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Optical behavior of 64 extragalactic radio sources*

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A 7-yr photometric study of nearly 200 extragalactic radio sources has shown that their optical variability is a complex and many-faceted phenomenon. Twenty optically violent variables were discussed in a previous paper by McGimsey *et al.* (1975). In the present paper 64 less-active sources with well-established comparison sequences are discussed. Light curves and photometric data are given for the 23 objects exhibiting variations that are significant at the 95% confidence level. The variability data do not appear to show strong evolutionary effects.

INTRODUCTION

IN a recent paper (McGimsey *et al.* 1975), referred to hereafter as Paper I, the authors discussed the optical behavior of 20 violently variable extragalactic radio sources presently being monitored photographically at the Rosemary Hill Observatory. The present paper is a report on 64 additional sources in the program that are of sufficient interest to have had comparison sequences established. The history of the 7-yr Rosemary Hill program, methods of data recording and reduction, and plate and filter combinations have been discussed in Paper I and will not be repeated here.

The photometric data for the sources discussed in the present paper were screened for variability by the chi-squared statistical test described by Penston and Cannon (1970) and adapted to the Rosemary Hill program by R. L. Hackney (1972). Sources were accepted as variable if the confidence level for variability was greater than 95%. Undoubtedly some sources that were classified by this rather rigid standard as not variable are, in fact, varying and this behavior will become apparent after further observation. In addition, there exists the possibility that a few of these objects may be reclassified as optically violent-variables (OVVs) upon further observation.

I. RESULTS

The results of the observations are summarized in three tables. It should be noted that, as in Paper I, the error quoted in Tables I and III is the rms scatter of the comparison-star magnitudes around the calibration curve. In Table I are listed those objects for which the chi-squared test indicated less than 95% confidence for variability. Column 1 gives the object name, column 2 the type of object (from the literature), and column 3 the number of plates exposed. A finder reference, mean magnitude in either m_{pg} or B, total range of variation observed, average rms error, and the confidence level for variability from the chi-squared test are given in columns 4–8, respectively.

The 23 objects that were variable at a confidence level of 95% or higher are listed in Tables II and III. Table II gives the object name in column 1, the equatorial coordinates (1950.0) in columns 2 and 3, a reference to a finding chart in column 4, the variability subclass in column 5 (explained in Sec. II), and the confidence level for variability in column 6. The photometric data for these objects are recorded in Table III with the UT date of observation, the Julian date, the observed magnitude, its associated error, and the magnitude system in which the observations were made appearing in columns 1–5, respectively. Plates taken in m_{pg} are denoted by a "*P*" in column 5, while a "*B*" represents the Johnson blue magnitude system.

The 23 variable sources are considered individually in the following remarks. As in Paper I, a short history, the light curve (which appears in Fig. 1), and the method of calibration of the comparison sequence for each object are discussed. In these remarks a time scale referred to as "long term" implies months to years, while "short term" implies weeks to a few months. All data from selected areas were taken from Brun (1957).

PKS 0519-11: This QSO has been reported to show little or no optical variation by Peach (1969) and Lü (1972). The Florida light curve indicates that long-term trends are present with a short-term "flicker" of about $0^m.5$ superimposed. The long-term variation, which also has a $0^m.5$ range, shows a minimum in 1972. The comparison sequence of Angione (1971) was used.

PKS 0222-23: This source was identified as a possible QSO by Bolton *et al.* (1965a). The Florida data show a long-term maximum in early 1971 with smaller maxima superimposed upon the subsequent decline. The total variation has been $1^m.5$, with short-term changes of up to $0^m.3$ observed. A comparison sequence was calibrated by photographic transfer from SA 119.

NRAO 140: The optical counterpart of the QSO NRAO 140 was identified by Kristian and Sandage (1970). Kraus *et al.* (1968) reported a radio spectrum with a peak of 4.1 f.u. at 700 MHz. Medd *et al.* (1972)

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TABLE I. Florida sources whose confidence level for variability is less than 95%.

Object	Type	No. plates	Finder[a]	Mean mag.	Range	error	χ^2
OA 33		8	r	20.21	0.46	0.16	23.0%
PKS 0013−00	QSO?	11	g	18.52	0.74	0.15	40.0%
PKS 0048−09	Gal.	24	g	17.75	0.51	0.11	92.5%
PKS 0056−00	QSO	18	e	15.98	0.42	0.16	23.0%
PKS 0119−04	QSO	25	f	16.55	0.60	0.12	56.0%
PKS 0139−09	QSO?	15	g	16.99	0.56	0.11	75.0%
PKS 0202−17	QSO	26	e	16.99	0.61	0.11	87.0%
3C 66A		8	x	15.52	0.72	0.14	94.0%
PKS 0229+13	QSO	25	q	17.12	0.53	0.13	85.0%
PKS 0251+18	QSO?	11	j	17.08	0.21	0.11	1.0%
PKS 0333+12	QSO?	13	d	17.46	0.29	0.11	2.5%
PKS 0340+04	QSO	7	j	17.93	0.34	0.08	84.0%
PKS 0350−07	QSO	6	e	16.71	0.17	0.13	11.0%
PKS 0451−28	QSO?	13	b	18.15	0.52	0.12	80.0%
OH 471	QSO	14	n	18.65	0.53	0.16	91.0%
OI 318	QSO	23	a	18.14	0.77	0.16	56.0%
PKS 0725+14	QSO	18	d	17.66	0.37	0.11	79.0%
OI −072	QSO?	5	i	16.94	0.34	0.09	50.0%
OI −187		5	u	17.20	0.43	0.13	70.0%
PKS 0850+14	QSO	7	j	17.25	0.31	0.10	53.0%
PKS 0957+00	QSO	9	j	16.74	0.48	0.14	53.0%
PKS 1004+13	QSO	29	h	14.88	0.40	0.19	26.0%
OL 333	BSO	18	m	16.75	0.37	0.15	26.0%
PKS 1049+21	QSO?	12	s	17.94	0.52	0.14	48.0%
PKS 1055+20	QSO	19	h	16.43	0.49	0.16	66.0%
B2 1101+38	BL Lac obj.	3	w	13.92	0.65	0.37	
ON 343		9	l	17.78	0.60	0.18	25.0%
3C 273	QSO	16	o	13.04	0.58	0.13	53.0%
OP 114		15	m	18.25	0.93	0.16	29.0%
PKS 1347+21	QSO?	17	h	15.13	0.52	0.13	88.0%
PKS 1354+19	QSO	9	d	16.08	0.37	0.06	25.0%
PKS 1402−012	QSO	11	i	18.82	0.75	0.16	69.0%
PKS 1437+22	N gal.	6	s	18.18	0.35	0.13	38.0%
4C 05.64	QSO	9	p	18.61	1.00	0.16	50.0%
PKS 1607+26	QSO?	30	s	17.82	0.58	0.10	93.0%
PKS 1618+17	QSO	7	j	16.48	0.24	0.13	3.0%
PKS 2111−25	QSO?	8	c	17.61	0.62	0.10	48.0%
PKS 2128−12	QSO	13	g	15.75	0.42	0.12	17.0%
PKS 2134+004	QSO	8	v	17.53	0.25	0.11	18.0%
PKS 2145+06	QSO	35	d	15.99	0.59	0.12	85.0%
PKS 2300−18	N gal.	16	e	17.86	0.47	0.13	55.0%

[a] See Finder Reference list at the end of Table II.

described the radio intensity as variable at 6.6 and 10.7 GHz. The Florida light curve suggests a long-term brightening of 0^{m}35 between 1971 and 1975 with the presence of significant short-term activity suggested by only one plate in early 1973. A comparison sequence was calibrated by photographic transfer from SA 48.

PKS 0336-01: Bolton and Ekers (1966c) identified the optical counterpart of this QSO. An alternate designation is CTA 26. Radio variability was reported by Wills (1971) at 2.7 GHz, by Medd *et al.* (1972) at 6.6 and 10.7 GHz, by Dent and Kojoian (1972) at 7.8 GHz, and by Dent *et al.* (1974) at 15.5 GHz. The optical light curve shows both long-term and short-term activity with ranges of 0^{m}75 and 0^{m}4, respectively. It is interesting to note that the general shape of the light curve through 1973 agrees with the radio data of Medd *et al.* (1972), Dent and Kojoian (1972), and Dent *et al.* (1974). A comparison sequence was calibrated by photographic transfer from SA 95.

NRAO 190: Medd *et al.* (1972) reported that the average intensity of this QSO gradually declined at 6.6 and 10.7 GHz between 1966 and 1971. This is in agreement with observations at 7.8 GHz reported by Dent and Kojoian (1972), which show a similar decline from 1969 to 1972. In more recent data published by the same group (Dent *et al.* 1974), a small peak superimposed upon this decline was observed in early 1972. Only three Florida observations were made from 1969 to early 1972; they suggest a constant average intensity. The peak observed in late 1972 may correspond to that of Dent *et al.* The object has shown a large decline in average intensity since that time, with moderate-to-large short-term activity present. The Rosemary Hill data suggest that NRAO 190 may be a marginal member of the OVV class. In October 1975 NRAO 190 flared over a magnitude in two weeks and declined equally rapidly, with a second rapid 1-mag flare following in early December. Thus, NRAO 190 definitely seems capable of OVV activity. A comparison sequence was established by photographic transfer from SA 96.

PKS 0458-02: The optical counterpart of this QSO was identified by Bolton and Ekers (1966c). Medd *et al.* (1972) found that the radio source varied by 25% over a 1-yr period at 6.6 and 10.7 GHz. There appears to be no significant long-term component in the optical data, in contrast to these radio results. Short-term variations ranging up to 0ᵐ.5 have been observed. A comparison sequence was calibrated by photographic transfer from SA 97.

OI 363: This QSO was observed to have a moderately peaked radio spectrum by Kraus *et al.* (1968). Medd *et al.* (1972) reported that the object showed little variability at 6.6 and 10.7 GHz, declining about 10% from 1967 to 1971. Folsom *et al.* (1971b) observed a 0ᵐ.5 decline on one plate. The present Rosemary Hill data follow a slow linear brightening trend that totaled about 0ᵐ.30 between 1969 and 1975. There appears to be very little short-term activity, but this inference could be due to the relatively few plates taken per year since 1971. A comparison sequence was calibrated by photographic transfer from SA 52.

4C 05.34: The optical counterpart of this QSO was identified by Wills and Bolton (1969). The large z of 2.877 reported by Lynds and Wills (1970) suggests that it is one of the most distant objects observed in the Florida program. At present only OH 471 (Carswell and Strittmatter 1973) and OQ 172 (Wampler *et al.* 1973) have been found to have larger redshifts. Florida observations reported by Hackney *et al.* (1972) and Scott *et al.* (1973) showed no large optical fluctuations, but suggested short-term changes of up to 0ᵐ.4 and possible long-term low-amplitude changes of 0ᵐ.1/yr. The current Florida observations suggest similar behavior. A comparison sequence was calibrated by photographic transfer from SA 99.

OK 290: This QSO has a radio spectrum that rises smoothly to 10 GHz with no observed maximum (Kraus *et al.* 1968). The optical counterpart was identified by Thompson *et al.* (1968). Stull (1972) observed a 20% decline in flux density at 8 GHz within eight months in 1971. Medd *et al.* (1972) observed a brightening of 1 f.u. between 1967 and 1971 at 6.6 and 10.7 GHz. Folsom *et al.* (1971b) observed a total range of 0ᵐ.3. The optical light curve shows a fairly constant mean, with fluctuations of about 0ᵐ.6 superimposed with periods of months to years. There appears to be some activity with amplitudes of 0ᵐ.25 or less, in periods of weeks to months. A comparison sequence was calibrated by photographic transfer from SA 54.

OL 318: The radio spectrum of this object is almost flat between 0.4 and 14 GHz (Kraus *et al.* 1968). Folsom *et al.* (1971b) observed a 1ᵐ.0 decrease in brightness of the optical object. The Rosemary Hill data suggest that from 1969 to 1974 the optical source varied around a constant mean near 19^{m} with a period of 1–2 yr between adjacent maxima. Although there is a relatively large error associated with observation of this faint source, there appears to be significant short-term activity since mid-1974. A comparison sequence was calibrated by photographic transfer from SA 54.

TABLE II. Florida sources whose confidence level for variability is greater than 95%.

Object	R.A.	Dec.	Finder	Subclass	χ^2
PKS 0159−11	01ʰ59ᵐ30ˢ.0	−11°47′24″	e	I?	99.5%
PKS 0222−23	02 22 45.6	−23 26 28	b	II	>99.5%
NRAO 140	03 33 22.4	32 08 36	a	III?	>99.5%
PKS 0336−01	03 36 58.6	−01 56 12	e	II (or III)	>99.5%
NRAO 190	04 40 04.7	−00 23 16	f	II	>99.5%
PKS 0458−02	04 58 41.1	−02 03 48	e	I (or IV)	>99.5%
OI 363	07 38 01.0	31 18 50	a	II	>99.5%
4C 05.34	08 05 20.9	04 41 36	y	I	>99.5%
OK 290	09 53 59.4	25 29 40	a	II	>99.5%
OL 318	10 10 54.6	35 00 35	m	III?	>99.5%
PKS 1021−00	10 21 56	−00 36 48	g	I	99.5%
PKS 1116+12	11 16 20.2	12 50 59	j	III	>99.5%
ON 325	12 15 21.3	30 23 39	z	I	>99.5%
PKS 1229−02	12 29 27.1	−02 07 35	f	II	>99.5%
PKS 1237−10	12 27 06.3	−10 07 12	e	II	>99.5%
4C 09.42	12 40 06.6	09 57 27	p	III	97.0%
PKS 1252+11	12 52 08.0	11 57 12	j	III	>99.5%
PKS 1510−08	15 10 09.0	−08 54 51	e	III	>99.5%
I Zw 1727+50	17 27 06	50 15	k	I	97.0%
3C 390.3	18 45 36	70 43	t	I	99.0%
OV 080	19 47 39.2	07 59 16	m	IV	>99.5%
PKS 2059+34	20 59 08.8	03 29 49	i	I	>99.5%
PKS 2349−01	23 49 22.5	−01 26 04	f	III (or II)	>99.5%

Finder References

a. Blake (1970).
b. Bolton *et al.* (1965a).
c. Bolton and Ekers (1966a).
d. Bolton and Ekers (1966b).
e. Bolton and Ekers (1966c).
f. Bolton and Ekers (1966d).
g. Bolton and Ekers (1967).
h. Bolton *et al.* (1968).
i. Bolton and Wall (1970).
j. Clarke *et al.* (1966).
k. Craine *et al.* (1975).
l. Folsom (1970).
m. Folsom *et al.* (1971b).
n. Gearhart *et al.* (1972).
o. Greenstein and Schmidt (1964).
p. Jauncey and Hazard (1970).
q. Kinman *et al.* (1967).
r. Lü (1969).
s. Merkelijn (1968).
t. Penston *et al.* (1971).
u. Radivich and Kraus (1971).
v. Shimmins *et al.* (1968).
w. Ulrich (1973).
x. Wills and Wills (1974).
y. Wills and Bolton (1969).
z. Wing (1973).

TABLE III. Observational data.

UT date	J. D. 2440000+	Mag.	rms error	Color	UT date	J. D. 2440000+	Mag.	rms error	Color
				PKS 0159−11					
12/14/69	569.000	16.82	0.07	*B*	9/07/73	1932.860	16.32	0.03	*B*
12/03/70	923.630	16.38	0.17	*B*	10/04/73	1959.831	16.80	0.12	*B*
1/16/71	967.571	16.58	0.05	*B*	10/19/73	1974.684	16.81	0.07	*B*
1/29/71	980.588	16.73	0.09	*B*	12/18/73	2034.546	16.52	0.09	*B*
9/13/71	1207.722	16.63	0.04	*B*	1/16/74	2063.587	16.67	0.08	*B*
12/10/71	1295.603	16.68	0.11	*B*	1/16/74	2063.598	16.82	0.09	*B*
9/13/72	1573.819	16.87	0.08	*B*	9/16/74	2306.872	16.61	0.12	*B*
10/05/72	1595.709	17.11	0.10	*B*	10/12/74	2332.756	16.40	0.08	*B*
10/09/72	1599.753	16.77	0.30	*B*	12/09/74	2390.653	16.40	0.06	*B*
11/03/72	1624.719	16.79	0.11	*B*	1/04/75	2416.595	16.46	0.12	*B*
9/07/73	1932.849	16.71	0.03	*B*	2/03/75	2446.590	16.55	0.03	*B*
				PKS 0222−23					
12/03/69	558.000	16.23	0.21	*P*	9/24/73	1949.803	16.50	0.16	*P*
1/01/71	952.672	15.77	0.10	*P*	9/30/73	1955.834	16.51	0.07	*P*
1/20/71	971.609	15.61	0.13	*P*	10/24/73	1979.724	16.72	0.19	*P*
2/17/71	999.540	15.89	0.06	*P*	12/15/73	2031.638	16.68	0.09	*P*
9/29/71	1223.873	16.30	0.05	*P*	1/16/74	2063.619	17.01	0.15	*P*
12/13/71	1298.687	16.45	0.11	*P*	9/24/74	2314.853	16.51	0.21	*P*
9/15/72	1575.809	16.17	0.33	*P*	10/21/74	2341.742	16.81	0.16	*P*
10/09/72	1599.775	16.05	0.12	*P*	12/09/74	2390.693	16.66	0.20	*P*
11/05/72	1626.726	16.36	0.20	*P*	2/03/75	2446.627	16.80	0.20	*P*
				NRAO 140					
8/30/71	1192.876	17.10	0.12	*P*	10/01/73	1956.842	16.93	0.21	*P*
10/26/71	1250.868	17.18	0.11	*P*	10/31/73	1986.732	17.41	0.03	*P*
10/11/72	1601.757	17.15	0.09	*P*	12/18/73	2034.568	17.10	0.09	*P*
1/29/73	1711.581	17.07	0.12	*P*	2/01/75	2444.556	16.74	0.24	*P*
				PKS 0336−01					
12/03/69	558.861	17.63	0.25	*P*	11/01/72	1622.801	17.88	0.18	*P*
1/31/70	617.576	17.64	0.10	*P*	1/23/73	1705.519	17.81	0.09	*P*
10/02/70	861.824	17.33	0.07	*P*	9/05/73	1930.874	17.78	0.16	*P*
11/22/70	912.708	17.28	0.13	*P*	10/06/73	1961.801	17.56	0.16	*P*
12/21/70	941.628	17.36	0.12	*P*	10/24/73	1979.753	17.89	0.11	*P*
2/20/71	1002.580	17.39	0.14	*P*	11/23/73	2009.731	17.82	0.28	*P*
2/24/71	1006.552	17.25	0.09	*P*	12/15/73	2031.655	17.72	0.13	*P*
9/30/71	1224.853	17.18	0.08	*P*	1/16/74	2063.641	17.61	0.15	*P*
11/25/71	1280.738	17.24	0.06	*P*	2/11/74	2089.522	17.56	0.08	*P*
12/10/71	1295.667	16.67	0.17	*P*	9/22/74	2312.872	17.62	0.13	*P*
1/10/72	1326.567	17.44	0.08	*P*	12/09/74	2390.731	18.09	0.13	*P*
2/06/72	1353.585	17.54	0.09	*P*	1/03/75	2415.588	17.63	0.04	*P*
9/15/72	1575.854	17.68	0.13	*P*	2/12/75	2455.542	17.94	0.12	*P*
				NRAO 190					
12/08/69	563.000	18.07	0.23	*P*	10/06/73	1961.875	18.41	0.11	*P*
9/30/71	1224.892	18.22	0.12	*P*	12/22/73	2038.693	18.20	0.14	*P*
12/13/71	1298.744	17.99	0.19	*P*	1/04/75	2416.678	18.82	0.21	*P*
10/13/72	1603.847	17.70	0.27	*P*	1/15/75	2427.612	18.68	0.03	*P*
11/05/72	1626.803	17.43	0.24	*P*	3/10/75	2481.576	19.05	0.12	*P*
1/31/73	1713.596	18.21	0.20	*P*					
				PKS 0458−02					
12/04/69	559.000	18.89	0.21	*P*	11/02/73	1988.821	19.35	0.05	*P*
10/11/70	870.889	19.10	0.13	*P*	12/18/73	2034.626	19.08	0.07	*P*
1/22/71	973.603	18.84	0.13	*P*	2/15/74	2093.580	19.12	0.20	*P*
1/29/71	980.641	19.06	0.13	*P*	10/18/74	2338.829	19.10	0.12	*P*
2/19/71	1001.599	18.87	0.12	*P*	12/11/74	2392.690	18.60	0.19	*P*
12/11/71	1296.750	18.96	0.14	*P*	1/03/75	2415.648	18.88	0.10	*P*
3/15/72	1391.540	18.80	0.16	*P*	2/05/75	2448.645	19.04	0.09	*P*
10/14/72	1604.908	18.82	0.16	*P*	3/03/75	2474.566	18.97	0.14	*P*
				OI 363					
2/10/69	262.000	16.32	0.07	*P*	1/28/71	979.735	16.09	0.10	*P*
2/12/69	264.000	16.35	0.03	*P*	2/19/71	1001.662	16.21	0.10	*P*
2/18/69	270.000	16.28	0.08	*P*	3/27/71	1037.645	16.31	0.05	*P*
3/10/69	290.625	16.30	0.09	*P*	11/26/71	1281.818	16.19	0.12	*P*
3/13/69	293.000	16.38	0.05	*P*	3/10/72	1386.583	16.25	0.10	*P*
4/20/69	331.622	16.32	0.11	*P*	1/29/73	1711.636	16.12	0.08	*P*
2/08/70	625.704	16.20	0.09	*P*	3/23/73	1764.632	16.19	0.35	*P*
10/01/70	860.887	16.24	0.21	*P*	2/23/74	2101.631	16.15	0.03	*P*
11/27/70	917.766	16.40	0.05	*P*	11/24/74	2375.885	16.05	0.04	*P*
12/22/70	942.717	16.32	0.08	*P*	3/03/75	2474.590	16.08	0.03	*P*

TABLE III (*continued*)

UT date	J. D. 2440000+	Mag.	rms error	Color	UT date	J. D. 2440000+	Mag.	rms error	Color
				4C 05.34					
5/26/70	732.586	18.39	0.09	*P*	2/22/71	1004.781	18.50	0.13	*P*
10/01/70	860.906	18.25	0.15	*P*	2/27/71	1009.646	18.34	0.13	*P*
10/05/70	864.885	18.33	0.13	*P*	2/27/71	1009.647	18.39	0.14	*P*
10/09/70	868.912	18.41	0.14	*P*	3/19/71	1029.654	18.19	0.05	*P*
11/06/70	896.925	18.45	0.07	*P*	10/19/71	1243.903	18.33	0.10	*P*
11/08/70	898.859	18.26	0.14	*P*	11/26/71	1281.866	18.59	0.10	*P*
11/09/70	899.833	18.32	0.24	*P*	12/15/71	1300.926	18.59	0.04	*P*
11/26/70	916.792	18.21	0.14	*P*	12/19/71	1304.765	18.41	0.10	*P*
11/28/70	918.810	18.15	0.12	*P*	2/20/72	1367.767	18.33	0.07	*P*
11/29/70	919.817	18.31	0.17	*P*	3/06/72	1382.635	18.46	0.06	*P*
12/03/70	923.849	18.29	0.08	*P*	3/13/72	1389.629	18.31	0.07	*P*
12/05/70	925.859	18.39	0.08	*P*	4/15/72	1422.571	18.59	0.04	*P*
12/07/70	927.871	18.27	0.05	*P*	11/05/72	1626.878	18.55	0.12	*P*
12/23/70	943.741	18.30	0.08	*P*	1/02/73	1684.794	18.51	0.07	*P*
12/27/70	947.803	18.35	0.07	*P*	1/29/73	1711.661	18.45	0.08	*P*
1/23/71	974.888	18.23	0.07	*P*	3/04/73	1745.660	18.21	0.08	*P*
1/31/71	982.674	18.43	0.11	*P*	4/22/73	1794.587	18.44	0.05	*P*
2/17/71	999.680	18.25	0.11	*P*	12/23/74	2404.831	18.23	0.15	*P*
2/19/71	1001.637	18.29	0.09	*P*	1/15/75	2427.757	18.14	0.09	*P*
2/21/71	1003.656	18.50	0.08	*P*	3/06/75	2477.653	18.50	0.22	*P*
				OK 290					
2/08/70	625.824	16.81	0.08	*P*	1/24/74	2071.862	16.79	0.09	*P*
4/30/70	706.711	17.14	0.16	*P*	1/27/74	2074.848	16.75	0.07	*P*
11/08/70	898.913	16.99	0.18	*P*	2/24/74	2102.787	17.05	0.06	*P*
11/28/70	918.882	17.08	0.13	*P*	2/24/74	2102.818	17.09	0.12	*P*
12/09/70	929.872	16.89	0.10	*P*	3/14/74	2120.670	16.84	0.09	*P*
12/23/70	943.799	17.22	0.10	*P*	4/11/74	2148.649	17.08	0.05	*P*
12/29/70	949.792	17.11	0.04	*P*	4/23/74	2160.669	17.06	0.16	*P*
1/29/71	980.788	16.77	0.10	*P*	5/15/74	2182.656	17.17	0.29	*P*
2/20/71	1002.674	17.03	0.05	*P*	12/19/74	2400.876	17.08	0.11	*P*
3/31/71	1041.760	16.84	0.07	*P*	1/10/75	2422.893	16.85	0.06	*P*
5/19/71	1090.622	16.77	0.06	*P*	1/18/75	2430.808	16.85	0.08	*P*
12/26/71	1311.905	16.56	0.13	*P*	2/16/75	2459.799	16.76	0.19	*P*
4/03/72	1410.619	16.75	0.09	*P*	3/06/75	2477.755	16.78	0.07	*P*
1/28/73	1711.692	16.84	0.08	*P*	4/06/75	2508.669	16.92	0.08	*P*
3/25/73	1766.665	17.25	0.10	*P*	5/01/75	2533.622	17.13	0.10	*P*
4/24/73	1796.637	17.22	0.12	*P*	5/12/75	2544.633	17.32	0.09	*P*
12/22/73	2038.876	16.82	0.07	*P*					
				OL 318					
1/31/70	617.738	18.58	0.24	*P*	3/25/74	2131.633	18.92	0.25	*P*
5/07/70	713.604	19.21	0.24	*P*	4/21/74	2158.694	18.24	0.39	*P*
1/01/71	952.868	18.94	0.21	*P*	4/24/74	2161.646	18.90	0.21	*P*
2/20/71	1002.700	18.91	0.20	*P*	2/09/75	2452.835	19.84	0.17	*P*
12/26/71	1311.937	18.62	0.17	*P*	3/07/75	2478.800	18.80	0.03	*P*
4/04/72	1411.606	18.42	0.24	*P*	5/12/75	2544.662	19.07	0.30	*P*
1/14/73	1696.938	18.97	0.28	*P*					
				PKS 1021−00					
12/12/69	567.000	18.20	0.18	*P*	1/21/75	2433.844	17.91	0.31	*P*
2/25/74	2103.737	18.38	0.08	*P*	3/10/75	2481.690	17.78	0.22	*P*
3/19/74	2125.676	18.00	0.19	*P*	4/06/75	2508.685	17.97	0.03	*P*
12/23/74	2404.901	18.04	0.18	*P*					
				PKS 1116+12					
3/17/71	1027.656	18.67	0.15	*P*	3/02/74	2108.801	18.55	0.20	*P*
3/21/71	1031.653	18.96	0.13	*P*	3/18/74	2124.803	18.64	0.19	*P*
3/28/71	1038.799	18.72	0.19	*P*	3/31/74	2137.780	18.36	0.25	*P*
3/30/71	1040.809	18.62	0.27	*P*	4/14/74	2151.681	18.51	0.20	*P*
4/01/71	1042.768	18.68	0.23	*P*	6/18/74	2216.614	18.67	0.43	*P*
4/24/71	1065.739	18.85	0.22	*P*	12/23/74	2404.937	21.44	0.48	*P*
2/20/72	1367.881	18.43	0.11	*P*	1/18/75	2430.880	18.59	0.09	*P*
3/15/72	1391.786	18.53	0.21	*P*	2/09/75	2452.734	18.06	0.13	*P*
4/13/72	1420.647	17.96	0.17	*P*	2/14/75	2457.878	18.18	0.14	*P*
1/31/73	1713.854	18.63	0.04	*P*	4/06/75	2508.746	18.45	0.19	*P*
5/02/73	1804.649	18.59	0.39	*P*	5/09/73	2541.600	18.52	0.24	*P*
1/24/74	2071.898	18.40	0.25	*P*					

TABLE III (*continued*)

UT date	J. D. 2440000+	Mag.	rms error	Color	UT date	J. D. 2440000+	Mag.	rms error	Color
				ON 325					
2/22/72	1369.742	16.06	0.10	*B*	6/11/74	2209.718	16.09	0.08	*B*
3/21/72	1397.736	15.94	0.12	*B*	6/13/74	2211.718	16.05	0.11	*B*
5/02/72	1439.672	15.80	0.18	*B*	6/14/74	2212.651	16.04	0.04	*B*
6/11/72	1479.588	16.00	0.19	*B*	6/16/74	2214.667	16.05	0.03	*B*
6/23/73	1856.646	16.02	0.15	*B*	6/17/74	2215.706	15.77	0.14	*B*
6/25/73	1858.623	15.76	0.12	*B*	6/18/74	2216.696	15.96	0.06	*B*
6/27/73	1860.645	15.94	0.12	*B*	6/19/74	2217.705	15.88	0.26	*B*
6/30/73	1863.615	15.72	0.10	*B*	6/21/74	2219.656	15.87	0.06	*B*
7/03/73	1866.673	15.83	0.10	*B*	6/23/74	2221.708	15.97	0.06	*B*
7/25/73	1888.585	15.82	0.20	*B*	6/24/74	2222.651	15.92	0.05	*B*
1/27/74	2074.913	16.00	0.13	*B*	7/14/74	2242.719	16.20	0.40	*B*
3/21/74	2127.755	16.39	0.08	*B*	7/15/74	2243.642	16.06	0.09	*B*
4/28/74	2165.797	16.62	0.09	*B*	7/16/74	2244.651	15.92	0.18	*B*
5/15/74	2182.694	16.45	0.17	*B*	7/17/74	2245.661	15.87	0.20	*B*
5/17/74	2184.674	16.58	0.13	*B*	2/07/75	2450.750	16.04	0.12	*B*
5/21/74	2188.753	16.56	0.10	*B*	3/13/75	2484.829	16.21	0.24	*B*
5/24/74	2191.674	16.43	0.11	*B*	5/08/75	2540.632	16.18	0.17	*B*
5/28/74	2195.760	16.43	0.05	*B*					
				PKS 1229−02					
5/26/71	1097.644	16.88	0.10	*P*	1/31/73	1713.913	16.89	0.05	*P*
6/21/71	1123.614	16.71	0.06	*P*	3/10/73	1751.892	16.92	0.06	*P*
3/13/72	1389.821	16.67	0.04	*P*	3/31/74	2137.796	16.96	0.08	*P*
4/13/72	1420.722	16.75	0.05	*P*	3/07/75	2478.827	17.09	0.07	*P*
				PKS 1237−10					
5/25/70	731.000	17.13	0.08	*P*	4/13/72	1420.684	17.22	0.10	*P*
5/31/70	737.607	17.22	0.07	*P*	4/24/73	1796.698	16.82	0.08	*P*
1/30/71	981.860	17.34	0.07	*P*	2/14/75	2457.934	16.90	0.06	*P*
6/21/71	1123.635	17.45	0.07	*P*	4/06/75	2508.766	16.95	0.03	*P*
				4C 09.42					
6/18/71	1120.642	18.07	0.09	*P*	1/24/74	2071.938	18.38	0.19	*P*
12/20/71	1305.910	18.41	0.11	*P*	2/20/74	2098.862	18.40	0.03	*P*
2/22/72	1369.840	18.14	0.08	*P*	4/14/74	2151.722	18.31	0.13	*P*
4/15/72	1422.715	17.96	0.12	*P*	2/14/75	2457.920	18.24	0.10	*P*
5/01/73	1803.702	18.38	0.07	*P*	4/06/75	2508.797	18.37	0.07	*P*
5/21/73	1823.651	17.94	0.28	*P*	5/09/75	2541.678	18.46	0.08	*P*
6/03/73	1836.594	18.30	0.14	*P*					
				PKS 1252+11					
6/08/69	380.000	16.20	0.12	*P*	4/28/73	1800.683	16.15	0.06	*P*
6/12/69	384.000	16.17	0.12	*P*	4/30/73	1802.659	16.23	0.11	*P*
7/05/69	407.648	16.11	0.09	*P*	6/01/73	1834.607	16.48	0.13	*P*
5/02/70	708.726	15.98	0.08	*P*	2/24/74	2102.856	16.22	0.04	*P*
1/30/71	981.884	16.30	0.15	*P*	5/15/74	2182.745	16.42	0.14	*P*
3/31/71	1041.844	16.11	0.05	*P*	5/24/74	2191.622	16.41	0.10	*P*
5/21/71	1092.693	16.09	0.15	*P*	2/08/75	2451.899	16.28	0.10	*P*
6/21/71	1123.000	16.12	0.04	*P*	3/13/75	2484.869	16.48	0.15	*P*
2/22/72	1369.857	16.17	0.15	*P*	4/19/75	2521.787	16.32	0.07	*P*
4/13/72	1420.705	15.93	0.07	*P*	5/09/75	2541.703	16.59	0.16	*P*
3/04/73	1745.824	16.26	0.12	*P*					
				PKS 1510−08					
6/13/69	385.667	16.92	0.08	*P*	6/04/73	1837.715	17.29	0.11	*P*
7/05/69	407.712	17.13	0.22	*P*	3/02/74	2108.923	17.03	0.05	*P*
8/10/69	443.599	16.86	0.08	*P*	4/21/74	2158.793	16.89	0.14	*P*
3/31/71	1041.868	16.89	0.05	*P*	5/24/74	2191.731	16.99	0.10	*P*
4/25/71	1066.860	16.87	0.07	*P*	6/19/74	2217.654	16.88	0.06	*P*
6/18/71	1120.722	16.58	0.07	*P*	7/15/74	2243.654	16.95	0.08	*P*
6/21/71	1123.767	16.81	0.08	*P*	4/04/75	2506.785	16.90	0.03	*P*
6/03/72	1471.659	16.45	0.10	*P*	4/19/75	2521.869	16.87	0.08	*P*
7/11/72	1509.610	17.20	0.06	*P*	5/09/75	2541.760	16.56	0.08	*P*
4/29/73	1801.793	17.25	0.05	*P*	5/16/75	2548.772	16.54	0.06	*P*

TABLE III (*continued*)

UT date	J. D. 2440000+	Mag.	rms error	Color	UT date	J. D. 2440000+	Mag.	rms error	Color
				I Zw 1727+50					
10/16/71	1240.584	15.87	0.12	*P*	5/26/74	2193.790	16.25	0.06	*P*
7/09/72	1507.774	16.21	0.11	*P*	6/14/74	2212.751	16.09	0.14	*P*
9/05/72	1565.592	16.14	0.17	*P*	6/19/74	2217.744	16.42	0.26	*P*
6/27/73	1860.758	16.18	0.10	*P*	6/20/74	2218.814	16.33	0.17	*P*
6/30/73	1863.724	15.97	0.13	*P*	7/13/74	2241.871	16.06	0.14	*P*
7/08/73	1871.758	16.01	0.08	*P*	8/13/74	2272.614	16.04	0.15	*P*
8/23/73	1917.718	16.31	0.13	*P*	8/18/74	2277.605	15.66	0.24	*P*
8/31/73	1925.630	15.87	0.21	*P*	9/09/74	2299.554	15.87	0.07	*P*
9/18/73	1943.566	15.99	0.07	*P*	10/11/74	2331.671	15.74	0.17	*P*
9/30/73	1955.600	15.91	0.12	*P*	5/07/75	2539.790	16.36	0.04	*B*
3/31/74	2137.881	15.91	0.07	*P*	5/16/75	2548.856	16.41	0.14	*B*
4/28/74	2165.882	16.00	0.06	*P*	6/04/75	2567.742	16.53	0.13	*B*
5/17/74	2184.773	16.31	0.17	*P*	6/04/75	2567.753	15.90	0.11	*P*
5/22/74	2189.747	16.03	0.11	*P*	6/04/75	2567.767	15.95	0.04	*P*
				3C 390.3					
7/03/73	1866.785	15.72	0.13	*B*	6/19/74	2217.730	16.22	0.42	*B*
8/29/73	1923.693	16.10	0.18	*B*	6/21/74	2219.777	15.58	0.11	*B*
10/01/73	1956.631	15.91	0.07	*B*	8/13/74	2272.657	15.74	0.09	*B*
10/17/73	1972.531	16.11	0.07	*B*	9/09/74	2299.606	15.62	0.04	*B*
10/21/73	1976.521	16.04	0.03	*B*	9/15/74	2305.598	15.73	0.03	*B*
4/19/74	2156.925	15.95	0.03	*B*	10/12/74	2332.545	15.96	0.13	*B*
5/19/74	2186.887	15.76	0.16	*B*	4/20/75	2522.843	15.87	0.08	*B*
5/24/74	2191.840	15.80	0.12	*B*	5/07/75	2539.824	15.89	0.07	*B*
5/30/74	2197.842	15.77	0.06	*B*					
				OV 080					
4/22/69	333.000	17.31	0.12	*P*	11/13/71	1268.000	17.43	0.11	*P*
5/16/70	722.868	17.34	0.10	*P*	8/11/72	1540.624	17.30	0.09	*P*
6/05/70	742.829	17.54	0.08	*P*	9/04/72	1564.610	17.53	0.08	*P*
6/11/70	748.777	17.49	0.13	*P*	6/27/73	1860.781	17.29	0.17	*P*
6/30/70	767.764	17.48	0.16	*P*	8/31/73	1925.685	16.99	0.13	*P*
9/24/70	853.564	17.50	0.16	*P*	5/22/74	2189.803	17.35	0.18	*P*
10/26/70	885.569	17.40	0.04	*P*	7/26/74	2254.838	17.44	0.13	*P*
5/02/71	1073.884	17.34	0.16	*P*	8/14/74	2273.715	17.44	0.24	*P*
5/04/71	1075.860	17.34	0.08	*P*	10/09/74	2329.527	17.06	0.03	*P*
6/02/71	1104.815	17.44	0.09	*P*	10/18/74	2338.537	17.50	0.12	*P*
6/23/71	1125.728	17.41	0.07	*P*	5/10/75	2542.843	17.39	0.20	*P*
9/19/71	1213.631	17.44	0.23	*P*					
				PKS 2059+034					
6/23/71	1125.798	16.73	0.11	*P*	10/08/72	1598.551	16.70	0.13	*P*
7/21/71	1153.798	16.64	0.21	*P*	9/19/73	1944.593	16.65	0.10	*P*
11/23/71	1278.504	17.09	0.15	*P*	6/17/74	2215.838	16.55	0.23	*P*
12/11/71	1296.500	17.00	0.33	*P*	7/17/74	2245.805	17.06	0.04	*P*
7/19/72	1517.722	16.76	0.10	*P*	8/18/74	2277.649	17.25	0.09	*P*
8/11/72	1540.654	16.75	0.18	*P*	10/13/74	2333.577	16.87	0.18	*P*
9/04/72	1564.632	16.89	0.14	*P*	12/09/74	2390.508	16.67	0.17	*P*
9/11/72	1571.592	16.74	0.17	*P*	5/19/75	2551.834	16.79	0.08	*P*
10/05/72	1595.535	16.74	0.06	*P*					
				PKS 2349−01					
12/08/69	563.750	15.77	0.13	*P*	8/25/73	1919.840	15.55	0.15	*P*
9/25/70	854.765	15.50	0.15	*P*	10/01/73	1956.745	15.95	0.11	*P*
9/30/70	859.678	15.31	0.21	*P*	10/20/73	1975.660	15.58	0.09	*P*
8/19/71	1182.819	15.66	0.21	*P*	11/23/73	2009.690	15.75	0.21	*P*
7/19/72	1517.874	16.20	0.09	*P*	8/16/74	2275.828	15.28	0.15	*P*
8/13/72	1542.829	16.10	0.07	*P*	8/24/74	2283.792	15.35	0.27	*P*
9/13/72	1573.753	15.85	0.42	*P*	8/28/74	2287.826	15.65	0.08	*P*
9/18/72	1578.823	15.93	0.23	*P*	9/12/74	2302.757	15.47	0.19	*P*
10/05/72	1595.662	16.09	0.14	*P*	9/24/74	2314.758	15.47	0.16	*P*
10/13/72	1603.672	16.02	0.11	*P*	10/11/74	2331.650	15.26	0.15	*P*
11/05/72	1626.603	16.04	0.27	*P*	12/04/74	2385.575	15.41	0.07	*P*
11/27/72	1648.538	15.67	0.31	*P*					

Those exposures for which exact times are not available have integral Julian dates.

PKS 1021-00: Bolton and Ekers (1967) identified the optical counterpart of this QSO. The Florida data are somewhat sparse but some short-term activity is suggested, accompanied by an increase in average intensity during 1974 and 1975. A comparison sequence was calibrated by photographic transfer from SA 101.

PKS 1116+12: The optical counterpart of this QSO was identified by Bolton *et al.* (1965b). The Florida light curve shows occasional short-term excursions of about $0\overset{m}{.}5$. A gradual long-term trend is also suggested. From 1971 to the present the average intensity appears to have increased by about $0\overset{m}{.}5$. A comparison sequence was calibrated by photographic transfer from SA 79.

ON 325: The optical counterpart of this source was identified by Browne (1971) as a $14\overset{m}{.}5$ object on the Palomar Sky Survey. An alternate designation is B2 1215+30. Like the source ON 231 discussed in Paper I, ON 325 appears neutral in color and it is placed in the class of BL Lacertae objects by Hall and Usher (1973). The Florida light curve suggests that ON 325 might be classified as a marginal OVV because of the large burst of activity seen in late 1973 and early 1974. The comparison sequence of Wing (1973) was used to reduce the observations.

PKS 1229-02: Bolton and Ekers (1966d) identified the optical counterpart of this QSO. The Florida data

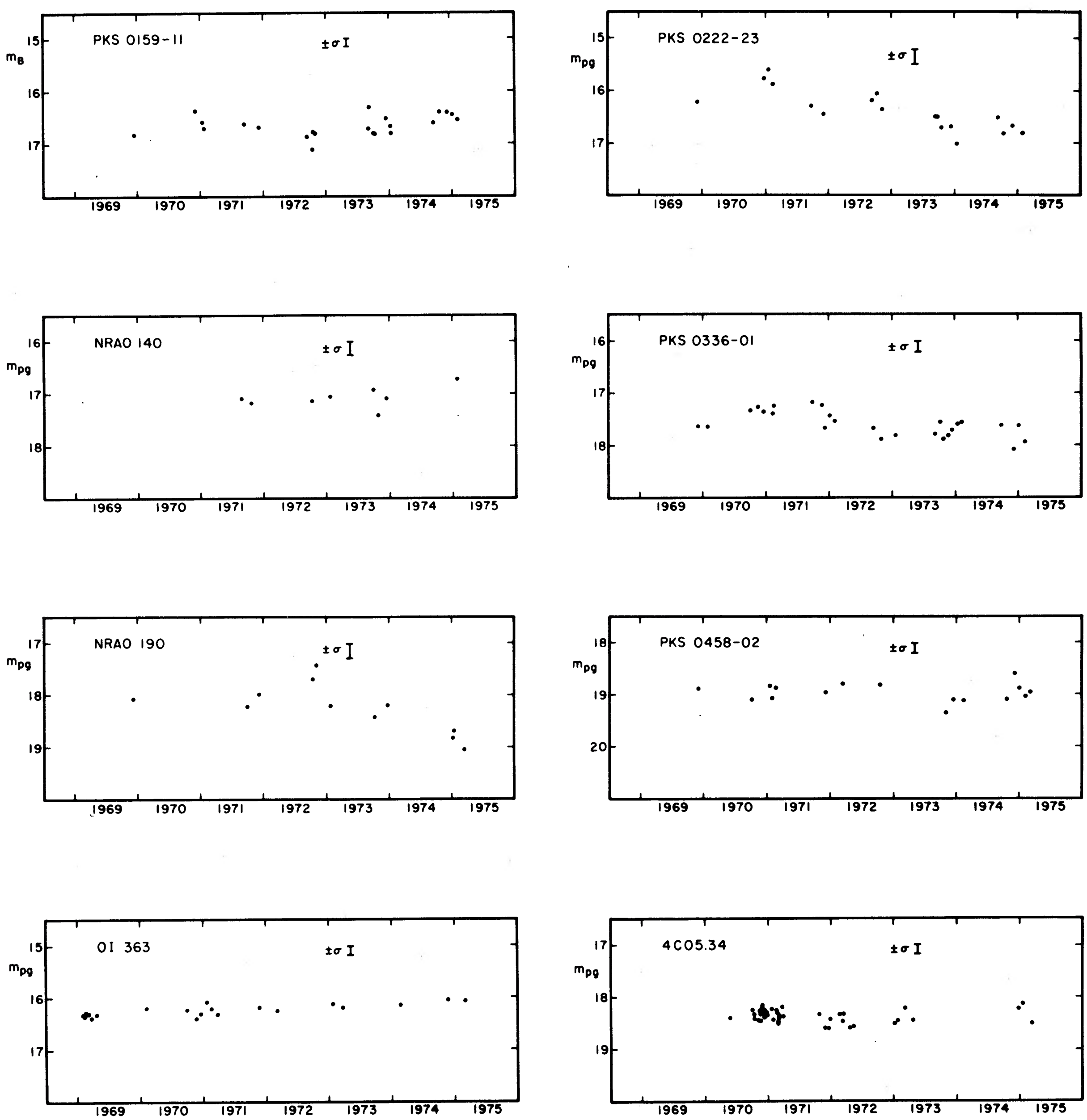

FIG. 1(a). Light curves of the 23 variable sources.

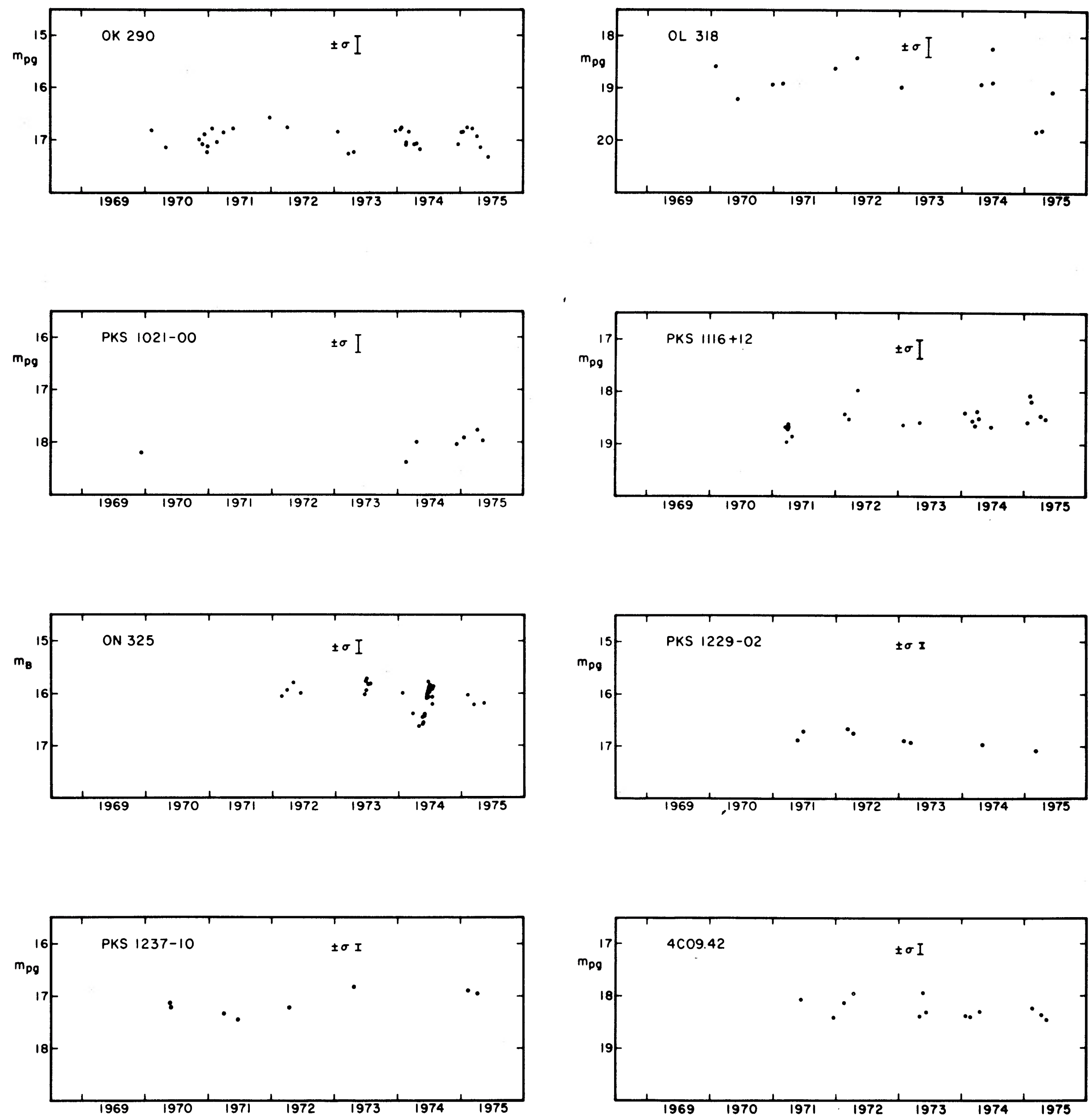

FIG. 1(b). Light curves of the 23 variable sources.

show no significant short-term excursions, but a gradual decline in average intensity since early 1972 is suggested. A comparison sequence was calibrated by photographic transfer from SA 104.

PKS 1237-10: The optical counterpart of this QSO was identified by Bolton and Ekers (1966c). Folsom *et al.* (1971a) classified it as moderately variable. The Florida light curve shows little short-term activity, but a long-term change greater than $0\overset{\mathrm{m}}{.}5$ is seen between 1971 and 1973. A comparison sequence was calibrated by photographic transfer from SA 129.

4C 09.42: This object was identified as a galaxy by Wills *et. al.* (1973). The optical light curve shows flares of up to $0\overset{\mathrm{m}}{.}5$ in periods of months, superimposed on a nearly constant minimum brightness level. A comparison sequence was calibrated by photographic transfer from SA 81.

PKS 1252+11: The optical counterpart of this radio source was identified by Bolton *et al.* (1965a). The object was confirmed as a QSO by Lynds *et al.* (1965) and Schmidt (1966), with the measurement of a redshift $z=0.871$. Penston and Cannon (1970) concluded that optical variability was doubtful, based on only three plates. Early Florida data (Folsom *et al.* 1971a) indicated that the source had varied since the

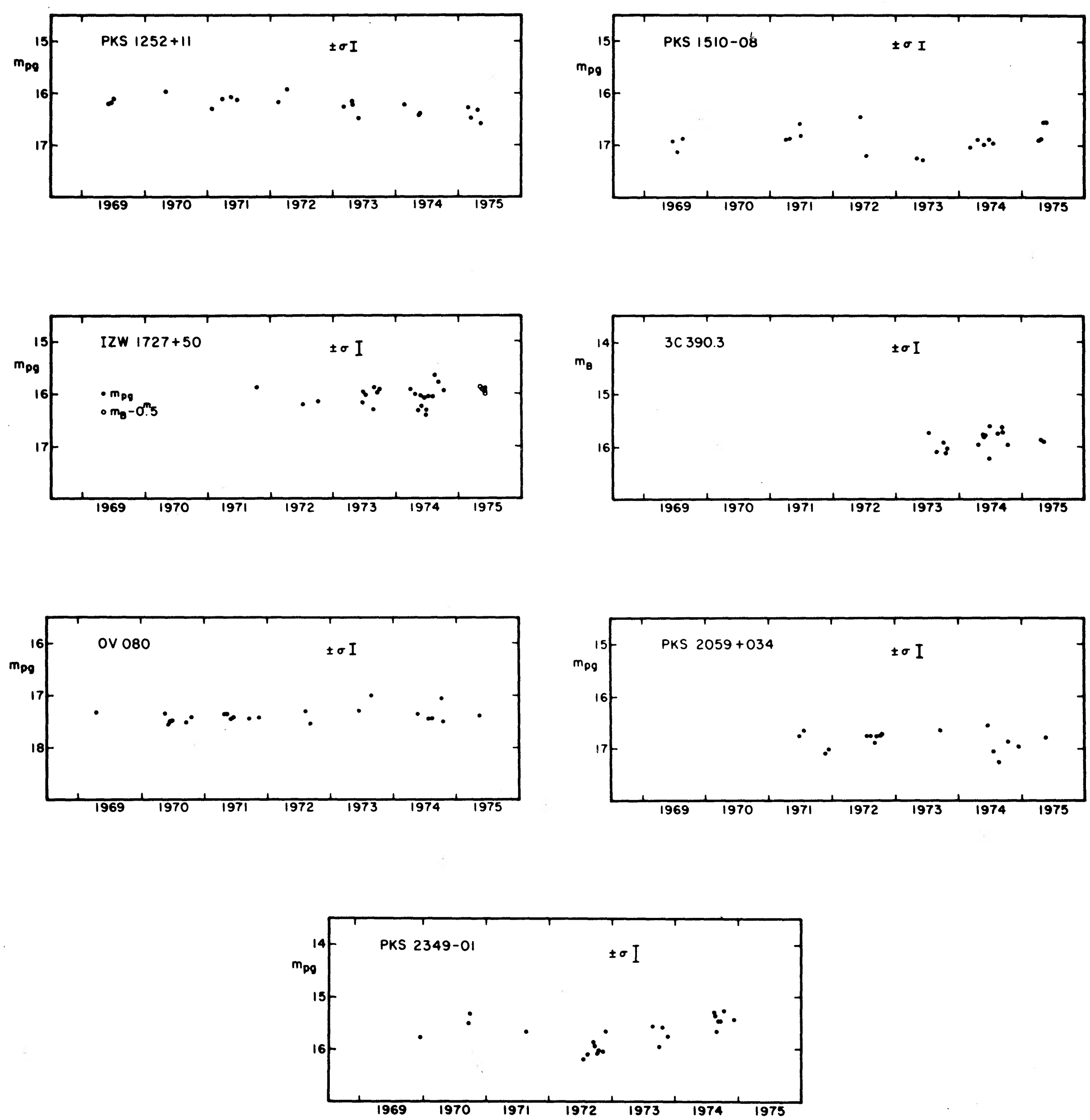

FIG. 1(c). Light curves of the 23 variable sources.

date of the Palomar Sky Survey. The Rosemary Hill data now show that this source is a slow variable with a decrease of $0^{m}.6$ between 1970 and 1975.

PKS 1510-08: Bolton and Kinman (1966) identified the optical counterpart of this QSO. Medd *et al.* (1972) reported rapid fluctuations at 6.6 and 10.7 GHz between 1967 and 1971, and they described the radio spectrum as having centimeter excess. Lü (1972) reported optical variations with a maximum range of about $0^{m}.6$. The optical source was classified as moderately variable by Folsom *et al.* (1972a). Dent *et al.* (1974) observed strong variability at 15.5 GHz with a large, rapid flare observed in late 1971. While the mean optical level seems relatively stable, the complete Florida light curve shows occasional short-term bursts of about $0^{m}.5$. A decline of nearly $0^{m}.8$ was observed in mid-1972. This may correspond to the declining phase of the flare observed by Dent *et al.*, but unfortunately only two plates were taken during this period. No long-term trends are apparent. A comparison sequence was calibrated by photographic transfer from SA 132.

I Zw 1727+50: It was suggested by Le Squeren *et al.* (1972) that this compact galaxy (alternate designation OT 546) belongs to the class of BL Lacertae objects.

On the basis of retrospective studies of plate collections, Hall and Usher (1973) reported that the total range of optical variability was at least 2^{m}1 between 1910 and 1967. A smaller range of activity is shown in the more recent Florida light curve, but as in many QSOs, the level of activity probably changes with time. The Florida data show no long-term trends, but rapid short-term activity is apparent. Two comparison sequences have been used to reduce the Florida observations. An m_{pg} calibration was obtained by photographic transfer from SA 37, and the majority of the observations were reduced with this sequence. Recently, m_B observations have been initiated, using the sequence of Craine *et al.* (1975).

3C 390.3: The optical variability of the N galaxy 3C 390.3 was established by Sandage (1967) and Cannon *et al.* (1968). Shen *et al.* (1972) reported a brightness decrease of 1^{m}15 in three days and a total range of variation of about 2^{m}0; they observed no long-term intensity trends. Such large variations are not seen in the Florida observations, which, however, cover a time span of less than three years, during which the object may have been in a more quiescent phase. The comparison sequence of Penston *et al.* (1971) was used to reduce the observations.

OV 080: Kraus *et al.* (1968) reported that this source has a radio spectrum peaked at about 3 GHz. Using the radio position of Thompson *et al.* (1968), the Rosemary Hill group made a tentative identification of the optical object (Folsom *et al.* 1971b). The light curve indicates that this object is fairly constant, at most times, around 17^{m}45. Variability manifests itself in sudden flares and subsequent returns to the minimum brightness. Because of its rapidity, this behavior is largely observed on single plates. A comparison sequence was calibrated by photographic transfer from SA 88.

PKS 2059+034: The optical counterpart of this QSO was identified by Bolton and Wall (1970). The Florida light curve suggests no significant long-term trends, but a period of moderate short-term activity occurred in 1974. A comparison sequence was calibrated by photographic transfer from SA 113.

PKS 2349-01: The Parkes catalog (Ekers 1969) identified this source as an N galaxy. The Florida light curve suggests short-term variations of approximately 0^{m}5 on a time scale of a few months. Long-term trends are also apparent; the average intensity appeared to decline from late 1970 to mid-1972, whereupon a burst of activity occurred, followed by a rise in long-term intensity continuing to the present. A comparison sequence was calibrated by photographic transfer from SA 92.

II. DISCUSSION

A 7-yr study of the optical behavior of a large sample of QSOs has shown that the optical variability exhibited by these objects is an extremely complex and sometimes transient phenomenon. Sources exhibiting violent optical activity were discussed in Paper I; the sources discussed in the present paper appear to exhibit similar behavior, but with smaller amplitudes. Variability subclasses have been assigned to the objects listed in Table II, i.e., those with a confidence level for variability of 95% or more. The following subclasses are identical with those discussed in Paper I.

Subclass I includes objects whose light curves are dominated by rapid, short-term "flickering." Long-term trends are inconspicuous and, if present, very gradual. Examples from the present paper are I Zw 1727+50 or 4C 05.34.

The light curves of subclass II are characterized by prominent, long-term variations in mean level. Flickering appears as minor excursions about this changing average. Examples of this subclass are PKS 0222-23 and NRAO 190.

Subclass III is dominated by neither short-term nor long-term effects, but is characterized by a mixture of the two with comparable amplitudes. An example is PKS 1116+12.

Subclass IV is episodic, with long periods of quiescence interrupted by relatively brief periods of activity. A probable member of this subclass is OV 080.

It is important to note that with decreasing amplitude of variations, the distinction between subclasses becomes less well defined. This problem is compounded by the generally smaller number of observations made of the less-active sources in the present paper relative to the OVV sources of Paper I. In addition, the rms error is a greater fraction of the total observed amplitude than is the case for the OVV sources.

The sources discussed in this paper appear to be equally divided between subclasses I, II, and III. As one might expect from the definition of the OVV class, the sources in Paper I were dominated by subclasses I and II. There does appear to be evidence for transient or episodic variability. The well-known QSO 3C 273 exhibited no significant variability in the Rosemary Hill data, but of course it has been classified as definitely variable by a number of other workers (e.g., see Penston and Cannon 1970). As was indicated earlier, Hall and Usher (1973) reported a 2^{m}1 range for I Zw 1727+50 between 1910 and 1967 whereas the present data indicate a range of only 0^{m}75. It is clear that the total variability range must in general be a monotonically increasing function of the length of the observing run. No periodic behavior was observed for any source.

The fact that the OVVs in Paper I and the objects discussed in this paper can be placed in the same subclasses suggests that the differences between these two categories may be one of degree. Specifically, the sources discussed in this paper lack the extremely violent variations that occur within a few days, but they do show all other characteristics of the OVV sources on a smaller scale. Any model successfully describing QSOs will have to account for the differing degree and transience of activity in these objects.

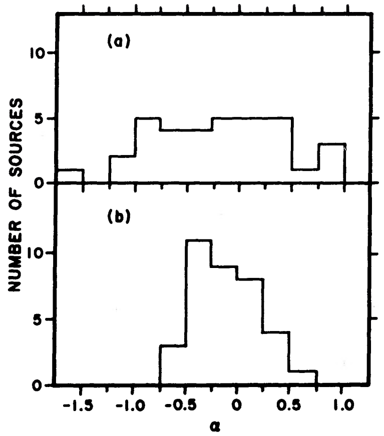

FIG. 2. Histograms of number of sources versus spectral index for (a) nonvariable Florida sources and (b) variable sources in the Florida program.

In an earlier paper (Folsom *et al.* 1971a), the authors noted that sources with flat radio spectra showed a strong tendency toward optical variability. This study has been extended with the larger set of data now available. Histograms of the number of sources versus average radio spectral index (Dixon 1970; Blake 1970) divided into bins of 0.25 width were constructed to compare the nonvariable sources [Fig. 2(a)] with the variable sources, including the 20 OVVs of Paper I [Fig. 2(b)]. The nonvariable QSOs show no apparent preference for any value of spectral index between −1.75 and +1.0, while the variable QSOs are strongly clustered near zero, with a skew toward slightly negative spectral indices. The large number of variable objects whose spectral indices lie between −0.5 and −0.25, suggests that the earlier conclusion of Folsom *et al.* (1971a) should be extended to include the importance of small negative radio spectral indices as an optical variability indicator.

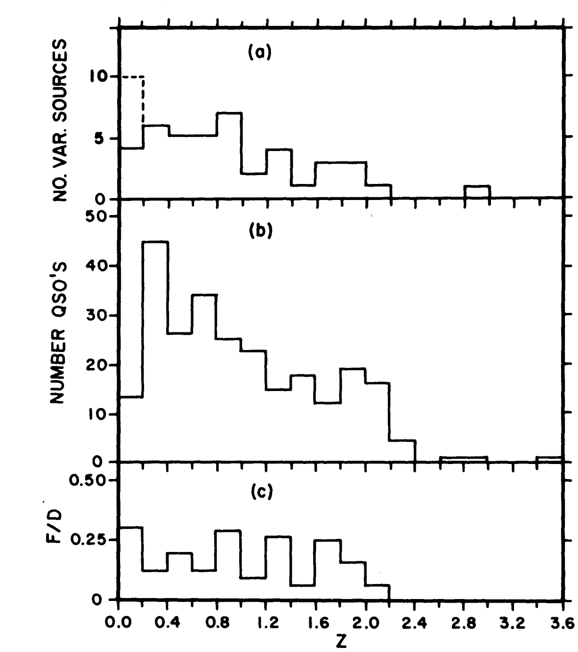

FIG. 3. Histograms of (a) number of Florida variables, *F*, versus redshift; (b) number of QSOs from DeVeny *et al.* (1971), *D*, versus redshift, (c) *F*/*D* versus redshift.

Another question that arises in connection with the large sample of variability data presented in Paper I and the present work is whether there is a relationship between variability and redshift. Such a relationship would imply that variability is perhaps an evolutionary trait, more likely to occur at a particular epoch in the age of the universe. Figure 3(a) shows the distribution of known redshifts among the objects in the two Florida papers, with the redshifts arbitrarily divided into bins of width 0.2. Variable galaxies or BL Lacertae objects (as opposed to ordinary QSOs) are indicated by the area enclosed by the dashed line. The relationship for the QSO population as a whole is shown in Fig. 3(b), where the redshifts have been taken from *A Catalogue of Quasars* by De Veny *et al.* (1971). In Fig. (3c) the number of Florida variables, *F*, occurring in each redshift bin has been divided by the corresponding number *D* of QSOs from De Veny *et al.* Variable galaxies and BL Lacertae objects are not included in Fig. 3(c). The figure suggests that there is no convincing difference between the Florida variables and the general QSO population as represented by the data of De Veny *et al.* Figure 3(c) shows that the number of Florida variables in each bin, as compared with the general QSO population, is roughly constant with no distinct peaks or troughs that might suggest a strong evolutionary effect.

Admittedly, there are selection effects that influence this result. Redshifts are available for only 48 of the 84 Florida sources; inclusion of the remaining objects might significantly alter the results. It might also be argued that the data of De Veny *et al.* are not representative of the QSO population as a whole, since the objects with known redshifts tend to be the brighter and presumably closer sources. In addition, as was pointed out earlier, the chi-squared test for variability may have excluded sources that in the future will prove to be variable. With these caveats in mind, it is concluded that the present data suggest that QSO variability is not an evolutionary trait since they are unable to demonstrate a significant relationship between redshift and the occurrence of variability.

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