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MAGNETOSPHERIC CUTOFF FOR 1.5-MeV EXTRATERRESTRIAL PROTONS*

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A study over the geomagnetic polar regions of the arrival of extraterrestrial low-energy protons during a period of low geomagnetic activity is important both for a physical description of the distant magnetosphere and for understanding the ionization of the upper atmosphere over the polar regions by solar flare protons. Investigations below ~20 MeV have been possible only recently with detectors on polar orbiting satellites. Pieper, Zmuda, and Bostrom[1] and Zmuda, Pieper, and Bostrom[2] reported some results obtained prior to the sudden commencement (SC) of magnetic storms. During the pre-SC observations, proton fluxes greater than 200 cm^{-2} sec^{-1} sr^{-1}, integrated over the 1.5- to 15-MeV energy interval, were measured up to ~78° geomagnetic latitude. They found these protons arriving down to ~65° geomagnetic latitude. However, the wide energy interval and the lack of a sharp cutoff made the interpretation of this threshold latitude difficult.

We report here some results from an oriented satellite whose orbit passed over the geomagnetic pole carrying detectors sensitive to 1.5-MeV protons from both the vertical and horizontal directions and insensitive to electrons. On 19 September 1961 the 1.5-MeV proton flux was of order 10 cm^{-2} sec^{-1} sr^{-1}, far below the flux levels where collective particle motions could be important. It is shown that protons of approximately 2 MeV arrive with full intensity down to a geomagnetic latitude of 65°, whereas Stoermer theory predicts their cutoff at approximately 75°. Since it has been generally assumed that protons of 50 MeV (Stoermer cutoff), and in no case less than 15 MeV, represented the lowest energy protons arriving down to 65° from interplanetary space during undisturbed periods of the geomagnetic field, these results clearly indicate the importance of re-examining present models of the geomagnetic cutoff mechanism and point to a revision in the energy range of solar-flare protons associated with cosmic radio noise absorption.

The basic instrument was a telescope composed of two Au-Si surface barrier detectors, one behind the other. An aluminum collimator defined an acceptance cone with a half-angle of 65°. Details of the telescope design have been published.[3] One telescope (V) was oriented in the vertical direction, with another telescope (H) in the horizontal direction as shown in Fig. 1. The count rates presented here will be those of the front detector of the V telescope (1.4 to 4.4 MeV) and the front detector of the H telescope (1.1 to 6 MeV). This instrument was carried by Discov-

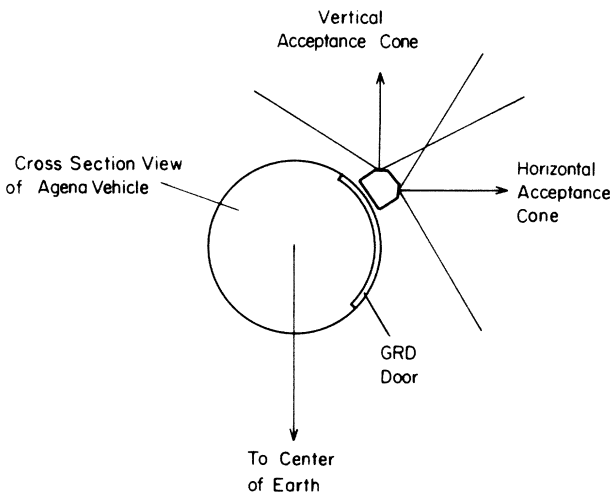

Fig. 1. Cross-section view perpendicular to the vehicle velocity axis, oriented as shown with respect to the earth. The view angles of the two solid-state detector telescopes are shown.

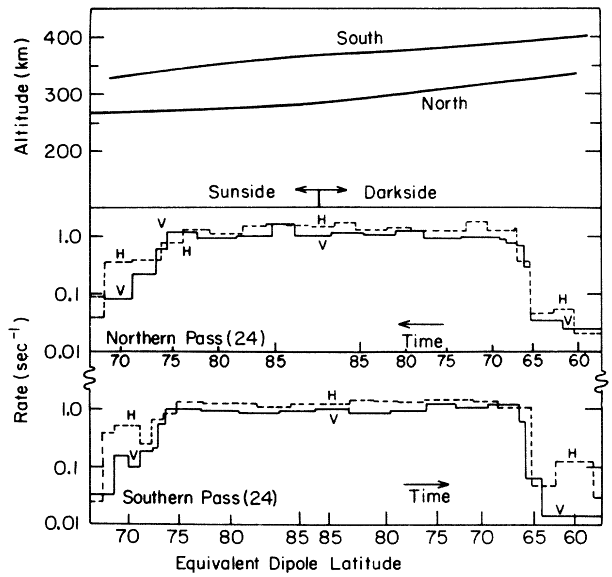

Fig. 2. Proton counting rates are shown for two consecutive polar passes and for both the vertical (V) and the horizontal (H) directions. The counting rate errors are ± 12 %.

erer XXXI into a low-altitude (300 kilometer) polar orbit on 17 September 1961. Data from many north and south polar passes have been studied. Figure 2 shows data from 19 September 1961 which were selected as an example to show the special case of consecutive passes almost directly over the north and south poles. There is an abrupt transition between the low-latitude background (mostly alpha-particle events from uranium used to check instrument performance) and the solar proton flux, which is essentially constant over the entire polar region. This indicates they could not be trapped protons. In addition, the count rates of the V and H telescopes, when adjusted for the different thresholds and for the geometrical correction to account for allowed pitch angles, are consistent with a flux isotropic over the upper hemisphere. Note that the transition in counting rate is more abrupt for the side away from the sun direction (dark side) than for the sun side. The latitude to reach full intensity is ~ 5° higher on the sun side. The vertical and horizontal transition latitudes are quite similar. These results are typical of all polar passes. This proton flux was simultaneously detected at >10 earth radii (R_e) by Bryant et al.[4] in Explorer XII. Thus, it is almost certain that the protons were of solar flare origin.

The count-rate data from the rear detectors of both telescopes (6 to 8 MeV) indicate a differential energy spectrum of $\sim E^{-2.5}$, so that the front detector count rate is to be assigned to the lowest detectable energy, namely 1.5 MeV. Cahill[5] found that the geomagnetic cavity was undisturbed at this time out to more than $12R_e$. Since the lines of magnetic force at 65° cross the equator at less than this distance, these results are for a relatively undisturbed geomagnetic field. Therefore, the observed cutoff energy of 1.5 MeV at ~ 65° is to be compared with the expected proton cutoff energy of at least 15 MeV. This discrepancy, and the diffuse cutoff on the sun side, are likely to arise from the interaction of the solar wind with the magnetosphere. The local time dependence of these non-Stoermer cutoff latitudes and their significance for a geomagnetic cutoff theory have been investigated by Stone[6] using the data from more than 30 polar traversals.

The authors are indebted to the Laboratories for Applied Sciences for the construction of the instrumentation, and to Dr. A. Tuzzolino and Mr. M. Perkins for the preparation of the gold-silicon detectors. The difficult data reduction was carried out by The Enrico Fermi Institute cosmic-ray group. The authors were especially grateful to Dr. L. Katz and Mr. D. Smart of the Cambridge Geophysical Research Directorate, and to the Livermore Laboratory staff for the flight arrangements and for assigning data channels on the in-flight tape recorder to our experiment. One of us (E. C. S.) thanks the National

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LIQUID HELIUM AS A BARRIER TO ELECTRONS*

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To explain the properties of extraneous electrons in liquid helium, three models have been proposed. These are as follows: (1) The electron is associated with a density maximum produced by electrostrictive forces.[1] (2) The electron is located in a self-formed cavity which serves to reduce its zero-point energy.[2,3] (3) The electron is essentially free, with an effective mass on the order of the electronic mass.[4]

In this Letter an experiment is described which indicates that liquid helium appears as an energy barrier of more than one electron volt to electrons.[5] This appears to represent decisive evidence in favor of model (2), the only one of the three consistent with this result.

The experimental chamber is shown schematically in Fig. 1. The electrons are supplied by a dc discharge ion source. A fraction of the electrons pass through the central hole in electrode 2 into the bottom chamber, where the interaction with the liquid surface is investigated by measurements made at electrodes 3 and 4. Electrode 3, which is shielded by dielectric ring *S*, is positioned half-way between electrodes 2 and 4, both spatially and in potential, so the applied field may be as uniform as possible. Holes in the bottom electrode allow both the liquid level and temperature in the chamber to be in equilibrium with the outer bath. The chamber may be raised and lowered in the Dewar to position the electrodes relative to the liquid surface.

A qualitative demonstration of the surface barrier effect may be made as follows. The chamber is lowered until the helium level is near the top of shield *S*. With several hundred volts between electrodes 2 and 4 and the electron source on, no electron current is detectable[6] at either electrode 3 or 4. The electron source is turned off at this stage and the system left undisturbed while the liquid level drops as the helium evaporates. When the helium level reaches the bottom of the shield (up to 10 minutes after the electron source has been turned off), a large negative current pulse is recorded at electrode 3. The pulses for long

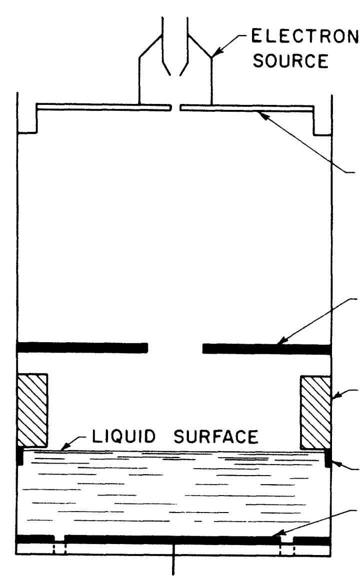

FIG. 1. The experimental chamber.