IS THERE A WEAK MIXED POLARITY BACKGROUND FIELD?
THEORETICAL ARGUMENTS

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Abstract. A number of processes associated with the formation of active regions produce ‘U-loops’: fluxtubes having two ends at the photosphere but otherwise still embedded in the convection zone. The mass trapped on the field lines of such loops makes them behave in a qualitative different way from the ‘omega-loops’ that form active regions. It is shown that U-loops will disperse though the convection zone and form a weak (down to a few gauss) field that covers a significant fraction of the solar surface. This field is tentatively identified with the inner-network fields observed at Kitt Peak and Big Bear. The process by which these fields escape through the surface is described; a remarkable property is that it can make active regions fields apparently disappear in situ. The mixed polarity moving magnetic features near sunspots are interpreted as a locally intense form of this disappearance by escape of U-loops.

1. Introduction

Figure 1 shows two ways in which two patches of opposite magnetic polarity can be connected below the solar surface. The ‘omega-loop’ configuration is the familiar geometry of active region fields emerging from a toroidal flux tube buried within the convection zone. The second, ‘U-loop’ configuration can arise in a number of ways, as discussed below. An important property of the U-loop is that the mass on the field lines is ‘trapped’. Whereas an omega-loop can break through the surface quickly by draining mass down the legs, U-loops are not able to leave the Sun until some more subtle process removes the mass from its field lines (Parker, 1984).

Since the mass on the U-loop is isolated, it must eventually come into temperature equilibrium with its surroundings (if it did not start its life in equilibrium already), due to radiation leaking in. It is then magnetically buoyant and as it starts rising, the loop expands laterally in response to the declining density of the surroundings, and its field strength decreases. Unless the loop is formed very close below the surface, the large decrease in density through the convection zone implies very low field strengths in those parts of the loop that manage to reach the surface.

The granulation and supergranulation acting on this weak field introduce smaller length scales into the field, thereby enhancing the magnetic diffusion rate, and allowing...
some mass to leave the field lines. Since very small length scales have to be present for the diffusion to become effective, U-loops leaving the Sun must necessarily have the characteristics of a weak, mixed polarity field. If U-loops are created in significant quantities during the solar cycle, they will, therefore, produce a weak, mixed polarity background field that could cover large parts of the surface. This idea is worked out somewhat in the next sections, where possible relations with the 'inner network fields' (Smithson, 1975; Livingston and Harvey, 1975; Martin, 1987), the apparent in situ disappearance of fields (Wallenhorst and Topka, 1982; Simon and Wilson, 1985; Wilson and Simon, 1983; Wilson, 1987), and the moving magnetic features around sunspots are pointed out.

2. Processes That Form U-Loops

2.1. MULTIPLE ACTIVE REGIONS FORMING ON A SINGLE TOROIDAL FLUX TUBE

In Figure 2 this situation is sketched. It shows an active region, newly erupted from a flux tube at the base of the convection zone, next to the dispersed field of an earlier active region on the same flux tube. The part of the flux tube between the old and the new region is a U-loop. The distance between the two 'ends' of the loop could be considerable, and the field of the older active region could already be widely dispersed, so that the connection between the two regions would not at all be obvious at the surface. The field of this loop, if brought to a depth of 500 km (density $10^{-6}$), would be about 3 G (see Section 3).