

SUGGESTED IDENTIFICATIONS FOR WEAK EXTRAGALACTIC RADIO SOURCES BETWEEN DECLINATIONS 0° AND -20°

By J. G. BOLTON* and JENNIFER EKKERS*

[Manuscript received July 4, 1966]

Summary

Sixty-eight identifications are suggested from inspection of the Palomar Sky Survey prints in the positions of 262 weak radio sources between declinations 0° and -20° . Forty-seven of the suggested identifications are galaxies and 21 possible quasi-stellar objects.

This paper is the last of a series concerned with identifications of radio sources in the area between declinations $+20^\circ$ and -33° that is common to both the Parkes Catalogue of Radio Sources and the Palomar Sky Survey. It reports the result of a search of the Sky Survey prints near positions of the weaker sources in the Parkes catalogue for 0° to -20° (Shimmins *et al.* 1966). Investigations of the stronger sources in this zone with flux densities greater than $1.6 \times 10^{-26} \text{ W m}^{-2} (\text{c/s})^{-1}$ at 1410 Mc/s have already been reported (Bolton and Ekers 1966c, 1966d). The present investigation covers 262 sources with flux densities in the range 0.8–1.6 flux units. For these sources only catalogue positions are available, and the accuracy of these positions is estimated as $\pm 1'$ arc (r.m.s. error) in both coordinates. Identifications were sought within these limits for both galaxies and possible quasi-stellar objects. The latter are distinguished by their relatively brighter images on the blue Sky Survey prints and require confirmation through photometric or, preferably, spectroscopic investigations.

As pointed out by Clarke, Bolton, and Shimmins (1966) in an earlier paper in this series, the probability of chance coincidence of a galaxy brighter than 17^m within a $2'$ square is about 0.01, and 0.04 and 0.16 for galaxies brighter than 18^m and 19^m respectively. A number of the suggested identifications are galaxies as faint as $19^m.5$, and thus for these the possibility of chance coincidence is quite high. Improved radio positions are desirable in order to confirm the identifications. In some cases, where there is more than one galaxy in or close to the search area, alternate possibilities are pointed out in the Remarks column of Table 1.

The reliability of the suggested identifications with quasi-stellar objects is probably lower than that for the galaxies. It is more difficult to assess, partly because

* Division of Radiophysics, CSIRO, University Grounds, Chippendale, N.S.W.

TABLE 1
LIST OF IDENTIFICATIONS

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Parkes Catalogue Number	Position (1950.0) R. A. h m s	Dec. ° ' "	Flux at 1410 Mc/s*	Spectral Index	Type	Magni- tude	μ °	b_{11} °	Remarks	Other Catalogue Number
0013-00	00 13 39.5	-00 32.0	0.8	-0.6	QSO?	18.5	104	-62		
0018-19	00 18 36.0	-19 26.7	1.1	-0.7	E 3	17	80	-79		00-19
0031-07	00 31 26.0	-07 46.9	1.1	-0.9	D	19	110	-70		
0047-02	00 47 15.5	-03 00.9	1.3	-0.9	QSO?	18	122	-66		00-014
0047-10	00 47 23.5	-10 22.7	0.8	-0.9	QSO?	20	122	-73		
0048-12	00 47 57.5	-12 18.6	1.1	-1.0	E	18	122	-75		00-121
0048-09	00 48 09.0	-09 45.4	1.1	+0.3	g	18	122	-72	Very blue; in small cluster	
0057-18	00 57 42.0	-18 03.9	1.2	-0.9	D	18	136	-80		
0108-14.2	01 08 39.0	-14 13.5	1.2	-0.8	E	15.8	143	-76		
0115-01	01 15 41.5	-01 36.0	0.9	-0.7	N	18	138	-63	Jet in p.a. 100°	
0116-19	01 16 03.5	-19 04.6	1.2	-0.8	E	18.5	161	-80		01-18
0118-00	01 18 30.0	-00 09.5	0.8	-0.9	Sp	17	139	-62	Star 0'.9 s.f. is blue	
0131-00	01 31 37.5	-00 12.0	1.2	-0.8	E	17.8	145	-61	Very blue nucleus	01-07
0137-10	01 37 44.5	-10 12.9	1.2	-0.9	N	18	159	-69		
0139-09	01 39 04.0	-09 41.7	1.0	-0.3?	QSO?	19.5	159	-69	Brighter star 0'.7 n.p. also blue	
0140-16	01 40 08.5	-16 43.7	1.1	-1.2	N	18	174	-74		01-115
0222-00	02 22 33.0	-00 49.6	1.2	-0.7	SO	16.8	167	-55		
0224-17	02 24 40.5	-17 27.8	1.2	-1.2	QSO?	19	194	-66	Galaxy 0'.6 s.f.	
0232-04	02 32 36.0	-04 15.3	1.5	-0.8	QSO?	17.7	174	-56	PHL 1377†	
0239-07	02 39 08.0	-07 00.9	0.8	-0.3?	QSO?	18.5	180	-57		
0246-13	02 46 16.0	-13 34.9	0.8	-0.9	g	19	192	-59		02-114

0300-00	03 00 40.0	-00 26.0	1.1	-0.5	E	18.2	178	-48	Brighter galaxies 2' n. and 1' s.f.	03-15
0304-12	03 04 30.0	-12 18.1	1.5	-1.0	SO	15.8	194	-55		03-17
0317-17	03 17 56.5	-17 13.8	0.9	-0.8	E	18	204	-54		
0327-16	03 27 38.0	-16 48.1	1.0	-0.9	QSO?	17	205	-52	Galaxy 1' s.p.	
0344-11	03 44 40.0	-11 15.3	1.0	-0.6	g	19.5	200	-46		
0424-13	04 24 48.0	-13 09.6	1.0	QSO?	17.5	209	209	-38		
0449-17	04 49 05.0	-17 35.2	0.8	-1.1	E	14.6	216	-34	Fainter galaxy 1' n.p.	
0456-04	04 56 29.5	-04 21.4	0.7	-0.9	N	18	203	-27		
0508-07	05 08 39.0	-07 38.0	1.0	-0.9	D	19	208	-26		
0539-12	05 39 25.0	-12 12.1	0.8	-1.1	E	18.5	216	-21	Or star + galaxy	
0600-13	06 00 49.5	-13 10.3	1.2	-0.9	db.	18	220	-17		
0718-00	07 18 40.0	-00 46.1	1.0	-0.4	E	18.5	217	6		
0726-00	07 26 15.5	-00 02.5	0.8		E	19	217	8	Explosive struc- ture?	
0736-06	07 36 33.5	-06 19.4	1.9	-0.5	QSO?	18.5	224	7		
0747-00	07 47 02.5	-00 02.1	0.7		db.	19	220	13		
0805-17	08 05 19.0	-17 15.9	1.0	-1.1	db.	18	237	8	Fainter galaxy 1' 2 n.f.	
0833-01	08 33 02.0	-01 40.7	1.1	-0.6	E	14.2	227	22		
0833-13	08 33 45.5	-13 27.5	0.7		g	18.3	238	16		
0837-12	08 37 28.0	-12 03.8	1.8	-0.9	QSO?	17.8	237	17	Galaxy 0' 7 s.p.	
0854-03	08 54 41.0	-03 29.0	0.9	-1.0	QSO?	18.5	232	26		
0920-07	09 20 19.5	-07 02.3	1.0	-1.2	QSO?	20	239	29		
0951-19	09 51 28.5	-19 32.8	0.8	-1.1	QSO?	19	256	26	In small cluster	
1021-00	10 21 57.0	-00 37.6	0.9	-0.1?	QSO?	18.5	245	45		
1133-17	11 33 28.5	-17 16.9	1.0	-0.2?	QSO?	19.5	279	42		
1146-11	11 46 33.5	-11 47.8	1.4	-0.9	E	18.3	280	48	11-173	
1158-05	11 58 56.5	-06 00.1	0.8		E 4	17.9	281	54		

* In units of $10^{-26} \text{ W m}^{-2} (\text{c/s})^{-1}$.

† Also suggested by Scheuer and Wills (1966).

TABLE 1 (*Continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1159-02	11 59 52.5	-02 24.0	0.7		E	18.2	279	58		
1237-17	12 37 43.0	-17 00.7	0.8		E 4	17.8	299	45		
1244-11	12 44 28.5	-11 14.4	0.9	-1.3	g	19.5	301	51		
1247-19	12 47 41.0	-19 29.7	1.2	-1.0	D	19	303	43	In cluster	
1254-08	12 54 44.5	-08 22.8	0.9	-1.0	D	18.5	305	54		
1256-17	12 56 16.5	-17 35.1	0.8		QSO?	18.5	305	45		
1307-00.7	13 07 49.5	-00 44.4	0.7		E 2	15.6	313	62		
1325-01	13 25 04.0	-01 47.6	1.1	-0.9	D	18.3	321	60	Small cluster?	
1328-05	13 28 49.5	-05 29.7	0.7	-0.9	D	18.5	321	56	In cluster; brighter galaxy 0'.6 n.p.	
1342-00	13 42 58.0	-00 43.0	0.9	-1.1	QSO?	17.7	330	59		
1452-05	14 52 30.5	-05 27.4	1.0	-0.7	E 3	17	350	46		
1602-00.2	16 02 09.5	-00 09.7	1.0		D	19.5	11	36	Very blue	
1617-04	16 17 25.0	-04 12.0	1.3	-1.3	E	19	9	31		
1636-03	16 36 19.5	-03 08.4	0.9	-1.3	db.	17.6	13	27		
1653-09	16 53 53.5	-09 00.8	0.9	-0.9	E	18	11	20	Or SO	
2117-11	21 17 06.0	-11 48.0	1.2	-0.7	E	19	40	-38		16-0/5
2121-01	21 21 06.5	-01 26.1	1.0	-0.8	QSO?	19	51	-34		21-16
2227-08	22 27 02.5	-08 48.5	1.1	-0.6	QSO?	18	55	-52		
2243-03	22 43 37.0	-03 16.4	1.1	-0.9	g	19	66	-52	Very blue; galaxy 0'.5 s.f.	
2335-18	23 35 20.0	-18 08.8	1.1	-0.8	QSO?	17.5	58	-71		
2355-08	23 55 37.5	-08 44.0	0.7		E	18.5	86	-67	Blue	

of the lack of published statistics on faint blue stars but also because of confusion with distant N-type galaxies and because of the existence of "interlopers" (objects which have the same optical characteristics as QSO's but are "radio quiet"). Dr. T. D. Kinman (personal communication) has investigated about 40 objects suggested by the authors on the basis of positions with an accuracy of $\pm 0\cdot2$. In this sample about 75% showed the ultraviolet excess characteristic of QSO's, about 20% had no u.v. excess but are possibly galaxies, and 5% were chance coincidences with stars. In another sample of 12 objects based on catalogue positions (i.e. $\pm 1'$) Sandage found that only six were QSO's (Bolton *et al.* 1965). However, the two faintest, 0106+01 and 1116+12, have the two largest red shifts presently known. The cosmological implications of such objects are sufficient to justify further selection of possible QSO's by photometric observations with large optical telescopes. Such observations are much less time-consuming than the determination of very precise positions of faint radio sources.

The examination of the Sky Survey prints was carried out with the aid of transparent overlays, each containing a $2'$ square centred on the radio position, and the positions of 10 stars from the Yale catalogue. The results of the examination of 262 positions were as follows:

- 47 fields contained galaxies;
- 21 fields contained blue stars which are possibly quasi-stellar objects;
- 3 fields contained galactic HII regions;
- 17 fields were in regions of high obscuration;
- 174 fields contained only stellar images of apparently normal colour.

The Identification List

The 68 possible identifications are listed in Table 1. Column 1 contains the Parkes catalogue number and column 11 the equivalent number from the MSH catalogue. The position of the proposed optical counterpart is given in columns 2 and 3. These positions were estimated from the Sky Survey prints with the aid of the transparent overlay and are given to $0^s\cdot5$ in right ascension and $0'\cdot1$ in declination. The uncertainty in these positions is probably of the order of $0'\cdot2$ arc.

Columns 4 and 5 contain the flux density at 1410 Mc/s and the spectral index, taken from the Parkes catalogue.

Column 6 gives the type of object, as follows:

- E elliptical galaxy;
- D elliptical galaxy with diffuse outer envelope;
- Sp spiral galaxy;
- SO spherical system with a possible dust lane;
- db. dumb-bell or double galaxy;
- N compact galaxy with starlike nucleus;
- QSO? possible quasi-stellar object.

Galaxies that could not be classified owing to poor print quality are denoted by g.

An estimate of the photographic magnitude for galaxies, and visual magnitude for quasi-stellar objects, is given in column 7. For faint objects these estimates may be in error by as much as one magnitude. Columns 8 and 9 contain the new galactic coordinates of the source, and column 10 contains remarks on individual objects, including other possible identifications within the search area.

Finding Charts

Finding charts for the suggested identifications are given in Plates 1–9. These were prepared from the Sky Survey prints, and contrast has been increased slightly over that of the original prints. Finding charts for the galaxies were made from the “E”, or red, print and for quasi-stellar objects from the “O”, or blue, print. The scale is approximately 5 mm = 1' arc, and north-east is at the top left-hand corner.

Corrections to Previous Papers

For many of the identifications suggested in previous papers, positions of higher accuracy or photometric measurements are now available. In some cases the identifications are not supported by these measurements, in many cases quasi-stellar objects have been confirmed, and in others a suggested QSO appears more likely to be a compact galaxy. The following corrections should be made to the lists of identifications given in previous papers.

Declination Zone -20° to -44° (Bolton, Clarke, and Ekers 1965)

0216–25, QSO?	}	Should be deleted; these identifications are not supported by position measurements of higher accuracy (Shimmins, Clarke, and Ekers 1966).
0231–23, QSO?		
1556–21, E		

1327–21, QSO?	}	Identifications supported by u.v. excess (Ekers and Bolton 1965).
2115–30, QSO?		

0237–23, QSO or N galaxy. Should be added to the list; this source has a strongly curved spectrum with a maximum of 7 flux units near 1410 Mc/s; its position is $02^{\text{h}} 37^{\text{m}} 53^{\text{s}}$, $-23^\circ 22' \cdot 0$ (1950), and a finding chart is given in Plate 9.

Declination Zone -20° to -30° (Bolton and Ekers 1966a)

0508–22, QSO?	Identified object shows no u.v. excess; a much fainter object $0' \cdot 2$ south preceding and within the limits of error of the radio position has u.v. excess (T. D. Kinman, personal communication).
---------------	---

0541–24, QSO?	No u.v. excess (T. D. Kinman, personal communication); radio and optical positions are in excellent agreement; object is probably a compact or N-type galaxy.
---------------	---

- 1233—24, QSO? Identification supported by u.v. excess (T. D. Kinman, personal communication).
- 1420—27, QSO? }
1422—29, QSO? } Identification supported by u.v. excess (B. Westerlund, personal communication).
- 0834—20, QSO? Should be added to the list; this source has a flux density at 1410 Mc/s of 3.5 flux units and a spectral index of -0.2 ; its position is $08^{\text{h}} 34^{\text{m}} 25^{\text{s}}.0$, $-20^{\circ} 06' .6$ (1950), and a finding chart is given in Plate 9.

Declination Zone 0° to $+20^{\circ}$ (Clarke, Bolton, and Shimmins 1966)

- 1107+10, QSO? }
1326+06, QSO? } Identifications are not supported by photometric observations (T. D. Kinman, personal communication).
- 0947+14, QSO? }
1352+16, D } Should be deleted; these identifications are not supported by position measurements of higher accuracy (Shimmins, Clarke, and Ekers 1966).
- 0347+13, QSO? }
0812+02, QSO? }
1055+01, QSO? } Identifications supported by u.v. excess (Bolton *et al.* 1966).
- 1514+00, QSO? Identification supported by u.v. excess (T. D. Kinman, personal communication).
- 2120+16, QSO? }
2249+18, QSO? } Identification supported by u.v. excess and spectrum (E. M. Burbidge, personal communication).
- 1318+11, QSO? Suggested object is a galaxy with bright u.v.; there is a fainter stellar object with u.v. excess $0'.2$ south following (T. D. Kinman, personal communication).
- 1455+11, QSO? Object shows no u.v. excess (T. D. Kinman, personal communication); it is possibly a compact galaxy.

Declination Zone 0° to $+20^{\circ}$ (Bolton and Ekers 1966b)

- 1005+07, galaxy Should be deleted; the optical position is in error and the identification incorrect.
- 0736+01, QSO? }
1354+19, QSO? } Identification supported by u.v. excess (T. D. Kinman, personal communication).
- 0940+00, QSO? Object has no u.v. excess (T. D. Kinman, personal communication); radio and optical positions are in excellent agreement; object is probably an N galaxy.

- 0319+12, QSO? Should be added to the list; this source has a flux density of 2.0 flux units at 1410 Mc/s and a spectral index of -0.4 ; its position is $03^{\text{h}} 19^{\text{m}} 08^{\text{s}}.0$, $+12^{\circ} 10' 5$ (1950), and a finding chart is given in Plate 9; it is not obviously blue on the Sky Survey prints, but all objects in this area appear to be highly reddened.

Declination Zone 0° to -20° (Bolton and Ekers 1966c)

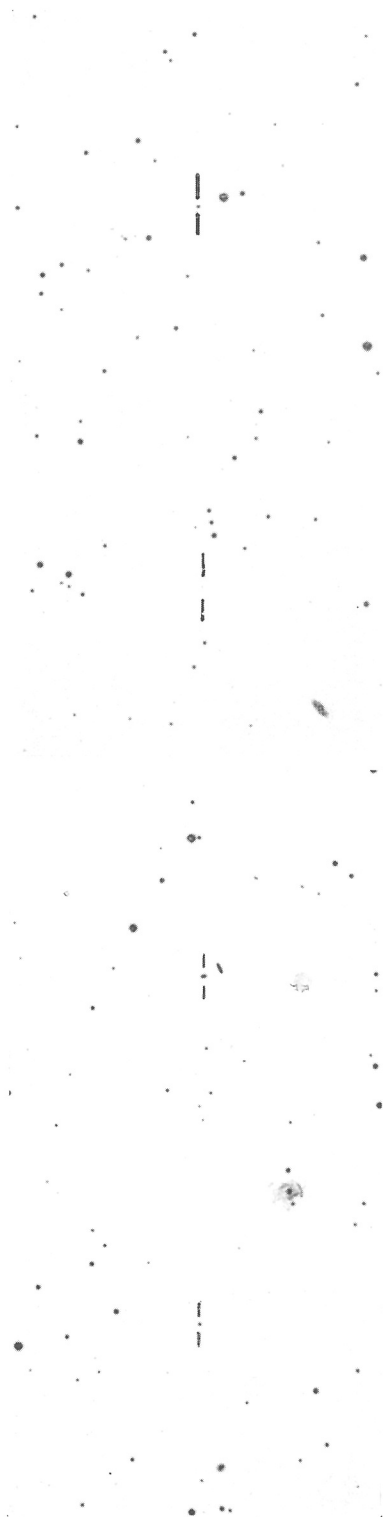
- | | | |
|---------------|---|---|
| 0825-20, QSO? | } | Identification supported by u.v. excess (T. D. Kinman, personal communication). |
| 1136-13, QSO? | | |
| 1510-08, QSO? | | |
| 0855-19, QSO? | } | (T. D. Kinman, personal communication). |
| 1404-01, QSO? | | |

Radio and optical positions of these two objects are in excellent agreement. They are probably N galaxies.

- 2128-12, QSO? Should be added to the list; this source has a flux density of 1.8 flux units at 1410 Mc/s and a spectral index of $+0.2$; its position is $21^{\text{h}} 28^{\text{m}} 52^{\text{s}}.5$, $-12^{\circ} 20' 3$ (1950), and a finding chart is given in Plate 9.

REFERENCES

- BOLTON, J. G., CLARKE, MARGARET E., and EKERS, R. D. (1965).—*Aust. J. Phys.* **18**, 627–33.
 BOLTON, J. G., CLARKE, MARGARET E., SANDAGE, A. R., and VERON, P. (1965).—*Astrophys. J.* **142**, 1289–90.
 BOLTON, J. G., and EKERS, JENNIFER (1966a).—*Aust. J. Phys.* **19**, 275–7.
 BOLTON, J. G., and EKERS, JENNIFER (1966b).—*Aust. J. Phys.* **19**, 471–3.
 BOLTON, J. G., and EKERS, JENNIFER (1966c).—*Aust. J. Phys.* **19**, 559–64.
 BOLTON, J. G., and EKERS, JENNIFER (1966d).—*Aust. J. Phys.* **19**, 713–15.
 BOLTON, J. G., SHIMMINS, A. J., EKERS, JENNIFER, KINMAN, T. D., WAMPLER, E., and WIRTANEN, C. A. (1966).—*Astrophys. J.* **144**, 1229–32.
 CLARKE, MARGARET E., BOLTON, J. G., and SHIMMINS, A. J. (1966).—*Aust. J. Phys.* **19**, 375–87.
 EKERS, R. D., and BOLTON, J. G. (1965).—*Aust. J. Phys.* **18**, 669–70.
 SCHEUER, P. A. G., and WILLS, D. (1966).—*Astrophys. J.* **143**, 274–6.
 SHIMMINS, A. J., CLARKE, MARGARET E., and EKERS, R. D. (1966).—*Aust. J. Phys.* **19**, 649–85.
 SHIMMINS, A. J., DAY, G. A., EKERS, R. D., and COLE, D. J. (1966).—*Aust. J. Phys.* **19**, 837–74.



0013—00

0018—19

0031—07

0047—02



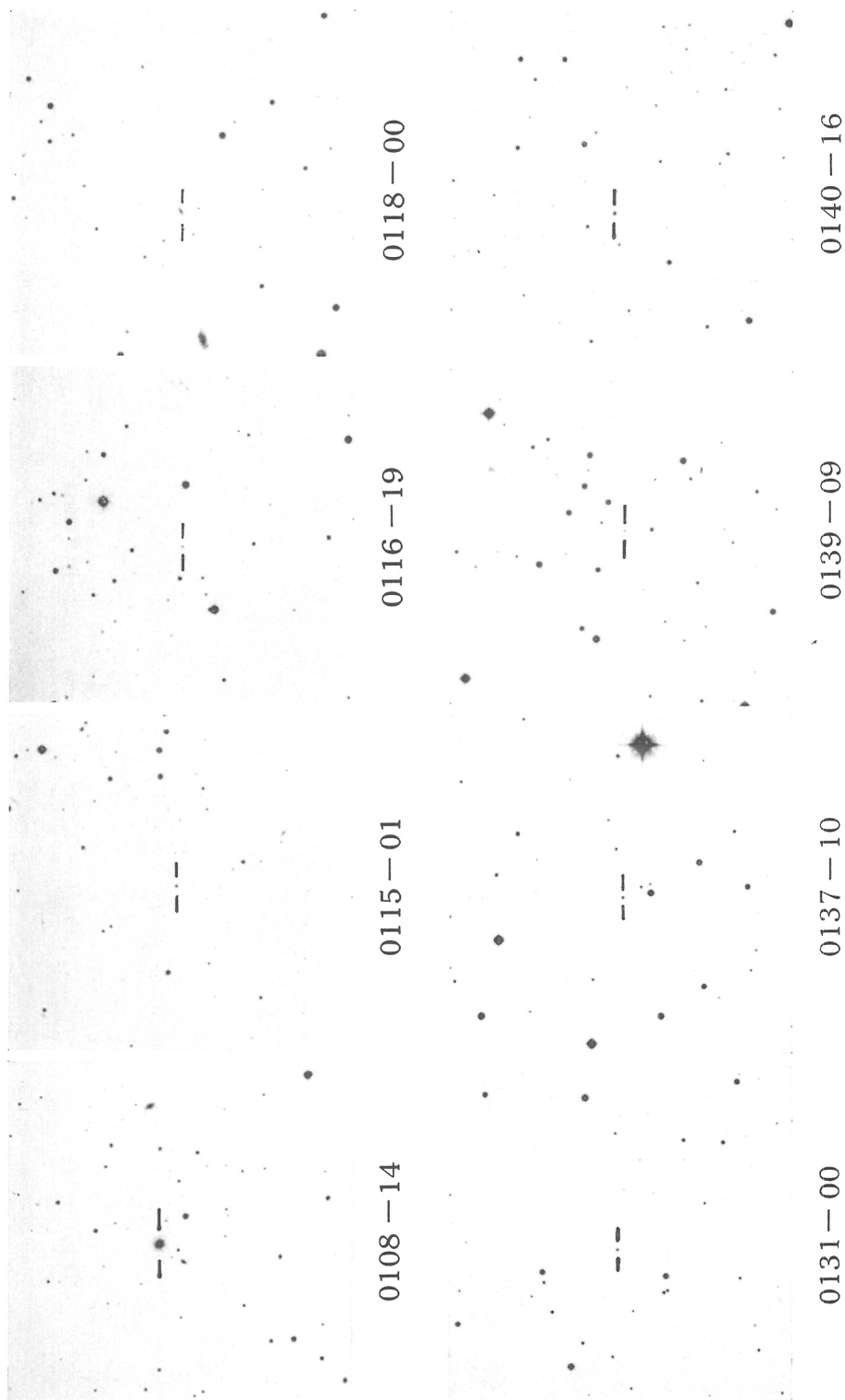
0047—10

0048—12

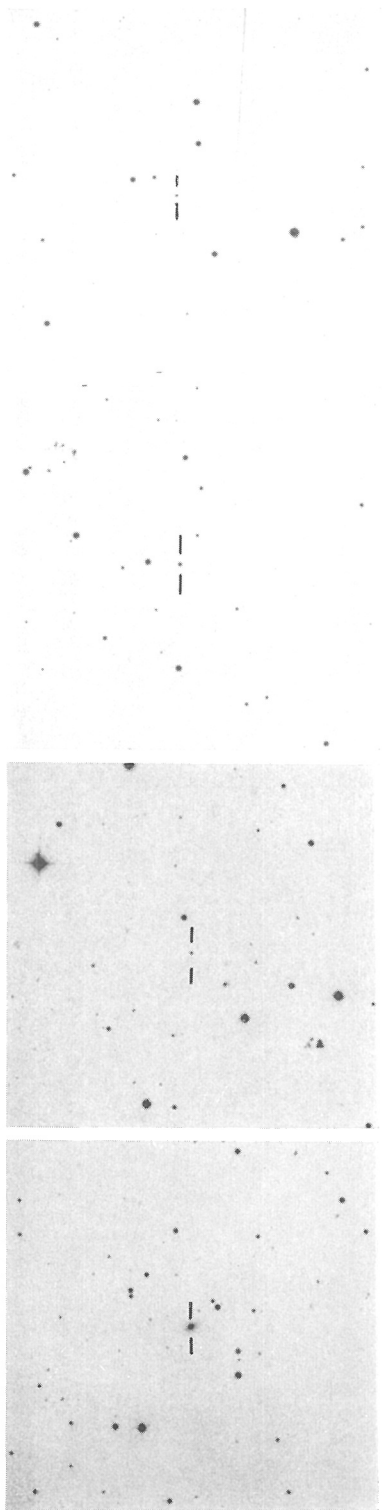
0048—09

0057—18

Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.



Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.

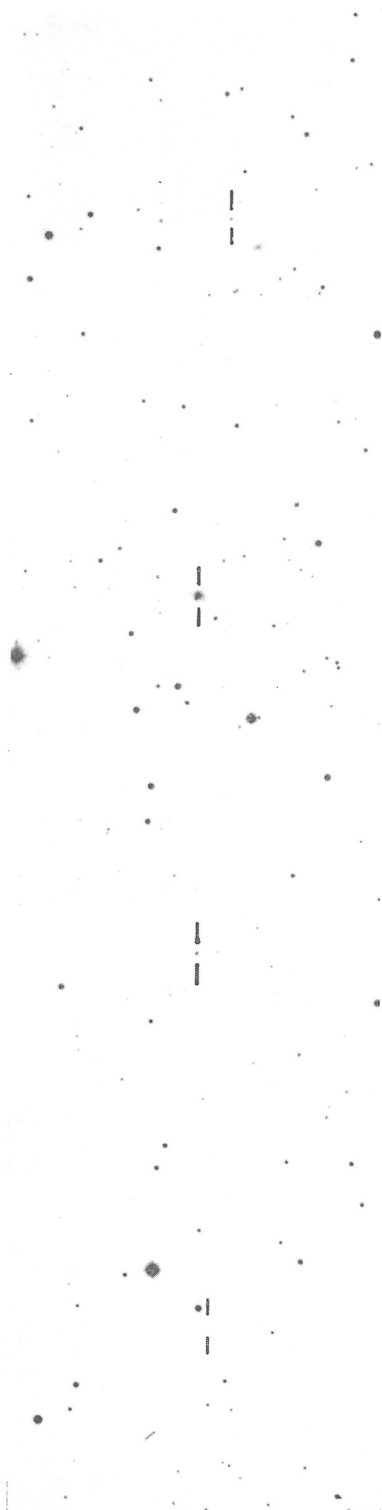


0239-07

0232-04

0224-17

0222-00



0317-17

0304-12

0300-00

0246-13

Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.

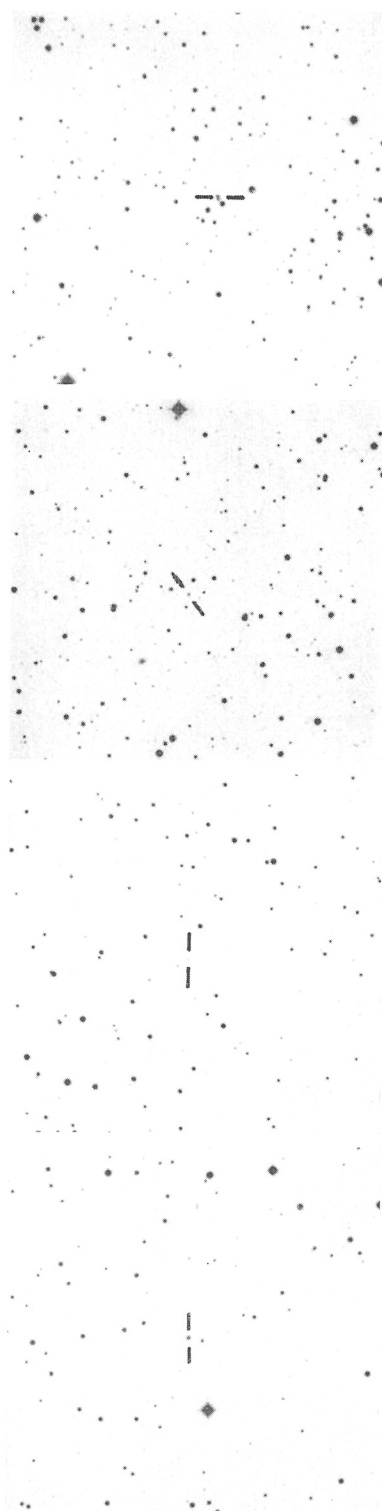


0327-16

0344-11

0424-13

0449-17



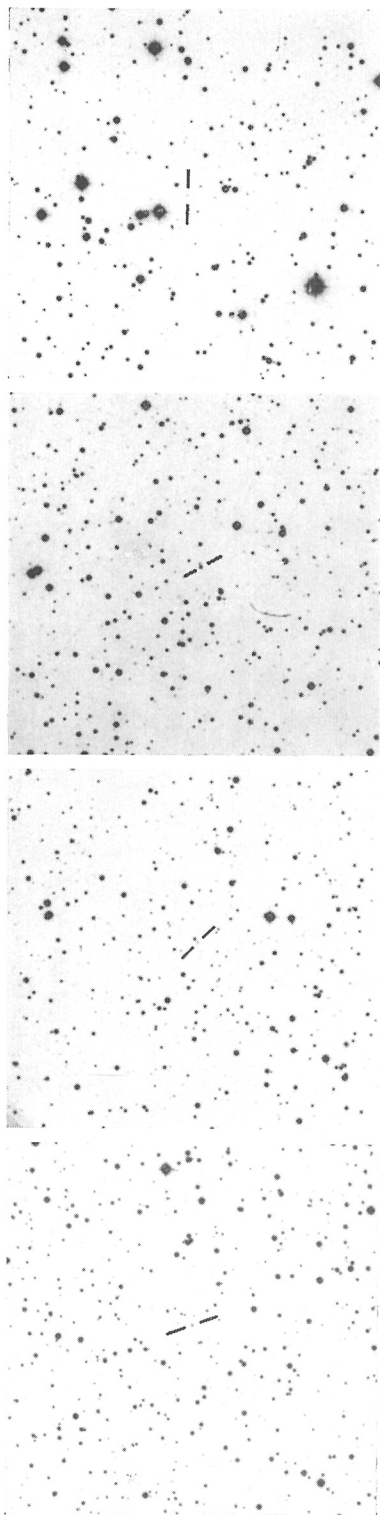
0456-04

0508-07

0539-12

0600-13

Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.

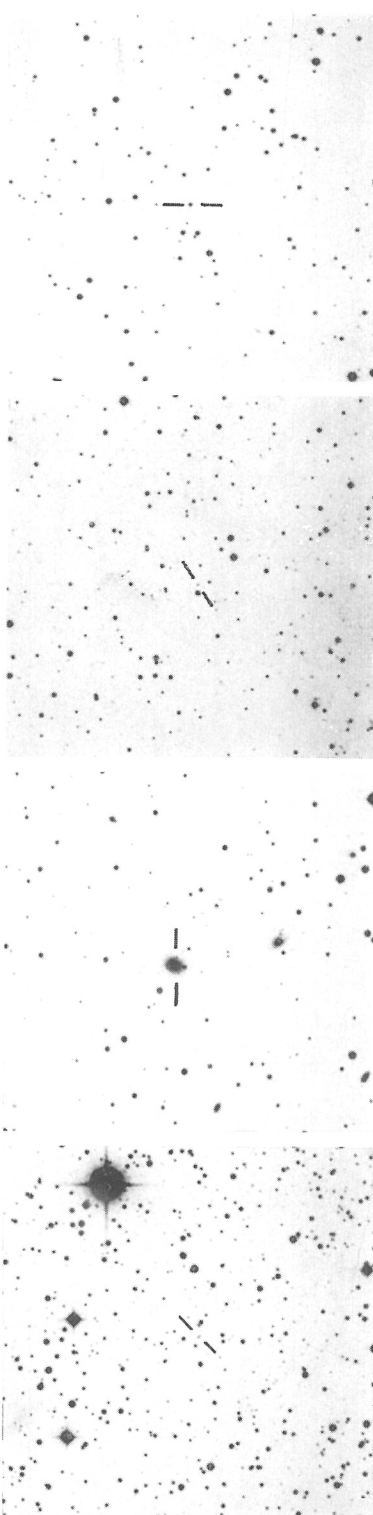


0747-00

0736-06

0726-00

0718-00



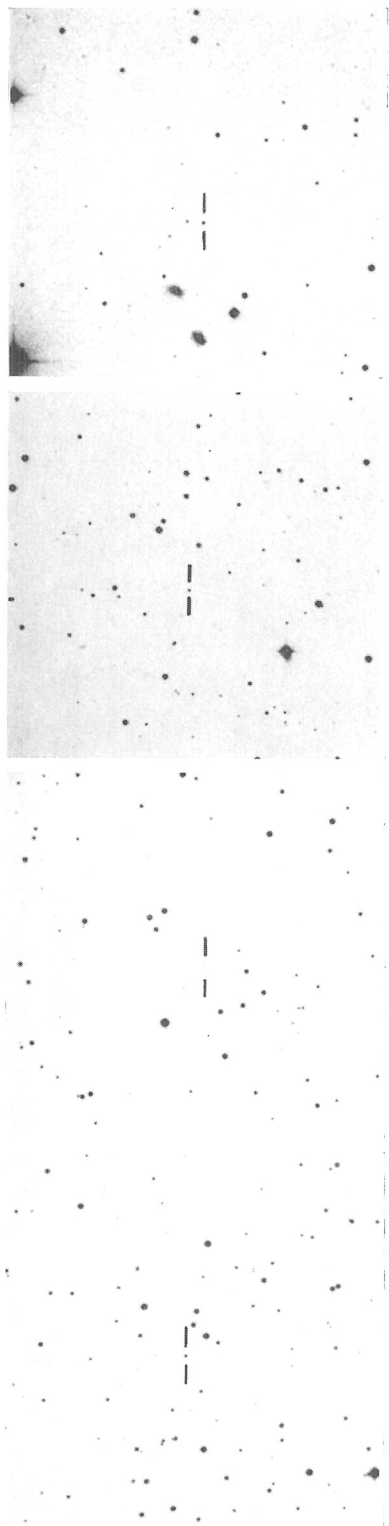
0837-12

0833-13

0833-01

0805-17

Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.

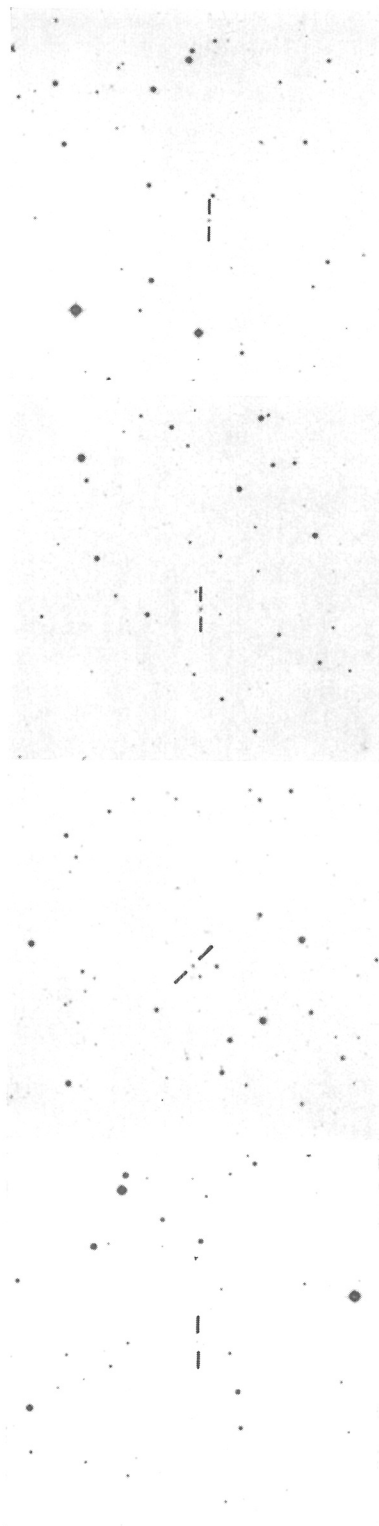


0854—03

0920—07

0951—19

1021—00



1133—17

1146—11

1158—05

1159—02

Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.

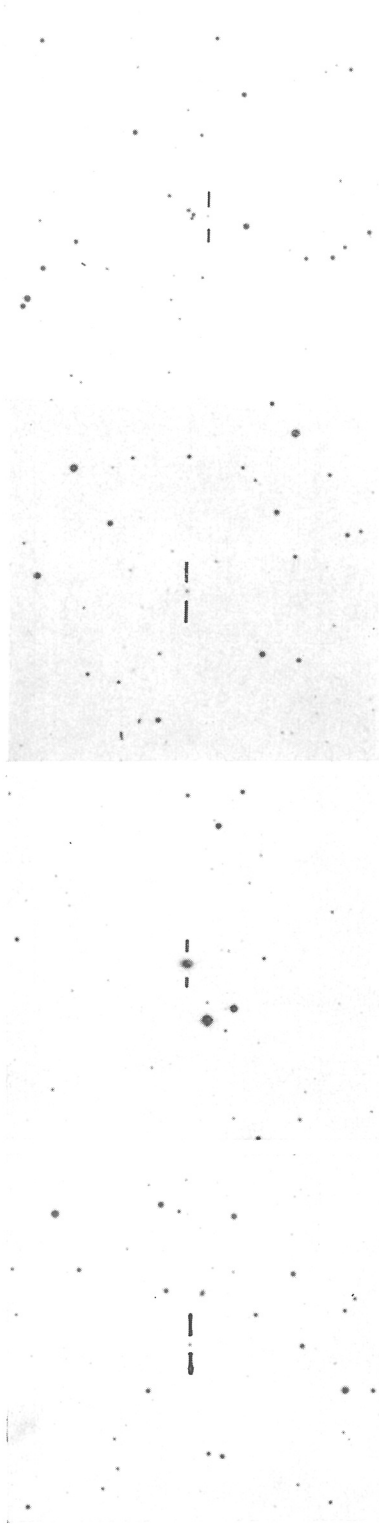


1237-17

1244-11

1247-19

1254-08



1256-17

1307-00

1325-01

1328-05

Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.

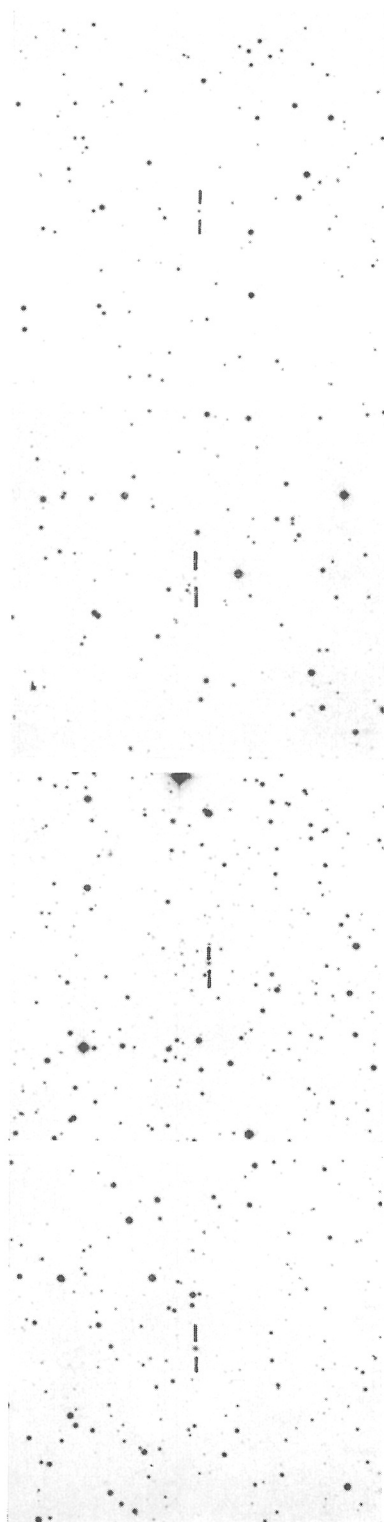


1342-00

1452-05

1602-00

1617-04



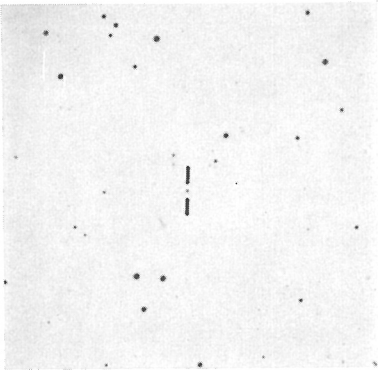
1636-03

1653-09

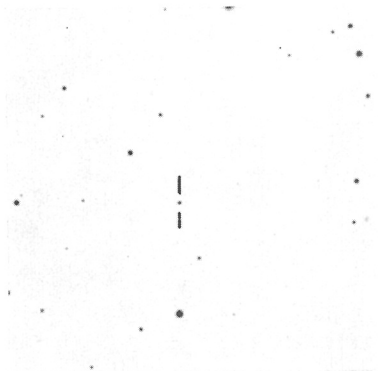
2117-11

2121-01

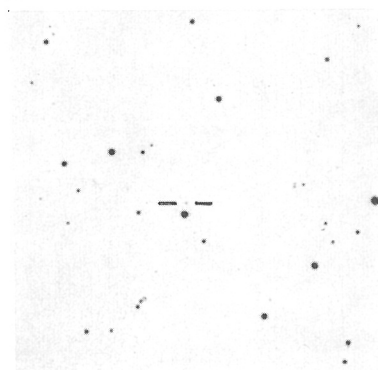
Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.



2355-08



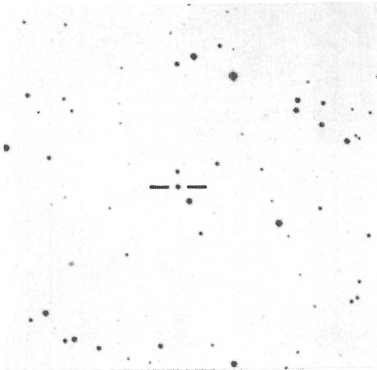
2335-18



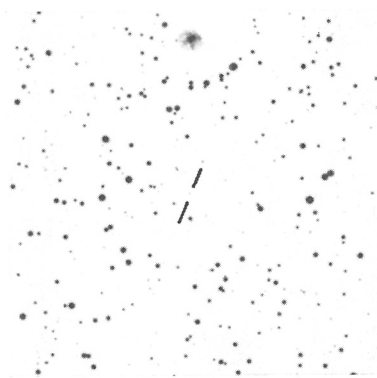
2243-03



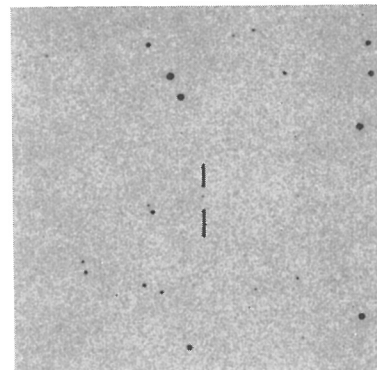
2227-08



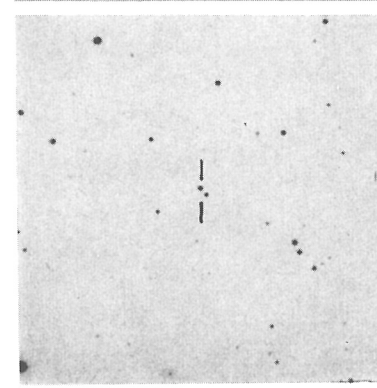
2128-12



0834-20



0319+12



0237-23

Finding charts for identifications (marked between the bars). Scale is 5 mm = 1' arc. North-east is at top left-hand corner.

