FUTURE RESEARCH DIRECTIONS: THEORETICAL APPROACH AND PERSPECTIVE

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Abstract:

It is difficult to provide a comprehensive theoretical explanation for the activity of red dwarf stars. Among particular problems that are ripe for further investigation are: the production of steady, cyclic or irregular patterns of activity by nonlinear dynamo action in stars; the effect of magnetic buoyancy in producing photospheric magnetic fields; the formation of isolated flux tubes and their interaction with convection. These topics are discussed and some future lines of research are suggested.

1. THE ROLE OF THEORY IN ASTROPHYSICS

In astronomy, theory is generally led by observations. Even for the sun, where magnetic fields have been observed in great detail over many years, a coherent theoretical description of their structure is only beginning to emerge. The papers presented at this meeting have shown how far theoreticians are from providing an adequate explanation of magnetic activity in red dwarfs. In this review, therefore, I shall attempt to make some general points, and to illustrate them with specific calculations. My choice of topics is somewhat arbitrary, and slanted towards my own interests. I have tried to avoid excessive overlap with other papers in these Proceedings and to focus on the interiors, rather than the atmospheres, of stars. Much of importance is therefore ignored.

It may be helpful to preface these examples with some remarks about the function of theory in astrophysics. I assume that we are dealing with situations where the basic physics is understood (thus we are not, for instance, considering the first $10^{-36}$ seconds after the big bang). The difficulty lies in applying known laws to a particular configuration. To proceed, we have to construct models that are drastically simplified in order to render them mathematically tractable. It is important to distinguish here between two different activities: producing models to

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rationalise the observations and using models to provide a basis for detailed theoretical investigations.

"Modelling" frequently implies the construction of the simplest model that fits the observational data. This is a problem in constrained optimization, shown schematically in the following flowchart.

![Flowchart]

The aim is to find the simplest description that is compatible with the relevant observations, subject to the constraint that some subset of the appropriate laws should be satisfied. For example, one may construct model atmospheres, models of the structure in magnetic loops or models of the flaring process. Such models are obviously important but I shall not discuss them further here.

A more fundamental approach is to introduce models as an aid to understanding physical processes. This leads to an iterative process, as illustrated below:

![Flowchart]

The observations are used to construct a simplified theoretical model, which provides the basis for a properly posed mathematical problem that can be rigorously solved (whether analytically or numerically). The solutions help to improve one's physical understanding and so enable one to improve the theoretical model, thereby generating further (often more complicated) idealized problems and so forth. The success of this procedure depends critically on the interaction between theory and observation. It is vital that theoreticians should listen carefully and sympathetically to observational results but it is also important that observers should appreciate the theoretical significance of their data and organize material so that theoreticians can assimilate it. Above all, effective communication between theoreticians and observers is needed to ensure that new and fruitful observing programs will continue to emerge.