B. MAGNETIC EFFECTS

79. MAGNETIC FIELDS AND SPIRAL STRUCTURE

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The most valuable new information on galactic magnetic fields is derived from the study of Faraday effects in extragalactic radio sources and pulsars. The rotation of the plane of polarization of an electromagnetic wave with a wavelength of 1 m – the so called Rotation Measure RM – which traverses a medium with electron density n_e (cm^{-3}) and magnetic field intensity **H** (in μG) is given by

$$\mathrm{RM} = 0.81 \int n_e \mathbf{H} \cdot \mathrm{d}\mathbf{l}, \tag{1}$$

where **dl** is the element of length along the line of sight expressed in pc. In the case of the pulsars, the delayed arrival of the pulses at the longer wavelengths immediately yields the integrated electron density along the line of sight, that is

$$\int n_e \, \mathrm{d}l. \tag{2}$$

If we make the *assumption* that the fluctuations in **H** and n_e are uncorrelated the average field strength along the line of sight can be obtained by comparing expressions (1) and (2). Results so far obtained range between 1 and 3 μ Gauss for the mean field parallel to the line of sight. From an analysis of the distribution of pulsars we conclude that the mean interstellar electron density is about 0.05 cm^{-3} in a layer which extends to no less than 200 pc from the galactic plane. In such a layer a mean line of sight field of 2 μ Gauss also suffices to account for the observed Faraday rotations in intermediate latitude extragalactic objects. On the basis of these data we provisionally conclude that the mean value of the large scale ($L > 100$ pc) magnetic field near the sun amounts to 3 or 4 μ Gauss. Small scale random fields do not contribute much to the Faraday effects and could be stronger. The intensity of the synchrotron radiation from the galactic disk indicates that such fields may exist. The strength of the systematic field derived here is compatible with the Zeeman measurements reported by Dr. Verschuur, which indicate that stronger fields may occur in dense clouds.

The energy density associated with a field of 3.5 μ Gauss is 5×10^{-13} erg cm^{-3}. For comparison a flow of interstellar gas with a hydrogen density of 0.5 cm^{-3} would have the same energy density at a velocity of 10 km s^{-1} and this indicates the order of magnitude of the motions that may be substantially influenced by the magnetic field. The systematic deviations from the circular velocity caused by this field are much smaller ($\simeq$ 0.1 km s^{-1}) because a small change ($\Delta\theta$) in the circular velocity θ leads to a large change in kinetic energy ($\Delta E \approx \rho \theta \Delta\theta$). The low energy density of the large scale field and its inability to affect the circular motions of the gas make it virtu-

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ally certain that the magnetic field cannot be the main cause of spiral structure. Of course this does not mean that it is also negligible when we consider the detailed structure of a spiral arm.

The structure of the field is still uncertain; in the future it may well give valuable information on the motions in the interstellar gas. Matthewson has shown that the interstellar polarization data (radio and optical) may be interpreted on the basis of a rather tightly wound helical field in the general neighborhood of the sun. The axis of the field would be directed towards $l=90°$. It is noteworthy that such a field would show no obvious relation to the local hydrogen structure. The origin of a helical component also poses problems; perhaps one could think of a torsional oscillation in a uniform unidirectional field, but the amplitude would have to be large to make a tight helix.

On a larger scale one would expect the field to follow the fluid motion. Hence in a density wave picture of spiral structure the magnetic field should be strongest in the arms, where the density is highest, and the field should be oriented more or less parallel to the arm. The winding-up problem is not affected because the field is tied to the fluid and not to the density wave as such. If the field had been originally uniform in the galactic disk and if it has been steadily wound up for 10^{10} years the thickness of each winding near the sun amounts to only 100 pc; from one winding to the next the field would change sign. The presently available Faraday rotation data do not support such a picture, although the low latitude data are too few for a definite conclusion. One simple way out is to have a basically toroidal field in which each field line is more or less circular. But it is difficult to judge the likelihood of such a field in the absence of a theory for the origin of magnetic fields in galaxies.