IDENTIFICATION OF EXTRAGALACTIC RADIO SOURCES BETWEEN DECLINATIONS —20° AND —44°

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Summary

Identifications with extragalactic objects are suggested for 55 radio sources with declinations between —20° and —44°. The identifications are based on a search of the Palomar Sky Survey plates in the position of sources in the Parkes catalogue. Eight of the identifications are with suspected quasi-stellar objects and the remainder with galaxies. Finding charts are provided for the fainter objects.

I. The Search for Identifications

The recently published Parkes catalogue of radio sources with declinations between —20° and —60° (Bolton, Gardner, and Mackey 1964; subsequently referred to as BGM) lists 297 sources with flux densities greater than 4×10^{-26} W m^{-2} (c/s)$^{-1}$ at 408 Mc/s. For the area north of —50° the accuracy claimed for the source positions is such that there is a 90% chance that both coordinates are within 0·6 min of arc of the true position. With this accuracy it is possible to make unique identifications with galaxies as faint as $m_{pg} = 17$, and, under favourable conditions, even as faint as $m_{pg} = 18$.

One hundred and eleven of the catalogue sources lie between declinations —20° and —33°, for which two-colour plates of the Palomar Sky Survey exist, and a further 101 sources lie between declinations —33° and —45°. In 1962 Dr. I. S. Bowen, then Director of the Mount Wilson and Palomar Observatories, agreed to the use of the 48 in. Schmidt telescope for an extension of the Sky Survey to this more southerly zone. He suggested a combination of 103a–E plates and an orange filter. With this combination, a limiting magnitude of about 19·5 is reached in the short exposure time of 20 min and effects of differential refraction are kept as small as possible. These extension plates have been taken by Dr. J. B. Whiteoak and many of them are of as high a quality as those of the standard survey, in spite of the unfavourable zenith distance. As plates of only one colour are available, quasi-stellar objects cannot be recognized by their characteristic blue colour, and thus identifications in this zone are restricted to galaxies. The declination limit of the survey is not uniform and varies between 44°·5 for the early hours of right ascension and about —45° near 20 hr.

To aid in a rapid examination of the Sky Atlas prints or plates, transparent overlays were prepared on which were marked the position of the source and the positions of between 6 and 10 reference stars from either the Yale or Cape photographic catalogues. Examination was made of an area 2 min of arc square, centred on the

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source position. Positions of sources in the region from $-20°$ to $-33°$ were examined initially on prints of the Sky Atlas and later, together with those south of $-33°$, on the original plates at the California Institute of Technology.

Suggested identifications were found for 55 sources out of a total of 192. Of the remaining 137 fields: 21 contain objects that could be galaxies near the plate limit (no identifications were made in these cases as either the radio position was not sufficiently accurate to distinguish between several possible objects or the peak quality was too poor to be sure the images were those of galaxies); 21 fields are either heavily crowded or obscured; 95 fields contain stars only, 37 of these in the northern zone contain no abnormally blue stars.

Radio positions for most of those sources for which an identification appeared likely have since been determined more precisely in a series of "transit" measurements with the 210 ft telescope at a frequency of 2650 Mc/s (Shimmins, Clarke, and Ekers, to be published). Calibration was obtained from well-accepted, but more northerly, identifications and the assumption of identification of a small number of objects in the present list. The right ascensions were measured from meridian transit observations with the telescope azimuth set on 0° or 180° (the 210 ft telescope has an altazimuth mounting but can be driven in equatorial coordinates through a *master equatorial* unit). Declination observations were made with the telescope under control of its master equatorial, but observations were restricted to a range of 10 min of hour angle either side of the meridian. The accuracy achieved in these transit measurements is at least a factor of three better than those of the position measurements of the BGM catalogue. This is because the method of observation ensured that the errors were a function of only one coordinate, and this error function could be precisely determined from the observation of calibrator sources.

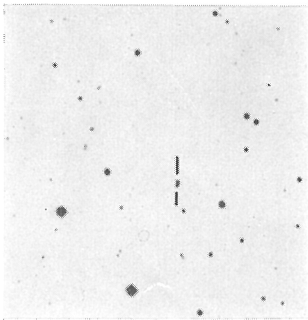
Positions of the optical counterparts were estimated from the 48 in. plates with the aid of the transparent overlays. For plates of good image quality, where either the overlay fitted precisely or where the object was close to a reference star, the estimated position is probably accurate to 0·1 min of arc in both coordinates. In less favourable cases the error could be two or even three times this. These positions are given in the table of identifications (Table 1) and the final digit stated is some guide to the relevant accuracy. The accuracy of the radio transit positions is of the same order, and in most cases the radio and optical positions agree to well within the sum of possible errors. The exceptions are a few cases where the optical position lies within the area covered by an extended radio source, or where the radio position lies within the image of a galaxy of large angular extent (e.g. NGC 253).

II. The Identified Sources

Details of the identified sources are given in Table 1. For the sake of completeness the list includes all previously suggested identifications that are substantiated by the present observations. In these cases references to original publications are given in column 10 and the footnote. The first column of Table 1 contains the Parkes

Plates 1 to 6.—Finding charts for identified sources. Scale is 5 mm = 1 min of arc. North-east is top left-hand corner.

EXTRAGALACTIC SOURCES BETWEEN −20° AND −44°



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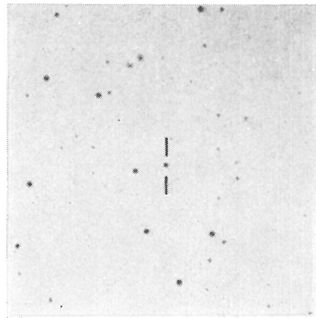

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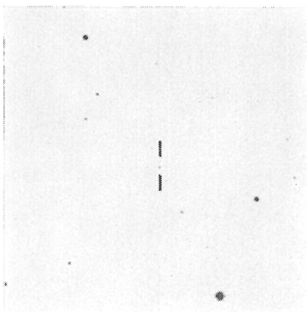
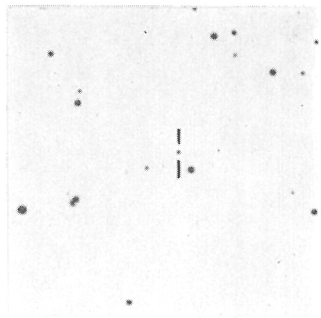


0043−42



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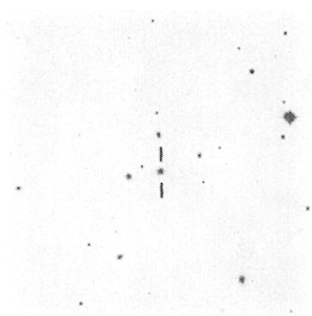
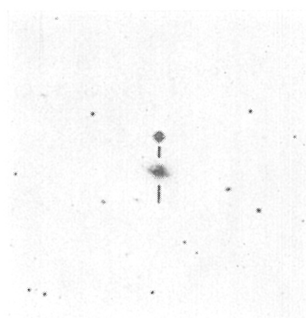
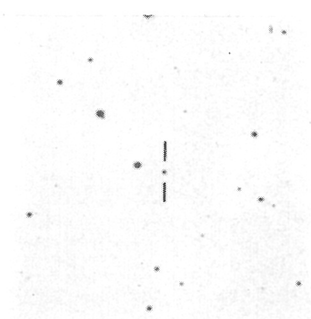


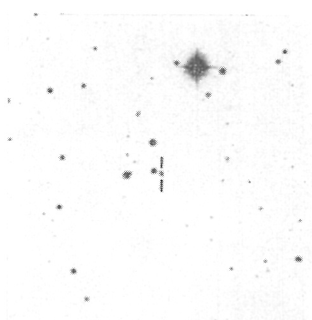
0023−33



0131−36

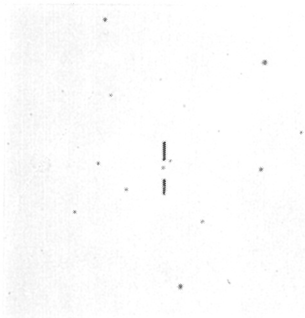


0022−29

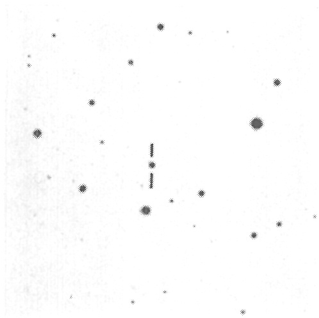


0122−25

EXTRAGALACTIC SOURCES BETWEEN −20° AND −44°



0332−39



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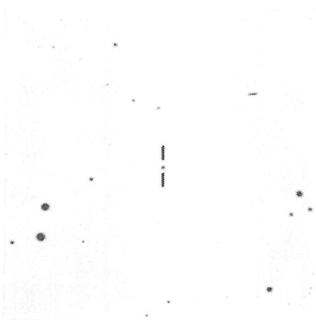

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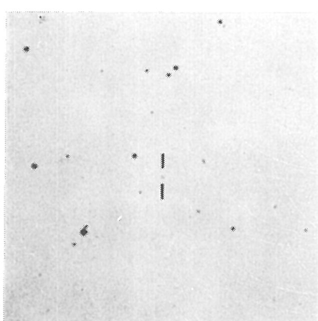

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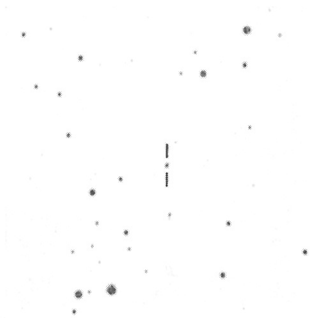
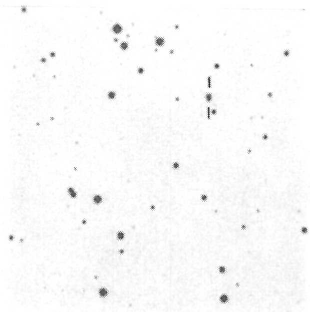


0442−28



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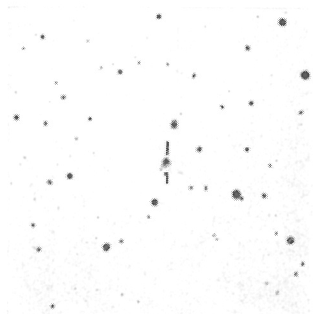

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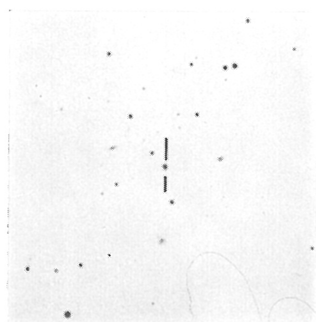

0344−34

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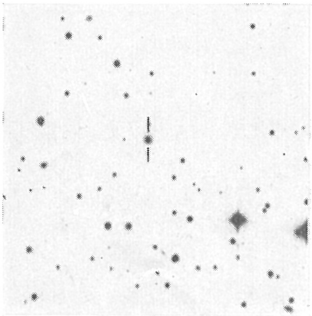
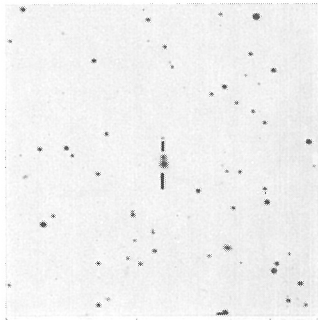


0511−30



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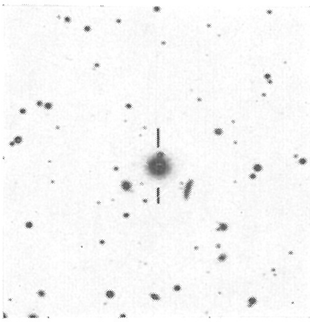

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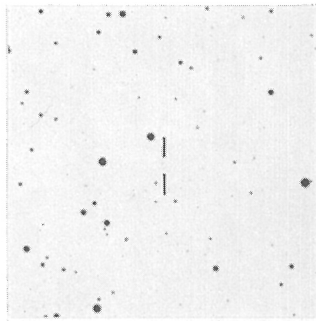

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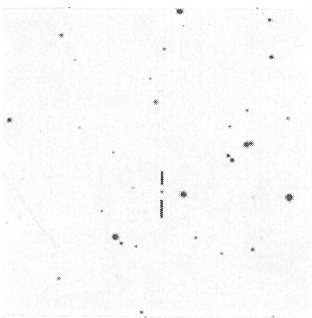

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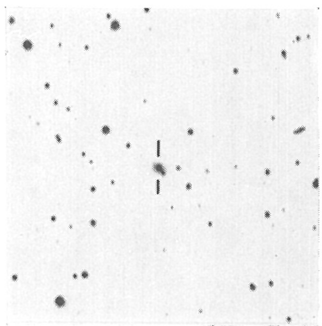

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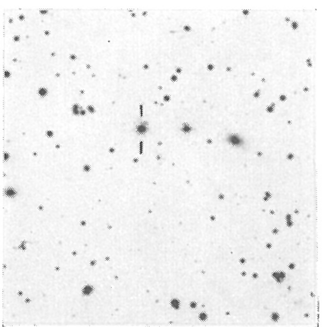

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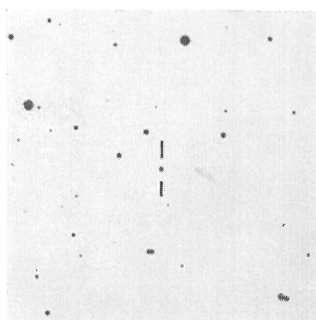
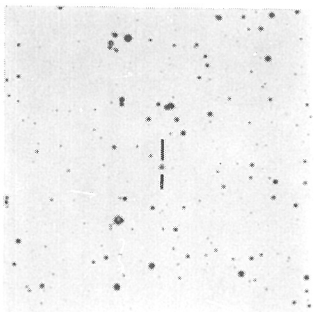


0521−36

EXTRAGALACTIC SOURCES BETWEEN −20° AND −44°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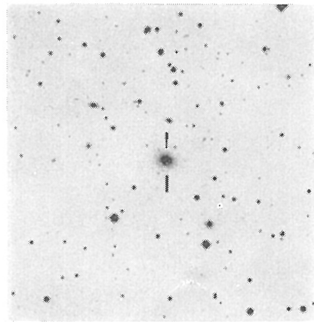
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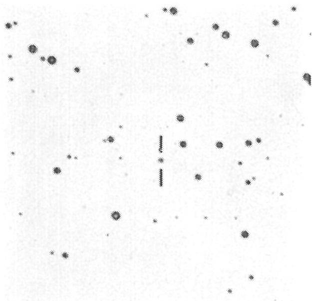
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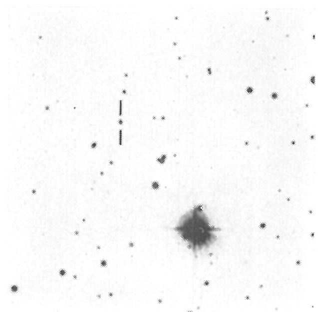
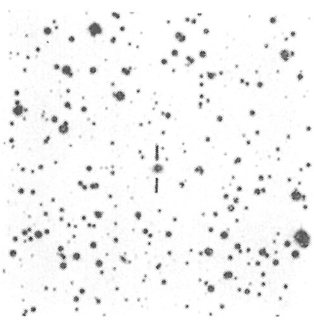

1103−20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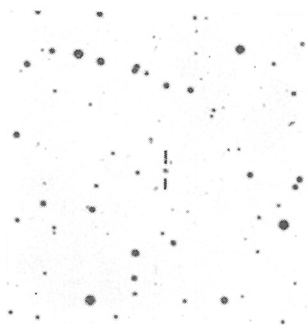
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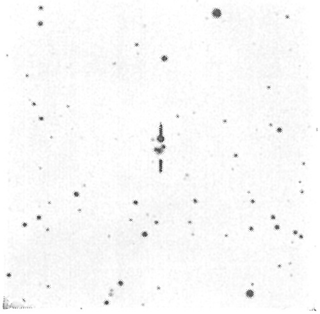
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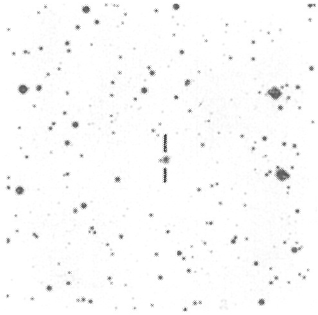
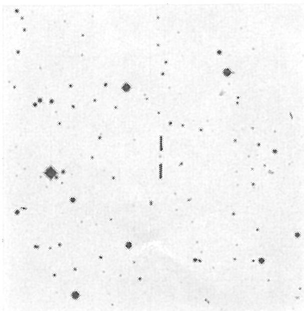
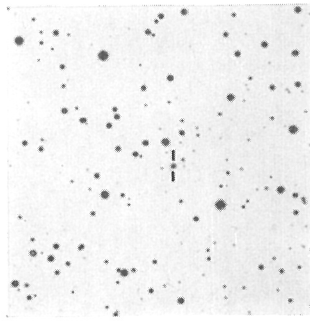

0718−34

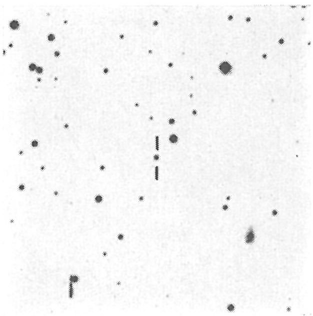
EXTRAGALACTIC SOURCES BETWEEN −20° AND −44°



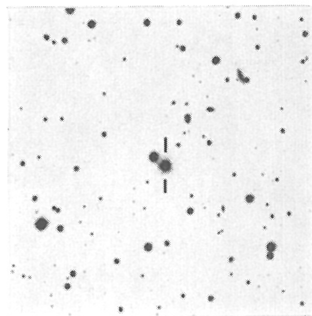
1413−36



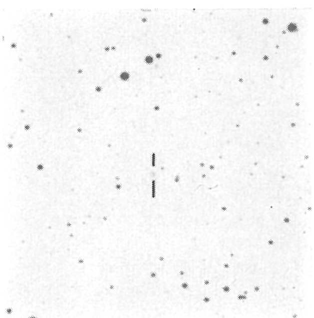
2053−20



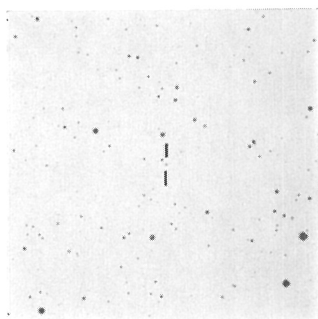
1327−21



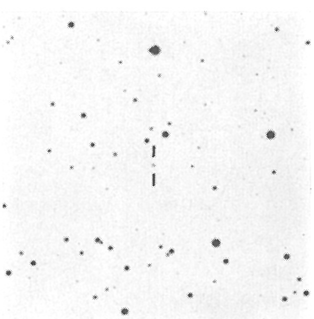
2040−26



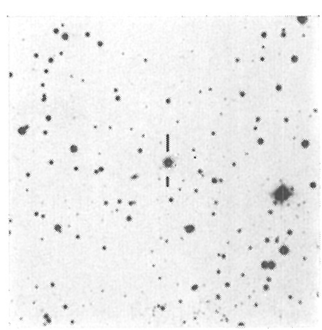
1221−42



1928−34

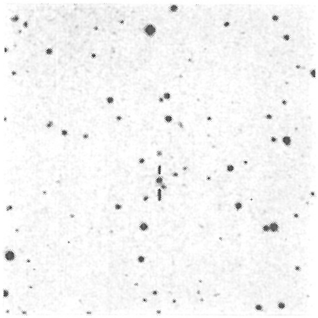


1211−41

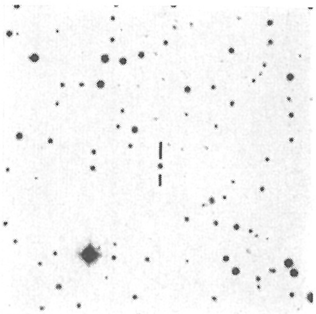


1514−24

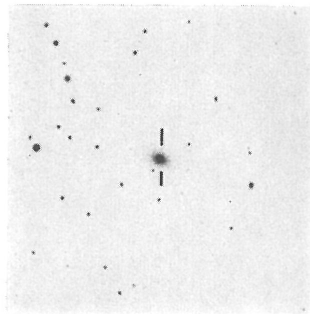
EXTRAGALACTIC SOURCES BETWEEN $-20°$ AND $-44°$



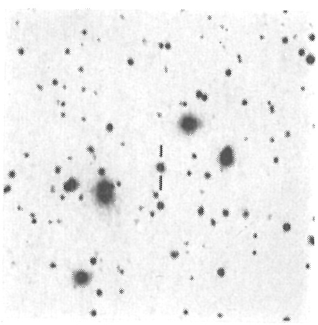
2216−28



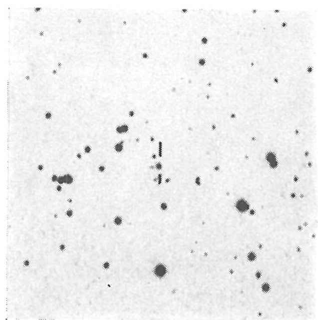
2115−30



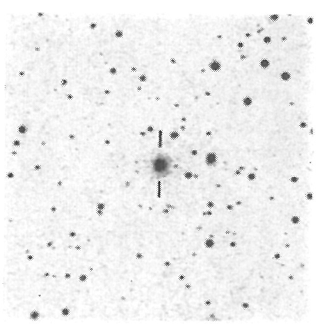
2354−35



2104−25



2317−27



2058−28

catalogue number for the source, and the final column, the equivalent number in the MSH catalogue (Mills, Slee, and Hill 1960). Columns 2 and 3 give the optical position for epoch 1950.0. Columns 4 and 5 contain the flux density of the radio source at a frequency of 1410 Mc/s and its spectral index, taken from BGM. For a source with a power-law spectrum, the flux density at 1410 Mc/s is approximately proportional to the total power emitted in the available radio spectrum (85–2650 Mc/s). Columns 6 and 7 give the type of galaxy and an estimated photographic magnitude. For galaxies the classification follows that of Matthews, Morgan, and Schmidt (1964): E, elliptical; D, spherical with an extended diffuse envelope; db, dumb-bell or double system; and N, compact galaxy with a very bright nucleus. QSO? indicates suspected quasi-stellar objects for which identification is suggested on the basis of a marked blue excess relative to the surrounding star images on the plates. Particularly for faint objects, colour differences are difficult to estimate and confirmation through photometric detection of an ultraviolet excess is necessary. Magnitudes have been visually estimated by comparing the plate images with those of galaxies in the list of Maltby, Matthews, and Moffet (1963). For relatively bright objects in unobscured regions the magnitudes are perhaps accurate to a few tenths, but for fainter objects in low galactic latitudes they may be in error by as much as one magnitude. Here again, photometric measurements are desirable. Columns 8 and 9 give the new galactic coordinates of the object. Additional points of interest on individual sources are given in column 11.

III. Finding Charts

Plates 1–6 contain finding charts for the 46 identified objects that are fainter than fourteenth magnitude. These charts were prepared photographically from the Sky Survey prints for objects north of declination −33°, and from Polaroid prints made from the extension plates for objects south of −33°. Contrast has been deliberately increased over that of the original prints.

IV. Some Interesting Galaxies

Three sources of particular interest are those apparently associated with the bright galaxies NGC 253, NGC 1399, and NGC 5419. In all three cases the radio sources are of small diameter (< 2 min of arc) but, although they are within the visible limits of the galaxies, they are not centred. The discrepancy in position for NGC 253 is quite small, only about 1% of the optical diameter, but for the other two sources it is of the order of the optical diameter. In these cases the sources may be associated with singular events such as supernovae rather than with the nuclei of the galaxies. This possibility was first suggested to us by Dr. J. A. Roberts, who noted the position discrepancy for NGC 253.

Fourteen of the identified galaxies are in small or medium clusters and in all cases but one, the identified galaxy is the brightest member. The exception is the source 2104–25 and, as can be seen from the finding chart in Plate 6, there are three other close systems that are at least a magnitude brighter. It appears possible that this source could be an exception to the generally accepted rule that the radio source

TABLE 1

LIST OF IDENTIFICATIONS

Catalogue Number	Position (1950.0) R.A. h	m	s	Dec. °	′	Flux Density at 1410 Mc/s (10^{-26} W m^{-2} (c/s)$^{-1}$)	Spectral Index	Type	m_{pg}	Galactic Coordinates l^{II}	b^{II}	Reference*	Remarks	MSH Cat. No.
0022–29	00	22	01	−29	45·5	3·3	−1·0	QSO?	20	13	−84	7		00–*29*
0023–33	00	23	02·2	−33	19·7	1·7	−1·0	E	16·7	346	−82	1		00–*37*
0043–42	00	43	55·9	−42	24·3	9·1	−0·7	E	18	306	−75	1		00–*411*
0045–25	00	45	06	−25	33·6	6·3	−0·7	Sc	7·0	96	−88	5	NGC 253	00–*222*
0114–21	01	14	22	−21	07·3	4·1	−0·8	db	19	166	−81	1	Curved spectrum	01–*26*
0122–25	01	22	23·5	−25	33·7	1·3	−0·8	E3	17·8	200	−88			01–*29*
0131–36	01	31	43·6	−36	44·9	7·1	−0·7	SO	14·2	261	−77	1		01–*36*
0157–31	01	57	58·4	−31	07·9	3·7	−0·7	QSO?	19	230	−74			01–*315*
0216–25	02	16	24·8	−25	03·6	1·3	−1·0	QSO?	18	270	−63			02–*25*
0220–42	02	20	18·5	−42	13·4	1·9	−0·7	db	19	257	−66			02–*45*
0222–23	02	22	46	−23	26·2	1·8	−0·9	QSO?	18	208	−68			02–*27*
0231–23	02	31	06·5	−23	33·7	1·3	−1·0	QSO?	15	251	−65			02–*211*
0320–37	03	20·7		−37	25	150	−0·7	SO	10	239	−57	4	NGC 1316	03–*31*
0332–39	03	32	14	−39	10·7	1·7	−0·8	E	17·4	243	−54		Curved spectrum. In small cluster	03–*32*
0336–35	03	36·6		−35	37	2·5	−0·8	E	10·9	236	−54	6	May be associated with NGC 1399. Source is 3′ north following	03–*33*
0344–34	03	44	36	−34	32·0	3·0	−0·9	E	17·4	234	−52		In small cluster	03–*36*
0349–27	03	49	32	−27	53·4	5·2	−0·8	E	16·8	224	−50			03–*212*
0424–26	04	24	37	−26	50·6	1·2	−1·0	E3	17·2	225	−43		Identification based on catalogue position only	
0442–28	04	42	38	−28	15·3	7·1	−0·9	E	18·2	228	−39			04–*218*
0446–20	04	46	20·7	−20	36·0	0·9	−1·2	E	16·2	219	−36		In small cluster. Identification based on catalogue position only	04–*219*

0451–28	04	51	15	−28	12·6	2·5	−0·1	QSO?	19	229	−37			
0453–20	04	53	14	−20	39·2	4·7	−0·5	E	14	220	−34	2		04–22*2*
0511–30	05	11	37·2	−30	32·2	2·7	−1·0	E	17	223	−33		Curved spectrum	05–3*5*
0521–36	05	21	13·7	−36	30·2	19	−0·6	N	16·8	240	−33		Curved spectrum	05–3*6*
0523–32	05	23	35·7	−32	44·9	1·2	−0·5	E	16·6	236	−31			
0614–34	06	14	48	−34	55·1	2·8	−0·4	db	19	242	−22			06–3*6*
0618–37	06	18	19	−37	10·3	3·0	−0·7	db	16·6	244	−22		Highly polarized	06–3*7*
0625–35	06	25	21	−35	27·2	4·5	−0·6	db	17·6	243	−20		Optically, close triple	06–3*8*
0634–20	06	34	23	−20	32·2	7·0	−0·8	E	16·8	230	−12	2	Extended radio source	06–2*10*
0642–43	06	42	55	−43	40·6	1·8	−0·7	E	17	253	−19			06–4*12*
0715–36	07	15	22·5	−36	16·4	2·2	−0·9	E	17·8	248	−11			07–3*5*
0718–34	07	18	57	−34	01·5	2·1	−0·9	E	16·5	246	−9			07–3*7*
0843–33	08	43	08·5	−33	37·1	2·0	−0·7	E3	12·3	256	6		NGC 2663	08–3*8*
1103–24	11	03	45·5	−24	28·5	1·3	−0·9	D	17·5	274	32		In small cluster. Identification based on catalogue position only	11–2*1*
1103–20	11	03	51·5	−20	51·7	2·4	−0·7	E3	18·2	272	35			11–2*2*
1123–35	11	23	28	−35	07·3	2·6	−0·7	E3	16·0	284	24		In cluster	11–3*3*
1211–41	12	11	42	−41	43·2	1·6	−0·8	E	19	296	21			12–4*1*
1221–42	12	21	04	−42	18·7	2·7	−0·6		18	298	20		Low surface brightness object with double nucleus	

* References to previous identifications are:

1, Bolton, Gardner, and Mackey (1964); identification based on 74 in. plates by Westerlund.

2, Bolton, Gardner, and Mackey (1964).

3, Bolton, Stanley, and Slee (1949).

4, Mills (1954).

5, Mills (1955).

6, Mills, Slee, and Hill (1960).

7, P. Veron (personal communication).

TABLE 1 (*Continued*)

Catalogue Number	Position (1950.0) R.A. h	m	s	Dec. °	′	Flux Density at 1410 Mc/s (10^{-26} W m^{-2} (c/s)$^{-1}$)	Spectral Index	Type	m_{pg}	Galactic Coordinates l^{II}	b^{II}	Reference	Remarks	MSH Cat. No.
1246–41	12	46	03·6	−41	02·3	4·1	−0·9	Sc	12·2	302	22	2, 6	NGC 4696	12–*45*
1322–42	13	22	28	−42	45·6	1330	−0·6	SO	6·1	309	19	3	NGC 5128	13–*42*
1327–21	13	27	23·7	−21	26·6	2·0	−0·7	QSO?	17	315	40			
1333–33	13	33	47	−33	42·7	7·0	−0·8	E	11·9	313	28	2, 6	Ic 4296. Triple radio source	13–*33*
1334–29	13	34	11·3	−29	36·7	2·6	−1·0	Sc	8·0	315	32	2, 5	NGC 5236	13–*25*
1400–33	14	00	42·2	−33	44·3	0·8		E	12·4	320	27		NGC 5419. Source centred 3′ north following	14–*32*
1413–36	14	13	32	−36	27·3	2·4	−0·7	D	18·5	321	23		In cluster	
1514–24	15	14	45·6	−24	11·3	2·7	−0·4	E	16·2	341	28			
1928–34	19	28	23·5	−34	01·2	1·2	−0·8	E	17	5	−22			
2040–26	20	40	46	−26	44·0	2·3	−0·8	E	15·4	19	−35	2		20–*212*
2053–20	20	53	12·5	−20	08·1	2·8	−0·7	E2	17·8	27	−36		In cluster	20–*214*
2058–28	20	58	38	−28	13·5	6·7	−0·8	E	15·6	18	−39	2	In small cluster	20–*215*
2104–25	21	04	26	−25	39·5	12	−0·8	E	16·8	21	−40		In cluster	21–*21*
2115–30	21	15	10·4	−30	32·1	2·4	−0·7	QSO?	17·5	16	−43			21–*34*
2216–28	22	16	55	−28	10·5	2·6	−0·9	E	18	22	−56		In cluster	
2317–27	23	17	16	−27	44·5	3·3	−0·8	E	18	28	−69		In cluster	23–*24*
2354–35	23	54	26·5	−35	02·3	1·3	−1·2	D	15·5	356	−76			23–*37*

is the brightest member of a cluster. An alternate explanation is that the three bright galaxies belong to a small foreground group and that the radio source is the brightest member of a more distant cluster.

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