A DISTANT HII REGION IN THE GALAXY*

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It has long been realized that 21 cm absorption studies can provide information about the distance of unidentified radio sources. When the radiation from a continuum source is absorbed by neutral hydrogen clouds in the foreground, an observation of the radial velocity range over which the absorption occurs indicates the position of the source in relation to the various hydrogen features along the line of sight. Whenever absorption effects can be seen, we can immediately tell whether the source concerned is galactic or extragalactic; if it is galactic, we can then place limits on its distance.

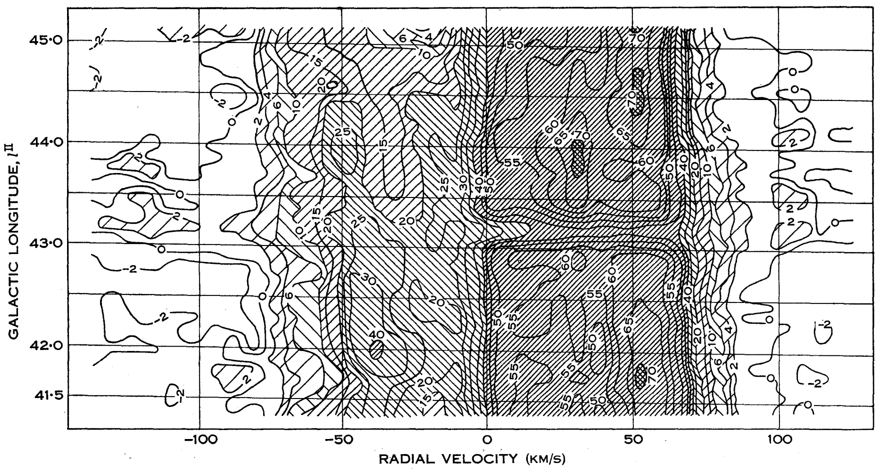

Fig. 1.—Contour diagram, on velocity–longitude plane, of the hydrogen-line emission along a section of the galactic equator. Unit $= 1\cdot 2°$K in T_A.

This method has been little applied to unidentified objects so far, but it is becoming more important as larger dishes come into use. Absorption effects have been observed on several dozen sources during an extensive hydrogen-line survey of the Milky Way region with the Parkes 210-ft telescope. This note discusses one such case in some detail, to demonstrate the application of the method under circumstances where a good distance estimate can be derived.

Figure 1 shows the hydrogen-line emission, as a function of radial velocity, along a section of the galactic equator from $l^{II} = 41°\cdot 4$ to $45°\cdot 0$. This diagram was constructed from a series of line profiles which were recorded with the multichannel receiver (McGee and Murray 1963) at intervals of 6 min of arc, as the telescope was

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slowly driven along the galactic equator. The beamwidth is 14′ between half-power points, and the bandwidth is equivalent to 8 km/s in radial velocity. A pronounced trough can be seen across the central part of the diagram around $l^{II} = 43^{\circ}\!.1$, corresponding to absorption by hydrogen of radiation from the source W49 (3C398).

In Figure 2, a comparison is made between profiles at neighbouring points with and without absorption. We see that the absorption is approximately constant (~ 30%) throughout the positive radial velocity region, while there seems to be no absorption at negative velocities. We conclude that a considerable amount of HI in the velocity range 0–70 km/s lies between our position and the source, and the HI at negative velocities is beyond the source.

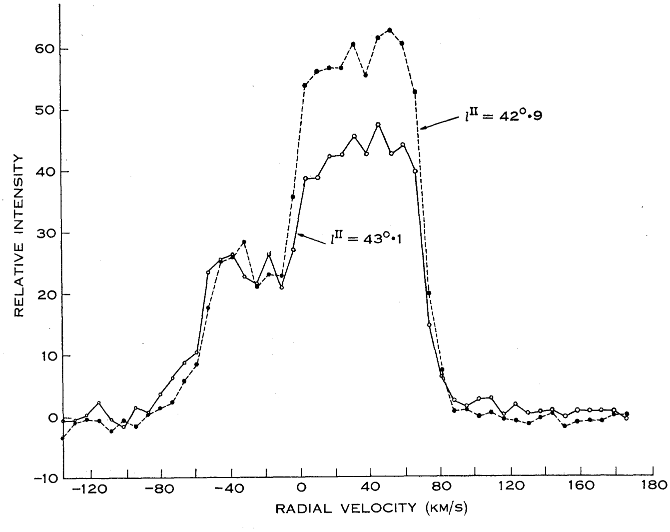

Fig. 2.—Profiles at position of W49 ($l^{II} = 43°·1$), and at a neighbouring point ($l^{II} = 42°·9$). Both profiles refer to points on the galactic equator.

At this longitude, the line of sight passes through the inner region of the Galaxy (see Fig. 3). The apparent radial velocity of the hydrogen increases from zero up to a maximum of about +70 km/s near the tangential point T, and then decreases to zero near U, where the line of sight intersects the circle through the Sun, after which the velocity is negative. Detailed studies show that there are two major spiral arms in the inner region, each of which is crossed twice by the line of sight, and there is a deficiency of hydrogen at the tangential point (Schmidt 1957; Kerr 1964).

The presence of absorption over the whole positive velocity range implies that the source is at least as far as T, but not beyond U. The approximate constancy of the absorption over this range suggests that the source must be either near T or near U. In this region of distance ambiguity, we cannot clearly say which of the spiral arm components are responsible for the absorption, but we can help to decide between the two alternative locations by considering the optical depth and the spin temperature of the absorbing material.

The optical depth of the hydrogen within the solid angle of the source $\tau(\nu)$ has been derived in the usual way. First, the source temperature in the absence of absorption is measured at a frequency outside the line. Then, at each frequency in the profile, the "absorption dip" is measured by comparing the observed absorption profile with the "expected profile", i.e. the interpolated emission profile which would have been obtained in the absence of the source absorption. The optical depth is then obtained from the ratio of the absorption dip to the source temperature. Once the optical depth is known from the absorption observations, the emission measurements can give the spin temperature of the hydrogen in the solid angle of the beam $T_s(\nu)$ from the derived optical depth values and the expected emission profile.

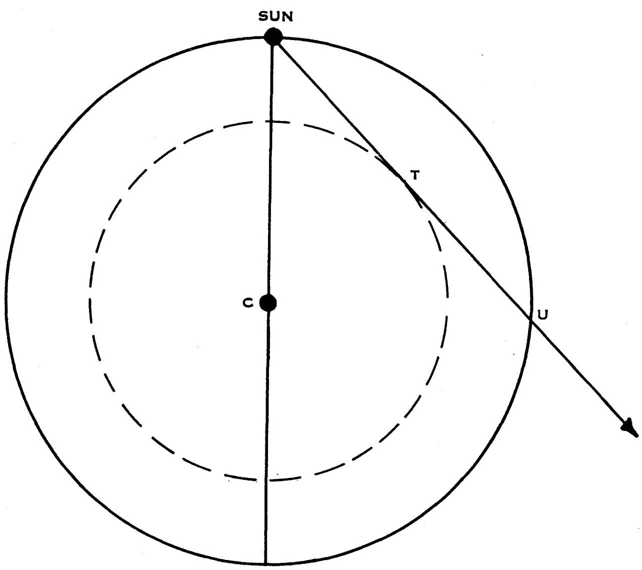

Fig. 3.—Diagram showing line of sight.

These two derivations are only precise for a smooth distribution of hydrogen over the sky in this region, but the fairly smooth variation outside the absorption trough in Figure 1 suggests that, in this case, the assumption is a fairly reasonable one.

The derived values of $\tau(\nu)$ and $T_s(\nu)$ are shown in Figure 4 for a source located near U, beyond all the positive velocity hydrogen. On this basis, $T_s(\nu)$ is fairly uniform over the range, with an average value of 150°K which is close to the highest brightness temperatures that have been observed in emission in the general survey. If we had assumed that the source was at T, with only the near portion of the hydrogen absorbing, we would have obtained lower values for T_s, below those often found in emission. Additional evidence on the likely location of the source has been obtained from a preliminary study of the latitude distribution of the hydrogen, in the velocity range of interest. This suggests that there is more hydrogen between T and U than there is between the Sun and T. If this is so, the observed depth of the absorption would require the source to be near U rather than near T.

We conclude from these arguments that the source W49 is probably about 15 kpc from the Sun (for a Sun-centre distance of 10 kpc). Certainly the source is more than 7 kpc away.

W49 was first observed at 22 cm by Westerhout (1958), who reported it to be a point source. The region is heavily obscured optically, and no identification has been proposed by Westerhout or by later observers. From interferometric observations, Wilson (1963) found a complex east-west structure, with two principal components of diameter 4′, separation 13′, and relative intensity 1·6 : 1; he adds that the source is "possibly extragalactic". However, the presence of unabsorbed HI over part of the velocity range excludes an extragalactic origin. No separation in the galactic equator direction has been observed in the present measurements. The flux density at 1400 Mc/s is 90×10^{-26} W m^{-2}(c/s)$^{-1}$.

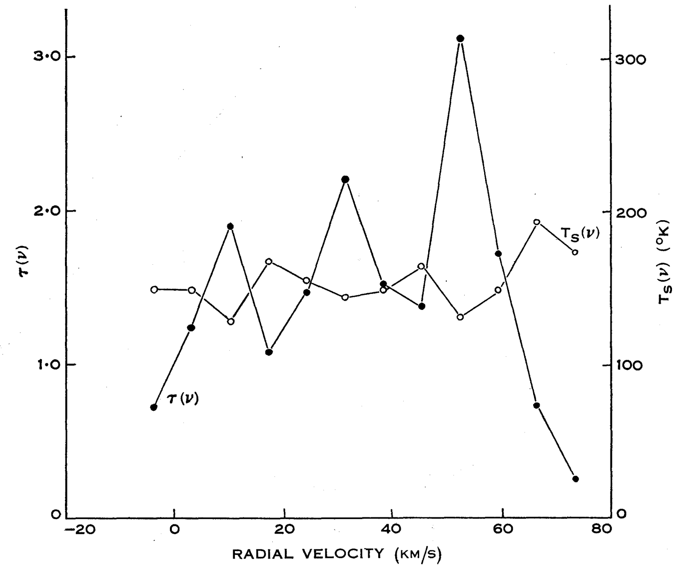

Fig. 4.—Derived values of optical depth and spin temperature.

The source spectrum is described as thermal by Conway, Kellermann, and Long (1962) and by Kellermann (1964). We therefore conclude that W49 (3C398) is an HII region, obscured optically, and at a probable distance of 15 kpc.

It is of interest to compare this object with two optically outstanding emission regions, the Orion nebula and 30 Doradus, for which the corresponding 1400 Mc/s flux densities are 350 and 40×10^{-26} W m^{-2}(c/s)$^{-1}$, and estimated distances, 0·45 and 50 kpc. We see that the intrinsic 1400 Mc/s output of W49, for a distance of 15 kpc, is 300 times as great as that of the Orion nebula, and 0·25 times that of 30 Doradus. For a distance of $7\frac{1}{2}$ kpc the corresponding ratios are 75 and 0·06 respectively.

This work was carried out while one of us (K.A.) was a visiting research fellow at the CSIRO Radiophysics Laboratory.

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