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Optical identifications of radio sources from the 1 Jy, S4 and S5 catalogues*

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Abstract. — CCD images of the fields of 115 radio sources from the 1 Jy, S4 and S5 catalogues are presented. New optical counterparts have been found for a total of 34 sources, a large fraction of which had as yet only been described as empty fields on Sky Survey Plates. Of the 54 radio sources with previously published identifications, 50 optical counterparts have been confirmed while for 4 sources new identifications are proposed. R band magnitudes, derived from the CCD images, are provided for all but a few identified optical counterparts. The fields at the positions of 27 radio sources are still empty down to a limiting magnitude of at least $m_R = 22$ mag, requiring much deeper optical as well as additional infrared images for establishing their optical counterparts.

Key words: catalogs — surveys — galaxies: active — quasars: general — radio continuum: general

1. Introduction

Radio source catalogues have proven to be an invaluable tool for the investigation of the various radio source populations as well as for finding interesting individual objects. Among the high frequency selected radio catalogues, the 1 Jy (Kühr et al. 1981a), the S4 Pauliny-Toth et al. (1978), and the S5 (Kühr et al. 1981b, 1987) surveys have gained substantial observational attention in recent years. The 1 Jy catalogue is an all-sky survey covering 9.81 sr and contains in its updated version (Stickel et al. 1994) 527 radio sources with a flux density limit of $S_{5\rm GHz} \geq 1$ Jy lying outside the galactic plane ($|\, b \,| \geq 10°$). The S4 survey covers the region between $35° \leq \delta \leq 70°$ and lists in its updated version (Stickel & Kühr 1994a) 270 radio sources with $S_{5\rm GHz} \geq 500$ mJy, while the S5 survey contains 185 sources with $S_{5\rm GHz} \geq 250$ mJy in the region $\delta \geq 70°$.

More than a decade after the compilation, however, complete optical identifications have not been achieved for these catalogues. With few exceptions, only subsamples, restricted in optical magnitude to be brighter than the limit of sky survey plates, have been used for statistical studies. For the 1 Jy and S4 surveys, this situation can soon be expected to improve significantly, since in both surveys only a few percent of the sources remain unidentified (Stickel et al. 1994; Stickel & Kühr 1994a). For the S5 survey, however, no large systematic search for new optical counterparts beyond the POSS limit (typically $m \approx 20$ mag) has as yet been carried out and a substantial increase of optical identifications using deeper CCD imaging data can be expected.

In this paper we present the results of an optical investigation of the fields of 115 radio sources from the 1 Jy, S4, and S5 catalogues. The observations are part of an on-going program to complete the optical identifications and redshifts of these three catalogues. The images obtained allowed the detection of 34 new, previously unknown optical counterparts. For 50 sources, the optical counterparts have been confirmed and additional optical R band photometry is provided. Revised optical counterparts are proposed for 4 radio sources, the identification of which had already been described in the literature. No optical counterparts have been detected for the remaining 27 radio sources. Additional optical imaging data of other 1 Jy, S4, and S5 radio sources have been given in conjunction with the optical spectroscopy of a large number of radio sources from these catalogues (Stickel et al. 1993; Stickel & Kühr 1993a, b; Stickel & Kühr 1994b).

2. Observations and data reduction

Direct CCD images of the fields of the 1 Jy, S4, and S5 radio sources have been obtained during a total of 13 observing runs between 1985 and 1994 carried out at the

*Tables are also available in electronic form at the CDS via ftp 130.79.128.5

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Table 1. Observed 1 Jy radio sources

Object (1)	RA (1950) (2)	Dec (1950) (3)	Pos.Ref (4)	m (5)	type (6)	z (7)	S_{5GHz} (8)	α_{11-6} (9)
0022 − 423	00 22 15.42	−42 18 41.0	M4	21.0	QSO	*	1.83	−0.72
0026 + 346	00 26 34.83	+34 39 57.7	P	20.7	GAL	*	1.27	−0.27
0403 + 768	04 03 59.20	+76 48 52.8	M2	21.2	GAL	0.5985	2.82	−0.57
0407 − 658	04 07 58.06	−65 52 59.7	AC	21.2	GAL	*	3.43	−1.13
0446 + 112	04 46 21.22	+11 16 17.6	M1	20.6	GAL ?	*	1.23	+0.56
0500 + 019	05 00 45.18	+01 58 53.8	M1	21.2	QSO	*	1.82	−0.39
0511 − 305	05 11 36.75	−30 32 15.4	EK	15.2	GAL	*	1.88	−0.87
0539 − 057	05 39 10.99	−05 43 15.1	P	20.4	QSO	0.839	1.55	+1.41
0615 + 820	06 15 32.71	+82 03 56.5	FY1	19.7	QSO	0.710	1.00	−0.03
0742 + 103	07 42 48.47	+10 18 32.7	FY1	*	FS_EF	*	3.68	−0.11
0834 − 196	08 34 56.15	−19 41 25.4	U	22.4	GAL	1.032	1.52	−0.92
0941 − 080	09 41 08.64	−08 05 44.1	U	18.1	GAL	*	1.09	−0.72
1213 − 172	12 13 11.69	−17 15 05.4	M1	21.4	GAL	*	1.47	+0.05
1518 + 046	15 18 44.70	+04 41 05.5	MK	22.2	QSO	1.294	1.06	−1.30
1555 + 001	15 55 17.70	+00 06 43.6	FY2	20.0	QSO	1.770	2.24	+0.34
1600 + 335	16 00 11.91	+33 35 09.7	M1	23.0	GAL	*	1.49	−0.71
1602 − 093	16 02 43.00	−09 19 09.0	J	*	SS_EF	*	1.19	−0.92
1622 − 253	16 22 44.11	−25 20 51.6	RO	20.3	QSO	0.768	2.08	−0.14
1638 + 124	16 38 27.91	+12 25 46.3	U	21.8	GAL	*	1.03	−0.63
1648 + 015	16 48 31.56	+01 34 26.0	M1	20.7	QSO	*	1.03	+0.33
1815 − 553	18 15 35.15	−55 22 37.9	RO	21.7	QSO	*	1.35	−0.02
1933 − 400	19 33 51.13	−40 04 47.5	RU2	18.0	QSO	0.966	1.48	+0.26
2008 − 068	20 08 33.73	−06 53 02.5	M1	21.1	GAL	*	1.37	−0.68
2149 − 287	21 49 10.47	−28 42 35.0	VLA	19.4	GAL	*	1.36	−0.61
2210 + 016	22 10 05.12	+01 37 59.4	U	21.7	QSO	*	1.00	−0.91
2324 + 405	23 24 31.04	+40 31 46.0	U	19.4	GAL	0.394	1.13	−0.47
2342 + 821	23 42 06.35	+82 10 01.3	D	20.2	QSO	0.735	1.33	−0.89

References to radio positions :

AC	White (1992)	M4	Morabito et al. (1986)
D	Pearson & Readhead (1988)	MK	Morganti et al. (1993)
EK	Ekers et al. (1989)	P	Perley (1982)
FY1	Fey et al. (1992)	RO	Robertson et al. (1993)
FY2	Fey et al. (1994)	RU2	Russell et al. (1994)
J	Kühr et al. (1981a)	U	Ulvestad et al. (1981)
M1	Morabito et al. (1982)	VLA	VLA Calibrator position
M2	Morabito et al. (1983)		

2.2 m and 3.5 m telescopes on Calar Alto, Spain, the 2.2 m telescope on La Silla, Chile, and the Steward Observatory 90″ telescope on Kitt Peak. The observed 1 Jy, S4, and S5 radio sources are listed in Tables 1-3, respectively, which give for each source its name (Col. 1), the radio position (Cols. 2, 3), the reference to the radio position (Col. 4), the brightness, the type, and the redshift (if available) of the optical counterpart (Cols. 5-7) as well as the radio flux density $S_{5\mathrm{GHz}}$ (Col. 8), and the radio spectral index α_{11-6} ($S_\nu \propto \nu^\alpha$) between 11 cm and 6 cm (Col. 9). The optical counterparts are classified as GAL or QSO, depending on their resolved or unresolved appearance on the CCD images. Uncertain classifications are indicated by a question mark. Radio sources without a detected optical counterpart are classified as flat-spectrum (FS_EF) or steep-spectrum (SS_EF) empty fields, the former of which have $\alpha_{11-6} \geq -0.5$, while the latter have $\alpha_{11-6} < -0.5$.

Journals of the imaging observations for the 1 Jy, S4, and S5 are given in Tables 4-6, respectively, which list for each source its name (Col. 1), the date of the observation (Col. 2), the telescope used (Col. 3), the total integration time (Col. 4), an estimate of the seeing during the observation (Col. 5), and the scale of the CCD image (Col. 6). An R - filter has been used for all observations except for the images of 0022 − 423 and 1027+749, where a B - filter was in place.

It should be noted that only the early observations of S5 radio sources as well as some observations of the optically faint or empty 1 Jy radio sources were specifically dedicated to the optical identification of these radio sources. Most of the other images have been obtained as a backup program carried out during inferior weather

Table 2. Observed S4 radio sources

Object (1)	RA (1950) (2)	Dec (1950) (3)	Pos.Ref (4)	m (5)	type (6)	z (7)	S_{5GHz} (8)	α_{11-6} (9)
0011 + 344	00 11 08.20	+34 25 02.0	S4	*	SS_EF	*	0.521	−0.82
0024 + 348	00 24 02.81	+34 52 06.3	M1	18.9	GAL	0.333	0.726	−0.30
0102 + 480	01 02 55.49	+48 03 01.5	K	*	FS_EF	*	0.982	−0.18
0246 + 428	02 46 15.55	+42 53 06.0	BV	17.3	GAL	0.159	0.536	−0.96
0327 + 408	03 27 08.10	+40 51 29.0	S4	16.9	GAL	0.201	0.558	−0.90
0620 + 389	06 20 51.52	+38 58 27.2	M3	20.0	QSO	3.470	0.874	−0.03
0657 + 687	06 57 34.76	+68 45 36.9	K	15.3	GAL	0.110	0.585	−0.63
0707 + 689	07 07 55.24	+68 57 12.7	K	19.9	QSO	1.139	0.749	−0.67
0816 + 526	08 16 01.86	+52 41 53.5	K	18.0	GAL	0.189	0.776	−0.73
1014 + 392	10 14 16.55	+39 16 23.0	K	19.1	GAL	*	0.531	−0.72
1020 + 593	10 20 18.60	+59 20 01.3	K	19.1	GAL	*	0.502	−0.82
1128 + 385	11 28 12.51	+38 31 52.0	M1	19.4	QSO	1.733	0.771	−0.22
1402 + 660	14 02 48.39	+66 05 57.5	P	20.0	GAL	*	0.697	−0.73
1656 + 482	16 56 24.99	+48 13 04.7	M1	21.6	GAL	*	0.776	−0.22
1734 + 508	17 34 36.73	+50 50 59.7	M1	23.1	GAL ?	*	0.803	+0.49
1818 + 356	18 18 56.10	+35 39 12.5	K	21.1	GAL	*	0.518	−0.51
1843 + 400	18 43 32.51	+40 04 38.7	K	21.0	GAL	*	0.565	−0.53
1926 + 611	19 26 49.65	+61 11 21.1	M1	16.9	BL/QSO	*	0.721	−0.09
2218 + 395	22 18 21.20	+39 33 40.0	K	18.0	QSO	0.655	0.685	−0.60
2311 + 469	23 11 29.09	+46 55 54.9	K	17.0	QSO	0.741	0.726	−0.69
2358 + 406	23 58 19.36	+40 37 20.3	K	21.4	GAL	*	0.586	−0.58

References to radio positions :

BV	Vigotti et al. (1989)	M3	Morabito et al. (1985)
K	Kapahi (1981)	P	Perley (1982)
M1	Morabito et al. (1982)	S4	Pauliny-Toth et al. (1978)

conditions which did not allow to accomplish the observational program the telescope time had been allocated for. This explains the wide range of seeing conditions listed in Tables 4-6 and the varying quality of the images shown in Figs. 1-3.

Image reductions followed standard procedures of debiasing and flat-fielding. For those fields where a sufficient number of images were available, the flatfield images had been constructed from a stack of images, which were first cleaned of objects and subsequently median-filtered and normalized. Otherwise the median of a stack of several domeflats had been used as flatfield image. The images of individual objects were then coadded, background subtracted, and flux-calibrated using observations of standard stars (Oke 1974; Stone 1977; Stone & Baldwin 1983) or the standard star fields of Christian et al. (1985) and Odewahn et al. (1992).

Isophotal plots of the fields around the positions of 1 Jy, S4, and S5 radio sources are presented in Figs. 1-3, respectively. Apart from 1 Jy 0511 − 305, S4 0657+687, and S5 1241+735, the identified optical counterparts of the radio sources is marked with a bar. The identifications of the former three radio sources are in each case the brightest galaxies in the fields. For radio sources, for which no optical counterparts have been found, a circle with 10″ diameter is plotted at the radio position. The plotted fields differ in angular size with the length of the bar indicating 10″ on the sky. They were chosen to show details of the immediate vicinity of the radio source on the one hand and to include sufficiently bright objects on the other hand, to allow a comparison with other published finding charts.

3. Identification procedure

The connection between the radio and optical reference frame has been established by using reference stars with previously known optical coordinates present on the CCD frames. The optical coordinates for the reference stars in the fields of 1 Jy and S4 radio sources have been taken from the Hubble Space Telescope Guide Star Catalogue (GSC, Lasker et al. 1990; Russell et al. 1990; Jenkner et al. 1990) and/or the APM Sky Catalogue (Irwin et al. 1994). For the S5 radio sources, the reference stars listed in Kühr et al. (1987) have almost exclusively been used, only occasionally supplemented (particularly in case of doubtful measurements) by GSC or APM reference star positions. In a few cases, the optical positions of reference objects have been taken from previous attempts to find optical counterparts (e.g. 0407 − 658, 0834 − 196, 1622 − 253)

For radio sources with a single compact radio component, an optical object has been accepted as its

Table 3. Observed S5 radio sources

Object	RA (1950)	Dec (1950)	Pos.Ref	m	type	z	S_{5GHz}	α_{11-6}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0036 + 744	00 36 34.80	+74 26 56.5	S5	*	SS_EF	*	0.285	−1.04
0048 + 892	00 48 18.92	+89 12 41.8	S5	*	SS_EF	*	0.540	−1.14
0123 + 731	01 23 10.33	+73 07 39.3	S5	*	SS_EF	*	0.259	−0.63
0124 + 845	01 24 55.27	+84 30 44.8	S5	23.7	GAL ?	*	0.257	−0.89
0153 + 744	01 53 04.33	+74 28 05.5	PA	17.5	QSO	2.338	1.513	−0.32
0200 + 751	02 00 54.19	+75 07 48.1	S5	*	SS_EF	*	0.467	−0.81
0201 + 796	02 01 37.22	+79 41 44.5	S5	22.2	GAL	*	0.418	−1.00
0205 + 722	02 05 26.86	+72 15 16.4	S5	20.7	QSO	*	0.549	−0.38
0238 + 711	02 38 50.07	+71 07 33.8	S5	18.2	BL/QSO	*	0.272	−0.02
0258 + 772	02 58 48.29	+77 15 48.9	S5	21.5	GAL	*	0.459	−0.78
0330 + 707	03 30 32.83	+70 45 58.6	S5	*	SS_EF	*	0.256	−1.13
0349 + 727	03 49 18.02	+72 45 50.2	S5	*	SS_EF	*	0.457	−1.01
0358 + 703	03 58 28.00	+70 18 36.2	S5	*	SS_EF	*	0.257	−0.93
0415 + 763	04 15 22.57	+76 19 59.7	S5	21.9	GAL	*	0.285	−1.03
0437 + 785	04 38 00.52	+78 33 23.0	S5	17.7	QSO	0.454	0.258	−0.72
0440 + 732	04 41 00.49	+73 14 10.3	S5	19.6	QSO	1.290	0.296	−0.75
0601 + 712	06 01 22.26	+71 16 32.4	S5	*	SS_EF	*	0.278	−0.44
0604 + 728	06 04 39.19	+72 49 27.1	PA	20.3	QSO	*	0.557	−0.55
0625 + 842	06 24 59.84	+84 13 24.1	S5	21.1	GAL	*	0.275	−1.06
0633 + 734	06 33 06.40	+73 27 35.9	PA	18.2	QSO	1.851	0.665	−0.32
0638 + 779	06 38 17.57	+77 57 56.9	S5	*	SS_EF	*	0.286	−0.91
0647 + 733	06 47 11.91	+73 20 33.2	S5	*	SS_EF	*	0.248	−0.87
0718 + 792	07 18 08.39	+79 17 22.8	S5	*	FS_EF	*	0.631	+0.03
0740 + 828	07 40 33.20	+82 49 24.2	S5	18.5	QSO	1.991	0.931	−0.53
0743 + 744	07 43 14.65	+74 28 10.0	S5	19.3	QSO	1.629	0.330	−0.05
0819 + 770	08 19 22.70	+77 02 59.0	S5	18.3	GAL	0.309	0.248	−0.85
0820 + 742	08 20 03.98	+74 14 16.5	S5	20.9	GAL	*	0.295	−1.07
0824 + 802	08 24 55.20	+80 16 07.8	S5	21.3	GAL	*	0.276	−0.95
0925 + 745	09 25 52.65	+74 33 16.5	S5	*	FS_EF	*	0.302	+0.09
0936 + 831	09 36 55.99	+83 07 50.9	S5	19.9	GAL	*	0.248	−0.79
0950 + 748	09 50 04.54	+74 50 07.7	S5	21.7	GAL	*	0.690	−0.57
1004 + 861	10 04 04.11	+86 08 39.8	S5	17.5	GAL	0.147	0.257	−0.90
1009 + 748	10 09 50.07	+74 52 32.5	S5	20.9	GAL	*	0.607	−1.11
1027 + 749	10 27 13.39	+74 57 22.7	S5	17.2	GAL	0.123	0.319	−0.20
1044 + 719	10 44 49.73	+71 59 27.0	PA	17.8	QSO	1.15	0.707	−0.08
1100 + 798	11 00 00.03	+79 49 02.9	S5	20.4	GAL	*	0.278	−0.58
1142 + 702	11 42 20.67	+70 14 55.3	S5	*	SS_EF	*	0.485	−0.98
1152 + 758	11 52 24.05	+75 51 23.0	S5	21.6	GAL	*	0.325	−0.74
1241 + 735	12 41 18.55	+73 32 24.2	PA	17.0	GAL	*	0.276	−0.86
1259 + 811	12 59 52.90	+81 10 45.8	S5	22.3	GAL	*	0.265	−1.23
1305 + 770	13 05 53.89	+77 05 18.5	S5	*	SS_EF	*	0.267	−0.90
1305 + 804	13 05 25.92	+80 24 22.4	S5	*	FS_EF	*	0.375	−0.45
1317 + 825	13 17 40.12	+82 34 59.4	S5	*	SS_EF	*	0.247	−0.94
1322 + 835	13 22 34.51	+83 31 51.3	S5	*	FS_EF	*	0.506	+0.24
1323 + 799	13 23 30.99	+79 58 27.6	VLA	21.5	GAL ?	*	0.458	+0.22
1448 + 762	14 48 56.59	+76 13 33.7	S5	22.3	QSO	0.899	0.683	+0.32
1531 + 722	15 31 45.73	+72 16 45.1	S5	17.7	QSO	0.899	0.456	−0.04
1635 + 742	16 35 02.39	+74 11 53.9	S5	22.9	GAL ?	*	0.372	−0.81
1650 + 758	16 50 21.49	+75 51 31.6	S5	19.2	GAL	*	0.648	−0.93
1654 + 866	16 54 31.42	+86 37 07.0	S5	*	SS_EF	*	0.315	−0.79
1728 + 774	17 28 14.07	+77 28 47.0	S5	*	SS_EF	*	0.401	−0.77
1811 + 738	18 11 34.20	+73 49 42.3	S5	20.1	GAL	*	0.332	−1.16
1914 + 855	19 15 00.21	+85 31 50.5	S5	21.1	GAL	*	0.276	−0.87
1920 + 744	19 20 21.53	+74 27 42.1	S5	21.6	GAL	*	0.315	−0.76
1939 + 813	19 39 33.50	+81 23 21.3	S5	21.1	GAL	*	0.339	−0.12
2010 + 723	20 10 16.14	+72 20 20.6	S5	19.4	BL/QSO	*	0.917	−0.26
2018 + 732	20 18 52.83	+73 17 26.7	S5	21.1	GAL	*	0.267	−0.97
2023 + 760	20 23 40.85	+76 01 40.6	VLA	17.1	BL/QSO	*	0.426	−0.13
2043 + 748	20 43 32.67	+74 52 11.0	S5	*	SS_EF	*	0.379	−1.17
2051 + 745	20 51 57.45	+74 30 18.1	S5	19.0	BL/QSO	*	0.528	+0.33
2059 + 732	20 59 47.50	+73 16 37.8	S5	*	SS_EF	*	0.298	−0.53

Table 3. continued

Object	RA (1950)	Dec (1950)	Pos.Ref	m	type	z	S_{5GHz}	α_{11-6}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2118 + 749	21 18 24.07	+74 59 02.0	S5	*	SS_EF	*	0.343	−0.84
2120 + 717	21 20 40.27	+71 42 20.7	S5	20.2	GAL	*	0.315	−0.74
2136 + 824	21 36 02.32	+82 25 39.0	S5	19.6	QSO	2.350	0.509	−0.47
2154 + 726	21 54 13.04	+72 37 24.1	S5	*	SS_EF	*	0.312	−0.76
2205 + 743	22 05 08.89	+74 21 41.7	S5	22.5	GAL	*	0.261	−0.20
2325 + 822	23 25 20.83	+82 15 26.7	S5	21.1	GAL	*	0.285	−1.00

References to radio positions :

PA	Patnaik et al. (1992)	VLA	VLA Calibrator position
S5	Kühr et al. (1987)		

Table 4. Journal of 1 Jy observations

Object	Date	Telescope	Integ.time [sec]	Seeing [″]	Scale [″/pixel]
(1)	(2)	(3)	(4)	(5)	(6)
0022 − 423	Oct. 30, 1986	LS22	900	2.2	0.35
0026 + 346	Sep. 8, 1989	CA35	100	1.8	0.50
0403 + 768	Dec. 16, 1985	CA22	1200	1.0	0.35
0407 − 658	Nov. 5, 1986	LS22	300	1.7	0.35
0446 + 112	Nov. 5, 1986	LS22	300	1.7	0.35
0500 + 019	Oct. 23, 1992	CA35	600	2.5	0.25
0511 − 305	Mar. 24, 1985	LS22	1200	1.1	0.35
0539 − 057	Dec. 19, 1985	CA22	900	1.3	0.35
0615 + 820	Oct. 23, 1992	CA35	300	2.0	0.25
0742 + 103	Dec. 16, 1985	CA22	1200	1.0	0.35
0834 − 196	Dec. 19, 1985	CA22	900	1.3	0.35
0941 − 080	Oct. 23, 1992	CA35	400	2.5	0.25
1213 − 172	June 24, 1993	CA35	540	1.5	0.41
1518 + 046	Mar. 20, 1985	CA22	1800	1.5	0.35
1555 + 001	Mar. 24, 1985	CA22	1200	1.3	0.35
1600 + 335	June 24, 1993	CA35	1800	1.5	0.41
1602 − 093	June 30, 1992	CA35	600	2.5	0.41
1622 − 253	Mar. 24, 1985	CA22	1800	1.3	0.35
1638 + 124	June 23, 1993	CA35	1200	1.5	0.41
1648 + 015	June 11, 1992	CA22	4800	1.1	0.29
1815 − 553	Sep. 25, 1990	LS22	1800	1.8	0.35
1933 − 400	Sep. 25, 1990	LS22	1800	1.8	0.35
2008 − 068	June 20, 1985	CA22	600	1.1	0.35
2149 − 287	July 12, 1994	SO90	1000	2.3	0.29
2210 + 016	June 14, 1991	CA35	300	1.2	0.25
2324 + 405	Oct. 22, 1992	CA35	600	2.7	0.25
2342 + 821	Dec. 19, 1985	CA22	600	1.3	0.35

Telescopes used :

CA22	Calar Alto 2.2m	LS22	La Silla 2.2m
CA35	Calar Alto 3.5m	SO90	Steward Observatory 90″

Table 5. Journal of S4 observations

Object	Date	Telescope	Integ.time [sec]	Seeing [″]	Scale [″/pixel]
(1)	(2)	(3)	(4)	(5)	(6)
0011 + 344	July 12, 1994	SO90	1000	2.3	0.29
0024 + 348	Oct. 23, 1992	CA35	400	2.5	0.25
0102 + 480	June 24, 1993	CA35	600	1.5	0.41
0246 + 428	Oct. 23, 1992	CA35	400	2.5	0.25
0327 + 408	Oct. 23, 1992	CA35	600	2.5	0.25
0620 + 389	Oct. 23, 1992	CA35	300	2.6	0.25
0657 + 687	Oct. 22, 1992	CA35	300	2.6	0.25
0707 + 689	Dec. 4, 1991	CA35	600	2.5	0.25
0816 + 526	Oct. 23, 1992	CA35	400	2.3	0.25
1014 + 392	Oct. 23, 1992	CA35	600	2.6	0.25
1020 + 593	Oct. 23, 1992	CA35	300	2.3	0.25
1128 + 385	Oct. 23, 1992	CA35	200	2.4	0.25
1402 + 660	June 9, 1992	CA22	1000	1.9	0.29
1656 + 482	June 30, 1992	CA35	600	2.0	0.41
1734 + 508	June 7, 1992	CA22	300	2.5	0.29
1818 + 356	June 7, 1992	CA22	300	2.5	0.29
1843 + 400	June 30, 1992	CA35	300	2.1	0.41
1926 + 611	June 15, 1991	CA35	400	1.1	0.25
2218 + 395	Oct. 22, 1992	CA35	600	2.5	0.25
2311 + 469	Oct. 22, 1992	CA35	300	2.7	0.25
2358 + 406	July 12, 1994	SO90	1200	2.3	0.29

Telescopes used :

CA22	Calar Alto 2.2m	LS22	La Silla 2.2m
CA35	Calar Alto 3.5m	SO90	Steward Observatory 90″

optical identification if at least two reference stars lead to optical positions of the radio source scattered within $1'' - 2''$ around the proposed optical counterpart. For radio sources with two separated components (presumably the lobes of classical triple sources) optical counterparts have been searched for near the midpoint along the axis joining the two components. Again, an optical object has been accepted as the optical counterpart if different standard stars gave optical positions within $1'' - 2''$ of the proposed optical identification. Occasionally, an optical object either somewhat off the axis or closer to one of the two components was accepted as the optical counterpart; these cases are mentioned in the notes on individual sources. Finally, for radio sources with a triple radio structure optical counterparts have been searched for near the central radio component and accepted as optical counterparts if different standard stars gave optical positions within $1'' - 2''$ of the proposed optical identification.

Unless described in the notes on the individual sources, the classification and magnitudes of the optical counterparts listed in Tables 1-3 are derived from the images presented in Figs. 1-3. For the classification of the optical counterparts as galaxies or unresolved QSOs, their widths on the CCD images have been measured and compared with those of stars in the field. This method works quite well down to $m_R = 20-21$ mag, depending on the limiting magnitude and the seeing of a particular image. However, it becomes increasingly uncertain at fainter magnitudes and inferior seeing conditions. Therefore, those few optical counterparts which could not be categorized as extended or unresolved were classified as 'GAL?' in Tables 1-3. In the notes on individual sources, they were described as tentatively identified with a faint galaxy. An unambiguous classification of these objects must await much deeper optical data and/or optical spectroscopy.

In fields where no optical objects have been found close ($< 2''$) to the radio position a circle of $10''$ diameter has been drawn centered at the radio position of compact sources, at the midpoint of the two components of double sources, or at the central component of triple sources. Only in a few cases an optical object was found within the circle of $10''$ diameter, which might or might not be the correct optical identification. For empty field sources, a rather conservative limiting magnitude of $m > 22$ mag for the brightness of any optical counterpart has been stated in the notes of individual objects, although most of the images reach a deeper limiting magnitude. It can be expected that the empty field classification of a few of these cases is due to a rather inaccurate radio position, which can be remedied with new and deeper radio maps. For

Table 6. Journal of S5 observations

Object	Date	Telescope	Integ.time	Seeing	Scale
			[sec]	["]	["/pixel]
(1)	(2)	(3)	(4)	(5)	(6)
0036 + 744	Dec. 16, 1985	CA22	600	1.1	0.35
0048 + 892	Dec. 16, 1985	CA22	1200	1.2	0.35
0123 + 731	Dec. 15, 1985	CA22	600	1.3	0.35
0124 + 845	Dec. 15, 1985	CA22	600	1.3	0.35
0153 + 744	June 24, 1993	CA35	800	1.5	0.41
0200 + 751	Dec. 15, 1985	CA22	600	1.3	0.35
0201 + 796	Dec. 15, 1985	CA22	1200	1.3	0.35
0205 + 722	Dec. 16, 1985	CA22	1200	1.2	0.35
0238 + 711	Oct. 23, 1992	CA35	300	2.4	0.25
0258 + 772	Dec. 16, 1985	CA22	1200	1.0	0.35
0330 + 707	Dec. 16, 1985	CA22	1200	1.0	0.35
0349 + 727	Dec. 15, 1985	CA22	600	1.3	0.35
0358 + 703	Dec. 16, 1985	CA22	1200	1.1	0.35
0415 + 763	Dec. 19, 1985	CA22	600	1.3	0.35
0437 + 785	Dec. 19, 1985	CA22	300	1.3	0.35
0440 + 732	Dec. 19, 1985	CA22	300	1.3	0.35
0601 + 712	Dec. 15, 1985	CA22	600	1.3	0.35
0604 + 728	Dec. 15, 1985	CA22	600	1.2	0.35
0625 + 842	Dec. 15, 1985	CA22	600	1.2	0.35
0633 + 734	Dec. 19, 1985	CA22	600	1.3	0.35
0638 + 779	Dec. 16, 1985	CA22	1200	1.1	0.35
0647 + 733	Dec. 16, 1985	CA22	600	1.1	0.35
0718 + 792	Dec. 16, 1985	CA22	600	1.1	0.35
0740 + 828	Dec. 19, 1985	CA22	300	1.3	0.35
0743 + 744	Dec. 4, 1991	CA35	110	2.3	0.25
0819 + 770	Dec. 15, 1985	CA22	200	1.1	0.35
0820 + 742	Dec. 16, 1985	CA22	600	1.1	0.35
0824 + 802	Dec. 15, 1985	CA22	600	1.1	0.35
0925 + 745	Dec. 20, 1985	CA22	600	1.6	0.35
0936 + 831	Dec. 15, 1985	CA22	200	1.1	0.35
0950 + 748	Dec. 20, 1985	CA22	600	1.4	0.35
1004 + 861	Dec. 19, 1985	CA22	300	1.5	0.35
1009 + 748	Dec. 15, 1985	CA22	600	1.3	0.35
1027 + 749	Dec. 19, 1985	CA22	600	1.3	0.35
1044 + 719	Dec. 15, 1985	CA22	600	1.2	0.35
1100 + 798	Dec. 20, 1985	CA22	600	1.5	0.35
1142 + 702	Dec. 20, 1985	CA22	600	1.4	0.35
1152 + 758	Dec. 16, 1985	CA22	600	1.1	0.35
1241 + 735	Dec. 16, 1985	CA22	600	1.1	0.35
1259 + 811	Dec. 16, 1985	CA22	600	1.1	0.35
1305 + 770	June 10, 1992	CA22	600	2.5	0.29
1305 + 804	June 9, 1992	CA22	300	2.1	0.29
1317 + 825	June 10, 1992	CA22	900	2.4	0.29
1322 + 835	June 10, 1992	CA22	900	2.3	0.29
1323 + 799	June 10, 1992	CA22	900	2.4	0.29
1448 + 762	June 9, 1992	CA22	600	2.6	0.29
1531 + 722	June 17, 1991	CA35	600	1.3	0.25
1635 + 742	June 10, 1992	CA22	600	2.6	0.29
1650 + 758	June 10, 1992	CA22	900	2.5	0.29
1654 + 866	June 10, 1992	CA22	900	2.5	0.29
1728 + 774	June 9, 1992	CA22	900	1.9	0.29
1811 + 738	June 8, 1992	CA22	300	1.7	0.29
1914 + 855	June 8, 1992	CA22	600	2.5	0.29
1920 + 744	June 20, 1985	CA22	600	1.4	0.35
1939 + 813	June 8, 1992	CA22	600	2.5	0.29
2010 + 723	June 18, 1991	CA35	500	1.6	0.25
2018 + 732	June 8, 1992	CA22	600	2.5	0.29
2023 + 760	June 18, 1991	CA35	500	1.6	0.25
2043 + 748	June 8, 1992	CA22	600	2.5	0.29
2051 + 745	June 18, 1991	CA35	300	1.6	0.25

Table 6. continued

Object	Date	Telescope	Integ.time	Seeing	Scale
			[sec]	[″]	[″/pixel]
(1)	(2)	(3)	(4)	(5)	(6)
2059 + 732	June 10, 1992	CA22	900	2.6	0.29
2118 + 749	July 12, 1994	SO90	1000	2.3	0.29
2120 + 717	Dec. 20, 1985	CA22	300	1.4	0.35
2136 + 824	Dec. 20, 1985	CA22	300	1.4	0.35
2154 + 726	June 11, 1992	CA22	300	1.2	0.29
2205 + 743	June 11, 1992	CA22	600	1.2	0.29
2325 + 822	Dec. 19, 1985	CA22	600	1.4	0.35

Telescopes used :

CA22	Calar Alto 2.2m	LS22	La Silla 2.2m
CA35	Calar Alto 3.5m	SO90	Steward Observatory 90″

most of the empty fields, however, the detection of an optical counterpart requires much deeper optical (limiting magnitude $m > 23$ mag) and/or IR imaging data.

4. Notes on individual 1 Jy sources

0022 − 423: A faint optical counterpart of unknown type has been found by Torres & Wroblewski (1987). Our (uncalibrated) B- band CCD image shows that this object is an unresolved QSO. The optical magnitude of $m_R = 21.0$ mag listed in Table 1 has been taken from O'Dea et al. (1991). This identification has previously been listed in the update of the 1 Jy catalogue (Stickel et al. 1994) and was recently confirmed by di Serego Alighieri et al. (1994).

0026 + 346: The image shows the optical counterpart to be a $m_R = 20.7$ mag galaxy, which confirms the classification given by Peacock et al. (1981), while the classification as a QSO by Rieke et al. (1979) is rejected.

0403 + 768: The optical counterpart is a $m_R = 21.2$ mag galaxy lying midway between the radio lobes, which confirms the identification given by Peacock et al. (1981). The redshift of $z = 0.5985$ is listed in O'Dea et al. (1991).

0407 − 658: The accurate radio position of 0407 − 658 given by White (1992) together with the optical position of a $m = 18$ mag nearby unresolved object (the previous tentative identification) given by Prestage & Peacock (1983) shows that the optical counterpart of the radio source is a faint, $m_R = 21.2$ mag galaxy, rather than the aforementioned stellar object. The tentative identification of the radio source given by Hunstead (1971) and Prestage & Peacock (1983) and listed in the update of the 1 Jy radio source catalogue (Stickel et al. 1994) is therefore incorrect. The correct (radio) position has also been marked on the finding chart of di Serego Alighieri et al. (1994), although their scanned plate was not deep enough to show the optical counterpart.

0446 + 112: This radio source has originally been identified with a galaxy by Hoskins et al. (1974). On our image the optical counterpart also appears to be nonstellar with a magnitude of $m_R = 20.6$ mag, thereby confirming that classification. However, 0446+112 has been detected as a gamma-ray source (Fichtel et al. 1994), which in contrast points toward a quasar as optical counterpart. As long as no deeper image and no optical spectrum is available, the classification as a galaxy must be considered tentative.

0500 + 019: Our CCD image shows an optical counterpart at the radio position, but it is neither deep enough nor has sufficient spatial resolution to allow the discrimination between resolved or stellar and to show the presence of two objects, as described by Fugmann et al. (1988). The classification and optical magnitude listed in Table 1 has been taken from Fugmann et al. (1988). In contrast, the optical counterpart has been described to be extended and classified as a galaxy by di Serego Alighieri et al. (1994).

0511 − 305: The optical identification as a galaxy is given by Bolton et al. (1965) and Jones & McAdam (1992). From our CCD image, we derive a magnitude of $m_R = 15.2$ mag. The long wisp noted by Jones & McAdam (1992) is likely the result of a gravitational interaction of the radio galaxy with a fainter galaxy 30″ west. No redshift has as yet been published for this relatively bright radio galaxy.

0539 − 057: Our CCD image confirms the identification as a QSO given by Fugmann & Meisenheimer (1988) and Chu et al. (1986), and a brightness of $m_R = 20.4$ mag has been measured. From a second CCD image taken in October 1990 a magnitude of $m_R = 20.7$ mag was derived. These measurements together with the magnitudes given by Chu et al. (1986) ($m = 20.4$ mag), Fugmann & Meisenheimer (1988) ($m = 19.2$ mag) and Impey & Tapia (1990) ($m = 18.5$ mag) indicate an optical variability of about 2 mag. The optical spectrum and redshift are given in Stickel & Kühr (1993b).

0615 + 820: An optical magnitude of $m_R = 19.7$ mag has been measured for this unresolved ($z = 0.710$, Stickel et al. 1994) quasar. The brightness of 0615+820 derived from the APM plate scan is $m = 18.2$ mag, which may indicate optical variability. The optical magnitude listed in Kühr et al. (1987) was derived from POSS and may possibly be too bright.

0742 + 103: The faint identification proposed by Fugmann et al. (1988) has not been detected on our R - and I - band CCD images. The radio source is thus classified as an empty field, which is also in disagreement with O'Dea et al. (1991).

0834 − 196: Our CCD image shows that the object closest to the radio position of Morganti et al. (1993) is actually an extended galaxy with $m_R = 22.4$ mag rather than an unresolved object, as suggested by Fugmann et al. (1988) and di Serego Alighieri et al. (1994). The steep radio spectrum characteristic for radio galaxies as well as the optical spectrum showing only narrow emission lines at $z = 1.032$ (di Serego Alighieri et al. 1994) support this new classification. The tentative identification of 0834 − 196 with the brighter galaxy 5″ northeast suggested by Fugmann et al. (1988) and listed in the update of the 1 Jy radio source catalogue (Stickel et al. 1994) is incorrect.

0941 − 080: The CCD image shows the optical counterpart to be a $m_R = 18.1$ mag galaxy, in agreement with the identification given by Stanghellini et al. (1993).

1213 − 172: Because this radio source lies close to the 2.6 mag star γ Corvus, no optical identification had previously been attempted. We succeeded in getting an image of 1213 − 172 by using a nearby SAO star as positional reference, placing the radio position extremely close to an edge of the CCD and taking a total of nine 60 s integrations to avoid saturation. Two isophotal plots of the field of 1213 − 172 are given in Fig. 1. In addition to the optical counterpart the first also shows a number of field stars, while the second covers only the immediate neighborhood of the identification, a $m_R = 21.4$ mag galaxy at the radio position. It should be noted that the morphologies of the objects close to the radio position are severely affected by strong fringing of the CCD due to γ Corvus, which could not be completely corrected. Nevertheless, the close-up shows that the optical counterpart of 1213 − 172 is likely the brightest member of a small group of galaxies.

1518 + 046: The identification as a quasar given by Biretta et al. (1985) is confirmed by our CCD image and a somewhat brighter optical magnitude of $m_R =$ 22.2 mag has been measured. The redshift has been listed by di Serego Alighieri et al. (1994).

1555 + 001: The optical identification of 1555+001 derived from our CCD image, a $m_R = 20.0$ mag unresolved quasar, is in agreement with the finding charts given by Véron (1971) and Brandie & Bridle (1974). The finding chart given by Hoskins et al. (1972) and referred to in Hewitt & Burbidge (1993) is incorrect. Additional bibliographic references can be found in Véron-Cetty & Véron (1993) and Hewitt & Burbidge (1993).

1600 + 335: Stanghellini et al. (1993) suggested a very faint, possibly extended object as the optical counterpart. Our deep R band CCD image confirms the optical counterpart to be a highly elongated or even morphologically disturbed $m_R = 23.0$ mag galaxy.

1602 − 093: On our CCD image, the field around the radio position remains empty down to a limiting magnitude of $m_R = 22$ mag.

1622 − 253: No optical counterpart has been found by Prestage & Peacock (1983), who marked a nearby stellar object on their finding chart, while Saikia et al. (1987) described the field as obscured. Using the optical position of the nearby stellar object given by Prestage & Peacock (1983) and the radio position listed in Robertson et al. (1993), 1622−253 is identified with a $m_R = 20.3$ mag unresolved QSO at the radio position. The optical polarization measured by Impey & Tapia (1990) probably refers to the nearby object of Prestage & Peacock (1983). The identification of 1622 − 253 with this unresolved QSO has previously been listed in the update of the 1 Jy catalogue (Stickel et al. 1994) and was recently confirmed by di Serego Alighieri et al. (1994), who also measured the redshift of $z = 0.786$.

1638 + 124: The optical counterpart of 1638+124 is a $m_R = 21.8$ mag compact galaxy with a nearby object of lower surface brightness.

1648 + 015: The identification of 1648+015 is a $m_R=$ 20.7 mag QSO showing at the lowest isophote levels an asymmetric extension towards the south and west. It should be noted that the optical magnitude of 1648+015 given above supersedes the value listed in the update of the 1 Jy catalogue (Stickel et al. 1994), which erroneously tabulated the brightness of the neighbouring object 8″ east of 1648+015.

1815 − 553: The brightness of the optical counterpart of 1815 − 553, derived from our CCD image, is only m_R = 21.7 mag, nearly 3 mag fainter than the value given by White et al. (1991), which indicates a significant, previously unknown optical variability of this quasar.

1933 − 400: For this quasar an optical magnitude of m_R = 18.0 mag has been derived from our CCD image, identical to the value given by Shimmins et al. (1971).

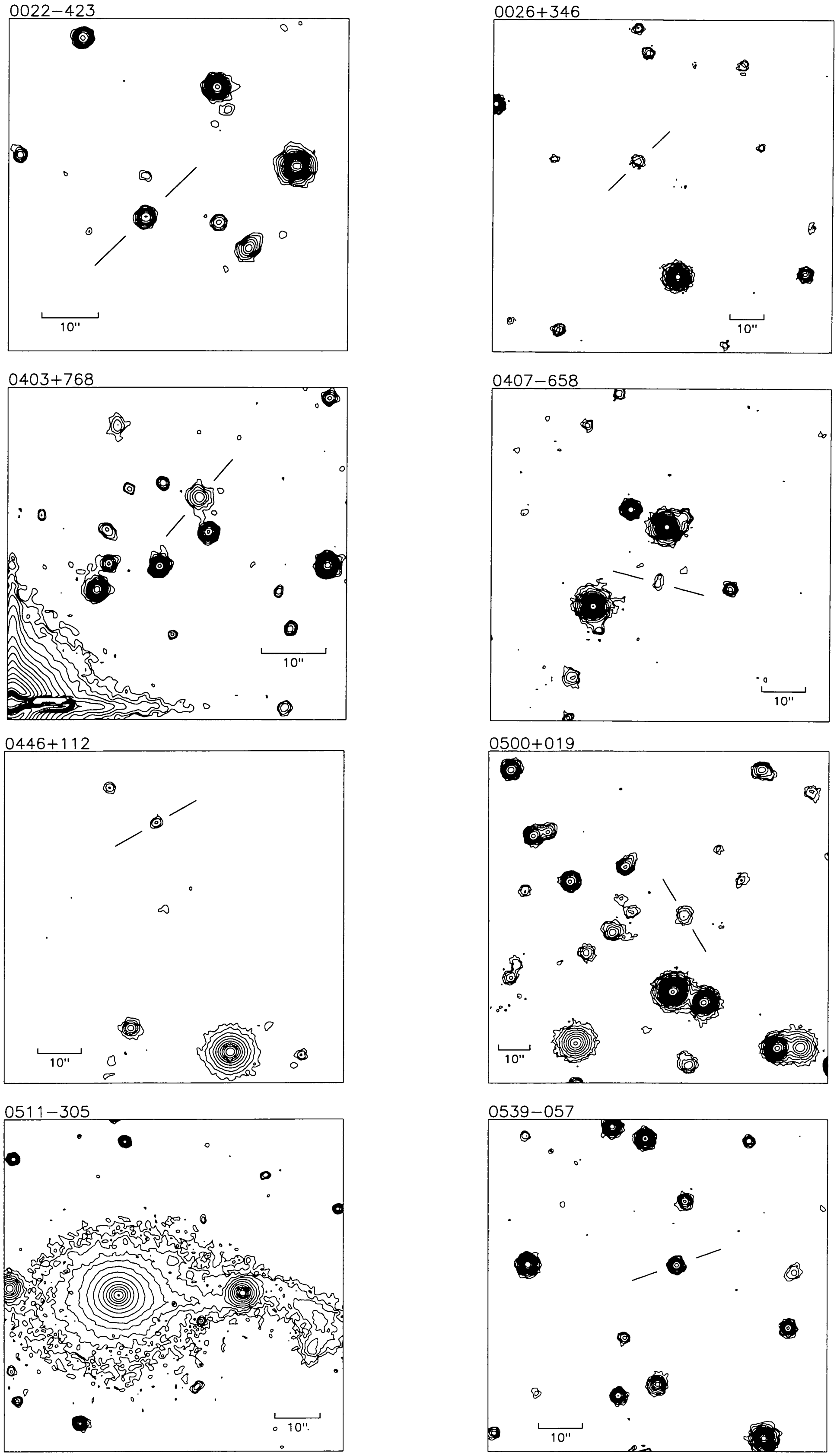

Fig. 1. Isophotal contour plots of the fields of 1 Jy radio sources. Except for 0511 − 305, the identified optical counterparts of the radio sources are marked. The optical counterpart of 0511 − 305 is the brightest galaxy in the field. For empty fields, a circle with 10″ diameter has been drawn at the radio position. North is up and east to the left

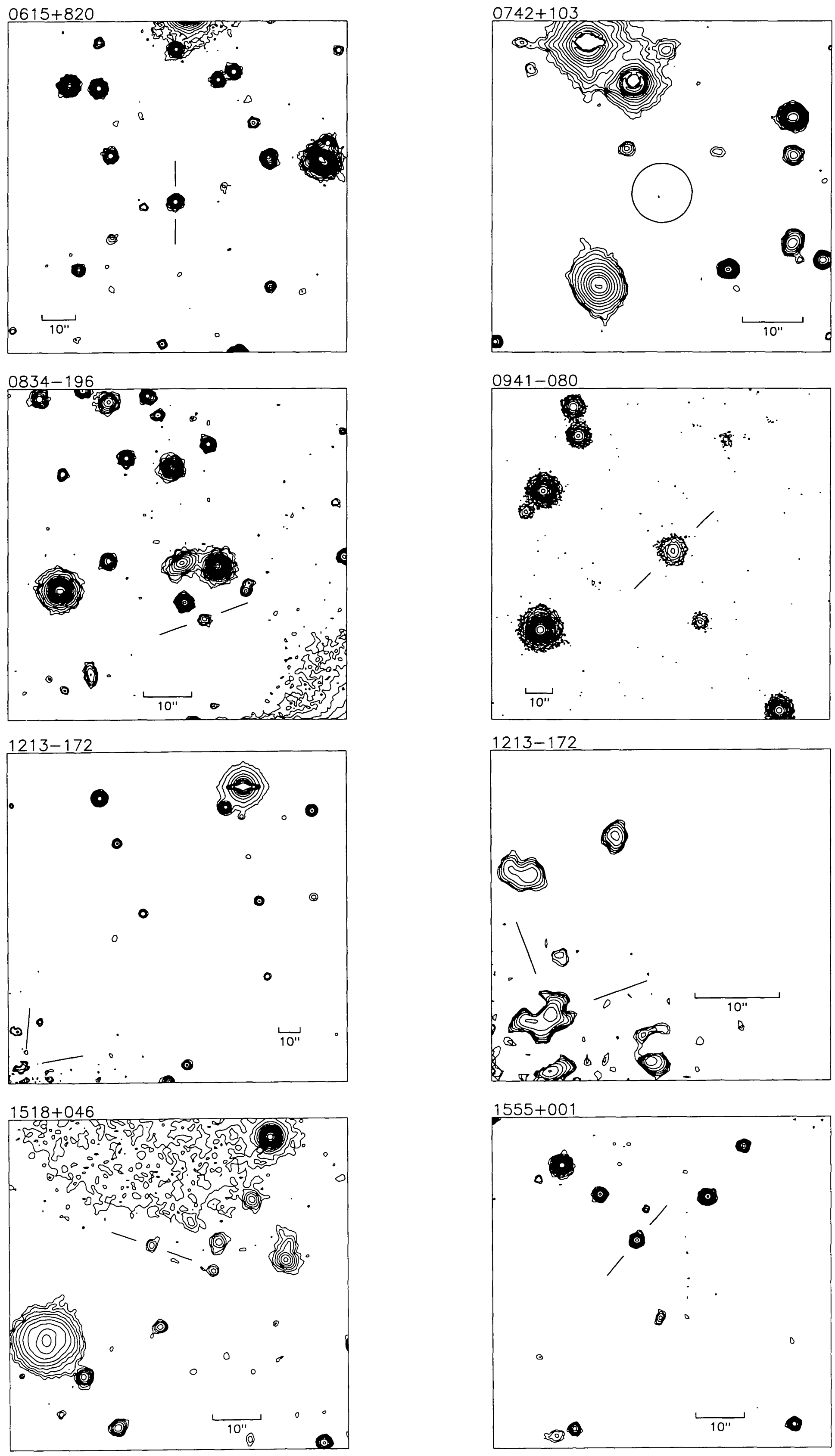

Fig. 1. continued

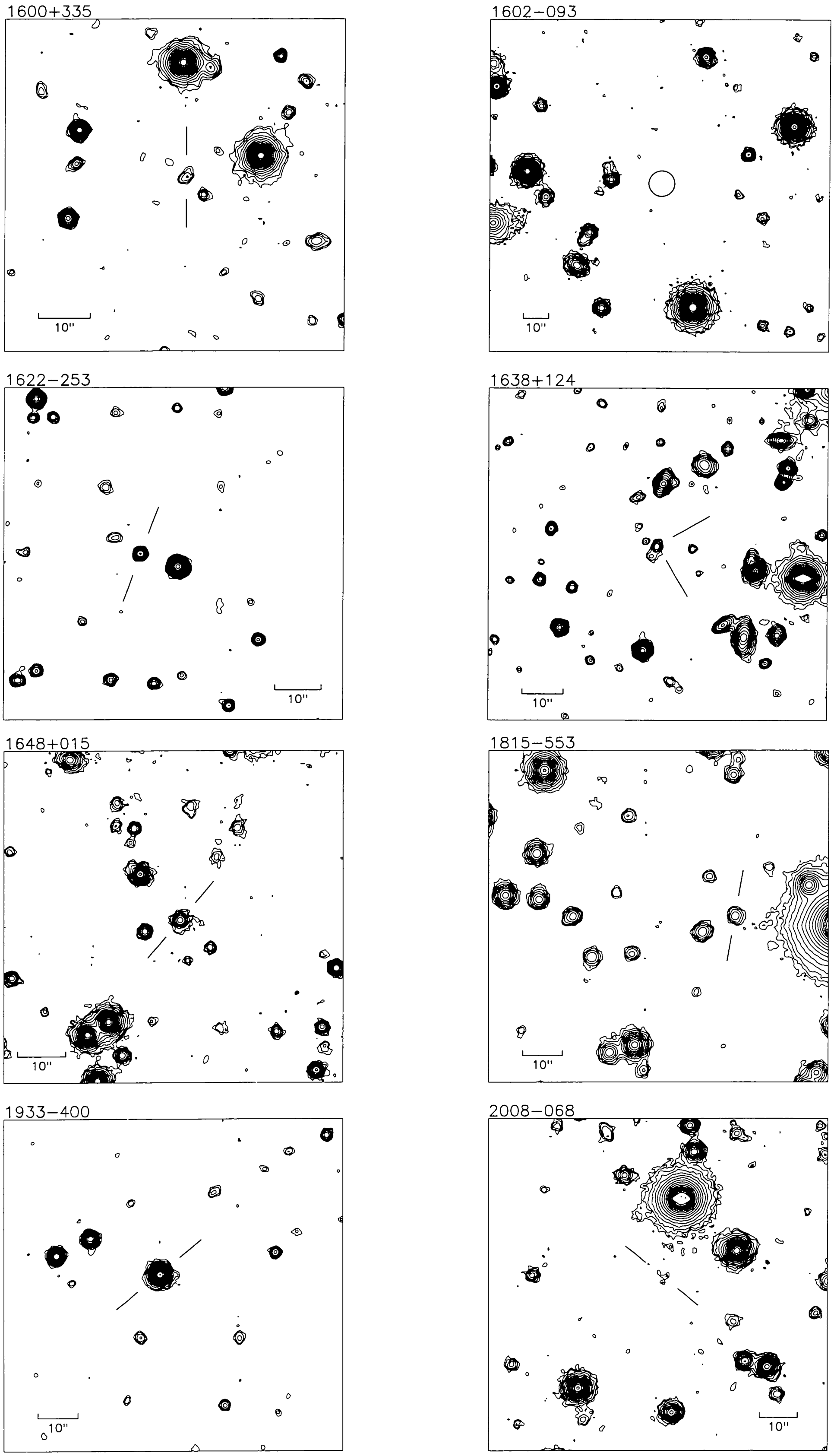

Fig. 1. continued

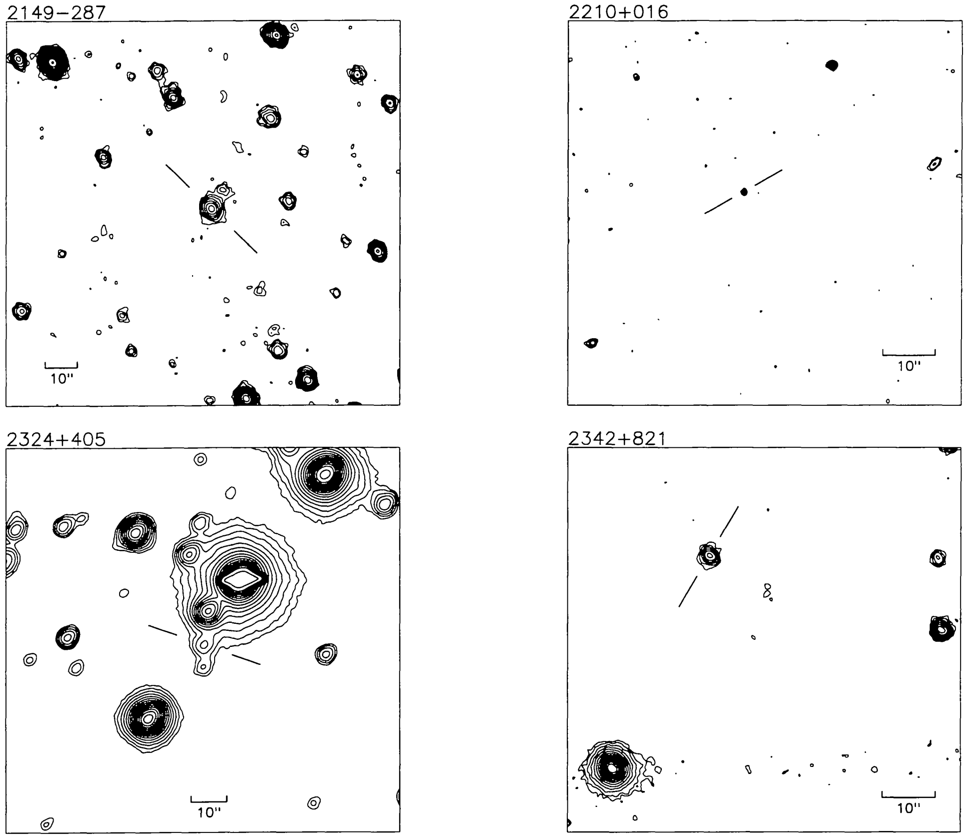

Fig. 1. continued

The optical spectrum and redshift are given by Wilkes et al. (1983).

2008 − 068: The radio source has previously been identified as a galaxy by Fugmann et al. (1988), O'Dea et al. (1990), Stanghellini et al. (1993), and di Serego Alighieri et al. (1994). Our CCD image, while confirming the presence of an object at the radio position, is not deep enough to show more details. The classification and optical magnitude listed in Table 1 have been taken from Stanghellini et al. (1993).

2149 − 287: The radio position listed by Ulvestad al. (1981) and included in the 1 Jy catalogue update (Stickel et al. 1994) differs by more than 5″ from the position given in the VLA calibrator list. While no object is seen at the former radio position, a m_R = 19.4 mag galaxy lies at the VLA calibrator position. The steep radio spectrum characteristic of radio galaxies supports the identification of 2149 − 287 with this galaxy.

2210 + 016: This radio source has tentatively been identified with a m = 21.7 mag QSO by Fugmann et al. (1988). Our CCD image has been obtained under non-photometric weather conditions but nevertheless confirms that the optical counterpart is an unresolved QSO. The optical magnitude of 2210+016 listed in Table 1 has been taken from Fugmann et al. (1988).

2324 + 405: The identification of the optical counterpart as a galaxy (Cohen et al. 1977) is confirmed with our CCD image, from which an optical magnitude of m_R = 19.4 mag was derived. The optical spectrum and the redshift have been given in Stickel & Kühr (1993b).

2342 + 821: The optical magnitude of m_R = 20.2 mag, derived from our CCD image, is somewhat brighter than that listed in Pearson & Readhead (1988). The redshift for this quasar is given there, too.

5. Notes on individual S4 sources

0011 + 344: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position listed in the S4 catalogue (Pauliny-Toth et al. 1978). A m_R = 19.8 mag galaxy lies just outside the 10″ circle centered at this radio position. The radio position of Gregory & Condon (1991) lies 14″ west and is also empty. Since both radio positions differ by about their accuracy, this may indicate that the galaxy in between is actually the correct optical counterpart of 0011+344. A new, deeper radio map is needed to resolve this discrepancy and to identify the optical counterpart unambiguously.

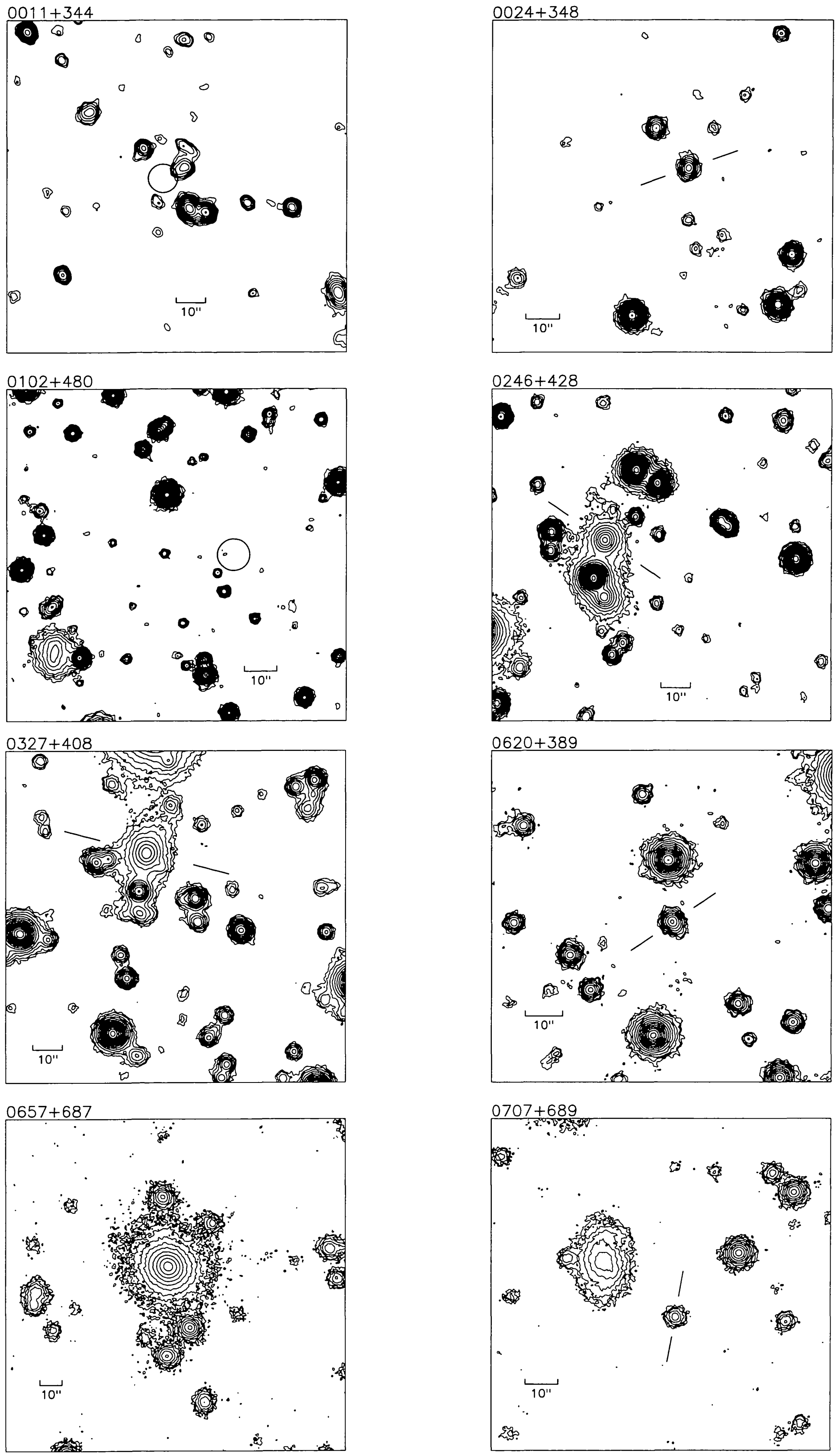

Fig. 2. Isophotal contour plots of the fields of S4 radio sources. Except for 0657 + 687, the identified optical counterparts of the radio sources are marked. The optical counterpart of 0657 + 687 is the brightest galaxy in the field. For empty fields, a circle with 10″ diameter has been drawn at the radio position. North is up and east to the left

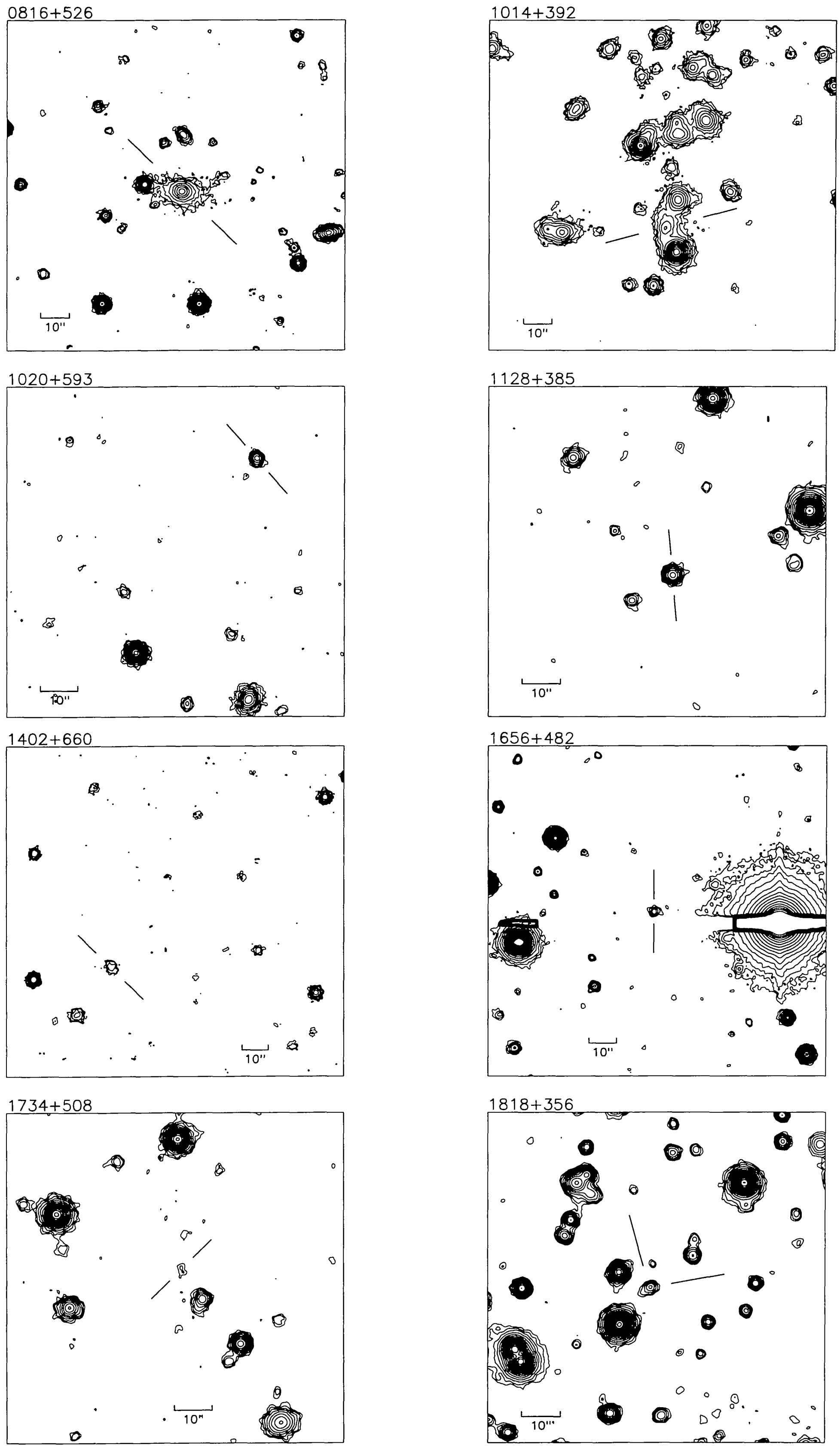

Fig. 2. continued

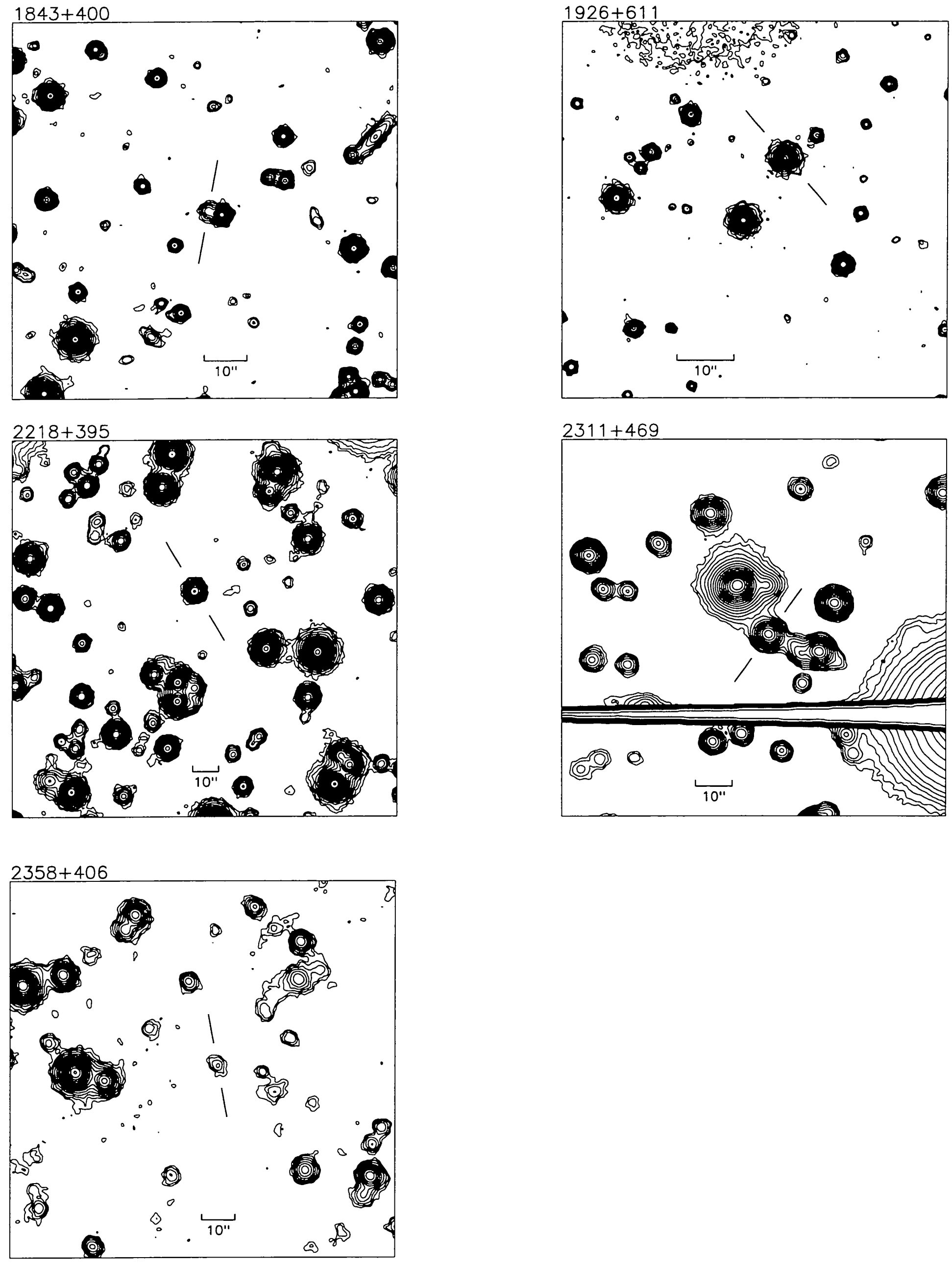

Fig. 2. continued

0024 + 348: The CCD image shows that the optical counterpart of 0024+348 is an m_R = 18.9 mag extended galaxy rather than a QSO. This new classification supersedes that given by Folsom et al. (1971) and Browne et al. (1973), which had been included in the update of the S4 radio source catalogue (Stickel & Kühr 1994a). The optical spectrum and redshift have been given in Stickel & Kühr (1993b).

0102 + 480: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

0246 + 428: For this galaxy, an optical magnitude of m_R = 17.3 mag was measured, which is somewhat brighter than the value given by Willson (1972). The optical spectrum and redshift have been given in Stickel & Kühr (1993b).

0327 + 408: An optical magnitude of m_R = 16.9 mag was measured for this galaxy, again somewhat brighter than the value given by Willson (1972). The optical spectrum and redshift have been given in Stickel & Kühr (1993b).

0620 + 389: This high redshift (z = 3.470, Xu et al. 1994) quasar appears extended on our CCD image, which is caused by a faint galaxy lying only 3″ from the line-of-sight. The measured optical magnitude of $m_R = 20.0$ mag is identical to the value given by Kühr (1977a).

0657 + 687: The measured optical magnitude of m_R = 15.3 mag for this radio galaxy lies between the values given by Kühr (1977b) and Cohen et al. (1977). The optical spectrum and redshift have been given in Stickel & Kühr (1993b).

0707 + 689: An optical brightness of m_R = 19.9 mag has been measured for this quasar (z = 1.139 lying only 28″ from a foreground galaxy with z = 0.069 (Stickel & Kühr 1993b). Since both objects had previously been claimed to be the optical counterpart of the radio source 0707+689 (see Stickel & Kühr 1993b) APM reference stars have been used to confirm that the quasar is indeed the correct identification, as had been suggested on the basis of its optical spectrum (Stickel & Kühr 1993b).

0816 + 526: An optical magnitude of $m_R = 18.0$ mag has been derived for this radio galaxy, somewhat brighter than the values given by Cohen et al. (1977) and McHardy (1978). The redshift is listed in Owen et al. (1988).

1014 + 392: An optical magnitude of $m_R = 19.1$ mag has been derived from the CCD image, somewhat brighter than the value given by Riley (1975). Remarkably, the radio galaxy has a shallower brightness profile compared to other galaxies in the field. 1014 + 392 lies in the direction of the cluster Abell 963, but the redshift of the optical counterpart has not been directly measured. The redshift given in Burbidge & Crowne (1979) refers to the central cluster galaxy of Abell 963.

1020 + 593: The CCD image shows the optical counterpart of 1020+593 to be a $m_R = 19.1$ mag galaxy. The classification as an unresolved QSO given by Wills et al. (1973) and Edwards et al. (1975) and listed in the update of the S4 catalogue (Stickel & Kühr 1994a) is incorrect.

1128 + 385: An optical brightness of $m_R = 19.4$ mag has been derived from our image for the unresolved optical counterpart of 1128+385, while the APM plate scan gives m_R = 19.5 mag. Both are significantly fainter than the value given by Condon et al. (1979) (m_B = 16), which may indicate optical variability of several magnitudes. However, their finding chart shows that the optical counterpart of 1128+385 is fainter than the stellar object ≈ 25″ northwest having m ≈ 17 mag, thus it is likely that the brightness of the former has been overestimated. The redshift of $z = 1.733$ has been measured by Xu et al. (1994).

1402 + 660: A m_R = 20 mag galaxy has been detected at the radio position.

1656 + 482: A faint optical counterpart has already been found by Cohen et al. (1977). Our CCD image shows it to be a m_R = 21.6 mag galaxy. The discrepancy between this value and the brighter magnitude given by Cohen et al. (1977) is most likely due to the diffraction spike of the bright star ≈ 50″ west of 1656+482.

1734 + 508: A very faint (m_R = 23.1 mag) object, tentatively classified as a galaxy, has been detected at the radio position.

1818 + 356: A $m_R = 21.1$ mag galaxy showing an asymmetric extension to the southeast has been detected at the radio position.

1843 + 400: The optical counterpart is a $m_R = 21.0$ mag galaxy with an overlapping unresolved object (presumably a galactic star) lying only 3″ west.

1926 + 611: An optical brightness of m_R = 16.9 mag has been measured for this BL Lac object, somewhat brighter than the value listed in Kühr (1977b). The lack of a noticeable host galaxy suggests a lower limit for the redshift of $z > 0.2$. A finding chart can also be found in Kühr (1977b). It should be noted that an incorrect reference to the finding chart of 1926+611 is listed in Table 4 of Stickel & Kühr (1993a).

2218 + 395: For this quasar, an optical brightness of m_R = 18.0 mag has been derived from our CCD image, close to the value given by Willson (1972). The optical spectrum and redshift have been given in Stickel & Kühr (1993b).

2311 + 469: For this quasar, an optical brightness of m_R = 17.0 mag has been derived from our CCD image, somewhat brighter than the value given by Veron (1971). Despite the poor seeing during the observation the CCD image shows a relatively bright galaxy, presumably a foreground object, about 5″ southwest of the quasar. The redshift has been measured by Thompson et al. (1992), Stickel & Kühr (1993b), and Xu et al. (1994).

2358 + 406: A $m_R = 21.4$ mag galaxy has been detected at the radio position, which confirms the uncertain identification suggested by Fugmann et al. (1988)

6. Notes on individual S5 sources

0036 + 744: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

0048 + 892: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

0123 + 731: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

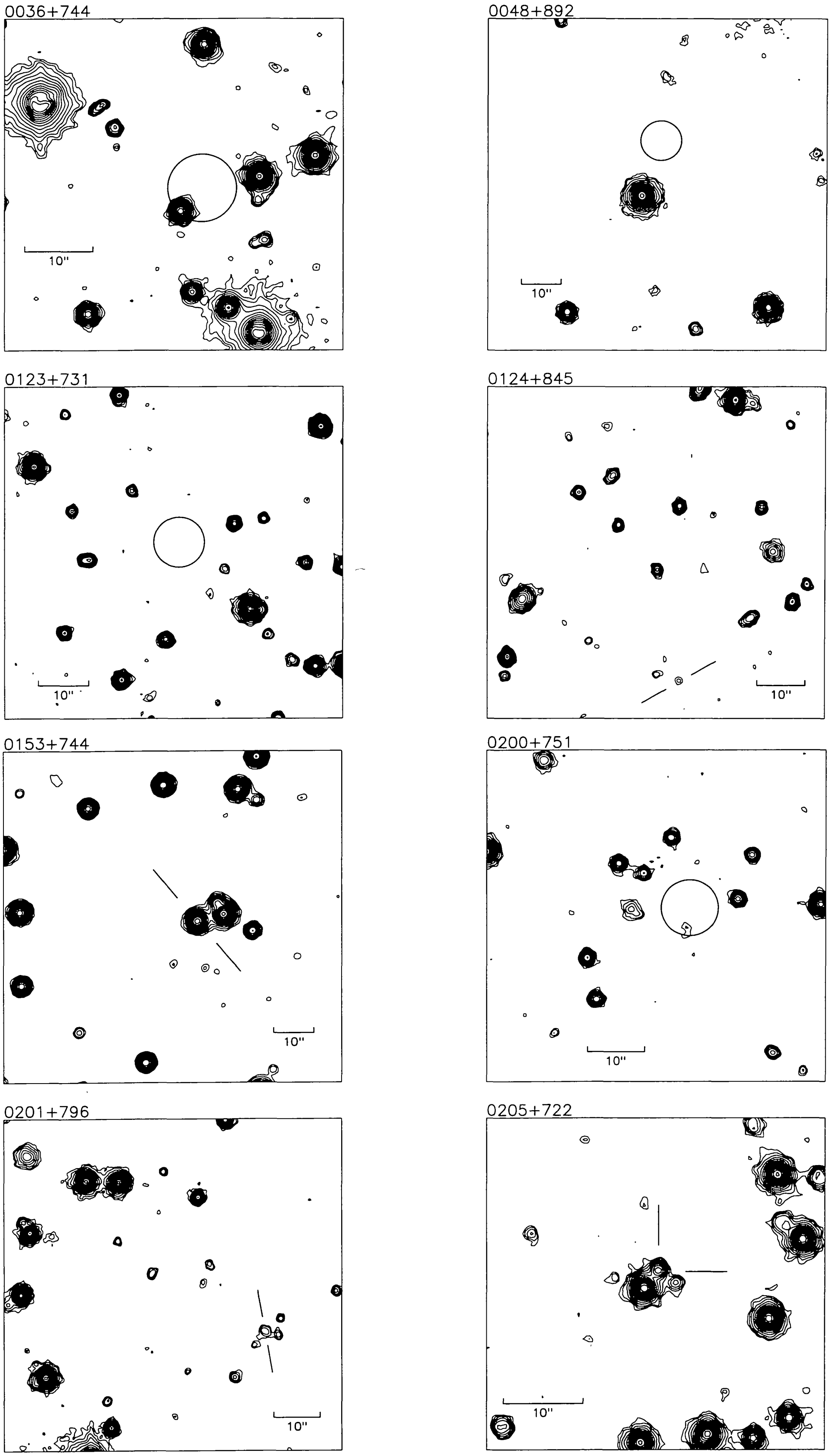

Fig. 3. Isophotal contour plots of the fields of S5 radio sources. Except for 1241 + 735, the identified optical counterparts of the radio sources are marked. The optical counterpart of 1241 + 735 is the brightest galaxy in the field. For empty fields, a circle with 10″ diameter has been drawn at the radio position. North is up and east to the left

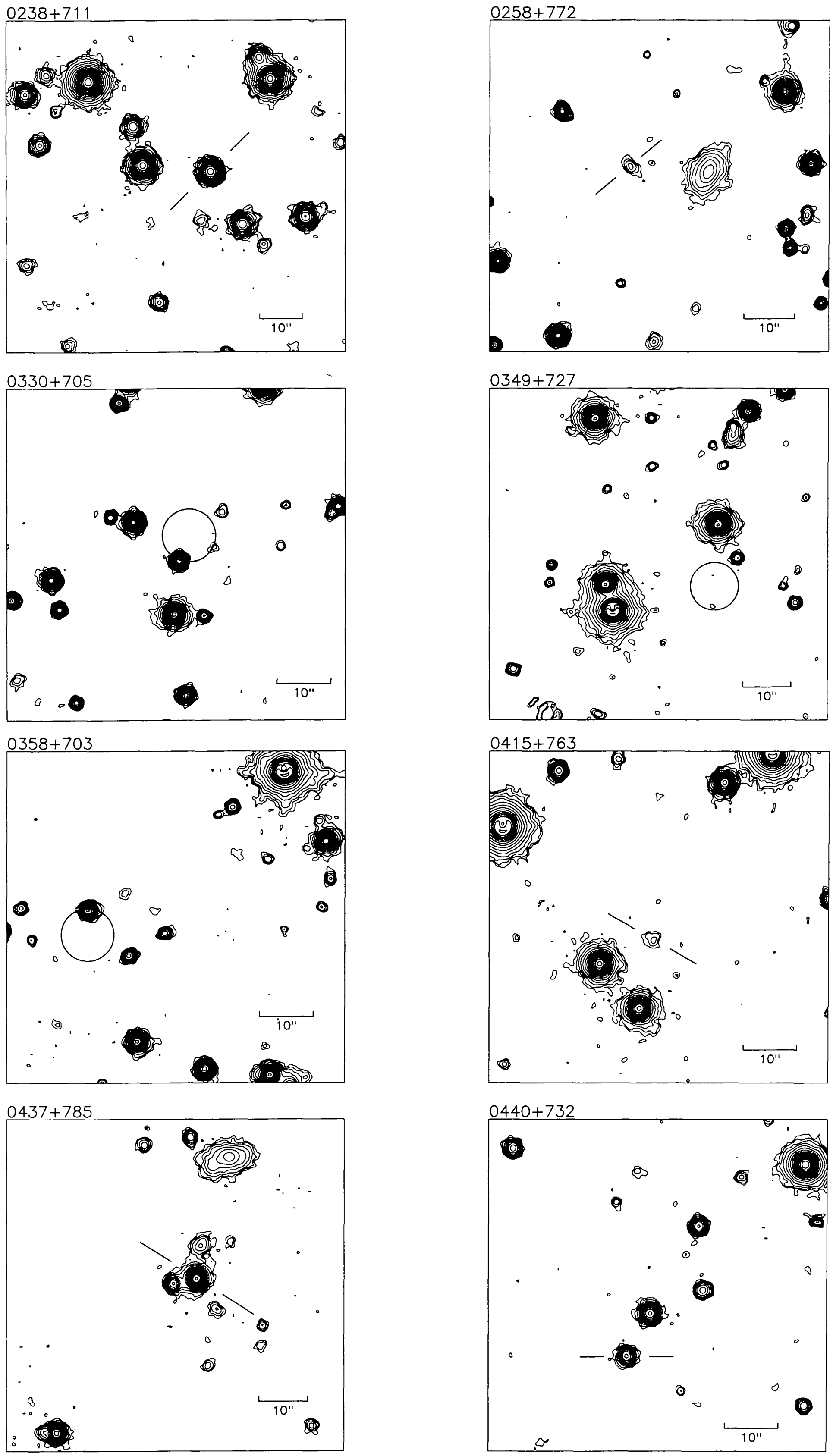

Fig. 3. continued

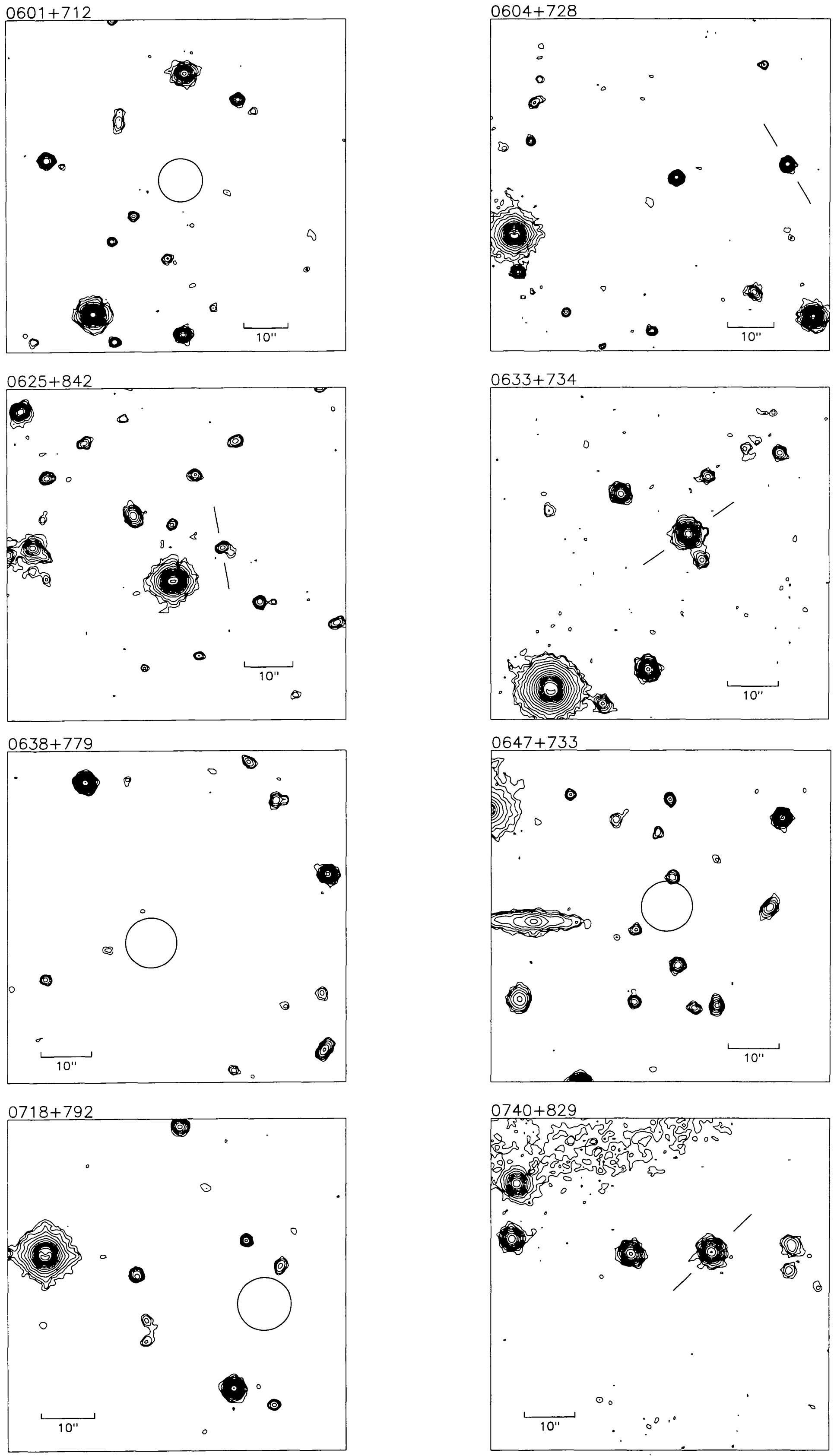

Fig. 3. continued

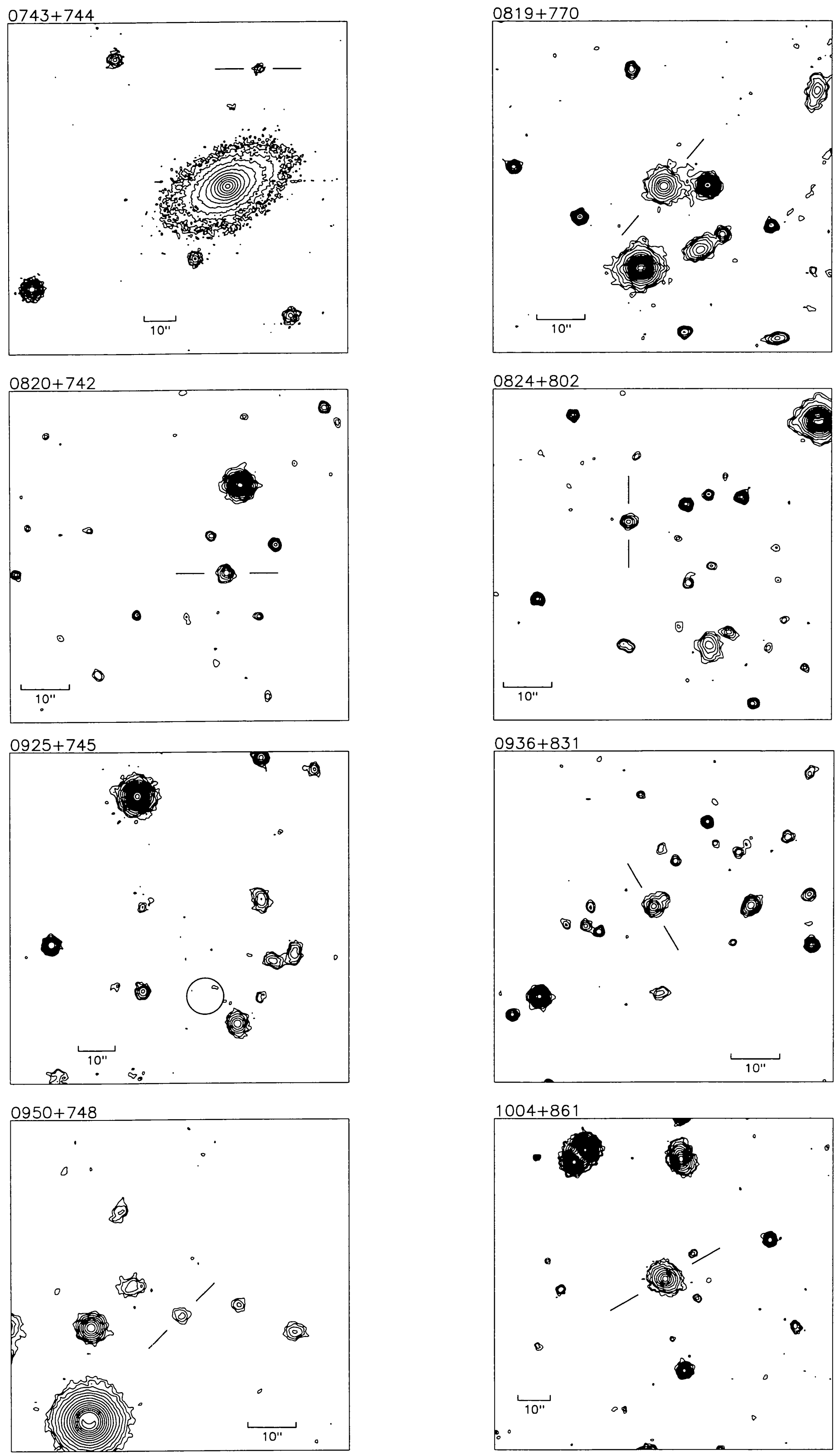

Fig. 3. continued

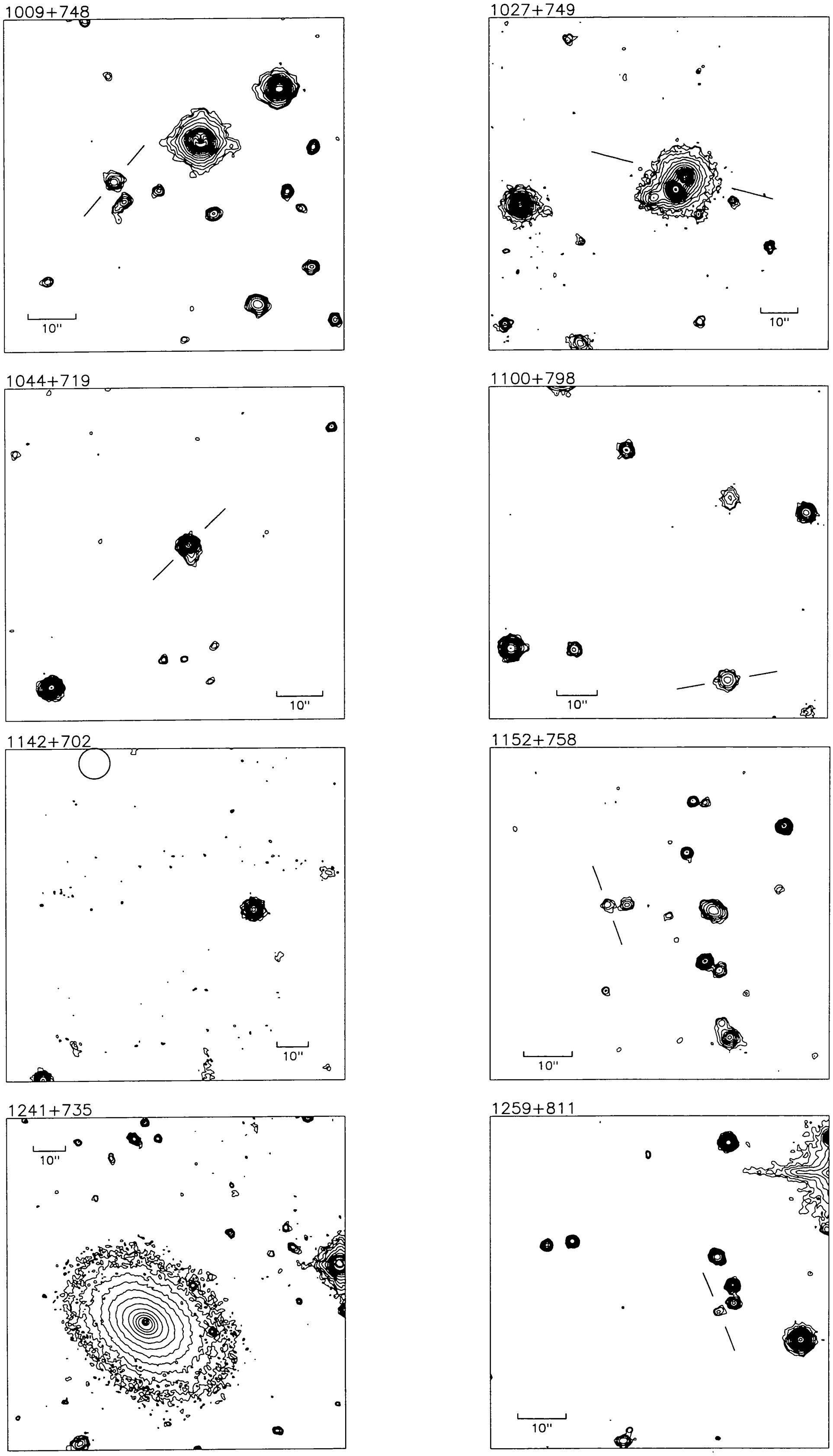

Fig. 3. continued

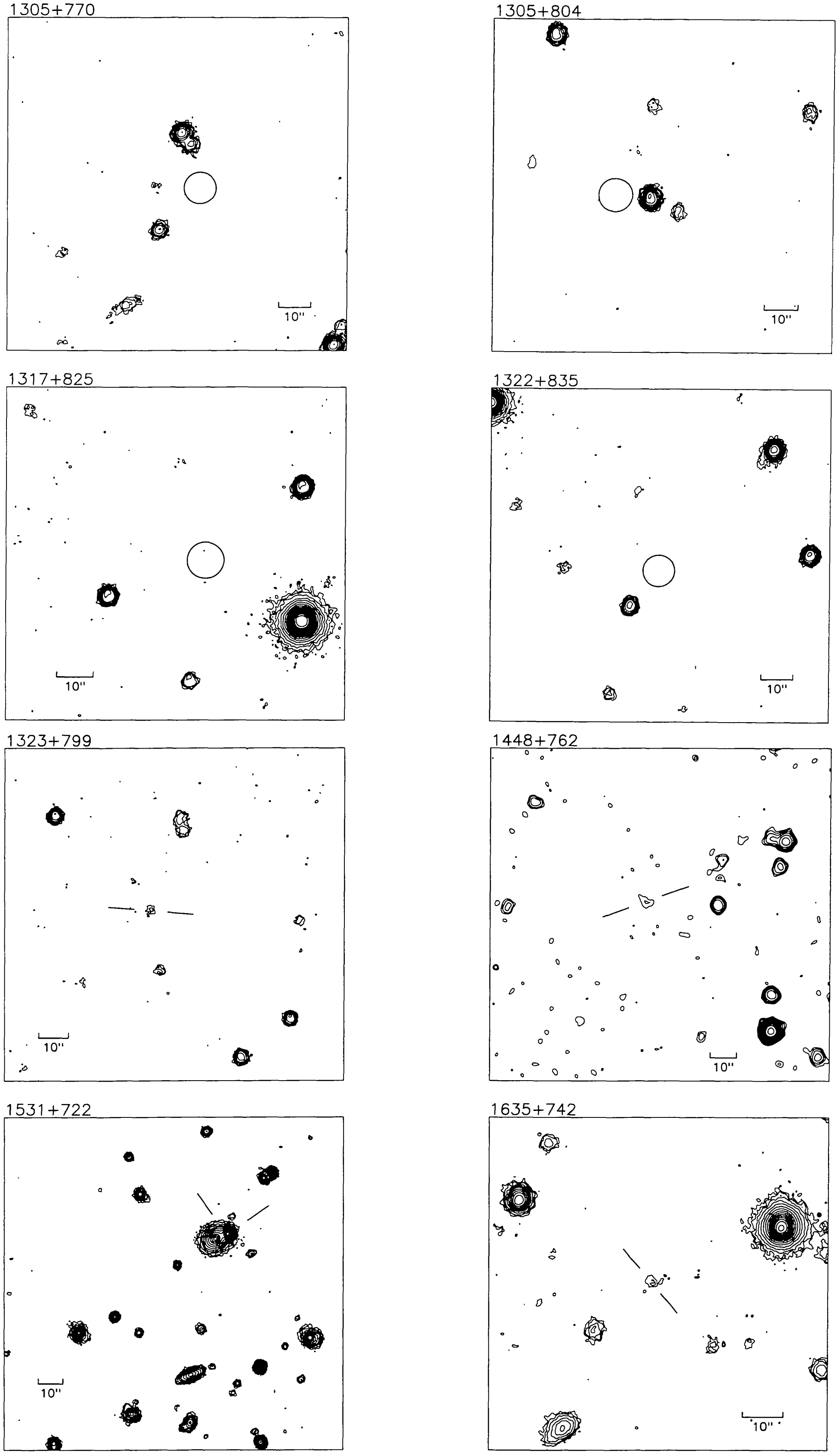

Fig. 3. continued

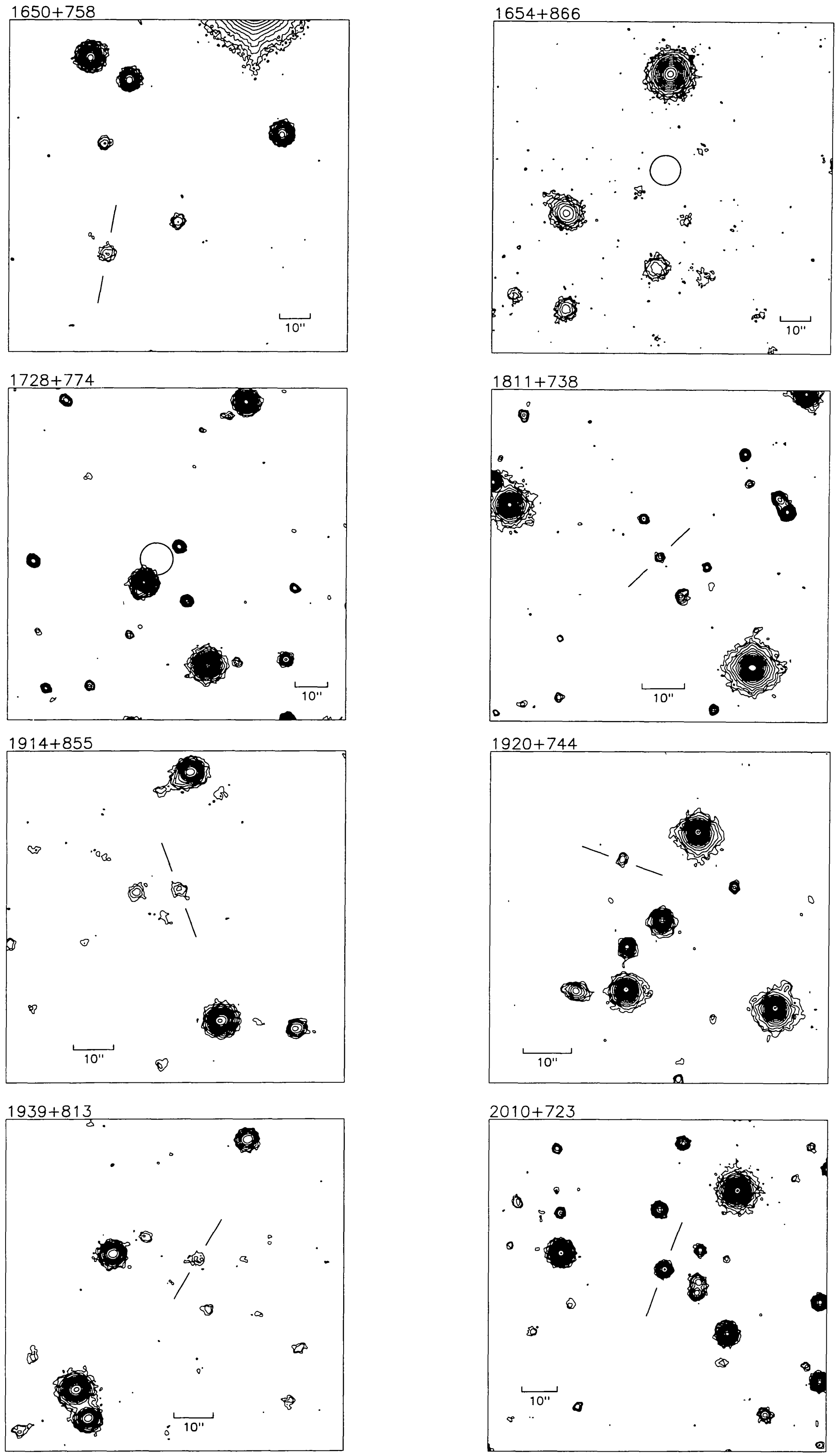

Fig. 3. continued

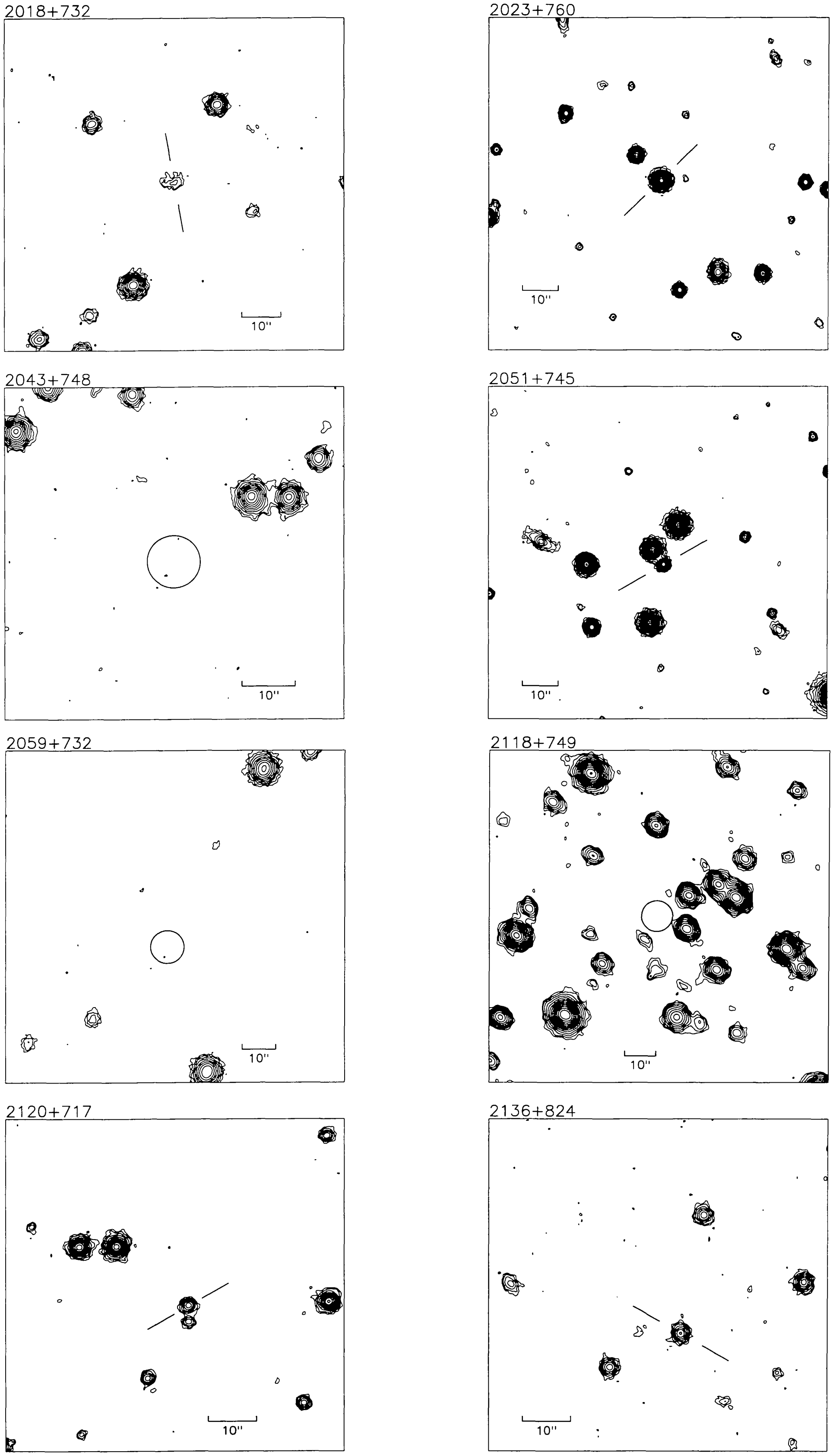

Fig. 3. continued

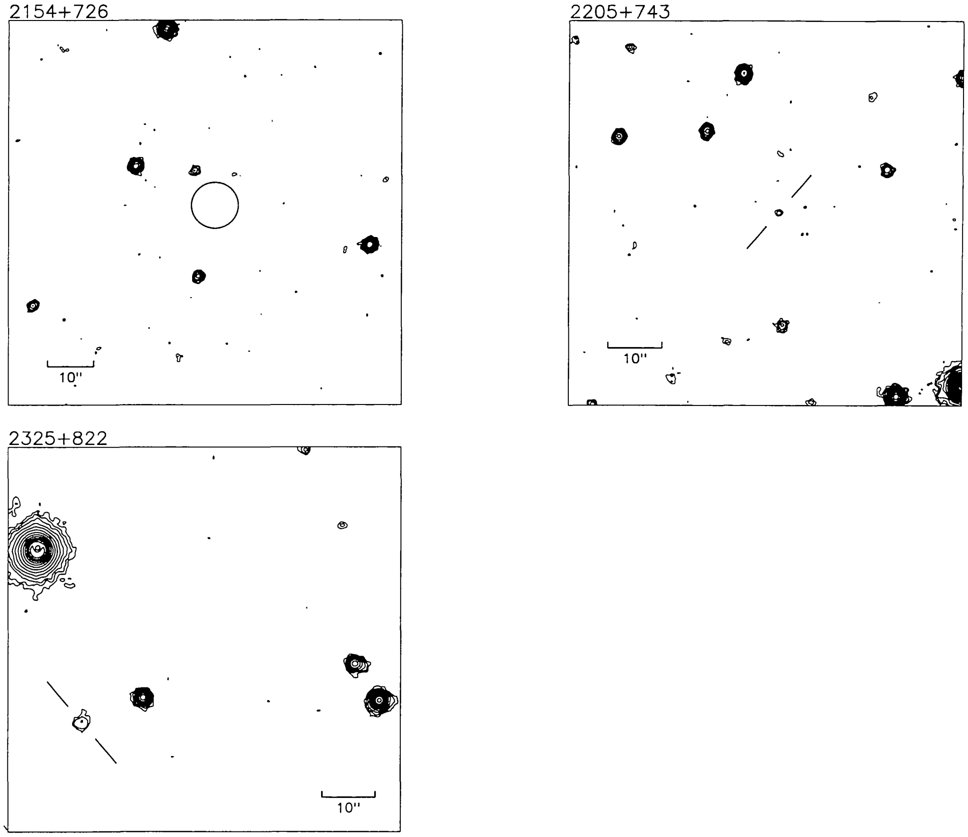

Fig. 3. continued

0124 + 845: A very faint object with m_R = 23.7 mag has been detected at the radio position on both an *R* and an *I* band CCD image, which supersedes the classification as an empty field listed in Kühr et al. (1987). Due to its faintness, the optical counterpart has tentatively been classified as a galaxy.

0153 + 744: An optical brightness of m_R = 17.5 mag has been measured for this quasar (z = 2.338), a magnitude fainter than the value listed in Kühr et al. (1987), which may indicate optical variability. The analysis of the image deconvolved with a Lucy-Richardson - restoration algorithm shows that the companion object 7″ west is unresolved and most likely a galactic star, whereas the second companion object 7″ northwest of 0153+744 is definitely extended and, because of the high redshift of the quasar, a foreground galaxy. Further bibliographic references for 0153+744 can be found in Hewitt & Burbidge (1993) and Véron-Cetty & Véron (1993).

0200 + 751: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position, although a faint (m_R = 23. mag) object lies 5″ to the south.

0201 + 796: The optical counterpart is the brightest member (m_R = 22.2 mag) of a close group of four galaxies, which lies midway between the radio lobes.

0205 + 722: The optical counterpart is a m_R = 20.7 mag unresolved QSO at the radio position. The fainter object 3″ southwest is a galaxy. The identification listed by Taylor et al. (1994) is incorrect (see also Kühr et al. 1987).

0238 + 711: An optical brightness of m_R = 18.2 mag has been measured for this BL Lac object, about a magnitude brighter than the value listed in Kühr et al. (1987). The lack of a noticeable host galaxy suggests a lower limit for the redshift of $z > 0.2$.

0258 + 772: The optical counterpart is a m_R = 21.5 mag elongated galaxy at the radio position.

0330 + 707: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position, although a faint (m_R = 23.0 mag) object lies 5″ to the west.

0349 + 727: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

0358 + 703: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

0415 + 763: The optical counterpart is a $m_R = 21.9$ mag galaxy lying midway between the radio lobes, which confirms the tentative identification suggested by Kühr et al. (1987).

0437 + 785: An optical brightness of $m_R = 17.7$ mag has been measured for this quasar ($z = 0.454$, Stickel et al. 1993), close to the value listed in Kühr et al. (1987).

0440 + 732: The classification as an unresolved QSO given by Kühr et al. (1987) was confirmed by our CCD image, from which a brightness of $m_R = 19.6$ mag has been derived. The optical spectrum and the redshift have been given in Stickel et al. (1993).

0601 + 712: The radio morphology of this source is a wide, unresolved double (separation 136″) with a weak north-western and a stronger south-eastern component (Kühr et al. 1987). No optical counterpart has been detected at either radio position. The field is also empty at the position midway between the radio components (shown in Fig. 3). The nature of this radio source can only be clarified with a deeper radio map.

0604 + 728: The optical counterpart is a $m_R = 20.3$ mag unresolved object at the radio position. The CCD image shows that star 'a' marked on the finding chart given by Kühr et al. (1987) does not exist. Since the optical counterpart of 0604+728 has about the same magnitude on the CCD image as reference star 'b' ($\approx 25''$ east of 0604+728, see also finding chart in Kühr et al. 1987) but has not been measured in the APM POSS plate scan (in contrast to star 'b'), the optical brightness of 0604+728 is likely to be variable and was possibly below the detection limit at the epoch of the POSS observation.

0625 + 842: The optical counterpart is the brighter member ($m_R = 21.1$ mag) of a close pair of galaxies lying midway between the radio lobes.

0633 + 734: The optical magnitude of this unresolved QSO is $m_R = 18.2$ mag, close to the value listed in Kühr et al. (1987). Since its redshift is $z = 1.851$ (derived from a spectrum taken by one of us (H.K.) with the Steward Observatory 90″ telescope), the close neighboring galaxy 5″ southwest is most likely a foreground object.

0638 + 779: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position.

0647 + 733: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position given in Kühr et al. (1987). However, since the radio structure resembles that of a Head-Tail source and since there are about ten galaxies of similar brightness scattered around the radio position indicating a group or small cluster, it is likely that one of the galaxies just outside the 10″ circle around the radio position is the correct identification.

0718 + 792: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position.

0740 + 828: The optical identification as a QSO given by Riley (1989) is confirmed by our CCD image. The derived optical brightness of $m_R = 18.5$ mag is in agreement with the value listed in Kühr et al. (1987). The redshift of $z = 1.991$ has been measured by Xu et al. (1994). The redshift based on a single emission line given in Stickel et al. (1993) and listed in Véron-Cetty & Véron (1993) is incorrect.

0743 + 744: The identification of this radio source with an unresolved optical counterpart lying close to the nearby galaxy Mkn 11 (Kühr et al., 1987) has independently been found Condon & Broderick (1988). The CCD image does not show more details since it had been obtained during non-photometric weather and poor seeing conditions. The identification and optical magnitude listed in Table 3 have been taken from Kühr et al. (1987). The optical spectrum and redshift of 0743+744 have been given in Stickel et al. (1993).

0819 + 770: The classification as a galaxy given by Kühr et al. (1987) is confirmed. The derived optical brightness of $m_R = 18.3$ is close to the value listed in Kühr et al. (1987). The optical spectrum and redshift have been given in Stickel et al. (1993).

0820 + 742: The optical counterpart of 0820+742 is a $m_R = 20.9$ mag galaxy lying midway between the radio lobes.

0824 + 802: The optical counterpart is a $m_R = 21.3$ mag galaxy lying at the radio position.

0925 + 745: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position. The tentative identification listed in Kühr et al. (1987) could not be confirmed.

0936 + 831: The CCD image shows a $m_R = 19.9$ mag galaxy with a fainter neighboring object at the radio position, which confirms the classification listed in Kühr et al. (1987).

0950 + 748: The optical counterpart is a $m_R = 21.7$ mag galaxy lying at the radio position.

1004 + 861: The classification as a galaxy given in Kühr et al. (1987) is confirmed with the CCD image, from which a magnitude of $m_R = 17.5$ mag was derived. There is a second galaxy of similar brightness about 30″ north of 1004+861. The optical spectrum and redshift of the optical counterpart have been given in Stickel et al. (1993).

1009 + 748: The CCD image shows the optical counterpart to be a $m_R = 20.9$ mag galaxy lying midway between the radio lobes, confirming the original identification given by Riley et al. (1984). The nearby object 5″ southwest, the nature of which remained uncertain in the observation of Riley et al. (1984), is also a galaxy. In addition to this pair, there are a number of galaxies lying to the west of 1009+748, indicative of a group or a small cluster. No redshift has as yet been measured for 1009+748, and the redshift estimates given in the literature (Riley et al. 1984; Gopal-Krishna & Kulkarni 1992) differ grossly.

1027 + 749: The optical counterpart of 1027+749 is the northwestern member of a close pair of possibly interacting galaxies ($z = 0.123$, Stickel & Kühr 1993a). Remarkably, both galaxies have very compact nuclei or even point sources in their centers, similar to nearby quasars, and in fact, the optical spectrum (Stickel & Kühr 1993a) shows strong emission lines superposed on a power law continuum, but only weak absorption lines. Further spectroscopic data is needed to verify whether this is actually a physical pair of nearby radio quasars. The optical magnitude listed in Table 3 has been taken from Kühr et al. (1987).

1044 + 719: The stellar object labeled 'a' in the finding chart of Kühr et al. (1987) coincides with the radio position given by Patnaik et al. (1992) and is therefore proposed as the optical counterpart, an $m_R = 17.8$ mag QSO. The radio position listed in Kühr et al. (1987) is considered to be incorrect. The identification as a QSO agrees with that given by Poladitis et al. (1995), who also list the redshift of $z = 1.15$. The CCD image shows that the quasar has an extension to the south, which, because of the high redshift, is likely a foreground galaxy.

1100 + 798: The optical counterpart is a $m_R = 20.4$ mag galaxy lying at the radio position.

1142 + 702: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position. The presence of an unresolved object (Kühr et al. 1987) could not be confirmed.

1152 + 758: The optical counterpart is a $m_R = 21.6$ mag galaxy lying close to the central radio component.

1241 + 735: The radio position listed in Kühr et al. (1987) is incorrect and superseded by that given in Patnaik et al. (1992). The optical counterpart of 1241+735 is a bright, $m = 17$ mag galaxy, member of a small group of galaxies (see finding chart in Kühr et al. 1987). The galaxy is also included in the Lick Northern Proper Motion Catalogue (NPM, Klemola et al. 1987), from which the optical magnitude has been taken. No redshift has as yet been measured for this relatively bright galaxy, but it is likely less than 0.1.

1259 + 811: A faint ($m_R = 22.3$ mag) galaxy has been detected close to the western radio component. If the radio position of Riley (1989) is used, this galaxy lies close to the midpoint of the two radio components, indicating that this is the correct optical counterpart.

1305 + 770: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position.

1305 + 804: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position.

1317 + 825: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position.

1322 + 835: To a limiting magnitude of $m = 22$ mag, the field remains empty at the radio position. The faint optical counterpart proposed by Kühr et al. (1987) could not be confirmed.

1323 + 799: An optical counterpart with $m_R = 21.5$ mag (tentatively classified as a galaxy) has been detected at the radio position taken from the VLA calibrator list. The radio position listed in Kühr et al. (1987) lies about $6''$ north and is considered to be incorrect.

1448 + 762: A very faint object ($m = 22.3$ mag) has been detected at the radio position. Its classification as a QSO is based on the emission lines at $z = 0.899$ observed by Vermeulen & Taylor (1995).

1531 + 722: This QSO ($z = 0.899$, Stickel et al. 1993) lies only $4''$ away from the center of a foreground galaxy with $z = 0.102$ and shines through its outer regions. Additionally, a number of relatively bright and therefore most likely also foreground galaxies can be seen on the CCD image, possibly member of a physical group. An optical brightness of $m_R = 17.7$ mag has been measured for the QSO, close to the value listed in Kühr et al. (1987).

1635 + 742: The optical counterpart is a faint ($m_R = 22.9$ mag) object, tentatively classified as a galaxy, lying close to the central radio component.

1650 + 758: The optical counterpart is a $m_R = 19.2$ mag galaxy lying at the radio position.

1654 + 866: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position.

1728 + 774: To a limiting magnitude of $m = 22$ mag, no optical counterpart has been detected at the radio position.

1811 + 738: The optical counterpart is a $m_R = 20.1$ mag galaxy lying at the radio position.

1914 + 855: The optical counterpart is a $m_R = 21.1$ mag galaxy lying on the line connecting the two lobes, but closer to the southern radio component.

1920 + 744: The optical counterpart is a $m_R = 21.6$ mag galaxy lying at the radio position.

1939 + 813: The optical counterpart is a $m_R = 21.1$ mag galaxy lying at the radio position.

2010 + 723: An optical brightness of $m_R = 19.4$ mag has been measured for the BL Lac object, close to the value given by Kühr et al. (1987). The unresolved appearance suggests a lower limit for the redshift of $z > 0.2$.

2018 + 732: The optical counterpart is a $m_R = 21.1$ mag galaxy lying midway between the radio lobes.

2023 + 760: An optical brightness of m_R = 17.1 mag has been measured for the BL Lac object, which is somewhat brighter than the value given by Kühr et al. (1987). The unresolved appearance suggests a lower limit for the redshift of $z > 0.2$.

2043 + 748: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

2051 + 745: An optical brightness of m_R = 19.0 mag has been measured for the BL Lac object, somewhat brighter than the value given by Kühr et al. (1987). The unresolved appearance suggests a lower limit for the redshift of $z > 0.2$.

2059 + 732: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

2118 + 749: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

2120 + 717: The optical counterpart is a m_R = 20.2 mag galaxy lying at the radio position. Its measured brightness is somewhat fainter than the value listed in Kühr et al. (1987).

2136 + 824: The classification and the optical magnitude given in Kühr et al. (1987) is confirmed with the CCD image, from which an optical magnitude of m_R = 19.6 mag is derived. The redshift of 2136+824 is z = 2.350, derived from a spectrum taken by one of us (H.K.) with the Steward Observatory 90″ telescope.

2154 + 726: To a limiting magnitude of m = 22 mag, no optical counterpart has been detected at the radio position.

2205 + 743: The optical counterpart is a faint (m_R = 22.5 mag) galaxy lying at the radio position.

2325 + 822: The optical counterpart is a m_R = 21.1 mag galaxy lying midway between the radio lobes.

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