THE INTERACTION OF THE SUPERNOVA REMNANT VRO 42.05.01 WITH ITS HI ENVIRONMENT

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Abstract: VRO 42.05.01 (G166.0+4.3) is a SNR which has broken into and re-energized an old interstellar cavity. Observations of HI in a field containing the SNR show features associated with it. An expanding shell of mass ~40 $M_{\odot}$ is associated with the semi-circular shell of the SNR. The cavity, which the SNR has re-energized, is seen in the HI. A cloud of HI of mass ~25 $M_{\odot}$ has apparently been hit by the shock and has been accelerated by the post-shock flow.

In the expansion of the supernova remnant (SNR) VRO 42.05.01 the blast wave appears to have encountered an abrupt density discontinuity in the interstellar medium (ISM). This hypothesis was suggested by the radio continuum appearance of the SNR seen in Figure 1 (Landecker et al. 1982 - Paper 1). In Papers 2 and 3 (Pineault et al. 1985, 1987) we proposed that the blast wave has broken into and re-energized an old interstellar cavity, itself the product of previous supernovae or stellar winds.

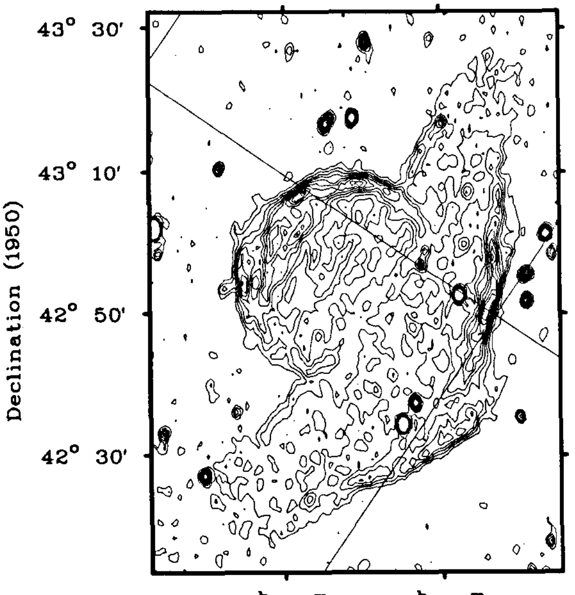

Figure 1: 1.4 GHz continuum map of VRO 42.05.01 (Paper 1)

HI line observations made with the DRAO Synthesis Telescope (Roger et al. 1973) are presented in part in Figure 2. Angular and velocity resolution as observed were 1 x 1.4 arcmin and 2.6 km s^{-1}, but these quantities have been altered for display to 4 x 4 arcmin and 2 km s^{-1}. The observations cover a 2.2° square field of which the central half is displayed, and encompass the entire range of galactic rotational velocities in this direction. Figure 3 displays the average observed spectrum in the 2.2° field; the range of velocities displayed in Figure 2 is indicated.

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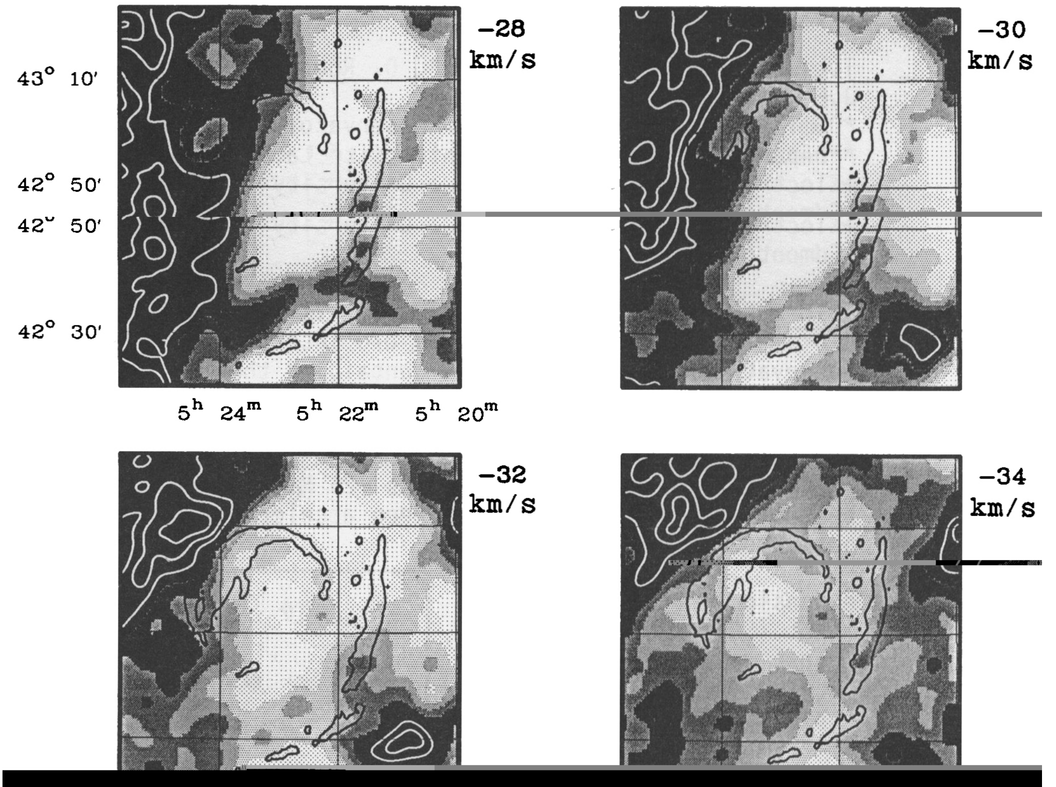

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Figure 2: HI in the field containing VRO 42.05.01. HI emission is represented by the grayscale; the increment between shades of gray is 2K in brightness temperature. Black represents bright emission and white contours extend the grayscale. A constant equal to the average emission in the field has been subtracted from each map; this does not affect the appearance of the HI features. The lsr velocity is indicated beside each map. Angular resolution is 4 x 4 arcmin. A single black contour indicates the 1.4 GHz continuum emission of the SNR.

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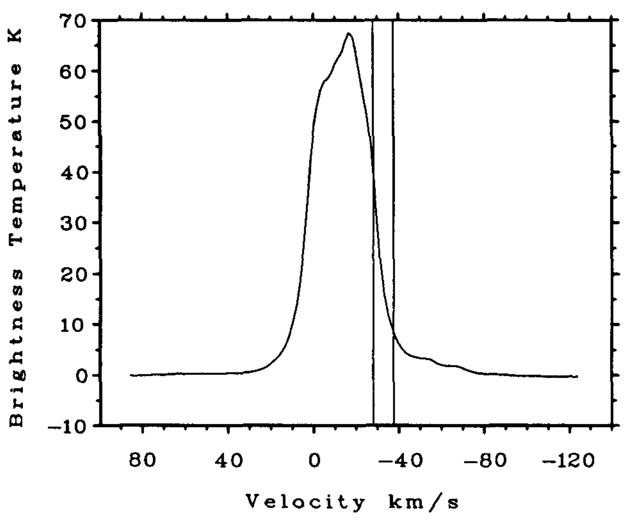

Figure 3: The average HI spectrum in the 2.2° field. The two vertical lines indicate the range of velocities displayed in the maps of Figure 2.

In this paper we simply point out some HI features related to the SNR. In describing them we use the term "shell" to denote the nearly circular component of diameter 31 arcmin in the east of the continuum object, and "wing" to refer to the western limb-brightened emission of extent ~1° (see Figure 1).

The semi-circular continuum shell appears to be completed by an HI feature, seen most clearly at -38 km s^{-1}. This HI shell can be seen from -34 to -40 km s^{-1}. Its diameter decreases as velocity becomes more positive, suggesting an expanding HI shell. A fit to the data yields (i) systemic velocity -40 km s^{-1} (ii) expansion velocity 10 km s^{-1} and (iii) radius 15 arcmin. This shell is confused with other HI between -30 and -40 km s^{-1}. The shell is incomplete: - an approaching component, expected between -40 and -50 km s^{-1}, is not seen.

Evidence of the cavity which the SNR has re-energized is found in the HI maps at -28 and -30 km s^{-1}, where it is seen as an elongated hole coincident with the interior of the wing. The northern part of the wing is clearly outlined by HI at -34, -36 and -38 km s^{-1}. The southern extremity of the wing appears to be a region of considerable confusion in the HI.

At velocities from -42 to -52 km s^{-1} (not shown in Figure 2) we find HI that has apparently been hit by the SNR shock. At -42 and -44 km s^{-1} we see an HI cloud which lies over the deep minimum at -28 km s^{-1} which we identify with the old cavity. With increasingly negative velocity the intensity peak of the cloud moves radially outward from the centre of the SNR towards the edge of the wing and splits in two. Figure 4 shows the location of HI features associated with the cloud at -44 and -52 km s^{-1}. We interpret this as evidence that the cloud has been overtaken by the shock, and is now being accelerated by the post-shock flow (McKee and Cowie, 1975). The gas is apparently being ablated by the flow in the manner predicted by Nittman et al. (1982).

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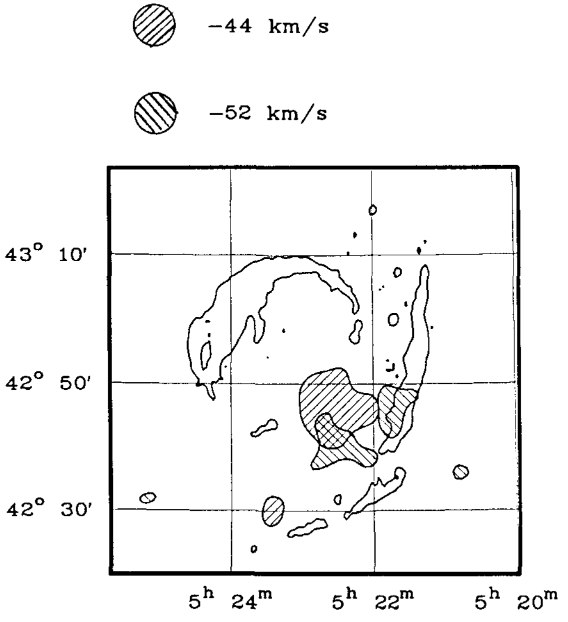

Figure 4: Shocked HI features. We interpret the -52 km s^{-1} features as gas ablated from the cloud at -44 km s^{-1} by the flow of post-shock gas.

The mass of HI which we can plausibly associate with the SNR is about 40 $M_{\odot}$ in the expanding shell and 25 $M_{\odot}$ in the accelerated cloud feature (based on a distance of 4 kpc). We cannot use the observed velocities to deduce a kinematic distance because of the proximity of the direction to the anticentre, and because of the probable effects of spiral density wave shocks in this direction (Roberts, 1972).

These observations demonstrate that our model of the interaction of VRO 42.05.01 with the ISM is substantially correct. We have been able to demonstrate for the first time that a SNR has re-energized an old interstellar cavity as envisaged by Cox and Smith (1974).

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