RADIO-FREQUENCY RADIATION FROM THE CONSTELLATION OF CYGNUS

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Summary

Observations are described of the radiation from portion of the constellation of Cygnus at frequencies of 1210 and 3000 Mc/s. Two sources of radiation were observed at the lower frequency, one being the well-known " radio star ", Cygnus-A. The other was a diffuse source of limited extent which might be called a " radio nebula ". Neither source could be observed at the higher frequency.

The properties of both sources, particularly their spectra, are discussed and it is shown that earlier discrepancies in observations of the Cygnus region may be explained. The diffuse source coincides in position with the secondary maximum in the lower frequency galactic contours, which Bolton and Westfold (1950*a*, 1950*b*) have interpreted as a spiral arm of the Galaxy. The new evidence suggests that the source is probably due to thermal emission from clouds of ionized interstellar gas, possibly in the region of γ Cygni and having a temperature and electron density of the order of 10^4 °K. and 10 cm.$^{-3}$ respectively.

I. INTRODUCTION

In a recent paper Piddington and Minnett (1951) described measurements of galactic radiation at frequencies of 1210 and 3000 Mc/s. Radiation from the constellation of Cygnus is of particular interest and was therefore omitted from the earlier paper to enable a more detailed discussion to be given in the present communication.

Fluctuations in the intensity of radiation from a small region in Cygnus were first observed by Hey, Parsons, and Phillips (1946) at 64 Mc/s., and were shown by Bolton and Stanley (1948) to originate in a small discrete source. The position of this source was measured by a number of workers whose results differed by more than the limits of error claimed.

A number of equal-intensity contour charts of radiation from the Cygnus region have been published for frequencies between 64 and 480 Mc/s. These show differing features which Bolton and Westfold (1950*b*) have attempted to explain in terms of a secondary maximum of galactic radiation combined with the radiation from the discrete source. They suggested that the secondary maximum was consistent with the Sun being in or near the arm of a spiral galaxy.

The measurements described in the present paper greatly extend the spectrum of the known discrete source in Cygnus, and show that there is a second discrete source which is spread over several square degrees and which

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had not previously been isolated from the general background of galactic radiation. It is suggested that this may account for the discrepancy in the position measurements of the unresolvable discrete source. Most of the differences between the contour charts at various frequencies are explained by the new evidence, which casts serious doubt on the spiral arm hypothesis. An alternative explanation of the diffuse source may be given in terms of thermal emission from clouds of ionized interstellar gas.

II. Experimental Procedure and Results

The apparatus and experimental methods used have been described in the earlier paper.

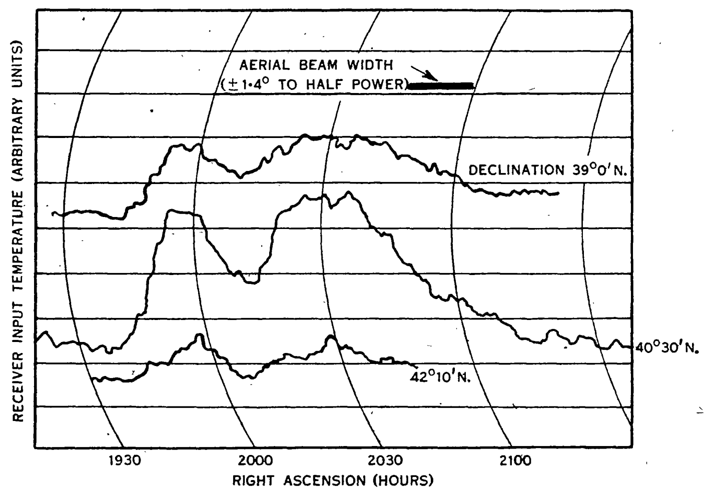

Fig. 1.—Three recordings of the power flux density from Cygnus-A and Cygnus-X (at 1210 Mc/s.).

(a) *The 1210 Mc/s. Measurements*

Measurements at 1210 Mc/s. were made with the 16 by 18 ft. paraboloid described earlier by Piddington and Minnett (1951). The aerial was kept at rest and the portion of the sky being investigated was allowed to drift through the beam, changes in flux density being recorded. The aerial beam width was $\pm 1\cdot 4°$ to half-power.

Three typical recordings of the flux density of radiation are shown in Figure 1. They were made with Declinations of the aerial beam of 39° 0′ N., 40° 30′ N., and 42° 10′ N. The width of the aerial beam (appropriate to the given declination) is shown as a thick line above the flux density record. The small fluctuations in the record are of a random nature, being inherent in the equipment which was operating at very high gain. Thus the high sensitivity may be gauged from the fact that the maximum deflection in the three records shown corresponds to a change in the temperature at the receiver input of only about 6° K. In the upper record a drift of the zero level occurred during the observations. Allowance for drifts was made by taking two or more records at the same declination.

It is of interest to compare the traces in Figure 1 with the corresponding traces for the centre of the Galaxy (Piddington and Minnett 1951, Fig. 3). The units of observed intensity in the two figures are the same within about 25 per cent. It is clear that for the frequency and aerial beam width used the intensity from the Cygnus region is comparable with that at the galactic centre.

A series of records of the type shown were made between Declinations 36 °N. and 47 °N. Excess radiation above the low background level received

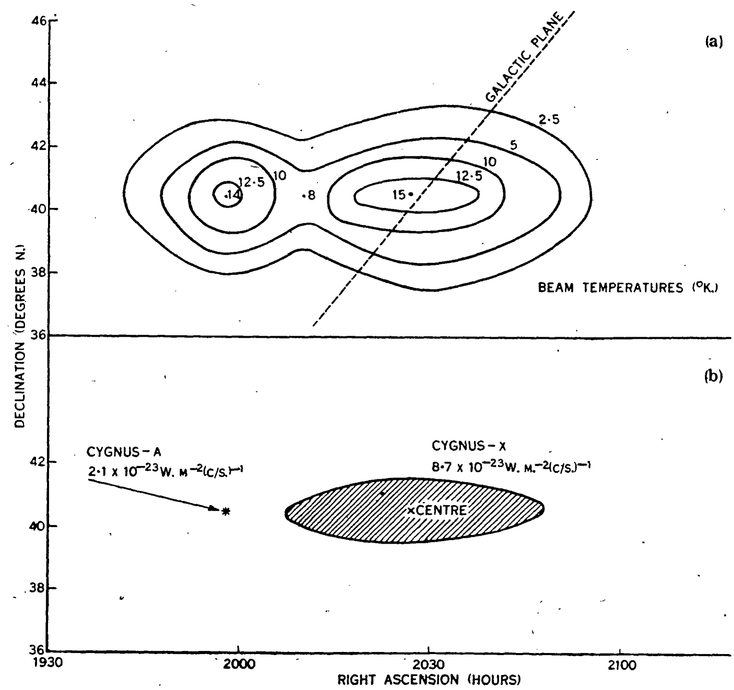

Fig. 2 (*a*).—Contours of equal aerial beam temperature in the Cygnus region at 1210 Mc/s.

Fig. 2 (*b*).—Flux densities from the Cygnus sources at 1210 Mc/s.

from regions well away from the galactic plane was only found in the vicinity of Declination 40·5 °N. The records have been reduced to a set of equal-intensity contours, shown in Figure 2 (*a*). The parameter plotted is the " equivalent beam temperature " which is similar to the " equivalent aerial temperature " except that allowance has been made for 35 per cent. losses in side lobes which were directed at cold parts of the sky (see Piddington and Minnett 1951).

Knowing the form of the aerial beam it is possible to reduce the set of contours in Figure 2 (*a*) to contours showing a distribution of flux density per unit solid angle (that is, to values of brightness) consistent with the experimental results shown in Figure 2 (*a*) (see for example, Hey, Parsons, and Phillips 1948). The result is shown in Figure 2 (*b*), where the radiation is seen to originate in two discrete sources, one of which has finite size while the other is too small to be resolved. The position of the small source is the same, within the present limits of accuracy, as that of the well-known discrete source in Cygnus mentioned in Section I. It is identified with that source and called, after Bolton, Cygnus-A. The second, diffuse source will be referred to here as Cygnus-X and may be the first " radio nebula " to be recognized.

The flux densities from the two sources at 1210 Mc/s. are as follows:

Cygnus-A .. .. $2 \cdot 1 \times 10^{-23}$ W.m.$^{-2}$ (c/s.)$^{-1}$

Cygnus-X .. .. $8 \cdot 7 \times 10^{-23}$ W.m.$^{-2}$ (c/s.)$^{-1}$.

The limits of error are probably about 25 per cent. in each case.

The position of Cygnus-A is: R.A. 19 hr. 58 min. ± 2 min., Dec. $40 \cdot 5$ °N. $\pm 1°$. The position of the centre of Cygnus-X is: R.A. 20 hr. 27 min. ± 3 min., Dec. $40 \cdot 5$ °N. $\pm 1°$. The uncertainties quoted are estimates of limits of error based on an examination of a number of records.

(b) *The 3000 Mc/s. Measurements*

Unfortunately the aerial used for earlier measurements at 3000 Mc/s. could not easily be directed towards the Cygnus region. It was necessary to reduce its size somewhat and hence the overall sensitivity. The sensitivity was further reduced by the fact that the aerial could not be moved during observations and hence the " beam-swinging " techniques described by Piddington and Minnett (1951) could not be used. The sources were allowed to pass through the aerial beam which remained stationary.

The estimated minimum detectable value of flux density from a point source was about 2×10^{-23} W.m.$^{-2}$ (c/s.)$^{-1}$ while the corresponding value for Cygnus-X was about 1×10^{-22} W.m.$^{-2}$ (c/s.)$^{-1}$. The latter value was larger because only about one-third of the total flux density from this extended source was received at any one time and also because the maximum of brightness was broader and took longer to pass through the beam, thus giving less discrimination against random drift.

Observations were made on several occasions but at no time was radiation from either source detected. It was concluded that the upper limits of flux density at 3000 Mc/s. were approximately as follows:

Cygnus-A .. .. 2×10^{-23} W.m.$^{-2}$ (c/s.)$^{-1}$

Cygnus-X .. .. 1×10^{-22} W.m.$^{-2}$ (c/s.)$^{-1}$.

III. The Small Discrete Source (Cygnus-A)

Some of the earlier determinations of the position of Cygnus-A were in error by amounts many times the quoted values of the experimental errors (compare, for example, the results of Bolton and Stanley (1948) with the most recent value quoted below). There is little doubt that large experimental errors were responsible for these discrepancies, and it may be noted that a determination of position from Reber's (1948) contours provided the most accurate result at the time of its publication.

More recent results still fail to show satisfactory agreement. Thus Mills and Thomas (1951) gave the position as R.A. 19 hr. 57 min. 37 sec. ± 6 sec., Dec. 40° 34′ while Stanley and Slee (1950) give a value of R.A.