PROPAGATION OF AN MHD SHOCK IN THE VICINITY OF A MAGNETIC NEUTRAL SHEET

D. J. Mullan
Bartol Research Foundation of the Franklin Institute, University of Delaware, Newark, DE 19711, and
R. S. Steinolfson
University of Alabama, PO Box 1247, Huntsville, AL 35807

The acceleration of solar cosmic rays in association with certain solar flares is known to be highly correlated with the propagation of an MHD shock through the solar corona (Svestka, 1976). The spatial structure of the sources of solar cosmic rays will be determined by those regions of the corona which are accessible to the flare-induced shock. The regions to which the flare shock is permitted to propagate are determined by the large scale magnetic field structure in the corona. McIntosh (1972, 1979) has demonstrated that quiescent filaments form a single continuous feature (a "baseball stitch") around the surface of the sun. It is known that helmet streamers overlie quiescent filaments (Pneuman, 1975), and these helmet streamers contain large magnetic neutral sheets which are oriented essentially radially. Hence the magnetic field structure in the low solar corona is characterized by a large-scale radial neutral sheet which weaves around the entire sun following the "baseball stitch". There is therefore a high probability that as a shock propagates away from a flare, it will eventually encounter this large neutral sheet.

In a study of small-amplitude MHD waves, Uchida (1973) used ray-tracing techniques to show that such waves are refracted away from (towards) regions of high (low) Alfven speed. Although these results cannot be immediately applied to the present problem (in which the thickness of the neutral sheet is too small to satisfy the ray-tracing criterion) they suggest that a neutral sheet should act as a wave-guide, allowing essentially no transmission across the neutral sheet to the other.

In our work, we studied the encounter between a finite amplitude wave and a neutral sheet, using the two dimensional MHD code described by Steinolfson et al. (1978) in which the solar atmosphere is treated as a single fluid of polytropic index γ. Radiation is neglected, and there is no dissipation (except at shocks). As an initial state, we neglected solar gravity. For purposes of calibration, we first impose a uniform radial magnetic field over the entire computational grid. A pressure pulse is introduced at time t=0 at the equator, on the solar surface, and a shock wave sweeps out in two dimensions. After a time of order 500 seconds, we take a radial cut of the pressure variation at two lat-

M. Dryer and E. Tandberg-Hanssen (eds.), Solar and Interplanetary Dynamics, 323-326.

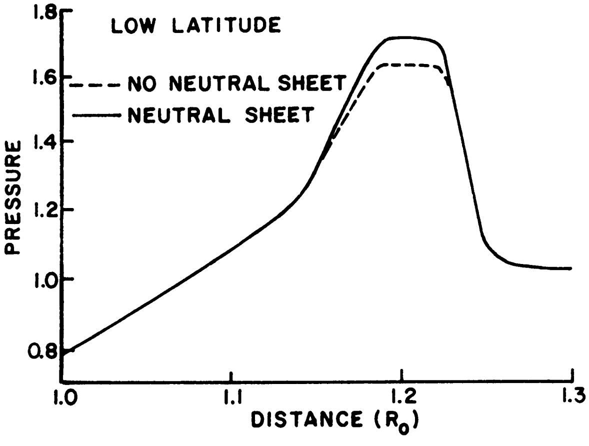

Figure 1

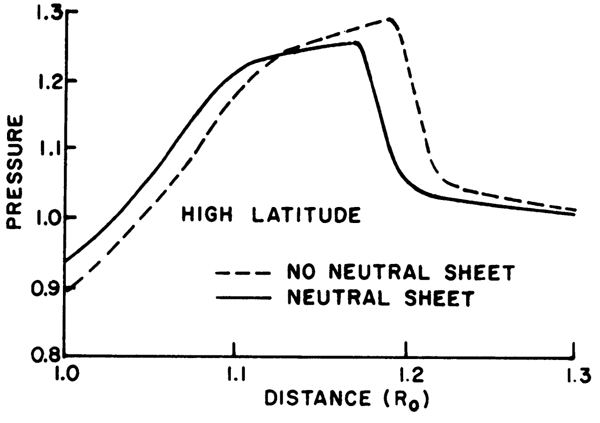

Figure 2

Figures 1 and 2. Variation of gas pressure as a function of radial distance at two latitudes. These curves have been derived by taking constant-latitude cuts through a two-dimensional flow field at a time t $\approx$ 500 seconds after the "flare". The flare occurred on the surface of the sun (1.0 R_0) at low latitudes. Figure 1 represents a cut at a latitude which lies between the flare and the neutral sheet: notice that the presence of the neutral sheet strengthens the shock in this region. Figure 2 is a cut at a latitude which lies beyond the neutral sheet, remote from the flare site: notice that the shock in this region is weakened when the neutral sheet is present.

itudes, one at "low" latitudes, the other at "high" latitudes (dashed lines in Figures). Here, "low" and "high" are taken with reference to latitude θ_o where the radial neutral sheet is to be located. We then inserted a neutral sheet at constant latitude θ_o. The magnetic field was taken to be uniform and directed outward from the sun at low latitudes, and uniform and inward at high latitudes. A smooth variation of field through zero was chosen, spread out over 12 grid points in latitude. To preserve equilibrium in the neutral sheet, the gas density was allowed to increase over the same grid points. Temperature was assumed to remain uniform at all points. Again, the same pressure pulse was inserted, and the pressure wave was followed. Radial cuts at the same two latitudes as before showed that the shock is strengthened at low latitudes, and weakened at high latitudes (solid lines in Figs. 1 and 2). The weakening of the shock at high latitudes is due partly to reflection of the shock off the density enhancement associated with the neutral sheet, and partly to dissipation of the shock in the neutral sheet. An examination of the temperature contours shows significant heating within the neutral sheet compared with the temperature which prevails at the same locations in the absence of the neutral sheet.

The weakening of the transmitted shock partially confirms our expectations based on Uchida's earlier work, although the neutral sheet does not block the transmission of the shock completely. Quantitative evaluation of transmission efficiencies in different regions of parameter space is currently underway.

The work of RSS was supported by NASA under Contract NAS8-33216 and by NOAA under Contract NOAA/04-78-B01-6. The work of DJM is partially supported by the National Science Foundation under Grant ATM-7820936. Acknowledgment is made to the National Center for Atmospheric Research, which is sponsored by the National Science Foundation, for the use of its computing facilities.

REFERENCES

McIntosh, P. A. 1972, Rev. Geophys. Spa. Sci. 10, p. 837.
McIntosh, P. A. 1979, paper presented at IAU Symp. No. 91, Cambridge Mass., August.
Pneuman, G. W. 1975, in IAU Symp. No. 57 (ed. G. Newkirk) [Dordrecht: Reidel] p. 35.
Steinolfson, R. S., Wu, S. T., Dryer, M., Tandberg-Hanssen, E. 1978, Ap. J. 225, p. 259.
Svestka, Z. 1976, Solar Flares (Dordrecht: Reidel).
Uchida, Y. 1973, in High Energy Phenomena in the Sun (eds. R. Ramaty and R. G. Stone) [Washington: NASA SP-342), p. 577.

DISCUSSION

Rosenau: (Comment) The effect that you have described is not a new one and in fact it is merely a composition of two well known phenomena: (a) shock moving in a decreasing magnetic field (like your case) is decelerated; (b) shock moving into increased density zone is weakened. Therefore, this work must be evaluated as a quantative treatment of these effects.