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An Atlas of Supernova Remnant Magnetic Fields*

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Abstract

Observations of polarised radio emission from supernova remnants are reviewed and maps presented for the projected magnetic fields deduced from these observations. It is fairly clear that the fields in the young objects are radial and that there is a strong bias towards finding these objects in polarisation surveys. Well-defined tangential fields can be seen only in older remnants which are located well off the galactic plane.

1. Introduction

We accept that the radio emission from supernova remnants (SNRs) is by the synchrotron process and that, of necessity, a magnetic field exists with which the relativistic particles interact. For synchrotron radiation from electrons in a uniform magnetic field the E vector of linear polarisation will be directed normal to the direction of the magnetic field and will have a degree (i.e. fraction) of linear polarisation independent of frequency and given in terms of α, the spectral index of the radio emission, by

$$p = (3-3\alpha)/(5-3\alpha);$$

that is, $p = 0 \cdot 7$ for $\alpha = -0 \cdot 5$. If the magnetic field is not uniform through the emission region the degree of polarisation is reduced, and if the magnetic field is completely random it is zero.

The observed polarisation will be decreased even in the presence of uniform magnetic fields by differential Faraday rotation of emission from regions at different depths. Models for this mechanism have been explored by Burn (1966) and Sazonov (1973). The observed polarisation may be further reduced by Faraday rotation across the receiver bandpass and by external rotation across the telescope beam (Milne 1980).

Faraday rotation of the polarisation 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 not. The constant of proportionality is the rotation measure RM (rad m^{-2}),

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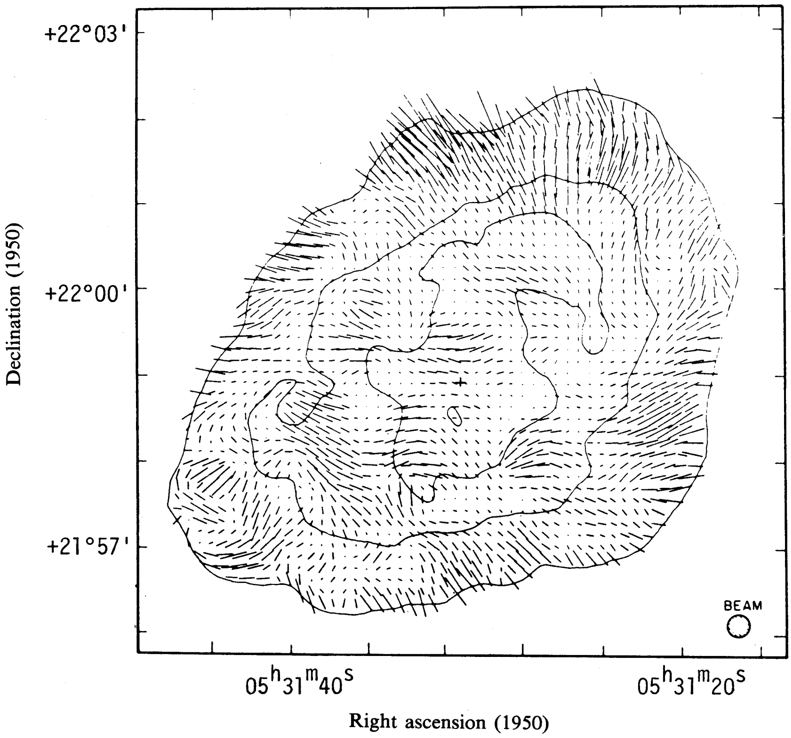


Fig. 1. The 1·4 GHz polarisation E vectors in the Crab Nebula (Velusamy 1985). This figure and Fig. 2 show the cellular structure common in SNR polarisation. It is suggested that, because there is Faraday rotation at $\sim 90°$ relative to the intrinsic position angle, the magnetic fields are directed approximately along these E vectors (see Section 1).

which depends on the total electron density N (cm^{-3}) and the component of magnetic field $B_{\|}$ (G) along the path L (pc):

$$\mathrm{RM} = 8\cdot 1\times 10^5 \int_L N B_{\|}\, \mathrm{d}L .$$

A definitive review of the theory of radio polarisation was presented by Gardner and Whiteoak (1966). For details of observational methods and of the numerous instrumental effects the reader is referred to Milne and Dickel (1975).

It has become customary to divide SNRs into two classes: (a) shell-type remnants, in which the radio emission is presumed to originate from relativistic particles and magnetic fields either generated at the time of the explosion (Shklovskii 1960) or during the early stages of the expansion (Gull 1973), or swept up from the interstellar medium (Van der Laan 1962); and (b) filled-centre, Crab-Nebula-like remnants which require a continuing source of relativistic particles, such as a pulsar, to sustain the optical and X-ray emission (Rees and Gunn 1974).

Amongst the earliest observations of SNR radio polarisation were the Mayer and Hollinger (1968) maps of Cas A and the Crab Nebula and observations of Vela X (Milne 1968). In the first of these studies the signals were very strong and working at only one fairly short wavelength (1 cm). Mayer and Hollinger were able to show

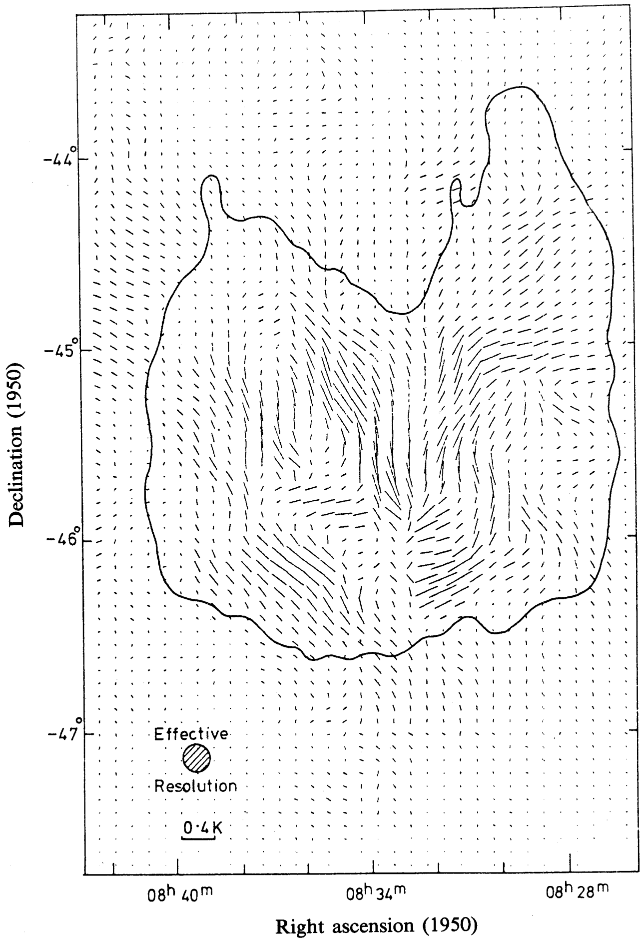


Fig. 2. Directions of the projected magnetic field in the Vela SNR (from Milne 1980). The contour shown outlines Vela X, the bright south-western portion of the Vela SNR.

fairly conclusively that Cas A, a young shell-remnant, has a radial magnetic field, while the Crab Nebula has a field directed uniformly across the bulk of the remnant and turning north over the most northern parts, giving the impression that the field is mainly radial around the edges. Milne used three frequencies to estimate the Faraday rotation and to show the magnetic field looping around the brightest parts of Vela X in a near tangential direction. Vela X is a large, old, close-by remnant, and remained for many years the most well-resolved SNR.

Since then the bulk of the older and larger SNRs have been mapped in polarisation at several frequencies, mainly using the NRAO 140-ft and 300-ft telescopes, the Parkes 64-m telescope and the Effelsberg 100-m telescope. There is a distinct advantage in using alt–azimuth mounted antennas, such as these latter two, since surface deflections and ground radiation are all altitude-dependent and therefore more amenable to correction. Examples of these single-dish observations are to be found in Milne (1972), Milne and Dickel (1974, 1975), Baker *et al.* (1973), Kundu and

Velusamy (1969, 1972), Velusamy and Kundu (1975), Haslam *et al.* (1980), Reich and Braunsfurth (1981), Furst *et al.* (1984) and Reich *et al.* (1986).

Younger and smaller objects have been mapped in polarisation using various synthesis instruments, examples being Cas A (Rosenberg 1970), the Crab Nebula (Wilson 1972; Velusamy 1985), Tycho's SNR (Herman and Dickel 1973; Duin and Strom 1975), Kepler's SNR (Strom and Sutton 1975), 3C 58 (Herman and Dickel 1973; Wilson and Weiler 1976) and G21·5−0·9 (Becker and Szymkowiak 1981).

The most general conclusion is that the polarisation is uniformly directed within cells extending over several beamwidths, and examples of this can be seen in Figs 1 and 2. In Fig. 1 we reproduce a VLA map of the 1·4 GHz polarisation E vectors in the Crab Nebula (Velusamy 1985). Velusamy suggested that the interstellar rotation at 1·4 GHz is about 90° and therefore this map displays the directions of projected magnetic field, at least around the edges, where the Faraday rotation and depolarisation is likely to be low. In Fig. 2 the magnetic fields in Vela X (the bright south-western part of the Vela SNR) are shown (Milne 1980). The cellular nature of the polarisation and magnetic fields can be seen in these two examples; there is some indication, particularly in the Crab Nebula, that these cells are bounded by the optical filaments.

In all, some 70 SNRs, about half of the known galactic remnants, have been examined for linear polarisation. In many of these the results are inconclusive, the polarisation is weak and tangled and frequencies used have been insufficient to define the rotation measure and hence the magnetic field direction. Many of the observations have been made at low frequencies, and although of high resolution, insufficient confidence in the Faraday rotation has precluded any extrapolation to zero wavelength and deduction of the magnetic fields. In many cases the detection of polarisation has been just sufficient to confirm the classification of the object as an SNR.

However, from the observations it is clear that a radical magnetic field exists in certain of the younger shell sources (e.g. Tycho's SNR; Duin and Strom 1975). A radial magnetic field in the younger remnants is expected to result from Rayleigh–Taylor instability stretching and intensifying the magnetic field in the radial direction (Gull 1973), and the scale of this turbulence has been shown to be of the order of the radius (~6 pc) in Tycho's SNR (Lerche and Caswell 1979), so that six or seven cells are located around the shell.

In contrast the old SNR Vela X contains turbulent cells of size about 2 pc or only about one-eighth or one-tenth of the shell diameter (Lerche and Milne 1980). These older remnants are expected to exhibit a tangential field from compression of the interstellar ambient field (Van der Laan 1962). Where in a few older SNRs there is a well-defined field, it is tangential.

These two mechanisms are regarded more favourably at present than the Whiteoak and Gardner (1968) interpretation of the Van der Laan model, wherein radial fields were interpreted as tangential fields viewed end-on, i.e. along the ambient field lines.

Perhaps the best examples of the two types can be seen in Dickel and Milne (1976), where G327·6+14·6—SN 1006 AD, a young remnant—is seen to have a radial magnetic field, and G296·5+10·0—PKS 1209−51/52, an old remnant—is one of the few with a very clear tangential field. Both of these objects are located well off the galactic plane where the gas density is low and uniform, and they exhibit an extremely symmetrical and somewhat similar shell structure (see Kesteven 1987; present issue p. 815).

For the majority of old remnants the field is rather poorly defined; for example, G84·2−0·8 in which Mathews and Shaver (1980) observed an alignment between the magnetic field and a filament, and G89·0+4·7 (HB 21) for which Kundu *et al.* (1973) have demonstrated, first, a high depolarisation due to steep gradients in the rotation measure across the beam and, second, a high rotation measure where the optical nebulosity is brightest. Similar effects were noted by Baker *et al.* (1973) for G189·1+2·9 (IC 443), which shows strong depolarisation associated with the bright optical features, and for the Crab Nebula, in which depolarisation is caused chiefly by bright filaments on the near side of the nebula (Swinbank 1980; Velusamy 1985).

Attempts to fit the rotation and depolarisation to Burn's (1966) model have generally been inconclusive owing to the small number of frequencies where data are available. However, from their data Velusamy and Kundu (1975) have suggested that G21·8−0·6 (Kes 69), G34·6−0·5 (W44) and G189·1+2·9 (IC 443) possess large internal Faraday rotation and that G120·1+1·4 (Tycho's SNR) and G130·7+3·1 (3C 58) have very small internal rotation. Milne (1980) showed that Vela X has very little internal Faraday rotation and that the depolarisation is due to gradients in rotation measure across the beam.

Maps of the distribution of rotation measure and depolarisation in 20 SNRs were published by Dickel and Milne (1976), but no relationship was found between these and the total intensity distribution. Suggestions that the SNR magnetic field or the gradient of RM is aligned with the galactic magnetic field are not supported by their study.

2. Magnetic Field Maps

It has been possible to derive fairly reliable directions for the projected magnetic field in 27 of the 70 or so remnants for which radio polarisation maps are available. They are listed in Table 1 and maps of the projected field are given in Fig. 3 and discussed below. In each of these figures all of the available maps of magnetic field have been considered in order to construct the field lines shown and these are superimposed generally on the highest resolution total intensity maps available. The field lines are consequently at a lower resolution than the total intensity contours and this explains why the magnetic fields are shown extending beyond the outer contours in many figures.

References to the magnetic field maps used are given in the discussion below and the references to the total intensity maps are given in Table 1. In this table we also quote values for the 1 GHz surface brightness from Milne (1979), together with our impressions of the form of the remnant in total intensity and the overall direction of the magnetic fields.

In the following discussion, and in Table 1, the ages for the remnants, where the supernova event was not recorded, were obtained from Caswell and Lerche (1979) using data from Milne (1979).

(*a*) G5·4−1·0 was suggested by Becker and Helfand (1985) as a member of a new, bizarre class of SNR, but more recently Caswell *et al.* (1987) discovered a faint arc to the east which suggests that it is in fact a normal shell remnant. Milne and Dickel (1971) found polarisation extending well beyond the brighter parts of the source, including the Caswell *et al.* eastern arc, but certainly strongest on G5·4−1·0. It is interesting to note that this early survey compares well with Becker and Helfand

Table 1. SNRs with observed projected magnetic field directions

Fig. No.	Remnant		Surface brightness[A]	Age (yr)	Structural form	Magnetic field direction	Ref. to total intensity map[C]
3(*a*)	G5·4−1·0		23	2500	Shell	Radial in northern arc	4
3(*b*)	G6·4−0·1	W28	20	6000	Shell	Tangential	1
3(*c*)	G7·7−3·7	PKS 1814−24	4	2000	Shell	Across shell	14
3(*d*)	G18·8+0·3	Kes 67	20	4000	Shell	Radial	5
3(*e*)	G21·5−0·9		980	500	Filled plus shell (?)	Radial	2
3(*f*)	G21·8−0·6	Kes 69	20	4000	Shell	?	19
3(*g*)	G34·6−0·5	W44	47	2500	Shell	Radial (?)	5
3(*h*)	G74·0−8·6	Cygnus Loop	1	12000	Shell plus blow-out (?)	Tangential in blow-out	9
3(*i*)	G89·0+4·7	HB 21	3	7000	Shell	?	8
3(*j*)	G93·3+6·9	DA 530	2	1500	Shell	Tangential	10
3(*k*)	G111·7−2·1	Cas A	29000	300	Shell	Radial	18
3(*l*)	G120·1+1·4	Tycho's SNR	140	414[B]	Shell	Radial	6
3(*m*)	G127·1+0·5		2	18000	Shell	Tangential	15
3(*n*)	G130·7+3·1	3C 58	260	805[B]	Filled	Longitudinal	21
3(*o*)	G184·6−5·8	Crab Nebula	12000	932[B]	Filled	Radial on periphery	20
3(*p*)	G189·1+2·9	IC 443	15	2500	Shell	Radial	7
3(*q*)	G260·4−3·4	Puppis A	9	3000?	Shell	Radial	13
2	G263·9−3·0	Vela SNR	4	11000	Shell	?	—

Table 1. *(Continued)*

Fig. No.	Remnant		Surface bright-ness[A]	Age (yr)	Structural form	Magnetic field direction	Ref. to total intensity map[C]
3(*r*)	G291·0−0·1	MSH 11−62	30	4000	Filled plus faint shell	Directed along central bar	17
3(*s*)	G296·5+10·0	PKS 1209−51	1	5000	Shell	Tangential	13
3(*t*)	G315·4−2·3	RCW 86	5	1800[B]	Shell	Radial	13
3(*u*)	G316·3−0·0	MSH 14−57	13	700	Shell plus blow-out (?)	Radial in shell, tangential in blow-out	13
3(*v*)	G320·4−1·2	MSH 15−52	14	1600?	Shell	Radial	11
3(*w*)	G326·3−1·8	MSH 15−56	17	3000	Faint shell, plus bright region	?	12
3(*x*)	G327·6+14·0	SN 1006 AD	3	980[B]	Shell	Radial	3
3(*y*)	G327·4+0·4	Kes 27	10	6000	Shell(s)	?	13
3(*z*)	G332·4+0·1	Kes 32	22	5000	Shell plus blow-out (?) plus jet	Tangential	16

[A] Units of $10^{-21}\,W\,m^{-2}\,Hz^{-1}\,sr^{-1}$.
[B] Age obtained from observation of SN outburst.
[C] 1, Altenhoff *et al.* (1978); 2, Becker and Szymkowiak (1981); 3, Caswell *et al.* (1983); 4, Caswell *et al.* (1987); 5, Clark *et al.* (1975); 6, Duin and Strom (1975); 7, Duin and Van der Laan (1975); 8, Hill (1974); 9, Keen *et al.* (1973); 10, Lalitha *et al.* (1984); 11, Manchester and Durdin (1983); 12, Milne *et al.* (1979); 13, Milne *et al.* (1985); 14, Milne *et al.* (1986); 15, Pauls *et al.* (1982); 16, Roger *et al.* (1985); 17, Roger *et al.* (1986); 18, Rosenberg (1970); 19, Shaver and Goss (1970); 20, Velusamy (1985); 21, Wilson and Weiler (1976).

over the limited region of their survey, in spite of their very much higher resolution. The magnetic field directions shown in Fig. 1 (after Dickel and Milne 1976) perhaps suggest a field that is at least radial over the north-western part of the shell. The remnant is about 2000 years old.

(*b*) G6·4−0·1 (W28) is usually classified as an old remnant (~6000 years). The magnetic field, from Dickel and Milne (1976) and Kundu and Velusamy (1972), is rather contorted but appears to follow tangentially around the shell. Note that it also flows around the 'hole' in the centre north of the shell.

(*c*) G7·7−3·7 (PKS 1814−24) is a shell remnant possibly superimposed on an extragalactic double source (Milne *et al.* 1986) and with strong polarisation projecting well beyond the remnant, but, similar to G5·4−1·0 and G327·4+0·4 (Kes 27), it is much more intense on the source. The deduced magnetic field (Dickel and Milne 1976; Milne *et al.* 1986) sweeps across the shell east to west converging near the south–west corner. It is not possible to describe the field as either radial or tangential.

(*d*) G18·8+0·3 (Kes 67). The Dickel and Milne (1976) data for Kes 67 are not of very high quality, but do suggest the radial field shown in Fig. 3*d*.

(*e*) G21·5−0·9 is of high surface brightness and therefore young, perhaps only a few hundred years old. It has been classified as a 'plerion' by Weiler (1983), but the VLA map of Becker and Szymkowiak (1981) shows a wisp of shell-like structure in the higher level contours. Furthermore, these authors suggested that there is very little Faraday rotation, and consequently their 5 GHz polarisation map indicates a radial magnetic field.

(*f*) G21·8−0·6 (Kes 69). The magnetic field directions are uncertain but are mainly radial in the brightest part of the shell. However, a higher resolution total intensity map and polarisation vectors at a third frequency are needed to understand this remnant (Fig. 3*f* is drawn from Kundu *et al.* 1974 and Dickel and Milne 1976).

(*g*) G34·6−0·5 (W44). The magnetic field (Kundu and Velusamy 1972; Dickel and Milne 1976) sweeps across the shell and could be considered to be mainly radial around its periphery.

(*h*) G74·0−8·6. The Cygnus Loop is a very old remnant, ~12 000 years. It appears to have a spherical shell to the north, well defined in radio, optical and X-ray emission and a 'tail' feature to the south seen only in radio emission. The Cygnus Loop is only weakly polarised and only in the tail. The magnetic field directions (after Kundu and Becker 1972 and Moffat 1971) suggest that the field is drawn out into the tail by a blow-out in that direction.

(*i*) G89·0+4·7 (HB 21). The map from Kundu *et al.* (1973) shows a fairly mixed-up magnetic structure. If there is any order then HB 21 has a field sweeping across the remnant north–east to south–west.

(*j*) G93·3+6·9 (DA 530). Despite the young age of ~1500 years, the magnetic field (Lalitha *et al.* 1984; Haslam *et al.* 1980) is clearly tangential in the two bright arcs of this remnant.

(*k*) G111·7−2·1 (Cas A). This is the first SNR for which a radio polarisation map was made (Mayer and Hollinger 1968). Fig. 3*k* is from Mayer and Hollinger (1968), Rosenberg (1970) and Flett and Henderson (1979). Cas A is thought to be the youngest known remnant with an age of only ~300 years.

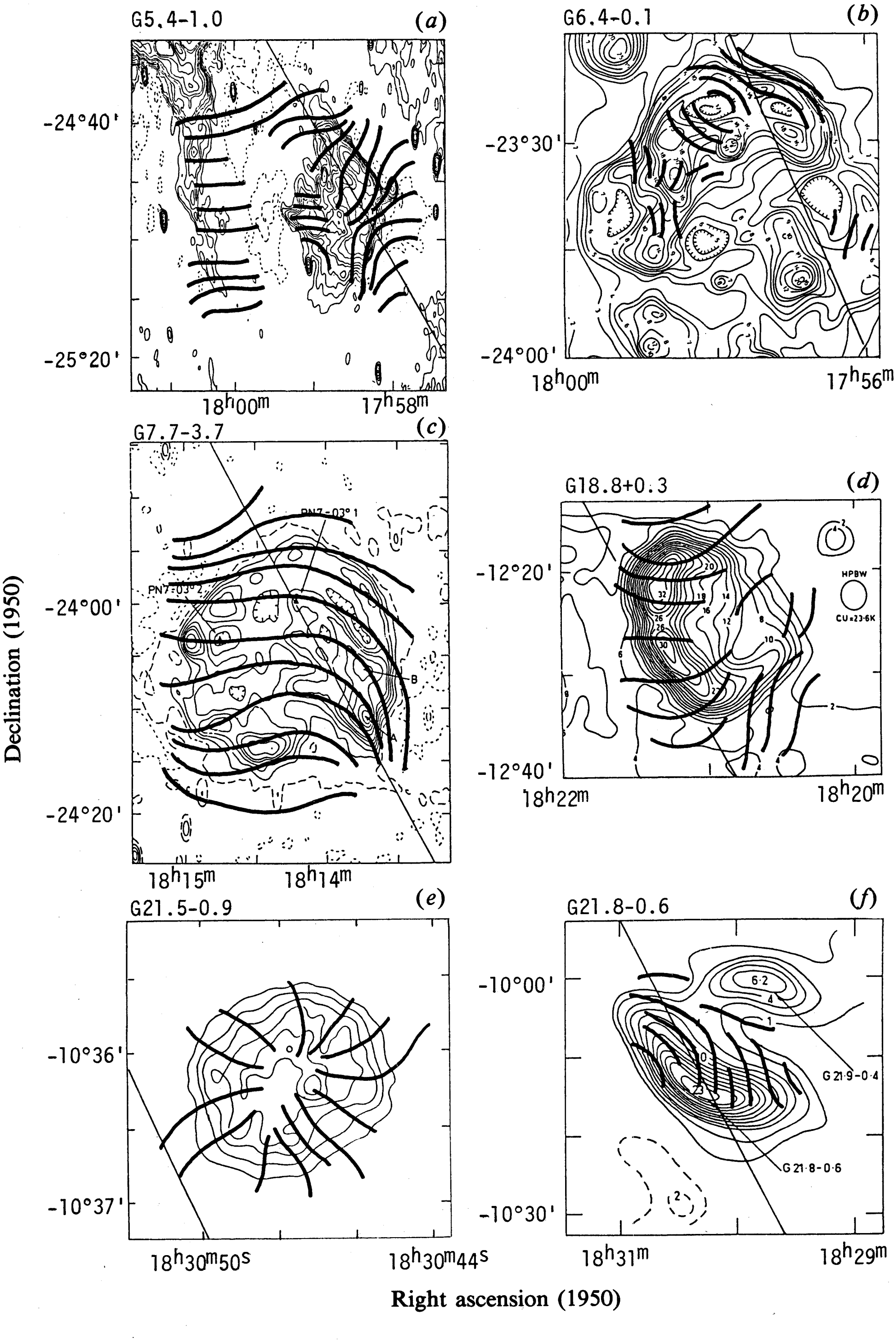
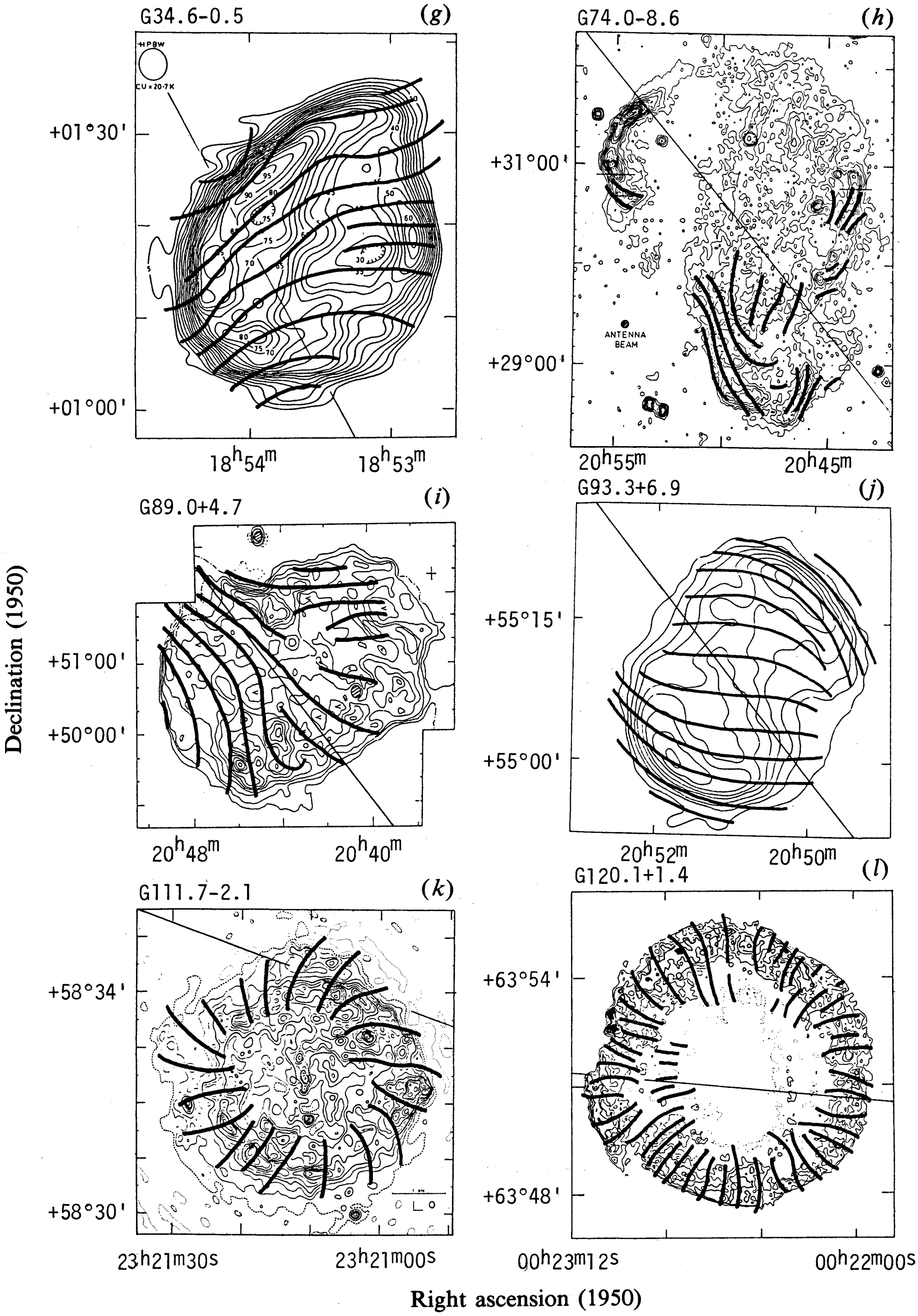
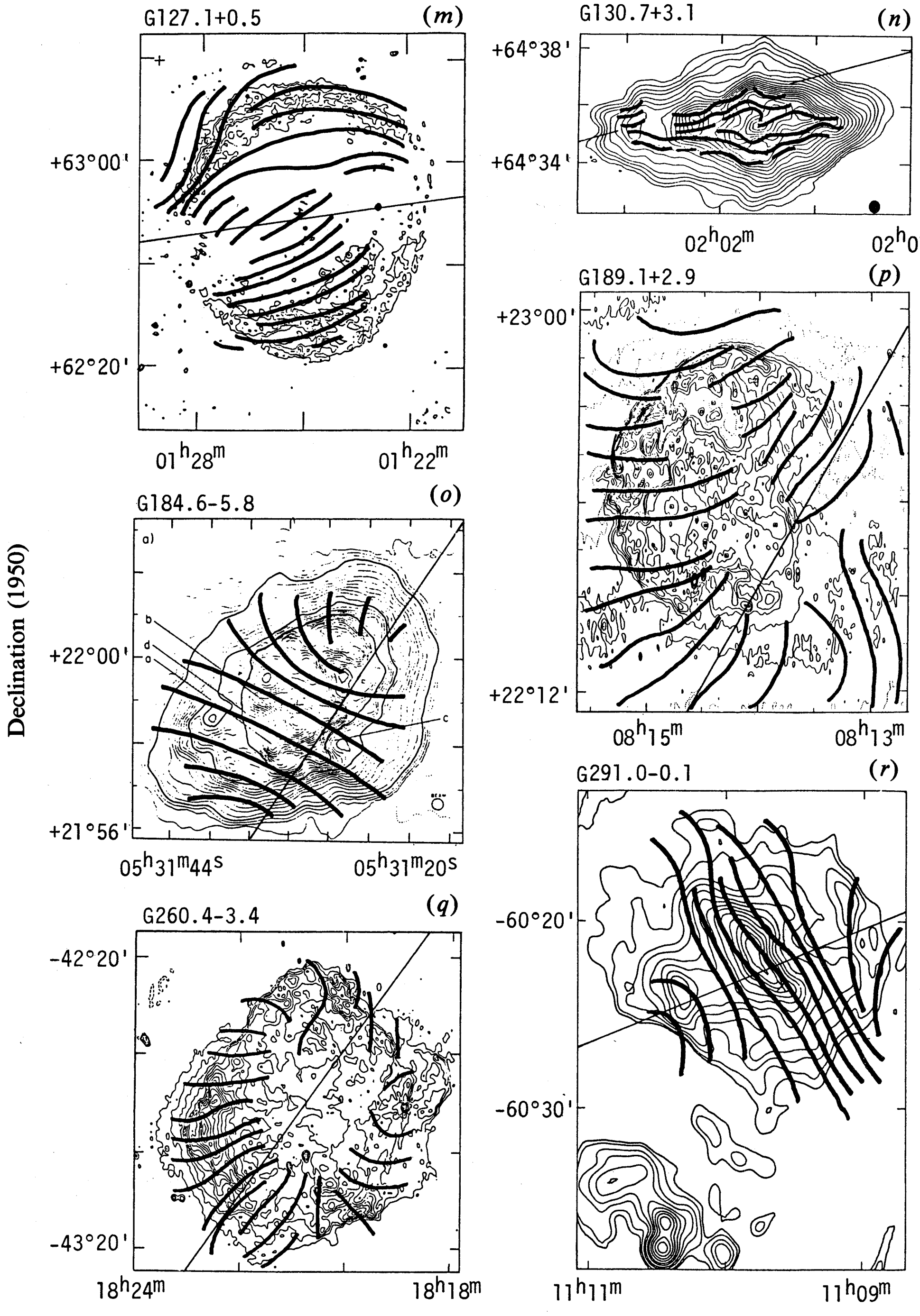


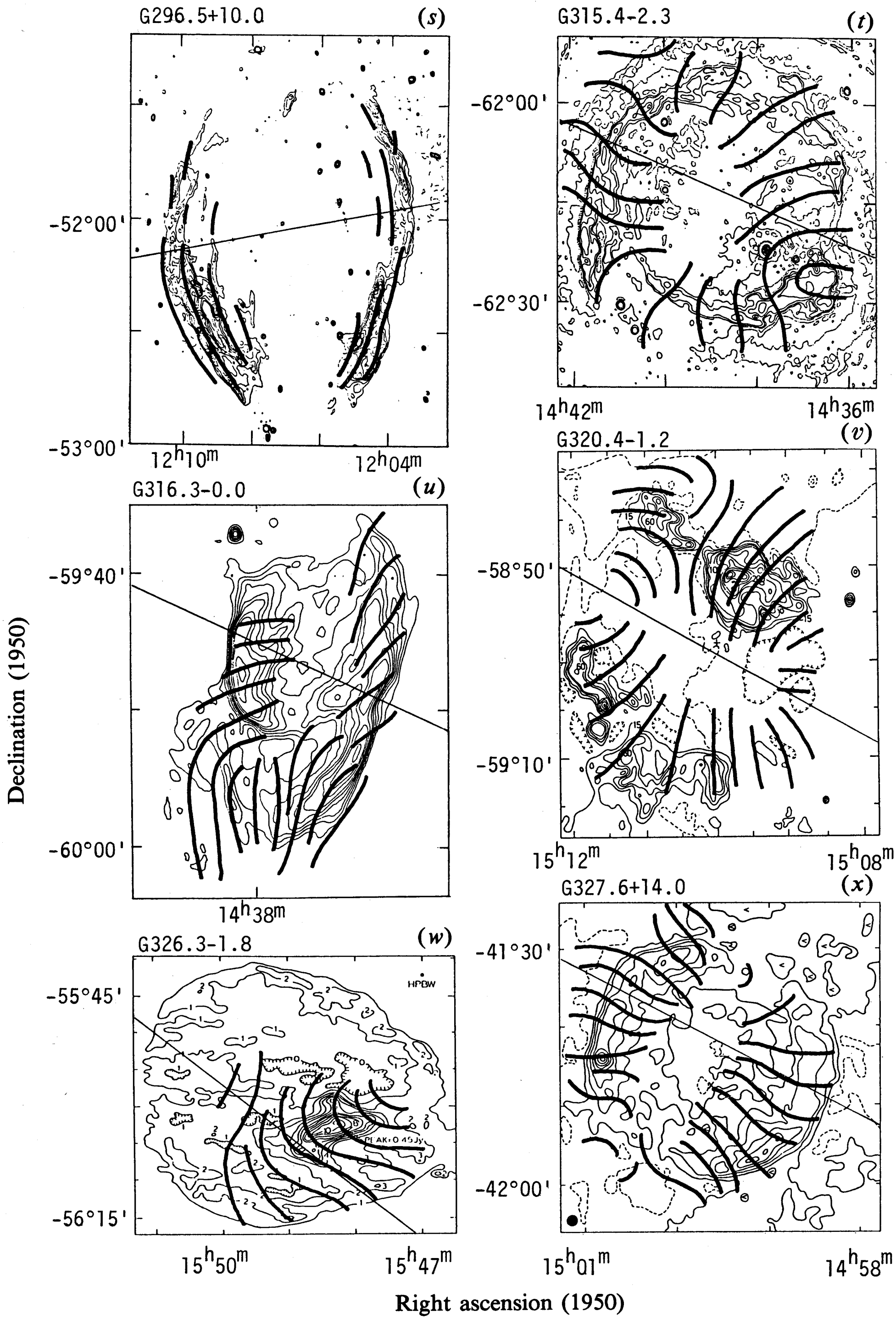
Fig. 3. Directions for the projected magnetic field in 26 of the SNRs listed in Table 1 (the Vela SNR G263·9−3·0 is shown separately in Fig. 2). References to the total-intensity maps are given in Table 1 and each figure is discussed in Section 2.


G34.6-0.5
(g)
HPBW
CU=20.7K
+01°30'
+01°00'
18h54m
18h53m
G74.0-8.6
(h)
+31°00'
+29°00'
ANTENNA BEAM
20h55m
20h45m
G89.0+4.7
(i)
+51°00'
+50°00'
20h48m
20h40m
G93.3+6.9
(j)
+55°15'
+55°00'
20h52m
20h50m
G111.7-2.1
(k)
+58°34'
+58°30'
23h21m30s
23h21m00s
G120.1+1.4
(l)
+63°54'
+63°48'
00h23m12s
00h22m00s
Declination (1950)
Right ascension (1950)

Figs 3*g*-3*l*

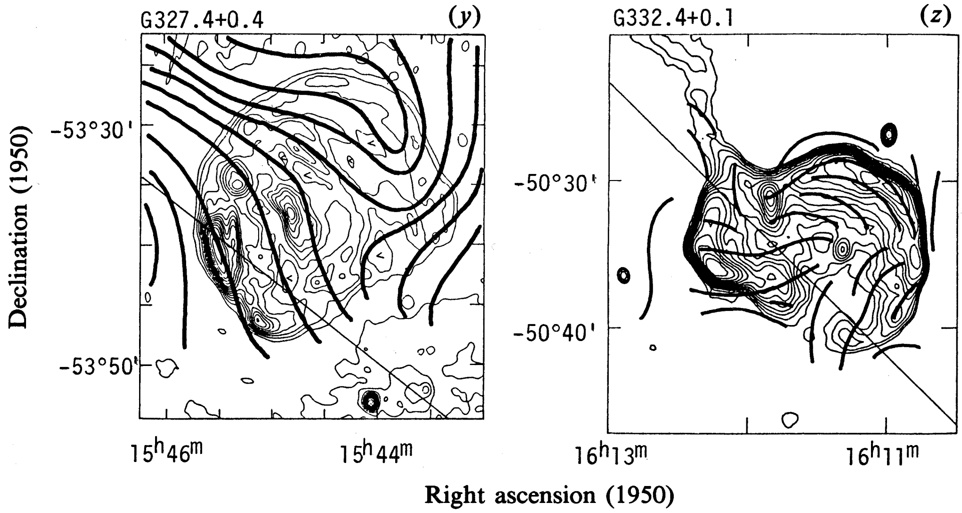

G127.1+0.5
(m)
+63°00'
+62°20'
01h28m
01h22m
G130.7+3.1
(n)
+64°38'
+64°34'
02h02m
02h01m
G189.1+2.9
(p)
+23°00'
+22°12'
08h15m
08h13m
G184.6-5.8
(o)
+22°00'
+21°56'
05h31m44s
05h31m20s
G291.0-0.1
(r)
-60°20'
-60°30'
11h11m
11h09m
G260.4-3.4
(q)
-42°20'
-43°20'
18h24m
18h18m
Declination (1950)
Right ascension (1950)

Figs 3*m*-3*r*



G296.5+10.0
(s)
-52°00'
-53°00'
12h10m
12h04m
G315.4-2.3
(t)
-62°00'
-62°30'
14h42m
14h36m
G316.3-0.0
(u)
-59°40'
-60°00'
14h38m
G320.4-1.2
(v)
-58°50'
-59°10'
15h12m
15h08m
G326.3-1.8
(w)
HPBW
PEAK=0.45Jy
-55°45'
-56°15'
15h50m
15h47m
G327.6+14.0
(x)
-41°30'
-42°00'
15h01m
14h58m
Declination (1950)
Right ascension (1950)

Figs 3*s*-3*x*



Figs 3*y* & 3*z*

(*l*) G120·1+1·4. Tycho's SN (3C 10), the supernova of 1572, clearly has a radial magnetic field (Duin and Strom 1975), although at the highest resolutions this tends to be lost in the increased detail (J. R. Dickel, personal communication).

(*m*) G127·1+0·5. This old shell source is centred on a bright, unassociated compact source which has been removed from the contours shown here. The magnetic field (Furst *et al.* 1984) is tangential in both arcs of the shell.

(*n*) G130·7+3·1 (3C 58), suggested as the AD 1181 supernova and therefore just 805 years old, has an elongated filled structure, and the magnetic field (Wilson and Weiler 1976) runs parallel to the major axis with some divergence around the central bright region.

(*o*) G184·6−5·8. The Crab Nebula, SN1054, is less than 1000 years old and powered by a pulsar. Velusamy (1985) argued that there is just 90° rotation between 20 cm and zero wavelength and that his 20 cm VLA *E* vector map (our Fig. 1) therefore shows the magnetic field directions, at least around the edges, where the internal Faraday rotation is expected to be small. Indeed comparison with the higher frequency maps at 22 GHz (Wright and Forster 1980) and at 5 GHz (Wilson 1972) indicates that this may also be fairly true for the central region. Unfortunately, these latter two maps and the optical polarisation map (Woltjer 1957) do not have sufficient sensitivity to make any comparisons outside of the central region (i.e. outside of the middle contour in Fig. 1); we accept Velusamy's (1985) 1·4 GHz map as a fairly good representation of the direction of the projected magnetic field in the Crab Nebula. The low-resolution magnetic fields (Fig. 3*o*) from Mayer and Hollinger (1968) and from Weiler and Seielstad (1972) certainly suggest that around the edges the field is radial.

(*p*) G189·1+2·9 (IC 443). The magnetic fields derived by Kundu and Velusamy (1972) and by Dickel and Milne (1976) sweep predominantly north–west to south–east across the shell with some divergence in the north and south; the net effect is a radial field.

(*q*) G260·4−3·4 (Puppis A). Although this remnant has a calculated age of 3000 years, it has been suggested by Dopita *et al.* (1977) that the optical spectra exhibit evidence of SN ejecta and hence this SNR is relatively young, perhaps only half this age. The magnetic fields from Dickel and Milne (1976) are radial.

G263·9−3·0 (not included in Fig. 3 but see Fig. 2). The Vela SNR contains a pulsar and is aged ~11 000 years. The polarisation is concentrated in the south-western bright feature, Vela X (Milne 1968, 1980), where the magnetic field loops around as though about to blow out in this direction.

(*r*) G291·0−0·1 (MSH 11−62). This centrally filled remnant is seen as an extended source of X rays and also contains a point X-ray source. The magnetic field (Roger *et al.* 1986) is directed along the central bar of the source. The structure of the source is not unlike Kes 69 (G21·8−0·6) (see Fig. 3*f*) if we omit the structure to the north–west.

(*s*) G296·5+10·0 (PKS 1209−51/52). Two symmetrical arcs form an open-ended shell [or barrel—see Kesteven (1987, present issue p. 815)]. The magnetic fields (Dickel and Milne 1976) are directed tangentially along these arcs.

(*t*) G315·4−2·3 (MSH 14−63) is thought to be the supernova of AD 185; a radial field is suggested from Dickel and Milne (1976).

(*u*) G316·3−0·0 (RCW 86). The 843 MHz Molonglo map (Milne *et al.* 1985) shows a remnant rather like the Cygnus Loop, with a spherical shell to the north and a possible blow-out to the south. The magnetic field directions, reproduced here from preliminary Parkes observations, show a radial field in the shell and a drawn-out field in the blow-out. It is a relatively old remnant, ~7000 years.

(*v*) G320·4−1·2 (MSH 15−52). A pulsar and two X-ray sources lie in the direction of this remnant. The pulsar characteristic age is 1690 years (Manchester *et al.* 1985). However, an age as young as this has been disputed by Van den Bergh and Kamper (1984) because of the small proper motions. The calculated age from the surface brightness is ~3000 years. It would appear that this remnant is relatively young; the magnetic fields from Dickel and Milne (1976) are radial.

(*w*) G326·3−1·8 (MSH 15−56). The image in Milne *et al.* (1985) suggests a low surface-brightness shell with a very bright feature embedded in it. This feature has a flat spectrum but is highly polarised. The polarisation is concentrated to the south–west and the magnetic field is directed radially (after Dickel and Milne 1976).

(*x*) G327·6+14·0 (SN 1006 AD). This SNR is 980 years old and with a radial magnetic field (Dickel and Milne 1976).

(*y*) G327·4+0·4 (Kes 27) appears to consist of a series of shells to the north–west as if there were a series of outbursts in this direction. The polarisation extends well beyond the remnant and in the 5 GHz map of Milne and Dickel (1975) extends northward, ending in a whorl in the position of a faint shell source in the MOST map (R. S. Roger, personal communication). The magnetic field direction is not clear in the Dickel and Milne (1976) map, but it appears to run from the north–east through Kes 27 and to then loop north.

(*z*) G332·4+0·1 (Kes 32) has been shown by Roger *et al.* (1985) to emit a jet and plume to the north–east. There is a suggestion in Fig. 3*z* (after Dickel and Milne 1976, and unpublished Parkes observations) that the magnetic fields are directed tangentially into a blow-out formed at the eastern end and possibly associated with the jet; the magnetic field is directed into this jet.

3. Discussion

It became apparent after examining all of the available polarisation maps that there is often a general field which is readily seen at low resolutions, but at higher resolution this may be concealed by additional detail. It appears on examination of the magnetic field maps that radial fields are more prevalent than tangential fields and that these are mainly in the young remnants. In fact all of the remnants for which we have a definite age (with the exception of G130·7+3·1—3C 58) have a projected field that is radial around the periphery.

We expect that these young objects would have the most ordered fields. First, they have not been broken up so much by interaction with the interstellar medium; second, a radial field in a spherical shell is seen as a radial field in any projection whereas, we imagine, a tangential field, whilst confined to a narrow shell around the remnant, has fairly random directions in that shell.

Since polarisation is seen only from directions normal to the field, the remnant with tangential fields should be bright in polarisation over the face of the remnant whereas only half of the field around the periphery would be observed (in contrast with the radial model). However, the depth of the emitting region is very small over the face of the remnant and so the net result is that we see fairly mixed-up polarisation which should be brighter around the edges. A detailed discussion of the polarisation from a thin slab of compressed random field has been given by Laing (1980). His conclusion that polarisation is seen only in directions lying within the slab and not from the direction normal to the surface is consistent with the above argument.

Because of the strong magnetic field component in the line of sight around the edges in this model we would also expect high peripheral rotation measure and depolarisation in these older remnants. In all, the polarisation will be of a much lower order and degree in the older remnants, perhaps leading to the bias towards objects with radial fields in this survey.

The other feature that emerges from this study is the possibility that a blow-out has occurred in some remnants—e.g. G74·0−8·6 (the Cygnus Loop), G316−0·0 (MSH 14−57), G332·4+0·1 (Kes 32) and possibly G327·4+0·4 (Kes 27)—and that a blow-out is perhaps imminent in one: G263·9−3·0, the Vela SNR.

Finally, whilst the total intensity maps indicate a slight tendency for the remnant to be brighter on the side closest to the galactic plane (Caswell 1977), there seems to be no preferred orientation of the magnetic field with respect to the galactic plane, although this may be expected if the field is formed from compression of the ambient galactic field.

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