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FINAL REPORT

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from

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RESEARCH RELATIVE TO PLASMA TRANSPORT ACROSS THE MAGNETOPAUSE

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to the reconnection assumptions by assuming a constant electric field in our magnetospheric model. In Figure 4 we have traced a 1 keV proton; the view in the equatorial plane shows the behavior expected for an eastward current, while the other view in the magnetic meridian shows a poleward motion, in conformity with reconnection theories. This shows that our tracing routine does in fact work correctly. We have also calculated the energy of the proton, and it does indeed gain energy (to 2.5 keV).

3. Tracing particles with electric field reversal at the magnetopause.

Next, we assumed an electric field profile which reverses sign of the E_y component at the magnetopause. Now we find that the particle does cross the magnetopause current sheet, as in Figure 5a; there is very little displacement in the meridian plane, Figure 5b. Because both fields are reversed in the boundary layer, $\underline{V_E} = \underline{E} \times \underline{B}/B^2$ remains earthward. The particle gains energy, because now it is similar to earthward convection in the plasma sheet on the nightside.

The work is still in progress, since it is a very difficult topic, and goes against the prevailing traffic. An invited paper will be delivered at the Chapman Conference on Solar Wind-Magnetospheric Coupling to be held at JPL, Feb. 12-15, 1985. We had hoped that we could have included a copy of this paper in this report. It will point out several features of this work.

a) The electric field must have a curl locally, so that stored magnetic energy can be tapped; our model does have this curl.

b) As the plasma particles cross the current layer, they first gain some energy, but they quickly lose all, or most, of it; this agrees with the finding by Eastman and Hones (1979) that the energy spectrum of the plasma particles shows hardly any difference on the two sides of the magnetopause.

c) The energization of the particles as they convect inward in the magnetospheric boundary layer may explain the observed spectral changes as reported by Reiff et al. (1977).

d) Because the net energy (or loss) gain will be small, the total dissipation by the magnetopause current will not be as high as predicted by reconnection theories, agreeing with the observations.

e) This model does agree with the ISEE-1 /2 observations on momentum changes, as reported by Sonnerup et al. (1981), and so their conclusion (that the reconnection model is the correct one) is not valid. We must look at energy changes as well to differentiate between the two models.

f) The frozen-in theorem does not hold, nor should it. The theorem does hold away from the magnetopause, but within the current layer both the necessary length and time scales are not satisfied. The magnetopause can be regarded as a sink of magnetic flux on one side, and a source on the other.

g) This model, with an inductive electric field with a finite electromotive force, can be incorporated in a theory of Flux Transfer Events (FTE).

Magnetotail

We have important new ideas on the magnetotail, and especially, on the interpretation of ISEE-3 data in the distant tail. However, we have had no opportunity to do the work on this grant, partly due to slow access to the data. These new ideas are explained in our newest proposal for a Guest Investigator on ISEE, submitted in October, 1984 (UTD #850025) and will be presented in another invited paper at the Chapman Conference on the Magnetotail, to be held at JPL, October 28-31, 1985.

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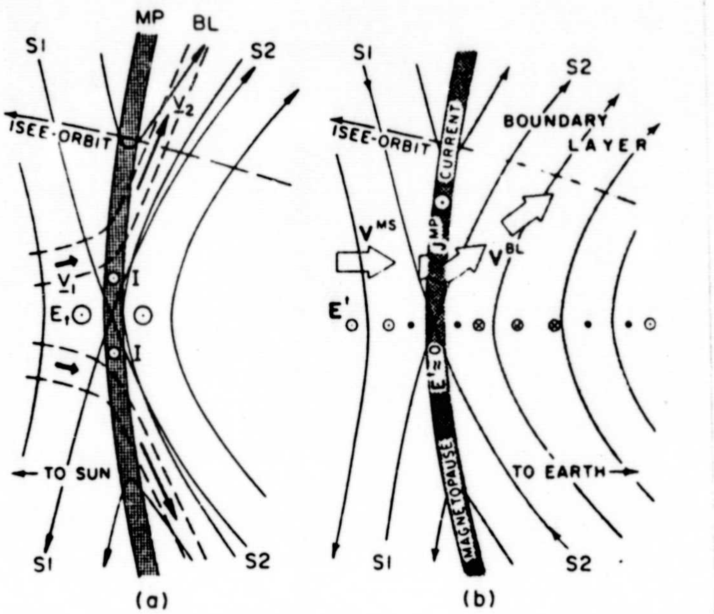

Fig. 1(a) Dungey's model of the dayside magnetopause. The J x B force produces a jet of plasma on open field lines, and a positive J . E implies power dissipation of about 5 x 10^{11} watts over the entire frontside magnetopause.

Fig. 1(b) Heikkila's model with the same magnetic field topology, but with the tangential electric field reversing direction. The J x B force also produces a jet of plasma, but this time toward closed field lines. Here J x E is positive on one side, but negative on the other; the current perturbation can be regarded as a dynamo followed by a load.

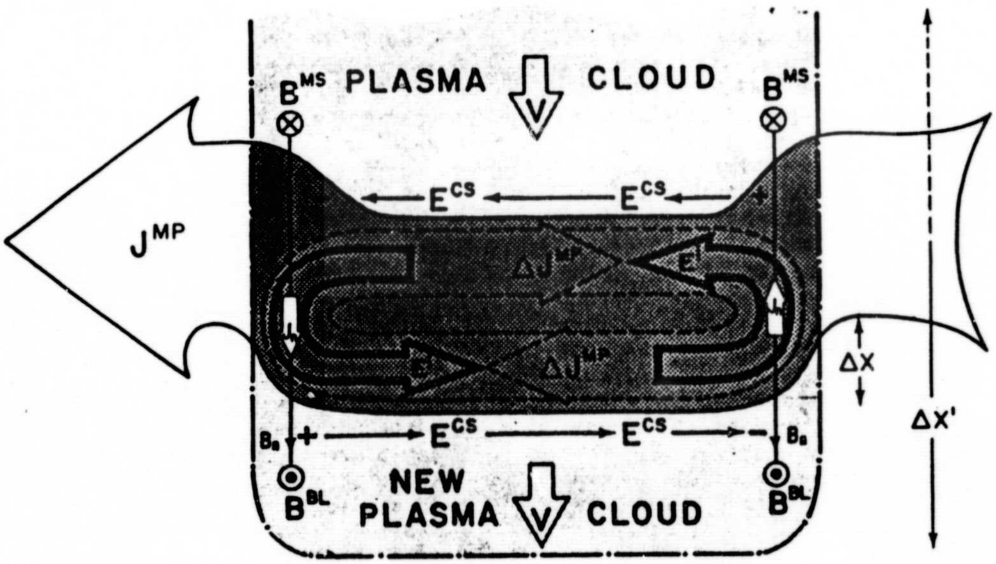

Fig. 1(c) Impulsive penetration is produced by an electrostatic field due to a charge distribution created by an induction electric field. Charged particles from the old plasma cloud go through the current sheet along B_n and form a new plasma cloud on closed magnetic field lines.

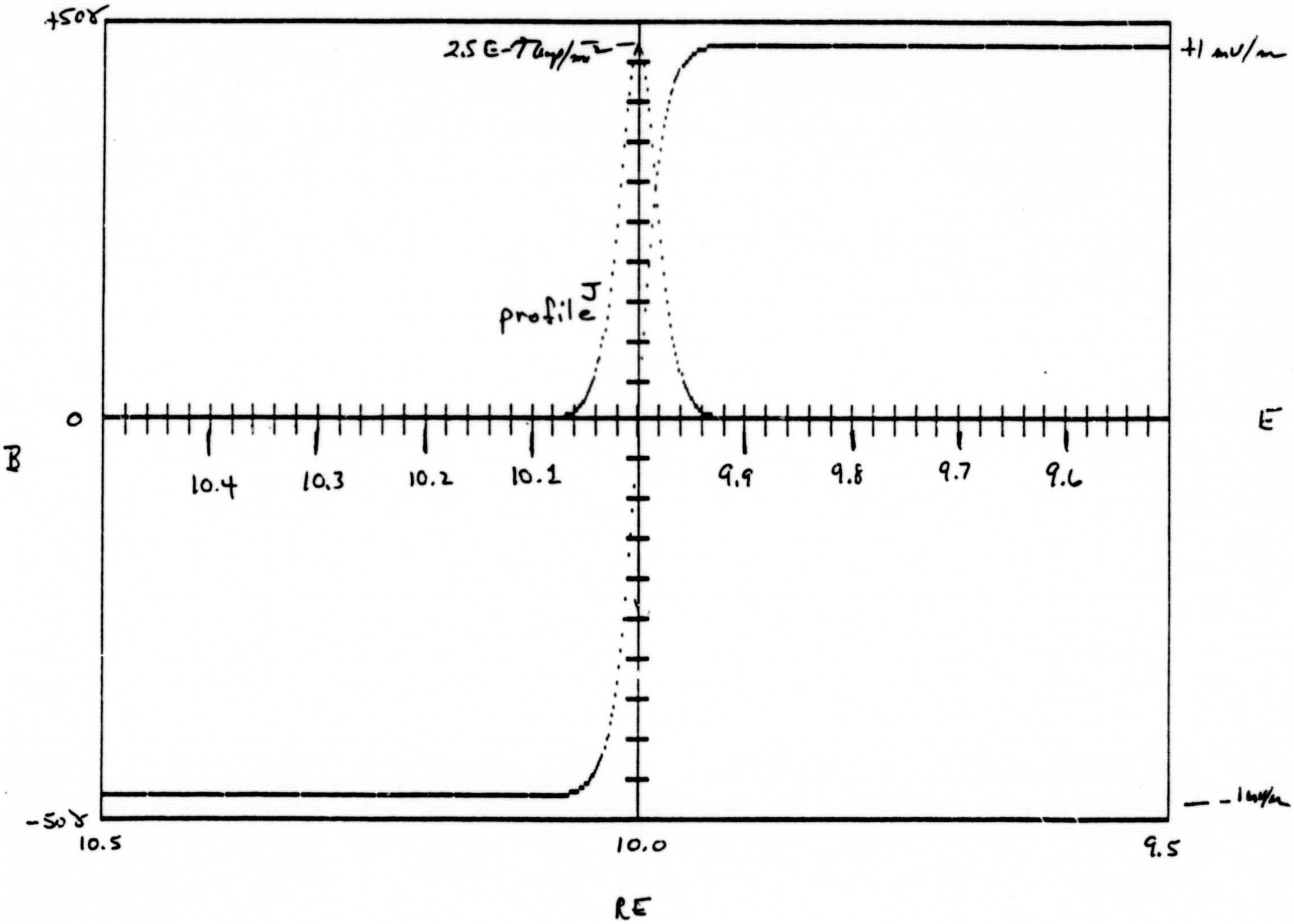

Fig. 2. Magnetopause current J profile and the resulting magnetic field, as a function of distance in earth radii R_e.

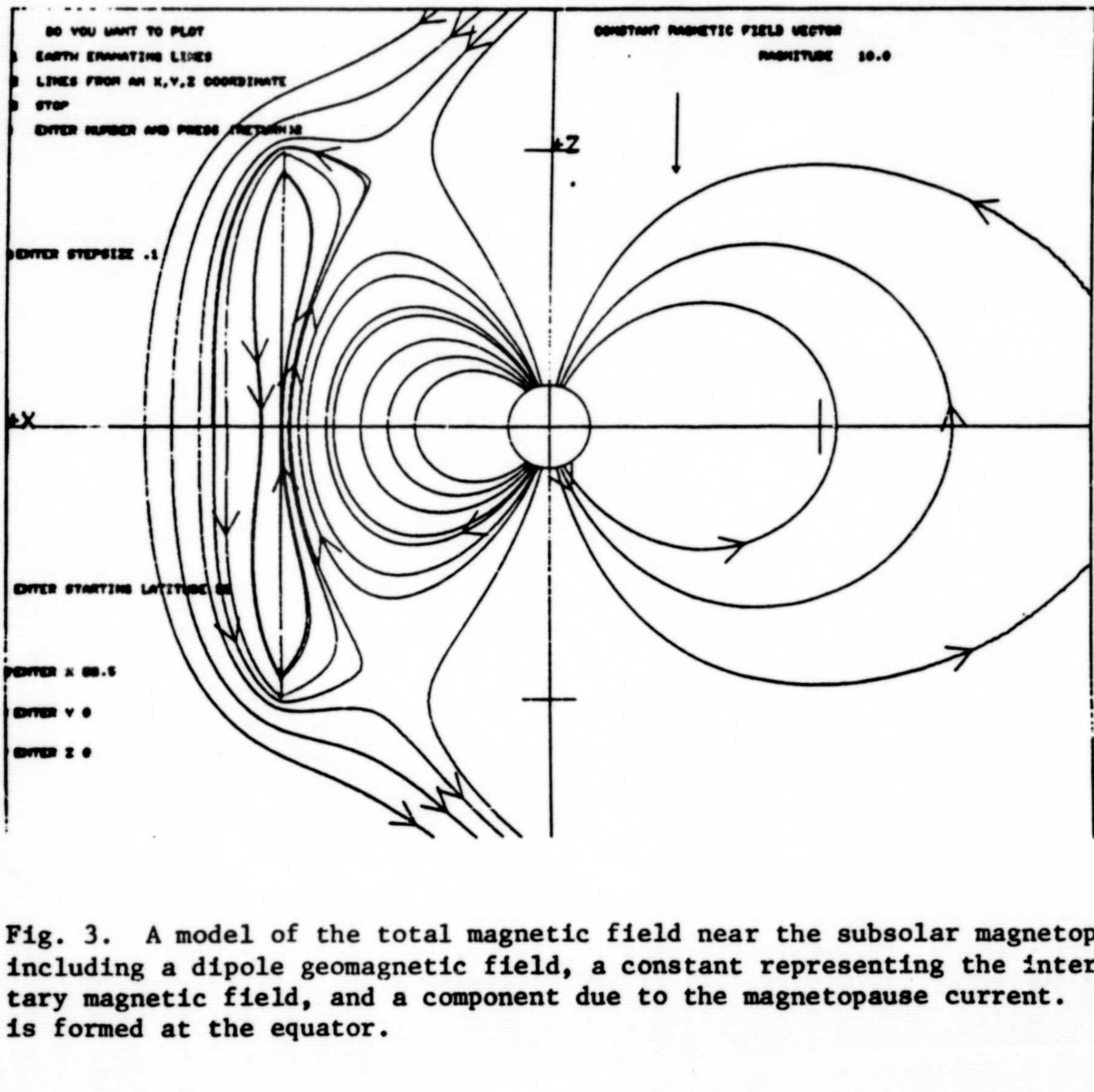

Fig. 3. A model of the total magnetic field near the subsolar magnetopause, including a dipole geomagnetic field, a constant representing the interplanetary magnetic field, and a component due to the magnetopause current. An x-line is formed at the equator.

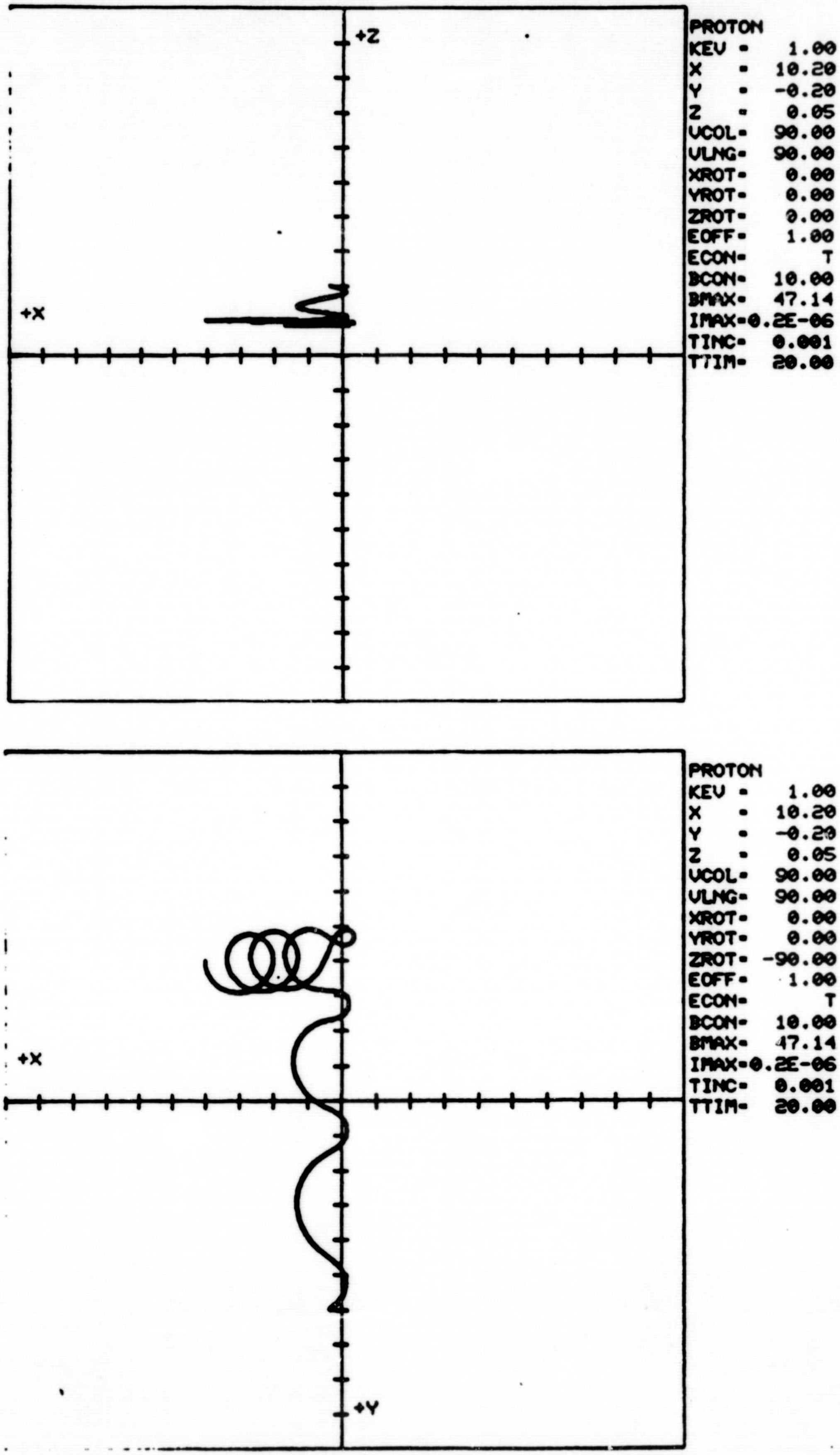

Fig. 4. Tracing of proton motion, with an initial energy of 1 keV. The upper curve shows poleward movement, in agreement with two-dimensional reconnection theories shown in Fig. 1(a); the lower curve shows that the main movement is, in fact, along the magnetopause contributing to the eastward current, and is associated with energization (indicated by the larger gyrations).

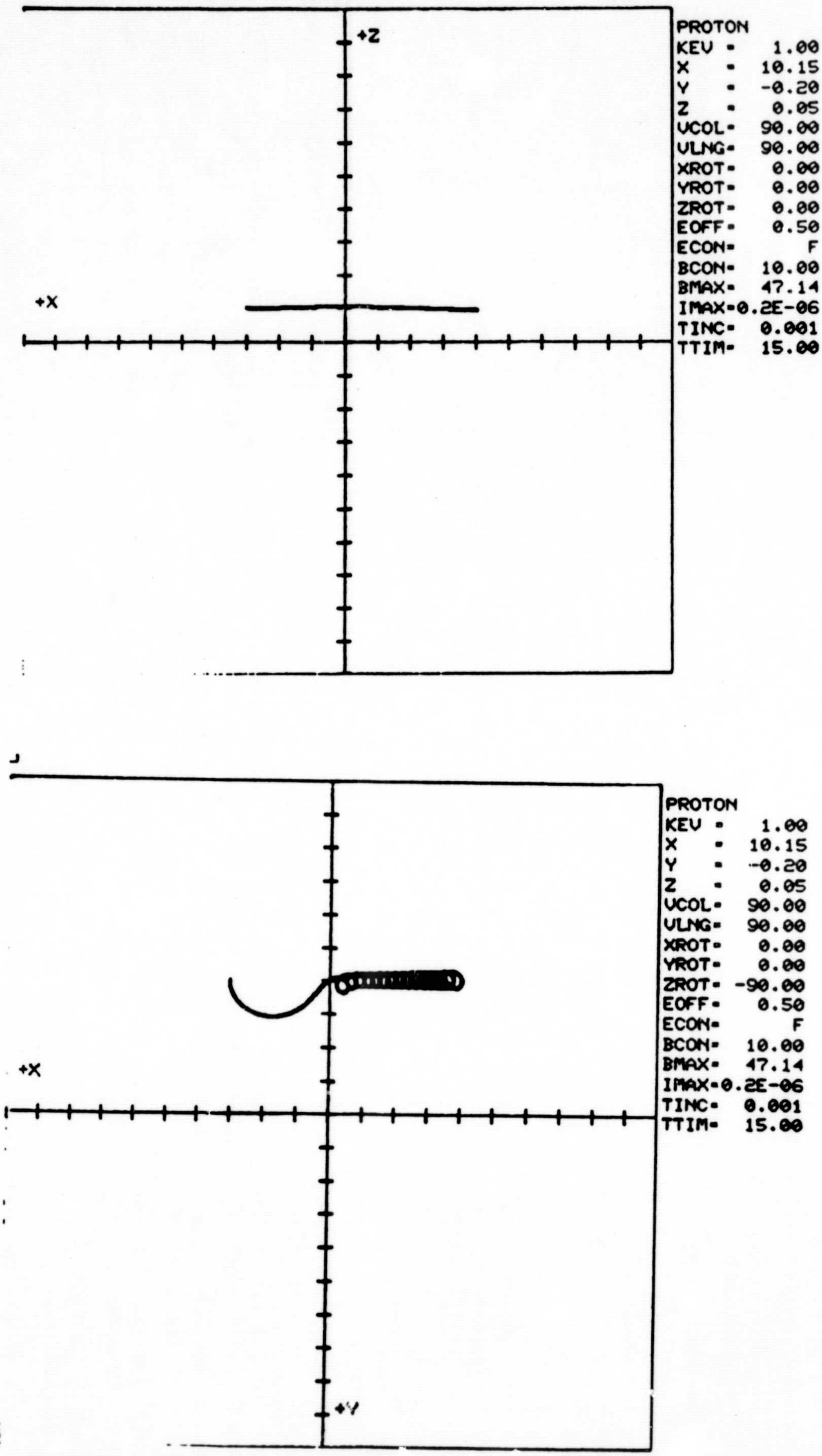

Fig. 5. Tracing of 1 keV proton with an electric field that reverses at the magnetopause, as in Fig. 1(b) and (c). Now the proton crosses the magnetopause, going into the low latitude boundary layer. The assumed electric field has a finite curl, and full consideration requires a three-dimensional viewpoint, as indicated by Fig. 1(c).

The concept of how magnetosheath plasma can cross the magnetopause (Heikkila, 1982) has been one of the key elements for a truly global view of the magnetosphere (Heikkila, 1983). According to this view, viscous interaction is the main process to produce convection of plasma in the magnetotail, resulting in auroral phenomena, and other related processes. The mechanism is illustrated in Figure 1. The key element here is that the electric field is not constant, as assumed in reconnection theories, but reverse within the magnetopause current sheet. A paper was read at the Chapman conference on Magnetic Reconnection (Heikkila, 1984), included with report, showing the implications of this model.

The main accomplishment of the work done under this grant has been to trace particles, representing magnetosheath ions, as they impinge upon the magnetopause.

1. Model of the magnetosphere.

Three kinds of magnetic fields are incorporated, these being a dipole geomagnetic field, an external interplanetary field, and fields due to current sheets carried by the plasma. The latter can include a cross-tail current, as well as a magnetopause current. For the work described below, a magnetopause current was included, as shown in Figure 2. The combined magnetic field lines are shown in Figure 3; the topology does include an X-line in the sub-solar region.

2. Tracing particles with the reconnection model.

Reconnection theories are based upon an electric field that is assumed to be constant near the X-line, pointing toward dusk. Since the magnetopause current also points in the same direction, $\underline{E} \cdot \underline{J}$ is positive, implying an energy dissipation of 10^{11} to 10^{12} watts (Heikkila, 1975). So far, there is still no conclusive evidence that this dissipation is observed, which is why we are seeking alternative models. However, we can trace particles (ions) appropriate