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# Observations of Magnetic Fields*

*David K. Aitken*

Physics Department, University College ADFA,
Campbell, A.C.T. 2600, Australia.

*Abstract*

A review of the methods of determining magnetic field parameters in astrophysical situations is presented. The role of radio observations is only briefly discussed because of recent review coverage, but a more detailed description is given of the optical and infrared polarisation produced by aligned dust grains, with particular reference to the relation between the grain alignment direction and the ambient magnetic field. Some recent results are outlined.

## 1. Introduction

The role played by magnetic fields is crucial to the understanding of the star formation process, but it is clear that the way in which the magnetic field influences the dynamics of the interstellar medium can only be understood when a sound observational database relating to field strengths and directions is obtained. It turns out that while it is possible to measure both the strength and sign of $B_{\|}$ only the direction of $B_{\perp}$ can be determined with the methods currently available.

A recent review of the measurement of interstellar magnetic fields has been given by Heiles (1987). In the present paper only a short outline of radio methods is given, and the main emphasis is on the information obtainable from polarised emission and absorption by aligned grains.

## 2. Line of Sight Magnetic Field: $B_{\|}$

### *(2a) Zeeman Splitting*

The interaction of the magnetic moment of an atom or molecule with an external magnetic field produces a splitting of energy levels. For an unpaired electron spin this leads to a frequency splitting of $\Delta\nu \sim 2B_{tot}$ Hz between lines ($B_{tot}$ in $\mu$G); $\Delta\nu$ is independent of $\nu$ so that the effect is relatively easy to see at radio wavelengths. In the case of the hydrogen atom the $1\cdot42$ GHz (21 cm) line is split into three elliptically polarised components separated by $1\cdot4B_{tot}$ Hz. In a purely transverse field the three components are linearly polarised with the two outer components polarised orthogonally to the central undisplaced line whose polarisation is along the field direction. When the field is parallel to the line of sight the central line is absent and the two outer components are oppositely

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circularly polarised. In masers the magnetic field can be strong and of order tens of mG, with $\Delta\nu$ large, and the linearly polarised Zeeman effect has been observed; more usually, however, internal Faraday rotation severely depolarises the transverse Zeeman effect in masers. Since the frequency splitting in almost all other regions of the interstellar medium or molecular clouds is very much smaller than the line widths, it is almost impossible to observe the linearly polarised components, but the change of sign of circular polarisation across the line can be observed. In this case the *amplitude* of the circularly polarised component is proportional to $B_{\|}/\delta\nu$ where $\delta\nu$ is the linewidth.

The strength and sign of $B_{\|}$ have been determined in some molecular clouds from observations of the Zeeman effect in the 21 cm HI line, the 18 cm OH line, the $2\cdot7$ cm $C_2S$ line, and in the recombination lines of hydrogen in ionised regions. This appears to be the only presently viable method for determining the amplitude of the field ($B_{\|}$) within dense clouds, but the increasing use of small synthesised beams offers a potentially powerful way of studying details of the magnetic field structure.

### *(2b) Faraday Rotation*

Faraday rotation of the plane of polarisation of a background linearly polarised radio source is given by $\lambda^2$ RM, where the rotation measure RM is proportional to $\int n_e B_{\|} dl$. In the interstellar medium and molecular clouds the effect is only observable at radio frequencies. The $n\pi$ angle ambiguity can be removed by observations at several closely spaced wavelengths.

When Faraday rotation is observed in the radiation from a background pulsar the contribution from the electron column density can be found by observing the pulsar's dispersion measure, $\propto \int n_e dl$, and in these cases the $n_e$ weighted average line of sight $B_{\|}$ can be found (e.g. Manchester 1974).

## 3. Transverse Magnetic Field: $B_{\perp}$

### *(3a) Linear Polarisation of Synchrotron Radiation*

The polarisation direction of synchrotron radiation is that of the acceleration of relativistic electrons by the magnetic field and therefore is at right angles to the transverse component of the field. If the field is uniform the polarisation may be large; the contribution from any random field component to the polarisation is zero and this dilutes the observed polarisation. Polarised synchrotron radiation has been observed at visible, near infrared, and radio wavelengths but is seldom an important contributor to polarisation at mid and far infrared wavelengths since other radiation processes usually dominate.

Faraday rotation along the line of sight may affect the direction of the inferred transverse field component, and this cannot always be corrected by observations at several wavelengths: if the relativistic electrons which give rise to the synchrotron radiation co-exist with the thermal electrons responsible for the Faraday effect, then the Faraday rotation dependence on $\lambda^2$ holds only for rotations $\lesssim 1$ rad: this is called the 'Faraday-thin' regime.

The main importance of synchrotron radiation in studies of molecular clouds is that it acts as a background source for observations of Faraday rotation, and then allows the determination of $B_{\|}$.

*(3b) Linear Polarisation of Spectral Lines at Radio Wavelengths*

It has been pointed out (e.g. Kylafis 1983; Kylafis and Shapiro 1983) that an anisotropic radiation field can make the interstellar medium exhibit linear dichroism and lead to line polarisation in absorption or emission either parallel to or perpendicular to the transverse component of magnetic field. Relatively large line polarisations are predicted from HII regions and dense molecular clouds; in principle this effect has considerable potential. However, it has not yet been observed.

*(3c) Polarisation of Starlight*

The first indication of the presence of an interstellar magnetic field was from the observed polarisation of starlight. The presence of polarisation implied that grains were non-spherical and could be aligned. This latter property was a complete surprise and while the alignment has been ascribed to magnetic effects there have been problems, and still are, with understanding the alignment mechanism; it seems possible that different mechanisms may apply in different regions. Thus, the association of the magnetic field direction with the polarisation is not obvious, and it is worth examining the phenomenon in some detail to define how it is related to the ambient magnetic field. As we shall see, it turns out that the position angle of polarisation will be controlled by the magnetic field irrespective of the alignment mechanism.

## 4. Linear Polarisation due to Dichroic Emission/Absorption by Aligned Grains

*(4a) Alignment Mechanism*

Interstellar grains of typical size $\sim 0 \cdot 1\ \mu$m in equipartition with interstellar gas will be spinning with angular velocities $\omega$ in the MHz range; alignment must be more subtle than that of a static 'picket fence'. Internal dissipative forces in a freely rotating grain will eventually cause it to spin about its axis of greatest principal moment of inertia, i.e. at right angles to a long grain dimension. Such dissipation can be through elastic hysteresis, but it turns out that internal magnetic hysteresis is a more important effect. Here the Barnett effect (e.g. Landau and Lifshitz 1960), by which spinning grains become self magnetised, induces magnetisation along the spin axis of a grain; unless the spin axis is also a principal axis of inertia, it and its associated magnetisation precess within the body of the grain. The Barnett magnetisation is then periodic and the dissipative component, due to the imaginary part of the magnetic susceptibility of the grain material, forces the grain angular momentum to align with the axis of major moment of inertia in a time $t_{geom}$ (Purcell 1979). The time $t_{geom}$ is short compared with the rate at which gas collisions tend to randomise the rotation, and so grains spin about an axis perpendicular to their longest dimension. Alignment of the grain geometry can now be achieved through alignment of their angular momenta.

The alignment can be driven by an external magnetic field through paramagnetic relaxation, a method first suggested by Davis and Greenstein (1951), and referred to as the DG mechanism. Unless the angular momentum axis is colinear with the ambient magnetic field the grain sees a varying field and undergoes magnetisation cycles and hysteresis losses which eventually align the grain angular momentum with the magnetic field. The radiation field $\boldsymbol{E}$ vector suffers a larger extinction when its direction is that of the long grain dimension, and hence the transmitted polarisation is aligned with the projection of the magnetic field on the plane of the sky.

Any alignment mechanism has to compete with the disorienting effect of gas–grain collisions. The time scale for the latter is roughly the time $t_{gas}$ for the grain to collide with its own mass of gas and (Martin 1978)

$$t_{gas} \sim \frac{a\rho}{N_H}(m_H k T_{gas})^{-1/2}\,.$$

Here $a$ is the grain radius, $\sim 0\cdot 1\,\mu$m, $\rho$ its density, $\sim 1$ gm cm$^{-3}$, $m_H$ and $N_H$ refer to the hydrogen atomic mass and number density and $T_{gas}$ is the gas kinetic temperature. If $T_{gas} \simeq 100$ K then $t_{gas} \sim (6\times 10^{13})/N_H$ s. In the interstellar medium $t_{gas} \sim 2\times 10^5$ yr and in molecular clouds $t_{gas} \sim 20$ yr. Grains essentially always spin about axes at right angles to their long axes because $t_{geom} \sim 10^{27}\rho a^2/\omega^2$ s (Purcell 1979) is only of order months, and is very much shorter than $t_{gas}$.

To be effective, the time scale for paramagnetic relaxation, $t_{mag} \sim I/\kappa V B^2 \sim \rho a^2/\kappa B^2$, must also be much less than the gas disorienting time, $t_{gas}$. Here $I$ and $V$ are the grain moment of inertia and volume respectively, and $\kappa = \chi''/\omega$, the ratio of the imaginary part of the magnetic susceptibility to the angular velocity. For paramagnetic materials $\kappa$ is very small and $\sim 10^{-13}$ s rad$^{-1}$ for grains of temperature $T_{grain} \simeq 10$ K (e.g. Martin 1978). With the above parameters $t_{mag} \sim 1000/B^2$ s and for this to be much less than $t_{gas}$, the DG mechanism requires magnetic field strengths in the interstellar medium of at least 15 $\mu$G, an order of magnitude larger than those determined from Faraday rotation of pulsar polarisation.

The originally proposed DG mechanism considered the grains to be paramagnetic and in rotational equipartition with the ambient gas. To counter the field strength problem it was suggested (Jones and Spitzer 1967; Mathis 1986) that grains contain superparamagnetic (SPM) inclusions; here $\kappa$ can be increased by very large factors, which allows magnetic relaxation in times short compared with $t_{gas}$. A further problem was that in order for magnetic alignment to take place at all, the grain rotational temperature $T_{rot}$ must differ significantly from the grain internal temperature, $T_{grain}$. If $T_{rot} < T_{grain}$, then thermal fluctuations of magnetisation within the grain dominate and drive the grain angular momenta to lie in a plane perpendicular to $\boldsymbol{B}$. This is called inverse DG alignment and is 'equatorial', as distinct from 'polar' where the spin axes are parallel with the field, and is only half as effective as 'polar' in producing polarisation. When $T_{rot} = T_{grain}$ the internal and external forces balance and there can be no DG alignment. Thus in dense molecular clouds where the grain and gas temperatures are tightly coupled then $T_{rot} \simeq T_{grain}$ and alignment should not occur, whereas polarisation is frequently observed. To overcome this problem Purcell (1979) proposed that grains spin suprathermally as a result of systematic changes of angular momentum taking place at specific sites on the grain surface which then produce a 'pin wheel' effect. Such effects as hydrogen recombination and molecule ejection from specific sites, or a locally enhanced photoelectric effect have been suggested, but the sites must be durable on the time scale of the alignment mechanism. Both SPM inclusions and suprathermal spin are necessary, and while neither modification is unreasonable, they do mean that observations of polarisation give information only on the field direction and not its strength; a bonus is that suprathermal spin ensures that the inverse DG alignment would not occur.

This modified form of the DG mechanism appears to be still the most promising way to align grains. Other alignment mechanisms have been proposed: by streaming of gas through grains (Gold 1952) and by a directional radiation field (Harwit 1970). The former may be faster than the classical DG alignment provided the streaming is supersonic and would lead to 'equatorial' alignment of grain spin with respect to the streaming direction. When the radiation field wavelength is comparable with or greater than the grain dimension, the intrinsic spin of the photons dominates and grains can become aligned with their angular momenta along the direction of radiation. Although this would be a very elegant alignment mechanism it is usually offset by the far more numerous longer wavelength infrared photons randomly emitted by a grain when in thermal equilibrium.

One of the more recent ideas on grain alignment involves ambipolar diffusion (Roberge and Hanany 1991): here the streaming of gas through grains is normal to the field direction and leads to angular momentum alignment along $\boldsymbol{B}$ by the Gold mechanism. This is expected to be important in moderately dense clouds such as Orion and the Galactic Centre molecular ring, but not in fully ionised HII regions, or at very high gas densities. In the first case there will be no ambipolar diffusion, and in the second, the gas and grains are closely coupled and there will be little streaming.

It seems that different mechanisms may operate in different physical environments. Whatever the alignment mechanism, however, each paramagnetic grain of angular momentum $L$ has magnetic moment $\mu \sim L$ erg $\mathrm{G}^{-1}$ by virtue of the Barnett effect (Dolginov and Mytraphanov 1976) and will precess about the direction of the external field with period $t_{prec} \sim 2\pi L/\mu B \sim 2\pi/B$. Even for a magnetic field strength as low as $3\times10^{-6}$ G this is only of order months and very much shorter than any of the alignment mechanisms. The precession does not produce alignment (as has sometimes been suggested), since it does not involve dissipation, but it does ensure that, irrespective of the mechanism which actually breaks the isotropy of the grain spin distribution, the *orientation* of the anisotropy will be controlled by the external magnetic field.

Due to this precession the net alignment of grain spin may be either 'polar' or 'equatorial' with respect to the field direction, i.e. either along the projected field direction or normal to it, depending on the angle between the direction of the alignment process and that of the magnetic field. This has been discussed by Dolginov and Mytraphanov (1976) and Dolginov (1990) who reached the following principal results. Streaming of gas or hard photons along the field direction leads to 'equatorial' alignment with respect to the magnetic field direction, whereas streaming normal to the field gives a net 'polar' alignment but with maximum amount only 25% of complete DG alignment. Streaming of soft photons along the field can in principle give complete 'polar' alignment, but in practice this is greatly weakened by thermal re-emission. In either case if the streaming direction is 55° from the magnetic field there is no net alignment.

There is thus some ambiguity as to whether the alignment is parallel or perpendicular to the projected field direction. The ambiguity can be at least partially resolved by considering some of the observational results. In many cases where polarisation is observed its morphology strongly suggests that it cannot be the result of two independent processes. If gas–grain streaming is invoked as the alignment mechanism it needs an independent external driving mechanism if it is directed along the field, such as radiation pressure or shocks, and is otherwise quickly damped by gas drag; however, streaming normal to the magnetic field can be driven by the field through ambipolar diffusion or Alfvén waves, as in the Roberge and Hanany (1991) mechanism. Here the alignment is 'polar' with respect to the magnetic field. There are cases too where the polarisation is so uniform and large that the only plausible alignment mechanism is by the magnetic field, as in the ionised filaments of SgrA (Aitken *et al.* 1986).

The bottom line, as it were, of all this is that alignment can be only either parallel or perpendicular to the magnetic field, and will be almost always parallel to it.

It is perhaps reassuring that these convoluted arguments are observationally supported: the polarisation of radio synchrotron radiation has been found to be orthogonal to the optical polarisation of starlight (Berkhuijsen *et al.* 1964).

A more detailed account of the spectral form of the polarisation and its relation to the grain chemistry is given in the review by Hildebrand (1988) and the article by Aitken (1989).

### *(4b) Polarisation from Scattering*

The visible light of reddened stars usually exhibits linear polarisation due to dichroic absorption, though sometimes there is a small intrinsic component due to scattering in the stellar atmosphere. Conversely polarisation in the visible and near infrared from diffuse sources may be largely due to scattering and the much smaller polarisation due to dichroic absorption requires great care to identify and extract.

With the advent of area detectors for the visible and near infrared, polarimetric imaging of extended sources has become possible, and the centro-symmetric polarisation distribution characteristic of scattering has frequently been observed at these wavelengths. Here the polarisation position angle is perpendicular to the plane of scatter and so the polarisation distribution is circumferential about the source of radiation, which itself is often heavily obscured. Optical studies of galaxies by Scarrot and co-workers (Scarrott *et al.* 1990) have shown that some morphological types show such a circumferential polarisation distribution about the nucleus. Since the individual stars are obviously unresolved, the polarisation could be contaminated by scattering effects; however, the uniform morphology of the distribution on galactic scales argues that the mechanism in these cases is dichroic absorption and that the corresponding field distribution is roughly circumferential.

In studies of Galactic star-forming regions, the results often clearly show a centro-symmetric scattering pattern about a source of radiation; deviations from symmetry, especially on or near local discrete sources, have been interpreted in terms of dichroic absorption and related to magnetic field directions (e.g.

Sato *et al.* 1985; Tamura *et al.* 1991). Sometimes an elongated region of much weaker polarisation, referred to as a 'polarisation disk', is superimposed upon the pattern. The weak polarisation component tends to be aligned with the 'disk' and has been variously attributed to dichroic absorption by aligned grains within the disk, or to multiple scattering in the disk. Bastien and Ménard (1988) contended that all the polarisation effects so far observed from optical jets and bipolar outflows are due to multiple scattering and give no information on their magnetic fields. This is clearly not the case when one considers observations of these sources which have been made at longer wavelengths.

*(4c) Polarisation from Dichroic Absorption and Emission*

At longer wavelengths, in the mid and far infrared, scattering effects are negligible and polarisation is due to the dichroism of aligned grains. That this is the case is observationally confirmed by the polarisation spectra of obscured sources. Here the $9 \cdot 7$ $\mu$m silicate absorption feature yields a polarisation spectrum which peaks at a wavelength about $0 \cdot 5$ $\mu$m longer, a result at variance with Elsasser and Staude's (1978) scattering model, but expected for dichroic absorption.

In the mid infrared, where both emissive and absorptive polarisation can occur, it is clearly important to be able to distinguish between them, since their polarisation position angles are mutually perpendicular. Fortunately, the spectral signatures of emissive and absorptive polarisation are easily distinguished, and the occurrence of both in the same observation is usually revealed by a variation of position angle with wavelength (e.g. Aitken *et al.* 1986; Aitken 1989). This demands spectropolarimetric observations from which it is relatively straightforward to separate the components.

At wavelengths of 100 $\mu$m and beyond only emissive polarisation is important and the field direction is normal to the polarisation.

Mid and far infrared observations of polarisation offer a means of probing fields deep within obscured sources. Absorptive polarisation near 10 $\mu$m probes the line of sight averaged magnetic field to embedded luminous sources, while the emissive component yields the field direction local to the source. In the far infrared much more of the volume of the source is sampled, and in the mm region essentially all of it enclosed by the beam.

## 5. Strength of the Field

The only methods which directly yield the magnitude of the magnetic field are radio observations of the Zeeman effect and of Faraday rotation, and these determine the strength and sign of the line of sight component $B_{\parallel}$. Because of the uncertainty of grain properties and the alignment mechanism, polarisation due to dichroic emission or absorption by aligned grains gives information only on the direction of $B_{\perp}$, and not on its strength.

In certain cases information on the field strength may be obtained from the polarisation following the method of Chandrasekhar and Fermi (1953). Here the scatter in the polarisation position angles is related to the relative sizes of the Alfvén velocity and the observed turbulent velocities within the source, thus yielding a value for the magnetic field. The method assumes only that the polarisation direction is controlled by the field and it does not otherwise depend on the alignment mechanism or the dust grain properties. The value of $\simeq 3 \times 10^{-6}$

G for the interstellar field was first determined in this way by Chandrasekhar and Fermi; the method can in certain cases be used to estimate field strengths in other sources.

## 6. Magnetic Fields in Clouds and Star-forming Regions

There have been recent reviews by Heiles (1987, 1991), and extensive coverage in the IAU Symposium No. 140 (1990). Here I will merely highlight some recent work and developments, mainly in the observations of polarisation at mid and far infrared wavelengths.

### *(6a) Orion*

Observations of the cool dust in OMC1 at mm wavelengths (Leach *et al.* 1991) using a 30 arcsec beam and at 100 $\mu$m with a 40 arcsec beam (Gonatas *et al.* 1990) show an emissive polarisation which has a nearly uniform position angle $\simeq 25°$ with implied magnetic field normal to the long axis of the Orion cloud. Gonatas *et al.* (1990) inferred a field strength of $1\cdot 3$ mG from the scatter in polarisation position angles using the method of Chandrasekhar and Fermi (1953); in a similar way Leach *et al.* (1991) found a value of 1 mG. These values are consistent with the determination of 40–100 $\mu$G (Troland *et al.* 1989) for $B_{\|}$ from the Zeeman splitting of the 21 cm hydrogen line, when allowance is made for an increase of magnetic field due to the increase in density between the HI region and the molecular cloud. Both infrared groups observed surprisingly large polarisation fractions in the range 2–7% with the smallest polarisation being observed close to the BN object. A possible reason for the polarisation minimum is the field complexity near BN as indicated in the following paragraph.

Studies of absorptive polarisation between 8–13 $\mu$m with a $5\cdot 6$ arcsec beam (Aitken *et al.* 1985; Aitken 1989); give a position angle of 118° at the BN object, closely normal to the far infrared results, but show organised variations of position angle within the neighbouring 20 arcsec; here the polarisation vectors point towards Irc2. Aitken *et al.* (1985) interpreted this as evidence for the Harwit photon spin alignment mechanism driven by radiation from Irc2, and while this may well be the cause of the local alignment, it is clear from the arguments of Section 4 that the polarisation position angles must indicate the field directions. Such a local distortion of the larger scale field to position angles directed towards Irc2 may well be a manifestation of bipolar outflow activity from Irc2. Observations of the polarisation of the S(1) molecular hydrogen line at $2\cdot 12$ $\mu$m (Hough *et al.* 1986; Burton *et al.* 1991) also show a twisting of the alignment direction in the vicinity of Irc2, although their position angles differ markedly from the mid infrared results.

### *(6b) Bipolar Flows in Young Stellar Objects*

A number of bipolar sources have been studied in the near infrared, especially in the K band, and more recently polarisation images have been produced by a number of groups. Early work by Sato *et al.* (1985) showed a general tendency for the $2\cdot 2$ $\mu$m polarisation to be perpendicular to the CO flow direction. Later polarimetric imaging (e.g. Tamura *et al.* 1991) of the diffuse region about these sources usually shows a strong centro-symmetric scattering pattern and that the much smaller polarisation orthogonal to the flow originates in and is colinear with the elongation of a 'polarisation disk'; as referred to in Section 4*b* it is not clear whether this polarisation is due to multiple scattering or dichroic absorption.

Some of these sources have been observed spectropolarimetrically in the mid infrared; this work is reported by Wright (1992 present issue p. 581). The sources show clear evidence for dichroic absorption and in the majority of cases the inferred field direction lies in the plane of the presumed disk, either as defined by the near infrared imaging or by dense molecular structures, and roughly orthogonal to the outflow. The result is at variance with the hydromagnetic models of Pudritz and Norman (1986) which predict a poloidal rather than toroidal disk field.

### *(6c) HII Regions*

Many HII regions show emissive polarisation in the mid infrared, usually overlaid with an absorptive component from the enveloping molecular cloud; the polarisation offers a means of studying the field structure in sources which are at an evolutionary stage where the luminous star is on or near the main sequence and the disk and bipolar structures have dispersed. Observations in the mid and far infrared and the mm region should show to what extent the magnetic field direction is related to the different phases of the molecular cloud.

## 7. Future Prospects

### *(7a) Polarimetric Imaging in the Radio and the Mid and Far Infrared*

Many astronomical sources show small scale spatial structure of the magnetic field distribution, as revealed by infrared polarisation studies. Whether the magnetic field controls the evolution or is just an indication of the fluid stresses, its morphology can give important clues to the processes and mechanisms involved in star formation. Fortunately, we appear to be at the threshold of technological advancement: camera systems for the mid (e.g. Gezari *et al.* 1988) and far infrared (Hildebrand 1988 and co-workers) are now becoming available or are being developed, and in some cases have already been applied to polarimetric imaging (Aitken *et al.* 1991; Hildebrand, personal communication). These polarimetric imaging techniques, allied with radio synthesis Zeeman studies, promise to be a powerful probe into the field distributions within star-forming regions.

### *(7b) Space-based Observations*

The observational sensitivity of ground-based mid infrared polarimetry is currently set by the shot noise of the ambient thermal background. Use of focal plane arrays will lead to a more efficient use of observing time and optimisation of background, but these limits still apply. Further, a significant fraction of accessible star-forming sources has already been observed, all of which have been high mass systems; a number of intermediate mass objects lie tantalisingly below current limits. What is required is a drastic reduction in the thermal background: cryogenic space telescopes with suitable instrumentation can significantly increase the number of observable sources. The first of these off the mark with polarimetric facilities is likely to be ISO late in 1993.

## 8. Conclusions

Observations of magnetic field strength and direction in dense molecular clouds are a prerequisite to understanding the star formation process. Polarimetric observations in the mid and far infrared are the key to this, for although the mechanisms of dust grain alignment are still uncertain, and may depend on local physical conditions, the *orientation* of the alignment will be controlled by the magnetic field. The observation of this polarisation position angle appears to be the only method presently available to determine the direction of the transverse component of magnetic field, but it carries little information regarding its strength; Zeeman studies of molecular and atomic lines in the radio can provide the strength and sign of the line of sight field component. With increasingly sophisticated imaging techniques and improving sensitivities these methods promise to reveal details of the magnetic field structure and help define its role in star formation.

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