000 Å. The difference of magnitudes between the visual and red bands has been transformed to the $(V-r)$ color index established by Sandage and Smith (1963). The integration times in each band were fixed to obtain a maximum statistical error for the signal from the star of 3%. A more detailed description of our observing and reduction techniques appears in Craine and Tapia (1975).

Color indices and magnitudes for the comparison sequences are presented in Table II where n represents the number of observations of each star. If $n > 1$ the observations were made on different nights; colors indicate that the mean squared error of one observation expressed in magnitudes is larger than 0^m04 but always less than 0^m08. The name assigned to each star refers to the label which appears on the finding chart for each sequence. The finding charts (Figs. 2-9) are reproduced from the Palomar Sky Survey blue prints. North is at the top and east is to the left. The optical counterpart of the respective radio source is marked with a broken line.

III. Analysis of the Radio-Source Observations

Our observations of the radio sources appear in Table III with the Julian Date and the air

TABLE I
RADIO SOURCE FIELDS OBSERVED PHOTOELECTRICALLY

Name	Other	$\alpha(1950)$	$\delta(1950)$	n	Spectrum
1538 + 14	4C14.60	15 ^h 38 ^m 30 ^s	14° 57' 22"	9	continuous
1656 + 05	OS 094	16 56 05	05 19 47	5	one line
1727 + 50	OT 546	17 27 06	50 15 00	12	continuous
1749 + 09	OT 081	17 49 10	09 39 43	9	continuous?
2141 + 17	OX 169	21 41 14	17 30 02	7	Z $\approx$ 0.21
2254 + 07	OY 091	22 54 46	07 27 10	10	continuous?
2335 + 03		23 35 34	03 10 24	6	continuous
0219 + 42	3C66A	02 ^h 19 ^m 30 ^s	42° 48' 30"	7	continuous

NOTES:

- 1538 + 14: Wills and Wills (1974a); Johnson, K. (1974)
 1656 + 05: Browne et al. (1973); Baldwin et al. (1973); Strittmatter et al. (1974)
 1727 + 50: = IZw 187 (compact galaxy), Warner (1972); Le Sequeron et al. (1972); Warner et al. (1975)
 1749 + 09: Browne et al. (1973)
 2141 + 17: Browne et al. (1973); Wills and Wills (1974a); Strittmatter et al. (1974)
 2254 + 07: Browne et al. (1973)
 2335 + 03: Strittmatter (1974)
 0219 + 42: Wills and Wills (1974b)

mass, X , of each observation. The observations of the radio sources were obtained before or after the observations of stars in the respective sequences and between the observations of secondary standards. Since our routine of observation eliminates the effects of short-term sky inhomogeneities, equipment drift, and extinction variations on the color indices, we expect the same random errors in the observations of the radio sources as the stars. However, for some of the radio sources the color indices and magnitudes have larger deviations from the average than the mean-square error of our observations as determined from the secondary standards. Since the B and V bands of our system are the most efficient, we have chosen the $(B-V)$ color index to illustrate the larger deviations of the radio sources.

We assume that the error of a signal registered by our instrument is proportional to the square of the air mass X , at the time of the observation (Stock 1969). Therefore the statistical weight of a measurement of the signal is proportional to X^{-4} . Let S_i be the signal corresponding to a value $(B-V)_i$ of the color index and $\langle S \rangle$ the weighted average. The percentage error of one measurement of the signal, reduced to unit weight, is given by

$$\epsilon_i = (1 - \langle S \rangle / S_i) X_i^{-2} \quad (1)$$

We have computed ϵ_i for each of the 25 observa-

tions of the radio sources and 54 observations of stars from the Selected Areas 46, 62, and 66 (Praiser 1974). The distributions of ϵ_i are presented in the histograms of Figure 1. Histogram A, for the stars in the Selected Areas, resembles a Gaussian distribution with a standard deviation of about 0.02, reaching zero at approximately ± 0.05 . About 10% of the ϵ_i values for the stars lie outside ± 0.03 . Histogram B, obtained from the observations of the radio sources, shows a flatter, more extended distribution. About 45% of the observations of the radio sources have $|\epsilon_i| > 0.03$.

Such a difference between the two distributions could be interpreted as the product of intrinsic behavior of the radio sources or as a very peculiar systematic error in our observations. We suggest that histogram B is indicative of short-term, small-amplitude variations of the radio sources.

Furthermore, we would like to note a significant decrease in brightness of 1538 + 14. At the telescope we were immediately struck by the faintness of this object with respect to its appearance on the Palomar Sky Survey plates. Wills and Wills (1974a) have estimated that $m_v = 15^m.5$ for 1538 + 14 on the Sky Survey prints. Our observed visual magnitude is about 1^m.7 fainter.

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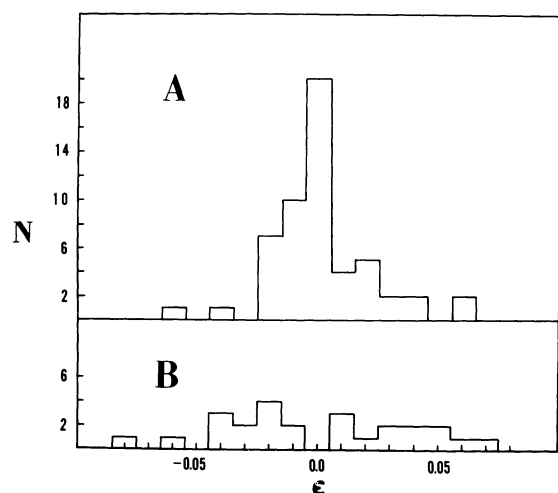


FIG. 1 — Histograms of N vs. ϵ for stars from Selected Areas (A) and radio sources (B).

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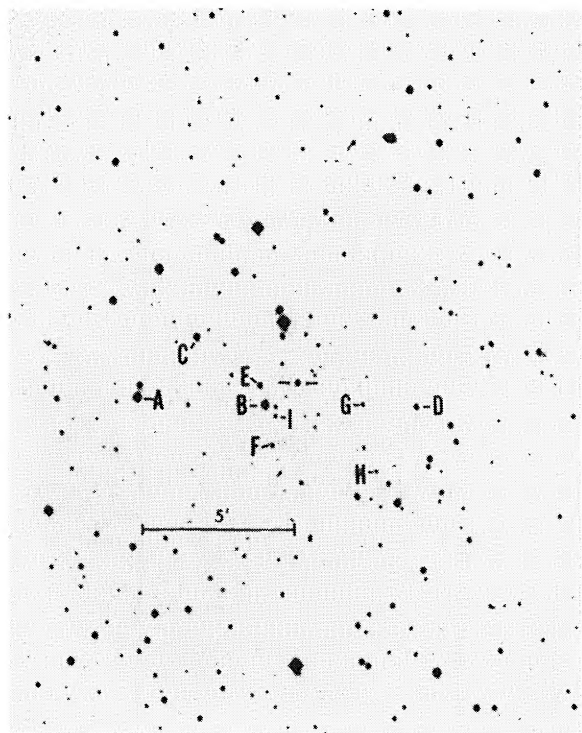


FIG. 2 — Finding chart for 1538 + 14.

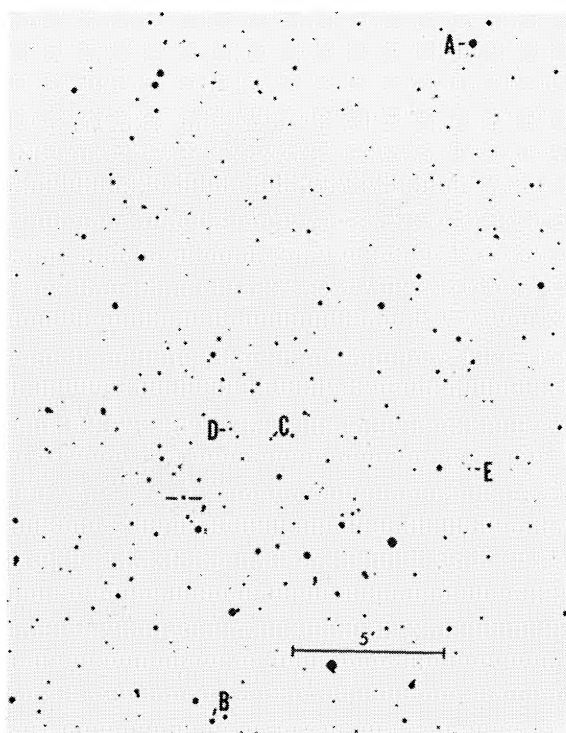


FIG. 3 — Finding chart for 1656 + 05.

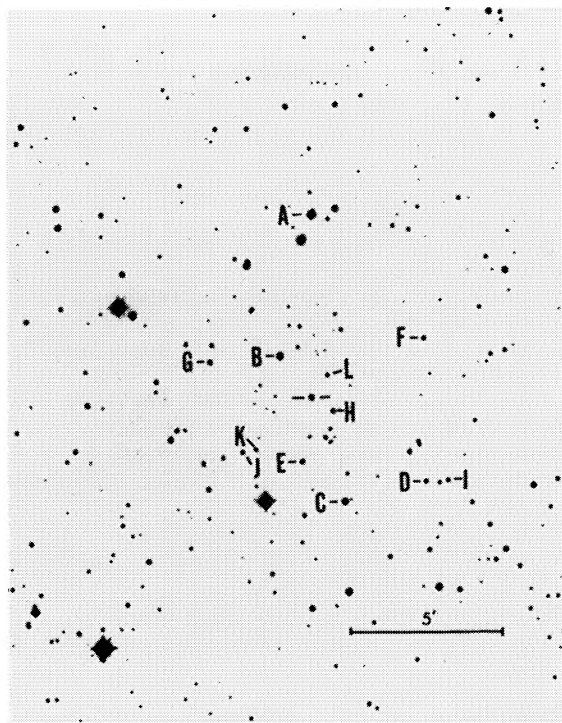


FIG. 4 — Finding chart for 1727 + 50.

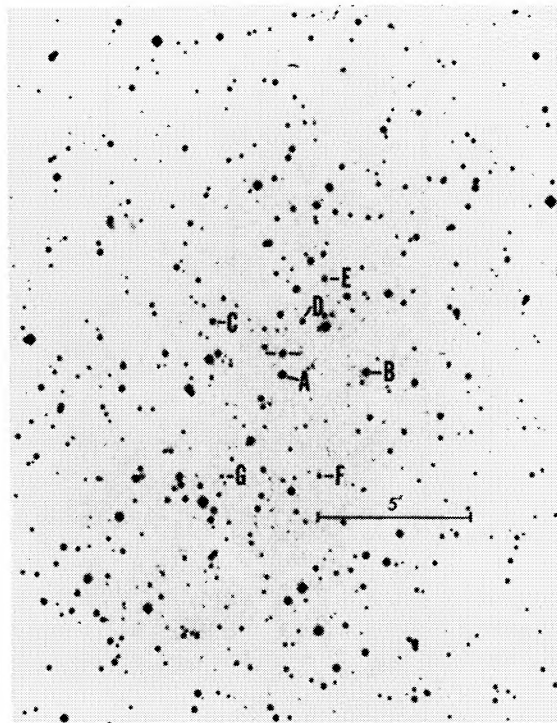


FIG. 6 — Finding chart for 2141 + 17.

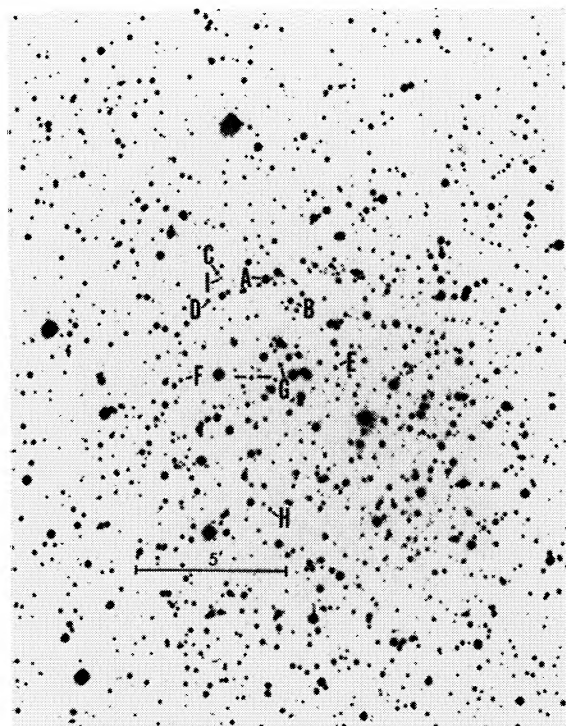


FIG. 5 — Finding chart for 1749 + 09.

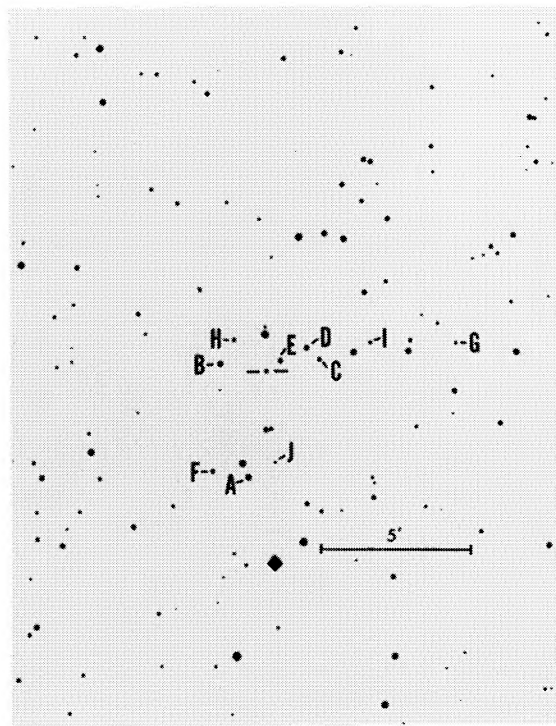


FIG. 7 — Finding chart for 2254 + 07.

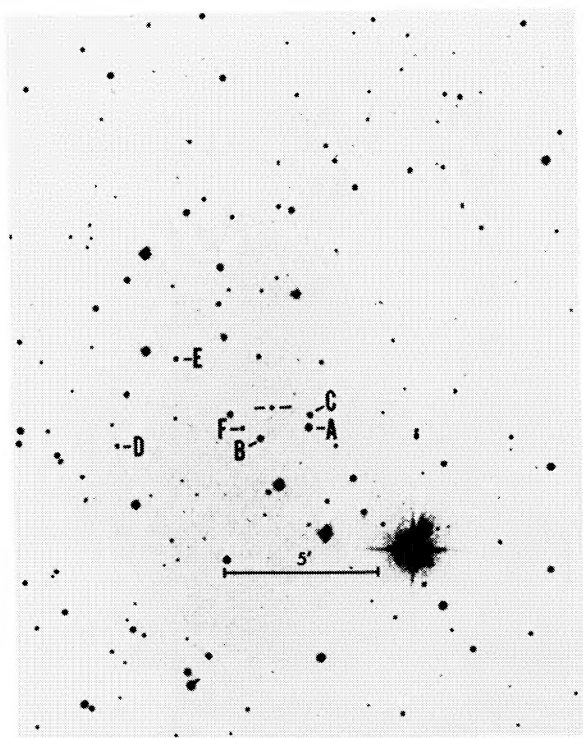


FIG. 8 — Finding chart for 2335 + 03.

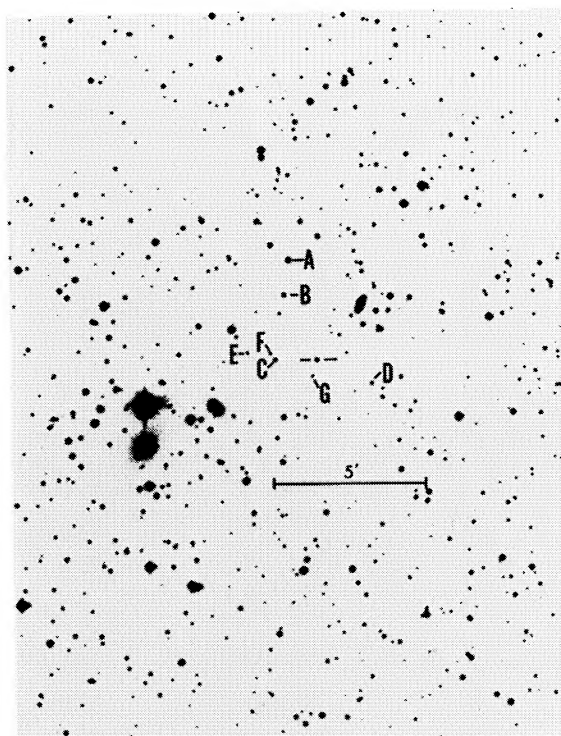


FIG. 9 — Finding chart for 0219 + 42.

TABLE II
MAGNITUDES AND COLORS OF SEQUENCE STARS

Star	V	B-V	U-B	V-r	n
1538 + 14					
A	13.06	0.76	0.36	0.61	1
B	13.40	0.92	0.52	0.67	1
C	14.63	0.91	0.74	0.72	1
D	15.59	0.77	0.13	0.47	2
E	16.15	0.61	-0.01	0.56	2
F	17.57	0.84	0.38	0.60	2
G	17.62	0.74	0.17	0.20	1
H	17.97	0.57	0.18	0.30	1
I	18.18:	0.37	0.02	0.40:	2

TABLE II (*Continued*)

Star	V	B-V	U-B	V-r	n
1656 + 05					
A	11.32	0.61	0.16	0.52	1
B	14.29:	0.17	0.29	0.01	2
C	16.56	0.79	0.41	0.57	2
D	17.06	0.66	0.11:	0.78	2
E	17.38	0.74	0.09	0.15	1
1727 + 50					
A	11.88	0.59	0.09	0.46	2
B	13.11	0.61	0.22	0.46	2
C	13.19	0.60	0.10	0.52	2
D	14.79	1.07	1.02	0.70	2
E	14.90:	1.00:	0.81	0.94:	2
F	15.27	0.44	-0.02	0.48	2
G	15.33:	0.60	0.04	0.53	2
H	15.33	0.56	-0.01	0.48	2
I	15.84	0.52	-0.13	0.44	2
J	15.98	0.51	0.02	0.57	2
K	16.13	0.93	0.51:	0.71	2
L	16.14	0.79:	0.25:	0.67:	2
1749 + 09					
A	14.14	0.74	0.23	0.58	2
B	16.14	1.03	0.57	0.77	2
C	16.81	0.76	0.33	0.71	2
D	17.14	0.86	0.56	0.77	1
E	17.21	0.93	0.33	0.47	1
F	17.42	0.72	0.20	0.72	3
G	17.61	0.71	0.24:	0.57	2
H	17.65	0.61	0.25	0.61	1
I	18.09:	0.83	0.23	0.69:	2
2335 + 03					
A	14.53	1.00	0.63	0.82	1
B	15.61	0.74	0.32	0.67	1

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TABLE II (*Continued*)

Star	V	B-V	U-B	V-r	n
C	15.81	1.02	0.74	0.94	1
D	16.92	0.39	0.16	0.62	1
E	17.17	0.38	-0.06	0.60	1
F	17.40	0.98	1.13:	1.07	1
2141 + 17					
A	13.96	0.57	0.13	0.50	2
B	14.64	0.43	0.28	---	1
C	15.58	0.60	0.01	0.56	1
D	15.86	0.78	0.15:	0.64	2
E	16.24	0.79	0.22	0.60	2
F	17.24	0.66	0.02	0.55	1
G	17.73:	0.65:	0.18:	0.69:	2
2254 + 07					
A	13.26	1.15	1.05	0.84	2
B	13.96	0.81	0.44	0.61	2
C	15.00	0.93	0.55:	0.69	2
D	15.05	0.61	0.01	0.47	2
E	15.32	0.57	0.02	0.57	2
F	15.76	0.59	0.09	0.52	2
G	16.19	0.77	0.50	0.69:	2
H	16.23	0.72	0.24	0.59	2
I	16.26	0.51:	0.07:	0.63	2
J	17.40	0.64	0.05	0.77	2
0219 + 42					
A	13.56	0.46	0.09	0.41	2
B	14.77	1.00	0.59	0.80	2
C	15.75	0.53	-0.04	0.44	2
D	16.10	0.67	-0.09	0.39	1
E	16.90	0.88	0.50:	0.80	2
F	17.08:	0.76	0.30:	0.75	2
G	17.22	0.76	-0.10	0.52	2

TABLE III
MAGNITUDES AND COLORS OF RADIO SOURCES

Object	JD 2442260+	V	B-V	U-B	V-r	X
1538 + 14	11.6861	17.22	0.64	-0.51	0.74	1.459
	20.6472	17.30	0.42	-0.59	0.77	1.254
	20.6757	17.22	0.66	-0.44	0.70	1.421
1656 + 05	11.7153	16.54	0.46	-0.60	0.34	1.306
	19.6812	16.41	0.41	-0.67	0.31	1.258
1727 + 50	8.7125	15.98	0.64	-0.42	0.62	1.094
	8.7465	15.94	0.66	-0.44	0.66	1.163
	20.7076	16.01	0.51	-0.54	0.75	1.259
	20.7792	15.99	0.54	-0.34	0.56	1.410
1749 + 09	8.7625	16.78	0.68	-0.47	0.87	1.268
	9.6639	16.87	0.64	-0.38	0.76	1.081
	20.7285	17.40	0.71	-0.54	0.97	1.259
2141 + 17	10.7632	15.73	0.18	-0.73	---	1.043
	19.7812	15.83	0.13	-0.77	0.33	1.036
	19.8159	15.80	0.21	-0.80	0.15	1.036
2254 + 07	10.8208	16.36	0.71	-0.46	0.80	1.169
	10.8625	16.44	0.59	-0.56	0.58	1.098
	19.8590	16.33	0.67	-0.45	0.74	1.099
	19.8743	16.37	0.60	-0.35	0.77	1.108
	20.8611	16.50	0.59	-0.42	0.80	1.100
	20.8819	16.54	0.56	-0.43	0.93	1.118
2335 + 03	20.9028	17.76	0.53	-0.41	0.65	1.155
0219 + 42	9.8965	15.44	0.47	-0.62	0.49	1.253
	9.9799	15.33	0.57	-0.53	0.42	1.056
	19.9180	15.54	0.43	-0.54	0.64	1.098
	19.9569	15.52	0.45	-0.52	0.53	1.036