FARADAY ROTATION OF THE EMISSION FROM LINEARLY POLARIZED RADIO SOURCES

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Summary

The variation of Faraday rotation with galactic coordinates is studied for 86 radio sources. It is concluded that most of the rotation takes place in our Galaxy. At low latitudes, $|b^{\mathrm{II}}| < 20°$, the distribution of rotation measure in galactic coordinates is consistent with a magnetic field directed towards $l^{\mathrm{II}} = 95° \pm 10°$, which is approximately along the local spiral arm. At intermediate latitudes, $20° < |b^{\mathrm{II}}| < 60°$, the field is directed towards $l^{\mathrm{II}} = 95°$ in southern latitudes but in the opposite direction towards $l^{\mathrm{II}} = 275°$ in northern latitudes. At high northern latitudes, $b^{\mathrm{II}} > 60°$, the field appears to be approximately parallel to the plane, but at southern latitudes $b^{\mathrm{II}} < -60°$ it has an inward component towards the plane.

An analysis of the scatter of rotation measure observed at high latitudes and in double sources indicates that the mean rotation measure arising in the sources themselves is less than 5 rad/m^2.

I. Introduction

Observations of linear polarization over a range of wavelengths have shown that for most radio sources the position angle of polarization is proportional to the square of the wavelength (Gardner and Whiteoak 1963). The constant of proportionality, the rotation measure (R.M.), is related to the parameters of the magneto-ionic medium between the source and the observer by the expression

$$\text{R.M.} = 8 \cdot 1 \times 10^5 \int N_{\mathrm{e}}\, B_{\mathrm{L}}\, \mathrm{d}L \quad \mathrm{rad/m^2},$$

where N_{e} is the electron density in cm^{-3}, B_{L} is the longitudinal component of the magnetic field in gauss, and $\mathrm{d}L$ is in parsecs. A positive value of the rotation measure denotes a magnetic field directed towards the observer.

The early measurements (Gardner and Whiteoak 1963) indicated that a significant amount of the Faraday rotation occurred in our Galaxy. Later measurements on a larger number of sources (Gardner 1964) showed that practically all the rotation took place there and that the rotation measure for sources with $|b^{\mathrm{II}}| > 60°$ was generally under 5 rad/m^2, compared with values around 100 near the plane. While it appeared possible from measurements of Faraday rotation to investigate the detailed structure of the galactic field, the network contained too few points, and no observations were available for the sky north of declination $+27°$. In the present paper, observations of a larger number of sources are described and the results combined with those from the northern hemisphere, principally from Morris and Berge (1964*a*, 1964*b*). The latter authors commented on the systematic variation of rotation measure with galactic longitude.

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TABLE 1

SOURCES WITH POLARIZATION AT THREE OR MORE WAVELENGTHS

Source: Parkes Number	Source: Other Designations	l^{II} (degrees)	b^{II} (degrees)	Rotation Measure (rad/m²)	Intrinsic Polarization Angle (degrees)	Wavelengths of Measurement (cm)
0043−42	00−*411*	306·6	−75·0	+2·6±0·4	136± 2	11, 20, 30, 50, 75
0054−01	3C 29(*b*)	126·4	−64·2	+2 ±1	156± 3	11, 20, 30, 50, 75
0106+13	3C 33	129·4	−49·3	−12·2±0·8	91± 2	11, 20, 30, 50, 75
0131−36	01−*311*(*a*)	261·9	−77·1	+5·4±0·6	105± 3	11, 20, 30, 50, 75
0213−13	3C 62(*a*)	181·4	−65·8	+12 ± 4	86±12	11, 20, 30, (18)
0235−19	02−*110*	201·3	−64·5	+9 ±2	168±15	11, 20, 30
0305+03	3C 78	174·8	−44·5	+9 ±3	93±10	11, 20, 30, 50
0307+16	3C 79	164·1	−34·4	−18 ±3	25± 8	11, 20, 50, 75
0319−37	Fornax A(*a*)	240·1	−56·9	−2·8±0·8	66± 3	11, 20, 30, 50, 75
0322−37	Fornax A(*b*)	240·2	−56·4	−3·5±0·8	112± 3	11, 20, 30, 50, 75
0356+10	3C 98	179·8	−31·1	+76 ±2	50± 6	11, 20, 30, 50, 75
0453−30	04−*314*(*a*)	231·6	−37·1	−2·9±0·7	100± 6	11, 20, 30, 50
0456−30	04−*314*(*b*)	231·8	−36·4	+3 ±2	123±15	11, 20, 30, 50
0518−45	Pictor A	251·6	−34·6	+46 ±1	104± 4	11, 20, 30, 50, 75
0518+16	3C 138	187·4	−11·3	−6 ±3	170± 4	11, 20, 30
0521−36	05−*36*	240·6	−32·7	+12 ±1	64± 5	11, 20, 30, 50, 75
0531+22	Taurus A	184·5	−5·8	−25 ±2	150± 2	11, 20, 30
0618−37		244·7	−21·9	0 ±1	69± 3	11, 20, 30
0624−05	3C 161	215·4	−08·1	+113 ±2	93± 5	11, 20, 30, 50
0634−20(*a*)	06−*210*(*a*)	229·9	−12·4	+48 ±3	74± 8	11, 20, 30, 50, 75
0634−20(*b*)	06−*210*(*b*)	230·0	−12·4	+48 ±3	119± 8	11, 20, 30, 50, 75
0637−75	06−*71*	286·4	−27·1	+22 ±2	01± 2	11, 20, 30, 50
0842−75	08−*71*	289·4	−19·9	+9 ±4	146±10	11, 20, 30
0945+07	3C 227	228·6	+42·3	−7 ±3	160± 6	11, 20, 30, 50, 75
1216+06	3C 270	281·8	+67·4	+8·4±0·6	94± 2	11, 20, 30, 50, 75
1222+13	M 84	278·2	+74·5	−5 ±3	149± 5	11, 20, 30
1226+02	3C 273	289·9	+64·4	−1·0±0·8	158± 3	11, 20, 30, 50, 75
1252−12	3C 278	304·1	+50·3	−10 ±2	11± 4	11, 20, (18)
1253−05	3C 279	305·1	+57·1	+16 ±2	101± 6	11, 20, 30, 50, 75
1322−42(*a*)	Centaurus A(*a*)	309·5	+19·4	−60 ±2	147± 3	11, 20, 30, 50, 75
1332−33	13−*33*(*a*)	313·4	+28·1	−32 ±1	119± 3	11, 20, 30
1333−33	13−*33*(*b*)	313·5	+28·0	−32 ±1	124± 2	11, 20, 30
1334−33	13−*33*(*c*)	313·7	+27·7	−33·5±1	119± 2	11, 20, 30
1343−60	13S6A	309·7	+1·8	+76 ±3	169± 6	11, 20, 30, 50
1502+26	3C 310	38·5	+60·2	0 ±7	30±12	11, 20, 30, (18)
1508−05	15−*05*					
1548−79		310·8	−19·8	+42 ±3	96± 6	11, 20, 30
1559+02	3C 327(*a*)	12·5	+37·8	+10 ±1·5	156± 5	11, 20, 30
1648+05	Hercules A	23·0	+28·9	+9 ±2	28± 3	11, 20, 30, 50
1717+00	3C 353	22·9	+20·6	+37 ±4	82± 8	11, 20, 30, 50
1949+02	3C 403	42·3	−12·3	−36 ±2	37± 6	11, 20, 30
2032−35	20−*37*	7·8	−35·6	0 ±0·8	97± 3	11, 20, 30, 50, 75
2104−25	21−*21*	21·4	−40·2	−6 ±4	28± 6	11, 20, 30, 50
2121+24	3C 433	74·4	−17·7	−80 ±4	166± 4	11, 20, 30, 50
2152−69	21−*64*	321·3	−40·6	+32 ±2	32± 3	11, 20, 30, 75
2211−17	3C 444	40·2	−52·4	−3 ±5	4±10	11, 20, 30, 50
2230+11	CTA 102	77·4	−38·6	−52 ±3	59± 6	11, 20, 30, 50
2314+03	3C 459	83·0	−51·3	−4 ±3		11, 30, 50
2356−61	23−*64*	314·0	−55·1	+22 ±2	7± 5	11, 20, 30, 50, 75

II. Measurements

The program of radio source polarization studies with the Parkes 210 ft radio telescope involved measurements of linear polarization on 160 sources, mostly taken between March and November 1963. Observations were made at 11·3, 21·3, and 31·3 cm wavelengths on most sources, and also at 29·7, 48·3, and 74·3 cm wavelengths on stronger sources. The details of the measurements, the reduction techniques, and the table of individual values of percentage polarization and position angle are to be published in a later paper (in preparation). Of the sources measured, 49 had sufficiently strong polarization at three or more wavelengths to obtain reliable estimates of position angle at these wavelengths. For each source, the observed position angle was plotted against (wavelength)^2 to derive the slope which gave the rotation measure. The position angle at each wavelength can be plotted in a number of different places (at intervals of π rad), and it is sometimes possible to draw different straight lines to fit the observations within the experimental errors. The 49 sources referred to above are free of such ambiguities.

Repeated measurements on most sources showed that the internal accuracy of the data was quite high. There was, however, some uncertainty in assessing the percentage polarization and position angle at the longer wavelength for some sources, owing to the variation in polarized background emission near these sources. This uncertainty is reflected in the larger errors assigned to rotation measure and the intrinsic position angles of these sources. For sources that have also been studied by the interferometry technique (Morris and Berge 1964*b*), where the errors are different in nature, the data agree within the stated errors.

Observations by other authors have been included, where they exist, to provide confirmatory data and to extend the data to other wavelengths when Parkes observations were limited. These are the results of Morris and Berge (1964*b*) at 21, 18, and 10 cm wavelengths with short baseline interferometers, of Bologna *et al.* (1965) at 21·2 cm with the Green Bank 300 ft dish, and of Haddock and Hobbs (1965, personal communication) at 3·75 cm with the Michigan 85 ft dish. Some preliminary 6 cm measurements at Parkes were also included.

The unambiguous values of rotation measure obtained from the Parkes polarization data are given in Table 1, which also includes the New Galactic Coordinates of each source as well as the intrinsic polarization angle which is the position angle of the electric vector at the point of origin of the radiation. Where an 18 cm value from the Caltech results has been used it is indicated in the column headed "wavelengths of measurement".

For a number of sources, reliable values of position angle are available only at 11·3 and 21·3 cm wavelengths, and, because of the ambiguity of $n\pi$ rad in position angle, a unique value of the rotation measure cannot be obtained for any of these sources. However, it is worthwhile to estimate several of the possible values. The ambiguity in rotation measure resulting from observations at 11·3 and 21·3 cm wavelength only is $96n$ rad/m^2. Table 2 lists these sources: two or three alternative rotation measure values within the overall range indicated by the sources of Table 1 are given, the values in italics being those closest to nearby Table 1 sources.

The sources 08−*219* and 3C 287 are also included in this list because, although position angles have been measured for them at three wavelengths, two possible values of rotation measure were found to be consistent with the data.

Table 1 contains one known galactic source, Taurus A, and one probably galactic, 13S6A. The sources 14−4*15* and 14−6*3* shown in Table 2 are also probably galactic.

TABLE 2

SOURCES WITH POLARIZATION AT TWO WAVELENGTHS

Source: Parkes Number	Source: Other Designations	l^{II} (degrees)	b^{II} (degrees)	Possible Values of Rotation Measure* (rad/m²)			Intrinsic Polarization Angle (degrees)	Wavelengths of Measurement (cm)
0035−02	3C 17	115·2	−64·8	−95	*+1*± *4*	+97	+1±10	11, 20
0038+09	3C 18	118·6	−52·7	−93	*+3*± *5*	+99	106±15	11, 20
0157−31	01−3*15*	231·1	−74·5	−83	*+13*± *5*	+109	64±12	11, 20
0511+00	3C 135	200·4	−21·1	−95	*+1*± *3*	+97	113±20	11, 20
0715−24	07−*24*	238·2	−5·9	−33	*+63*± *8*	+159	64±10	11, 20, 30
0806−10	3C 195	231·4	+12·0	−129	*−33*± *4*	+63	98±12	11, 20, 30
0859−25	08−*219*	251·8	+13·4		*−36*± *2* +71± 2		116± 6 24± 6	11, 20, 30
1017−42	10S4A	275·6	+11·8	−140	*−44*± *6*	+52	128±12	11, 20
1151−34	11−3*14*	289·9	+26·3	−109	*−13*± *5*	+83	173±10	11, 20
1215−45	12−4*3*	296·9	+16·5	−118	*−22*± *4*	+74	30±12	11, 20
1323−61		307·1	+1·2	−14	*+87*± *5*	+178	88± 4	11, 20, 30
1328+25	3C 287	22·5	+81		−49±10 +140±15		149±12 10±20	11, 20, 30, (18)
1335−06	13−0*11*	323·2	+54·6	−108	*+12*± *4*	+84	156±10	11, 20, 30
1459−41	14−4*15*	327·4	+14·5	−104	*−8*± *5*	+88	158± 8	11, 20
1508−05	15−0*5*	353·9	+42·9	−121	*−25*± *5*	+71	75± 6	11, 20
1602−09	16−0*1*	1·9	+30·4	−104	*−8*± *3*	+88	28± 3	11, 20
1954−55	19−5*7*	342·8	−31·4	−106	*−10*± *4*	+86	133± 8	
2045+06	3C 424	53·7	−22	−149	*−53*± *5*	+43	77±15	11, 20
2058−28	20−21*5*	17·8	−39·6	−97	*−1*± *3*	+95	66±10	11, 20
2140−43	21−4*7*	357·2	−49·0	−92	*+4*± *3*	+100	92± 5	11, 20
2212+13	3C 442	75·1	−34·1	−149	*+53*± *7*	+43	179±15	11, 20
2221−02	3C 445	61·8	−46·7	−90	*+6*± *7*	+102	115± 4	11, 20
2250−41	22−4*6*	355·6	−62·0	−81	*+15*± *3*	+111	62± 5	11, 20

* Values in italics are those closest to nearby Table 1 sources.

The italicized values of rotation measure given in Table 2 were always within 20 rad/m² of the values expected for the galactic coordinates of the source found by interpolating between sources with unambiguous rotation measures. Since the ambiguity in rotation measure is 96 rad/m² in all cases except 08−2*19* and 3C 287, where it is 107 and 189 respectively, the italicized values are very likely to be the correct alternatives. The corresponding values of intrinsic polarization angle are listed in Table 2.

The estimates of rotation measure for sources studied by other authors are given in Table 3. Only those sources that showed significant polarization at three or more wavelengths have been included. The values of rotation measure and intrinsic position angle are those given by the authors where the sources have been measured at only one observatory; otherwise, estimates of rotation measure and intrinsic position angle were made from the combined data of the various authors. The sources 3C 446 and 3C 454·3 were observed only at 11·3 cm at Parkes and are included here because most of the data have come from other observatories.

III. Discussion of Results

(a) *Linearity of the Rotation Measure Plots*

The linearity of the plots of position angle against (wavelength)^2 can be examined over nearly a decade in wavelength for a number of the sources. Some of the sources that showed appreciable polarization over a wide wavelength range were 3C 33,

Table 3

SOURCES MEASURED BY OTHER OBSERVERS

Source	l^{II} (degrees)	b^{II} (degrees)	Rotation Measure (rad/m^2)	Intrinsic Polarization Angle (degrees)	Wavelengths of Measurement (cm)	Observers†
3C 27	123	+6	-91 ± 8	2 ± 8	10, 18, 21	CIT
3C 48	134	−28	-42 ± 15	100 ± 10	3, 10, 18,* 20*	CIT, M
3C 86	144	−1	-400 ± 15	100 ± 10	10, 18, 21	CIT
3C 111	162	−9	-19 ± 4	141 ± 10	3, 10, 18, 20	CIT, M, GB
3C 219	174	+45	-10 ± 8	140 ± 10	10, 18, 21	CIT
3C 286	57	+81	0 ± 2	32 ± 4	3, 10, 18, 21	CIT, M, GB
3C 330	99	+41	$+30\pm 4$	90 ± 10	10, 18, 21	CIT, GB
3C 345	64	+41	$+21\pm 3$	43 ± 6	10, 18, 21	CIT, GB
3C 380	77	+24	$+29\pm 5$	172 ± 25	3, 10, 18, 21	CIT, M, GB
Cygnus A	76	+6	−750	30	3, 5, 9	NRL
3C 410	70	−4	-216 ± 20	177 ± 10	10, 18, 21	CIT, GB
3C 430	100	+8	-162 ± 15	139 ± 20	10, 18, 21	CIT
3C 446	59	−49	-27 ± 2	5 ± 8	10, 11, 18, 21	CIT, GB, Parkes
3C 454·3	86	−39	-50 ± 4	13 ± 6	10, 18, 21	CIT, Parkes

* Weak polarization at two lowest frequencies.

† CIT = Caltech; M = Michigan; GB = Green Bank–NRL; NRL = Hollinger, Mayer, and Mennella (1964).

Fornax A components (*a*) and (*b*), 05—36, 3C 270, 3C 273, Hercules A, 3C 353, and 23—64. The observed position angles with the estimated errors at each wavelength are plotted for each of these sources in Figure 1. The position angle is proportional to (wavelength)^2 except for 3C 353, where there are systematic departures from linearity, and for Hercules A where the relationship is distinctly curved. This curvature accompanies a rapid fall in the percentage polarization from 5·1% at 2650 Mc/s to 1·0% at 1410 Mc/s. For Cygnus A (beyond the declination limit of the Parkes telescope), Hollinger, Mayer, and Mennella (1964) have found more extreme departures from linearity. It should be noted that the characteristics of the sources listed in

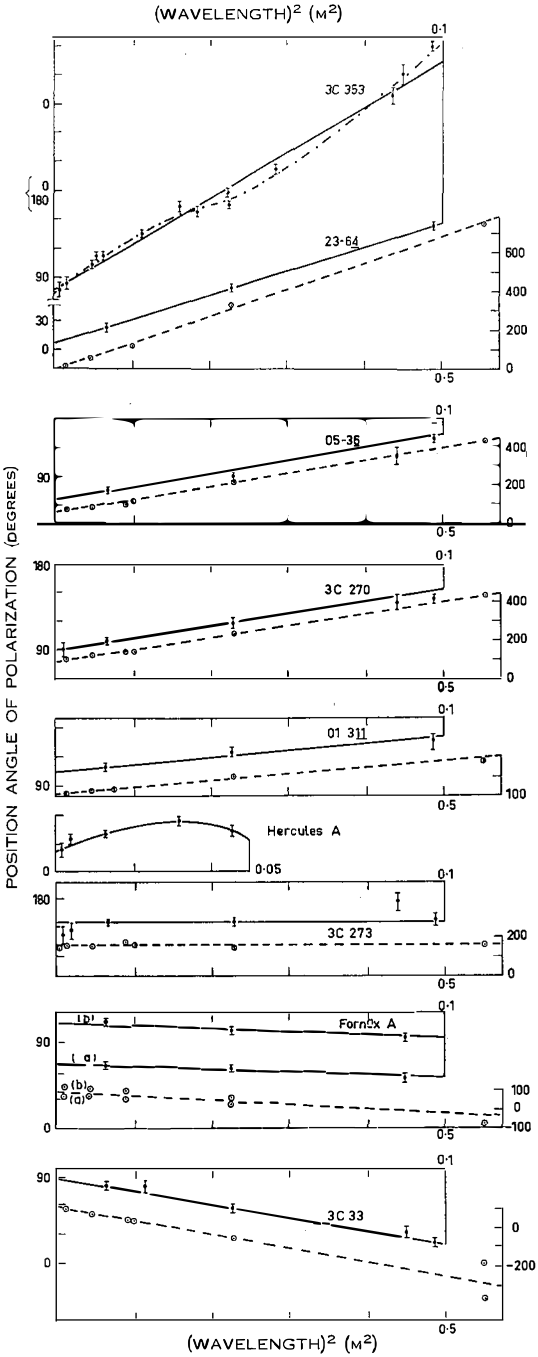

Fig. 1.—Plots of position angle of the electric vector against (wavelength)² for polarized sources observed over a wide range of wavelengths. Two scales are used, differing by a factor of 5 : 1 in both ordinate and abscissa values. The lines of best fit are parallel in the two scales if the rotation measure is constant.

Table 2 differ from those in Table 1 in that an appreciable number have a low percentage polarization at 20 cm (the polarization is below the limits of measurement at 30 cm), and for a number of these the position-angle–(wavelength)^2 relationship might not be linear.

(b) *The Distribution of Rotation Measure in Galactic Coordinates*

The values of rotation measure given in Tables 1, 2, and 3 have been plotted in Figure 2 on a galactic coordinate grid. The italicized values of rotation measure taken from Table 2 have been included with distinctive symbols.

The *separation* of regions of positive and negative rotation measure is clearly evident. A zero rotation measure contour has been interpolated between the observed values to show this separation. The variation of rotation measure with angle is so smooth that it seemed justifiable to represent this variation by a series of contour lines at ± 20, ± 40, ± 80, and ± 160 rad/m^2, derived by linear interpolation between observed values. However, in certain regions, particularly that near $l^{\mathrm{II}} = 180°$, $b^{\mathrm{II}} = -30°$, the low source density leads to a reduced contour accuracy.

A major feature of the rotation measure distribution is the cyclical variation of the large values of rotation measure along the galactic plane. In the sector $200° < l^{\mathrm{II}} < 330°$ the rotation measures are positive; elsewhere they are negative. The best fitting sinusoid to the longitudinal variation observed has a maximum at $275° \pm 10°$. This corresponds to a magnetic field in the plane of the Galaxy directed towards $l^{\mathrm{II}} = 95° \pm 10°$. Since this is so near the direction of the local spiral arm, it seems reasonable to infer that this is the local spiral arm field. However, the values of rotation measure are considerably greater in the negative sector than in the positive. The simplest interpretation of this is that the average electron density is greater in the direction $l^{\mathrm{II}} \sim 90°$ than in the reverse direction $l^{\mathrm{II}} \sim 270°$; alternatively, the magnetic field might diverge in the 270° direction.

The intermediate latitude (20°–60°) distribution of rotation measure shows one significant difference from the low latitude distribution in that, although the sense of the rotation measure at southern latitudes is much the same as in the plane, the sense in northern latitudes is opposite. The reversal of sign of the rotation measure occurs at $b^{\mathrm{II}} \sim +20°$ in the longitude range $60° < l^{\mathrm{II}} < 140°$ and at $b^{\mathrm{II}} \sim +8°$ in the longitude range $210° < l^{\mathrm{II}} < 320°$. The observed pattern might be caused by some local anomaly in which the fields on the upper and lower edges of the spiral arm are oppositely directed. The orientation of this field is within about 20° of the general spiral arm field which predominates at $|b^{\mathrm{II}}| < 10°$.

At high northern galactic latitudes ($b^{\mathrm{II}} > +60°$) the mean rotation measure is $+1 \cdot 8 \pm 3 \cdot 5$ rad/m^2, indicating that the magnetic field is parallel to the plane here, on the likely assumption that the electron density is not negligible in these regions. The anomalously high value of rotation measure in 3C 287 (see next section) has not been taken into account for the assessment, since it does not seem typical of the other sources near the northern galactic pole. At high southern galactic latitudes ($b^{\mathrm{II}} < -60°$) the mean rotation measure is $+7 \cdot 5 \pm 3 \cdot 5$ rad/m^2, indicating a dominant component of magnetic field directed inwards from the southern galactic pole.

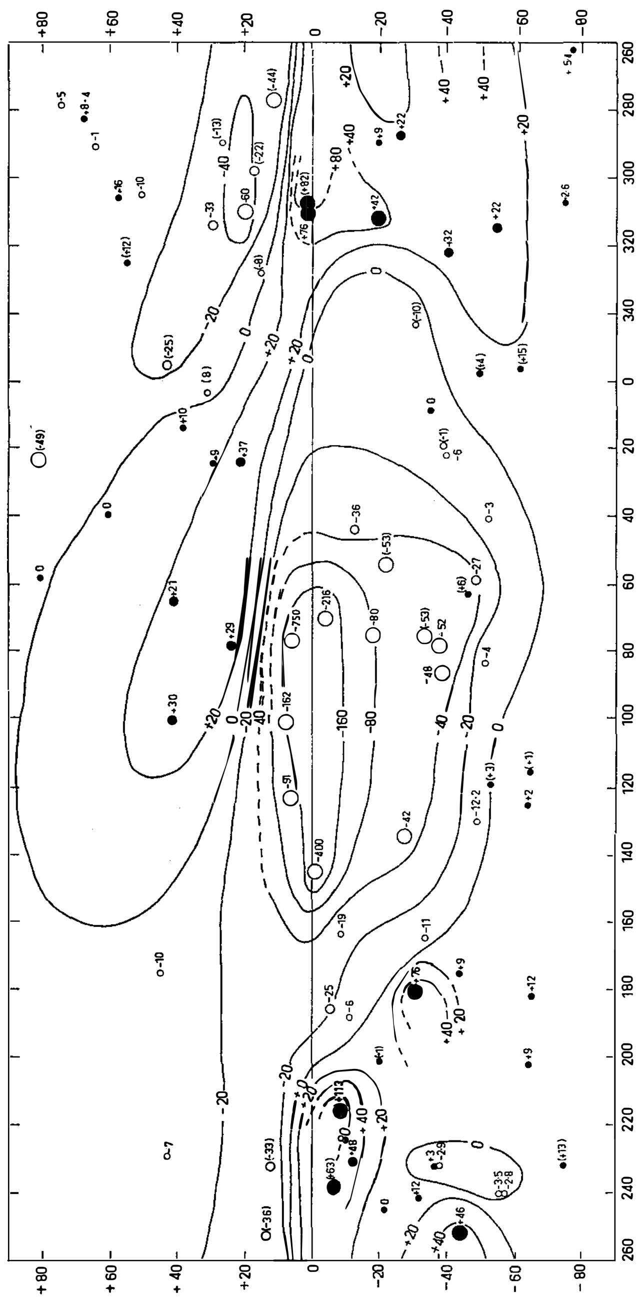

Fig. 2.—The distribution of rotation measure in galactic coordinates. The values of rotation measure are shown alongside the points and are bracketed for sources listed in Table 2. Contour lines of constant rotation measure have been interpolated between the observed values. ○ $|R.M.| \geqslant 40$; ○ $20 \leqslant |R.M.| \leqslant 40$; ∘ $|R.M.| \leqslant 20$. (● positive R.M.; ○ negative R.M.)

The variation of rotation measure with galactic latitude is summarized for northern and southern latitudes separately in Figure 3. A large scatter at intermediate and lower latitudes is evident, including many low values of rotation measure (< 20 rad/m^2) at latitudes lower than 20°. This is the result of the longitude variation at each latitude discussed previously. The values of high rotation measure (> 50 rad/m^2)

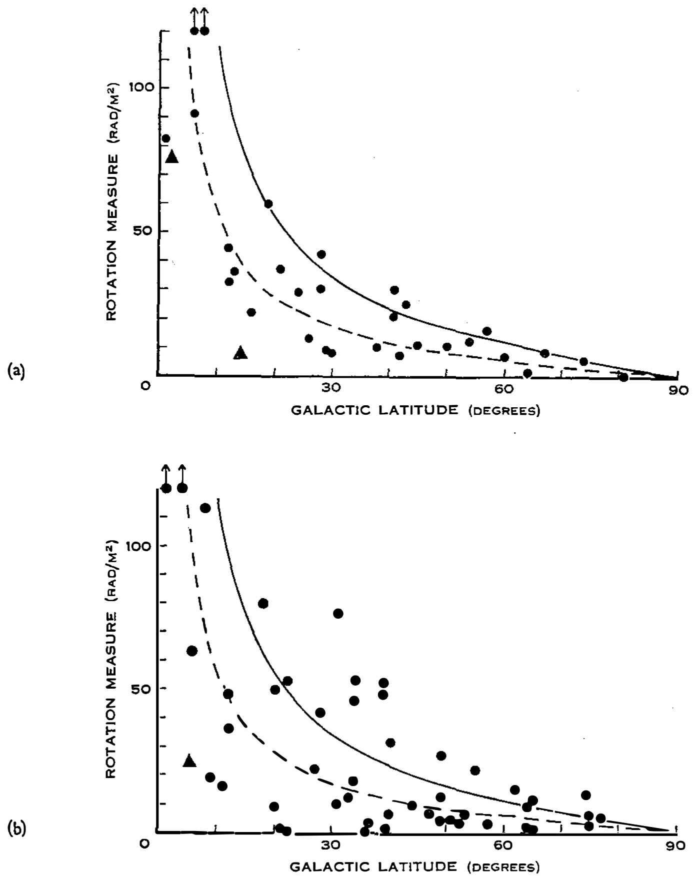

Fig. 3.—The rotation measure plotted (●) as a function of galactic latitude for (*a*) northern (*b*) southern latitude sources. Curves of R.M. $= 10 \cot b^{\mathrm{II}}$ (– – – –) and R.M. $= 20 \cot b^{\mathrm{II}}$ (———) are shown for comparison. ▲ indicates probable galactic source.

are confined to latitudes less than 20° and, as deduced earlier, refer to the general spiral arm field. Another feature of the latitude distribution is the greater spread (r.m.s. variation) in individual values of rotation measure in southern latitudes (± 18 rad/m^2) compared with northern latitudes (± 10 rad/m^2) in the range $20° < |b^{\mathrm{II}}| < 50°$. The mean values are similar, being 22 ± 4 and 20 ± 3 rad/m^2 respectively. Figure 3 also contains curves for R.M. $= 10 \cot b$ and R.M. $= 20 \cot b$. This is the latitude dependence expected for an ionized slab, stratified parallel to the galactic plane, containing a uniform magnetic field also parallel to the plane.

(c) *Contribution to the Faraday Rotation from within the Source*

The large-scale distribution of rotation measure in galactic coordinates is evidence that the bulk of the rotation measure is of galactic origin and that only a small fraction arises in Faraday rotation in the intergalactic medium or in the sources themselves. The data presented here can be used to obtain upper limits to the contributions from the sources, which may be expected to be random in nature since the magnetic fields of the sources will be randomly oriented in the line-of-sight. The most useful data are those from the high latitude ($|b^{II}| > 60°$) sources, which will show a minimum of galactic effects. In the northern region there are five sources which give a mean deviation of rotation measure of 4·7 rad/m^2, and in the south eight sources also give a mean deviation of 4·7 rad/m^2. This scatter will give the maximum value of the mean source rotation measure, since some of the scatter could arise from irregularities in magnetic field or electron density in our own Galaxy or in intergalactic space. Source 3C 287, which has an abnormal rotation measure, has been excluded from the analysis.

TABLE 4

SCATTER IN ROTATION MEASURE

Data	Number of Sources	Scatter (rad/m^2)
Northern latitudes ($b^{II} > 60°$)	5	4·7
Southern latitudes ($b^{II} < -60°$)	8	4·7
Double sources	5	5

Another method for obtaining the amount of rotation measure in the sources themselves is to investigate the differences between the rotation measures of the components of resolved double sources. This method assumes that the contribution from an envelope common to the components and having a uniform magnetic field and electron density can be neglected. The sources used in the analysis were Fornax A, 04—3*14*, 06—2*10*, Centaurus A (the central source and the highly polarized extension to the north-east), and 13—3*3* (Gardner and Davies 1963). The mean difference was 5 rad/m^2. All the data on the scatter of rotation measure in sources are summarized in Table 4, from which it is concluded that the upper limit to the mean rotation measure in the sources themselves is of the order of 5 rad/m^2. Thus any source model (see, for example, Woltjer 1962) that assigns the major part of the rotation measure at low and intermediate latitudes to the sources themselves appears to be at variance with the data. However, there is still the possibility that there are some sources in which appreciable Faraday rotation does take place. These sources might also show a rapid decrease in percentage polarization with wavelength and a non-linear variation of position angle with (wavelength)^2 at wavelengths where depolarization sets in; 3C 287 is in the former category. The source most likely to possess appreciable internal Faraday rotation is, of course, Cygnus A. The interpretation by Hollinger, Mayer, and Mennella (1964) favours an external rotation of -750 rad/m^2, with large and different values of internal rotation for the two components.

However, because of Cygnus A's galactic situation (in the direction of the spiral arm through the Sun), there is still a possibility of galactic depolarization.

IV. Discussion of a Magnetic Field Model

The distribution of rotation measure derived in the present investigation can be used to construct models of the magnetic field distribution in the Galaxy. A number of models can be devised that fit the data, including models that envisage the high- and intermediate-latitude Faraday rotation as arising either locally or at a greater distance in the halo of the Galaxy. These will be considered in more detail in a separate paper (in preparation), which will include an attempt to estimate the strength of the galactic magnetic field. However, it should be remembered that rotation measure is proportional to $\int N_e B_L \, dL$, and that it is necessary to introduce additional information on the electron density distribution in order to obtain magnetic field strengths. As an example of the magnitudes involved, a rotation measure of 80 would be obtained from $B_L = 10^{-6}$ G, $N_e = 10^{-1}$ cm^{-3}, and $L = 1$ kpc.

It is obvious that a number of models do not fit the data. A random low field of about 2×10^{-6} G as envisaged by Spitzer (1962), which is twisted and drawn out by the movement of interstellar clouds, would not produce the apparently large-scale fields found in the rotation measure observations. Also, a radial field in either the disk or the halo of the Galaxy is at variance with the observations.

V. Conclusion

The systematic variation of rotation measure with galactic coordinates shows that we are observing the effects of galactic magnetic fields. However, there are still some gaps in the rotation measure distribution within 30° of the plane that require more observations. Several sources show significant departures from a linear position-angle versus (wavelength)^2 relationship; more sources should be observed over a wide range of wavelengths to determine how common this effect is.

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VII. References

Bologna, J. M., McClain, E. F., Rose, W. K., and Sloanaker, R. M. (1965).—*Astrophys. J.* **142**: 106.

Gardner, F. F. (1964).—Symp. IAU–URSI No. 20 (Canberra 1963). p. 143.

Gardner, F. F., and Davies, R. D. (1963).—*Nature* **201**: 144.

Gardner, F. F., and Whiteoak, J. B. (1963).—*Nature* **197**: 1162.

Hollinger, J. P., Mayer, C. H., and Mennella, R. A. (1964).—*Astrophys. J.* **140**: 656.

Morris, D., and Berge, G. L. (1964*a*).—*Astrophys. J.* **139**: 1388.

Morris, D., and Berge, G. L. (1964*b*).—Obs. Owens Valley Radio Observatory No. 6.

Spitzer, L. (1962).—*In* "The Distribution and Motion of Interstellar Material in Galaxies". (Ed. L. Woltjer.) p. 98. (W. A. Benjamin: New York.)

Woltjer, L. (1962).—*Astrophys. J.* **136**: 1152.