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Letter to the Editor

HI Absorption in the Direction of CL 4

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Summary

HI absorption has been observed in the direction of the compact radio source CL 4, near the centre of the Cygnus Loop, using the 5120 channel digital line backend of the Westerbork Synthesis Radio Telescope. The HI absorption data are consistent with an extragalactic origin of CL 4, however a galactic origin cannot be excluded.

Key words: HI absorption - radio sources - supernova remnants.

Introduction

A variable radio source whose time averaged spectrum is flat, CL 4, was found by Keen et al. (1973) in a survey of the Cygnus Loop at 2.7 GHz. An extensive series of observations at 0.4, 1.4, 5 and 15 GHz was carried out by Webster and Ryle (1976), who suggested that CL 4 may be located within the galaxy and be physically associated with the Cygnus Loop. A possible optical identification was mentioned by Keen et al. (1973) and discussed in more detail by Webster and Ryle (1976). More recently this identification with a 17^m stellar object has been discussed by Argue et al. (1978) and De Vegt et al. (1978). The radio source and the stellar object are separated by 2".3 arc, which makes the identification far from certain. Finally, VLBI observations have been carried out at 3.6 cm by Geldzahler et al. (1979). The angular size of the radio source is $\lesssim$ 0".001 arc.

A problem in the identification of CL 4 with the Cygnus Loop is the uncertain distance of the SNR (cf. Kirshner, 1976). The optical estimates suggest a distance < 0.8 kpc. Recent estimates of the distance based on the radio Σ-D relation (surface brightness - diameter) are 0.8 kpc (Milne, 1979) and 1.2 kpc (Caswell and Lerche, 1979).

HI absorption observations in the direction of CL 4 were made by Webster and Ryle (1976) with the Half-Mile Telescope; the velocity resolution was 13.2 km s^{-1}. No HI absorption was found ($\tau < 0.1$). This lack of absorption has formed one of the most compelling arguments for a galactic origin of CL 4 and hence a possible physical association with the Cygnus Loop. As Webster and Ryle point out "there is evidently no absorption feature in the spectrum of CL 4 corresponding to the peak of emission near 0 km s^{-1} ... a result which strongly suggests that the source lies within the galaxy".

The velocity resolution used in the HI observations by Webster and Ryle (1976) was rather coarse compared with the widths of typical galactic HI absorption features (~ 3-5 km s^{-1} - e.g. Radhakrishnan et al., 1972), and the resulting dilution would have diminished the sensitivity of those observations accordingly. We have undertaken new HI absorption observations of CL 4, using the high velocity resolution available with the 5120 channel digital line backend (DLB) of the Westerbork Synthesis Radio Telescope (WSRT).

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Observations

CL 4 was observed with 20 interferometers (single polarization) of the WSRT for 11 hours in August 1978. The total bandwidth was 625 kHz with 127 frequency points; the resolution was 5.9 kHz or 1.2 km s^{-1}. The observations were calibrated by observations of 3C286 and 3C147 for 3 hours before and 3 hours after the observation. To avoid the effects of HI absorption in the calibrators at 0 km s^{-1} and of HI emission at 0 km s^{-1} in the shorter spacings, the calibrators were observed at ± 1 MHz with respect to the frequency of the CL 4 observations. Test observations of 3C147 indicate that this is a valid calibration procedure; in particular the phase can be interpolated to better than 1°. The system temperature was 90 K. The baselines range from 54 m to 1422 m. The three shortest baselines (54, 126, and 198 m) show the effects of HI emission and were eliminated from the average. The presence of HI emission effects at these baselines is obvious from phase and amplitude differences relative to the continuum; both of these effects vary with hour angle.

The HI emission profile in the direction of CL 4 (ℓ = 74°.6, b = −8°.0) was measured with the Dwingeloo 25 m telescope. The system temperature was 41 K and the total bandwidth 1.25 MHz; with 256 channels and Hanning smoothing the resolution is 9.8 kHz or 2.1 km s^{-1}.

Results

The HI emission profile is shown in Fig. 1 (a); the average absorption spectra formed from the 17 baselines over 11 hours is shown in Fig. 1 (b) (amplitude) and 1 (c) (phase). There is an obvious absorption line, of optical depth 0.49; the velocity of this feature arising in the local gas is 0.5 km s^{-1} with a half-width of ~ 4 km s^{-1}. This detection is consistent with the upper limit quoted by Webster and Ryle (1976); the line occurs midway between two of their broad (13.2 km s^{-1}) channels. In addition the continuum flux density was higher during the present observations than during the HI observations by Webster and Ryle 485 ± 20 mJy compared with 350 mJy.

The Perseus arm at −43 km s^{-1} can be clearly seen in the emission profile in Fig. 1 (a); the kinematic distance of this feature is ~ 9.5 kpc. The upper limit on the optical depth at this velocity is ~ 0.09 (2σ).

Discussion

HI absorption measurements can only be used to set a lower limit to the distance of a source. The presence of absorption in the spectrum of a continuum source indicates that the source is beyond the HI. The absence of absorption does not necessarily imply that the source is in front of the HI, but can also be due to holes in the hydrogen distribution or to a low optical depth caused by a high spin temperature (see e.g. Lockhart and Goss, 1978).

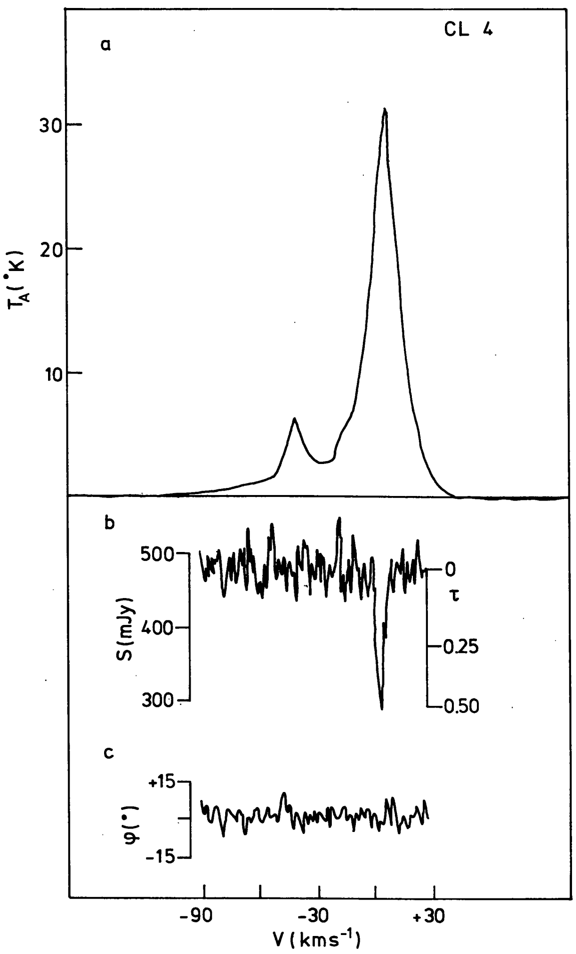

Figure 1.
The 21 cm spectrum in the direction of CL 4. 1(a) is the emission profile obtained with the Dwingeloo 25 m telescope. The velocity resolution is 2.1 km s^{-1}. 1(b) and 1(c) are the Westerbork absorption observations: 1(b) the amplitude, and 1(c) the phase. Note the displaced zero in the amplitude scale. The velocity resolution is 1.2 km s^{-1}. The field centre used is the radio position given by Webster and Ryle (1976). All velocities are with respect to the local standard of rest.

The absorption feature at zero velocity indicates that at least part of the local HI is in front of CL 4. At this longitude the radial velocity of the gas varies slowly with distance, which makes it impossible to set a firm lower limit to the distance of CL 4. In any case, the presence of HI absorption has removed one of the more compelling arguments for a galactic origin of CL 4.

The absence of absorption in the Perseus arm, on the other hand, is not in contradiction with an extragalactic origin of CL 4. At the distance of the Perseus arm the z distance is 1.3 kpc, while the full scale height of HI clouds is only 330 pc (Radhakrishnan and Goss, 1972). Thus the probability of the line of sight intersecting a cold cloud is low at these high values of z. In fact from the data of Weaver and Williams (1973) we see that the HI emission from the Perseus arm only extends to $b \sim -8^{\circ}$, the latitude of CL 4 itself; at $\ell = 74^{\circ}.5$ there is no detectable emission at the velocity of the Perseus arm.

In conclusion, while the current observations do not prove that CL 4 is extragalactic, they do remove one of the strongest arguments for a galactic origin. The absorption data are consistent with the suggestion that CL 4 is extragalactic, with similarities to many other compact, opaque, time-variable radio sources.

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