Cosmic magnetic fields in the Sun: Current Outstanding Problems (Invited Review)

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Abstract. In the Sun there has been much progress towards answering fundamental problems with profound implications for the behaviour of cosmic magnetic fields in other stars. A review is given here of such problems, including identifying some of the outstanding questions that remain. In the solar interior, the main dynamo operates at the base of the convection zone, but its details have not been identified. In the solar surface, recent observations have revealed many new and surprising properties of magnetic fields, but understanding the key processes of flux emergence, fragmentation, merging and cancellation is rudimentary. Sunspots have until very recently been an enigma. In the atmosphere, there are many new ideas for coronal heating and solar wind acceleration, but the mechanisms have not yet been pinned down. Also, the detailed mechanisms for solar flares and coronal mass ejections remain controversial. In future, new generations of space and ground-based measurements and computational modelling should enable a definitive physical understanding of these puzzles.

Keywords. Magnetic fields, MHD, sun: corona, sunspots, sun: photosphere.

1. Introduction

There has been a revolution in solar physics over the past 10 years, with many advances that have far-reaching implications for other stars, where similar processes are operating but under different parameter regimes. Major progress has been made on fundamental questions about the nature of the Sun, such as the dynamo generation of its magnetic field, sunspot structure, coronal heating, solar wind acceleration, solar flare and coronal mass ejection origin, but as yet no definitive answers have been given. Here I give a brief overview of this new Sun, referring to the review talks that follow and leaving the listeners to make their own connections to similar phenomena on other stars.

These advances have arisen from a combination of ground-based observations, theoretical and computational modelling, and especially space observations from the following satellites: the Yohkoh mission (1992–2002) which revealed the dynamic nature of the corona; the SoHO mission (1995–...) which viewed the interior and atmosphere; the TRACE satellite (1998–2010) which showed the fine-scale nature of the corona; RHESSI (2002–...) which has been studying high-energy processes in solar flares. More recently, the Stereo spacecraft (2006–...) has built up stereoscopic images of coronal mass ejections from two locations, and the Hinode satellite (2006–...) has studied the connections between photosphere and corona, as described in the talk by Saku Tsuneta (Fig. 1a).

In future, we expect to learn much from the Sunrise mission (see talk by Sami Solanki) and from the Solar Dynamics Observatory (launched in February, 2010), which includes EVE (extreme ultraviolet variability experiment), HMI (heliospheric and magnetic...