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AUTHOR(S): K. Lee, C. H. Aldrich, S. J. Bame, D. W. Forslund, S. P. Gary,  
J. T. Gosling, K. B. Quest, M. F. Thomsen, D. Winske, & M. M. Mellott

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**Los Alamos** Los Alamos National Laboratory  
Los Alamos, New Mexico 87545

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## INVESTIGATION OF LAMINAR SHOCKS

K. Lee, C. H. Aldrich, S. J. Bame, D. W. Forslund, S. P. Gary,  
J. T. Gosling, K. B. Quest, M. F. Thomsen, D. Winske  
Los Alamos National Laboratory  
Los Alamos, NM 87545 USA

M. M. Mellott  
U. of Iowa, Iowa City, IA 52242 USA

Abstract: Studies of laminar shocks based on ISEE observations of terrestrial bow shocks, simulation, and theory are presented.

### 1. Observations

We report several investigations of subcritical (laminar) shocks, motivated by high time resolution data of electron and ion distributions across quasiperpendicular terrestrial bow shocks from the ISEE-1 and 2 spacecraft.<sup>1-3</sup> Contrary to the conventional wisdom that at subcritical shocks the bulk of the energy dissipation occurs as resistive heating of the electrons, the observations show that the ion temperature increase exceeds that of the electrons. The increase in the ion temperature is typically a factor of 10-20, predominantly in the perpendicular direction, and due to heating of the entire distribution rather than the formation of a high energy tail. The electron temperature increases by only a factor of about two, equal to that of the magnetic field jump, and remains fairly isotropic, while the downstream electron distribution exhibits the characteristic flat top seen also at supercritical shocks. An example of such a laminar shock is given in Fig. 1, which shows the plasma parameter profiles for the shock crossing at 2105 UT on 27 August 1978.<sup>3</sup> Plotted are the logarithms of the density (solid curve from electron measurements, symbols from the ion measurements) and the maximum and minimum values in the diagonalized ion and electron temperature matrices. The vertical lines indicate the location of

the ramp in the magnetic field profile. The upstream ion measurements were made with the ISEE-1 solar wind ion instrument; all other measurements were obtained with the ISEE-2 Fast Plasma Experiment. In this case the electron temperature increase across the shock is a factor of 2.5, while the ion temperature increase is 10.

## 2. Simulations

These observations are interpreted as evidence for the possible operation of various plasma instabilities in the shock layer, which are being investigated by means of computer simulation. To study the effect of short wavelength (ion acoustic) modes, simulations with the explicit particle code WAVE have been initiated. The simulations are initialized with uniform upstream and downstream states consistent with Rankine-Hugoniot relations, with plasma continuously injected at one end to maintain the shock. One-dimensional calculations show that a stationary state can be maintained for long periods of time in this manner. In this case cross-field instabilities cannot be excited, and the shock forms by reflecting some ions. Two-dimensional calculations are in progress. In order to study the effects of longer wavelength, lower hybrid (modified two stream and lower hybrid drift) instabilities, simulations with the implicit particle code VENUS have also been conducted, similar to previous calculations for supercritical shocks.<sup>4</sup> However, such lower hybrid instabilities (ion acoustic modes are not resolved) are not strongly excited; rather, a small amount of ion reflection occurs. In this case the shock is created by the piston, which may be giving some extra dissipation in the downstream region.

## 3. Theory

The damping of whistlers observed as precursors standing upstream of laminar shocks has also been addressed.<sup>5</sup> Results of a linear Vlasov analysis show that electron Landau damping can

attenuate oblique whistlers with damping lengths that are the same order of magnitude as those observed. Figure 2 shows an example of such calculations, the ratio of damping rate to real frequency ( $\gamma/\omega_r$ ) as a function of propagation angle for one value of the wavevector ( $kc/\omega_1=5.0$ ). The figure indicates that the determining parameter is the electron beta ( $\beta_e$ ), that the relative rate of damping increases with  $\beta_e$ , and that  $|\gamma|/\omega_r$  is maximum over a definite range of  $\theta$  (roughly  $50^\circ < \theta < 80^\circ$  for the parameters used here).

#### 4. Summary

We have presented results of various studies of laminar shocks: an analysis of ISEE observations which show strong ion heating of subcritical terrestrial bow shocks, preliminary results of particle simulations to understand the microscopic processes which give rise to such heating, and theory which explains the damping of whistler precursors.

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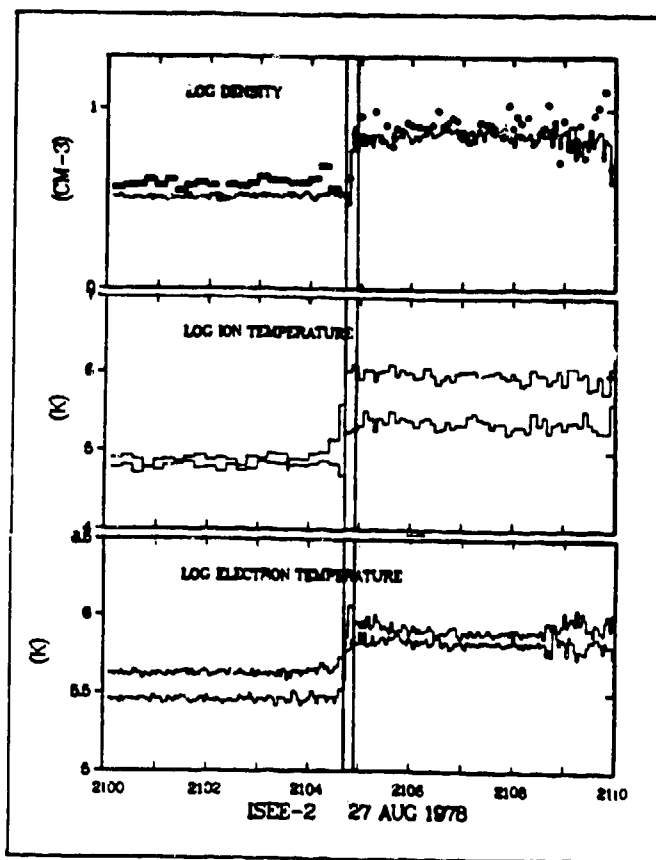


FIGURE 1

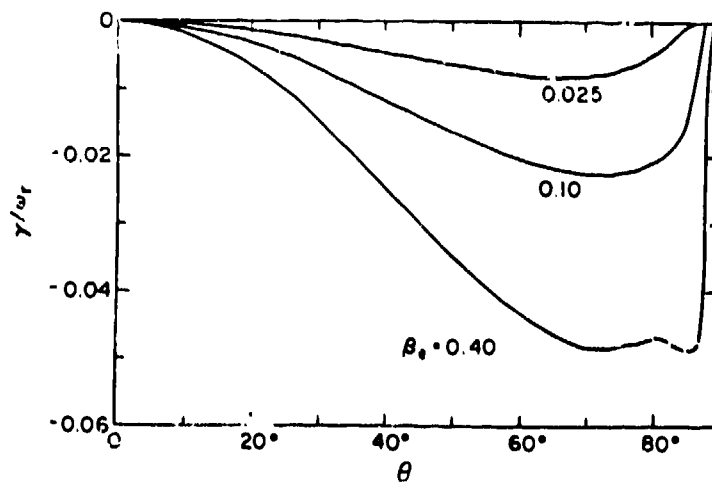


FIGURE 2