NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, West Virginia

INTERNAL REPORT

THE 11 CM FLUXES OF 14 EXTRAGALACTIC RADIO SOURCES

Nigel J. Keen

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Abstract

The relative and absolute fluxes of 14 small diameter extragalactic sources have been determined. Previous published flux measurements appear to be systematically lower than the measurements herein reported. The observation frequency was 2695 MHz.

Introduction

Most of the early interferometer observations [1] were confined to the following 3C sources: 48, 71, 84, 111, 119, 123, 147, 161, 196, 273, 279, 286, 295, 345, 380, 405, and 461. The fluxes of 3C 405 and 3C 461 have been measured extensively in this frequency region and their fluxes determined [2]; the flux of 3C 84 has been measured at 11 cm by Wendker [3]. The other sources have been measured in this region by Heeschen and Meredith [4], Conway, Kellerman and Long [5], and by Kellerman [6]; it was felt, however, that a further measurement of these fluxes was required.

The purpose of these measurements was to confirm the relative fluxes as measured in [4], [5], and [6], and to estimate the absolute fluxes by comparing them with Virgo A. The system used was the original 85-foot antenna with a switched parametric amplifier and a standard NRAO back-end.

Equipment

The original NRAO 85-foot antenna was used, which has an efficiency of 53 percent at a wavelength of 10 cm [7]. A MPC parametric amplifier was used, which gave system noise temperature of approximately 250 °K. The receiver and synchronous detector were switched at 400 Hz. The standard NRAO back-end was used, with a center IF of 30 MHz and an approximate bandwidth of 8 MHz. The RC integration time constant was 2 seconds. Analog output was provided on a Sanborn recorder. Digital output was on punched paper tape and print-out.

An uncalibrated noise tube was provided as comparison source.

Method of Observation

Source fluxes were compared with the flux of Virgo A via the noise tube. An observation comprised three runs alternating on and off of the source: the sequence is off-on-off-on-off-on-off-on-off, the first run being with the antenna tracking a point away from the source and the noise tube as source. In the second and third sequences the noise tube was not used, but the source itself was tracked. In the second sequence the off-source positions were alternately ~~east~~ north and ~~west~~ south of the source, and in the third sequence east and west of the source. A typical east-west sequence for 3C 273 is shown in Figure I.

Possible inaccuracies in positioning telescopes or determining source positions are small, but are anyhow taken into account in the flux determinations. Furthermore, since all sources but Virgo A have small diameters, good positions are available: for Virgo A, drift curves and ~~right ascension~~ declination scans gave its position to better than one minute of arc (the half-power beamwidth of the 85-foot antenna at 11 cm was 18 minutes). It is assumed that all the flux of Virgo A is in an area of diameter < 3 arc minutes.

The Reduction of Observations

All observations were corrected for extinction, according to Altenhoff, et al [8]. Drifts and declination scans of Virgo A were taken every day in addition to on-off sequences, in order to determine systematic changes in parametric amplifier gain and noise tube output: this latter effect was somewhat surprising in view of the stability previously experiences from such noise tubes. The curves showing changes in noise tube output and system gain are shown in Figure II.

The rms flux uncertainty was calculated from the scatter of the experimental results. In addition, maximum corrections for the detector law $\left({}^{+\,0\%}_{-\,2\%}\right)$ and pointing errors $\left({}^{+\,2\%}_{-\,0\%}\right)$ were taken. A further ± 1.5% was allowed for noise tube drifts between daily calibrations on Virgo A and short-term receiver gain fluxtuations. Wendker has estimated the uncertainty in flux value for Virgo A at 11 cm is ± 4.5%, which is taken into account when determining absolute flux errors.

Results

The results of the observations are shown in Table I: 11 cm fluxes from NRAO are designated S_N. The fluxes of 3C 84 [3], 3C 144 [2], 3C 274 (Virgo A) [2], 3C 405 [2], and 3C 461 [2] are also given in the table, for purposes of comparison. Fluxes are determined assuming the flux of Virgo A at this frequency to be 124 (± 5.6) x 10^{-26} W m^{-2} Hz^{-1}. Absolute and relative flux errors are shown.

Three comparisons to the fluxes herein report are given: the extrapolated fluxes of (a) Heeschen and Meredith, (b) Kellerman, and (c) Conway, Kellerman and Long.

The measurements of Kellerman are conspicuously low, by comparison with the other measurements. Figures III and IV compare the fluxes herein reported with, respectively, Kellerman and Heeschen and Meredith. For all sources except 3C 84, 3C 273, 3C 279 and 3C 345, a spectral index of -0.7 is assumed for the short extrapolation. No extrapolation is made for the four mentioned sources, since they appear to have spectral indices which differ significantly from -0.7 in this frequency range. The fluxes of Heeschen and Meredith have been derived from their value of Virgo A/Cas A, and the assumption that the flux of Virgo A is 115.3 flux units at 3000 MHz: all of their sources quoted here appear to have normal spectra (i.e., $\alpha \approx -0.7$). The measurements reported here fit well the results of Dent and Haddock at 8 GHz and 16.5 GHz [9], whereas Kellerman's fluxes appear to be low.

Conclusions

There is evidently a need for further relative and absolute flux measurements at 2695 MHz, and possibly at 4995 MHz. In particular, it would be of interest to make direct flux measurements on many of the small sources, using the interferometer technique suggested by Seeger [10]. Improved crystal mixers and the success of the correlation technique in interferometry [1], [11] permit signal-to-rms noise ratios of 10 for each observation of a source of 10 f.u. (unresolved), by employing two 40-foot antennas, 700 °K crystal mixers and a 120 meter baseline. The calibration of these antennas may be made periodically with an antenna whose absolute gain has been measured, such as a parabolic horn.

References

[1] Keen, N. J., 1964, NRAO Electronics Division Internal Report No. 40.

[2] Baars, J. W. M., Mezger, P. G., and Wendker, H., 1964, A. A. S Meeting, Flagstaff, June 1964.

[3] Wendker, H., 1964, Communication submitted to Nature, Dec. 1964.

[4] Heeschen, D. S. and Meredith, B. L., 1961, Pub. NRAO, 1, 121.

[5] Conway, R., Kellerman, K. I. and Long, R. J., 1963, M.N.R.A.S., 125, 261.

[6] Kellerman, K. I., 1964, A. J., 69, 205.

[7] Mezger, P. G., 1963, NRAO Electronics Division Internal Report No. 17.

[8] Altenhoff, W., et al, 1960, Veroff. Univ. Sternwarte zu Bonn, No. 59.

[9] Dent, W. A. and Haddock, F. T., 1964, Communication submitted to Nature, Dec. 1964.

[10] Seeger, C. L., 1956, BAN, 13, 100.

[11] Blum, E. J., 1959, Ann d'Ap., 22, 140 (English translation at NRAO).

TABLE I

3C Source	S_N	Extrapolated S_K	$\frac{S_N}{S_K}$	Extrapolated S_H	$\frac{S_N}{S_H}$	Extrapolated S_{CKL}	Record noise (f.u.)	Absolute E_{TOT}	Relative E_{TOT}
		2841 MHz		3000 MHz		3200 MHz			
48	9.81	8.5	1.16	8.74	1.12	10.7	0.50	.74	.56
71	3.42	3.8	0.89	3.34	1.02	--	0.77	.79	.77
111	10.69	10.2	1.05	--	--	10.4	0.66	.89	.71
119	5.85	4.9	1.20	--	--	--	0.66	.73	.68
123	29.60	25.2	1.18	27.18	1.09	28.5	0.59	1.70	.95
147	14.00	12.0	1.17	--	--	14.5	0.50	.92	.60
161	11.32	10.8	1.05	12.24	0.92	11.9	0.50	.80	.57
196	7.96	7.7	1.03	7.95	1.00	9.3	0.50	.66	.54
273	40.56	33.5⊙	1.17	--	--	*	0.54	2.20	1.13
279	7.78	4.6⊙	1.63	--	--	*	0.59	.73	.62
286	12.44	11.2	1.11	--	--	12.1	0.50	.84	.58
295	12.39	11.4	1.09	12.40	1.00	13.6	0.50	.84	.58
345	7.45	5.7⊙	1.26	--	--	*	0.47	.62	.51
380	10.74	8.8	1.21	--	--	11.4	0.54	.80	.60
	S_N [2] / [3]								
84	8.3 ± 0.4	7.4	1.12	8.59	(Assuming zero spectral index [10])				
144	763 ± 14	--	--	762.8	(Assuming spectral index = -0.25 [2])				
274	124 ± 5.6	--	--	124.0	(Taking 11 cm flux)				
405	780 ± 30	--	--	764.7					
461	1490 ± 37	--	--	--					

⊙ Peculiar spectra: no extrapolation made from 2841 MHz.

* Peculiar spectra: extrapolation too long for comparison.

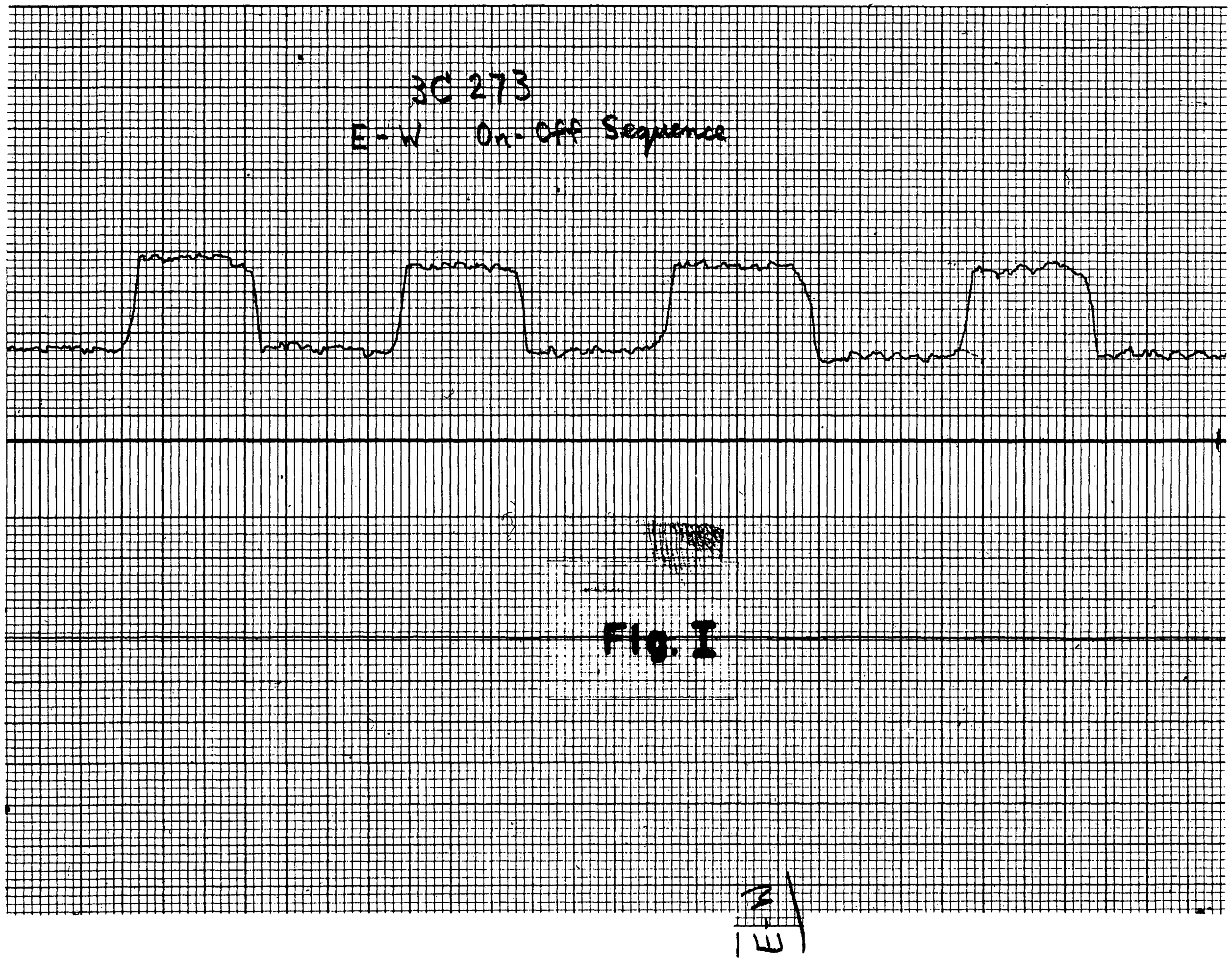
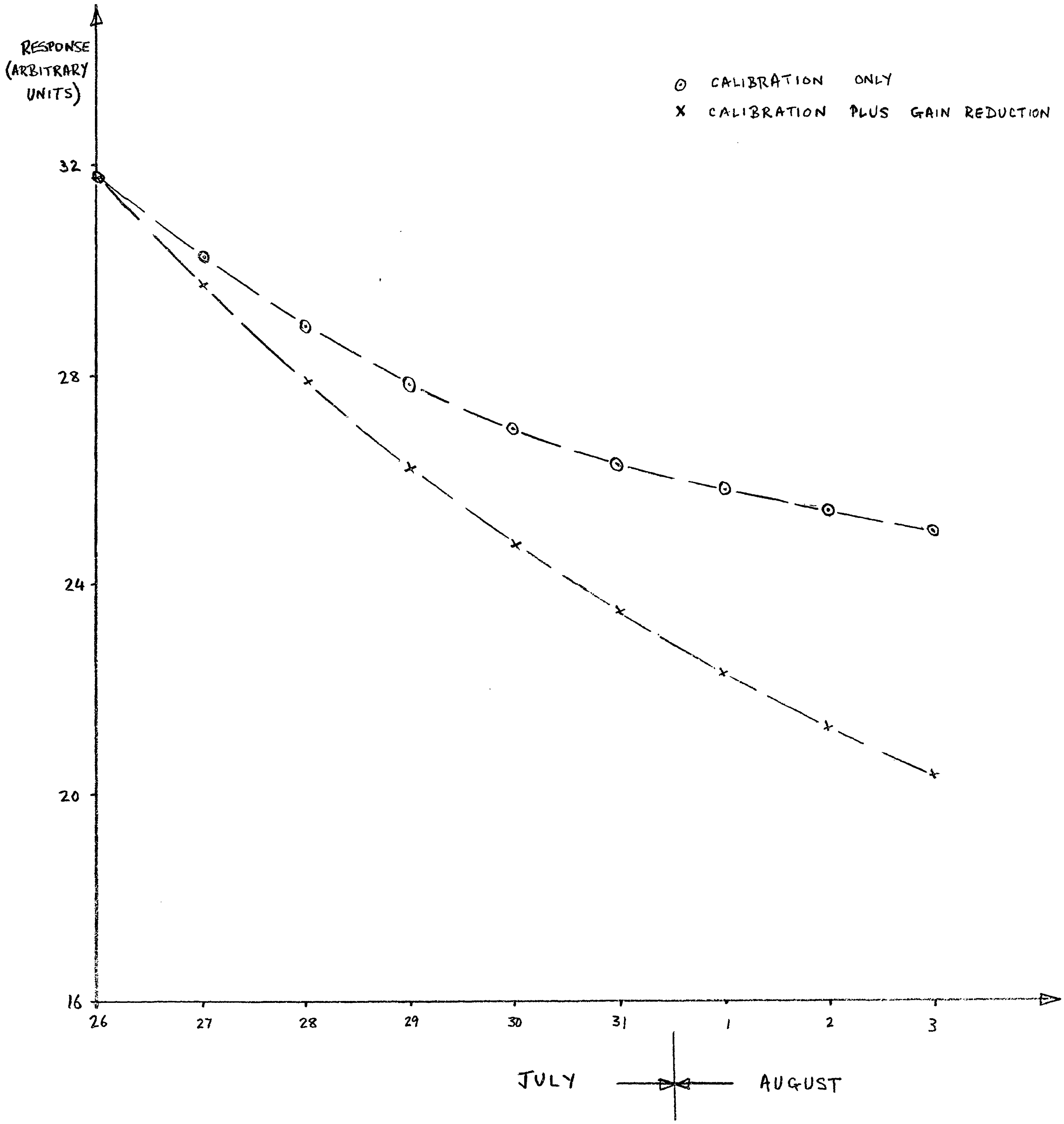
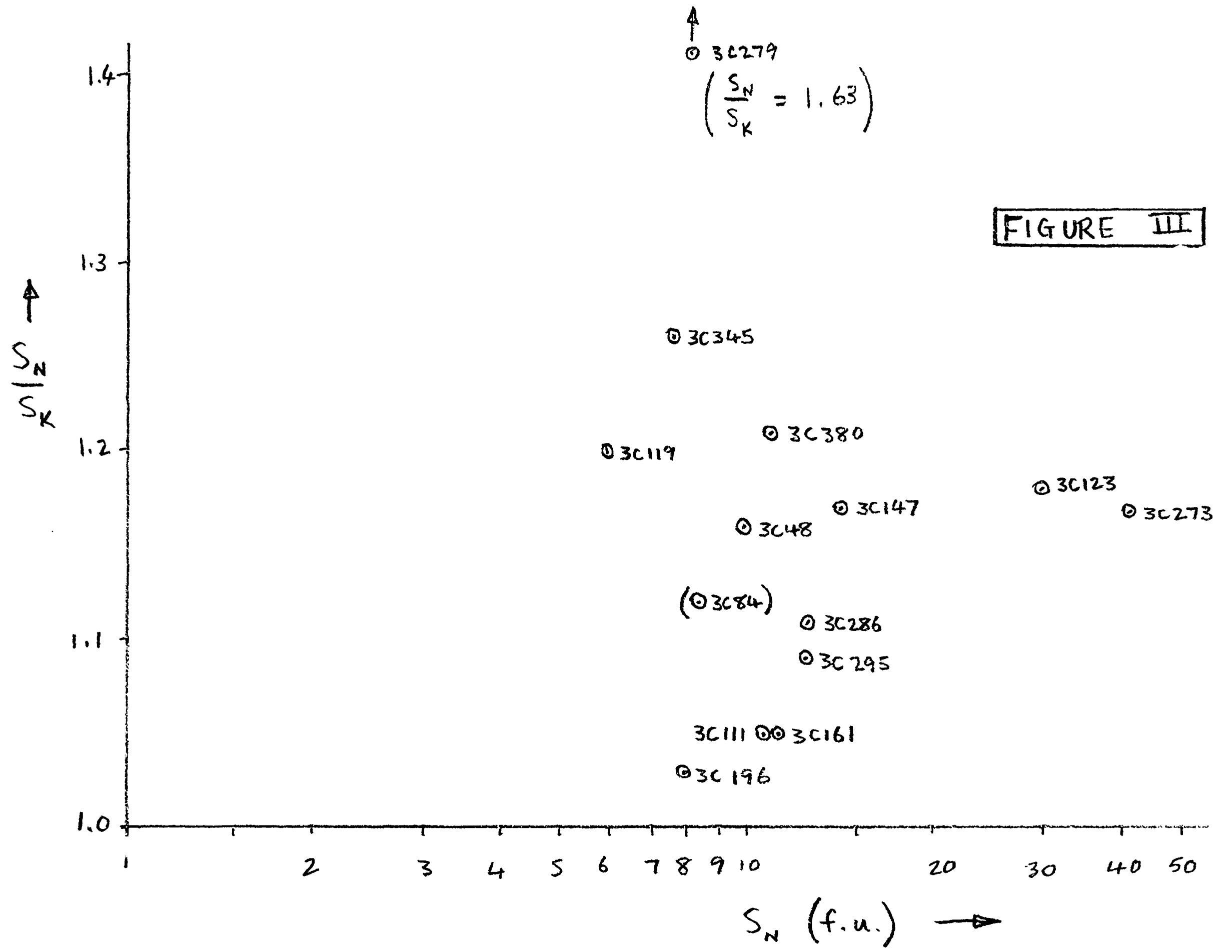


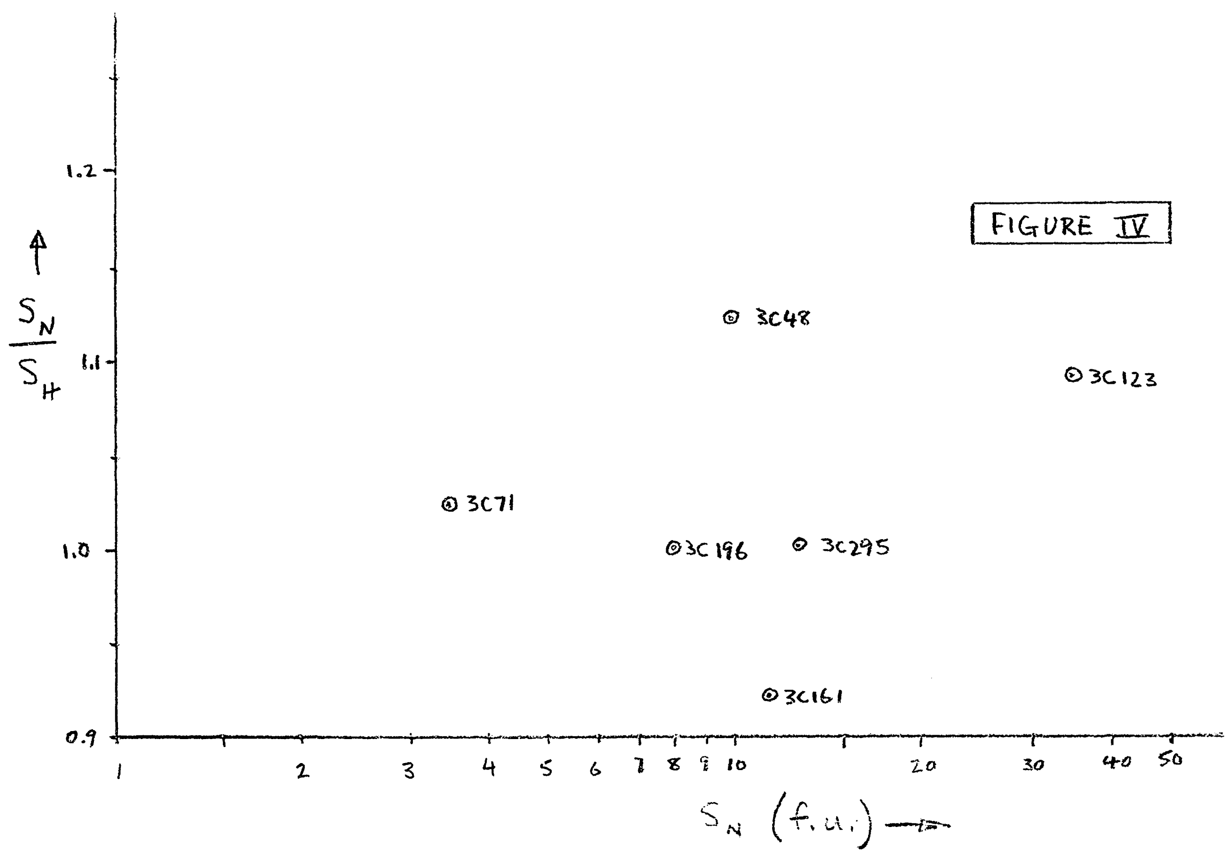
Fig. I



RESPONSE (ARBITRARY UNITS)
32
28
24
20
16
CALIBRATION ONLY
CALIBRATION PLUS GAIN REDUCTION
26
27
28
29
30
31
1
2
3
JULY
AUGUST

FIGURE II


3C279
($\frac{S_N}{S_K}$ = 1.63)
FIGURE III
$\frac{S_N}{S_K}$
1.4
1.3
1.2
1.1
1.0
3C345
3C380
3C119
3C123
3C273
3C147
3C48
(3C84)
3C286
3C295
3C111
3C161
3C196
1
2
3
4
5
6
7
8
9
10
20
30
40
50
S_N (f.u.)


1.2
FIGURE IV
$\frac{S_N}{S_H}$
1.1
1.0
0.9
3C48
3C123
3C71
3C196
3C295
3C161
1
2
3
4
5
6
7
8
9
10
20
30
40
50
S_N (f.u.)

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ERRATA

TO

"THE 11 CM FLUXES OF 14 EXTRAGALACTIC RADIO SOURCES"

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Page 2

Line 7, change to read: "...the off-source positions were alternately north and south of the source, and in the third sequence east and west of the source."

Line 12, change to read: "...Virgo A, drift curves and declination scans..." (not "right ascension scans").

Line 16, add: "[8]." after "Altenhoff, et al".

Nigel J. Keen
January 15, 1965