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Westerhout, G.

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SEARCH FOR POLARIZATION OF THE CRAB NEBULA AND CASSIOPEIA A AT 22 CM WAVELENGTH

BY G. WESTERHOUT

Intensity measurements of the Crab nebula and the radio source Cassiopeia A have been made with a $2^\circ.5$ beam width near 22 cm wavelength. The polarization of both these sources is certainly less than 1 %.

To provide information for the theory on the emission of the Crab nebula discussed in the preceding article, some provisional measures have been made of the polarization of the Crab nebula. As a by-product, the polarization of the radio source Cas A was also measured.

The radio telescope used was the azimuthally mounted 7.5 metre Würzburg antenna of the P.T.T.

transmission station in Kootwijk, used by the Netherlands Foundation for Radio Astronomy for observations of the 21 cm line of hydrogen. These measurements were interrupted and a few modifications in the receiver were made by C. A. MULLER in order to adapt it for the present purpose. The receiver used may be briefly described as follows.

The local oscillator worked at a frequency of 1390

TABLE I

Crab nebula						Cassiopeia A					
No	q	T °K	m.e.	n	w	No	q	T °K	m.e.	n	w
1	40°	10.23	$\pm .06$	7	3	1	162°	28.60	$\pm .06$	5	3
	100	10.34	$\pm .10$	8	3		60	28.52	$\pm .10$	4	3
	160	10.27	$\pm .14$	7	3	2	125°	27.9	$\pm .2$	6	1
2	155°	10.23	$\pm .09$	14	2		10	27.4	$\pm .3$	6	1
	65	10.30	$\pm .09$	14	2	75	28.5	$\pm .3$	6	1	
3	40°	10.15	$\pm .23$	13	1	3	150°	28.5	$\pm .3$	6	1
	85	10.55	$\pm .14$	6	1		23	28.2	$\pm .3$	6	1
	130	10.15	$\pm .20$	6	1		76	28.2	$\pm .3$	6	1
	175	10.37	$\pm .18$	6	1						

A				B			
q	T °K	m.e.	n	q	T °K	m.e.	n
40°	10.20	$\pm .09$	20	16	27.79	$\pm .24$	12
65	10.30	$\pm .09$	14	60	28.52	$\pm .10$	4
85	10.55	$\pm .14$	6	75	28.33	$\pm .21$	12
100	10.34	$\pm .10$	8	125	27.95	$\pm .21$	6
130	10.15	$\pm .20$	6	155	28.58	$\pm .09$	11
158	10.25	$\pm .05$	21				
175	10.37	$\pm .18$	6				

A. Antenna temperatures at various positions of the dipole, for three series of measurements.

B. The same, but with approximately equal dipole positions averaged, for all series together.

q = dipole position (position angle counted anti-clockwise from north)

n = number of individual settings. w = weight of the series.

Mc/s obtained from a 6.44 Mc/s crystal through a $216 \times$ frequency multiplier. It mixed with two bands, symmetrical on each side of the local-oscillator frequency, at frequencies of 1424 and 1356 Mc/s. The I.F. amplifier was centred at 34 Mc/s and had a 2 Mc/s band width. Through a diode detector the signal was fed into a D.C. amplifier, where an integrating network provided a time constant of 0.9 sec. The 34 Mc/s stage was built for the present measurements.

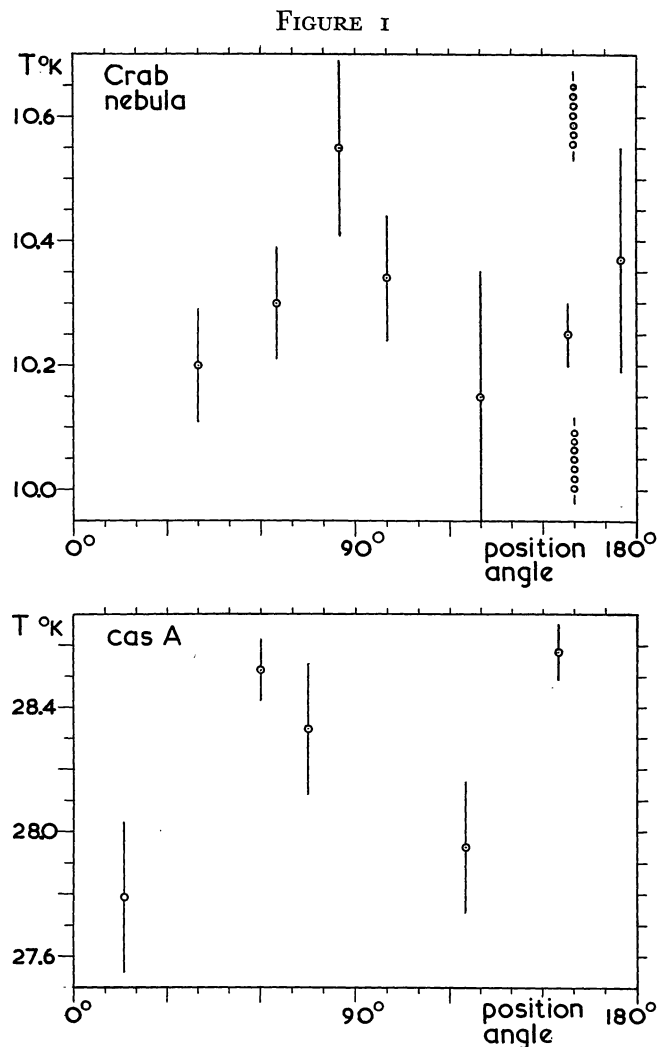
The noise figure of the receiver was measured by pointing the antenna into a woody hill nearby and

assuming this to radiate as a black body at 280 °K. The noise figure thus found was $N = 3.3$ (5.2 db).

As power stabilization to a high degree is not necessary in the 21-cm line receiver, some trouble was experienced with zero-line drifts. The most serious trouble, however, was the interference from many different signals from the near-by Kootwijk transmitting station.

The theoretical value of the output fluctuations, based on the noise figure, was 0.4 °K.

Only on one night, when most of the transmitters were apparently closed down, the measured fluctua-



Average values of antenna temperature at various dipole positions. Vertical lines give mean error. —ooooooo— is the direction of polarization at optical wavelengths.

tions came down close to the theoretical value. On all other nights both the amplitude of the fluctuations and the zero-line drift were much worse, amounting to 1.5 °K and 5 °K, respectively, during the 4 or 5 minutes necessary for one measurement.

The measuring procedure was the following. The 2°.5 beam was moved through the source, parallel to the horizon, at a speed of 2° per minute in azimuth at the position of the source, and 15° per minute for 15° at each side of it. The faster speed was chosen so as to obtain a zero line which is rather independent of local background variations. The galactic background temperature appeared to be 1 °K or less.

The half-wave dipole in the focus could be rotated by hand. The sensitivity in different positions was checked on the sun and on the point source Cas A. As the antenna is symmetrical around the optical axis, and, as far as could be discerned, no serious deviations from a perfect paraboloid surface exist, equal sensi-

tivity was expected in all positions. No differences exceeding 0.2 % could be found in the measurements on the sun; those on Cas A gave an uncertainty of about 1 % in the sensitivity.

One series consisted of some 30 measurements at different positions of the dipole; on the average 6 measurements were made at each position. The whole procedure took about 3 hours. Only during the evening hours of three out of nine days, the interference appeared to be sufficiently low to make reliable measurements.

The results, which were obtained between April 4 and April 14, 1955, are shown in Table 1 and Figure 1.

TABLE 2
Mean antenna temperature and flux of the Crab nebula and Cas A.

	T_a °K	Flux $W/m^2_{c/s}$
Crab nebula	10.27	$110 \times 10^{-25} \pm 30\%$
Cas A	28.36	$310 \times 10^{-25} \pm 30\%$

The temperature scale used is based upon the assumptions made in measuring the noise figure, as described above, and may have an uncertainty of about 20%. The mean antenna temperature and the flux of the Crab nebula and Cas A are given in Table 2. We may define the degree of polarization as the percentage of the total flux which is completely polarized. If T_1 and T_2 are the temperatures in two dipole positions perpendicular to each other,

$$\frac{P}{100} = \frac{T_1 - T_2}{T_1 + T_2}.$$

If ΔT is small compared with T ,

$$\frac{P}{100} = \frac{\Delta T}{2T}.$$

Separate determinations of the polarization from each series of measurements seem to be the most reliable, as in the 3 hours in which the measurements were made, changes in receiver characteristics and interference are not likely to be large. Series No 1, obtained on the best night, gives for the Crab nebula a maximum temperature difference, for dipole positions 60° apart, of 0.11 °K, which amounts to a value of the order of 0.5 % for the degree of polarization. For Cas A this value is 0.2%. Series No 2 gives about the same results for the Crab nebula, and a somewhat higher value for Cas A.

In part B of Table 1 all series are combined and the temperatures are averaged at approximately equal dipole positions. Probably because of instrumental effects and interference the values for the different series do not fit very closely together, al-

though the mean temperatures were brought to the same level.

From the figure it may be seen, however, that there is certainly no systematic temperature increase in one dipole position. The root mean square deviations from the mean value of the temperature are 1.2% for the Crab nebula and 1.0% for Cas A. Some measurements on the source Cyg A yielded about the same result.

We may therefore conclude that the degree of

polarization of the Crab nebula and Cas A at 22 cm, measured with a $2^{\circ}.5$ beam width, is less than 1%.

I am grateful to Prof. OORT for suggesting this investigation, to Ir MULLER for modifying his receiver and kindly putting it at my disposal, and to Messrs VAN AGT and WOLTERBEEK MULLER, who assisted in the observations.

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