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RADAR OBSERVATIONS AND THE EXTENT OF CORONAL HEATING

A recent paper in this *Journal* (James 1966) contains the results of a radar investigation of the corona at 38 Mc/s. The purpose of this brief communication is to note that the radar measurements appear to have delineated the extent of coronal heating, and that the result found is in good agreement with the extent of heating deduced from coronal densities.

James (1966) reports that velocities as high as 150 km/sec are always observed at the 38 Mc/s reflecting level in the corona and notes that the cause could be bulk motions of plasma and/or some type of wave motion. He further finds a substantial slowing down of velocities at about 1.6 $R_\odot$ and points out that a slowing down is incompatible with a bulk motion of the solar wind type; hence, James concludes "that at least part of the echo may be reflected from wave-motion irregularities such as shock-wave fronts."

Any steady-state interpretation of velocities as high as 150 km/sec at the 38 Mc/s reflecting level encounters severe difficulties with the equation of continuity. The 38 Mc/s reflecting level is located at approximately 1.5 $R_\odot$ with an electron density of some 2×10^7 electrons/cm^3; a velocity of 150 km/sec at this level would imply a density of about 400 electrons/cm^3 at the orbit of Earth—a result which is close to two orders of magnitude above currently accepted mean values (e.g., Neugebauer 1966).

Thus, the velocities must result from some type of wave motion such as hydromagnetic shocks, and I follow James (1966) in suggesting that these shocks are responsible for coronal heating; if this is true, then the slowing down at 1.6 $R_\odot$ should be identified with effective termination of the deposition of mechanical energy and the heating of the corona.

This conclusion is strongly supported by the results of an entirely independent investigation. Brandt, Michie, and Cassinelli (1965) were able to combine the equation of continuity, the equation of motion, the first law of thermodynamics, and empirical density determinations in the corona and directly determine the amount of mechanical energy deposition required for maintenance of the corona as a function of distance. In all cases considered, Brandt *et al.* (1965) find that energy deposition effectively ceases at 1.6 $R_\odot$, and that the sharp decrease occurs in the range 1.3–1.4 $R_\odot$ to 1.6 $R_\odot$; the agreement with James' radar results is striking. A similar but less detailed result has also been obtained by Noble and Scarf (1963).

Thus, a fairly reliable limit for the extent of coronal heating of 1.6 $R_\odot$ is indicated by the two independent methods. This is a useful requirement for distinguishing among the various detailed heating mechanisms and, when included in future theoretical discussions, should contribute to the longstanding problem of coronal maintenance. The former possibility may have already occurred because the results of Wentzel and Solinger (1967) indicate that dissipation of shocks in the corona must begin within 0.5 $R_\odot$ of the solar surface; this is in contradistinction to the assumptions used in the treatment by Bird (e.g., 1965).

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REFERENCES

Bird, G. A. 1965, *Ap. J.*, **141**, 1455.
Brandt, J. C., Michie, R. W., and Cassinelli, J. P. 1965, *Icarus*, **4**, 19.
James, J. C. 1966, *Ap. J.*, **146**, 356.
Neugebauer, M. 1966, Jet Propulsion Lab. Rept. No. 32-991.
Noble, L. M., and Scarf, F. L. 1963, *Ap. J.*, **138**, 1169.
Wentzel, D. G., and Solinger, A. B. 1967, *Ap. J.*, **148**, 877.