HIGH-RESOLUTION OBSERVATIONS OF GALACTIC NONTHERMAL SOURCES AT 160 MHz

O. B. SLEE and G. A. DULK*

Division of Radiophysics, CSIRO, Sydney, Australia

Abstract. Preliminary maps of the brightness distributions of 11 supernova remnants are presented. The sources, with diameters $\lesssim 10'$, were observed at 160 MHz with resolution better than 2'. Ten of the supernova remnants are significantly resolved, and at least six show evidence of a shell-like structure. For those sources where high-frequency maps are available with comparable resolution the brightness distributions are generally very similar.

I. Introduction

This paper presents some preliminary maps of the brightness distributions of 11 suspected galactic supernova remnants (SNRs). The observations were made at 160 MHz with the radio-heliograph operated by the Division of Radiophysics, CSIRO, at Culgoora, N.S.W. At this frequency the radioheliograph's beamwidth, $1.85' \times 1.85'$ secant $(30°18' + \delta)$, is small enough to partially resolve many of the SNRs near the galactic equator. Each observation consisted of a series of drift scans of the source. A detailed description of the observing method and reductions is given by Dulk and Slee (1972). The flux density scale was established from observations of several strong sources with well-known spectra from Kellermann *et al.* (1969).

Each of the sources was observed on several different occasions; the maps selected for presentation here show the features commonly found on the different maps of a particular source. No two maps of a source are exactly alike because of the effects of noise, ionospheric refraction changes, and, in some cases, perturbations caused by other sources in the grating lobes of the instrument. Later we plan to publish more accurate brightness contours obtained by averaging many separate maps taken at a variety of hour angles; the resulting partial synthesis will reduce the effects of grating responses. In addition, we will publish the flux densities of these and other galactic sources and discuss them from the point of view of interstellar absorption.

II. Comments on 160-MHz Maps

G348.5+0.1. This source (CTB 37*A*) has long been recognized as a probable SNR. The present 160-MHz map shows a definite shell-like structure which is particularly enhanced to the north-east. Dickel *et al.* (1973) have observed this source with 2.8' resolution at 8.8 GHz, where it shows a remarkably similar brightness distribution. At 80 MHz, if we take into account the lower resolution, the brightness distribution is again similar (Dulk and Slee, 1972). Two important conclusions flow from this similarity:

* Exchange visitor from the Department of Astro-Geophysics, University of Colorado, Boulder, Colo., U.S.A.

F. J. Kerr and S. C. Simonson, III (eds.), Galactic Radio Astronomy, 347–351.

(i) The low-frequency absorption reported for this source by Dulk and Slee (1972) is fairly uniformly distributed over the $9 \times 6'$ area occupied by the remnant.

(ii) There is little change in the radio spectrum over the area of the source, implying that the electron energy distribution is similar in various parts of the remnant.

G349.7+0.2. This source is barely resolved by the 1.85′ beam so that no structural detail is seen.

G357.7−0.1. The source is well resolved by the 160-MHz observations. The crowding of the contours, especially in the south-west quadrant, is suggestive of a shell-like structure. Dickel *et al.* (1973) published a map of this source at 8.8 GHz with a 2.8′ beam showing a similar general elongation. Once again it appears that the electron energy distribution remains constant over the remnant.

G04.5+6.8. Kepler's SNR is barely resolved by the 1.85′ beam. It shows a weakly elliptical distribution with major axis at $PA \sim 60°$. Dickel *et al.* (1973) published a map at 8.8 GHz with 2.8′ resolution which shows a similar distribution, but with the major axis at $PA \sim 0°$.

G11.2−0.4. The source is significantly resolved at 160 MHz with the 1.85′ beam. The flat top suggests that the source has a shell-like structure which is approximately symmetrical. The source was observed by Shaver and Goss (1970) at 408 MHz with a 2.8′ beam, but the shell-like structure of the source was not apparent at their resolution.

G25.3−0.1. The source is barely resolved in declination but is significantly resolved in hour angle. Because this source is quite weak the reliability of the contour map is questionable. Shaver and Goss's (1970) map at 408 MHz with a 2.8′ beam showed no structural detail; on that basis, they suggested that the source is an extragalactic object.

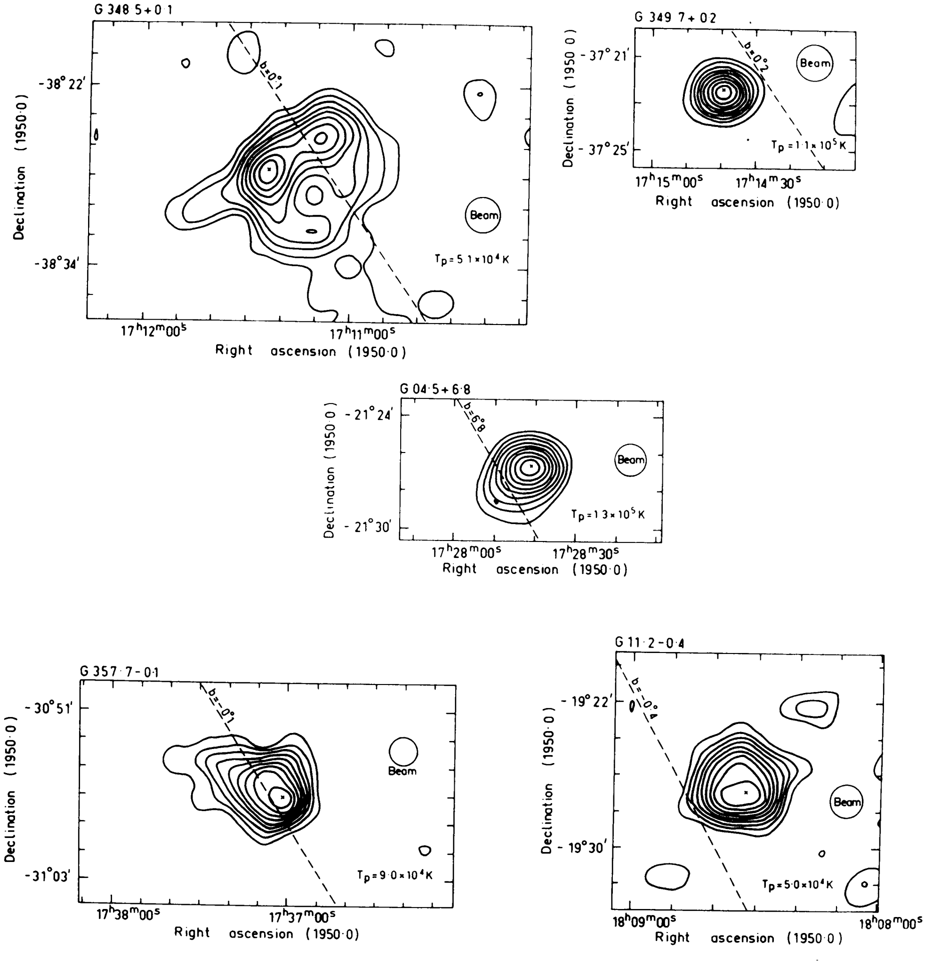
G29.7−0.2. The source is significantly elongated in hour angle, but there is little evidence of shell structure or other brightness details. Shaver and Goss (1970) published a 408-MHz map in which the source was not significantly resolved.

G31.9+0.1 (3C391). The $1.85' \times 2.12'$ beam at 160 MHz resolves the source and shows an apparent shell-like structure, particularly in the north and west. The 8.8-GHz map of this source given by Dickel *et al.* with a 2.8′ beam does not match the 160-MHz map very closely; in particular the tongue-like projection to the south in the 160-MHz map is not a feature of the 8.8-GHz map. If the differences in the two maps are real, they imply that there are spectral changes over the SNR, either because of the presence of a separate component with a different spectrum, or because the electron energy distribution for this particular remnant is not constant throughout. Patchy, low-frequency absorption can be ruled out in this case because the optical depth is small at 160 MHz. (Caswell *et al.* [1971] showed that $\tau \approx 1$ at 80 MHz.)

G39.2 − 0.3 (3C396). The source is significantly resolved by the 1.85′ × 2.27′ beam at 160 MHz. The distribution is approximately spherical with some indication of a shell-like structure, especially to the north-east and south-west of the peak. The 408-MHz map of Shaver and Goss (1970) with 2.8′ resolution is generally similar and indicates a shell structure extending from the north through west.

G41.1 − 0.3 (3C397, CTB 67). The source is significantly extended at $PA-57°$ but is barely resolved in the perpendicular direction. There is weak evidence for a shell structure.

G43.3 − 0.2 (3C398, W49B). The 1.85′ × 2.32′ beam of the radioheliograph has partial-



Figs. 1a–b. Representative contour maps showing the brightness distributions of 11 galactic nonthermal sources at 160 MHz. The contour levels are 10, 20, …, 90% of T_p, the peak beam brightness temperature measured by the radioheliograph. The value of T_p given is the average value found from all maps of the source; it is only approximately correct for the representative map presented here.

https://doi.org/10.1017/S0074180900026644 Published online by Cambridge University Press

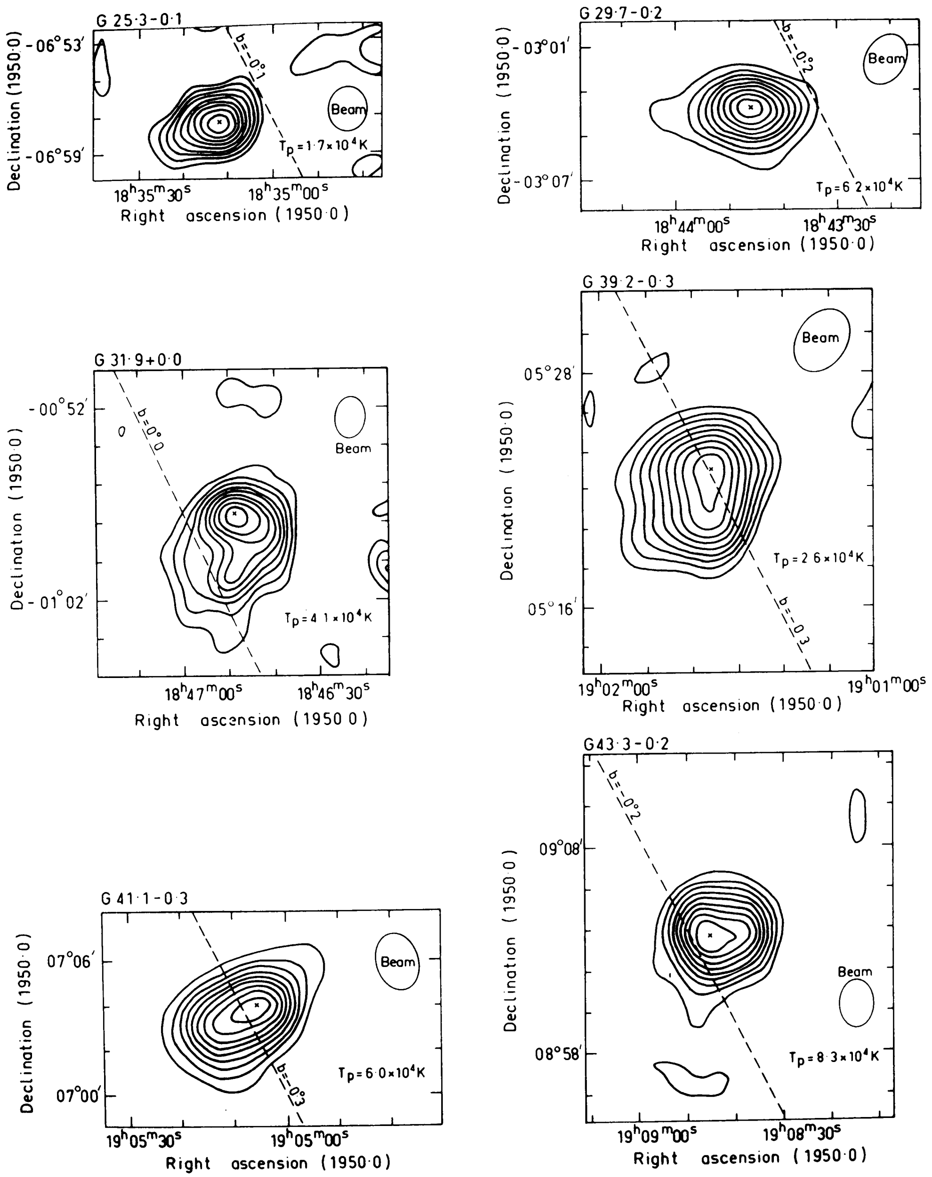


Fig. 1b.

ly resolved this source. The symmetrical radio brightness distribution with a flat top is indicative of a shell structure.

III. Discussion

The present preliminary maps of 11 nonthermal galactic sources have demonstrated the feasibility of high-resolution observations at metre wavelengths, provided care is taken to make enough observations to ensure that the effects of noise, ionospheric refraction and grating responses can be recognized. Shell-like structure appears to be a common characteristic of these small-diameter SNRs. For four of the five sources for which high-frequency maps of similar high resolving power are available, the radio brightness distributions at the high and low radio frequencies are generally very similar. This agreement indicates, first, that the energy distribution of the relativistic electrons responsible for the synchrotron emission from the SNR is similar throughout the remnant. Secondly, for those galactic sources showing pronounced absorption at low frequencies, the agreement between the radio brightness distributions at high and low frequencies shows that the optical depth varies on a scale which is larger than the angular extent of the source. The details of the brightness distributions (for example, the orientation of the major axis of the deconvolved elliptical brightness distribution) does not show any consistent relationship with the direction of the galactic equator. Such a relationship might be expected if the structure of the source were determined by the interaction of the expanding gas cloud with the general field of the Galaxy.

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O. B. Slee
G. A. Dulk
Division of Radiophysics, CSIRO,
P.O. Box 76,
Epping, N.S.W. 2121, Australia

(Discussion follows paper by R. M. Duin et al., p. 361.)

https://doi.org/10.1017/S0074180900026644 Published online by Cambridge University Press