SNR POLARIZATION AND THE DIRECTION
OF THE MAGNETIC FIELD

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Abstract: At the CSIRO Division of Radiophysics we
are currently engaged in a program to map polarization
in SNRs at 8.4 GHz. These results are compared with
earlier Parkes 5 GHz maps to deduce the direction of
magnetic field, Faraday rotation and depolarization.

Over the past decade or so linear polarization observations have been
published for ~70 supernova remnants. We accept that this polarized radio
emission is generated by the synchrotron process, which implies a magnetic
field directed normal to the intrinsic electric vector. For a uniform
magnetic field the degree of polarization is independent of frequency and is
given in terms of the spectral index (α) by

$$P = (3-3\alpha)/(5-3\alpha), \qquad \text{i.e. } P = 0.7 \text{ for } \alpha = -0.5.$$

If the magnetic field is not uniform throughout the emission region
the degree of polarization is reduced, and if the magnetic field is completely
random it is zero. The observed polarization will be decreased even in the
presence of uniform magnetic fields by differential Faraday rotation of
emission from regions at different depths. The observed polarization may
be further reduced by Faraday rotation across the telescope beam.

Faraday rotation of the polarization position angle is generally
observed and, in summary, the position angle should vary proportionally to
wavelength squared if the rotation is outside the emitting region and will
follow a more complicated relationship if it is inside.

Measurements of the distribution of polarization, Faraday rotation,
depolarization and the direction of the magnetic field could tell us much
about the energy process and evolution of these objects.

At the CSIRO Division of Radiophysics we are mapping SNR
polarization at 8.4 GHz (3' arc beam) and comparing these with the Parkes 5
GHz maps (Milne and Dickel, 1975) to obtain the distribution of rotation
measure, depolarization and direction of the projected magnetic field over
the remnants; the first results, for the remnants G291.0-0.1 and G7.7-3.7,
have been published (Roger et al., 1986 and Milne et al., 1986 respectively).
A further 10 fields are currently being investigated.

In Figure 1 we illustrate this work with a preliminary map of G316.3-0.0, which shows the projected directions of the magnetic field, deduced from 5 and 8.4 GHz measurements, superimposed on an 843 MHz Molonglo synthesis map (Milne et al., 1987).
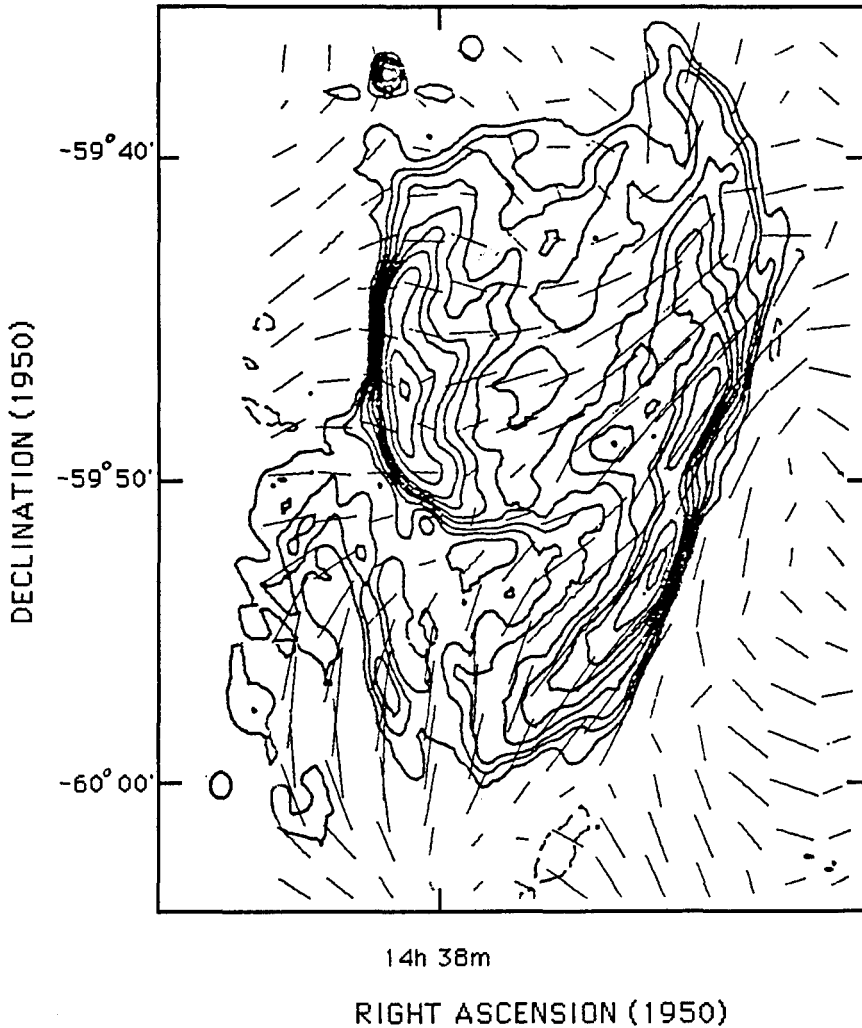

Fig. 1 - Direction of the projected magnetic field in the SNR G316.3-0.0 deduced from 5 and 8.4 GHz polarization. The magnitude of these vectors indicates the mean polarization intensities at these two frequencies. The vectors are shown superimposed on the 843 MHz Molonglo total power map (Milne et al., 1987).

At present there are 27 SNRs for which polarization observations have been published - sufficient to deduce the direction of the projected magnetic field over the remnant. These results have been collated to form "An Atlas of SNR Magnetic Fields" (Milne, 1987). In Table 1 we list these remnants, together with their ages, structural form and the suggested direction of the projected magnetic field.

Table 1   SNRs with observed magnetic field directions

Remnant	Age (yrs)*	Structural form	Magnetic field direction
G5.4-1.0	2500	Shell	Radial in northern arc
G6.4-0.1	6000	Shell	Tangential
G7.7-3.7	2000	Shell	Across shell
G18.8+0.3	4000	Shell	Radial
G21.5-0.9	500	Filled + shell(?)	Radial
G21.8-0.6	4000	Shell	?
G34.6-0.5	2500	Shell	Radial (?)
G74.0-8.6	12000	Shell + blow-out (?)	Tangential in blow-out
G89.0+4.7	7000	Shell?	
G93.3+6.9	1500	Shell	Tangential
G111.7-2.1	300	Shell	Radial
G120.1+1.4	413*	Shell	Radial
G127.1+0.5	18000	Shell	Tangential
G130.7+3.1	805*	Filled	Longitudinal
G184.6-5.8	932*	Filled	Radial on periphery
G189.1+2.9	2500	Shell	Radial
G260.4-3.4	3000?	Shell	Radial
G263.9-3.0	11000	Shell	?
G291.0-0.1	4000	Filled + faint shell	Directed along central bar
G296.5+10.0	5000	Shell	Tangential
G315.4-2.3	1800*	Shell	Radial
G316.3-0.0	700	Shell + blow-out (?)	Radial in shell
G320.4-1.2	1600	Shell	Radial
G326.3-1.8	3000	Faint shell + bright region	?
G327.6+14.0	980*	Shell	Radial
G327.4+0.4	6000	Shell(s)	?
G332.4+0.1	5000	Shell + blow-out (?) + jet	Tangential

* Age obtained from observation of SN outburst, otherwise calculated from the relationship of Caswell and Lerche (1979) using the data from Milne (1979).

The conclusions that can be drawn from our current knowledge can be summarized:

(a)   A general large-scale field is readily seen at low resolutions, but at higher resolutions this may be concealed by increased detail.

(b) Radial fields are more prevalent than tangential fields.

(c) Radial fields predominate in the young remnants. All objects for which we have a definite (and consequently young) age have a field that is radial around the periphery; this is as we would expect it to be, since firstly, the young SNR has not been broken up as much by interaction with the ISM, and secondly, a radial field in a spherical shell is seen as a radial field in all projections.

(d) Blowouts have possibly occurred in G74.0-8.6 (the Cygnus Loop), G316.3-0.0 (MSH 14-57) and in G332.4+0.1 (Kes 32). In these objects and perhaps others it appears that an otherwise spherical shell has been breached, dragging the magnetic field into the blowout at this point (e.g. the most southern part of G316.3-0.0 in Figure 1).

(e) In spite of the preference for alignment of the brightest parts of a remnant nearest the galactic plane (Caswell, 1977) there seems to be no evidence for any preferred orientation in the direction of magnetic field.

Finally, there does not appear to be an answer yet to the question whether polarization or the magnetic field direction exhibits any interaction with the ISM or with the interstellar magnetic field.

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