EXTENDED RADIO SOURCES. I

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Summary

Twenty-one "extended sources" from the catalogues of Mills, Slee, and Hill have been observed with a 14′ arc pencil beam at 1400 Mc/s. Some appear to be irregularities in the galactic radio emission, but most, especially those at high galactic latitudes, are resolved into groups of sources of small angular diameter. Maps of the regions are shown, and so far as possible radio spectra of the component sources have been assembled. An optical identification is given for the principal component of MSH 00–0*17* (3C29), and tentative identifications are suggested for some other sources.

The interpretation of the observations will be considered in paper II.

I. Introduction

In their well-known survey of radio sources in the southern sky, Mills, Slee, and Hill‡ (1958, 1960, 1961) listed a large number of sources which they called "extended", that is to say, sources which covered an area comparable with the beam of the Mills Cross. (The width of the beam, between half-power points, is 50′ in R.A. and 50′ $\sec(\delta+34°)$ in declination.)

Many of the extended sources lie near the galactic equator, and these could be understood as emission nebulae or old supernova remnants, but a large proportion of them are situated at high galactic latitudes. The latter do not coincide with nearby extragalactic nebulae, and Mills and Slee (1957) concluded that they must either represent some new type of source or else that they must consist of two or more of the normal small-diameter sources in a compact group, not fully resolved by the beam of their aerial. Mills and Slee estimated the number of such groups which may be expected to occur by chance in a random distribution of sources and found it to be much smaller than the number of "extended sources" in their catalogue; hence, if the extended sources are groups of sources, then most of these groups must be physically connected in some sense.

Nearly half of the sources in the MSH catalogue with flux density greater than 40 by 10^{-26} $Wm^{-2}(c/s)^{-1}$ are extended, so that extended sources are by no means a negligible feature of the sky. It is well known that they are now the chief cause of the difference between Mills's and Ryle's source counts. Very few of the extended sources appeared in the 3C catalogue (Edge *et al.* 1959), but independent evidence of their reality has accumulated. In particular, several groups of workers (Kellerman and Harris 1960; Bennett and Smith 1961; and Mills's own group) have shown, using interferometers, that there is appreciable fine structure in many

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‡ These catalogues will be referred to by the letters MSH.

of the extended sources, an observation which favours the suggestion that extended sources are clusters.

The present investigation concerns the "extended sources" at high galactic latitudes. We want to emphasize that it is no part of our purpose to revive an old controversy: we do not wish to label extended sources as "real" or "spurious". We do wish to find out what there is in these patches of sky that has been neglected in other surveys. In particular, we wish to answer the question: do "extended sources" represent clusters of physically associated radio galaxies?

For such an investigation, one needs a pencil-beam instrument with a beam several times (say n times) narrower than that of the Mills Cross, and enough sensitivity to detect $1/n^2$ of the flux density of the extended source. Until 1962, there was no instrument which satisfied both conditions, but then the 210-ft radio telescope at Parkes, used with a parametric amplifier at 1400 Mc/s, enabled us to make a serious attempt on the problem. This instrument has a beam 14′ arc wide between half-power points, and (when driven at 1°/min) can detect point sources of flux density $0 \cdot 2 \times 10^{-26}$ $\mathrm{Wm^{-2}(c/s)^{-1}}$.

II. Observations

In general, a region of about 3° by 3° centred on the nominal position was scanned in declination, at 30^{s} intervals of right ascension, at a rate of 1°/min (occasionally 30′/min). The right ascensions and flux densities of the brighter sources were then determined by scanning in right ascension at the declination of the source. In addition to the 1400 Mc/s observations, observations were made on 408 Mc/s (beamwidth 48′ arc); they serve to draw attention to faint areas of diffuse radio emission, which might be missed on the 1400 Mc/s records, and also provide some information on the spectra of the sources. The aerial beam on 408 Mc/s is similar to that of the Mills Cross and the records are limited only by resolution.

So far as the observing program allowed, the brightest extended sources were selected, and regions close to the galactic equator were avoided. Sixteen of the sources in Table 1 were covered in our observing program; in addition, information on MSH 00−1*6*, 00−1*7*, 10+0*10*, and 21+0*5* was obtained incidentally in other observing programs and made available to us. The source 01+0*3* is also included in Table 1, as its nature seems sufficiently clear from low frequency observations.

III. Presentation of Results

(*a*) *Units*

Throughout the rest of this paper, all flux densities will be quoted in units of $10^{-26}\,\mathrm{Wm^{-2}(c/s)^{-1}}$.

(*b*) *Scales of Flux Density*

The investigation of a particular extended source cannot be regarded as satisfactory unless we can either account for the flux density reported by Mills, Slee, and Hill, or show good evidence that this flux density was an over-estimate. As spectra vary, this cannot be done satisfactorily on the basis of 1400 Mc/s

TABLE 1

FLUX DENSITY AT 85 Mc/s

MSH No.	MSH × 0·75		From Spectra		Assuming $\alpha = 0 \cdot 75$		Assuming $\alpha = 1 \cdot 05$		Do Small-diam. Sources account for MHS Flux Density?	Diffuse Bright Patches at 1400 Mc/s?	Galactic Latitude b^{II}	Component Sources in Same Cluster (from Identifications)
	Total	Peak	Total	Peak	Total	Peak	Total	Peak				
00−*16*	25	15	—		11·5	6	26·5	14	?	No	−75°37′	—
00−*17*	39	25	—		35	26			Yes	No	−73°41′	—
00+*06*	51	15	—		21	9·4	49	22	No	No	−60°34′	—
00−*09*	90	50	75	37					?	No	−64°25′	No
00−01*7*	67	54	52	34						No	−64°13′	Perhaps
01+*03*	25	12	25	14					Yes	—	−58°20′	—
01−21*7*	47	32	43	39	40	36			Yes	No	−76°42′	—
08+*03*	94	45		40	(51)		(66)		No	No	+22°56′	—
10+0*10*	18	10	16	9	(20)		(27)		Yes	No	+52°40′	—
12−*12*	36	12		10	16	7·6	23	18	No	No	+43°33′	—
13+*06*	37	20		6	18	11	42	25	No	No	+63°39′	—
14+0*10*	35	23	17	14					No	No	+55°11′	Probably not
14−*14*	25	16	20	12					Yes	No	+41°56′	—
14−*16*	19	12	15	7	24	9	57	20	Yes	?	+42°37′	—
15−*16*	37	22			25		57		No	Yes	+33°00′	—
17+*01*	58	37	—	—	—	—	—	—	—	Yes	+27°40′	—
18−*41*	58	34	—	—	—	16	—	36	No	Yes	−12°01′	—
20+01*2*	78	17	100	—	—	—	—	—	No	Yes	−27°43′	—
21−*06*	21	11	—	17	(23)	—	—	—	—	Yes	−33°05′	—
21+*05*	50	19	—	—	15	—	34		No	No	−33°47′	—
23+*03*	38	22	(36)	24	—	—	—	—	Yes	No	−48°08′	—

observations alone. To facilitate the use of data from various observers, all flux densities have been reduced to one self-consistent scale, and the scale of Conway, Kellerman, and Long (1963)* has been adopted for this purpose. By adopting this scale, we do not assert that it is right and all others are wrong; it merely allows us to interpolate or extrapolate to the 85 Mc/s flux density of a source (on the CKL scale) from observations at other frequencies (reduced to the CKL scale).

The 1400 Mc/s flux densities given below were obtained by the same procedure and using the same conversion factors as those used by Bolton and Gardner for a number of catalogued radio sources, and where these sources are included in CKL,

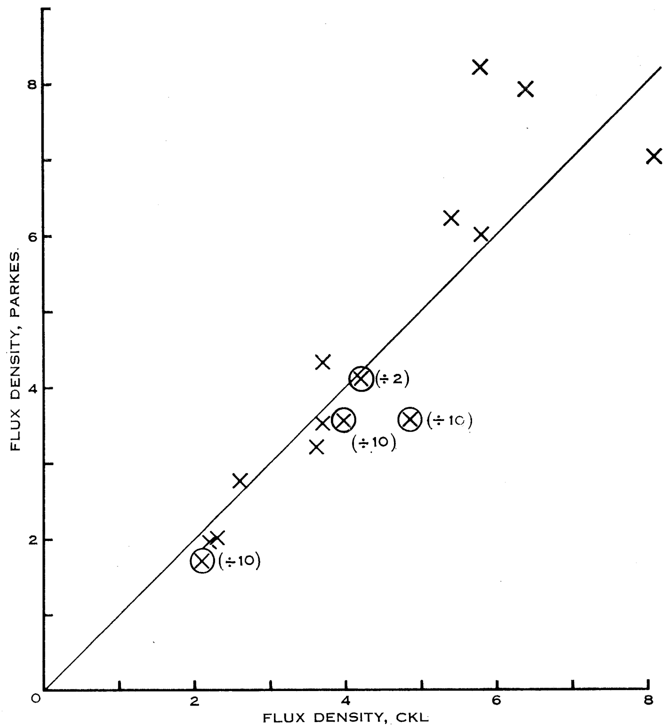

Fig. 1(*a*).—Comparison between "Parkes" and Conway, Kellerman, and Long 1400 Mc/s flux densities.

a comparison becomes possible. The comparison between "Parkes" and CKL 1400 Mc/s flux densities is shown in Figure 1(*a*); there is no significant systematic difference between the two scales.

A similar comparison at 408 Mc/s is shown in Figure 1(*b*).

The comparison between the 85 Mc/s flux densities of sources common to MSH and CKL is shown in Figure 1(*c*). To avoid extrapolation, only sources for which CKL quote a 38 Mc/s flux density have been used. The MSH flux densities are systematically greater than the CKL values. Therefore, in the rest of this paper, all flux densities quoted from the MSH catalogues will be multiplied by 0·75.

* This paper will be referred to by the letters CKL.

(c) *Charts of the Regions Observed at 1400 Mc/s*

The results of the 1400 Mc/s observations are exhibited in Figure 2. The full circles represent 1400 Mc/s sources, the area being roughly proportional to the 1400 Mc/s flux density. Some of the faint sources were found on one scan only, or are uncertain for some reason; these are plotted as squares. The positions of MSH sources are shown by crosses, and surrounded by open circles if marked "extended".

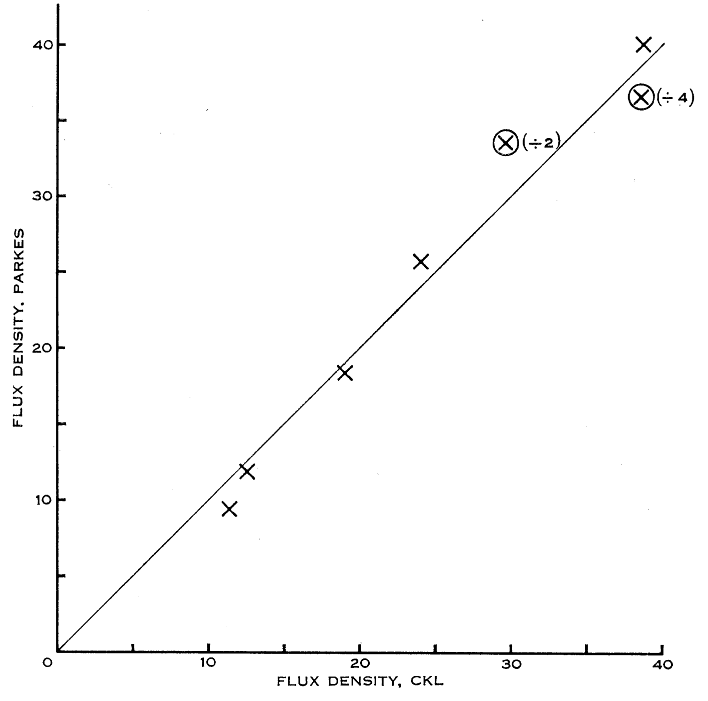

Fig. 1(*b*).—Comparison between "Parkes" and Conway, Kellerman, and Long 408 Mc/s flux densities.

All coordinates are reduced to epoch 1950.

The outline of each chart shows the region scanned at 1400 Mc/s. Patches of radio emission not resolved by the 14′ beam are shown by shading.

(d) *Spectra*

Information on the spectra of the sources has been compiled from all available data, and is also shown in Figure 2.

The crosses denote observations made with insufficient resolution to distinguish the components of the extended source, or represent the total flux density of sources associated with the "extended source." Triangles, squares, etc. denote flux densities of individual components.

The following data have been used:

(i) The MSH catalogues (85·5 Mc/s). For each extended source, two crosses are plotted, the upper representing the total flux density, the lower the peak flux density observed with the 50′ beam. (All catalogue values multiplied by 0·75, see Subsection (*b*) above.)

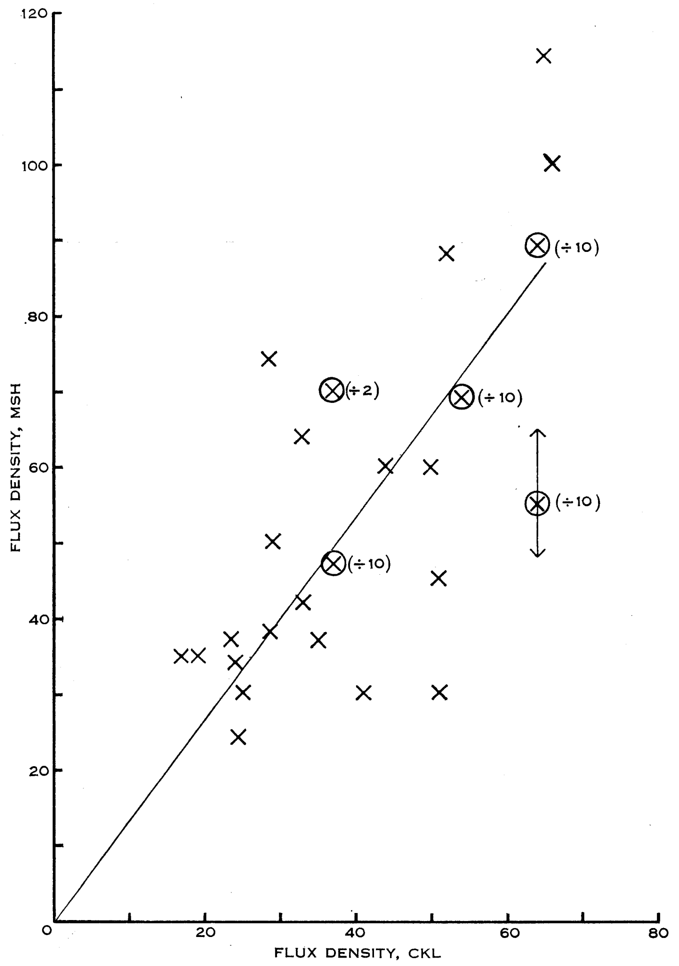

Fig. 1(*c*).—Comparison between the 85 Mc/s flux densities of the sources common to Mills, Slee, and Hill, and to Conway, Kellerman, and Long.

(ii) 178 Mc/s observations by the Cambridge group (Bennett, personal communication), some made with a 13·6′ by 4·6° fan beam, others by aperture synthesis.

(iii) 408 Mc/s observations (Parkes). Where a 408 Mc/s point represents several sources not resolved by the aerial beam, a correction has been made for the broadening of the profile.

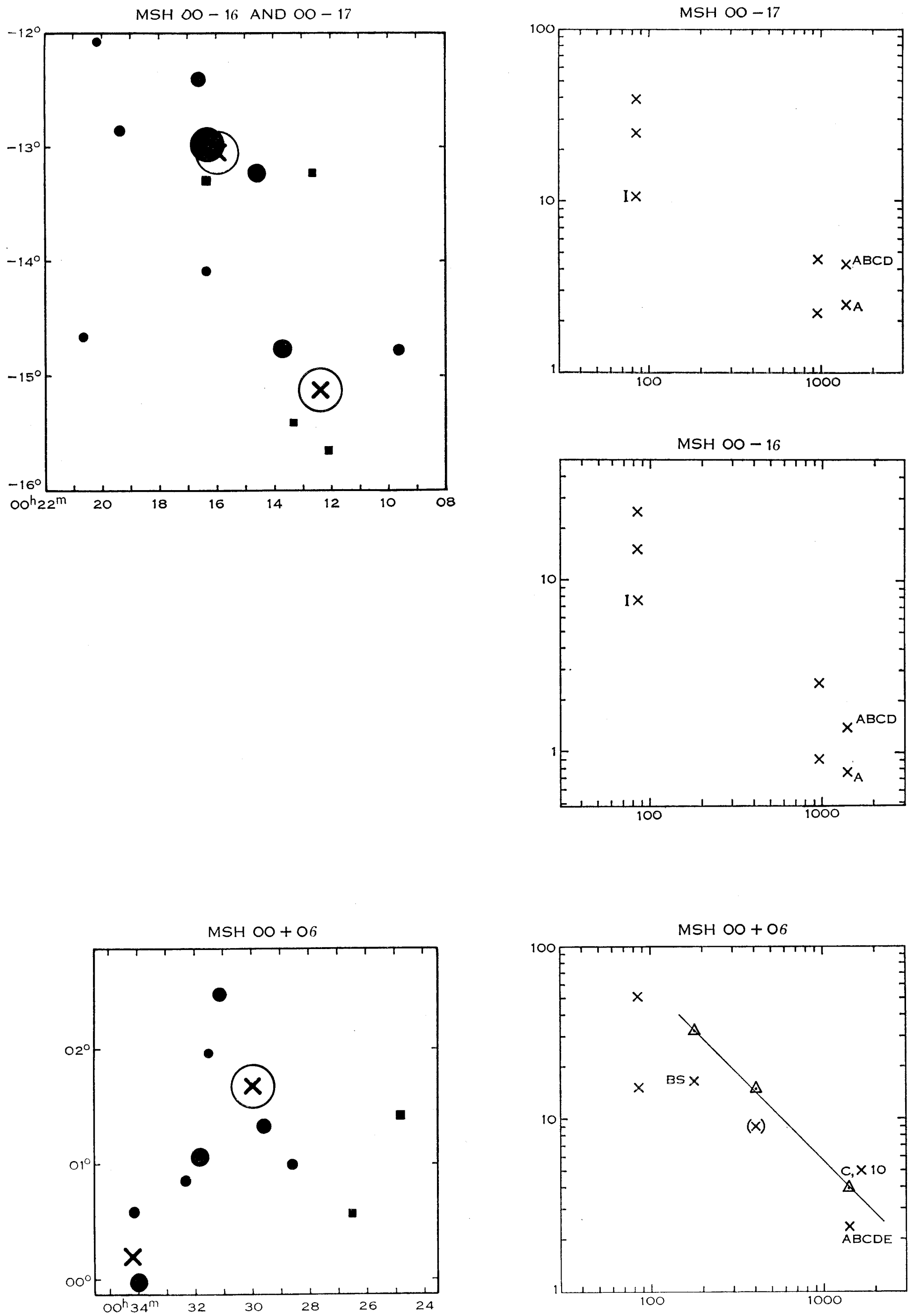

Fig. 2(*a*).—Charts of regions observed at 1400 Mc/s.

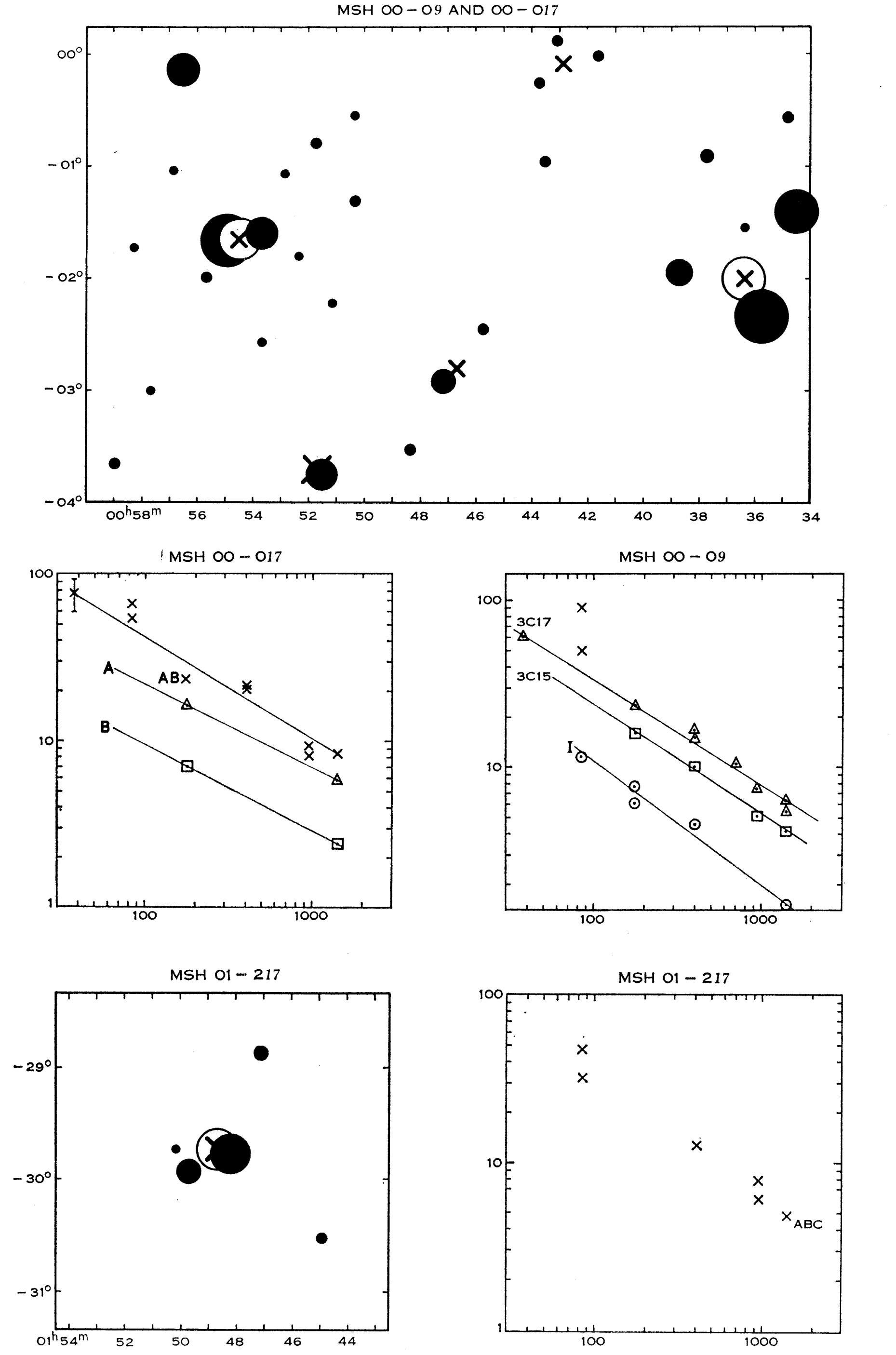

Fig. 2(*b*).—Charts of regions observed at 1400 Mc/s.

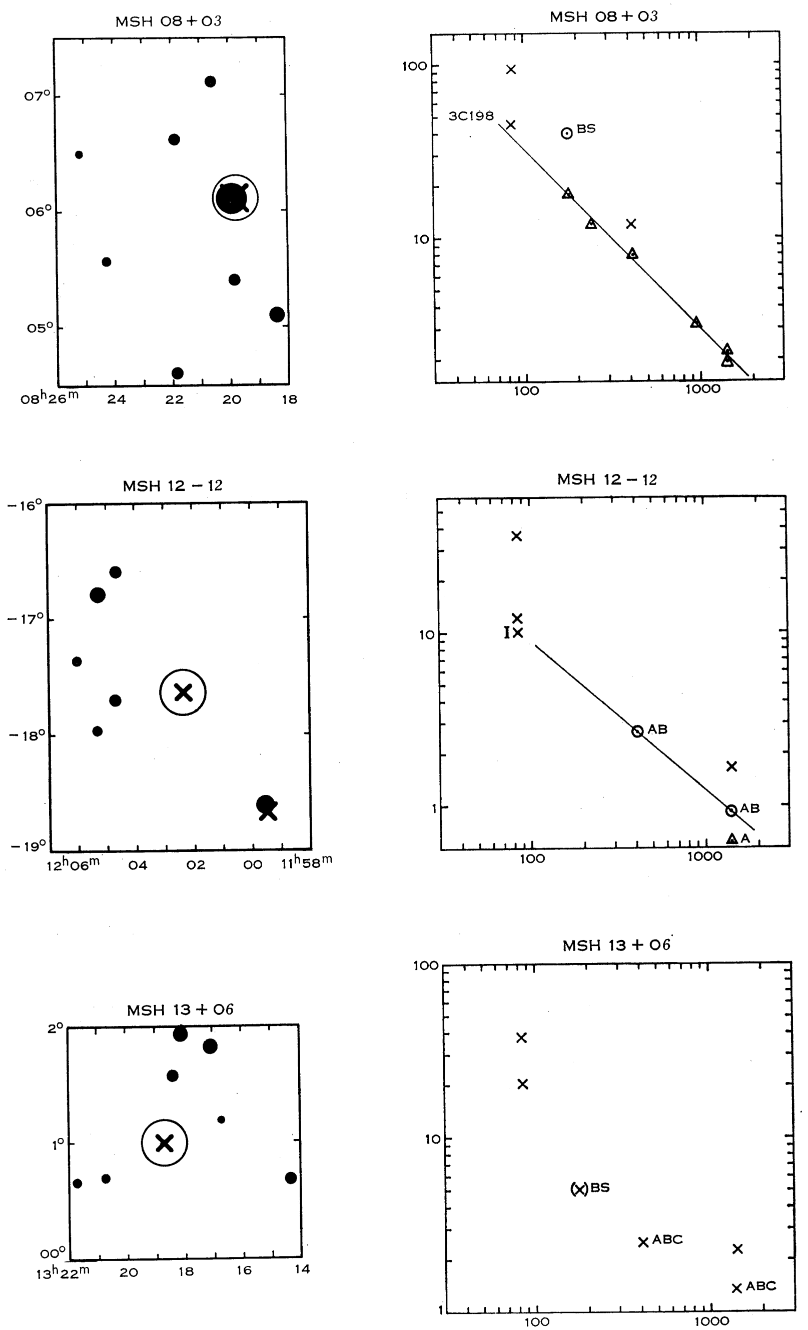

Fig. 2(*c*).—**Charts of regions observed at 1400 Mc/s.**

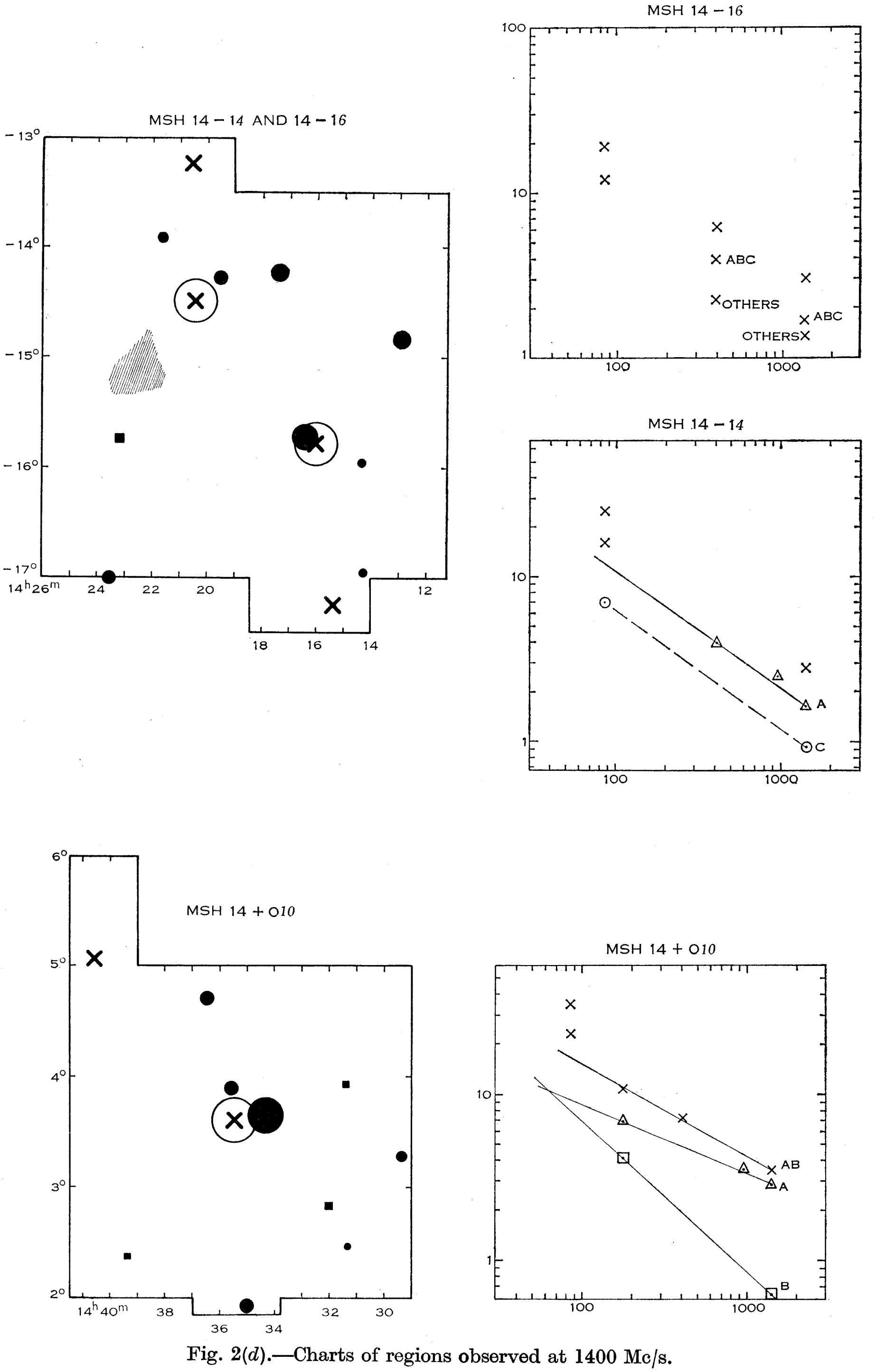

Fig. 2(*d*).—Charts of regions observed at 1400 Mc/s.

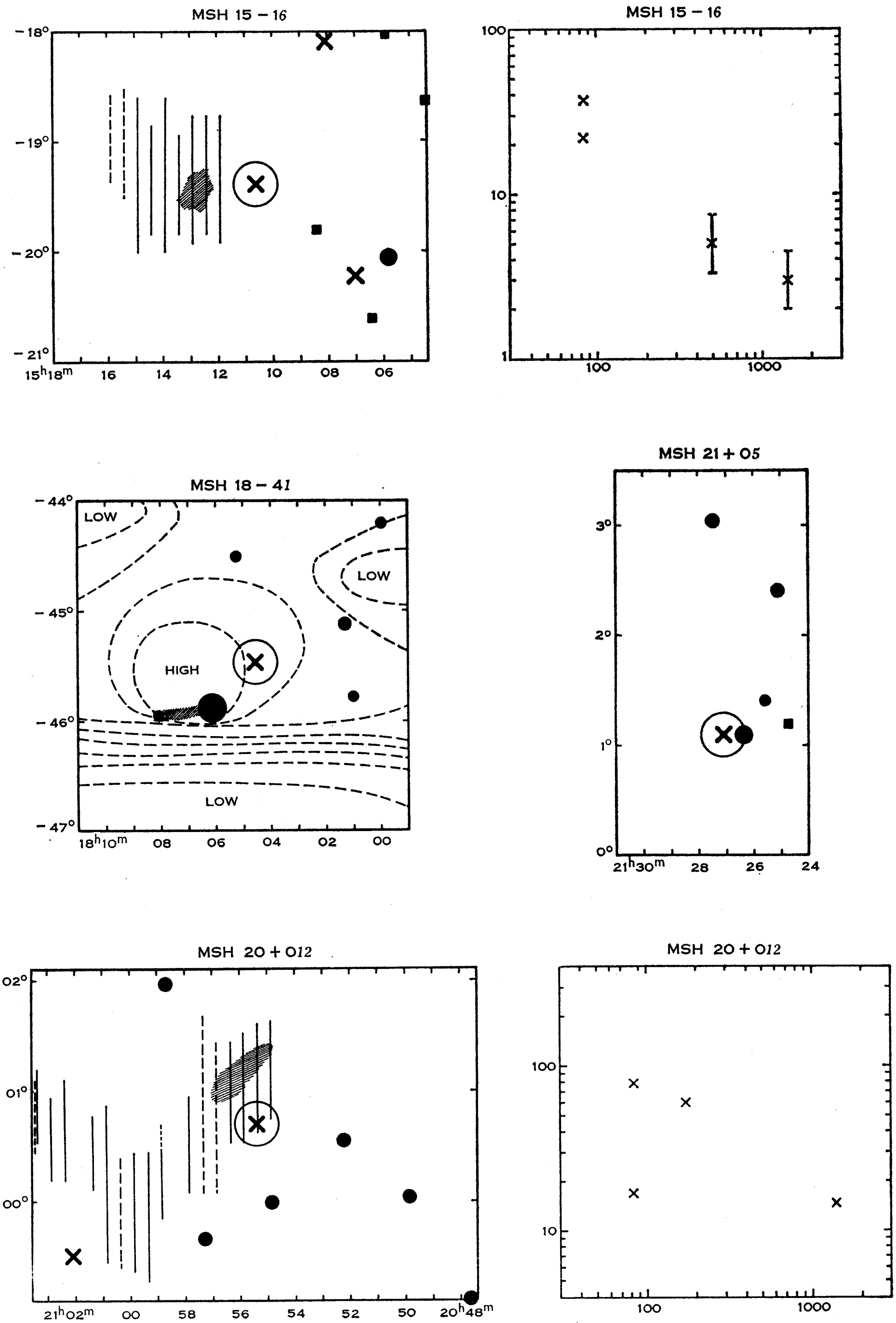

Fig. 2(*e*).—Charts of regions observed at 1400 Mc/s.

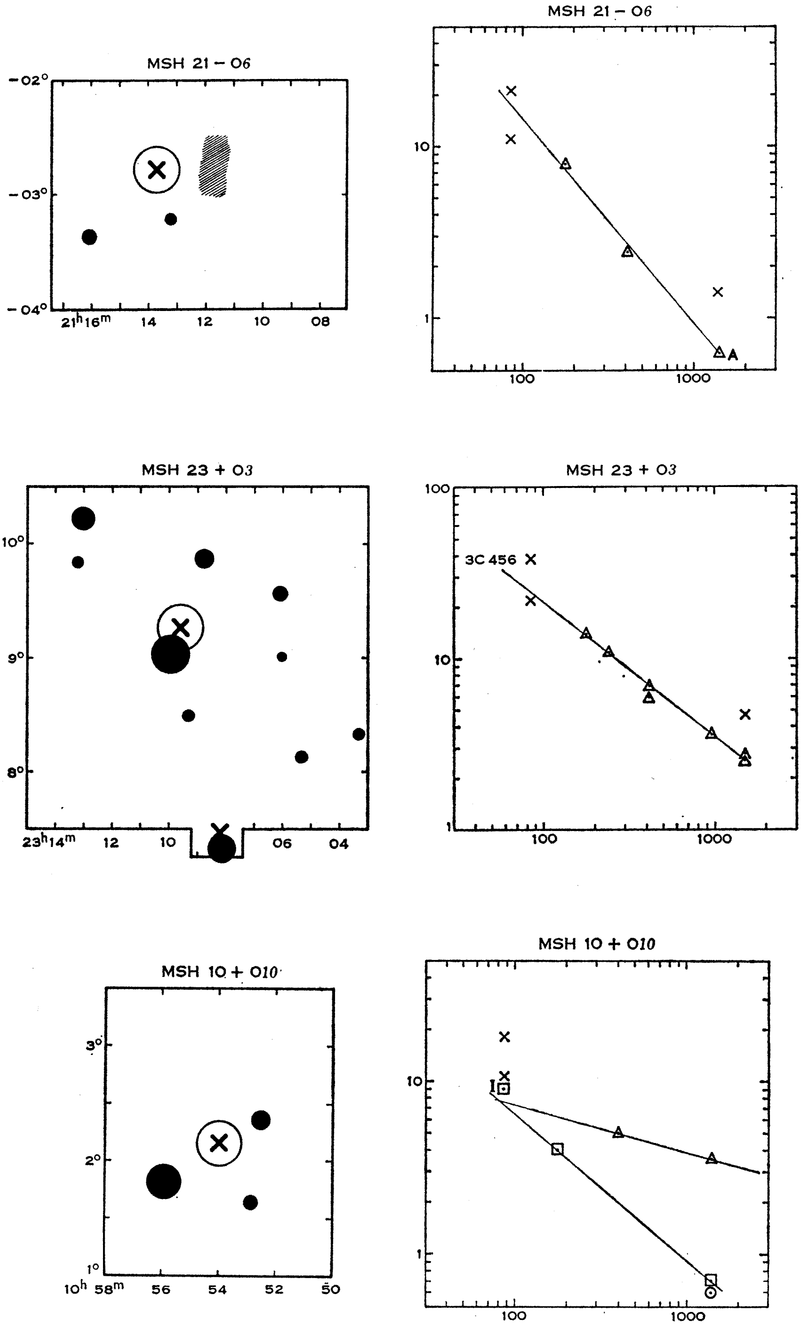

Fig. 2(*f*).—Charts of regions observed at 1400 Mc/s.

(iv) 960 Mc/s observations. Kellerman and Harris (1960) used an interferometer of two paraboloids, each steered to follow the MSH catalogue position. We have converted these data into total flux densities at 960 Mc/s, using the positions of the component sources determined at 1400 Mc/s and assuming that the *relative* flux densities of the components are the same at 960 as at 1400 Mc/s. This process is often uncertain, as the positions of very faint sources are often not known precisely enough in relation to the lobes of Kellerman and Harris's interference pattern. Where a total flux density has been computed, two crosses are plotted, the upper representing the total flux density and the lower the catalogue value.

(v) 1400 Mc/s observations (Parkes).

(vi) Long-baseline interferometer observations at 85·5 Mc/s (Scheuer, Slee, and Fryar, unpublished data 1963) shown in Figure 2 by points marked I. These points are sometimes particularly useful because they require no correction for spectrum and can be compared directly with MSH. Together with Moffet and Maltby's work (1962), these observations show that, in general, the component sources are very small compared to the distance between them.

(*e*) *Details of Individual "Extended Sources"*

For each source, the following information is given:

(i) The MSH number and coordinates, and the MSH total and peak flux densities reduced to the CKL scale.

(ii) Sources which may be associated with the MSH source, with new coordinates and flux densities measured at 1400 Mc/s. They are labelled A, B, C for reference.

(iii) Evidence relating to the flux density at 85 Mc/s.

(iv) Identification of component sources, when positional accuracy justifies a search.

MSH 00−1*6* R.A. $00^h\,12^m\,24^s$ 15°07′ S. $S_{85} = 25(15)$
1400 Mc/s: declination scans only. 408 Mc/s: none.

Sources	A	$00^h\,13^m\,42^s \pm 10$	14°45′.5 S.	$S_{1400} = 0{\cdot}75$
	B	$00^h\,09^m\,37^s \pm 10$	14°46′ S.	0·30
and probably	C	$00^h\,12\frac{1}{2}^m$	$15\frac{1}{2}°$ S.	0·2
	D	$00^h\,13\frac{1}{2}^m$	$15\frac{1}{4}°$ S.	0·15
			Total 1400 Mc/s flux density	= 1·40

The position and broadening given in MSH are consistent with the supposition that A, B, C, and D constitute the extended source, but both the peak flux and the total flux seem insufficient. The 85 Mc/s interferometer shows a small-diameter (<30″) source with $S_{85} \simeq 7$, which is probably source **A**.

MSH 00−17	R.A.	$00^h\,15^m\,54^s$	13°02′	S.	$S_{85} = 39(25)$
	(MSH remark "Extended N.–S., may be two sources")				
	1400 Mc/s: declination scans only. 408 Mc/s: none				
Sources:	A	$00^h\,16^m\,17^s \pm\ 5$	12°58′	S.	$S_{1400} = 2{\cdot}5$
	B	$00^h\,16^m\,36^s \pm 10$	12°24′	S.	0·5
	C	$00^h\,14^m\,34^s \pm 10$	13°13′.5	S.	0·9
and possibly	D	$00^h\,16^m\,22^s \pm 15$	13°17′	S.	0·33
			Total 1400 Mc/s flux density		= 4·23

The brightest sources, A and C, both lie close to the MSH position; the remark that the source is extended N.–S. suggests that B should also be included. With a 50′ beam, the peak intensity observed at 1400 Mc/s would be 0·75 of the total flux density, which is in tolerably good agreement with the ratio peak: mean = 0·64 from the MSH data. There is no difficulty in accounting for the flux densities of MSH, assuming quite normal spectra.

The 85 Mc/s interferometer data indicate that the principal source, A, is less than 30″ in diameter.

MSH 00+*06*	R.A.	$00^h\,30^m\,00^s$	01°40′	N.	$S_{85} = 51(15)$
		1400 and 408 Mc/s observations			
Sources	A	$00^h\,28^m\,36^s \pm 15$	00°59′ ±2	N.	$S_{1400} = 0{\cdot}35$
	B	$00^h\,29^m\,35^s \pm\ 2$	01°19′.5	N.	0·6
	C	$00^h\,31^m\,06^s \pm 15$	02°28′.5±1·5	N.	0·4
	D	$00^h\,31^m\,49^s$	01°03′.5	N.	0·8
(not fully resolved from D)	E	$00^h\,32^m\,20^s \pm 15$	00°51′ ±5	N.	0·25
	F	$00^h\,31^m\,30^s \pm 10$	01°58′	N.	0·2
			Total 1400 Mc/s flux density		= 2·6

The position given in MSH, and the broadening over three beamwidths indicated by the ratio of total to peak flux density, indicate that sources A to F and possibly one or two fainter sources should all be regarded as part of 00+*06*; the source

G	$00^h\,34^m\,00^s$	00°02′	S.	0·65

is listed separately as MSH 00+*09*.

Source C is sufficiently resolved from A, B, D, and E to allow a separate estimate of its S_{408}; there is also a 178 Mc/s point (Bennett). Table 1 shows that the MSH flux density is consistent with the 1400 Mc/s sources only if most of the sources A, B, D, E, F have exceptionally high spectral indices. One source with $\alpha \simeq 1{\cdot}1$ would be plausible; a whole group seems improbable.

Sky survey prints were searched at the positions of A, B, and D. No galaxy brighter than 18^m lies within 5′ of B; galaxies are visible within 3′ of A and D, and the radio positions are not precise enough to exclude the possibility of an identification.

MSH 00−*09*	R.A.	$00^h\,36^m\,24^s$	02°00′	S.	$S_{85} = 90(51)$		
		1400 and 408 Mc/s observations					
Sources	A						
	(3C15)	$00^h\,34^m\,30^s$	01°24′	S.	$S_{1400} =$	4·1	$S_{408} = 10$
	B						
	(3C17)	$00^h\,35^m\,46^s.5$	02°22′	S.		6·2	16·5
	C	$00^h\,38^m\,43^s.5$	01°56′.5	S.		1·5	4·5
and possibly	D	$00^h\,36^m\,20^s$	01°32′.5	S.		0·2	
		Total 1400 Mc/s flux density			=	12·0	

There are sufficient data to determine the individual spectra of the three significant components. That of B(3C17) reproduces the CKL data plus present observations. For source C, two 178 Mc/s points are plotted, the upper and lower representing the Cambridge interferometer and total power observations respectively. The visibility of C (85·5 Mc/s interferometer) is about the same at 1500 and 2300 λ (though much reduced at 4100 λ spacing), so that the point I probably represents the full 85 Mc/s flux density of C. From the spectra of Figure 2, $S_{85} = 26$, 37, 12 for A, B, C respectively. The peak flux for a 50′ beam would be obtained with the beam centred on source B and is 37. Thus it is difficult to account for the whole of the flux density reported by MSH.

Identification

A (*3C15*).—The position given above yields no clear identification, but the declination appears to be in error, by 1′.5, for the declinations measured by Joshi (1962) (01°25′.7 S.) and by Matthews (01°25′38″±11″—J. Bolton, personal communication) agree precisely. Adopting the latter declination, the position agrees well with a round compact 15^m–16^m E galaxy; there is another fainter E galaxy about 30″ Sf. Both appear to belong to a cluster.

B (*3C17*).—No galaxies brighter than 18^m within 2′ (this remains true if one adopts Matthews' declination, 2°23′53″ S.).

C.—The radio position is about 1′ Np from a large bright spiral, probably about 13^m, but not in the NGC. This is a possible identification, but not a convincing one. The radio diameter is about 30″.

MSH 00−*017*	R.A.	$00^h\,54^m\,30^s$	1°39′ S.	$S_{85} = 67(54)$	
	1400 and 408 Mc/s observations				
Sources	A(3C29)	$00^h\,54^m\,58^s$	1°40′ S.	$S_{1400} =$	5·8
	B	$00^h\,53^m\,40^s$	1°36′ S.		2·4

There are also some faint sources, $S_{1400} \simeq 0{\cdot}2$, within 1° of the main sources, and they may raise the total S_{1400} to 10. The MSH position lies very close to the centroid of A and B.

The Cambridge fan-beam observations include a source at

$$00^h\,53^m\,45^s \quad 00°48' \text{ S.} \quad S_{178} = 7$$

and in view of the large uncertainty in declination in these observations we may accept this source as referring to source B. Extrapolating the spectra of A and B, we obtain $S_{85} = 34$ for A and B combined, and this is much lower than the total or even the "peak" flux density derived from MSH. The 38 and 408 Mc/s points, and a Cambridge observation giving a total flux density of 30–40 at 178 Mc/s, suggest that the spectrum of 00−0*17* as a whole is steeper than that of A and B, and that S_{85} might be 50 or 60. If the mean spectrum of the faint sources surrounding A and B corresponds to a spectral index of 0·75, then they contribute about 18 to S_{85}, and the total S_{85} becomes 52.

Identification

A (3C29).—Previous measurements of the position of this source are unreliable owing to the proximity of source B. The position given above coincides with a bright compact round E galaxy (about 14^m, but not in NGC). The nearest other galaxy is 5′ away. The radio diameter is about $2\frac{1}{2}'$ (the 85 Mc/s interferometer measurements show that 00−0*17* disappears beyond 1500 λ spacing, so that Moffet and Maltby's (1962) results cannot be attributed to the effect of source B). This appears to be a good identification.

B.—The radio position lies in a small compact cluster of bright galaxies, but is not precise enough to permit identification with any one galaxy.

The cluster around source B appears to extend in the direction of source A, and it is just possible that A is a cluster member. MSH 00−0*17* is the one extended source we have found in which two component sources may be identifiable with members of the same cluster of galaxies.

MSH 01+0*3* R.A. 01^h 17^m 18^s 3°20′ N. $S_{85} = 25(12)$

Sources (Cambridge aperture synthesis; Bennett, personal communication)

A	01^h 15^m 44^s.5	2°45′	N.	$S_{178} = 10$
B	01^h 18^m 26^s.6	3°34′.7	N.	6
C	01^h 20^m 19^s.7	3°21′.3	N.	2·5

This region was not observed with the Parkes telescope. However, the 85 Mc/s interferometer records show faint sources at approximate right ascensions 01^h 15$\frac{1}{4}^m$ and 01^h 19^m. The former is evidently source A; its diameter is $<30''$ and its S_{85} is 14 ± 4. The latter is a combination of B and C, with an estimated S_{85} of 11. Fortuitously, the total S_{85} is exactly 25.

MSH 01−2*17* R.A. 01^h 48^m 42^s 29°44′ S. $S_{85} = 47(32)$

1400 and 408 Mc/s observations

Sources	A	01^h 48^m 18^s	29°48′	S.	$S_{1400} = 3{\cdot}37$
	B	01^h 49^m 49^s	$29°57\frac{1}{2}'$	S.	1·25
and possibly	C	01^h 50^m 11^s	29°44′	S.	0·23

The MSH position lies between sources A and B, but the peak flux density observed with a 50′ beam should be only 10% below the total. The total S_{85} obtained by extrapolating through the total flux density at 408 Mc/s is in fair agreement with the MSH value and corresponds to quite a normal spectral index (Table 1).

No galaxies brighter than 19^m were found near either A or B.

MSH 08+0*3*	R.A.	$08^h\ 19^m\ 48^s$	06°07′	N.	$S_{85} = 94(45)$
	1400 and 408 Mc/s observations				
Sources	A (3C198)	$08^h\ 19^m\ 54^s$	06°06′.4	N.	$S_{1400} = 1\cdot94$
and much fainter sources, all >30′ away:					
	B	$08^h\ 18^m\ 24^s$	05°06′	N.	0·54
	C	$08^h\ 19^m\ 52^s$	05°25′	N.	0·28
	D	$08^h\ 20^m\ 36^s$	07°07′	N.	0·31
	E	$08^h\ 21^m\ 51^s$	06°38′	N.	0·25

The MSH position is extremely close to source A (3C198). The spectrum of this source is given in CKL; its S_{85} is 38, and the other sources contribute very little to the peak flux density observed with a 50′ beam. The total S_{85} shown in brackets in Table 1, 51 and 66, are computed by assuming that B, C, D, etc. contribute $S_{1400} = 1\cdot5$ and have spectral indices 0·75 and 1·05 respectively. Bennett (personal communication) finds a diffuse source which presumably includes B, C, . . . but has a larger S_{178} than could reasonably be attributed to these sources. The 408 Mc/s contours show an elongated source extending from A through B as far as 4° N.

Minkowski has identified 3C198 with a 17^m elliptical galaxy. Sources B and D also lie in regions rich in 18–19^m galaxies, but their positions are not sufficiently precise to show whether they should be identified with any of these galaxies.

MSH 10+0*10*	R.A.	$10^h\ 54^m\ 00^s$	02°09′	N.	$S_{85} = 18(10)$

Observations from other programs: 1400 Mc/s R.A. scans (Cooper and Milne, unpublished data), 408 Mc/s (Scheuer), 178 Mc/s aperture synthesis (Cambridge).

Sources	A	$10^h\ 55^m\ 55^s \pm 8$	$01°49' \pm 2$	N.	$S_{1400} = 3\cdot6$
					$S_{408} = 5$
	B	$10^h\ 52^m\ 35^s \pm 20$	$02°21' \pm 5$	N.	$S_{1400} = 0\cdot78$
		$10^h\ 52^m\ 44^s$	02°26′	N.	$S_{178} = 4\cdot0$
	C	$10^h\ 52^m\ 50^s \pm 8$	$01°38' \pm 2$	N.	$S_{1400} = 0\cdot62$

Source A is the dominant source at 1400 Mc/s, but has an unusually flat spectrum; the extrapolated S_{85} of A is comparable with that of B. No spectral information is available on C, and the total S_{85} in Table 1 are computed assuming spectral indices of 0·75 and 1·05 for this source. The 85 Mc/s interferometer shows a source at the R.A. of B and C, but source A is not observed and presumably extends over more than 1′ in declination. The relative positions and the satisfactory agreement in flux density indicate that MSH 10+0*10* is simply a blend of sources A, B, and C.

There are several bright galaxies around source A, but the positional accuracy is not good enough to suggest an identification.

MSH 12−1*2*	R.A.	$12^h\ 02^m\ 24^s$	17°39′	S.	$S_{85} = 36(12)$
	1400 and 408 Mc/s observations				
Sources	A	$12^h\ 05^m\ 18^s$	16°48′	S.	$S_{1400} = 0\cdot62$
	B	$12^h\ 04^m\ 40^s$	16°36′	S.	0·31
	C	$12^h\ 06^m\ 03^s$	17°22′	S.	0·2
	D	$12^h\ 05^m\ 23^s$	17°59′	S.	0·2
	E	$12^h\ 04^m\ 43^s$	17°42′	S.	0·3
The source at		$11^h\ 59^m\ 35^s$	18°37′.5	S.	0·65

is listed separately as MSH 11−1*18*.

A and B are very close together, and could be one elongated source. The positions of C, D, E are uncertain by 2 or 3′ arc. Separate 408 Mc/s observations show a source at approximate position

$$12^{h}\,05^{m}\,20^{s} \quad 16°44' \quad S. \quad S_{408} = 2\cdot67$$

which must represent sources A and B. The 85 Mc/s interferometer also shows an object at $12^{h}\,05^{m}$ with an apparent flux density of 10, which is roughly the flux one would expect if sources A to E are all point sources and appear in the interference pattern with random relative phases. The extrapolated S_{85} of A plus B is 10; the total S_{85} given in Table 1, 16 and 23, are computed assuming that C, D, E have spectral indices 0·75 and 1·05 respectively.

The inadequate flux densities of sources A to E, combined with the difference of 3^{m} in R.A., show that the discrete sources cannot account for MSH 12−*12*. The extended source cannot be discerned on a 408 Mc/s contours chart. The observations with the Mills Cross could perhaps have been affected by side-lobe responses from Hercules A.

MSH 13+*06*	R.A.	$13^{h}\,18^{m}\,42^{s}$	01°00′ N.	$S_{85} = 37(20)$
	1400 and 408 Mc/s observations			
Sources	A	$13^{h}\,18^{m}\,03^{s}$	01°56′ N.	$S_{1400} = 0\cdot47$
	B	$13^{h}\,17^{m}\,03^{s}$	01°49′ N.	0·54
	C	$13^{h}\,18^{m}\,23^{s}$	01°34′ N.	0·31
	D	$13^{h}\,16^{m}\,43^{s}$	01°11′ N.	0·15
	E	$13^{h}\,14^{m}\,21^{s}$	00°40′ N.	0·31
	F	$13^{h}\,21^{m}\,43^{s}$	00°40′ N.	0·23
	G	$13^{h}\,20^{m}\,43^{s}$	00°42′ N.	0·23

(All positions ±3′ arc)

408 Mc/s records show a source at approximately

$$13^{h}\,18^{m} \quad 01°50' \quad N. \quad S_{408} = 2\cdot5,$$

which includes A, B, and probably C. Bennett finds "one small diameter source 2 minutes late", with $S_{178} = 5$; because of the discrepancy in R.A. this cannot be connected with sources A, B, and C. The total flux densities in Table 1 include all the sources A to G; the peak flux densities are those for the group A, B, C. Since several sources make comparable contributions to the total flux density, it is very unlikely that the mean spectral index should have an extreme value, and one must conclude that the discrete sources do not account for the flux densities given in MSH. The only possibility of the side-lobe effects on the MSH observations would appear to come from Centaurus A ($13^{h}\,23^{m}$ 43° S).

MSH 14−*14*	R.A.	$14^{h}\,16^{m}\,00^{s}$	15°47′ S.	$S_{85} = 25(16)$
	1400 and 408 Mc/s observations			
Sources	A	$14^{h}\,16^{m}\,23^{s}$	15°43′ S.	$S_{1400} = 1\cdot63$
	B	$14^{h}\,14^{m}\,20^{s}$	15°57′ S.	0·23
and possibly	C	$14^{h}\,12^{m}\,50^{s}$	14°50′ S.	0·93

The MSH position is very close to source A, which suggests that C should not be regarded as part of the extended source. Kellerman and Harris's $S_{960} = 2\cdot5$

must refer to source A (plus a small contribution from B), and 408 Mc/s records show a source near A with $S_{408} = 4$. Extrapolating the spectrum of A gives $S_{85} = 12$; thus, to account for the total flux density, as well as for the extension, of the MSH source, we must assume that C does form part of it. The 85 Mc/s interferometer shows nothing at the position of A (resolved ?), but there is a faint source at $14^h\,14^m$, $14\frac{1}{2}° \pm 1°$ S., estimated $S_{85} = 7$, which is probably C. Allowing a nominal 1 unit for B, we obtain the total $S_{85} = 20$ shown in Table 1. Thus we can obtain fair agreement in flux density (by including C), or in position (by excluding C), though not in both.

MSH 14−*16* R.A. $14^h\,20^m\,24^s$ 14°29′ S. $S_{85} = 19(12)$

1400 and 408 Mc/s observations

Sources	A	$14^h\,17^m\,20^s$	14°13′ S.	$S_{1400} = 0{\cdot}78$
	B	$14^h\,19^m\,31^s$	14°16½′ S.	0·62
	C	$14^h\,21^m\,35^s$	13°54′ S.	0·31

D A patch of emission at $14^h\,22^m$, 15° S., perhaps three unresolved sources, which, together with the source at $14^h\,23^m$, 15°45′ S., contributes. $S_{1400} = 1{\cdot}4$

The source A has a northward extension.

It is not at all clear what should be included in MSH 14−*16*. By including all the above sources, we obtain a collection of objects whose centroid is near the MSH position, and whose extrapolated S_{85} is in tolerable agreement with that given in MSH. On the 408 Mc/s contour chart, both 14−*14* and 14−*16* lie on a ridge 2° wide extending from $14^h\,20^m$, 2° S. to $14^h\,16^m$ 18° S.

MSH 14+0*10* R.A. $14^h\,35^m\,30^s$ 03°36′ N. $S_{85} = 35(23)$

1400 and 408 Mc/s observations

Sources	A	$14^h\,34^m\,20^s$	03°39′ N.	$S_{1400} = 2{\cdot}86$
	B	$14^h\,35^m\,50^s$	03°53′ N.	0·62

A and B are not resolved on the 408 Mc/s records but are observed separately at 178 Mc/s (aperture synthesis; Bennett, personal communication). From the spectra of A and B we obtain a total S_{85} of only 17. The source

C $14^h\,36^m\,29^s$ 04°43′ N. $S_{1400} = 0{\cdot}47$

is more than 1° distant from A and from the MSH position, and it probably contributes little to S_{85}, for it was not found at 408 Mc/s or in the 178 Mc/s list.

Identification

A.—An independent position measurement by Bolton and Gardner (personal communication) gave $14^h\,34^m\,24^s$, 03°36′ N. No galaxies were found on sky survey prints near either this position, or that given above, or between them. The nearest galaxy is about 19^m and 3′ following, and is outside the limits of error in right ascension.

B.—The radio position of source B lies in a compact cluster (2 mm diam. on print) of faint (? 21^m) galaxies. Very close to the radio position (about 1′ Nf) are:

(i) a spiral galaxy, 18–19^m, seen well on the E print but faint on the O print.

(ii) a curious ring-shaped object, seen on the O print only; this is almost certainly a plate defect.

The cluster is the core of Zwicky's (Zwicky, Herzog, and Wild 1961)

No. 8 $14^{\mathrm{h}}\,35^{\mathrm{m}}\!.8$ 03°55′ N.,

compact, 96 members, 1·2 cm diameter, very distant (i.e. $c\Delta\lambda/\lambda \simeq 50\,000$ km/s).

MSH 15−*16* R.A. $15^{\mathrm{h}}\,10^{\mathrm{m}}\,36^{\mathrm{s}}$ 19°23′ S. $S_{85} = 37(22)$
1400 and 408 Mc/s observations.

The source at $15^{\mathrm{h}}\,05^{\mathrm{m}}\,45^{\mathrm{s}}$, 20°03′ S. is MSH 15−*24*. Despite the poor positional agreement, MSH 15−*16* should most probably be associated with the bright area, about 1° by 1°, indicated by vertical lines in Figure 1. This area has a central concentration, or perhaps a superposed source of small diameter, at $15^{\mathrm{h}}\,12^{\mathrm{m}}\,45^{\mathrm{s}}$, 19°30′ S., with $S_{1400} \simeq 1 \cdot 0$; the total flux density is difficult to estimate owing to the low surface brightness of most of the source; if our estimate of $S_{1400} = 3$ is correct, a spectral index of 0·9 would be required to account for the S_{85} from MSH.

MSH 17+0*1* R.A. $17^{\mathrm{h}}\,03^{\mathrm{m}}\,12^{\mathrm{s}}$ 09°16′ N. $S_{85} = 58(37)$
1400 Mc/s observations only.

We searched for this source by scanning in R.A. from $16^{\mathrm{h}}\,40^{\mathrm{m}}$ to $17^{\mathrm{h}}\,20^{\mathrm{m}}$, at intervals of 1° in declination from 07° N. to 14° N. There is much large-scale irregular structure throughout the region; presumably MSH 17+0*1* represents some portion of this structure, but on the 1400 Mc/s records there is no single outstanding feature at the MSH position. Bennett finds a bright region 2° by 3° with a total flux density $S_{178} = 300$, which is both larger and more intense than the MSH source.

MSH 18−4*1* R.A. $18^{\mathrm{h}}\,04^{\mathrm{m}}\,36^{\mathrm{s}}$ 45°28′ S. $S_{85} = 58(34)$
1400 and 408 Mc/s observations

Source A $18^{\mathrm{h}}\,06^{\mathrm{m}}\,09^{\mathrm{s}}$ 45°54′ S. $S_{1400} = 1 \cdot 9$

This is the only "extended source" with galactic latitude below 20° observed in the present program. In addition to the sources observed at 1400 Mc/s, Figure 2 shows a sketch of the 408 Mc/s contours. The small-diameter source A is perched on the edge of a "precipice" in the galactic brightness distribution (which also appears quite clearly on the 1400 Mc/s records), and Figure 2 shows how smoothing with the 408 Mc/s aerial beam (which is similar to that of the Mills Cross) gives the impression of an extended source. However, in this complex situation it is impossible to guess what "total" and "peak" flux densities should be attached to the extended source.

MSH 20+0*12* R.A. $20^{\mathrm{h}}\,55^{\mathrm{m}}\,24^{\mathrm{s}}$ 00°42′ N. $S_{85} = 78(17)$
1400 and 408 Mc/s observations.

Each of the six discrete sources shown in Figure 2 has $S_{1400} \simeq 0 \cdot 5$. The significant feature is the very large emitting region indicated by vertical lines in Figure 2, with a surface brightness of about 0·25°K at 1400 Mc/s, rising to 0·35 or 0·4°K (cross-hatched). For this region we estimate that $S_{1400} = 15$. Bennett finds the same region at 178 Mc/s—5^{m} late, extending over $2\frac{1}{2}$° of R.A.,—with

$S_{178} \simeq 60$. These flux densities are not well defined, but are quite consistent with the MSH value, and with the spectral index of about 0·5 usually associated with galactic radiation. The size of the emitting region is also consistent with the large ratio of total: peak flux density given in MSH. The positional agreement is perhaps less satisfactory.

MSH 21−*06*	R.A.	21^h 13^m 42^s	02°47′ S.	$S_{85} = 21(11)$
	1400 and 408 Mc/s observations			
Sources	A	21^h 16^m 06^s	03°22′ S.	$S_{1400} = 0{\cdot}62$
	B	21^h 11^m 30^s	02°45′ S.	0·5
	C	21^h 13^m 12^s	03°14′ S.	0·27

Source A is included in the Cambridge 178 Mc/s fan-beam and interferometer observations (Bennett, personal communication); it is partially resolved at 465 λ spacing. Its spectrum is unusually steep; according to the spectrum drawn in Figure 2, $S_{85} = 17$. Source B is a faint patch of emission extended N.–S. There is no difficulty in accounting for the flux density reported by MSH, assuming quite normal spectra for B and C, but one might expect the MSH position to lie closer to source A.

MSH 21+*05*	R.A.	21^h 27^m 06^s	01°06′ N.	$S_{85} = 50(19)$
	1400 Mc/s declination scans only			
Source	A	21^h 26^m 17^s	01°05′ N.	$S_{1400} = 0{\cdot}7$,

the two faint sources shown in Figure 2 ($S_{1400} = 0{\cdot}3$ and $0{\cdot}2$), and perhaps 2 or 3 still fainter sources.

If the greatest possible allowance is made for the contributions of the faint sources, the total S_{1400} is 1·8, and, even if we assume an improbably large mean spectral index for the sources, the resulting S_{85} is well below the MSH value. Bennett finds a bright region 5^m preceding the MSH position, which extends over 3° in R.A. and has $S_{178} \simeq 100$. Side-lobe effects cannot be expected to have affected the MSH observations of this source.

MSH 23+*03*	R.A.	23^h 09^m 36^s	09°16′ N.	$S_{85} = 38(22)$
	1400 and 400 Mc/s observations			
Sources	A			
	(3C456)	23^h 09^m 57^s	09°02½′ N.	$S_{1400} = 2{\cdot}75$
	B	23^h 06^m 07^s	09°34′ N.	0·52
	C	23^h 08^m 47^s	09°52′ N.	0·75
	D	23^h 13^m 41^s	10°13′ N.	1·08

and fainter sources (Fig. 1).

The MSH position is close to the principal source A, whose spectrum (Fig. 2, mostly from CKL) gives $S_{85} = 24$. Thus source A accounts for the peak flux density reported by MSH. Sources B, C, D are further than one beamwidth of the Mills Cross from A, but they are not listed separately in MSH and may account for the "extended" part of MSH 23+*03*. The 408 Mc/s observations indicate that the spectral indices of these sources are about 0·5, and together they contribute 10 to 15 units to S_{85}. Individually, B, C, and D are probably below the limit of the MSH catalogue.

IV. Conclusion

We have examined the regions surrounding 20 of the "extended sources" of Mills, Slee, and Hill with a 14′ arc pencil beam. In nearly every case, we have found either a group of sources of small diameter or a broad patch of emission not resolved into sources. The present paper simply shows the observations; the results will be discussed in a separate paper.

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