Interstellar Polarization and Magnetic Fields

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Since the work of Davis and Greenstein, polarization of starlight is quite generally considered as one of the most spectacular manifestations of the presence of magnetic fields in the interstellar space. If polarization measurements are qualitatively able to indicate the general pattern of the magnetic fields, a quantitative analysis seems more difficult to work out. A first purpose of this paper is therefore to present a synthetic view of the theory, in order to discuss the relationship between the magnetic field strength and the observed quantities. Using then some recent observations of particular interest, because they correspond to different interstellar physical conditions, it is shown that any attempt to make a quantitative determination of the magnetic field from polarization results remains somewhat hazardous. However, rough estimates and scaling appear possible in some cases.

1. Introduction

Since its discovery in 1951 by Hall /1/ and Hiltner /2/ there have been so many observations of interstellar polarization that it would be somewhat tedious to review them completely. This would also bring us quite far from the general frame of this meeting. Therefore I shall limit my talk to the aspects of the problem which are in some way connected with interstellar fields, and try to answer the question: "what kind of information can we deduce from optical polarization measurements?"

Most of the "first generation" observations have been collected by Mathewson and Ford /3/, and references therein, in order to construct the famous fig. 1, which shows a plot of polarization vectors through the Milky Way. Whether or not it represents the projection on the sky of the general pattern of the Galactic magnetic field(s) is certainly no more an open question, since the fundamental theoretical work of Davis and Greenstein /4/ is now generally accepted. Although there have been several subsequent developments and improvements of the theory, the basic idea has remained the same: a dust grain, elongated or flattened, driven to high rotational speed, will be submitted to a dissipative torque originating in the coupling of its induced magnetic momentum with the external field, and will tend to align its shortest axis of inertia along the field. The grain then scatters (or absorbs) starlight differently following the direction of polarization of the
incident radiation and because the grains are roughly aligned the same way, a net large scale effect is observed. 

Expressing the dependence of optical polarization in terms of the magnetic field appears then as the crucial point from which we can be able to obtain informations about the field direction and strength. I shall therefore devote a great part of my talk to review and summarize the most significant contributions to the theory, starting with Davis and Greenstein initial paper, in order to discuss the relationship between the degree of alignment and the magnetic field.

The second part will review some recent observations of particular interest, namely of individual nearby clouds, because of the probable absence in such circumstances of a significant amount of polarizing material in front of the cloud. Emphasis will also be put on infrared polarization, which is a very promising way to study molecular clouds. The last part will consist in some conclusive remarks about the manner of interpreting polarization in terms of the magnetic field.

2. Theory of Polarization

There are two aspects in the theory of polarization:

2.1. The Optical Theory of Dust Grains

This is a very important field of research, so large that it not possible to review it completely in this paper; furthermore, it would bring us too far from our purpose (see, for more information, Aannestad and Purcell /5/, Wickramasinghe and Morgan /6/, Huffman /7/, Greenberg /8/, Rogers and Martin /9/, Hong and Greenberg /10/, Aannestad and Greenberg /11/, and other references therein). These contributions to the theory, combined with refined observations of optical extinction, polarization, absorption features, infrared emission from grains, and laboratory experiments have led to recent important improvements in the knowledge of dust composition, grain size distribution, grain temperature and other dust properties (Serkowski et al. /12/, Mathis et al. /13/, Aannestad and Kenyon