CORONAL MAGNETIC FIELDS AND FORBIDDEN EMISSION LINE POLARIZATION

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1. Introduction

It is generally assumed that the morphology of the solar corona as seen, for example, in white light provides a map of the coronal magnetic field. Not only are coronal structures such as loops and streamers strongly suggestive of magnetic fields, but also on theoretical grounds one expects the field to be frozen into the highly ionized coronal plasma. A standard test of the morphology hypothesis is to extrapolate from photospheric field measurements into the corona by means of a potential field calculation (Altschuler and Newkirk, 1969). However, as noted by Picat et al. (1979), such calculations yield only a rough fit to the white light corona. Some crude estimates of the orientation of coronal magnetic fields also can be obtained from polarization measurements of radio bursts (e.g., Kai, 1970).

At present the most direct technique for inferring the direction of the coronal magnetic field is by observations of forbidden line polarization. The first substantial application of this method was by Charvin (1965). The most recently published data are by Arnaud (1977) and Picat et al. (1979) using the so-called green line Fe XIV 5303Å and by Querfeld (1977) using the Fe XIII 10747Å line. House (1977) reviews earlier work. All these observations were ground-based, the measurements being limited to heights $\lesssim 1.5\ R_\odot$. Observations are now being made to heights $\gtrsim 1.7\ R_\odot$ by the High Altitude Observatory Coronagraph/Polarimeter on the Solar Maximum Mission Satellite. House et al. (1980) report detection of green line emission out to $3.2\ R_\odot$.

As a prelude to the analysis of data from the HAO/CP experiment, a detailed study of the formation of green line polarization has been carried out following the theoretical work of Sahal-Bréchot (1974) and House (1977). The rest of this article outlines some of the essential features of the theory and reports on progress and goals. The work has been done in collaboration with Drs. L. House and C. Querfeld, and a full account is in preparation.

2. Theory of Green Line Polarization

The central problem in modelling coronal emission line polarization is to solve the statistical equilibrium equations for the magnetic sublevel populations of the coronal ion. The green line is formed in the $3s^2 3p$ ground configuration of the ion as a ${}^2P_{3/2} \rightarrow {}^2P_{1/2}$ transition. Polarization in the line arises because of the inequality of the sublevel populations of the ${}^2P_{3/2}$ excited state. This inequality is due to the anisotropy of excitation by radiation from the photosphere. Depolarizing collisions within the ground configuration, as well as electron collisions to excited configurations followed by cascades, tend to equalize these populations.

The full details of the method of solution of the equations of statistical equilibrium are given by House (1977). We applied his method to the 9-level (34-sublevel) model Fe XIV ion illustrated in Figure 1. Table 1 summarizes the sources of atomic data used to calculate the various transition rates. We neglected radiative absorption from the ground to excited configurations, radiative rates between sublevels of any given term, electron depolarization rates and all rates between terms in excited configurations.

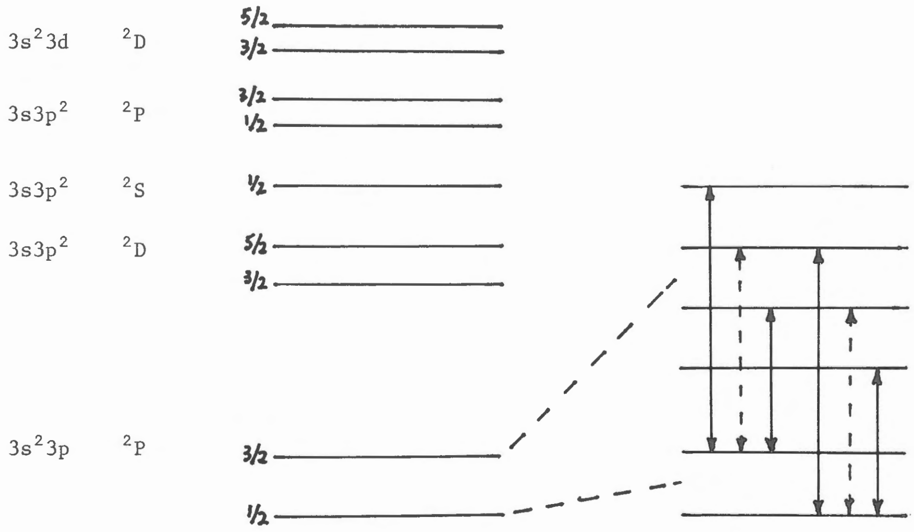

Figure 1. Energy levels of model Fe XIV ion. Details of magnetic sublevels and Zeeman transitions are shown only for the ground configuration.

Table 1.

	Within Ground Configuration	Ground-Excited Configurations
Spontaneous Decay	Krueger and Czyzak (1965)	Blaha (1971)
Radiative Absorption	Radiation Temp. 6275K	Neglected
Electron Excitation	Petrini (1970)	Blaha (1971)
Proton Rates	Landman (1975)	Neglected

Our initial calculations have concentrated on testing the sensitivity of the sublevel populations and emergent polarization to collisions, magnetic field configuration and thermodynamic structure. One of our primary aims has been to improve the efficiency of the calculations which are very time-consuming especially if line of sight integration effects are included. Querfeld (priv. comm.) has recently derived a convenient numerical fit to the solutions of statistical equilibrium equations, giving specifically the sublevel populations of the $^2P_{3/2}$ state of the ground configuration.

The observed polarization is related in a highly non-linear fashion to the three-dimensional coronal structure. The inverse problem of deducing magnetic field directions directly from data poses considerable uniqueness difficulties. The above simplified fit will play an important role in the development of a fast deconvolution method. For the moment, however, we are concentrating on model calculations in order to gain insight into the best way to attack this inverse problem.

3. Goals

It is envisaged that this theory will be used in routine analysis of the HAO/CP green line data to derive the magnetic field structure in coronal features. Since electron densities are required to calculate polarization, the analysis will need to be concurrent with deconvolution of polarization observations in the broad band continuum. A further complication is worth noting: the line polarization is preferentially radial, while the continuum polarization is tangential to the limb.

Our intention is to test directly whether indeed the morphology of dense structures follows the coronal magnetic field and to assess the accuracy of potential field calculations. This program should be quite feasible for long-lived coronal structures. Ideally one would like to be able to measure field directions in coronal transients as well. However, integration times necessary to obtain green line data pose serious difficulties here. Certainly it will be of great interest to study the magnetic structure before and after the passage of a transient.

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