NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, West Virginia

A SURVEY OF RADIO SOURCES AND THE POSSIBILITY OF OBSERVING THEM WITH THE NRAO INTERFEROMETER

Edward W. Ng and Nigel J. Keen

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Introduction

This report is mainly the result of work by Edward W. Ng, while working as a summer student at NRAO (1963). Since the NRAO interferometer should be in operation in the near future, it was felt that a review of previous work on radio sources would give some indication of the most fruitful areas of investigation with our interferometer.

The first part of this report is concerned with twelve well-investigated discrete sources. The second part considers other sources which appear in the catalogs, and considers the sources which should give measurable signals and those which should not. The third part considers very briefly a few miscellaneous sources.

The extrapolation of much of the data obtained from the various authors has required some speculation, especially when considering the weaker sources.

For the sake of brevity, this report has been left in note form.

Contents

In the following reports we will frequently refer to certain quantities. Therefore, we first define them with symbols for the sake of convenience.

S = flux density

or s = spacing of interferometric element, in units of

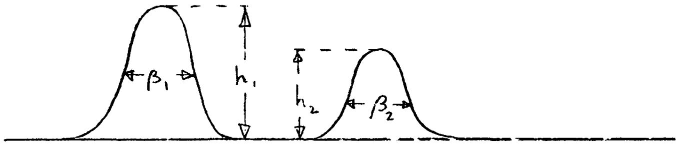
λ = wavelength at which observations are made

ν = frequency

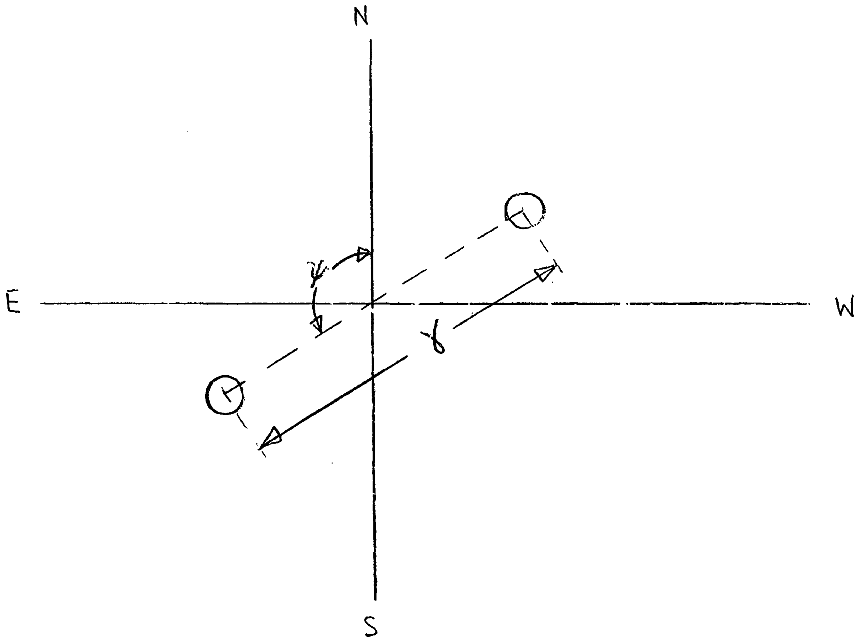
β = half-power angular diameter (for a single source).

For a double source, refer to the following diagrams:

Brightness distribution



Source orientation



β_1 and β_2 are the half-power angular diameters. In the case $\beta_1 = \beta_2$, we just call it β.

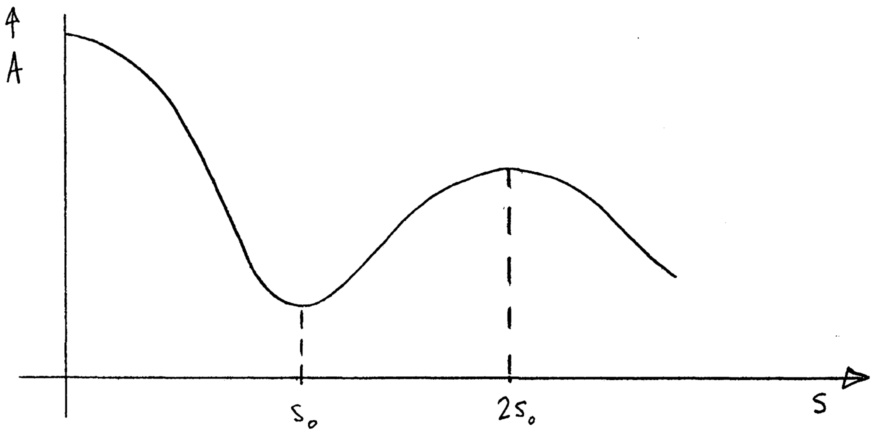
ψ = position angle of major axis of source

p = position angle of fringes (e.g., EW is p = 90°)

r = ratio of intensities of 2 components.

One dimensional visibility curve.

This term has been used by Lequeux for the curve of normalized amplitude of the Fourier transform of the brightness distribution. It will also be called the A curve.



s_0 = spacing where A is at first minimum

$2s_0$ = spacing where A is a first maximum

To "see" a particular projection of the source distribution.

The angle p will be mentioned frequently. It is given by the following equation.

$$\tan p = \frac{\sin a \cos h - \cos a \sin \phi \sin h}{\sin a \sin \delta \sin h + \cos a (\cos \phi \cos \delta + \sin \phi \sin \delta \cos h)} \tag{1}$$

where

a = azimuth of baseline

h = hour angle of source

δ = declination

ϕ = geographical latitude of observing station.

In the case of the NRAO interferometer

$$a = 63^\circ \quad \phi = 38^\circ\, 26'$$

Then

$$\tan p = \frac{A \cos h - BC \sin h}{A \sin \delta \sin h + B\,(D \cos \delta + c \sin \delta \cos h)} \tag{2}$$

where

$$A = \sin 63^\circ$$

$$B = \cos 63^\circ$$

$$C = \sin 38^\circ\, 26'$$

$$D = \cos 38^\circ\, 26'$$

In order to "see" the distribution of the source along a particular direction with the NRAO interferometer, we put in δ and p into (2) and solve for h. Then we know at which hour angle (and hence at which sidereal time) we should observe the source.

Example. Assume that we wish to observe the NS distribution of Cygnus A using the NRAO interferometer. For NS, $p = 0^\circ$. Equation (2) simplifies to $A \cos h - BC \sin h = 0$, or $\tan h = \frac{A}{BC}$.

This gives $h \approx 72^\circ\, 26' \approx 4^h\, 50^m$. Taking the right ascension of Cygnus A to be $19^h\, 58^m$ (from revised 3C), sidereal time $\approx 4^h\, 50^m + 19^h\, 58^m = 0^h\, 48^m$. We can "see" the NS distribution of Cygnus A at

$$\mathrm{HA} \approx 4^h\, 50^m$$

$$\text{sidereal time} \approx 0^h\, 48^m$$

$$\delta \approx 40^\circ\, 36'$$

Of course, we also have to worry whether at this HA the source is below our horizon. This can be easily achieved by the following equation:

$$\cos h_o = -\tan \phi \tan \delta \tag{3}$$

where h_o is the HA of the source at rising or setting. (For derivation of (3) see, e.g., M. Davidson, Mathematical Astronomy, page 75.)

In our example, $h_o = \cos^{-1} (\tan 38^\circ\, 26' \,.\, \tan 40^\circ\, 36') \approx 132^\circ\, 51' > h$, Cygnus A is above our horizon at that HA.

For-shortening of baseline with HA.

At h = 72° (or any h), the baseline is effectively forshortened by a factor of cos Θ where

$$\Theta = \sin^{-1} \cos a\,(\cos\phi \sin\delta - \sin\phi \cos\delta \cos h) - \sin a \cos\delta \sin h \qquad (4)$$

in our case.

$$\Theta = \sin^{-1} B(D \sin 40^\circ 36' - C \cos 40^\circ 36' \cos 72^\circ 26') - A \cos 40^\circ 36' \sin 72^\circ 26'$$

$$\approx \sin^{-1}(-0.4784)$$

$$\approx -28^\circ 35'$$

and $\cos\Theta \approx 0.878$

effective NRAO baselines become

10,560 λ instead of 12,000 λ
13,200 λ instead of 15,000 λ
15,840 λ instead of 18,000 λ
18,840 λ instead of 21,000 λ
21,120 λ instead of 24,000 λ
23,760 λ instead of 27,000 λ

ORION NEBULA, 3C 145, NGC 1976, M 42

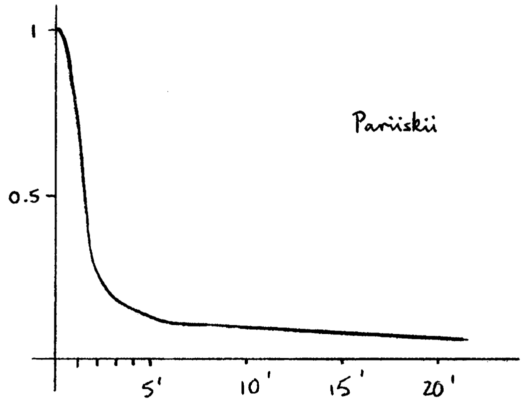
The results of different groups are summarized as follows:

ν Mc	Observing Group	Ref.	β_{EW} x β_{NS}	Instrument	Max. Spacing	Half-power beamwidth
960	Cal Tech	MM	4.1' x 4.8'	Interferometer	1600 λ	
1420	Sydney	T	3' x --	Christensen Cross		
1420	Nancay	L	4' x --	Interferometer	7000 λ	
2700	Bonn	W	5' x 5'	Pencil Beam		
2930	U.S. Naval	SN	7' x 7'	Pencil Beam		18.2' x 18.6'
3300	Stanford	Li	3.5' x --	Fan Beam		
3600	Pulkovo	P	2.2' x 2.2'	Fan Beam		3' x [illegible]
* 7600	NRAO		3.7' x 3.9'	Pencil Beam		6.3' x 6.3'
8000	NRAO	M	3.2' x --	Pencil Beam		6' x 6'
9400	Lebedev	K	5.1' x 5.1'	Pencil Beam		6.4' x 6.4'
16,700	Ann Arbor	B	4.0' x 4.1'	Pencil Beam		3' x 3'

MM = Maltby and Moffet (1962) Ap. J. Sup. 7, 93
T = Twiss, et al (1960) Observatory 80, 153
L = Lequeux (1962) Ann d'As. 24, 221
W = Westerhout, et al (1960)
SN = Sloanaker and Nichols (1960) Ast. J. 65, 109
Li = Little (1961) Stanford Rad. Ast. Inst. Pub. No. 16
P = Pariiskii (1960) Soviet Ast. 5, 611
M = Menon (1961) NRAO Pub. No. 1
K = Karachun, et al, Sov. Ast. 5, 59
B = Barrett, Ap. J. 134, 945
* Not yet published.

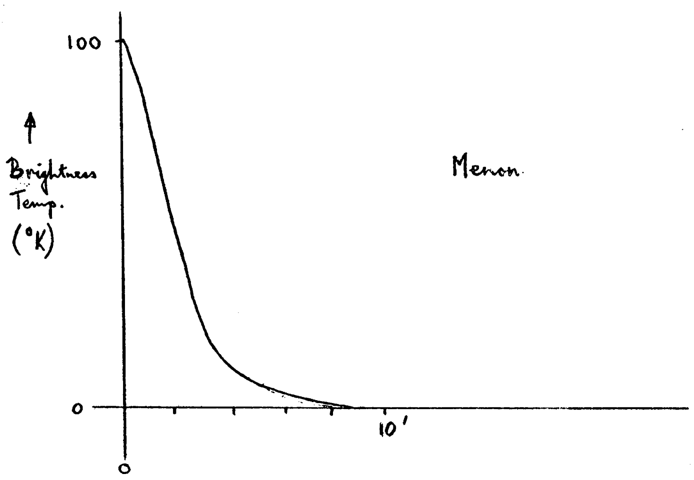
1. Models

(i) Pariiskii obtained a brightness distribution with a half-power beam width about 2.2'. Based on this he derived a model consisting of a mass of ionized gas within a sphere of 10' of about 115 M_o. The central concentration has a diameter of 3', beyond 10' an envelope < 40 M_o.

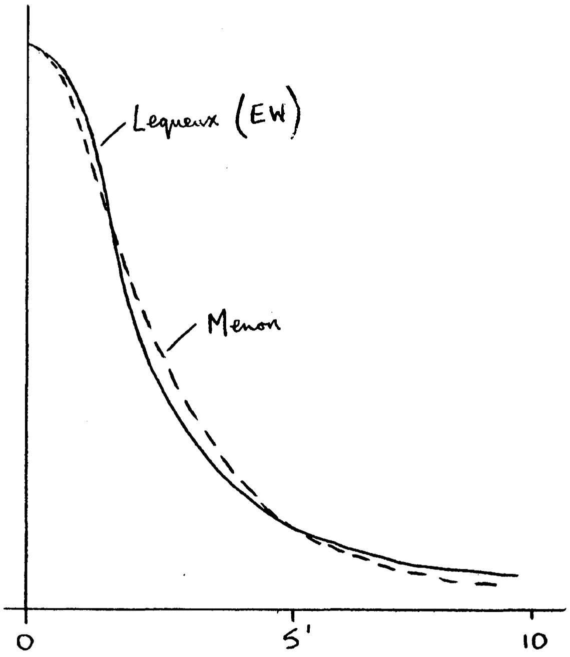


T_B vs. angular distance from center of nebula

(ii) Menon's model has a bigger central concentration than Pariiskii's, about 4' - 5'. Total mass up to about 10' is 100 M_o for this model. Menon's brightness distribution is shown:



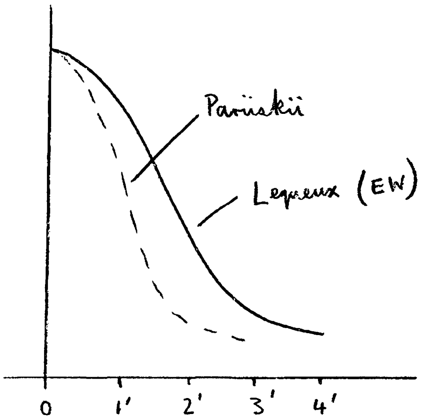
(iii) Lequeux found his observation agrees very well with the curve calculated for 1400 Mc from Menon's, except for a small part. (See figure below.)



Comparison between EW profiles of the Orion Nebula, as measured by Lequeux and Menon

(iv) Lequeux found disagreement with Pariiskii in the EW profile. He gave a possible explanation as follows:

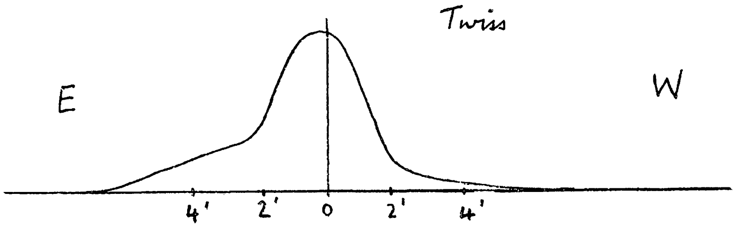
> The discrepancy is considerable. This arises because Pariiskii has corrected his readings for the antenna beamwidth (~ 3 min), which introduces errors, especially when the angular dimensions of the source are comparable with the beamwidth.



Comparison of the EW profile of the Orion Nebula at 21 cm (corrected for self-absorption) with the EW profile obtained at 8.3 cm at Poulkovo

2. Asymmetry

(i) Twiss, et al, found the existence of asymmetry in EW, with E having higher intensity than W. Menon also observed some asymmetry on his 3.75 cm isophotes:

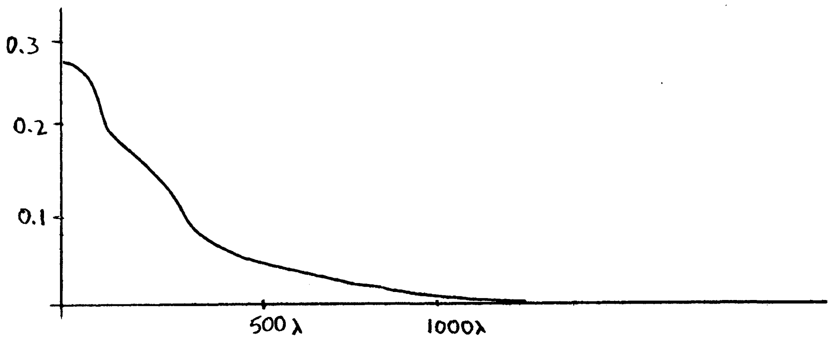


One-dimensional brightness distribution over Orion Nebula

(ii) Maltby and Moffet observed asymmetry in NS, with central concentration extended toward the south.

3. Fine Structure

(i) For p = 90° (i.e., EW), the A curve dies out at 1600 λ for both MM and L data, though Lequeux's observations are up to 7000 λ (i.e., A ≈ 0 from 1600 λ to 7000 λ).



Visibility curve by Lequeux

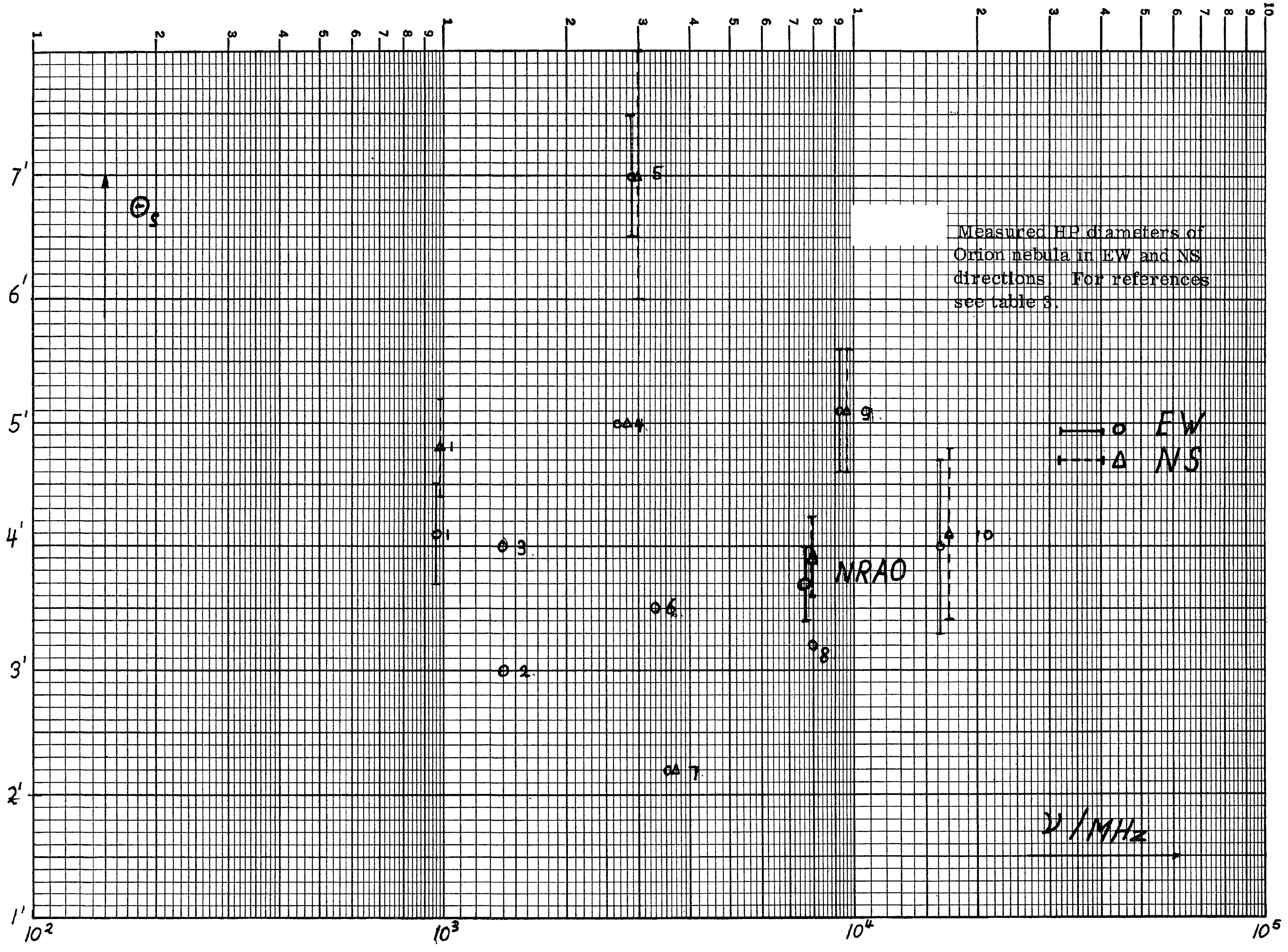
Allen, et al, got no information at 32,000 λ and 61,000 λ. For 2200 λ and 9700 λ their results are

$$A_{2200} < 0.2 \qquad\qquad A_{9700} < 0.1$$

which are effectively zero. It appears that the source is single in the direction EW, and if there is fine structure, it can only be small relative to existing measurement. Hence it appears that NRAO interferometry will not help much in this direction.

(ii) For p = 90° (NS) the A curve also dies out at 1600 λ. This seems to help models with spherical symmetry. But one cannot be sure the source is single in this direction, because only MM did interferometer work in the NS direction, and they only go out to 1600 λ. Beyond this point, we are not sure if A = 0 all the way up to 12,000 λ.

(iii) For p = 30° and p = 150°, MM's results also show that A curve reaches zero at 1600 λ, which infers that the source also has a gaussian brightness distribution in the NS direction and little or no fine structure.



Measured HP diameters of Orion nebula in EW and NS directions. For references see table 3.

CYGNUS A, 3C 405

The results of different observers are summarized.

Mc	Observing Group	Ref.	γ	β	ψ	h_1/h_2	Instrument	Max. spacing
127	Jodrell Bank	JL	81"	52"	97°	1.2 ± 0.1	Interferometer	3000 λ
960	Cal Tech	MM	95"	42"	109°	1.2 ± 0.3	Interferometer	1600 λ
1420	Nancay	L	100"	25"	109°	1.2	Interferometer	7000 λ
1420	Sydney	T	88"(EW)	---	---	---	Christensen C.	1700 λ
2800	Jodrell Bank	R	104"	---	109°	---	Interferometer	1700 λ
3292	Stanford	STB		See page 17 for model.				

JL = Jennison and Latham (1959) MN 119:174

MM = Maltby and Moffett (1962) Ap. J. Sup. 7:93

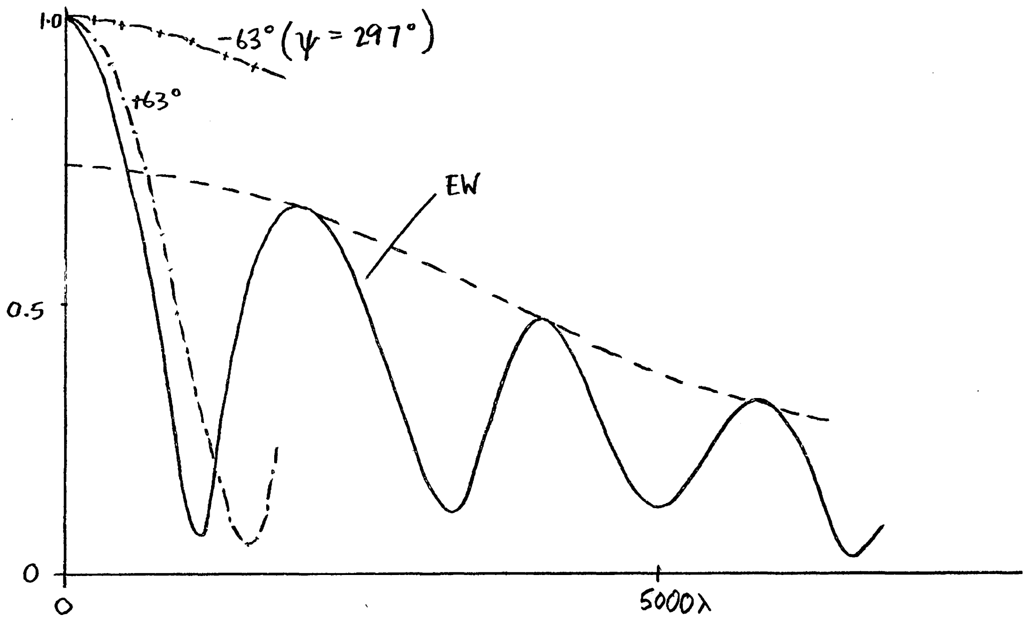
L = Lequeux (1962) Ann. d'As. 24:221

T = Twiss, et al (1960) Observatory 80:153

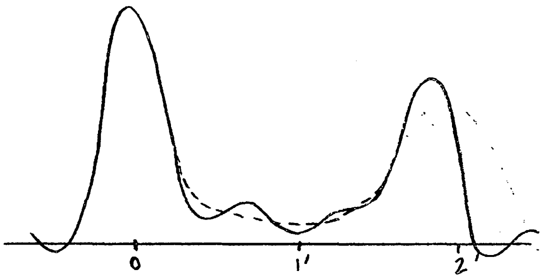
R = Rowson (1959) MN 119:26

STB = Swarup, et al (1963) Ap. J. 138:305

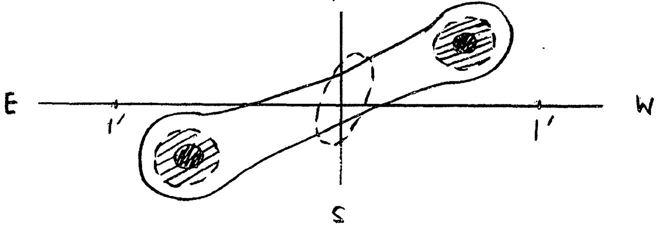
CKL = Conway, Kellerman and Long (1963) MN 125, 261



Visibility curves of Cygnus A on EW baseline, and for position angles +63° and -63°
[Lequeux]



EW profile of Cygnus A
[Lequeux]



The structure of Cygnus A. At the center, the optical model.
[Lequeux]

1. Three groups did phase measurements. According to results of JL and T, the stronger component is toward the West. But, according to MM's results, it is toward the East. This disagreement is to be settled by further phase measurements (MM, p. 157).

2. From the fact that the "pseudo-period" of the A curve decreases with increasing spacing, L deduces that the brightness distribution of each component has a steeper exterior slope than interior. This phenomenon is uniquely observed by L, because other observers do not go out as far in spacing.

3. From measurements with $p = 63°$ and $-63°$, L found that the width of each component along the minor axis is of the order of 18".

4. Using Rowson's data for 2800 Mc, we estimate β and h_1/h_2. Taking $A\ (2S_0)$ from his visibility curve to be 0.68 (see MN 119:32), one gets

$$\beta = 28'' \text{ for a double gaussian}$$

$$h_1/h_2 = 1.1 \pm 0.1$$

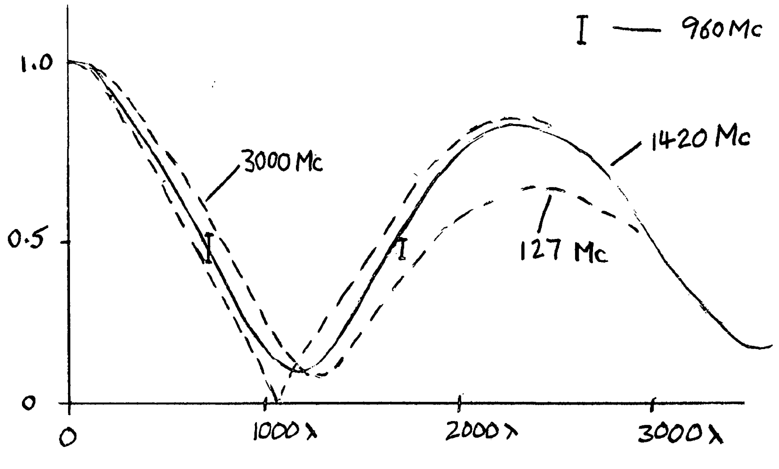
Thus a rough model at 2800 Mc would be $\gamma = 104''$, $\beta = 28''$, $\psi = 109°$, $h_1/h_2 = 1.1 \pm 0.1$. With such a model the visibility curve will be very small in EW at large spacings such as 12,000 - 27,000 λ. This is reinforced by data of Allen, et al, (MN 124:492) where

$$\left.\begin{aligned} A_{9700} &= 0.05 \\ A_{32,000} &= 0.01 \\ A_{61,000} &= 0.003 \end{aligned}\right\} \text{ in EW}$$

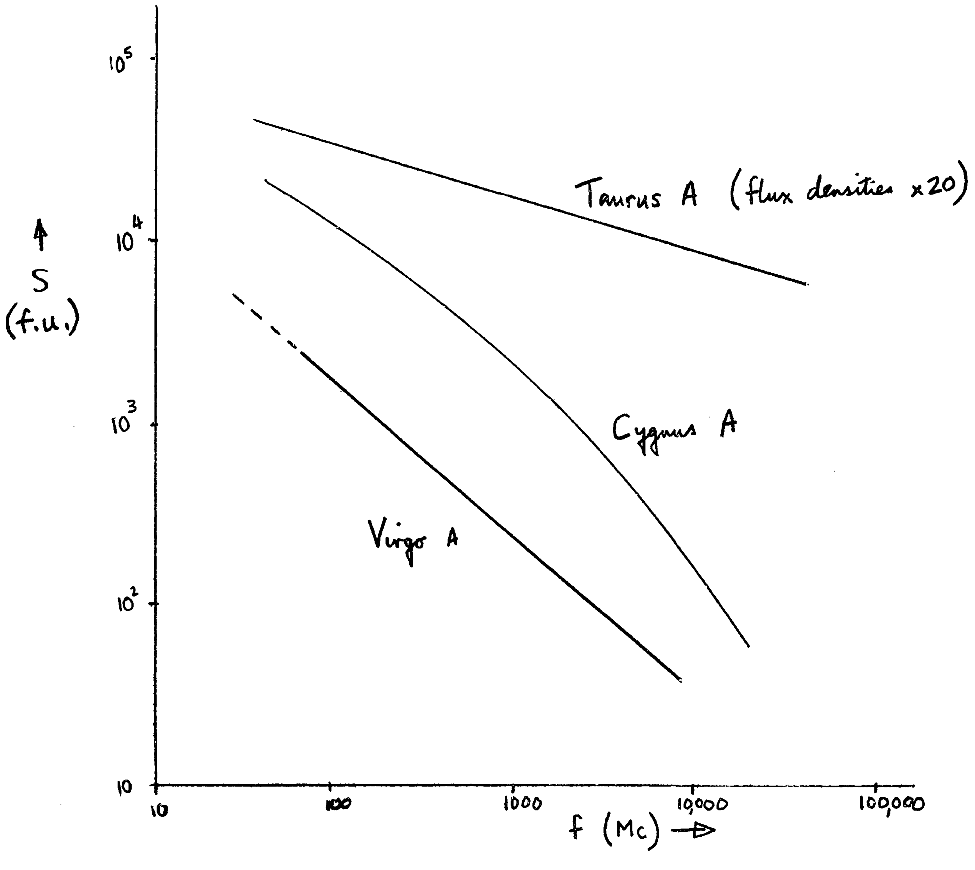
However, in NS the curve dies out much more slowly. Therefore, there may be some information at large spacing, near $p = 0°$.

5. The variation of brightness distribution with frequency in Cygnus A is well known. We see (i) as ν increases, S_0 decreases, and hence γ increases; (ii) as ν increases $A\ (2S_0)$ increases, and β decreases.

This means, according to Lequeux, that as ν increases the central part gets weaker in comparison with the extremities.



Visibility curves of Cygnus A at different frequencies
[Lequeux]



Spectra of Tau A, Cyg A, and Vir A based on flux densities relative to Cas A
[CKL]

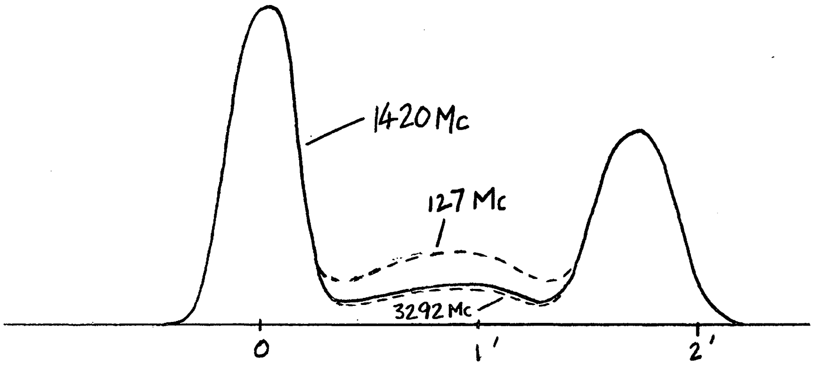
6. The spectrum of Cygnus A is shown in the model of Conway, et al (MN 125:269). The flux density at 2700 Mc is found to be 760 f.u. by Altenhoff, et al.

$\Delta\alpha$ is found to be 0.35, where they have defined

$\Delta\alpha = \alpha$ (spectral index) at 1000 Mc - α at 100 Mc

and where $\Delta\alpha$ gives a quantitative measure of the curvature of the spectrum.

7. In a recent study, Swarup, et al (Ap. J. 138:305) compared their grating interferometric results to those of Lequeux and Jennison, et al, and derived a "frequency-independent" model, in contrast to all previous suggestions of frequency-dependence. Their model is a triple gaussian one shown as follows:



Model of Cygnus A involving a wide central component. Based on a frequency independent spacing of 101" and interferometry of Lequeux and Jennison and Latham

DERIVED MODEL FOR CYGNUS A

Component	Relative Flux Density	Width to Half Power	Abscissa
1 --------	0.375	15"	0
2 --------	0.375	23"	101"
3 --------	0.25	78"	43"

The spacing between components 1 and 2 is taken as 101" and is not required to vary with frequency. Component 3 has a markedly different spectrum from that of 1 and 2, and is responsible for the apparent dependence of frequency on γ found by different observers. (See Swarup, et al, p. 307).

It is interesting to note a conclusion given by Swarup, et al, which we quote: "The present contribution, and a previous one by Little (1963, Ap. J. 137:164), shows that it is possible for the grating interferometer to resolve directly radio sources whose structure has previously been painstakingly built up from observations over a period of time with variable spacing interferometers."

TAURUS A, 3C 144, NGC 1952, M 1

Observations of β_{EW} and β_{NS} are given in the table on the following page.

Boishot, et al, performed occultation measurements at 170 Mc. Although no explicit results are given (Boishot, et al (1956), C. R. 242, 1849), Little estimated (Ap. J. 137 (1963), 171) $\beta_{EW} = 3.5'$ and $\beta_{NS} = 2.5'$. See Comment 1.

RESULTS OF ANGULAR SIZE OF TAURUS A AT VARIOUS FREQUENCIES

TABLE I

ν Mc/s	β'_{EW}	β'_{NS}	Method of Observing	Yr. of Publ.	Reference
38	6.0′		Occultation	1956	Costain, et al, MN 116, 380
81	2.5′		Occultation	1956	Costain, et al, MN 116, 380
86	8.5′	8.5′	Occultation	1958	Udaltsov, et al, Soviet Ast. 2
101	4.3′	4.2′	Interferometer	1953	Mills, Aust. J. of Physics 6, 452
214	5.0′ ± 0.6′		Interferometer	1954	Baldwin, Observatory 74, 120
400	3.5′		Occultation	1957	Seeger and Westerhout, B.A.N. 13, 313
960	3.3′	2.9′	Interferometer	1962	Maltby and Moffett, Ap. J. Sup. 7, 93
1420	3.2′	2.9′	Interferometer	1962	Lequeux, Ann d'As. 24, 221
1420	3.5′	3.5′	Interferometer	1962	Twiss, et al, Aust. J. Phys. 15, 378
2700	<1.5′	<1.5′	Pencil Beam	1960	Altenhoff, et al, U. of Bonn Pub. 59
2930	Not resolved		Pencil Beam	1960	Sloanaker and Nichols, Ap. J. 65, 109
3300	3.3′	3.9′	Fan Beam	1963	Little, Ap. J. 137, 164
* 7600	3.0′	2.6′	Pencil Beam	1963	Mezger and Stumpff
9400	3.4′		Pencil Beam	1961	Karachum, et al, Soviet Ast. 5, 59
9400	3.5′		Fan Beam	1960	Pariiskii, Izv. G.A.O. Pulkovo 21, 45
10,000	3.4′ ± 0.1′	>6.0′	Pencil Beam	1959	Apushkinskii, et al, Soviet Ast. 3, 717
16,700	4.1′ ± 0.5′	3.4′ ± 0.5′	Pencil Beam	1961	Barrett, Ap. J. 134, 945
37,500	4.5′		Pencil Beam	1961	Kuzmin, et al, Doklady 140, 81

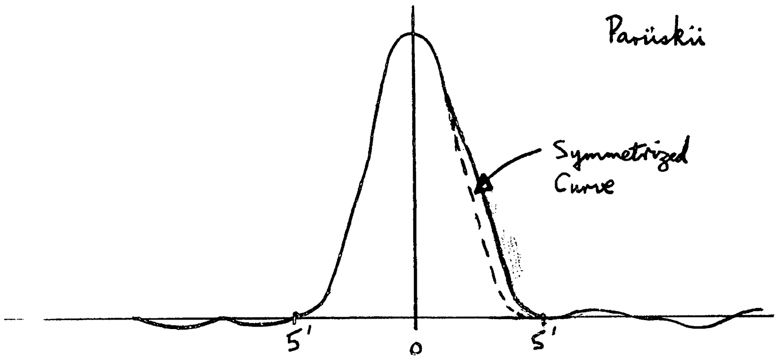
* Not published yet.

Comments:

1. Boishot, et al, also performed occultation measurements but the results are unreliable, according to Woltjer (B. A. N. 14:39 (1958)). We did not include their results in the table above.

2. The results of 81 Mc by Costain, et al, are from one set of observations from which they found two possible brightness distributions. Again, Woltjer remarked that the results by them are not reliable.

3. Pariiskii found EW asymmetry in the distribution. This is in qualitative agreement with occultation observations by Seeger and Westerhout. Lequeux also found the same phenomenon — West half is brighter than East.

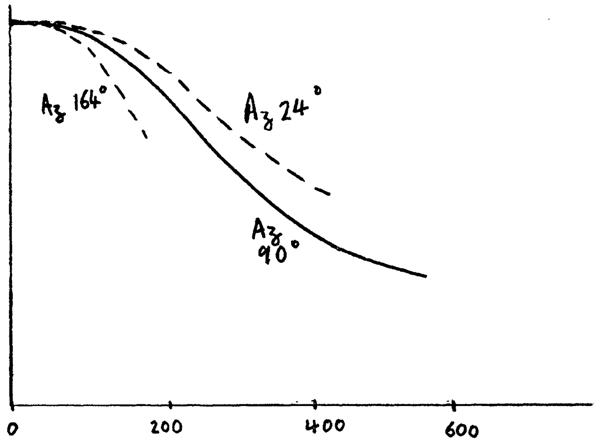


4. Maltby and Moffet describe this source as having "nearly gaussian distribution in p = 90° — less central concentration in p = 0° ".

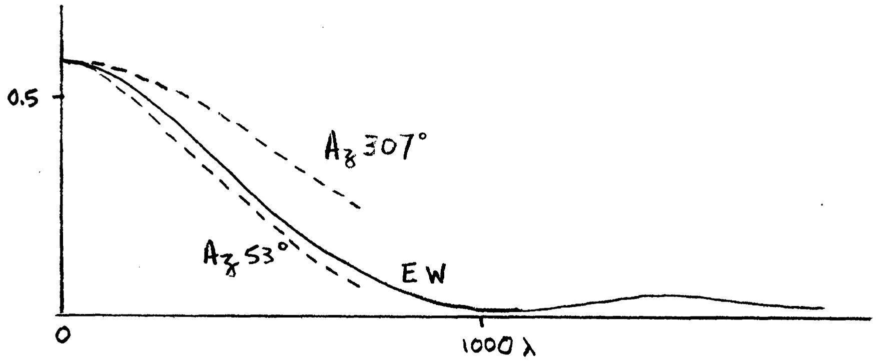
5. Lequeux did some work with p = 53° and 307°. From this he built a rough 2-dimensional model: "We assume that the isophotes are elliptical, and hence that the shape of the source is the same for all position angles. This appears justified by the visibility curves for oblique baselines." The position angle of the major axis of the ellipse is 126° in this model.

Mills did some work with p = 24° and 164°. He also derived an elliptical model of the same form as Lequeux, except the major axis has a position angle of 140°.

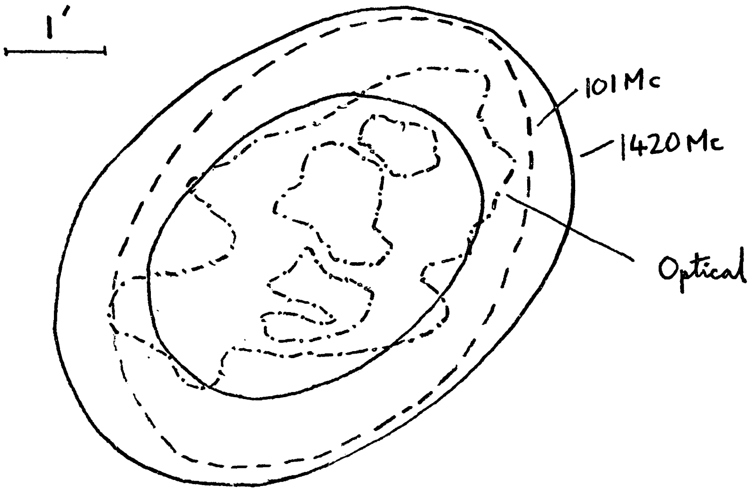
The visibility curves of the two observers are shown in the following figures. The models are shown with the optical isophotes.



Mills' visibility curves

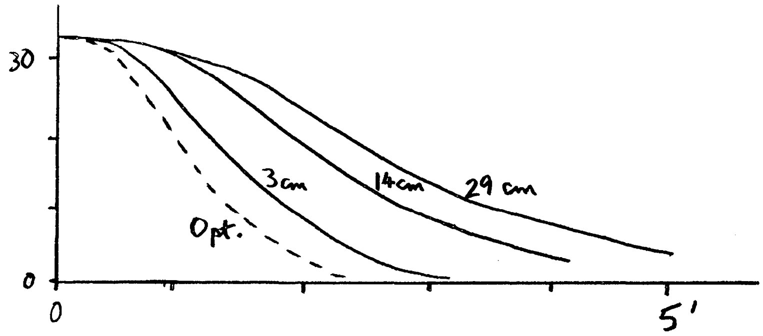


Lequeux's visibility curves

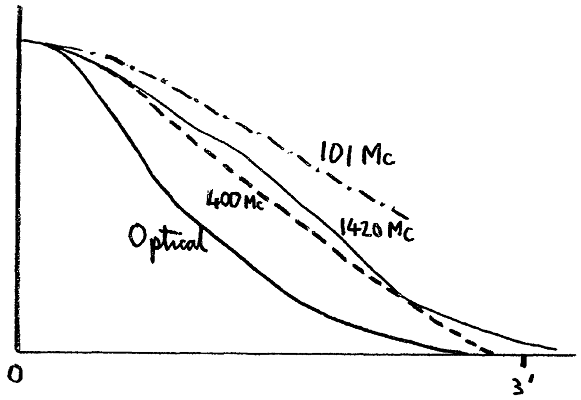


Comparison of isophotes of Taurus A at 101 and 1420 Mc
and for optical (continuum) frequencies
[Lequeux]

6. Pariiskii first compared the brightness distribution at different ν. It seemed to suggest that as ν decreases β decreases.



But one cannot be so sure when one compares the results by Lequeux, Seeger and Westerhout and Mills (see below).



EW profiles of Taurus A at different ν and in optical
continuum (symmetrized)
[Lequeux]

Lequeux mentioned that the results by Seeger and Westerhout are "rather inaccurate". But according to Westerhout (private communication), there is no ground to assume the work at Nancay was any more accurate than this. Furthermore, one can see that the Cal Tech distribution curve would fall somewhere between the optical curve and the 400 Mc (very near to the 400 Mc). So the situation of variation of β with λ is not so clearcut.

7. Woltjer built a model of Tau A and attempted an extensive theoretical study of it (ref. 10). But according to Lequeux, we cannot get too far until the source is studied with a resolution of at least 30'' in both directions.

8. As to studies at large spacing, we first summarize the results of several groups.

For $p = 90°$

Allen, et al (MN 124, 485)	Mills	Lequeux
$A_{2200}\ \lambda = 0.02$	$A_{1800}\ \lambda < 0.1$	$A \approx 0$ from 2000 λ up
$A_{9700}\ \lambda = 0.006$		
$A_{3200}\ \lambda =$ —	$A_{3400}\ \lambda < 0.1$	
$A_{6100}\ \lambda =$ —		

This suggests that in $p = 90°$ it is definitely single and if there exists fine structure, it must be extremely small.

9. In the case of $p = 0°$, MM only went as far as 1600 λ, where $A_{1600}\ \lambda = 0.06$. Some more work along or near this direction is desirable to confirm models by Mills and Lequeux.

10. The spectrum of Tau A is shown in the section on Cygnus A, where

$$\alpha = 0.27 \pm 0.02 \qquad \text{(MN 125, 273)}$$

$$S_{2700\ \mathrm{Mc}} = 790\ \text{f.u.} \qquad \text{(from Altenhoff, et al)}$$

11. A further result was given in a recent paper by Little, from which an extract is quoted. Little's conclusion is that: "The actual variation of the source size with frequency is thus not very well-defined" (Little (1963) Ap. J. 137, 179).

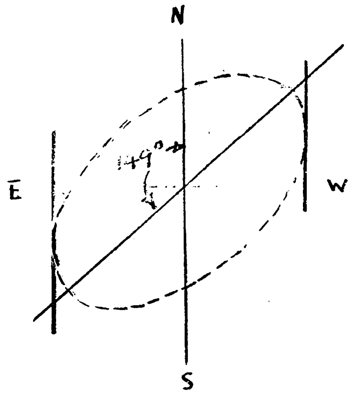
(Little (1963) Ap. J. 137, 170)

V. Discussion

a) Taurus A

Consider, first, the source Taurus A. We have measurements of the width in three directions as in Table 1, from which it is possible to construct a half-power contour. This is shown in Figure 6. The contour is elliptical and is 4'.3 by 2'.7, with the position angle of its major axis at 149°. In 1953, Mills studied this source with an interferometer at 3.7 meters, and he obtained an elliptical half-brightness contour 5'.5 by 3'.5, with a position angle of 140° for the major axis. The source appears to be smaller at the higher frequency. Pariiskii (1960) has noted this trend and gives the angular sizes at four frequencies which clearly show the effect. However, there are many more measurements now available which have to be considered, and these are shown in Table 3, where widths in the right ascension and declination directions only are given.

Considering all the values given in Table 3, the reduction in size with decreasing wavelength is no longer quite so clear-cut. This may be in part due to the use of circularly symmetric models in the derivation of some of the widths, which is incorrect. Also, it is not clear whether all the values given in Table 3 refer to the half-brightness width, as has been assumed; so this may be a limitation on the present comparison.



Half-brightness contour of Taurus A

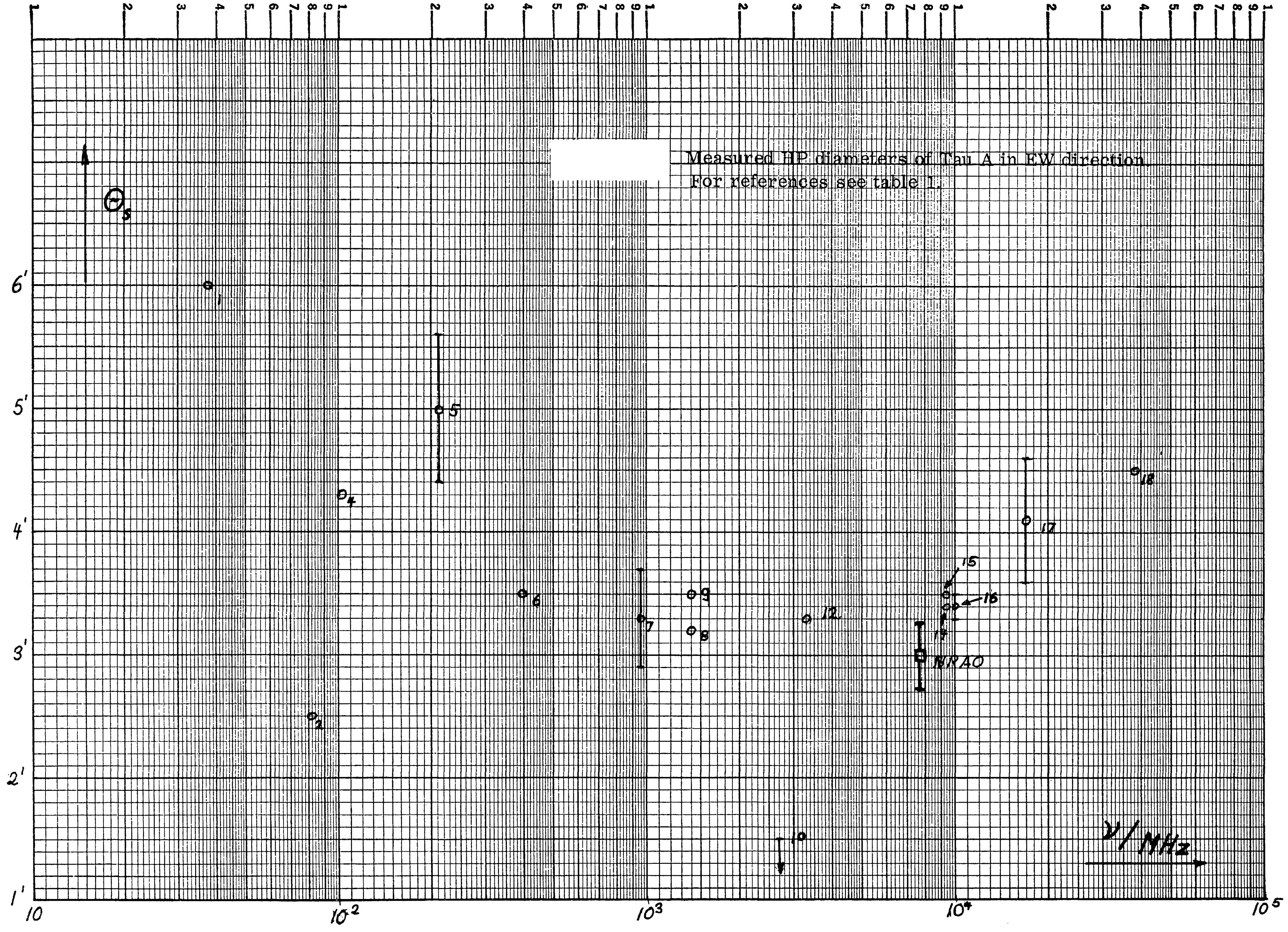
TABLE 3

References	Wave Length (cm)	Width (minutes of arc)	
		R. A.	Dec.
Kuzmin, et al (1961)	0.8	4.5	---
Barrett (1961)	1.8	4.1	3.4
Apushkinskii, et al (1959)	3.0	3.4	---
Karachun, et al (1961)	3.2	3.4	---
Pariiskii (1960)	3.2	3.5	---
Little (1961)	9.1	3.25	3.9
Twiss, et al (1962)	21	3.5	3.5
Baldwin (1954)	140	5.0	---
Mills (1953)	297	4.3	4.8
Udaltsov, et al (1958)	350	8.5	8.5
Costain, et al (1956)	370	2.5	---

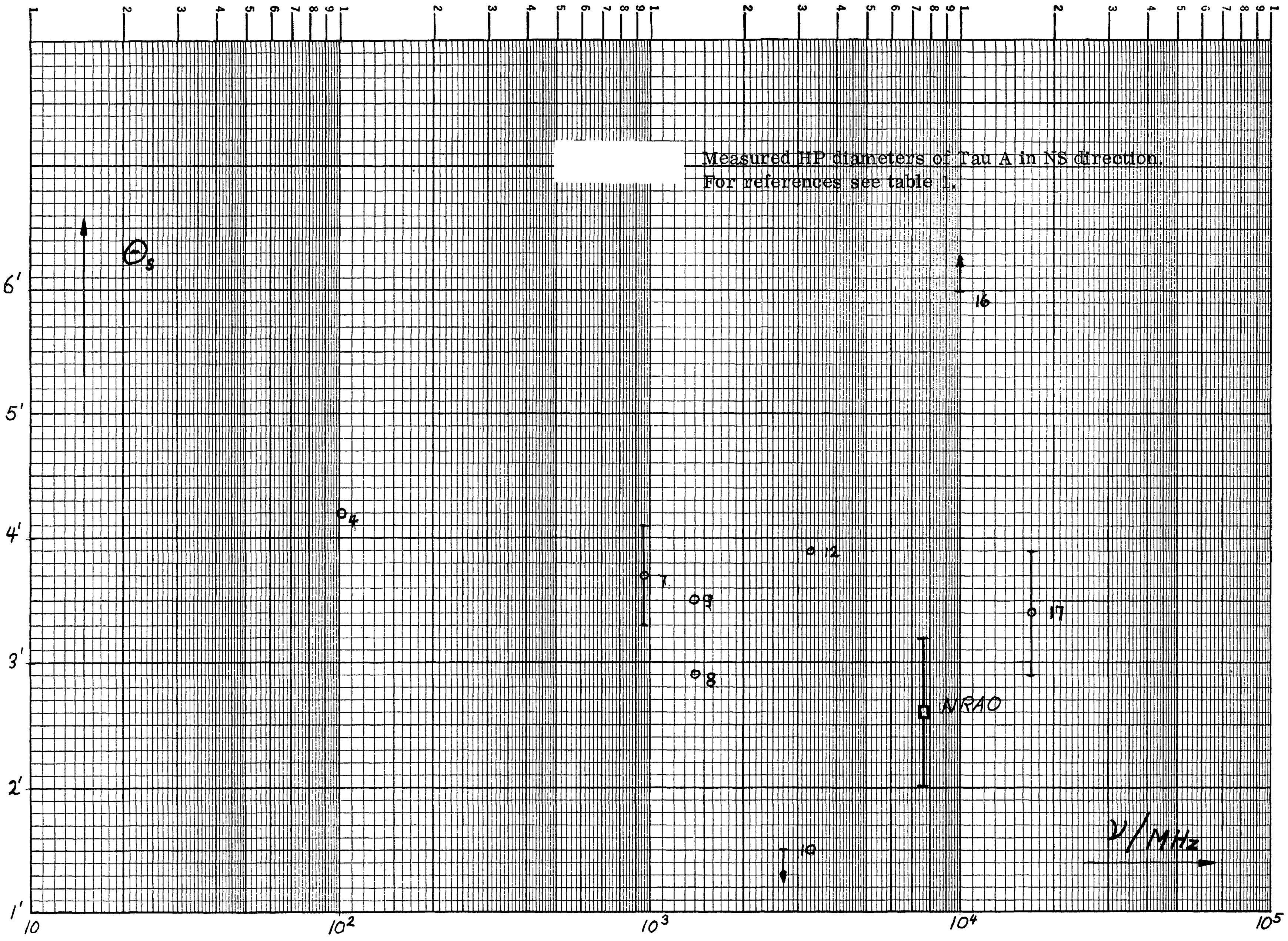
(End of quoted material)

References in order listed above

Doklady 140:81
Ap. J. 134:945
Soviet Ast. 3:717
Astr. Zhur. 38:83
Izv. G.A.O. Pulkovo 21:45
Stanford Rad. Ast. Inst. Pub. 16
Aust. J. Phys. 15:378
Observatory 74:120
Aust. J. Phys. 6:462
Astr. Zhur. 35:713
MN 116:380



Measured HP diameters of Tau A in EW direction.
For references see table 1.



Measured HP diameters of Tau A in NS direction.
For references see table 1.

CASSIOPEIA A, 3C 461

ν Mc	Observing Group	Ref.	β_{EW}	β_{NS}	Method	Maximum spacing
127	Jodrell Bank	JL	4'		Interferometer	2200 λ
960	Cal Tech	MM	>3.5'	3.8' ± 0.5	Interferometer	1600 λ
1420	Nancay	L	4.0'	4.0'	Interferometer	7000 λ
2700	Bonn	A	< 1.5'		Pencil Beam	
2800	Jodrell Bank	R	3 - 4'	3 - 4'	Interferometer	2000 λ
2930	U.S. Naval	SN	---Not resolved---		Pencil Beam	
7600	NRAO		3' ± 0.3'	2.6' ± 0.3'	Pencil Beam	
9400		K	4'	4'	Pencil Beam	
16,700		B	3.7' ± 0.5'	3.8' ± 0.5'	Pencil Beam	

JL = Jennison and Latham (1959) MN 119, 174   R = Rowson (1959), MN 119, 26

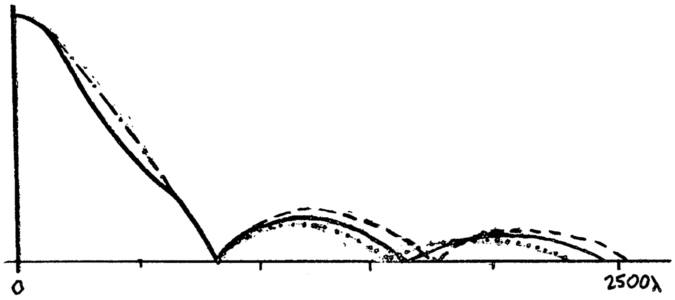
The other references are found in studies of Tau A.   * Not yet published.

Comments

1. MM describes the brightness distribution they get as "less centrally concentrated than a Gaussian distribution" (MM, p. 158).

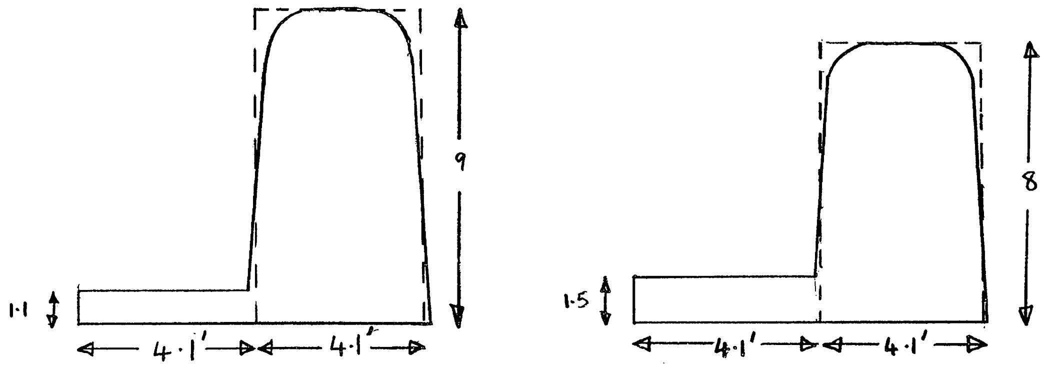
2. In Rowson's data, (1) The first subsidiary maximum is about 10 percent to 15 percent of primary maximum. From this he concluded that Cas. A has no large scale fine structure; (2) the E-W and N-S A curves are very similar. From this he concludes a circular structure.

3. In JL's results both the amplitude and phase curves show a "depression" at short spacing. This indicates "an assymmetrical extension of the object seen as a projection into p = 90°."



The amplitude of the visibility function of the Cassiopeia A (23N5A) source along the East-West axis. The dotted curve on the diagram represents the transformation of a simple disk source. The dashed curve represents a simple slit while the full curve is the transformation of the mean of the two distributions shown below.

From their work they derive the following models:

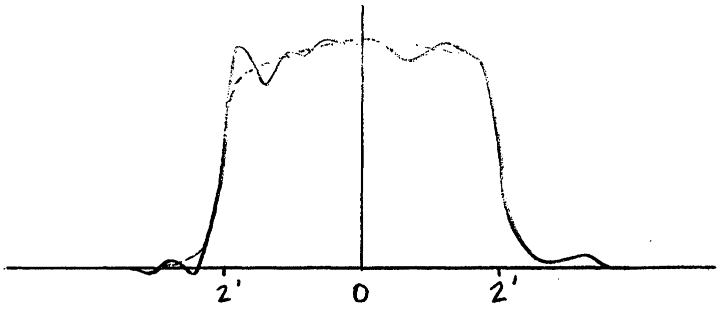


Limiting brightness distribution for the Cassiopeia A (23N5A) source along the East-West axis at a frequency of 172 Mc.

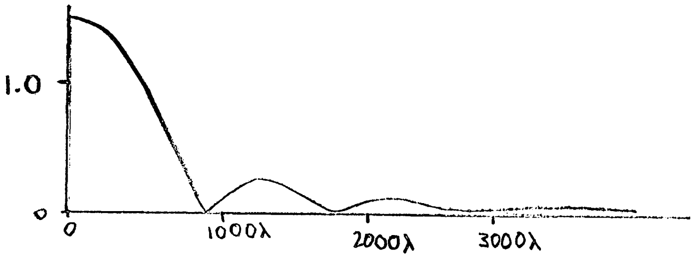
These are two limiting models permitted by their experimental results.

4. Conway attempted to find evidence of variation of brightness distribution by comparing results of 125 Mc, 210 Mc and 500 Mc (Observatory 76, 235). He found no such evidence. Lequeux compared his A curve with those of Rowson and JL and observed that the form and dimension of the source is essentially independent of frequencies.

5. Lequeux obtained the following distribution by numerical restitution from the visibility curve shown.

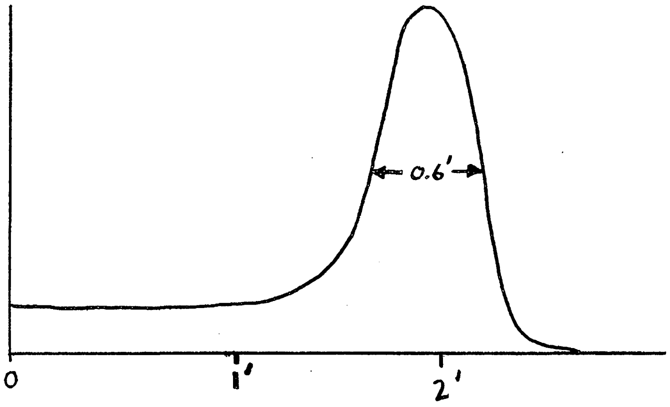


EW profile of Cassiopeia A at 1420 Mc
[Lequeux]



Visibility curve at 1420 Mc by Lequeux

6. From his measurements with p = 33° and 327°, and his derived brightness distribution, Lequeux derived a 3-dimensional model "in the form of a spherical envelope". With such a model he calculated the radial energy density distribution (per unit vol) as follows:



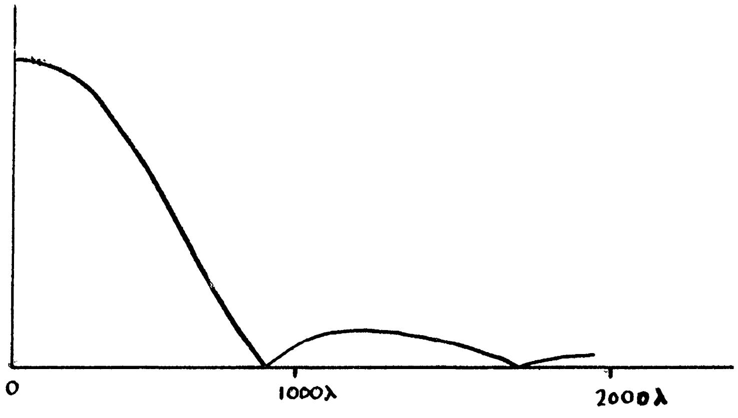
Emissivity of Cassiopeia A at 1420 Mc (Arbitrary Ordinates)

About this he commented as follows: "We see that almost all (94 percent) of the energy is provided by a spherical envelope of radius 2.0' and half-power width 0.6'. This is similar to the optical model." (L, p. 230).

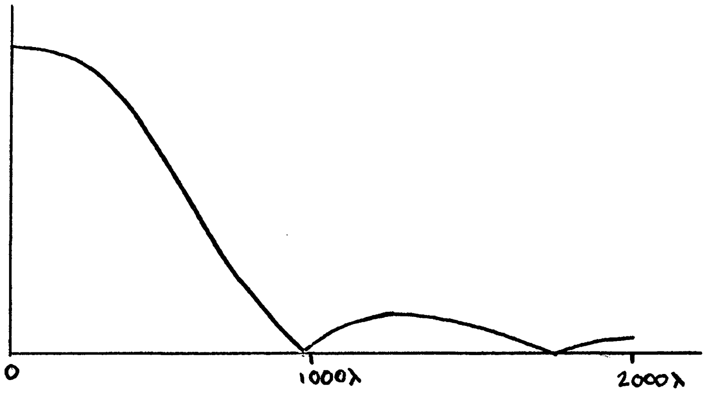
7. Lequeux did not find the "depression effect" described by JL. He remarked that this effect is within the limit of experimental errors.

8. From measurements with oblique baselines, Lequeux found for spacings < 150 λ some trace of structure continuous background around the radio source. Their total S is less than 10 percent of Cas A. But one should bear this in mind if one uses Cas A as a standard for flux density.

9. As to work with large spacings, it does not seem helpful in either p = 0° or p = 90°, because looking at results of different observers, it seems that fine structure is small (from measurements to date). This we can infer from Rowson's visibility curves at 2800 Mc, and hence which are relevant to our work.



Cassiopeia (23N5A) East-West. Abscissa: length of baseline in wavelengths.
Ordinate: normalized fringe amplitude.
[Rowson]



Cassiopeia (23N5A) North-South. Abscissa: length of baseline in wavelengths.
Ordinate: normalized fringe amplitude.
[Rowson]

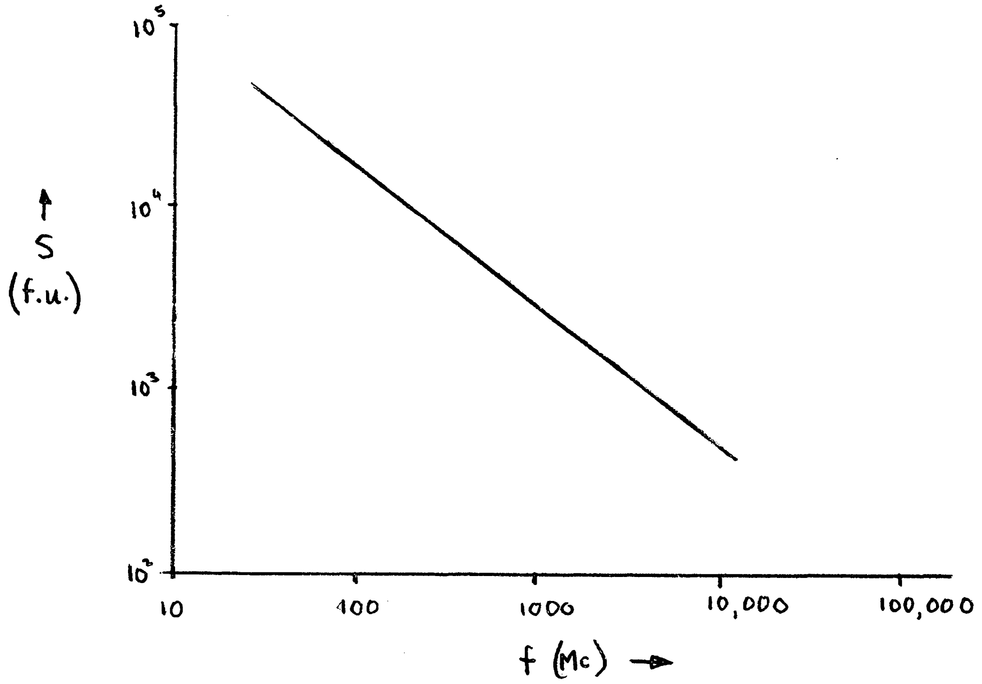
This is reinforced by the results of Allen, et al (MN 124, 493):

$$\text{EW}\left\{\begin{array}{l} A_{2200} = 0.04 \\ A_{9700} = 0.004 \\ A_{32000} < 0.0008 \\ A_{61000} < 0.002 \end{array}\right.$$

10. The spectrum of Cas A is shown (MN 125, 268), and gives

$S_{2700\ \text{Mc}}$ = 1390 f.u. by Altenhoff, et al

$\alpha = 0.77 \pm 0.02$ by Conway, et al (MN 125)



Spectrum of Cas A from absolute flux density measurements published since 1956. All measurements have been corrected to the epoch 1961.0, assuming a secular decrease of 1 percent per year in flux density.

Key to table.

Lamden, R. J., and Lovell, A. C. B., 1956, Phil. Mag., Ser. 8, I, 725	16.5 19.0 22.6 30.0
Wells, H. W., 1958, Proc. IRE, 46, 205	18.5 27, 50, 87, 108.
Braude, S. Y., Men, A. V., Jook, I. N., and Babenkov, K. A., 1962, Astron. Zhur. 39, 163.	19.5, 20.5, 22, 24, 25, 28, 29.5 31.
Adgie, R., and Smith, F. G., 1956, Observatory, 76, 181.	38, 81.5 210, 500.
Long, R. J. (unpublished).	38.
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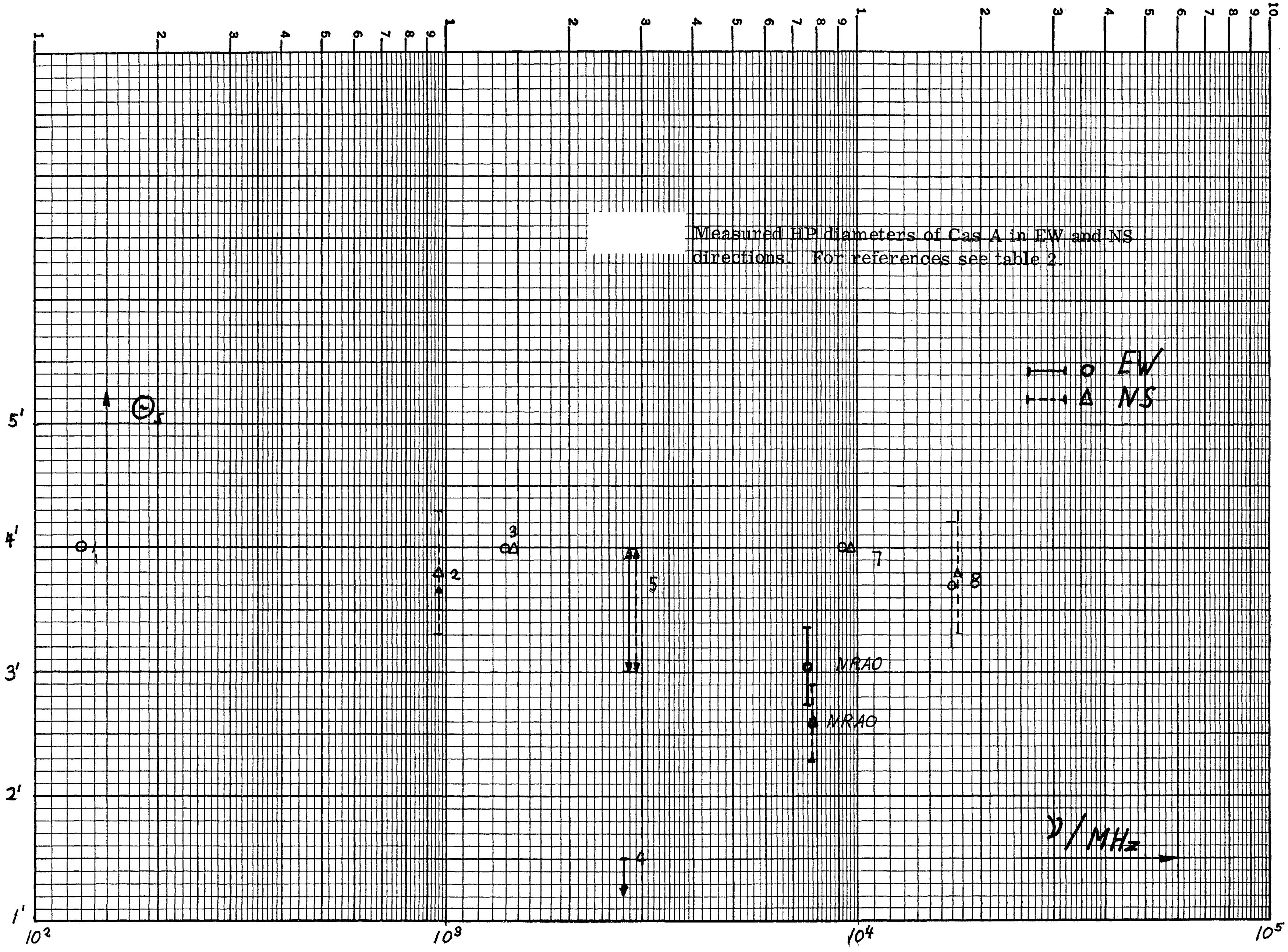
Muller, H.G., 1959, Veroff. Univ. Sternwarte zu Bonn, No. 52	1420.
Sloanaker, R.M., and Nichols, J.H., 1960, A. J., 65, 109.	2930.
Broten, M.W., and Medd, M.J., 1960, Ap.J. 132, 279.	3200.
Razin, V.A., and Pletchkov, V.M., 1957, I. A. U. Symposium, No. 4, 155.	3200, 9400.



Measured HP diameters of Cas A in EW and NS directions. For references see table 2.

VIRGO A, 3C 274, NGC 4486, M 87

Mc	Observing Group	Ref.	Method	S_{tot}	S_h	S_j	β_h	β_j	ψ_h	ψ_j
* 101	Sydney	M	Interferometer	1300	80%	20%	7' x 4'	---	45°	---
* 158	Jodrell	JB	Interferometer	1100	75%	25%	7' (EW)	---	---	---
960	Cal Tech	MM	Interferometer	300	50%	50%	6.5' ± 0.7'	36'' ± 12''	---	300°
1420	Nancay	L	Interferometer	200	40%	60%	10' x 5.5'	31''	55° ± 15°	285° ± 15°
2700	Bonn	A	Pencil Beam	100	---	---	[< 1.5']	---	---	---
2930	NRL	SN	Pencil Beam	100	---	---	Not resolved	---	---	---
3300	Little	Li	Pencil Beam	60	---	---	< 1' x 1.5 (EW x NS)	---	---	---
† 3450	Pulkovo	P	Pencil Beam	---	20%	80%	10'	< 60''	---	---

Notes.

S_{tot} = total flux density of source (in units of 10^{-26} wm^{-2} cps^{-1})

S_h = flux of halo (in % of total)

S_j = flux of jet (radio jet)

β_h = angular diameter of halo ($\beta_{\text{major axis}} \times \beta_{\text{minor axis}}$ unless otherwise specified)

β_j = angular diameter of jet

ψ_h = position angle of halo

ψ_j = position angle of jet

[ ] = see comments on following page

* = S_h, S_j and β_h were estimates by Lequeux using data of the two observing groups.

References to table.

M = Mills (1953) Aust. J. Phys. 6, 452
JB = Allen, et al (1962) MN 124, 477
MM = Maltby and Moffett (1962) Ap. J. Sup. 7, 93
L = Lequeux (1962) Ann d'As. 25, 221
A = Altenhoff, et al (1960) U. of Bonn Pub. 59
SN = Sloanaker and Nichols (1960) A.J. 65, 109
Li = Little (1961) Stanford Pub. 16
P = Pariiskii (1961) Doklady 137, 49
† = some results were privately communicated to Lequeux by Pariiskii
T = Twiss, et al (1962) Aust. J. Phys. 15, 378. (This study is made at 1427 Mc. No interpretation has been given yet. Polarization is also taken into account.)

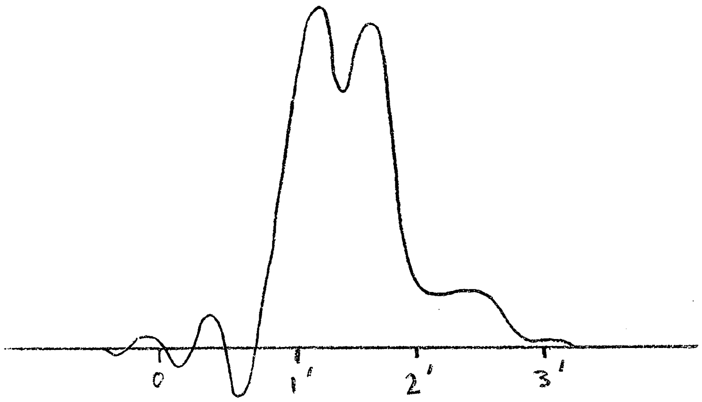
Comments.

1. Pencil beam measurements. The results at 2700 Mc - 3300 Mc are supposedly those of measuring Virgo A as a whole. At those frequencies the jet probably has 70% of the total flux. Therefore they were essentially "looking at" the jet. This seems the most reasonable account for their results of small angular sizes for Virgo A.

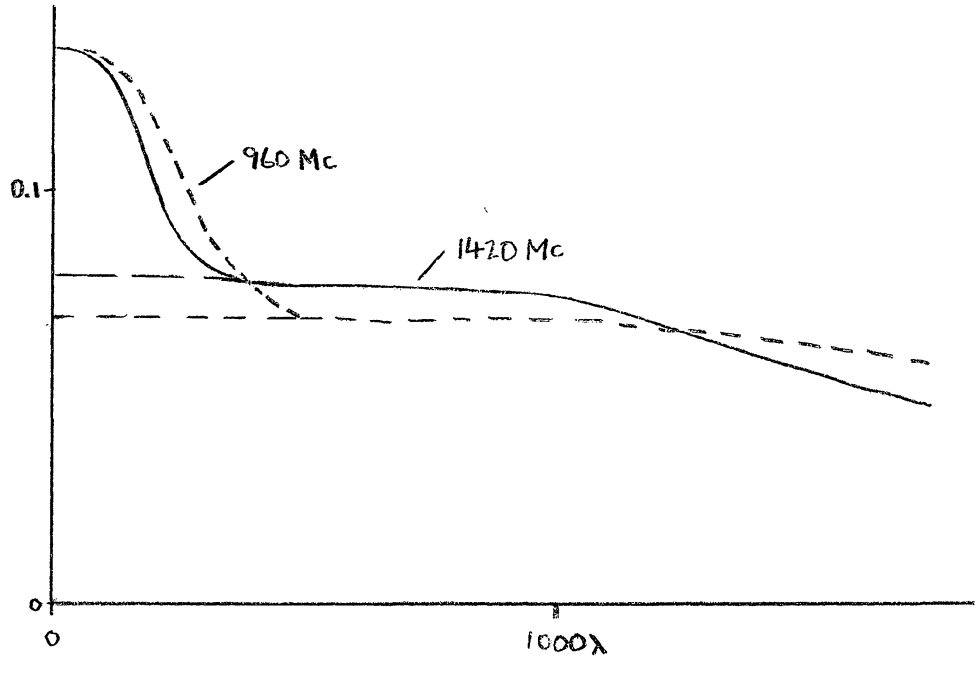
2. Complex structure of halo. From his study with oblique baselines, Lequeux found that between 300-1200 λ the dispersion of experimental points is larger than he expects. This can be due to complex structure. According to him, the interpretation of this strucutre is "highly problematical", and other authors, notably Bracewell, have observed the same thing. MM also did oblique baseline work, but only 3 pts. for $p = 30°$ and 1 for $p = 150°$.

3. Fine structure of jet. Lequeux is the only one who went out far enough in spacing to detect any fine structure in the jet. The EW profile obtained from numerical restitution is shown. Since numerical restitution does not give unique results, he tried various models and found that no "single" models are compatible with results, and therefore concluded the jet must be double. His double gaussina model for the jet is

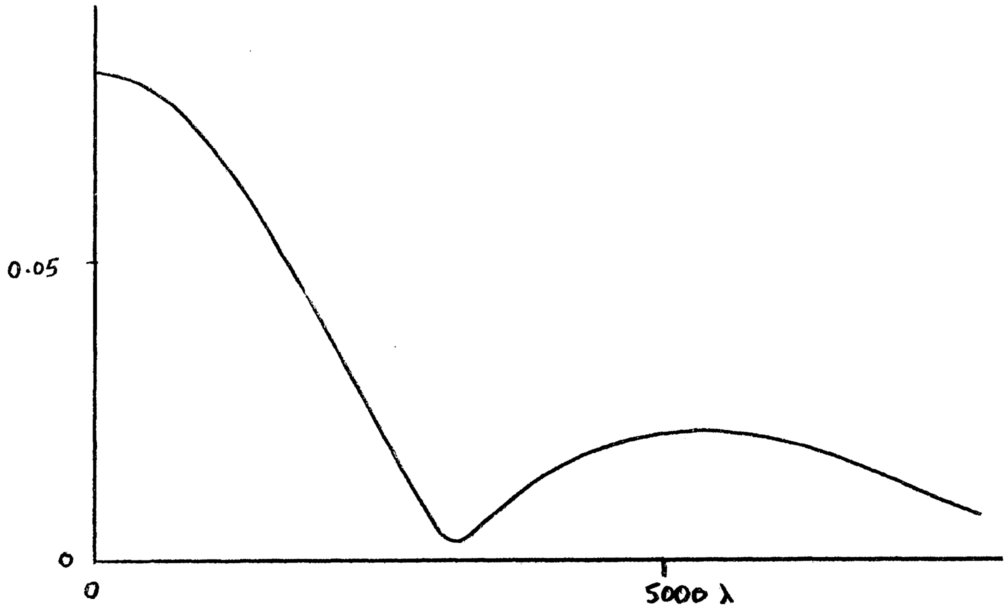
$$\gamma = 31'' \text{ (EW)}; \ \beta = 23'' \qquad h_1 = 65 \text{ f.u.}; \ h_2 = 55 \text{ f.u.}$$



EW Profile of the jet of Virgo A
[Lequeux]



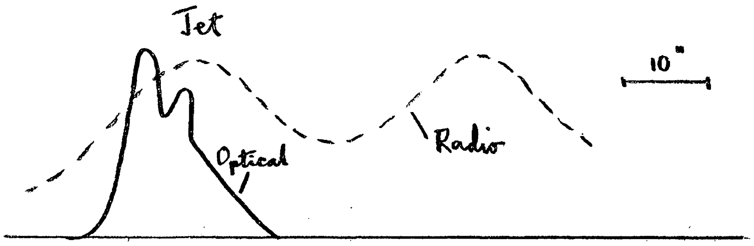
Visibility curve of Virgo A at two frequencies
[Lequeux]



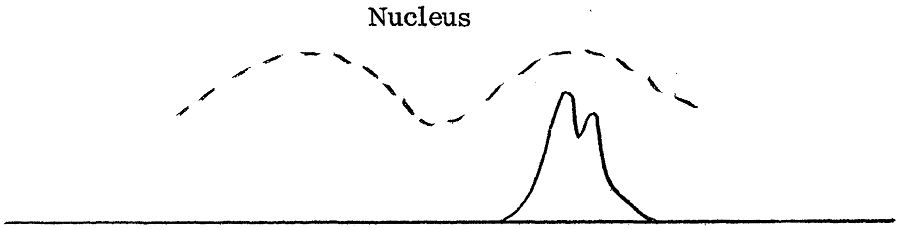
Visibility curve of the jet of Virgo A at 1420 Mc
[Lequeux]

This agreement with experimental points is quite satisfactory.

4. Radio and optical jets compared. Assuming same ψ for optical and radio jets (opt . 290°; radio, 285° from Lequeux, 300° from MM),. Lequeux combined his radio data and Van Houten's optical data to form a model shown. In the diagram the two radio components are treated as equal because (due to lack of phase measurement) it cannot be decided which one is west.



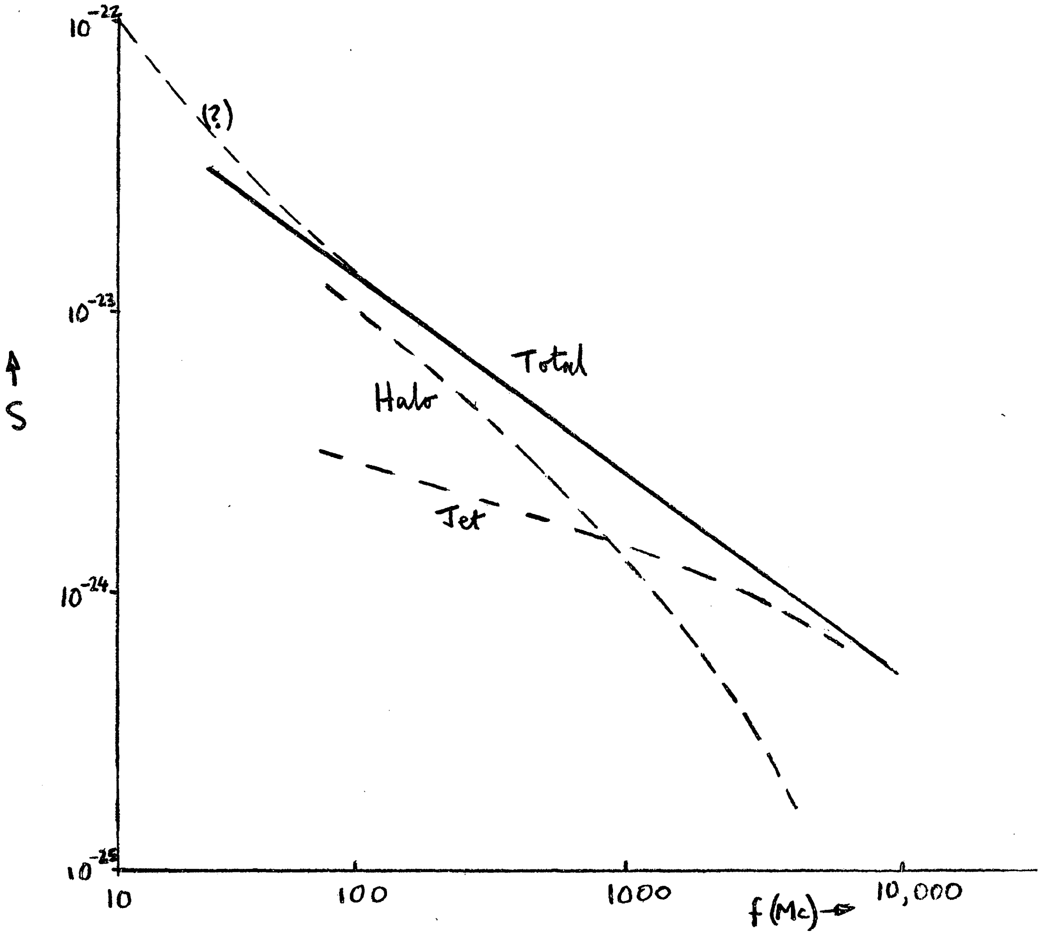
It is interesting to note that Cal Tech gets a different model as follows:



(Qualitative figure)

(This result has been privately communicated to H. M. Johnson by Matthews.) We bear in mind similar disagreement of Cal Tech results with others for Cygnus A.

5. Variation with frequency. From the results of different observing groups mentioned, Lequeux formed the spectra of jet and halo shown in the following figure:



Spectrum of the components of Virgo A
[Lequeux]

Lequeux also concluded that the dimensions of halo increase as ν increases (in contrast to the case of Tau A).

$$100 - 1400 \text{ Mc: } \alpha_{\text{halo}} \approx 1.0$$

$$\alpha_{\text{jet}} \approx 0.3$$

Lequeux assigned $\alpha = 0.74$ to the total source whereas Conway, et al gave $\alpha = 0.83$ (MN 125).

6. Results at large spacing. From the work by Allen, et al (MN 124:477) we see

$$A_{9700\,\lambda} = 0.006$$

$$A_{32000\,\lambda} = 0.005$$

$$A_{61000\,\lambda} = 0.006$$

From these results it seems that work at 12,000 - 27,000 λ will be unrewarding. But, estimating from Lequeux's EW visibility curve, we could expect a second subsidiary maximum at about 10,000 λ with $A_{10000} \approx 0.1$. This is only the EW direction. We need some work between p = 0° and p = 70°, where we may detect more fine structure with large spacing.

CENTAURUS A, NGC 5128

This source has been found to consist of an extended part and a compact central core. Some earlier results are as follows:

1. 400 Mc. Pencil beam by McGee, et al (1955) Aust. J. Phys. 8, 347
   extended part — 5° x 3°
2. 85.5 Mc. Pencil beam by Sheridan (1958) Aust. J. Phys. 11, 400
   - (i) extended part - 6° x 2°
   - (ii) central source not resolved. Its flux 25 percent of total.
3. 19.7 Mc. Pencil beam by Shain (1958) Aust. J. Phys. 11, 517.
   Central source has flux 11 percent of total.
4. 960 Mc. Pencil beam by Bolton and Clark, PASP 72, 29
   - (i) central source has flux 26 percent of total.
   - (ii) extended source — 3° x 8° made of 2 components each 3° x < 2° separated by 4°.
   - (iii) Similar features discussed by Wade (1959) Aust. J. Phys. 12, 471.

The central core, being more important to us, has been studied by various groups and we first summarize the references, and predicted structures.

ν Mc	Ref.	Method	Max. spacing	γ_{EW}	β_{EW}	h_1/h_2	ψ	Major Axis
101	Mi	Interferometer	3400					
960	MM	Interferometer	1600	5.1' ± 0.4'	2.4' ± 0.4'	< 1.3	46.5° ± 2°	7.1' ± 0.5'
1420	T	Interferometer	700	5'	2.5'	---	---	---
3000	B_2	Pencil Beam (210-foot)	---	4.6'	2.6' x < 1'	1.8	---	---
3300	B_1	Fan Beam	---	4.8'	---	---	43°	7'

Mi = Mills (1953) Aust. J. Phys. 6:452
Maltby (1961) Nature 191:793
MM = Moffett and Maltby (1962) Ap. J. Sup. 7:93
T = Twiss, et al (1960) Observatory 80:153
Little and Bracewell (1961) A.J. 66:290
B_1 = Bracewell (1961) Stanford Pub. 15
Little (1963) Ap. J. 137:170
B_2 = Bracewell (1962) Nature 195:1289

1. Mills' results are summarized as follows:

(i) extended source of large angular size with a strong concentration near the center.
(ii) 45 percent of total flux contributed by central source.
(iii) size and shape of central core: ellipse 6.5' x 3', $\psi = 130°$.
(iv) central source associated with dust band of NGC 5128.

One this last conclusion MM commented as follows, "His (Mills') conclusion that the central source lies roughly in the dust lane of NGC 5128 would seem to be in error." (MM, p. 156).

2. Sloanaker found the angular size of central core to be 8' ± 0.5' in EW and 5' ± 1.5' in NS. Sloanaker (1960) A.J. 65, 109.

3. Variation with frequency. Based on the results by Mi, MM, T, and B_1, Bracewell concluded that "the absence of any noticeable dependence of fringe visibility on frequency would mean that data taken on different frequencies could be combined," (B_1, p. 10).

Maltby and Moffett, however, compared results of MM, T, and B_1, and suggested a dependence of structure on frequencies (MM, p. 156).

4, Polarization. Bracewell, et al, in their work with the 210-foot telescope, detected linear polarization of the radio emission from the central core. They also found that the degree of polarization is higher than has been observed for other sources, such as Cyg A, Cas A and Tau A.(B_2).

5. Fine structure of central components. No work has been done with large spacing yet. Mills' results at 1800 λ and 3400 λ were negative. The amplitude of interference pattern being less than noise fluctuations of equipment. Moffett has $A_{1600} = 0.08$.

It seems that any finer structure will be negligibly small.

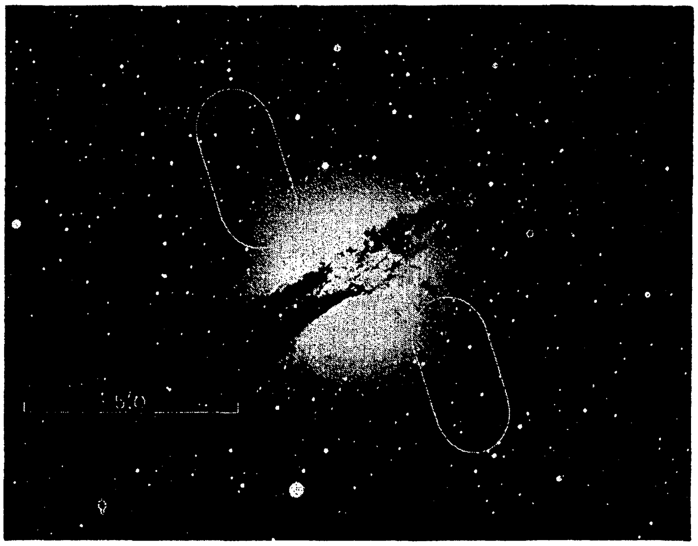
6. Spectrum. According to Lequeux (C.R. 255, 1866) for the central components,

$$\alpha = 0.25 \quad \text{for } \nu < 150 \text{ Mc}$$
$$\alpha = 0.80 \quad \text{for } \nu > 150 \text{ Mc}$$

Using this and the flux density obtained by Sloanaker (A.J. 65, 109) we estimate the flux density of the central core to be

$$170 \pm 20 \text{ f.u.} \quad \text{at } \nu \simeq 2700 \text{ Mc.}$$

7. Following is a picture showing the relative positions of radio and optical sources. For more discussion of this aspect, see H. M. Johnson (1963) NRAO Pub. No. 15.



Photograph of NGC 5128 from the Mount Wilson and Palomar Observatories

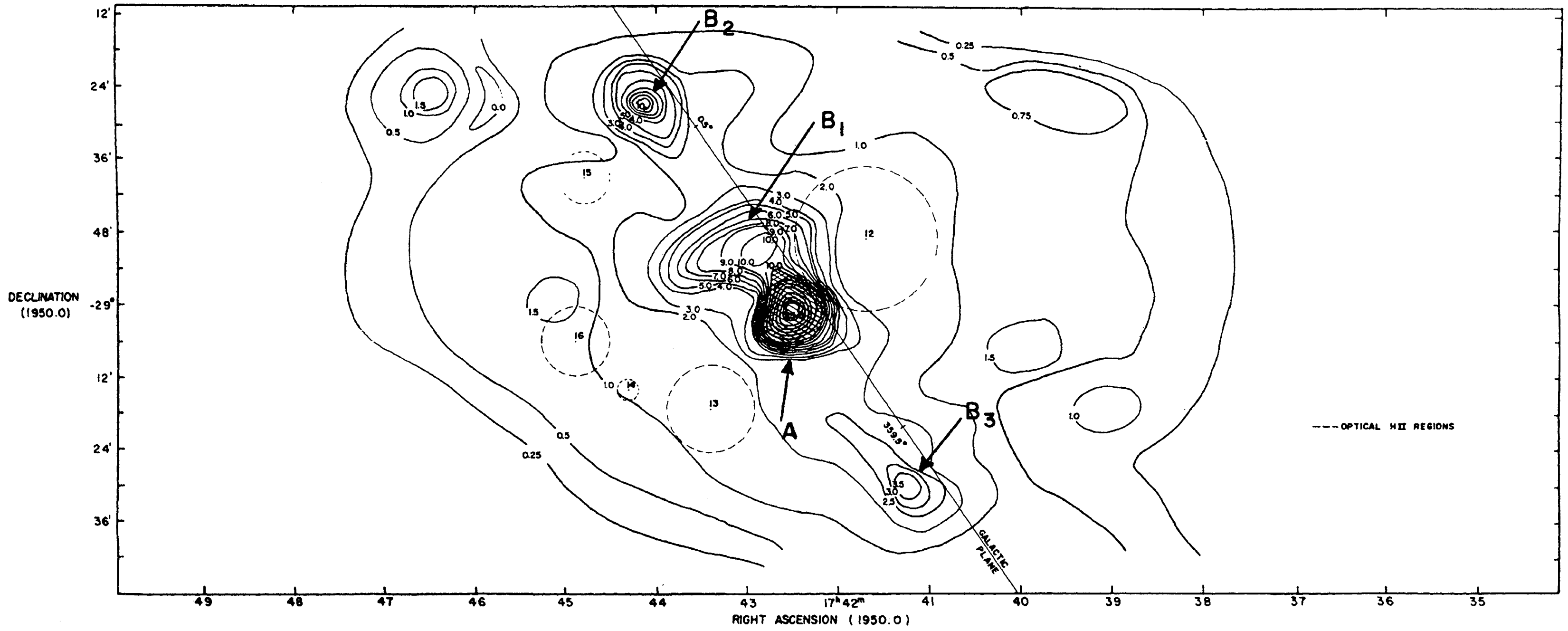
SAGITTARIUS A

Earlier observations

TABLE I*

Authors	λ	Angular Size	Remarks
Haddock, et al (1945)	3 cm	15'	Also a more extended source.
Hagen, et al (1954)	21 cm	30'	Also a more extended source.
Kraus, et al (1955)	1.2 m	>1.5°	Possibly includes the extended source.
Mills (1956)	3.5 m	>0.5°	Observed in absorption.
Shain (1956)	15.2 m	2.5°	Observed in absorption.

* From Shain, p. 202.



REGION OF GALACTIC CENTER — ISOPHOTES OF BRIGHTNESS TEMPERATURE IN °K AT 8000 MC.

[DRAKE, F.D.]

Recent observations

Authors	λ	Method	Results
Pariiskii (1959)	3.2 cm	Pencil Beam	2 components -- No. 1(3') and No. 3 (30').
Drake (1959)	3.75 cm	Pencil Beam	See photo and notes below.
Little (1963)	9.1 cm	Fan Beam	"brighter part 4.5' wide" (probably includes Drake's A and B_1)
Pariiskii (1959)	9.4 cm	Pencil Beam	3 components -- No. 1 (3'), No. 2 (very extended) and No. 3 (30')
Sloanaker (1960)	10.3 cm	Pencil Beam	"bright central part" is (14 ± 0.3') in EW and (16' ± 0.5') in NS
Lequeux (1962)	21 cm	Interferometer	3 components -- No. 1 (3.5'), No. 2 (1° x 2°) and No. 3 (28')
Twiss (1963)	21 cm	Interferometer	No interpretation given. Did phase and polarization measurements.
Drake (1959)	22 cm	Pencil Beam	No interpretation.
Malumyan (1959)	33.3 cm	Pencil Beam	2 components -- No. 1 (5') and No. 2 (1.25°). No. 2 probably includes No. 3.
Burke (1959)	74 cm	Pencil Beam	Much like the result of Drake, except nonthermal radiation predominates (see p. 38, No. 4(ii)).

References

Haddock, et al, A.J. 60:161

Hagen, et al, Ap. J. 120:368

Kraus, et al, Ap. J. 122:139

Mills, Observatory 76:65

Shain, Aust. J. Phys. 10:195

Pariiskii (1959) Soviet Phys. 4:1172

Pariiskii (1960) Soviet Ast. 5:182

Drake (1959) Sky and Telescope 18:428

Drake, A.J. 64:329

Drake (1960) NRAO Report

Little, Ap. J. 137:170

Sloanaker, et al, A.J. 65:109

Lequeux, Ann d'As. 25:233

Twiss, et al, Aust. J. Phys. 15:378

Malnumyan, Soviet Phys. 4:1170

Comments:

1. In the results of the Russian and French groups, component No. 1 is equivalent to Drake's source A, No. 3 to everything inside the 2° isophote except A, and No. 2 to a more extended source not quite well defined. In "Recent Observations" all angular sizes are in EW unless otherwise specified, and they are all half-power widths.

2. The earlier observations were best summarized in Mills' paper. We quote, "At λ shorter than about 50 cm, the source is very prominent and is easily separated from the general galactic radiation, but at metre λ the situation is obscure, mainly because pencil-beam aerials of sufficient resolution have not been available and interferometer observations have been difficult to interpret...It is apparent that at centimeter and metre wavelengths the situations are entirely different."

3. So far only Drake, Lequeux and the Russians have resolved the source. Lequeux compared the results of three groups, and we summarize his discussion and conclusion as follows.

(i) Spectra of components 1 and 3.

Lequeux: $$\left.\begin{array}{l} S_1 \approx 300 \text{ f.u.} \\ S_3 \approx 730 \text{ f.u.} \end{array}\right\} \text{Cyg A taken to have 1500 f.u.}$$

Pariiskii: (private communication to Lequeux)

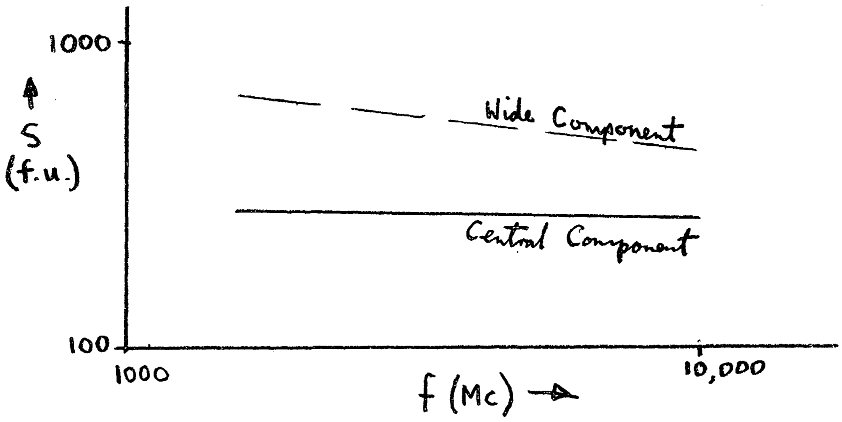
$$\left.\begin{array}{ll} 3.2 \text{ cm} & S_1 \approx 170 - 380 \text{ f.u.} \\ & S_3 \approx 560 \text{ f.u.} \\ 9.4 \text{ cm} & S_1 \approx 300 \text{ f.u.} \\ & S_3 \approx 560 \text{ f.u.} \end{array}\right\} \begin{array}{c} \text{Tau A} \\ \text{taken to have 710 f.u.} \end{array}$$

With these results he estimated the spectral indices of the two components as

$$\alpha_1 \approx 0.0 \pm 0.2$$

$$\alpha_3 \approx 0.14 \pm 0.40$$

The spectra are shown in the following figure.



Spectra of components of Sag A
[Lequeux]

(ii) From his results with p = 19°, Lequeux fround the fine structure at the center to be the same as Drake's result, viz., A and B_1 separated by 15' along the galactic plane. Furthermore, the large dimensions of B_1 (about 15') explain the fact that the amplitude of oscillations of the visibility curve is small.

4. For theoretical interpretation of these results, see Lequeux, p. 235, and Pariiskii (1960), p. 182. It sufficies for us to put down some important points of the two authors.

(i) Both authors agree that component A is the central core of the galaxy. Some quantities concerning it are

	Lequeux	Pariiskii	
Diameter ----------	8.3 pc	8 pc	(assume spherical)
Electron density ----	1000 cm^{-3}	6000 cm^{-3}	
Mass --------------	7500 M$_o$	10,000 M$_o$	

(ii) The source as a whole radiates with both thermal and nonthermal components. At 3.75 cm thermal emission predominates. At 33 cm nonthermal emission predominates. At 9.4 cm two components are nearly equal (according to Lequeux).

5. Interferometric work. Twiss, et al, and Lequeux were the only interferometer observers. The maximum spacing for Twiss is 1000 λ, while for Lequeux it is 7000 λ. But the latter got effectively zero from 1000 λ to 1500 λ, so probably he did not go further in spacing. Twiss also got effectively zero at about 1000 λ. From these we feel that there is much need for work at short spacing (0-1000 λ) rather than long spacing, which will not be very useful.

FORNAX A, NGC 1316

Studies previous to 1961 have been summarized in Wade's paper. He found the source to be double with $\gamma = 30'$

$$\beta > 16' \qquad \frac{h_1}{h_2} \approx 2$$

Moffett and Maltby's work did not yield fruitful results because their spacings were taken at too great intervals for this source. The only thing they suggest from their study is that the source does not contain bright cores of small diameter on account of the very small visibility amplitudes. Pencil beam work at Cal Tech (mentioned by MM) yields results which agree with those of Wade.

Our interferometer will not be useful for this source.

References

Wade (1961) NRAO report.

Moffett and Maltby (1962) Ap. J. Sup. 7, 148.

Ω NEBULA, NGC 6618, M 17

λ	Authors	* Beam width or maximum spacing	Angular Size
Cm			
1.8	Barrett (1961)	3.0'	7.0'
3.2	Karachun (1961)	6.4'	5.8'
3.2	Pariiskii (1960)	1.0'	7'
3.75	Hobbs (1961)	6.6'	9'
9.1	Little (1963)	2.3 (fan beam)	2 components superimposed -- 4.1' and 4.5' (see notes below).
9.4	Pariiskii (1960)	3.4'	7'
10.2	Sloanaker (1960)	18.2'	7'
21.0	Lequeux (1962)	1800 λ	5' - source asymmetrical in EW
21.1	Twiss (1962)	930 λ	2 components superimposed -- 4.7' and 5.9' (see notes).
31.3	Moffet (1962)	1600 λ	4.5' ± 0.6' - slightly asymmetrical
Infra-red	Gershberg (1961)	---	Central part of annular nebulosity about 4' of exterior diameter.
Optical	Sharples (1959)	---	25' of H II region -- obscured by interstellar matter.
Optical	Cederblad (1946)	---	

* Beam width for pencil beam method and maximum spacing for interferometer. Lequeux's experiment had 7000 λ as maximum, but he evidently did not need to go as far.

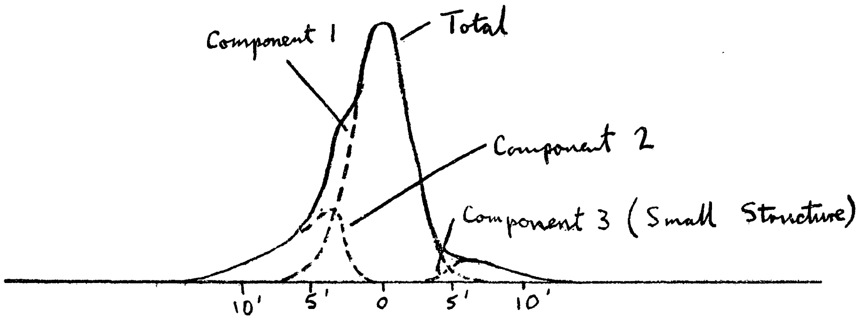
References

Barrett, Ap. J. 134:945
Karachun, et al, Soviet Ast. 5:59
Pariiskii, Pulk. Bull. 21, 465
Hobbs, A.J. 66:517
Little, Ap. J. 137:172 and Obs. 82:165
Sloanaker, et al, A.J. 65:109
Lequeux, Ann d'As. 25:227
Twiss, et al, Aust. J. Phys. 15:378
Moffet, Ap. J. Sup. 7:158
Gershberg, Annals of Crimean Observatory 26:313
Sharpless, Ap. J. Sup. 4:258
Cederblad, Pub. Lund Obs. Ser. 2, 119:120

For a theoretical discussion see Pariiskii, Soviet Ast. 5:358

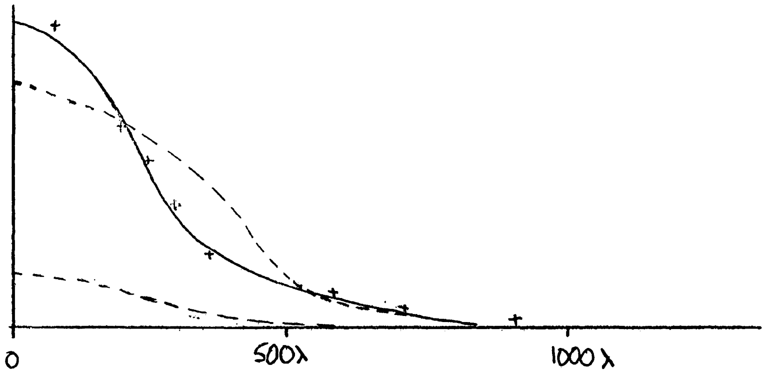
Comments

1. Most authors interpret this source as having a single, nearly gaussian, distribution. But Little has a model of 2 superimposed components to explain his 9.1 cm fan beam, and 21 cm interferometer results (by Twiss, Carter and Little). The two models are shown in the following figures, together with their agreement with experimental points.



Observed 9.1 cm fan beam drift curve (full curve) with positions (Epoch 1950) of two derived sources (broken curves)
[Little]

9.1 cm: $\beta_1 = 4.1'$; $\beta_2 \approx 4.5'$; $\gamma = 4.9'$ and $r = 0.28$.



Visibility function observed at 21 cm (crosses) with visibility functions of two-source model. Dashed curves—individual source functions; full curve—combined visibility function of model.
[Little]

21.1 cm

$\beta_1 = 4.7'$; $\beta_2 = 5.9'$

$\gamma = 4.8'$

$r = 0.33$

where β_1 and β_2 are the half-power width of the two components, γ is the separation between their centers of gravity, r is the ratio of intensity of component two to that of one.

The positions of these components relative to the optical center are as follows:

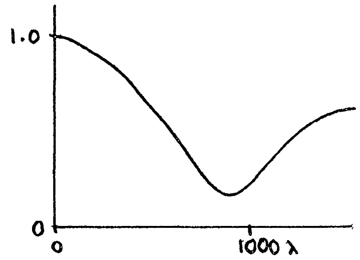
Component 1	$18^h\ 17^m\ 35^s$
Component 2	$18^h\ 17^m\ 55^s$
Optical Center	$18^h\ 17^m\ 54^s$

2. It would be interesting to see how well Lequeux and Moffet can interpret their data with such a model.

3. This source is too large for our spacings.

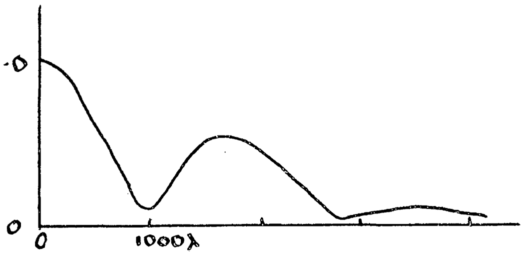
HERCULES A, 3C 348

From the interferometer work of MM (960 Mc), the A curve of Hercules A is as shown



Maltby, Matthews and Moffet (Ap. J. 137, 153) describe a double source with two nearly equal components of halfwidth 45 arc seconds and separation 117 arc seconds. The ratio of radio component half-power diameters to optical diameters is 10, and ratio of radio component separations to optical component separations is 25.

L states that (at 1400 Mc) the half-power diameter of each component in the EW direction is 47 arc seconds, and the EW separation is 109 arc seconds. L also finds the ratio between fluxes to be 1.3. The A-curve obtained by L in the EW direction is shown.



L also made measurements with the projected interferometer baseline in two other positions on the source. From these measurements, L found the position angle of the major axis to be 98°. These results are in good agreement with those of MM and MMM, and with those of Williams, Dewhirst and Leslie (Observatory, 81 (1961), 64). The A-curves have been normalized to the zero spacing.A. In fact, L found that the zero-spacing value of A for Hercules A was only 3 percent of that of Cygnus A. Hence it would appear that (projected) EW interferometer measurements at NRAO will give no significant information on this source. According to Conway, Kellerman and Long (MN RAS, 125, 1963, p. 261)

$$\alpha \simeq 0.93$$

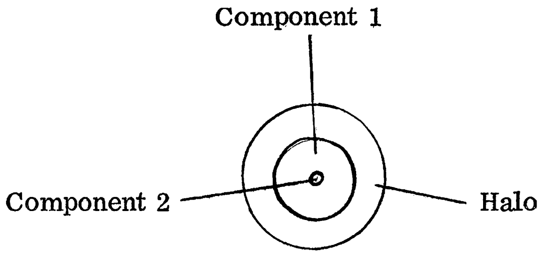
$$S_{1420} = 48.5 \text{ f.u.}$$

$$S_{3200} = 19.3 \text{ f.u.}$$

This suggests that no information on Hercules A will be available from the NRAO interferometer, due to the degree of resolution and the low source temperature.

HYDRA A, 3C 218

The general model is qualitatively shown as follows.



Moffet and Maltby -- Halo 5' with 12 percent ± 5 percent of flux

Core (1 and 2) 1.2' in p = 30°, < 0.6' in p = 90° and 150°

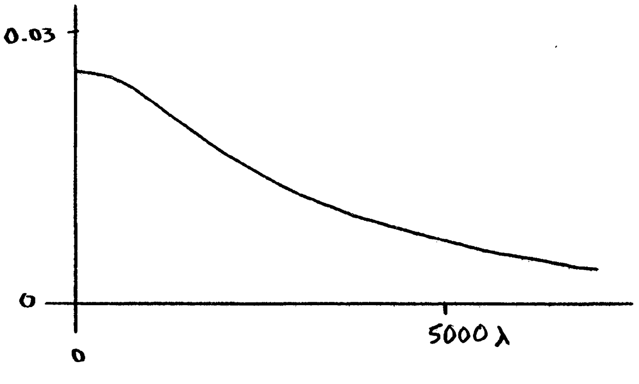
Lequeux -- Component 1 "essentially gaussian" - 42"

Component 2 10" (?), one-fifth of flux.

Halo - maybe

Allen, et al -- $A_{2200\,\lambda} = 0.2$, $A_{9700\,\lambda} = 0.08$

$A_{32,000\,\lambda} = < 0.02$, $A_{61,000\,\lambda} < 0.02$



Visibility curve of Hydra A.
[Lequeux]

The value of Allen, et al, at 2200 λ appears incorrect. Judging from the values of A at 7000 λ, 9700 λ, 32,000 λ, 61,000 λ, it is likely that the A curve "dies out" as shown, and thus the work at long spacing does not seem fruitful in p = 90°.

In other directions only MM made observations. Their A curves for p = 0°, p = 30° and p = 150° show the same trend as the curve shown above. (Up to 1600 λ see MM, p. 138).

According to Conway, et al, $\alpha = 0.87$. From their data, we estimate the flux at 2700 Mc to be 25 f.u., approximately.

PERSEUS CLUSTER (Region of NGC 1275) 3C 84

Three important recent papers on this source are

LE = Leslie and Elsmore (1961) Obs. 81:14

LS = Lynds and Sobieski (1961) NRAO Pub. 10

L = Lequeux (1962) Ann d'As. 25:255

Our comments will be more or less a summary of these three papers.

Observations at various frequencies (some earlier ones omitted). See LS, paragraph 1, for more references.

No.	Mc	Method	Results
1.	81.5	Interferometer	75 percent radiation originates from a small source very near NGC 1275, and remaining 25 percent seems to come from a more extended source (presumably the whole cluster).
2.	178	Interferometer	Two sources -- a strong component, near NGC 1275, and a weaker about 22' east of the former.
3.	178	Interferometer	Confirm results of No. 2.
4.	178	Interferometer	Three components -- a and c are the same as in 2. In addition, a more extended source b is found (see details on next page).
5.	3000	Pencil Beam	Two components, no b.
6.	1420	Interferometer	Three components, good agreement with 4.
7.	960	Interferometer	Spacing intervals too large for fruitful measurements.
8.	178	Interferometer	Two components listed only. Maybe they did detect the third.

References

1. Baldwin, et al (1954) Nature, 173:818
2. Elsmore, et al (1959) Mem. RAS 68:61
3. Scott, et al (1959) MN 122:95
4. Leslie, et al (1961) Observatory 81:14
5. LS
6. L
7. Maltby and Moffet (1962) Ap. J. Sup. 7:93
8. Bennet (1962) Mem. RAS 68:163 (revised 3C catalogue)

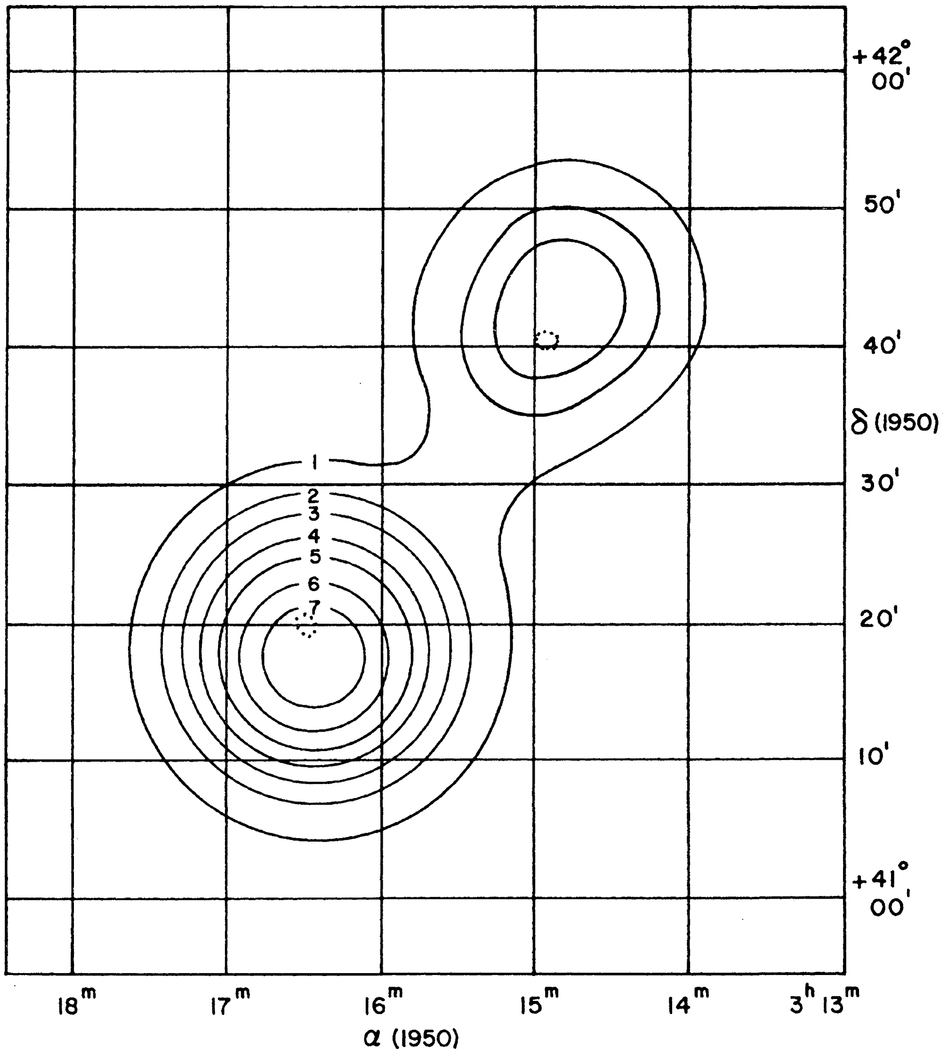
LS -- Radio and Optical Positions and Flux Densities

Name	α(1950)	p.e.	δ(1950)	p.e.	ν (Mc)	Flux Density*	p.e.
3C 84a	$3^h\ 16^m\ 25.7^s$	4^s	+41° 18.1'	1'	3000	8.4	0.4
3C 84a	3 16 28.6	1.5	+41 20.4	1.5	178	41	4
NGC 1275	3 16 27.6	1	+41 19.8	0.2			
3C 84b	3 14 53	5	+41 42.8	2	3000	3.7	0.4
3C 84b	3 14 54.2	1.5	+41 44.1	1.5	178	15.5	2
NGC 1265	3 14 54.6	1	+41 40.5	0.2			

* Units are 10^{-26}w m^{-2}(c/s)$^{-1}$.

Note. There is some confusion in notation. We give Leslie's notation and diagram for the three components (b is only approximately located). The corresponding names used by other authors are as follows:

Leslie	Lequeux	Lynds	Revised 3C (observations by Leslie)
a	NGC 1275 a	3C84 b	3C83.1
b	NGC 1275 b	---	---
c	NGC 1275 c	3C84 a	3C84



Brightness distribution in the Perseus source (3C 84) at 3000 Mc. The distribution is uncorrected for antenna smoothing. The unit of intensity for the contours is 0.1 °K antenna temperature. The two dotted sllipses represent the size and position of NGC 1275 and NGC 1265

[LS]

<u>Angular diameters and fluxes</u> (a, b, c are used in Leslie's convention)

ν Mc	Observers	β_a	S_a	β_b	S_b	β_c	S_c	δ_{ac}^{EW}
178	Leslie	2.0'	15.5 ± 2	26'	40 ± 10	1.0'	41 ± 4	18'
178	Revised 3C	3.3' ± 1.0'	28	---	---	2.3' ± 1.0'	58	18'
1420	Lequeux	<2'	3.9 ± 1.5	25-30'	7.5	<12"	9.0 ± 1.0	18'
3000	Lynds	---	3.7	---	---	---	8.4	18'

β_a = angular diameter of a, etc. (at half-power)

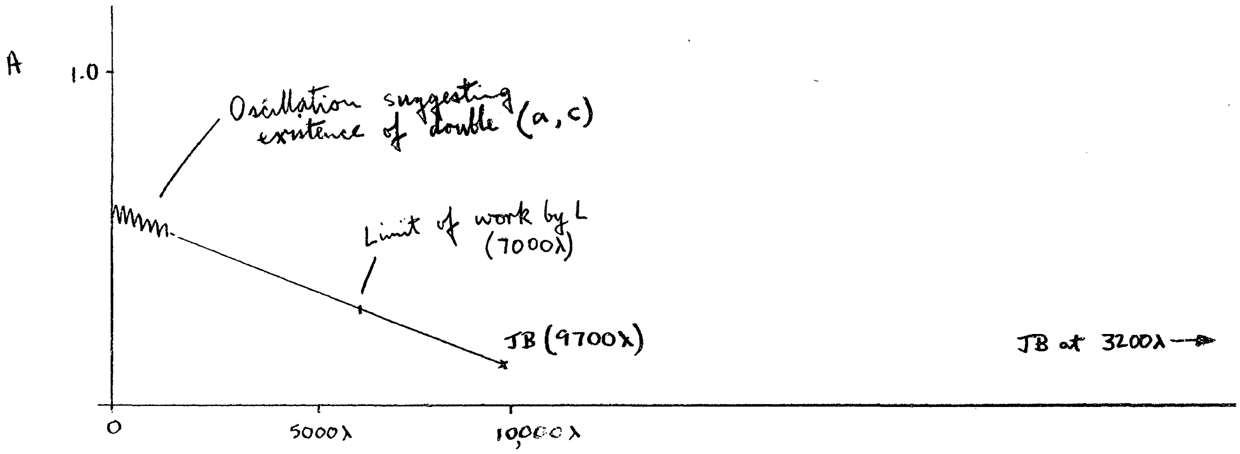
S_a = flux density of a, etc., in units of 10^{-26} watts in^{-2} cps^{-1}

δ_{ac}^{EW} = EW separation of a and c.

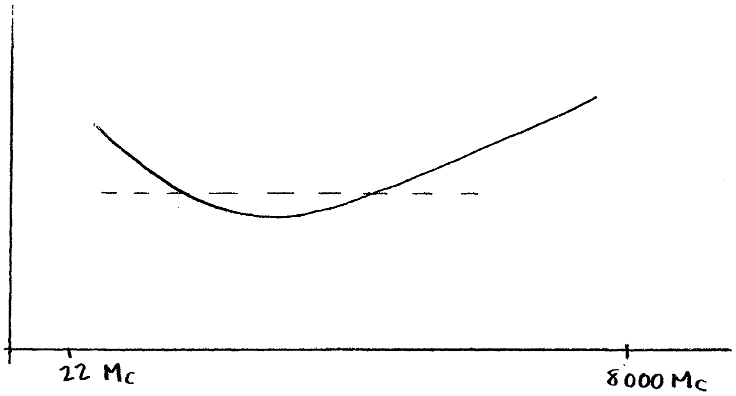
1. According to Lequeux, this radio source is the only known double-galaxy system where the components have a high relative velocity (at least 3000 km/sec), and hence it is the most likely candidate for a case of collision of two galaxies. But, now that he has found the radio source has a much smaller dimension than the optical, the idea of collision has to be discarded. (L, p. 257 and also Shklovsky, Sov. Ast. 4, 885 for a more theoretical agrument.)

2. Lynds and Sobieski suggested that a and c are probably physically connected, Lequeux believes that a, b, and c are three individual galaxies belonging to Perseus Cluster.

3. Work at long spacings. If Lequeux's estimate for the angular size of c (about 10") is correct, then the first min. occurs at 20,000 λ and our work would be most helpful in confirming this. Furthermore, if the Jodrell Bank value at 32,000 λ is correct (A = 0.2), then there must exist some finer structure than that detected by Lequeux, and our work at 12,000 λ to 27,000 λ would be most useful in detecting this. The following figure shows the visibility curve qualitatively. (See Lequeux, p. 256, for details.)



4. Spectrum. LS found the spectrum for c (relative to Cas A) to have the following shape.



They exclude many flux values which they think to be uncertain due to confusion. Heeschen made a similar extensive study and found the same shape (private conversation). If this is correct, then this source will have the most unusual spectrum.

Conway, et al, obtained a spectrum for this source with $\alpha = 0.70$ and for Cas A $\alpha = 0.77$. This means we have an almost flat relative spectrum (dashed line in figure). Their spectra are from 178 Mc to 3200 Mc only. We need more measurements of flux at high frequencies (> 4000 Mc) and at low frequencies (< 100 Mc) to confirm the situation.

II. OTHER SOURCES

Description of Table I - "Other Sources"

Four important papers which we shall refer to frequently are:

MM = Maltby and Moffet (1962) Ap. J. Sup. 7, 93
L = Lequeux (1962) Ann d'As. 25, 221
JB = Allen, et al (1962) MN 124, 477
CKL = Conway, Kellerman and Long (1963) MN 125, 261
MM = interferometric work up to 1600 λ with NS and EW baselines; $\lambda = 31.3$ cm; also phase measurements.
L = interferometer work up to 7000 λ with EW baseline; $\lambda = 21$ cm.
JB = interferometer work with 2200 λ, 9700 λ, 32,000 λ and 61,000 λ; $\lambda = 1.89$ cm; baseline EW or nearly EW.
CKL = study of spectral indices which are defined by

$S \quad \nu^{-\alpha}$ where
s = flux density
ν = frequency
α = spectral index.

In MM there is a table for extragalactic sources which summarizes their results (p. 149-155). In order to avoid unnecessary repetition, our table is put in a form supplementary to the MM table, so the following pages should be used along with the MM table. There is also a similar table in L (p. 237), but ours will include the information from it.

Column I - Source

Each source is given by its 3C number unless it is not contained in such catalogue, in which case it is given by its number in MSH, CTA or CTB, where

MSH = Mills, et al (1958) Aust. J. of Phys. 11, 360
CTA = Harris and Roberts (1960) PASP 72, 237
CTB = Wilson and Bolton (1960) PASP 72, 331

A number of 3C sources also have MSH numbers. See Table II in CKL for such corresponding number.

Column II - Structural Class

We use the same abbreviations as used in MM (p. 147).

S = simple (single)
E = 2 components of roughly equal intensity (< 1.4:1)
U = 2 components of unequal intensity
H = core superimposed on halo
( ) where classification is uncertain, the letter is enclosed in parentheses.
N = not resolved (we shall put these in different lists)
* in MM's table, by the source number, means it is described in text.

The letter p and numbers 3 and 15 have nothing to do with class; they are just put there for convenience.

p in upper corner means there is phase measurement for this source by Moffet (EW). See MM, p. 107, for such measurement.

p in lower left corner means there is phase measurement for this source by Maltby (NS). See MM, p. 133, for such measurement.

3 in upper right corner means there is measurement with fringe position angle (p or PA) 30° by Maltby. See MM, p. 134, for results of such measurement.

15 in lower right corner means there is measurement with p = 150° by Maltby. See MM, p. 135.

Column III - Models

Where only MM has produced a model, we shall refer to the page in MM's table where one can find the model described. For example, MM 149. Where L's model exists, we put down both for comparison. Other models are given in this report.

We also give the values of A (relative amplitude) from JB. For example, $A_{2.2}$ means the value of A at 2200 λ, and $A_{2.2} = [0.4]$ means that the error for this value is large. S_{960} is the flux density (in 10^{-26} MKSU) taken from MM. This is given in the cases where no analysis is given in CKL.

Column IV -- Spectral Class

We use the abbreviation and data in CKL (their analysis goes from 38 Mc to 1400 Mc or 3200 Mc for some sources).

S = α constant below 1400 Mc (no information beyond 1400 Mc).
C = α varies with ν over observed range.
S_1 = α constant up to 3200 Mc.
S_2 = constant up to 1400 Mc, but becomes greater above this frequency.

We put this value of α in parenthesis after the class designation.

Column V -- S_{2700}

This is the flux density at 2700 Mc (extrapolated or interpolated) assuming the values of α given in the previous column.

Column VI -- Notes

Where possible, we give a remark as to whether long spacing work applies. Such a phrase as "expect information at NRAO spacings" should be interpreted with care, because we only mean "expect information as far as relative amplitude is concerned", i.e., regardless of the intensity of the source. For example, suppose a hypothetical source is expected to have the first minimum of the A curve at about 1500 λ with

$A \approx 0.2$ at 12,000 λ
$A < 0.1$ at 15,000 λ
$A \approx 0.4$ at 18,000 λ

and its S_{2700} is estimated to be one flux unit, Assumeparametric amplifiers. We say "expect information" , but actually the apparent intensities will be 0.2, < 0.15, 0.4 f.u. at the mentioned spacings, too weak for the NRAO interferometer to detect. Thus, when we read the notes, we should also bear in mind the order of magnitude of S_{2700} (estimated) is to determine the degree of resolution, although previously undetected fine structure could occur.

Sources with A significantly greater than 1.0.

In Jodrell Bank results, we find a number of sources whose A at some spacings are significantly greater than 1.0. Allen, et al, account for this discrepancy with "background irregularity" (JB, p. 480). But, we think another alternative account is that the 3C flux values are too small. In any case, the JB values for these sources should be treated with caution, since both explanations may be valid. Here we list them for convenience. This phenomenon does not occur for MM results.

$A_{2.2} > 1$	$A_{9.7} > 1$	$A_{32} > 1$	$A_{61} > 1$
3C 15			
18			
42			
119	119		119
153			
190	190		
191			
205			
299	299		
236			
237			
303			
352			
411			
437			
441			
	345		
		49	
		85	
		456	
		459	

TABLE I

OTHER 3C SOURCES

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
MSH 00-222	$(U)^{3}_{15}$	MM 149			Identification with NGC 253. No EW obs. by Moffet.
3C 29	$(U)_{15}$	MM 149			No EW obs. except Allen, et al ($A_{2.2} = 0.5$, $A_{9.7} < 0.3$) Too large for NRAO.
3C 33	${}^{p}_{p}U_{15}$	L — $\gamma_{EW} = 69''$, β_1 & $\beta_2 < 20''$, $r \leq 2$, $\psi = 18° \pm 3°$. MM — $\gamma = 3.8' \pm 0.6'$, $r = 2.5 \pm 0.7$, $\psi = 20° \pm 8°$, stronger component toward SW, 0 to 20 percent could be a third component near centroid of 2. JB — $A_{9.7} = 0.3$, $A_{32} = 0.3$.	$S_2(0.62 \pm 0.02)$	9.3	NRAO work useful to continue EW A-curve and obtain points to estimate β_1 and β_2. (Fig. T1)
3C 38	U^{3}_{15}	MM 149 — $S_{960} = 7.0 \pm 0.7$. JB — $A_{2.2} \approx 0.5$, $A_{9.7} = 0.3$, $A_{61} < 0.7$.			Lack information between 2200 λ and 9700 λ for a model. Expect information at NRAO spacings.
3C 40	${}^{p}_{p}U_{15}$	MM 149 — JB — $A_{2.2} < 0.4$, $A_{9.7} < 0.2$.	$S(0.75 \pm 0.04)$	3.9	No expected information at NRAO spacings.
3C 41	$p^{(U)}$	MM 149 — JB — $A_{2.2} < 0.6$, $A_{9.7} = 1.0$.	$S(0.40 \pm 0.15)$	4.0	Complex, expect information at NRAO spacings. Lack information between 2200 λ and 9700 λ for a model.

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
3C 62	U^{3}_{15}	MM 149 — JB — $A_{2.2} = 0.6$, $A_{9.7} < 0.4$, $S_{960} = 7.0 \pm 0.7$			Only NS information by MM. Their model seems doubtful (based on study of A at different spacings).
3C 66	${}^{p}_{p}U$	MM — $\gamma = 6.6' \pm 1.0'$, $\psi = 115° \pm 7°$. L — no model, results not being very accurate owing to weakness of source. JB — $A_{2.2} = 0.3$, $A_{9.7} < 0.2$.	$S_{1}(0.60 \pm 0.04)$	7.6	See Figs. T2 and T3. It seems MM's model of a double is questionable. Visibility curves seem to suggest superimposed gaussian distributions, i.e., a halo type. NRAO spacings not helpful. See Fig. T4.
3C 75	${}^{p}_{p}E^{3}_{15}$	MM 150 — $A_{2.2} = 0.4$, $A_{9.7} = 0.1$	S(0.73 ± 0.02)	3.6	Too large for NRAO spacings.
3C 86	${}_{p}U$	MM 150 — JB — $A_{2.2} = 1.2$, $A_{9.7} = 0.7$.	S)0.61 ± 0.10)	6.0	No EW results by MM. NS too large for NRAO. From JB's results EW information obtainable at 12,000-27,000 λ which will help to decide EW structure.
3C 89	${}^{p}_{p}U^{3}_{15}$	MM 150 — JB — $A_{2.2} = 0.5$, $A_{9.7} < 0.3$.	S(0.75 ± 0.05)	2.6	Too large for NRAO.

TABLE I (CONTINUED

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
CTA 26	p^{U}	MM 150	(?) (< 0.3)	2.4 at 1420 Mc	No work beyond 1600 λ. NS too large for NRAO. Information may still be obtained in EW, but unlikely.
3C 98	p_{U}^{3} p^{U}_{15}	MM — $\gamma = 3.4' \pm 0.5'$, $\psi = 2.5° \pm 10°$. L — seems like two distributions superimposed. Measurements not very accurate due to weakness of source. JB — $A_{2.2} < 0.2$, $A_{9.7} = 0.1$.	$S_1(0.70 \pm 0.02)$	6.5	See Figs. T5, T6, and T7. EW visibility curves by L and MM both suggest two superimposed gaussians. Results at p = 0° and p = 150° are not incompatible with such model (as shown qualitatively by dotted lines). No expected information at NRAO spacings.
3C 103	p^{E}	MM 150 — JB — $A_{2.2} = 0.6$, $A_{9.7} = 0.3$, $A_{32} < 0.3$, and $A_{61} < 0.09$	$S(0.50 \pm 0.03)$	2.9	$A \approx 1$ up to 1600 λ in EW. First min. quite certainly occurs between 2200 λ and 9700 λ. Expect some information at NRAO spacings (probably second min.).

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
3C 105	H^{3}_{15}	MM 150 — JB — $A_{2.2} = 0.7$, $A_{9.7} < 0.5$	S(0.50 ± 0.5)	4.2	Need information above 1300 λ in NS. In EW only two values obtained. Need more information at small spacings.
3C 111	${}^{p}_{p}E$	MM — $\gamma = 2.5' \pm 0.3'$, β_1 and $\beta_2 = 1.2' \pm 0.3'$, $r = 1 \pm 0.15$, $\psi = 60° \pm 7°$. L — in good agreement with Cal Tech results. JB — $A_{2.2} = 0.3$, $A_{9.7} < 0.1$.	$S_1(0.73 \pm 0.03)$	7.4	See Figs. T8, T9 and T10. Too large for NRAO.
3C 123	(E)	MM — not resolved. L — combine with JB results at 9700 λ and 32,000 λ and suggest double with $\gamma_{EW} = 12.5''$, $\beta_1 = \beta_2 = 5''$ or $6''$. In EW $A_{32} = 0.08$ and $A_{61} = 0.08$. This suggests the existence of a structure with a very small diameter. L also made observations with $p = \pm 51°$. In both cases, γ of source seems to be of same order as γ_{EW} (up to 1800 λ).	$S_2(0.69 \pm 0.02)$	35.4	NRAO spacings most useful to confirm L's model. If it is right, the first subsidiary max. should occur between 15,000 λ and 18,000 λ. If L is wrong, an alternative model would be two superimposed gaussians (as shown qualitatively by dotted line) which NRAO spacings would also help to confirm.

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
3C 129	$^{p}_{p}$(U)	MM 151 JB — $A_{2.2} < 0.4$, $A_{9.7} < 0.4$, $A_{61} < 0.2$, $S_{960} = 10.6 \pm 1.1$			Complex structure. Need much work at short spacings. NRAO spacings not helpful at present. (See A curves on MM, pp. 116 and 137.)
3C 133	(U)	MM 151 JB — $A_{2.2} = 0.7$, $A_{9.7} = 0.3$, $A_{32} = [0.4]$, $A_{61} < 0.3$.	S(0.67 ± 0.04)	3.7	No EW obs. by Moffet. But JB results show that there is fine structure in EW so that at NRAO spacings information can be expected.
3C 134	$_{p}^{E}$	MM — $\gamma = 120'' \pm 12''$, $\psi = 175° \pm 5°$, $r = 1 \pm 0.15$, $\beta_1 = \beta_2 = 30'' \times 60''$ with elongation along major axis. L — $\gamma_{EW} = 39'' \pm 14''$ (MM— $\gamma_{EW} = 36'' \pm 12''$) - suspects fine structure on components. JB — $A_{2.2} = 0.6$, $A_{9.7} = 0.1$, $A_{32} < 0.04$.	S(0.96 ± 0.02)	5.4	Will get some information at NRAO spacings, but A will be very small. See Fig. T12
3C 135	$^{p}_{p}(U)^{3}_{15}$	MM 151 JB — $A_{2.2} < 0.6$, $A_{9.7} = 0.4$, $A_{61} < 0.5$.	S(0.74 ± 0.05)	2.2	Expect information at NRAO spacings, but lack information between 2200 λ and 9700 λ for a model.

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
Pictor A	$p_{(U)}{}^{3}_{15}$	MM 151 and 148			Complex structure - probably more than a two-component model. Need much short spacing work in EW. Too large for NRAO.
3C 172	p^{E}	MM 151 — JB — $A_{2.2} = 0.4$, $A_{9.7} = 0.3$, $A_{61} < 0.4$	S(0.70 ± 0.05)	2.1	No EW obs. by Moffet. Expected A at NRAO spacings small.
3C 180	(S)	MM 151 — JB — $A_{2.2} = 0.7$, $A_{9.7} = 0.3$, $A_{32} < 0.2$, $A_{61} < 0.5$.	S(0.82 ± 0.05)	1.7	Expect information at spacings.
3C 187	p^{U}	MM 151	S(1.00 ± 0.10)	0.8	No EW work by Moffet and JB.
3C 192	S	MM 151 — JB — $A_{2.2} = 0.4$, $A_{9.7} < 0.4$.	S(0.70 ± 0.04)	3.2	No Moffet obs. Seems too large for NRAO.
3C 198	H^{3}_{15}	MM 152 — JB — $A_{9.7} < 0.2$.	S(1.01 ± 0.04)	1.3	No expected information at NRAO.
3C 208	${}^{p}_{p}U$	MM 152 — JB — $A_{2.2} = 0.5$, $A_{9.7} < 0.3$, $A_{32} = 0.2$, $A_{61} < 0.2$. $S_{960} = 4.9 \pm 1.2$.			Too weak. Fine structure suitable for long spacing work, but due to weakness of source and no α, NRAO possibilities unpredictable.

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
3C 219	p^E	MM 152 — JB — $A_{2.2} = 0.5$, $A_{9.7} < 0.2$	$S_2(0.77 \pm 0.03)$	(5.2)	Too large for NRAO spacings. Work needed between 1500 λ or 6000 λ.
3C 225	p^U	MM 152 — $A_{2.2} = 0.7$, $A_{9.7} = A_{32} = A_{61} = 0.5$	$S(0.81 \pm 0.05)$	2.7	Very interesting source for long spacings. Considerable fine structure possible.
3C 227	$p^{U^3_{15}}$	MM 152 — $A_{2.2} = 0.3$, $A_{9.7} < 0.1$.	$S(0.69 \pm 0.04)$	5.4	Too large for NRAO in EW. May get information in NS (not resolved up to 1600 λ).
3C 230	(U)	MM 152 — $A_{2.2} = 0.6$, $A_{9.7} = 0.7$, $A_{32} = 0.2$, $A_{61} < 0.1$	$S(0.84 \pm 0.10)$	2.5	Expect information at NRAO spacings, at least in EW.
3C 234	(U)	MM 152 — $A_{2.2} = 0.7$, $A_{9.7} = 0.3$, $A_{32} < 0.1$, $A_{61} < 0.1$.	$S(0.80 \pm 0.03)$	3.4	Expect information at NRAO spacings.
3C 238	(U)	MM 152 — $S_{960} = 5.5 \pm 0.6$			No EW observations at all. Need more work at short spacings.
3C 243	p^U	MM 152 — $A_{2.2} = 0.6$, $A_{9.7} = 0.3$, A_{32} and $A_{61} < 0.3$.	$S(0.98 \pm 0.15)$	0.5	Expect information.

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
3C 264	H	MM 152 — $A_{2.2} = 0.2$, A_{32} and $A_{61} < 0.1$.	S(0.59 ± 0.04)	5.4	Too large for NRAO.
3C 270	$p_{E}{}^{3}_{15}$	MM 152 — $A_{2.2}$ and $A_{9.7} < 0.3$	S_2(0.41 ± 0.03)	(17.7)	Too large for NRAO.
3C 273	(U)	MM — not resolved. L — $\gamma_{EW} = 14''$, $r < 1.5$, $\beta_1 = \beta_2 \approx 4''$ besides the two components, L also suggests a large-scale structure ("halo or bridge"). If this is true, then β_1 and $\beta_2 < 4''$ still. JB — $A_{32} = 0.3$, $A_{61} < 0.1$ L suggests the identification of 3C 273 with a galaxy similar to that associated with Cyg A, but six times farther away.	S_1(0.33 ± 0.04)	32.4	Expect much information at NRAO spacings, where first or second subsidiary maxima occur, and source strong enough. See Fig. T13.
3C 278	$p_{S}{}^{3}_{15}$	MM 153 — $A_{2.2}$ and $A_{9.7} < 0.2$	S(0.66 ± 0.04)	5.4	Too large for NRAO.
MSH 13-33	S	MM 153 — $S_{960} = 6.9 \pm 0.7$	---	---	No EW measurement. NS too large for NRAO.

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
3C 310	$p^{(E)}$	MM 153 — $A_{2.2} = [0.1]$, $A_{9.7} < 0.07$, $A_{61} < 0.1$.	S(0.94 ± 0.02)	4.2	Too large for NRAO.
3C 313	$p_U{}^3$	MM 153 — $A_{2.2} = 0.3$, $A_{9.7} < 0.2$.	S(0.80 ± 0.10)	2.5	Too large for NRAO.
3C 327	$p_U{}^3$	MM 153 — $A_{2.2} = 0.5$, $A_{9.7} = 0.1$, A_{32} and $A_{61} < 0.1$.	S(0.79 ± 0.04)	5.0	May obtain information in NS because $A_{1557\ \lambda} = 0.82$, i.e., up to 1600 λ, far from being resolved yet.
3C 343	p_E	MM 154 — considerable complexity (see MM 119 for A curve), $A_{2.2} = 1.3$, $A_{9.7} = 0.7$, $A_{32} < 0.1$, $A_{61} < 0.5$, $S_{960} = 10.5 \pm 0.9$.			No NS measurement. May obtain information in NRAO spacing.
3C 347	p_U	MM 154 — $A_{2.2} = 0.4$, $S_{960} = 2.5 \pm 0.6$.			No NS measurement. Probably no information at NRAO spacing.
3C 353	p_U	MM — $\gamma_{EW} = 2.5' \pm 0.1'$, $\beta_1 = \beta_2 = 1.4' \pm 0.2'$, $r = 2.0 \pm 0.3$. Stronger component toward east. L — $\gamma_{EW} = 2.3'$, $\beta_1 = \beta_2 = 1.2'$, $r = 2$. JB — $A_{9.7}$, A_{32}, A_{61} all < 0.1. See Mills (1960) Aust. J. Phys. 13, 559 for optical identification (listed as MSH 17-06).	S(0.64 ± 0.02)	39.5	No expected information at NRAO. No NS and oblique base measurement -- cannot determine ψ. See Fig. T14.

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
3C 365	(U)	MM 154 — $A_{2.2} = 0.3$, $A_{9.7} < 0.3$, $S_{960} = 3.5 \pm 0.5$.			No NS measurement. EW most likely too big for NRAO.
CTA 80	P_U	MM 154 — also measurements with p = 69° and p = 125°, $S_{960} = 7.8 \pm 0.8$.			Seems too large for NRAO.
3C 386	(S)	MM 154 — $A_{2.2}$ and $A_{9.7} < 0.2$.	S(0.64 ± 0.02)	4.9	Only EW measurement. Too large for NRAO.
3C 388	(U)	MM 154 — $A_{2.2} = 1.0$, $A_{9.7} = [0.2]$, $A_{32} < 0.1$.	S(0.58 ± 0.03)	5.0	Only EW measurement. Probably too large for NRAO.
3C 402	$P_{(U)}$	MM 154 — $A_{9.7} < 0.4$, $A_{61} < 0.4$	S(0.57 ± 0.05)	2.8	Only EW measurement. May obtain information.
3C 403	$P_{(E)}$	MM 154 — $A_{2.2} = 0.5$, $A_{9.7}$ and $A_{61} < 0.2$.	S(0.65 ± 0.04)	4.9	Only EW measurement. Too large.
3C 413	$P_{(E)}$	MM 154 — $A_{2.2} < 0.5$, $A_{9.7} < 0.8$			Only EW measurement - information possible.
3C 442	S	MM 155	S(0.83 ± 0.04)	2.6	No EW measurement -- too large.

TABLE I (CONTINUED)

Source	Structural Class	Models	Spectral Class	S_{2700} (10^{-26} MKS)	Notes
3C 444	Double	MM — not resolved. $\gamma_{EW} = 0.6' \pm 0.3'$, $\gamma_{NS} = 2.0' \pm 0.5'$. L — $\gamma_{EW} = 24''$, β_1 and $\beta_2 \sim 15''$, $\psi = 12° \pm 5°$ or $\psi = 78° \pm 5°$. JB — $A_{2.2} = 0.8$, $A_{9.7} < 0.1$	(C) (0.92 ± 0.04)	< 7.0	Expect information at NRAO spacings. See Fig. T15.
3C 445	$p^{(E)}_{15}$	MM 155 — $A_{2.2} = 0.6$, $A_{9.7} = [0.3]$, $A_{32} < 0.4$, $A_{61} < 0.2$	S(0.72 ± 0.03)	3.9	Possibly information at NRAO.
3C 446	U_{15}	MM 155 — $A_{2.2} = 1.0$, $A_{9.7} = 1.1$, $A_{32} = [0.7]$	S(0.53 ± 0.04)	4.3	Expect information at NRAO but need information between 2200 λ and 9700 λ for a model. Structure expected to be quite complex.
3C 452	$P_{(U)}$	MM 155 — $A_{2.2}$ and $A_{9.7} < 0.2$	S_1(0.78 ± 0.02)	6.6	Too large. Need much information between 1000 λ and 4000 or 5000 λ.
3C 456	U	MM 155 — $A_{9.7} = 0.6$, $A_{32} = 1.5$, $A_{61} < 0.5$	S(0.81 ± 0.04)	0.9	Expect information at NRAO but need work between 1600 λ and 9700 λ for a model.
3C 465	$P_{(H)}$	MM 155 — $A_{2.2} = 0.2$, $A_{9.7} < 0.2$	S(0.74 ± 0.03)	5.2	Too large

Figure T1 - Visibility Curve of 3C33 (L)

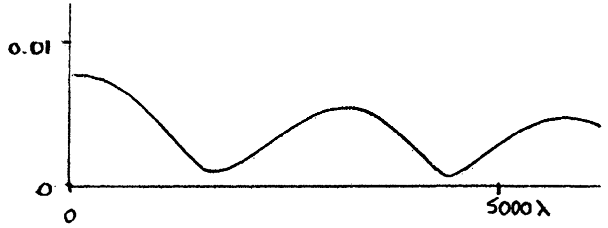


Figure T2 - Visibility Curve of 3C66 (MM-EW)

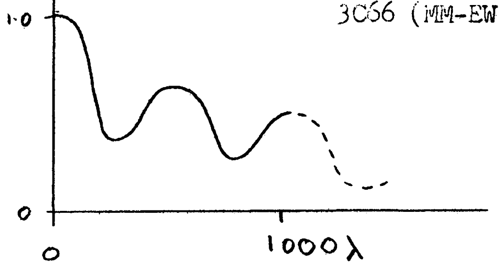


Figure T3 - Visibility Curve of 3C66 (L)

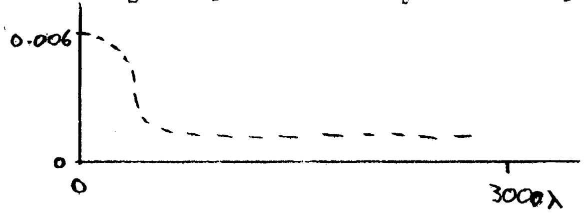


Figure T4 - Visibility Curve of 3C66 (MM-NS)

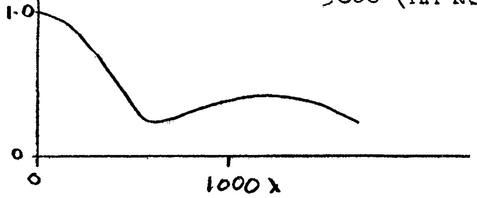


Figure T5 - Visibility Curve of 3C98 (L)

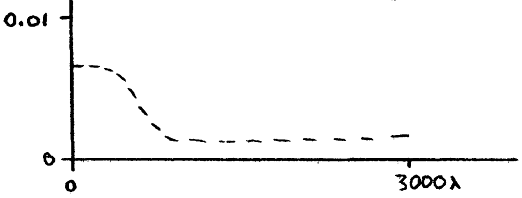


Figure T6 - Visibility Curve of 3C98 (MM)

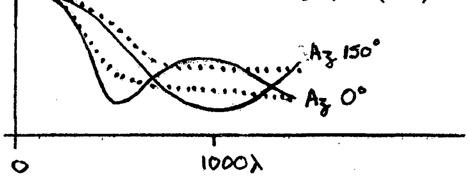


Figure T7 - Visibility Curve of 3C98 (MM)

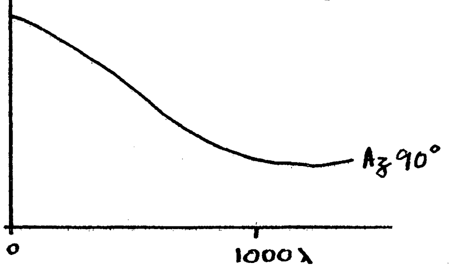
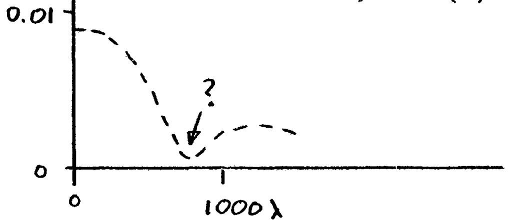


Figure T8 - Visibility Curve of 3C111 (L)



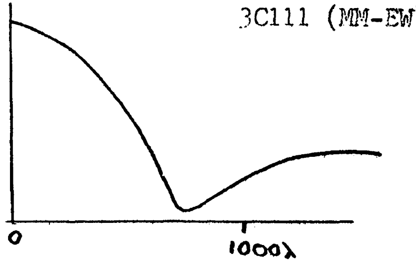


Figure T9 - Visibility Curve of 3C111 (MM-EW)

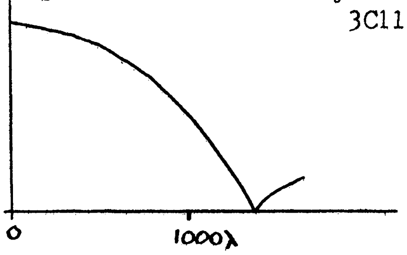


Figure T10 - Visibility Curve of 3C111 (MM-NS)

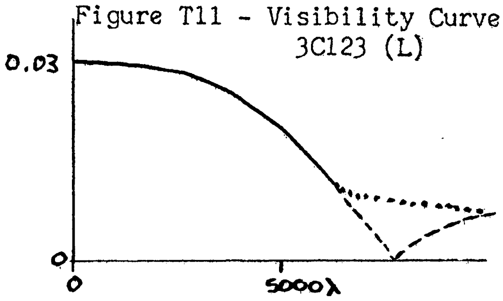


Figure T11 - Visibility Curve of 3C123 (L)

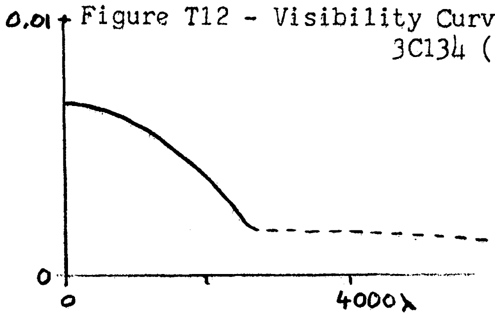


Figure T12 - Visibility Curve of 3C134 (L)

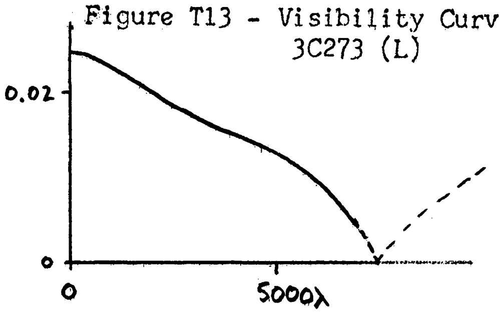


Figure T13 - Visibility Curve of 3C273 (L)

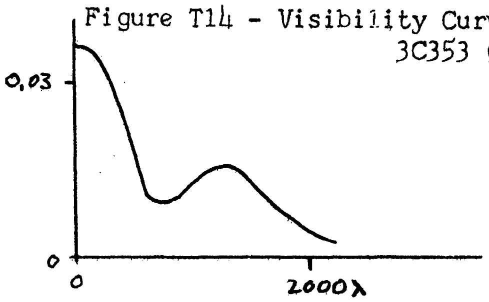


Figure T14 - Visibility Curve of 3C353 (L)

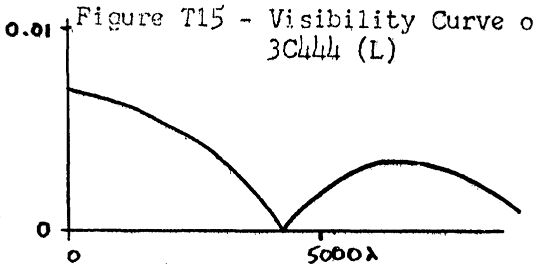


Figure T15 - Visibility Curve of 3C444 (L)

Description of Tables II, III and IV

These three tables contain sources for which no models exist.

Table II

This table contains sources for which we expect information at NRAO spacings. For doubtful cases we enclose the source number in parentheses.

S_{2700} is obtained as before.

γ is the angular diameter estimated by Bennett based on results by JB, MM, and Leslie (MM 122, 51), with the assumption that the sources have a circular gaussian distribution (see Bennett, Mem. RAS 68, 164).

$A_{9.7}$ and A_{32} are just taken from BJ for the convenience of rising this table.

For cases where no S_{2700} is given, see MM, pp. 104-106, and 129-132 for S_{960}.

Table III

This table contains sources of which will probably be too weak for the NRAO interferometer. Most of these sources were observed by JB only. Where the sources are also observed by others, we state the observer. γ is again the angular size estimated by Bennett. S_{159} is the flux value from 3C because high frequency fluxes, such as at 1400 Mc or 960 Mc, are not available for most sources. $A_{2.2}$ and $A_{9.7}$ are stated for convenience. Most of these sources will be too weak for 2700 Mc.

Table IV

This table contains "point sources" which, as far as we can deduce, are unresolved up to 32,000 λ.

TABLE II

SOURCES FOR WHICH WE EXPECT "INFORMATION" AT LONG SPACINGS

Source (3C)	γ	S_{2700}	$A_{9.7}$	A_{32}	Notes
1			0.6		
(4)			< 0.4		
(6)			< 0.3		
7			0.3		
11			< 0.5		
13	< 20'		0.7	< 0.2	
14	< 20"		0.8	< 0.4	
15	< 40"		[0.4]	< 0.2	
16	< 1'.0"		< 0.6		
17	< 40"	3.9	[0.3]		
18	< 40"	4.3	0.3	< 0.6	
19	< 12"	2.3	0.9	[0.7]	Maybe a point source — $A_{2.2} = 0.7$
(20)	< 1'.0	< 8	0.2	< 0.1	
22	< 2'.0		[0.7]	< 0.4	
23		~2	0.7		
(28)	< 3'.0	~1.5	< 0.4		$A_{2.2} = 1.0$
42	< 2'.5		0.7		
43	< 3'.0	~2.5	1.0		$A_{2.2} = 0.4$
47	< 1'.6	2.3	0.3		
53			0.8	< 0.4	
54	< 12"		1.0	< 0.8	Maybe a point source
55	< 2'.5		0.5		
60			0.5		
61			< 0.6		
(63)	< 40"	2.2	0.2	< 0.3	

Continued --

TABLE II (CONTINUED)

Source	γ	S_{2700}	$A_{9.7}$	A_{32}	Notes
65	3.7' ± 1.0'	2.3	0,3	< 0.2	
69	< 12"	1.9	0.6	[0.4]	
71	< 40"	4,0	0,5	< 0,8	
73			[0.5]		
76			[1.0]	< 0.7	< 0.7 — maybe a point source
78	< 2.0'	5.9	0.4		
(79)	< 1,5'	3.2	0,2	< 0.4	
82			0.4	< 0,3	
(90)			< 0,8		
91	< 15"		0.7		
94			0.8	< 0.4	
114	< 3.0'		[0.3]	< 0.6	
126			< 0.7		
141	< 40"	1.5	0.4		
143			0.8		
153	< 40"	2.6	0.5	0.4	
154	1.0' ± 1.0'	3,5	0,7		
155			0.5		
158	< 12"	1,3	0.6		
159			0.5		
161		∼10	0,5	0.1	
166	< 2,5'	∼ 2	0.3		
168			0.6	< 0.4	
173	< 3.0'		[0,3]		
175	< 45"	∼ 2	0.3	< 0.1	
180	< 3,0'	∼ 2	0,3	< 0.2	
181	< 2.5'		0.6		

Continued --

TABLE II (CONTINUED)

Source	γ	S_{2700}	$A_{9.7}$	A_{32}	Notes
184	< 2.5′		[0.6]		
186	< 12″		1.0	0.2	
191	< 40″	~1	[1.1]		A_{61} < 0.6 — maybe a point source.
194	< 3.0′		0.4	< 0.2	
196	< 12″	9.5	0.8	0.2	
199			0.8	< 0.5	
205	< 40″		0.6		
206			< 0.6	< 0.3	
210	< 12″		1.3	< 0.3	
212	< 15″	1.3	0.5	< 0.1	
215	< 3.0′		0.3	< 0.2	
216	< 12″	2.8	0.8	0.4	
228	< 40″	2.6	0.3		
235			0.9	< 0.2	
237	< 12″	4.2	0.9		
245	< 40″		0.3	< 0.3	
252	2.0′ ± 1.5′		0.3	< 0.2	
254	< 12″	2.0	0.7	< 0.2	
258			[0.3]		
261		< 1	[0.4]		
263	< 15″		0.7		
272	< 3.0′		0.5	< 0.3	
280	< 40″	3.3			
282			1.2	< 0.1	$A_{61} = 0.2$
(285)	3.0′ ± 2.0′		< 0.5		
287	< 12″	9.7	0.7	0.3	
288	< 40″		0.5		

Continued --

TABLE II (CONTINUED)

Source	γ	S_{2700}	$A_{9.7}$	A_{32}	Notes
293	< 2.5'		0.6	0.5	$A_{22} = 0.4$
(294)	< 40"		< 0.6		
295	< 12"	11	0.9	0.9	
303	< 40"		0.8	< 0.4	
305	< 12"		0.7	< 0.2	
318	< 15"	2.3	1.0		
(321)			< 0.5		
325	< 40"		< 0.4		
330	< 2.0'	4.8	[0.2]	0.3	
333			0.4	< 0.4	
342			0.3	< 0.3	
345	< 12"	5	1.5	< 0.3	
346	< 15"		0.6		
349	< 40"		[0.4]		
351	< 3"		[0.5]		
352	< 12"		1.0	< 0.3	
(354)			< 0.7		
(356)	1.5' ± 1.5'		< 0.6		
360			< 0.8		
361			[0.3]	< 0.3	
362			0.5	< 0.4	
368	< 3.5'		[0.3]	< 0.2	
377			0.6	< 0.2	
380	< 20"	9	0.6	0.2	
381	< 20"		0.5	< 0.2	
390	< 40"	3.2	0.4	0.2	
394	< 1.0'		[0.3]		

Continued --

TABLE II (CONTINUED)

Source	γ	S_{2700}	$A_{9.7}$	A_{32}	Notes
401	$< 40''$	3.7	[0.3]		
404			[0.5]		
409	$< 30''$	5	0.3	0.1	
410	$< 12''$	6	0.5	[0.1]	
411	$< 30''$	1.7	0.4	< 0.2	
429			0.6		$A_{61} = 0.5$
431	$< 1.5'$	1.5	0.4	0.3	
432	$< 40''$		[0.5]	< 0.3	
433	$< 30''$	7	0.4		
437	$< 40''$		0.4	< 0.7	
440			0.8	< 0.6	
447			[0.6]	[0.5]	
449	$3.0' \pm 1.5'$		[0.3]		
455	$2.5' \pm 1.5'$		0.7	< 0.7	
457			[0.4]		
463			0.4	< 0.3	
470	$< 2.5'$		0.7	< 0.9	

TABLE III

SOURCES WHICH ARE ESSENTIALLY TOO WEAK AT 2700 MC

Source (3C)	γ	S_{159} (10^{-26} MKS)	$A_{2.2}$	$A_{9.7}$	Notes
9	< 3.0'	15.0		< 0.4	
21		10.0		< 0.4	
24		9.5		< 0.5	
27	< 2.0'	24	< 0.4	< 0.4	
30		14.5	1.0		
31	2.5' ± 1.5'	15.5		< 0.6	
32		20	0.3	< 0.3	
34	< 2.5'	11.0		< 0.5	
74		8.5	< 0.6	< 0.5	
97		10.0		< 0.5	
99	< 3.0'	14.5		< 0.4	
100		8.5		< 0.7	
101		9.0	1.1	< 0.6	
104		9.0		< 0.8	
108		10.0	< 0.7	< 0.7	
109	< 1.5'	19.5	0.6	< 0.5	Work done by Moffet. A curve probably reaches zero 7000 λ - 10,000 λ.
116		12.5		< 0.5	
121		12.0	< 0.4	< 0.7	
127		12.0		< 0.4	
128		11.5		< 0.5	
132	< 1.0'	16.5	0.8	< 0.4	Work done by Maltby.
137	< 40''	8.5	1.4		
139		1.9	< 0.8	< 0.5	
149		12.0	< 0.6	< 0.7	

Continued --

TABLE III (CONTINUED)

Source (3C)	γ	S_{159} (10^{-26} MKS)	$A_{2.2}$	$A_{9.7}$	Notes
165	$< 2.5'$	12.5	< 0.7	< 0.7	
167		8.0	0.8	< 0.4	
171	$< 45''$	30. $S_{2700} = 2.4$	0.6	0.2	Work done by MM. A curve reaches minimum probably at 10,000 λ - 12,000 λ. NRAO spacings useful to see whether double or not. No work bebetween 2200 λ - 9700 λ.
174		10.0	< 0.7	< 0.7	
177	$< 3.0'$	12.5	0.5	< 0.3	
185		8.5	0.5	< 0.4	
192	$< 2.5'$	17.0	0.4	< 0.4	Work done by Maltby — probably single source.
195		21.0	0.3	0.2	Work done by Maltby — possibly some information at NRAO spacings.
220		10.5	< 0.7	< 0.5	
224		14.5	0.6	< 0.5	
229		10.0		< 0.7	
231	$< 1.5'$	12		< 0.7	
239	$< 2.5'$	15	0.4	0.2	Expect some information at NRAO.
241	$< 45''$	13	0.9	< 0.4	
242		11.5	0.5	< 0.3	
244		12.0	< 0.8	< 0.3	
246		8.5		< 0.6	
249	$2.5' \pm 1.5'$	14.5	0.9	< 0.3	
250	$< 3.0'$	14.0	< 0.3	< 0.2	

TABLE III (CONTINUED)

Source (3C)	γ	S_{159} (10^{-26} MKS)	$A_{2.2}$	$A_{9.7}$	Notes
255	< 2.5'	15.0	< 0.4	< 0.4	
257	< 4.0'	11.0	0.5	< 0.3	
262		10.5	0.3	< 0.5	
265	< 1.0'	30	0.4	< 0.2	Work done by MM also.
267	< 3.5'	14.5	0.4	< 0.2	Work done by Maltby.
268		8.5	0.8		
271		11.5		< 0.2	
275	< 3.0'	18.0	0.6	< 0.2	Work done by Maltby.
276		8.0	< 0.8		
277	4.0' ± 2.0'	12	< 0.7		
279		20.5	0.7	< 0.2	Work done by MM.
281		14.0	0.7	< 0.2	
284	3.0' ± 2.0'	10.0	[0.3]	< 0.2	
291		10.0	0.9		
296	3.0' ± 1.5'	10.0	0.5		
297	4' - 10'	14.5	0.5		
301		9.5	< 0.6	< 0.4	
302		8.5	< 0.8		
304		11.0	< 0.6		
308		10.0	< 0.6		
309		11.5	[0.4]		
314		8.5	< 0.7	< 0.7	
315	< 2.0'	26	< 0.3	< 0.2	Studied by MM.
316		8.5	< 0.4	< 0.5	
317	< 40''	55	0.8	< 0.1	Studied by MM.

Continued --

TABLE III (CONTINUED)

Source (3C)	γ	S_{159} (10^{-26} MKS)	$A_{2.2}$	$A_{9.7}$	Notes
319	< 2.5'	16.5	0.3	< 0.4	
320	< 40''	8.0	1.2	< 0.6	
323	2.7' ± 2.0'	9	1.3		
324	< 40''	18	0.8	< 0.4	Studied by MM.
328		8.0	< 0.6	< 0.3	
329		11.0	< 0.6	< 0.5	
331		10.5	0.5		
334	< 40''	16.0	0.6	< 0.5	
336	< 40''	13.5	1.0	< 0.3	
337	< 3.0'	8.5		< 0.8	
338	< 2.0'	49	0.2	< 0.1	Studied by Moffet (EW)
339		14.5		< 0.1	
357	< 3.0'	9.0	< 0.5	< 0.3	
359		12.0	< 0.5	< 0.3	
369		13.0	0.5	< 0.5	
375		11.0	< 0.5	< 0.6	
376		12.0	< 0.5	< 0.7	
379		8.5	< 0.5		
385		17.0	< 0.8	< 0.7	
387		22.0	< 0.5	< 0.4	
389	3.3' ± 2.0'	17.0	< 0.3	< 0.4	
391	2.0' ± 2.0'	27	0.4	< 0.3	
393		10.0	< 0.7	< 0.8	
400	1.0° ± 0.2°	25	< 0.5	[0.2]	
407		11.5	< 0.4	< 0.8	
419		10.5	< 0.5	[0.4]	

Continued --

TABLE III (CONTINUED)

Source (3C)	γ	S_{159} (10^{-26} MKS)	$A_{2.2}$	$A_{9.7}$	Notes
421		13.5	< 0.4	< 0.4	
423		8.0		< 0.9	
424		16.0	0.7	< 0.5	Studied by Moffet.
425		8.0		< 0.8	
434	< 3.5′	10.5	< 0.7		
435	< 40″	12.5	0.7	< 0.5	
436	< 40″	21.0	0.8	< 0.2	Studied by MM.
438	< 40″	43	0.7	< 0.07	Studied by Maltby (NS).
439		8.0		< 0.6	
441	< 40″	12.5	1.4	< 0.5	Studied by Maltby.
443		8.0		< 0.5	
448		9.5		< 0.5	
451		9.0		< 0.7	
458	2.2′ ± 1.5′	12.5	< 0.4	< 0.6	
462		10.0		< 0.7	
468		8.0	< 0.9	< 0.8	
469		12.0	0.8	< 0.5	Studied by MM.

TABLE IV

POINT SOURCES

Source (3C No.)	γ	S_{2700} (10^{-26} MKSU)
2	$< 5''$	2.4
48	$< 1''$	~ 8
49	$< 4''$	
85		
107	$< 12''$	
119	$< 1.5''$	< 8
147	$< 2''$	~ 11
152	$< 12''$	
190	$< 4''$	
222	$< 4''$	
256	$< 12''$	
286	$< 1.5''$	~ 10
298	$< 4''$	< 5.8
299	$< 2''$	< 3.0
418	$< 3''$	3.7
422		
446		5.0
459	$< 3''$	1.6
237	$< 12''$	4.8

III. MISCELLANEOUS SOURCES

1. Tables of galactic sources.

All the galactic sources studied by L and MM are only good for short-spacing work (< 5000 λ). Thus we only include the well known sources. There are three tables which should be consulted for these sources.

(i) Lequeux, p. 226 — thermal sources (p. 224 for diagrams)
(ii) Lequeux, p. 228 —non-thermal sources (p. 229 for diagrams)
(iii) Maltby and Moffet, p. 158.

2. MSH sources.

There are a number of sources with MSH number, but no 3C number. Maltby and Moffett studied a few of them and their models are given in their table of extragalactic sources (pp. 149-155). Allen, et al, studied a number of them and their results are given on JB, p. 494. Most of these sources are too weak for 2700 Mc. The previous ones are the stronger ones from which we may get information (taking into account both the flux and the degree of resolution).

Source (MSH No.)	S_{158}(10^{-26} MKS)	$A_{9.7}$
01-115	12	0.8
03-19	19	0.7
06-119	16	0.7
19-04	12	0.6
19-111	16	0.9
21-19	13	0.7
*18-13	70	<0.07
*18-18	65	<0.09
*18-113	100	<0.06

* These are a few strong sources, but only good for work at short spacings.