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THE X-RAY STRUCTURE OF THE SUPERNOVA REMNANT W49B

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PERSONNEL

Professor John R. Dickel was the principal investigator and received a salary for 3/4 month in the summer of 1993. Professor You-Hua Chu acted as an unpaid consultant to the project. Guillermo Garcia was a graduate assistant who was paid for two months on the grant. Rosa Murphy and Daniel Goscha were students in a research course working with these data.

PUBLICATION

J. Dickel, R. Murphy, Y.-H. Chu, and D. Goscha "X-ray and Radio Emission from W49B and Other Supernova Remnants" Proceedings of ROSAT Science Symposium, ed by E. M. Schlegel, GSFC, NASA, 1994.

SCIENTIFIC REPORT

Abstract

Comparison of x-ray and radio images of W49B and other SNRs provides detailed information on the mechanisms responsible for the emission and on the evolution of the remnants.

1. Introduction

X-ray observations of supernova remnants (SNRs) delineate shock-heated gas while radio observations delineate the relativisitic particles and magnetic fields. The two forms of emission should be related, however, because the shocks that heat the thermal gas to x-ray emitting temperatures are also responsible for the acceleration of the relativistic electrons which produce the synchrotron radiation. Statistical studies indeed show a rough linear correlation between the x-ray and radio surface brightnesses of SNRs although individual remnants show large deviations from the mean relation (Berkhuijsen 1986 A&A, 166, 257; Dickel, Norton, and Gensheimer 1990 in High resolution X-ray Spectroscopy of Cosmic Plasmas, ed. by Gorenstein and Zombeck, 168). In addition, there can be very significant variations in the x-ray/radio brightness ratio across individual remnants.

These variations may have many causes, including:

1. Variable extinction which can affect the observed x-ray brightness
2. Different circumstellar densities which affect:
   a) shock speed - inversely dependent on density - which controls:
      temperature for x-ray brightness
      relativistic particle acceleration and magnetic field amplification for the synchrotron radiation
   b) x-ray emissivity - proportional to density^2
3. Strength and direction of ambient magnetic field for the radio synchrotron emission
4. Clumpiness of surroundings which affects the turbulent amplification for the synchrotron emission processes
5. Explosion energy -
   a) x-ray luminosity approximately proportional to E
   b) radio luminosity approximately proportional to $E^{7/4}$
6. Evolution -

a) The initial x-ray emission arises in a shell between the forward shock and a reverse shock going back into the ejecta. Then, with time, the shock-heated ejected gas and engulfed clouds which have evaporated can expand to fill the entire volume of the SNR cavity. Eventually the gas in the center will cool and fade due to adiabatic work of expansion.
b) The initial radio synchrotron emission is enhanced by turbulence in the shell. Next, the dense filaments responsible for the brightest radio emission will undergo thermally unstable compression and then evaporate in the hot surrounding gas so they will not be seen in the interior of the SNR. The enhanced magnetic field in the outer part of the shell will also inhibit the movement of the radio emitting material back into the interior.

7. Presence of a compact central object which can power a filled volume of non-thermal emission at both x-ray and radio wavelengths.

Investigation of these various possibilities requires high resolution multi-wavelength comparisons of a large selection of SNRs, preferably at known distances. This project is being undertaken using both HRI and PSPC observations from *ROSAT* together with high-resolution radio observations. Carefully chosen Galactic and Large Magellanic Cloud SNRs of different ages in a variety of environments are being used in this study to separate the individual effects. Comparison of global properties as well as variations in the relative x-ray and radio brightnesses across individual SNRs allows determination of the detailed physics of the emission processes in both wavelength regimes plus assessment of the interaction with the surroundings as a remnant expands and evolves.

2. Results on W49B

The remnant W49B shows characteristics indicative of its evolutionary age. This SNR, at a distance of 10 kpc, has a diameter of 12 pc and is probably in the adolescent phase of its lifetime, just entering the Sedov blast-wave stage. Figure 1 shows a grey-scale image of a 33.7 ksec exposure with the *ROSAT* HRI and superimposed contours from a *VLA* radio image (Moffett and Reynolds, 1994 ApJ, in press). The x-ray data have been convolved with a 15-arcsec Gaussian for improved signal-to-noise. Some x-ray emission is seen throughout the remnant but most of it comes from a very bright x-ray core in contrast to the radio emission from a complex shell with no central component. Only one small part of the shell, on the southeast corner, is prominent in x-rays. Full-resolution (6 arcsec) cuts across the bright central region of W49B show that the emission is extended and there is no point source above a 3-sigma level of 4 counts/beam. This result, combined with the thermal nature of the spectrum with a temperature of 2 keV deduced by Smith et al. (1985 ApJ, 296, 469) from *EXOSAT* ME and GSPC observations, confirms the conclusion that the interior x-ray emission is entirely from hot shocked gas. Most of the gas in the shell heated by the forward shock has already cooled while the interior gas heated by the reverse shock and expanding back into the central region is still hot. The relatively soft response of the *ROSAT* HRI does pick up some parts of the cool shell.

3. Conclusion

There is faint x-ray emission from all parts of the SNR W49B but most of it is concentrated near the center of the remnant unlike the radio emission which arises in a shell near the perifery. This structure indicates that this SNR is in the adolescent phase of its lifetime.

Figure 1. Grey-scale of the *ROSAT* HRI image of the supernova remnant W49B. The image has been convolved to a 15-arcsec point spread function. The units on the greyscale bar are counts/beam. The contours represent radio emission at a wavelength of 6.1 cm observed with the *VLA* by S. Reynolds and D. Moffett. The half-power beamwidth was 4 arcsec.