PAPER 19

RECENT RESULTS IN RADIO ASTRONOMY AT THE OHIO STATE UNIVERSITY

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Research in radio astronomy at the Ohio State University covers a wide range of astronomical and engineering phases. In this paper the principal topics currently under investigation are briefly discussed. Reference is made to more detailed papers or reports published within recent months or now in the press.

1. MAPPING PROGRAMME

Last year a map of the summer sky including the region of the galactic nucleus was published [1]. This map is shown in Fig. 1. The radio-isophotes have a temperature difference of about 20°. It was obtained by means of the 96 helix antenna. At a frequency of about 250 Mc./s. this antenna has a beam width of about 1° in Right Ascension and 8° in declination.

During the winter and spring of this year the same antenna was used to make a map of the radio radiation from the winter sky including the region of the galactic anti-centre. This map is shown in Fig. 2. It is both more accurate and more detailed than the one of the summer sky. The contour interval corresponds to a temperature difference of about 7° or about one-third the interval on the other map. Moreover, the map is corrected for the effects of individual intense localized and extended sources so as to show only the residual background radiation. This map has been published in preliminary form [2] and in more complete form [3].

2. INTENSE RADIO SOURCES IN THE REGION OF GALACTIC ANTI-CENTRE

In the map of the winter sky (Fig. 2) nineteen intense localized and extended sources are shown by small circles. The solid circles correspond to sources of less than 1° angular extent while the open circles correspond to sources of 1° angular extent or greater. The size of the open circle is equal to the source extent assuming a uniform source distribution.

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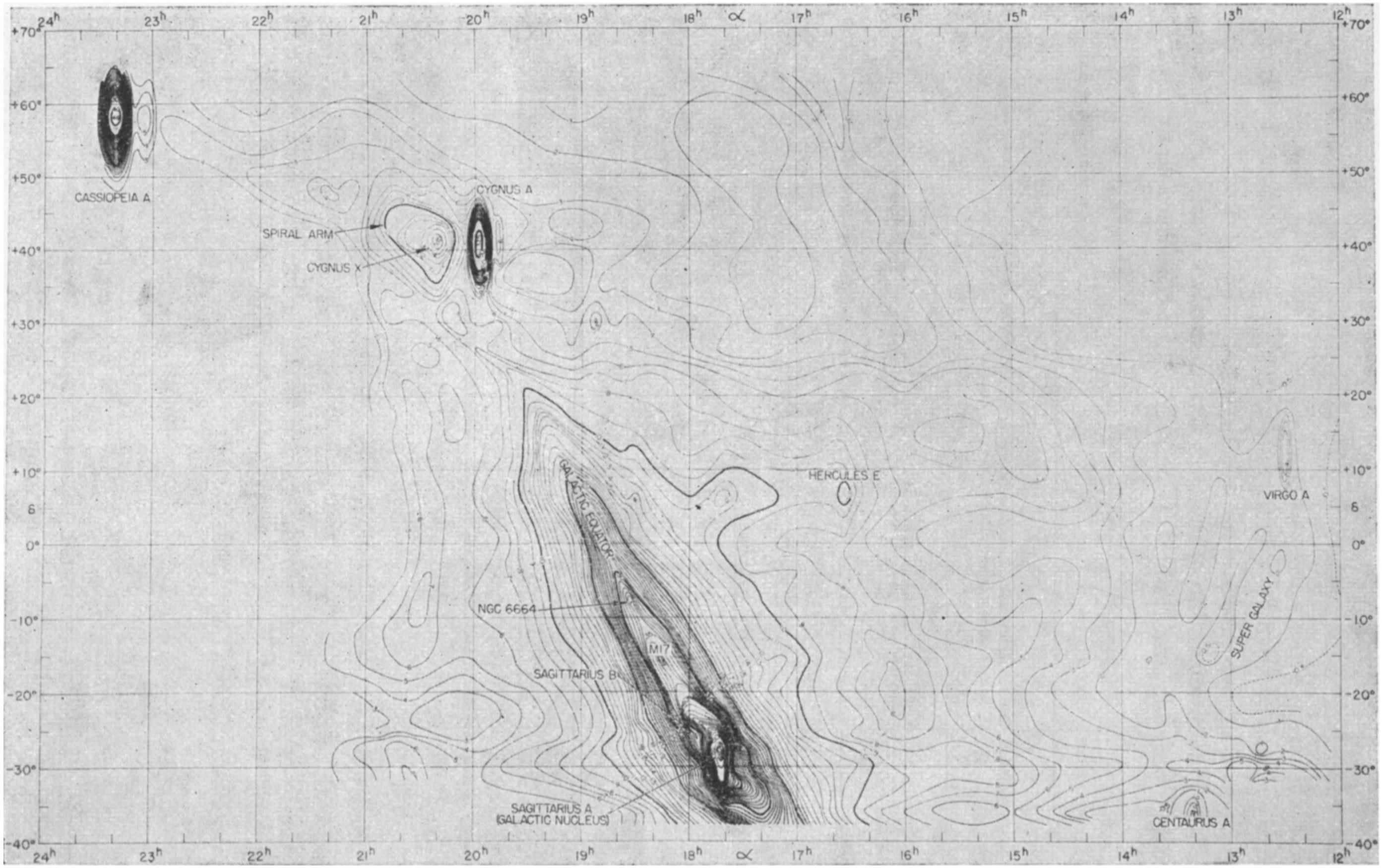

Fig. 1. Map of summer sky at 250 Mc./s. made with O.S.U. radio telescope.

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The power flux of the sources is expressed by their radio magnitude with sources of the first magnitude having a power flux of at least 5×10^{-24} janskys (1 jansky = 1 watt per square metre per cycle per second). On this magnitude scale the Crab nebula is a first-magnitude source.

A list of the nineteen intense sources is presented in Table 1. A striking feature of the map and table is the existence of a considerable number of

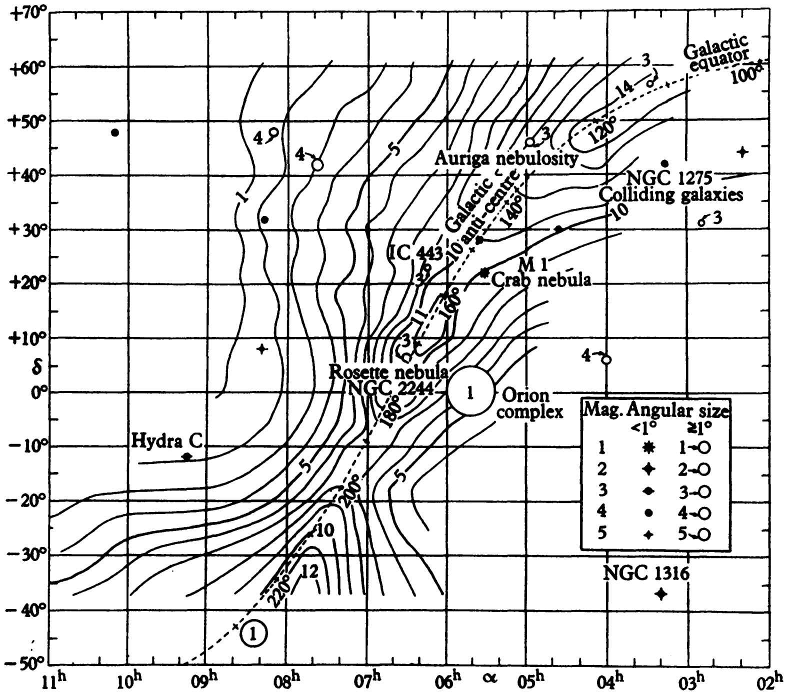

Fig. 2. Map of winter sky at 242 Mc./s. made with O.S.U. radio telescope.

extended sources lying close to the galactic plane and presumably associated with our own Galaxy. The existence of such galactic radio sources and their concentration near the galactic equator has also been reported by Bolton, Westfold, Stanley and Slee [4], by Mills [5], and by Hanbury Brown, Palmer, and Thompson [6].

3. RADIO EMISSION FROM H II REGIONS AND IN PARTICULAR FROM THE ROSETTE NEBULA

A number of the sources in the table correspond to H II emission regions, as, for example, the extended first magnitude sources in Orion and Puppis.

Of particular interest is our source No. 12 which corresponds in position

Table 1

No.	R.A. (1950) h. m.	Dec. (1950) (°)	Flux density (10^{-26} w.m.$^{-2}$ (c./s.)$^{-1}$)	Other catalogue number	Remarks
1	02 19 ±2	+44±2	30	R02.01, BH4, BH5	NGC891?
2	02 48 ±2	+31±2	90	KKM Ari B	1° extended source
3	03 16 ±1	+42±2	60	KKM Per B, R03.02, M03+4, BH6, BSS40	NGC1275
4	03 20 ±1	−37±2	200	M03−3, BSS10, S03−4	NGC1316
5	03 27·5±1·5	+56±2	80	BH7	
6	03 59 ±2	+ 6±2	70	KKM Tau E	1°·5 extended source
7	04 35 ±1·5	+30±2	90	KKM Tau B, R04.01? M04+3, BWSS−B	
8	04 57 ±1	+46±1	90	KKM Aur A? M05+4 BH9, BSS76	Auriga nebulosity 1°·7 extended source
9	05 31·5±0·5	+22±1	800	KKM Tau A, R05.01, M05+2, BSS2, HMS2	Ml, Crab nebula
10	05 42 ±3	0±3	—	KKM Ori A, BWSS−D	Orion complex 9° extended source
11	06 15 ±1	+23±1	160	KKM Gem B, HMS22, HMH13, Baldwin and Dewhirst	IC443 1°·2 extended source
12	06 30·5±0·5	+ 5±1	160	KKM Mon A	Rosette nebula, NGC2244 1°·5 extended source
13	07 38 ±2	+42±2	45	R07.02	2° extended source
14	08 11 ±2	+48±2	60	R08.01, BH11, BSS84	1°·5 extended source
15	08 18 ±2	+32±2	45	KKM Lyn A, R08.03	
16	08 20 ±2	+ 8±4	20	KKM Hya P	Fluctuating source
17	08 24 ±3	−44±4	—	KKM Pup A (Vel A), BWSS−F	H II region 5° extended source
18	09 15·5±1	−12±2	170	KKM Hya C, M09−1A, BSS26, S09−1	
19	10 12 ±2	+48±2	60	New	

to the Rosette nebula. This source was also detected in our survey of 1953 [7] but the position was not accurate enough to permit an identification at that time.

Fig. 3 is a sample signature of the Rosette nebula taken with the O.S.U. radio telescope. Shown also in this illustration are photographs of the nebula in red (above) and blue (below) taken by Dr Minkowski of the Mount Wilson and Palomar Observatories.

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A discussion of our radio observations of the Rosette nebula is given in *Nature* and in an *O.S.U. Radio Observatory Report* [8].

Our measurements indicate an apparent black-body temperature for the nebula of 200° K. Assuming an electron temperature of 10^4° K. in the

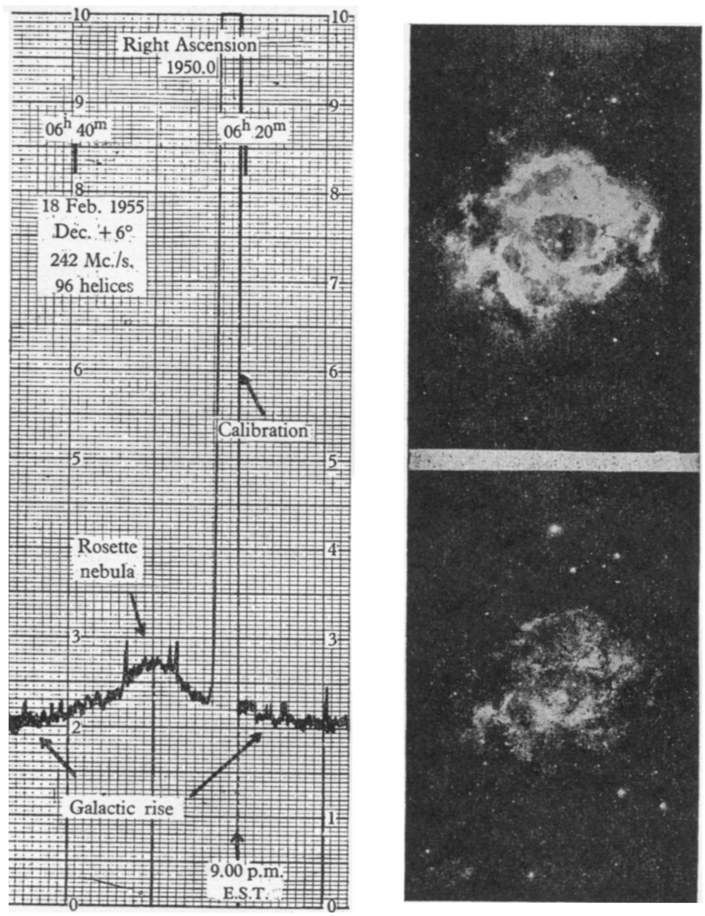

Fig. 3. Record of the Rosette nebula and direct photographs.

nebula, the average optical thickness at 242 Mc./s. over this region is then 0·02. According to the analysis of Greenstein and Minkowski [9] this will correspond to an emission measure of 3000. Assuming the nebula is spherical with a diameter of 37 parsecs at 1400 parsecs, this leads to an average electron density of 9 per cubic centimetre. This value is in good agreement with the recent value of 14 per cubic centimetre given by

Minkowski [10] as based on improved measures of the surface brightness by Kron and supports the hypothesis of thermal emission by free-free transitions from the Rosette nebula.

4. FLUCTUATING RADIO SOURCE

During the mapping survey of the winter sky a source was found that exhibits remarkable fluctuations. Since either scintillations (of ionospheric or tropospheric origin) or inherent variations in intensity of the source, or both, may be involved, the term 'fluctuation' is used to describe the effect whatever its cause.

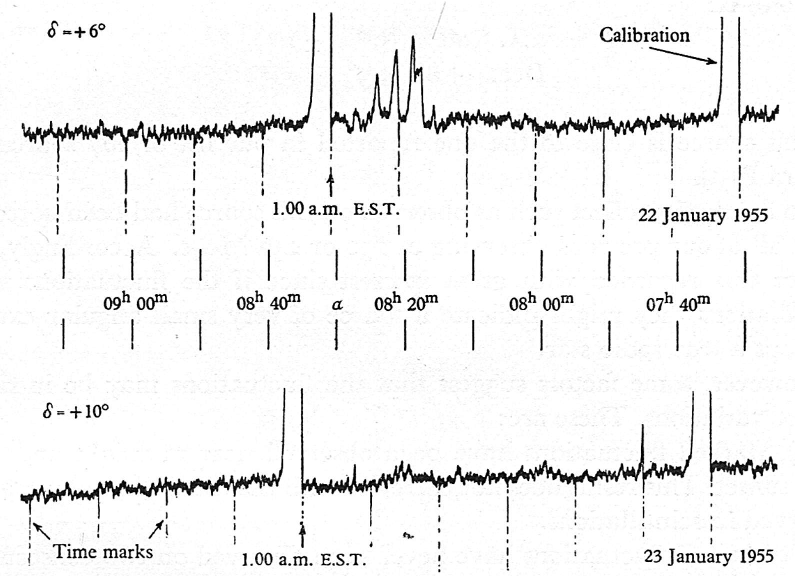

Fig. 4. Records of 22 and 23 January 1955, showing fluctuating source.

The first fluctuation record of the object was obtained 22 January 1955. A photograph of this record is shown by the upper trace in Fig. 4. It is to be noted that the peaks of the fluctuations (near $\alpha = 8^h\ 20^m$) outline an envelope having the shape of the antenna pattern. The source was detected again as a slight rise but without the marked fluctuation on 23 January. A photograph of this record is shown by the lower trace in Fig. 4. The large deflections on the record at 1.00 a.m. are calibrations impressed automatically once each hour. The marks extending below the traces at 10-minute intervals are time marks impressed automatically from WWV time signals at the beginning of each 600 c./s. tone interval.

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Observations of the source were interrupted after 23 January by the routine sky survey but were resumed again in April and May. A total of fourteen good records of the source have been obtained. On four occasions the source showed marked fluctuations as on 22 January but on the other ten days the source was almost indistinguishable from the background (as on 23 January).

Without fluctuations the source intensity is about 1×10^{-25} janskys. With fluctuations the peak intensity rises by a factor of 5 or 10. The fluctuations have a period of 2 to 3 minutes.

Owing to the weakness of the source and its fluctuating nature it is difficult to determine its position accurately. Our present best position (1950·0) is:

$$\begin{array}{llll} \text{R.A.} & 08^{h} & 19^{m} & \pm 1^{m} \\ \text{Dec.} & +8^{\circ} & \pm 3^{\circ} & \end{array}$$

This source is close to the one reported in our list of 207 sources as Hydra P [11].

No fluctuation effect such as observed on this source had been noted by us in all of our previous observing at 250 or 242 Mc./s. Accordingly, the source was regarded with great interest since if the fluctuations were scintillations they might indicate a source of very small angular extent, perhaps a true radio star.

However, some factors suggest that the fluctuations may be intrinsic source variations. These are:

(1) Marked fluctuations have been observed near midnight and also near sunset. This result does not correlate with the usual diurnal variation observed in scintillations.

(2) Marked fluctuations have never been observed on two consecutive days or in fact at a more frequent interval than eleven days.

(3) It has not been possible to establish any correlation between the marked fluctuations and any solar or ionospheric phenomena.

If the fluctuations are intrinsic variations in the source an explanation is that the source is a star with variable radio emission having a period of hours or days and also a short-period variation of a few minutes. Or the fluctuations may be a true scintillation effect observed only when the source is at or near maximum intensity and ionospheric conditions are suitable. Whatever the explanation, the observations suggest that the source may be a true star or a new class of radio object. Attempts to identify the source with an optical object have not yet been successful. There are several 8th and 9th magnitude stars near the radio position.

A 12th magnitude star, KZP 1284, in Kukarkin's list of stars suspected to be variable, is also close to the radio position. During the summer the source has been in a poor position for observing but it is planned to resume observations later this year. A more complete discussion is given by Kraus, Ko, and Stoutenburg in *Nature* [12].

5. STUDIES OF THE GALACTIC NUCLEUS

Fig. 5 is a profile through the galactic nucleus obtained from a record taken at 242 Mc./s., with the O.S.U. radio telescope at a declination of $-29°$ on 26 February 1955. The ordinate is inches of deflection of the recorder (proportional to power) and the abscissa is the hour angle. The peak signal-to-noise ratio on this profile is over 5000 to 1. Since the

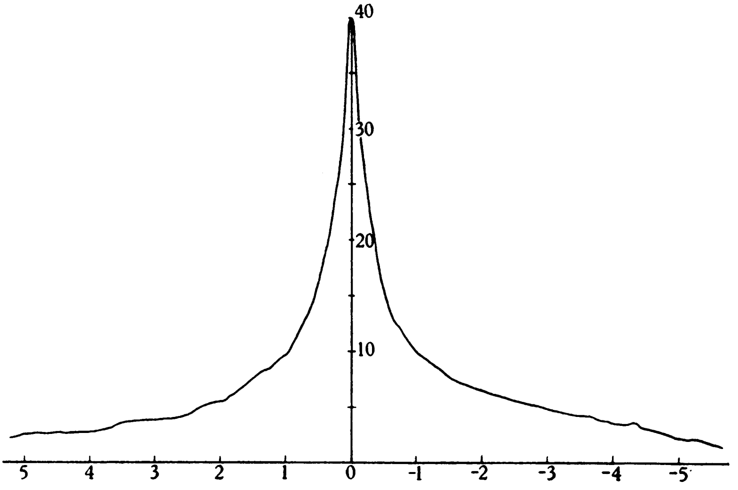

Fig. 5. Profile through the galactic nucleus taken with O.S.U. radio telescope.

antenna pattern is only about 5 minutes in time between half-power points the effect of antenna smoothing on this record is significant only near the very peak of the record.

Using the profile out to an angle of about 10° but not including the smoothed peak, the observed distribution is found to correspond to that which would be produced by a spherically symmetrical source having an intensity per unit volume that varies as the inverse 2·5 power of the radius. This value is in agreement with one deduced theoretically for the nucleus by Keller.

The radio position of the nucleus in galactic (Ohlsson) co-ordinates is: $l = 327^{\circ}.8$, $b = -1^{\circ}.4$ (Kraus and Ko [13]). This position is close to the centre of a highly obscured emission region which shows up as a dark band on the remarkable photograph published by Morgan, Strömgren, and Johnson [14]. It is apparent that their photographic technique enables one to observe emission regions near the galactic nucleus in spite of a tremendous amount of obscuring matter.

6. RADIO MODELS OF THE GALAXY

Based on our radio maps of the Milky Way and studies of the region of the galactic nucleus, a radio model for our Galaxy has been deduced. This model has been developed by Ko [15].

7. ANTENNA RESOLUTION AND SOURCE DISTRIBUTION STUDIES

We have given considerable attention to a number of problems related to the fundamental characteristics of radio-telescope antennas [16, 17]. These are:

(1) The effect of the source distribution on the observed antenna pattern and the inverse problem of determining, in so far as possible, the source distribution from the observed pattern.

(2) The resolution of radio-telescope antennas and the ultimate number of celestial sources that a radio telescope can resolve. According to Ko's criterion this number is numerically equal to the directivity of the antenna.

(3) The range of radio telescopes and other problems.

8. RESEARCH ON RECEIVERS

Research and development on the receiving equipment used at the Ohio State University is continuing. As a result of this work the noise figure of the present 242 Mc./s. receiver is 1·5 and the ultimate sensitivity for a single record and 30-sec. time constant is about 1×10^{-26} janskys, or less than one-tenth of a degree Kelvin.

9. DESIGN FOR A SUPER RADIO-TELESCOPE AND ITS TEST BY MEANS OF A SCALE MODEL

Progress in radio astronomy is to a large extent dependent on the development of larger radio telescopes. A design for a transit telescope which has been under development at Ohio State provides a maximum of effective aperture per dollar of cost [18]. The incoming celestial waves are deflected by a tiltable flat reflector into a standing paraboloid and thence to a horn at the prime focus. An antenna 2000 ft. across by 200 ft. high would have half-power beam-widths of about one-tenth degree in right ascension and 1° in declination at a wave-length of 1 metre. The ground is electrically part of the antenna acting as an image plane for the structure above it. One of the great economies of the design results from the fact that the ground itself is the principal supporting structure.

To test the design a scale model was constructed for operation at 1·2 cm. The model is 12 ft. across, which would correspond at 1 metre to a length of 1000 ft. The tests indicate excellent characteristics with side lobes 1 % or less of the main lobe power. The beam-widths between half-power points are one-quarter degree in right ascension by 1·9° in declination.

The performance of the scale model has been so satisfactory that the model itself is now being put into use as an astronomical instrument for solar and galactic observations at a wave-length of 1·2 cm. The 1·2 cm. receiver is nearing completion and it is expected that actual observations will begin within a few weeks.

Acknowledgment

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