SMALL MAGNETOSTATIC FLUX TUBES

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In an attempt to interpret the observed properties of small scale magnetic fields at the solar surface, a set of models has been calculated based on the assumption of a magnetostatic equilibrium. The basic assumptions made are:

i. The observed magnetic elements are magnetostatic flux tubes.
ii. The efficiency of convective heat transport inside the tube is reduced with respect to that in the normal convection zone; the *horizontal* convective heat transport in the tube is suppressed completely by the magnetic field.
iii. Close to the tube, horizontal convective heat transport is reduced due to the proximity of the magnetic field.

In addition to these assumptions, a number of approximations has been made in the calculations:

1. Energy transport (both by radiation and by convection) is described by a diffusion process with anisotropic, inhomogeneous coefficients. The diffusion coefficients are fixed in advance, taking into account some of the properties (notably the Wilson depression) of the expected solution.
2. The tube is axially symmetric, perpendicular to the solar surface.
3. The magnetic field of the tube is a potential field, bounded by a current carrying outer surface.
4. The heat flux inside the tube, flowing from the deeper layers to the surface, is specified; it is estimated by comparison with the flux of large tubes (sunspots). (This is necessary, because the mechanism of heat transport in a magnetic field is not known sufficiently to derive the appropriate diffusion coefficients theoretically).

The consequences of the magnetostatic character of the tubes shown by these models, are:

a. The tube shows a Wilson depression, like a sunspot does. The value (z_w) depends on the magnetic field strength (at a specified level), and (indirectly) on the radius of the tube. For a given field strength, z_w increases with the radius (R) of the tube.

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Some representative cases are:

Facular point (R = 50 km, B = 1700 G): z_w = 90 km
Pore (R = 500 km, B = 2000 G): z_w = 260 km

b. Because the interior of the tube is more transparent than the normal convection zone, heat flows laterally into the tube. The depth range over which this influx is important is somewhat larger than z_w. The amount of influx depends on the details of the assumed convective heat flow in the convector close to the tube, on the Wilson depression and on the radius of the tube. If the ratio $2R/z_w$ is of the order of unity, the influx can be comparable in magnitude to the normal solar flux through an area corresponding to the cross section of the tube

c. Through the lateral influx effect, small tubes channel an additional heat flux through the solar surface, i.e. the lateral influx is not a completely local effect; it also taps the heat reservoir of the whole convection zone. Representative values of the additional heat flux F_e caused by the tube (averaged over its cross section) are:

Facular point: $F_e \approx 0.6$
Pore $F_e \approx 0.15$
(spot $F_e \approx 0.0$)

d. Geometrical (projection) effects dominate the CLV of the tubes seen in the continuum. Seen near the solar limb, the walls of the tubes can contribute strongly to the contrast of the observed features. The temperature of the wall is not large (5900-6200 K), but near the limb the wall looks bright compared to the ambient photosphere because its radiation has a different angular dependence. The models suggest that this effect may explain the strong CLV of faculae in the continuum.

e. In spectral lines which are formed at a height higher than $h \approx z_w$ above the continuum, the wall effect (see above: d) is much smaller, because the temperature difference between the tube and its surroundings decreases rapidly with height. The CLV in moderately strong lines, therefore, is expected to be much weaker than in the continuum. This fact may indicate an explanation of the observed behaviour of facular contrast in lines.

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