CONSEQUENCES OF A NEW DISTANCE DETERMINATION OF 3C58

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Introduction

In this paper we present new observations that show 3C58 is much closer than has been assumed in the past. This necessitates a reappraisal of many of the quantitative comparisons that have been made between 3C58 and the Crab Nebula or other 'filled-centre' remnants.

The observations also show that the structure of the neutral hydrogen in the ISM is, in practice, the limiting factor for HI absorption distance determinations, a factor that has not been taken into account in previous observations. This must raise doubts about the validity of many previous HI absorption distance determinations, which include the majority of the Galactic 'Σ-D' calibrators.

Observations

We have observed the supernova remnant 3C58 at 21 cm with the Cambridge Half-Mile Telescope (HMT). Two complete syntheses, overlapping in velocity coverage, were made in November 1981. Details of the telescope, receivers and the survey are given in table 1. In order to derive accurate HI absorption measurements towards the source it is important to include the contribution from HI emission on all scales. Data containing large-scale structure, unobtainable with the HMT, were derived from the Berkeley HI survey (Williams 1973a, Weaver & Williams 1973), and added to the synthesis maps. Continuum emission was subtracted from these 'composite' line maps to give the final channel maps, some of which are presented in fig. 1.

We derived optical depth and column density profiles for HI along the line of sight to 3C58 using (see, for example Spitzer 1978),

$$\tau = \mathrm{LOG}_e(T_{cont}/(T_{comp} - T_{em})), \quad (1)$$

and $N_{HI} = 1.823 \times 10^{23} \times V \times T_{em}\ m^{-2}$ where $V = 2.0\ km\ s^{-1}$. (2)

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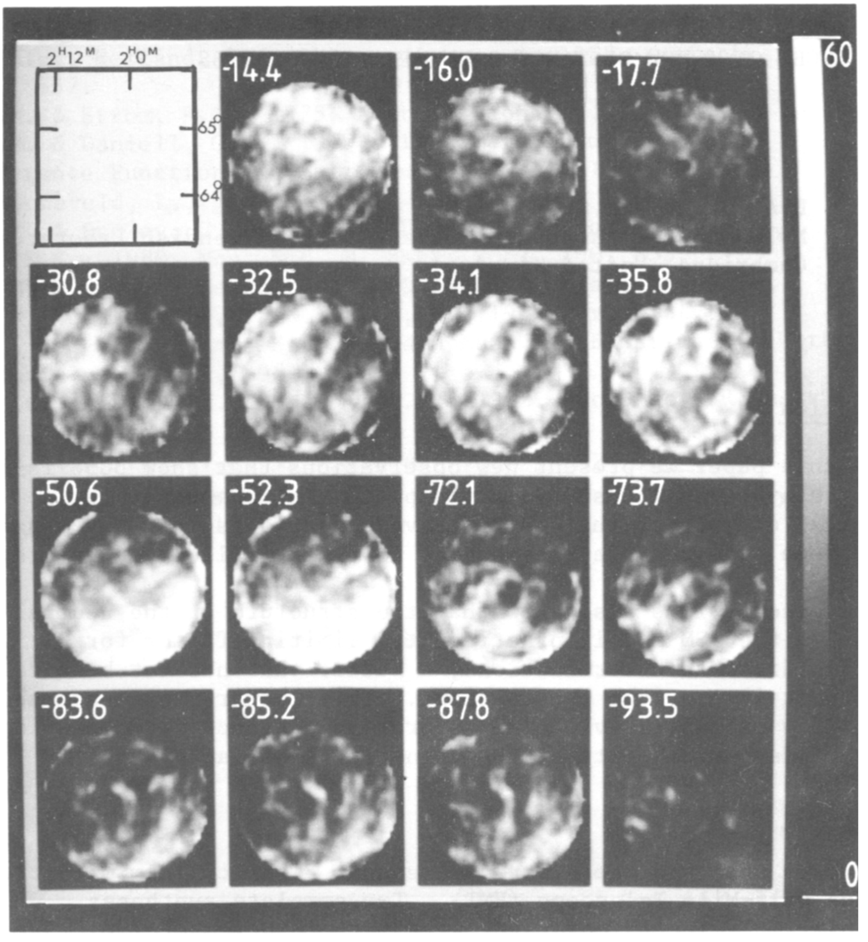

Figure 1. Photographic representations of some of the channel maps. The range, black to white, is 0 to 60 K, as shown by the scale on the right. The velocity of each channel (in km/s w.r.t. the Local Standard of Rest) is marked above each map. The field of view is sharply cut off at a radius of 80 arcmin. Notice the dark 'spot' of absorption in the centre of the maps with velocities below -36 km/s.

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On-axis temperatures for the continuum (T_{cont}) and for each channel (T_{comp}) were taken directly from the continuum and composite maps. The emission temperature (T_{em}) in the direction of 3C58, for each channel, was estimated from the surrounding area on each channel map. The errors shown in fig. 2a, b are ± 2σ errors and are almost solely due to the complicated structure of the ISM

Table 1: Specification of the HMT as used in the observations in the direction of 3C58.

Primary beam	94 arcmin HPBW
Spatial resolution	7.1 x 7.9 arcmin (RA x Dec)
Continuum receiver	10 MHz
Line receiver	Digital cross-correlation spectrometer with 80 delay channels/spacing 32 frequency channels for each synthesis channel separation 1.65 km s^{-1} (each of width 2.0 km s^{-1} to half power points)
Noise on synthesis maps	∿ 0.4 K
Field centre (1950.0)	RA = 2^h 2^m Dec = 64^o 35'

Figure 2a shows only two distinct absorption features, one from -14.6 to -17.6 km s^{-1}, corresponding to the edge of the local arm, and another centred at -34.1 km s^{-1}, corresponding to the Perseus

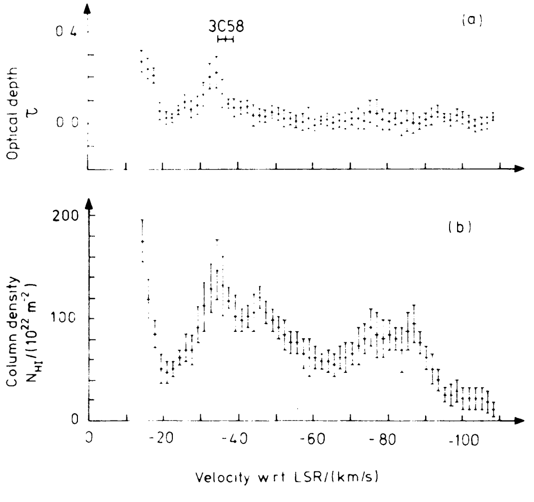

Figure 2. a) Plot of optical depth (τ) against velocity. b) Plot of column density N_{HI} against velocity. (Error bars are 2σ on both plots).

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arm. It is clear that there is no absorption past -39.1 km s^{-1}. Thus we can place 3C58 as being at a distance equivalent to a velocity of -36.6 ± 2.5 km s^{-1}. This corresponds to a distance of 2.6 ± 0.2 kpc on the Schmidt model (Schmidt 1965), but any systematic difference from the Schmidt model would give larger errors. For example the work of Roberts (1972) would place 3C58 at only 2 kpc.

Consequences

With a distance of 2.6 kpc, 3C58 is comparable in size to the Crab Nebula. Associating 3C58 with the SN of 1181 (Stephenson 1971), the mean expansion velocity of the remnant is $\sim$ 3900 km s^{-1}. From our data, and that of Williams (1973b) for velocities < -14.6 km s^{-1}, we estimate the integrated neutral hydrogen column density is to 3C58 of $2.55 \pm 0.3 \times 10^{25}$ m^{-2}. This is in good agreement with the value of $2.0 \pm 0.5 \times 10^{25}$ m^{-2} derived by Becker *et al*. (1982) from Einstein observations. Then, the optical absorption to 3C58 can be estimated as 1.3 mag, giving an absolute magnitude for SN1181 at max of -14.4 mag. This is subluminous compared to extragalactic SN, but these are in any case biased towards the brighter SN.

It has been suggested (Becker *et al*. 1982) that 3C58 is not the remnant of the SN of 1181. This was based on a comparison of several 'filled-centre' remnants for which X-ray observations are available. However, it is not clear how the X-ray dependent properties of these remnants indicate an evolutionary sequence, and indeed there may be beaming effects. The simplest, and perhaps the safest comparison is of linear sizes. With our revised distance 3C58 it is not much larger than the Crab Nebula (AD 1054). Bearing in mind that we do not know how typical the Crab or 3C58 are of 'filled-centre' remnants, we conclude there is no compelling evidence for doubting the association of 3C58 with the SN of 1181.

Acknowledgements

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DISCUSSION

VAN DEN BERGH: You may have solved the pulsar problem but at the cost of pushing the Hubble constant above 200 km s^{-1} Mpc^{-1}!

GREEN: I am afraid we have no control over where 3C58 actually is! Our distance makes SN1181 severely subluminous; so much so that supernovae of this absolute magnitude would scarcely be detectable in the spiral arms of external galaxies.

WEILER 1) The "normal" HI absorption distance for 3C58 is based partly on high velocity weak absorption at -60 to -100 km s^{-1}. These are reported to have TAU 0.1 which is less than your error bars. How can you rule these out? 2) You dismiss the utility of single-dish HI absorption measurements, but by inserting a zero spacing in your own observations you have, with great effort, synthesised a 100 m single-dish. Why are your "single-dish" observations better than previous ones? 3) If you feel you have maintained the advantage of an interferometer, why do your results disagree with two previous sets of interferometric measurements, at least one of which had superior spatial resolution and sensitivity?

GREEN: 1) Previous measurements of weak high velocity absorption features are spurious; they reflect the difficulties of obtaining good spectral baselines. To do this it is necessary to take account of the structure of the neutral hydrogen. Our measurements are in fact very sensitive, but the thermal noise accounts for less than 20% of our quoted errors, the bulk being due to the uncertainty in estimating the emission on the line of sight to 3C58. If there were any large holes in the neutral hydrogen, we could detect a TAU of 0.005. However, there are no holes of this type. 2) We believe that a 100 m single-dish would be just as good for work of this type, provided that sufficiently large maps are made, to enable good estimates of the emission on the line of sight. Averaging of a few neighbouring points is simply not good enough! 3) The principal previous interferometric measurement had a velocity resolution of 40 km s^{-1}. This is of the order of the velocity difference between the LSR and the position of 3C58!

GOSS: In your abstract you appear to be dubious about the use of HI absorption to obtain distances to SNRs. This criticism is based on a sample of only one or two. A large number of Galactic SNRs have been observed by the HI absorption technique. The distances derived are, in general, lower limits; upper limits are more difficult. (In fact the present determination for 3C58 is only a lower limit.) The HI absorption technique in our galaxy has been tested using HII regions. For these objects the intrinsic velocities are known from H recombination lines and often spectroscopic parallaxes of the

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exciting stars are known. These do NOT indicate that HI absorption distances are, in general, unreliable.

GULL: If there are other factors that indicate a true distance, then one knows which baseline wiggles in the absorption spectra are real, and which to discount! The fact that our absorption baseline is beautifully flat from −39 km s^{-1} tells us that this is a distance measurement, not a lower limit. There are, for example, bright (30 K) filaments which cross the line of sight at −45 km s^{-1}, and no absorption is seen. It is true that we have obtained, from our sample of two (3C10 (Albinson & Gull 1982) & 3C58), distances which are less than half of previous HI distance estimates. This understandably makes us sceptical of many other similar distance determinations. However, far from being dubious of the value of neutral hydrogen absorption techniques, we believe that it is a principal method for determining Galactic distances provided that sufficient care is taken to estimate the emission on the line of sight. This is painfully difficult; there is no cheap and cheerful way of doing it.

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