SOLAR CORONAL MAGNETIC FIELDS

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Abstract. A short compilation of various radio methods of the determination of magnetic fields in the solar corona is given which, completed by observations in other spectral ranges (e.g. the optical and X-ray ranges), results in a complex picture of the magnetic field. Some topics of interest are the following:

(1) Comparison with a standard reference magnetic field in the solar corona,

(2) Possible evidence of substantial small-scale fluctuations of the magnetic field (e.g. in active regions),

(3) Indication of magnetic fields substantially in excess of the standard distribution (e.g. in limb flare events).

1. Introduction

The physics of the solar atmosphere is closely related to the existence of magnetic fields generated by dynamo processes in the convection zone and penetrating outward through the photosphere, thus finally resulting in interactions with the plasma medium of the chromosphere and corona. However, measurements of the magnetic field outside the photosphere are difficult to obtain. This situation forces the use of indirect methods where radio measurements provide unique candidates for a determination of coronal magnetic fields.

2. Estimation of magnetic fields by radio methods

Radio astronomy offers a multitude of different methods of the estimation of magnetic fields related to either the source or propagation regions of the radiation. A compilation of some basic methods is presented in Table I.

Principal difficulties in the application of these methods to the solar corona consist in (i) the necessity of an identification (or postulation) of the underlying emission process and (ii) in the required knowledge of additional parameters, e.g. of the electron density in the radiation source and the propagation region. Direct estimations of source heights above the photosphere can be obtained in the case of limb or behind-limb sources (Krüger *et al.*, 1991). Reviews on the state of the field were given by Dulk and McLean (1978) and by Krüger and Hildebrandt (1992).

F. Krause et al. (eds.), The Cosmic Dynamo, 59–61.

TABLE I: RADIO METHODS OF THE ESTIMATION OF CORONAL MAGNETIC FIELDS

Method (physical process)	Application (indicator)
Coulomb bremsstrahlung	Polarization of S-component sources
Gyromagnetic radiation	S-component, microwave bursts
Gyro-synchrotron radiation	Spectral shape of continuum bursts
Razin effect	"
Wave propagation crossing QT-regions	Polarization reversal of microwave emission
Determination of Mach number of MHD shocks	Type II bursts
Band splitting by magneto-ionic resonances or density gradients	"
Harmonic plasma radiation	Degree of polarization of type III bursts
Magneto-ionic cutoffs	Time profile of polarization of type III bursts
Double plasma resonance, Whistler waves	Spectral characteristics of burst fine structures, e.g. zebra patterns and fiber bursts

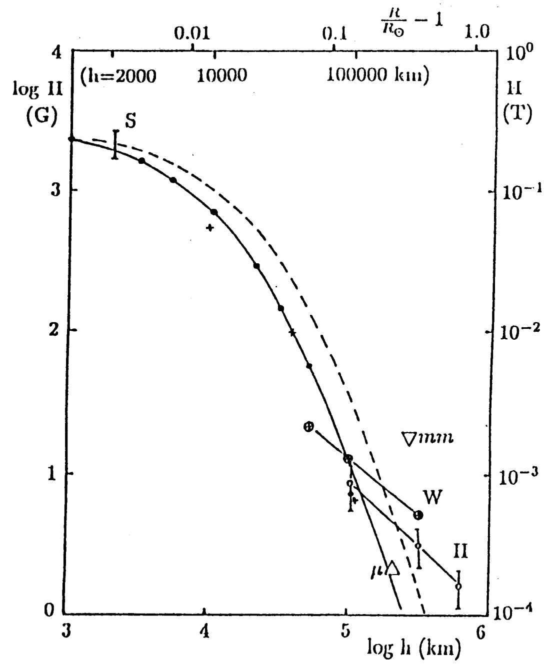

Fig. 1. Measures of magnetic fields compared with dipole distributions above the centre of a large sunspot ($B_m = 2500$ G, full line: dipol depth $z_d = 2 \times 10^4$ km, broken line: $z_d = 3 \times 10^4$ km); black dots refer to a force-free photospheric field extrapolation; S - S-component, W - fiber bursts (whistler waves), II - type II bursts, μ - microwave burst (16.02.1984), mm - mm-λ burst (29.09.1989).

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3. Results of magnetic-field diagnostics

Some results of the estimation of coronal magnetic fields are compiled in Figure 1. The magnetic dipole can be used as a general reference field for the modeling of the S-component sources above sunspots (Krüger *et al.*, 1985, 1986) in accordance with different kinds of S-component observations and force-free extrapolations of photospheric magnetic fields (Hildebrandt *et al.*, 1984).
On the other hand, magnetic fields derived from radio burst observations (i.e. for disturbed coronal conditions) can exceed the above reference distribution by more than one order of magnitude, as illustrated by the point designated by "*mm*" in Figure 1 which was derived from a mm-λ solar map of a large burst event on September 29, 1989 (Krüger and Urpo, 1992).
Moreover, the comparison of S-component model calculations with spatially resolved microwave observations of solar active regions showed that the magnetic field must possess a substantial irregular component. This component, which leads to local deviations in magnetic field direction, must be nearly as high as the regular large-scale active region field component in order to blur the ring structures in the gyromagnetic emission intensity around sunspots that would otherwise be observed more frequently (Krüger and Hildebrandt, 1991).

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