SYNCHROTRON RADIATION
AND GALACTIC FIELD CONFIGURATIONS

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Abstract. Models of the galactic magnetic field are discussed with respect to their influence on calculated contour maps as well as longitudinal distributions of the synchrotron brightness temperature. A comparison is made with Landecker-Wielebinski (1970) data.

1. Introduction

Galactic radio frequency radiation has become an important source of information on the structure of our Galaxy. Measurements concerning the distribution of radiation temperature on the celestial sphere have been published by various authors (Dröge and Priester, 1956; Seeger et al., 1965; Landecker and Wielebinski, 1970; Berkhuijsen, 1971; Green, 1974). The range of frequency which has been investigated extends from about 20 to 1500 MHz. The nature of this radiation has been identified largely as synchrotron radiation by the relationship between the spectral index of radio frequency radiation and the energy spectrum of primary electrons. This has been suggested by Kiepenheuer (1950). At 150 MHz the contribution of thermal radiation is estimated to be smaller than 10% (Hirabayashi, 1974).

Consequently the radiation intensity received from a specified direction of the celestial sphere is represented by a line-of-sight integral involving the density of relativistic electrons and a given power of the transverse component of the interstellar magnetic field. Interpretation of these empirical data in terms of field configuration is essentially derived from comparison with model calculations; cf. Hanbury Brown and Hazard (1960), Price (1974), Beuermann (1974), Paul et al. (1975). After the present results had been written down, we received a reprint of French and Osborne (1976) leading largely to the same conclusions.

These investigations are connected with analogous calculations of cosmic gamma radiation, the intensity of which is represented essentially by a line-of-sight integral over the density of cosmic ray particles and interstellar gas.

Further contributions to galactic radiation are provided by bremsstrahlung of relativistic electrons in the energy range about 1 GeV (Cummings et al., 1973) and by inverse Compton effect on the photons of universal black body radiation and star light. In view of the correlation existing in the distribution of interstellar plasma, the interstellar magnetic field and cosmic ray particles, a consistent notion may be derived.
from the simultaneous consideration of galactic synchrotron and gamma radiation (Schlickeiser and Thielheim, 1974a, b; Paul et al., 1974).

The following calculations are based on three models of the large scale interstellar magnetic field which should be looked upon as preliminary suggestions: Model I is considered as a test version which is based essentially on plausibility arguments. It has been originally constructed for the calculation of Störmer trajectories of high-energy charged particles in our Galaxy (Thielheim and Langhoff, 1968). Model III is based on theoretical arguments concerning the stratification of the various constituents with respect to a coordinate vertical to the galactic equator (Fuchs et al., 1975). In Model IIIa a given fraction of this magnetic field strength exhibits random orientation in order to provide for a stochastic contribution to the interstellar field. The dependence from the two coordinates within the galactic plane is of ad hoc character in both models.

The influence of the global features of the field topography on calculated contour maps as well as on the longitudinal distribution of radiation temperature is discussed. Calculated data are compared with observational ones of Landecker and Wielebinski (1970) which we have not tried to correct for discrete sources and spurs.

2. Field Models

Models I and III of the interstellar magnetic field considered here describe an idealized vision of the global field structure. Field irregularities present in the turbulent interstellar gas as well as distortions produced by supernova explosions are considered in Model IIIa.

As is suggested by different types of measurement (H I and H II distribution, stellar polarization and Faraday rotation) a correlation exists between the overall alignment of magnetic field lines and the direction of the spiral arms. Plausibility arguments (persistence of spiral structure, possible origin of the interstellar field) are in favor of longitudinal (magnetic field vector parallel within a given spiral arm) or quasi-longitudinal models (magnetic field vector antiparallel on both sides of the galactic equatorial plane). A global helical field topography seems to be incapable to account for the reproduction of the spiral pattern in a differentially rotating disk. Field models which have been discussed by us are reproduced in Table I.

In what follows \( H_{a0} \) is the field component tangential to the spiral arm, while \( H_{z0} \) is the component perpendicular to the equatorial plane calculated from \( H_{a0} \) by means of \( \text{div} \, \mathbf{H} = 0 \) and adequate boundary conditions. Models are formulated in terms of \( H_0 \) since the tangential component is found to give the major contribution to the total field strength: \( |H_{z0}| \ll |H_{a0}| \).

Ad hoc-model I (Thielheim and Langhoff, 1968) represents a quasi-longitudinal configuration. In this case,

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H_{a0} = c P(z) S(r, \phi);
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