Environments of Bilateral Supernova Remnants with Neutron Stars

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Abstract. We report on Australia Telescope Compact Array (ATCA) H\textsc{i} observations carried out in the direction of bilateral supernova remnants (SNRs) with associated neutron stars: G296.5+10.0 and G320.4–1.2, in a search for the origin of such morphology. From these studies we conclude that in the case of G296.5+10.0, located far from the Galactic plane, the H\textsc{i} distribution has not influenced the present morphology of the SNR. In the case of G320.4–1.2, evolving in a denser medium, the combined action of the central pulsar, PSR B1509-58, with the peculiar distribution of the surrounding medium, has determined the observed characteristics of the SNR.

1. Introduction

Several Galactic supernova remnants (SNRs) exhibit an unusual bilateral morphology, characterized by a clear axis of symmetry, two bright limbs on either side and low level of emission near the top and bottom along the symmetry axis. The origin of this “barrel-shaped” appearance has provoked considerable debate for the past few years. A detailed study of the gaseous environs of bilateral

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SNRs is a very useful tool to disentangle intrinsic origins (like the presence of biconical beams from a central neutron star (NS), asymmetric explosions, etc.) from extrinsic causes (stratification of the interstellar density, the strength and orientation of the ambient magnetic field, etc.).

As a part of an ongoing project to observe the environs of bilateral SNRs, we have conducted a detailed H\textsc{i} study around G296.5+10.0 and G320.4–1.2. These two bilobular SNRs share the characteristic of harbouring an eccentric X-ray pulsar in the interior (the source 1E 1207.4–5209 inside G296.5+10.0, Helfand & Becker 1984, and PSR B1509-58 associated with G320.4–1.2, Seward & Harnden 1982). Using the Australia Telescope Compact Array (ATCA) we surveyed wide fields around these extended SNRs, looking for peculiar alignments, and/or properties of the surrounding gas which may give clues as to the origin of the observed radio morphology.

2. Observations

Mosaic interferometric λ 21 cm H\textsc{i} observations were carried out using the Australia Telescope Compact Array (ATCA), during four sessions of 13 hours each in 1998. Short spacing data were added to the interferometric database in order to recover structures at all spatial frequencies. The single dish data were taken with the Argentinian 30-m radiotelescope (IAR) for G296.5+10.0, and with the Parkes 64-m telescope (from the SGPS survey, McClure-Griffiths et al. 2001) for G320.4–1.2. Table 1 summarizes the observational parameters.

|                | Source        | Observed field | Mosaic pointings | Velocity resol. (km/s) | Beam (arcmin) | Noise (mJy/beam) |
|----------------|---------------|----------------|------------------|----------------------|---------------|-----------------|
| G296.5+10.0    | 3°.5 × 3°.5   | 109            |                  | 0.82                 | 4.0 × 2.7     | 53              |
| G320.4–01.2    | 1°.1 × 1°.1   | 19             |                  | 0.82                 | 4.0 × 2.7     | 30              |

3. Results

3.1. The SNR G296.5+10.0

This SNR has a bilateral appearance both in radio and X-rays. Its symmetry axis is oriented almost perpendicular to the Galactic plane. The radio quiet neutron star 1E 1207.4-5209 is located about 6′ from the geometric center.

After inspection of the H\textsc{i} emission within the observed velocity range (–225,+350) km s\textsuperscript{−1}, we find that the best morphological correspondence between the surrounding H\textsc{i} gas and the radio, X-rays and optical emission associated with G296.5+10.0, occur between V\textsubscript{LSR} ∼ –17 km s\textsuperscript{−1} and –14 km s\textsuperscript{−1}. In this velocity range some good matches are observed to the NE and along a short portion of the western limb of the SNR (Figure 1, left panel).

The distribution of the absorbing column density integrated between the observer and the G296.5+10.0 shows a striking hole in the H\textsc{i} emission, exactly coincident with the X-ray source 1E 1207.4-5209 in all the three coordinates (l,
b and $V_{\text{LSR}}$). From this fact we independently confirm the association between the NS and the SNR. The X-ray flux from the radio quiet NS must be heating the local gas around 1E 1207.4-5209, thus providing a hot background against which the emission of the cold foreground H I is self-absorbed.

### 3.2. The SNR G320.4–1.2

This SNR has a bilateral appearance in the radio range. The optical/radio/X-ray nebula RCW 89 is located on the NW extreme of G320.4–1.2. The young pulsar PSR B1509–58 lies between the two main radio components. In the X-ray wavelengths the system is dominated by the pulsar emission (also detected at radio wavelengths and in $\gamma$–rays). Recent Chandra images show with great detail the bright X-ray synchrotron nebula associated with the pulsar, with a collimated feature that is interpreted as a relativistic jet directed along the pulsar spin axis (Gaensler et al. 2002, this proceedings).

The H I survey of the environs have shown that G320.4–1.2 evolves within an elongated cavity, with the NW radio lobe interacting with a dense wall (atomic density $n \sim 12–15 \text{ cm}^{-3}$) (Figure 1, right panel). Such wall would be responsible for the flat appearance of the NW half of the SNR. The interaction between the collimated relativistic outflow from the pulsar and the densest clump of this H I feature near RCW 89, would be responsible for the formation of the bright radio and X-rays knots and for the H $\alpha$ emission of the nebula. To the SE, the SNR expands into a lower density medium, thus explaining the farther distance attained by this lobe, as well as its semi-circular morphology. An extended version of this work is presented in Dubner et al. (2002).
4. Conclusions

Based on a detailed study of the distribution and kinematics of the H\textsc{i} around the SNRs G296.5+10.0 and G320.4–1.2, we conclude: (a) in the case of G296.5+10.0, which is placed far from the Galactic plane, the surrounding gas has had little influence in the morphology of the SNR. Our observations have confirmed the physical association between this SNR and the isolated radio-quiet neutron star 1E 1207.4-5209. Asymmetric explosion, and/or biconical outflows from the neutron star, must have contributed to the present bilateral morphology of G296.5+10.0.; (b) in the case of G320.4–1.2, located in a higher density environment, the properties of the surrounding medium combined with the characteristics of the associated pulsar have conditioned the present morphology of the SNR. The H\textsc{i} observations have revealed the existence of a cavity in the interstellar medium. We propose that as a consequence of the interaction of the expanding SN shock with the northern wall of this cavity, the NW radio lobe of G320.4–1.2 acquired a flatten appearance. Also, the encounter of the relativistic pulsar outflow with this wall is probably responsible for the formation of the optical nebula RCW 89.

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References

Dubner, G., Gaensler, B.M., Giacani, E.B., Goss, W.M., & Green, A.J. 2002, AJ, in press [astro-ph 0110218]
Gaensler, B.M., Brazier, K.T.S., Manchester, R.N., Johnston, S., & Green, A.J. 1999, MNRAS, 305, 724
Giacani, E.B., Dubner, G., Green, A.J., Goss, W.M., Gaensler, B.M. 2000, AJ, 119, 281
Helfand, D.J., & Becker, R.H. 1984, Nature, 307, 215
McClure-Griffiths, N.M., Dickey, J.M., Gaensler, B.M., Green, A.J., Haynes, R.F., Wieringa, M.H. 2001, ApJ, 551, 394
Seward, F.D., & Harnden Jr., F.R. 1982, ApJ, 256, L45