from the $2P$ orbit is smaller than the s-wave capture from the $2P$ orbit by a factor $\gtrsim 7$. Much more data on (K^-, p) collisions in flight will be necessary to make the above estimate reliable.

The non-spin-flip amplitude of the p-wave capture process can interfere with the s-wave capture process in the calculation of the probability of formation of the (Σ^-, n) compound. Unfortunately, not enough is known experimentally so as to determine whether this interference is constructive or destructive. Experimentally, Tripp[2] reports no (Σ^-, n) compounds out of 49 events of the type $K^- + d \rightarrow \Sigma^- + n + \pi^+$. The analysis presented here indicates that this experimental result does not as yet exclude the possibility that a (Σ^-, n) bound state exists. Hence a continued, intensive search for such a compound is indicated.

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*Supported in part by the U. S. Atomic Energy Commission, while one of the authors (G. A. S.) was in residence at the University of Wisconsin.

[1]A. Pais and S. Treiman, Phys. Rev. 107, 1396 (1957), hereinafter referred to as PT.

[2]R. D. Tripp, 1958 Annual International Conference on High-Energy Physics at CERN, edited by B. Ferretti (CERN, Geneva, 1958), p. 184.

[3]Jackson, Ravenhall, and Wyld, Nuovo cimento 9, 834 (1958).

IONIZATION OF THE UPPER ATMOSPHERE BY LOW-ENERGY CHARGED PARTICLES FROM A SOLAR FLARE

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Excess ionization of the upper atmosphere at high latitudes following solar flares has been observed on several occasions during the International Geophysical Year, through studies of the absorption of cosmic radio noise. One such event, discussed in this note, occurred on July 29, 1958 following the class 3 solar flare at 03:03 UT.[1] The recordings of the 27.6-Mc/sec cosmic noise received on this date at Thule, Greenland and Barrow and College, Alaska are reproduced in Fig. 1. Identical receiving equipments, consisting of riometers[2] connected to wide beam, vertically-directed Yagi antennas, were used at each station. The dashed curve on each trace shows the strength of the cosmic noise signal that would have been received under undisturbed conditions. The computed values of absorption in decibels are also shown on the respective recordings.

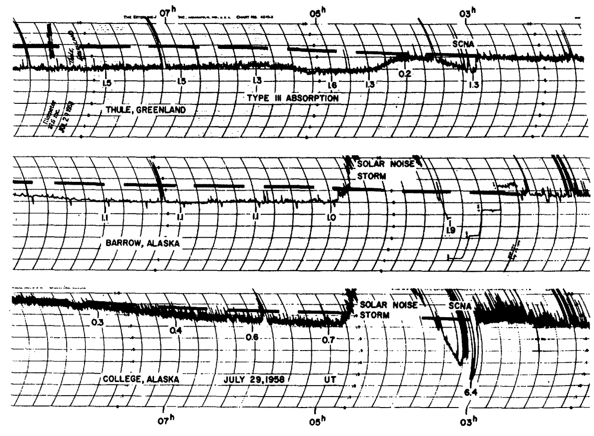

FIG. 1. Cosmic noise absorption on July 29, 1958. The dashed curves show the cosmic noise signal received under quiet conditions at each station; the computed values of absorption in decibels are shown for representative times. A constant amount of interference is present on the Barrow recording and has been included in the Barrow quiet-day curve (the actual cosmic noise level can be seen during the half-hour keying tags of the interfering transmitter).

The sudden cosmic noise absorption (SCNA) coincident with the visible flare is evident on the College and Thule recordings. The Barrow equipment was being calibrated at this time. The SCNA is known to be the result of ionization of the D region by the enhanced ultraviolet and x-ray flux from the flare. The difference in magnitude of the SCNA at College and Thule is a reflection of the greater solar zenith angle at the latter station ($\chi = 83.5°$ at Thule and $\chi = 73.5°$ at College during the peak of the SCNA).

A very intense 27.6-Mc/sec solar noise storm was recorded at College and Barrow which obscured the recovery of the SCNA at those stations. This noise storm was not seen at Thule, through a fortunate combination of large solar zenith angle and orientation of the antenna, which placed the sun in a null of the beam pattern. Thus it is possible to follow the recovery of the SCNA at Thule, and we find that the absorption had decreased to about 0.2 db by 04^{h} UT.

Approximately sixty-five minutes after the onset of the SCNA the absorption again increased at Thule. We interpret this increase as arising from ionization of the upper atmosphere by charged particles originating at the sun at the time of the flare. On this assumption is is possible to obtain the penetration depth and magnetic cutoff latitude of the particles, assuming them to be protons. For example, using Bailey's Fig. 4,[3] we find that protons traveling in Störmer orbits from the sun to the earth in 65 minutes would have an anergy of 10 Mev, a penetration depth of about 67 km, and a magnetic cutoff latitude of 72 degrees.[4]

The inferred penetration depth is consistent with the observed absorption. The absorption in decibels is proportional to the product of the electron density and the electron collisional frequency, integrated throughout the absorbing region; it can be shown[5] that only a small number of incoming protons penetrating to between 60 and 70 km would be required to produce the observed absorption.

Both Barrow and College also show the post-SCNA absorption. The duration of the absorption at Barrow was similar to that at Thule; however, the absorption at College was weak and decreased rapidly. The riometer at Farewell, Alaska (250 miles southwest of College) showed no post-SCNA absorption. We therefore conclude that College was close to the cutoff latitude. In Table I we have given both the geomagnetic latitude and the dip-pole "latitude" of each of the stations. We have arbitrarily defined the latter quantity as the complement of the angular separation between the station and the north magnetic dip-pole. The presence of absorption at College, and the similarity of the event at Thule and Barrow with regard both to duration and magnitude, indicate that the particles were influenced by a field more nearly like the dip-pole field than the dipole field. This conclusion is consistent with the observation[6] that the cosmic ray equator corresponds more nearly to the dip equator than to the dipole equator.

Table I. Magnetic latitudes of IGY riometer stations.

Station	Geomagnetic latitude[a]	"Dip-pole" latitude[b]
Thule	88.0°	81.9°
Barrow	69.0°	74.8°
College	64.9°	71.8°
Farewell	61.6°	68.4°

[a]Coordinates of geomagnetic pole taken as 78.6°N, 70.6°W.

[b]Coordinates of dip-pole taken as 76°N, 102°W. A field concentric with the earth was assumed for these computations.

Two general approaches to the problem of the long duration of the post-flare absorption, seen in this event at both Barrow and Thule (at least 22 hours at both stations) are possible: (a) the absorption may be due to a continuing bombardment of the atmosphere by particles of the correct energies, or (b) the duration may be a consequence of unusually slow recombination processes in the absorbing region. Bailey[3] has used the latter approach in treating the February 23, 1956 event; however, the question still seems open at this time.

Three other examples of high-latitude absorption of cosmic noise following solar flares, called Type III absorption by Reid and Collins, have been published. Little and Leinbach[7] gave the College data for the February 23, 1956 event; Reid and Collins[5] discuss two similar events observed at Churchill, Manitoba in July and October, 1957.

We conclude that observations of the absorption of 27.6-Mc/sec cosmic radio noise can be used to detect the presence of low-energy particles originating at the sun during solar flares. The cosmic noise technique is most sensitive to those particles which penetrate to heights of between 90 and 50 km, corresponding to proton energies of the order of 1 to 30 Mev. Ionization by these particles can be observed at stations located at magnetic latitudes of greater than about 68 degrees.

The authors wish to express their thanks to the field station operators, Mr. A. R. Franzke at Barrow, Mr. Harvey Seabrook at Farewell, and the Air Force IGY team at Thule, for the successful operation of the IGY riometers. Establishment of the field stations has been made possible by the National Science Foundation through IGY contracts 6.20 and 1.43. One of us (H.L.) is indebted to Dr. C. G. Little for many helpful discussions of cosmic noise absorption.

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[1]Preliminary Report of Solar Activity, TR-361, High Altitude Observatory, Boulder, Colorado.

[2]A description of the IGY riometers (relative ionospheric opacity meters) is scheduled for publication in the Proc. Inst. Radio Engrs. The cosmic noise technique has already been discussed. C. G. Little and H. Leinbach, Proc. Inst. Radio Engrs. 46, 334 (1958).

[3]D. K. Bailey, J. Geophys. Research 62, 431 (1957).

[4]We have not as yet given any detailed consideration to the possible existence of localized impact zones for

this particular event.
[5]G. C. Reid and C. Collins, J. Atmos and Terrest. Phys. (to be published).
[6]J. A. Simpson, Geophysical Monograph No. 2 (American Geophysical Union, Washington, D. C., 1958), pp. 65-70.
[7]C. G. Little and H. Leinbach, Proc. Inst. Radio Engrs. 46, 334 (1958).

γ_5-INVARIANCE AND STRONG INTERACTIONS

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The study of the weak interactions has shown that parity conservation is not a universal law. It rather seems that only the conservation of CP is strictly valid.[1] In addition there is now much evidence that the weak interactions possess a typical invariance, which is called the γ_5-invariance or chirality invariance. It states that the interaction Hamiltonian for weak interactions is invariant under the transformation $\psi \rightarrow \gamma_5 \psi$ for each spinor particle involved. This invariance automatically leads to a four-fermion interaction of the form V-A.[2-4] It should be pointed out that the electromagnetic interaction also has this chirality invariance and one may state that the nonexistence of a direct anomalous magnetic moment coupling of bare elementary particles with the electromagnetic field is a special consequence of this law.

The purpose of this note is to discuss the possibility of extending the γ_5-invariance to strong interactions. At first sight this seems impossible since parity conservation is well established for nucleon-nucleon and nucleon-pion interactions.[5-7] The γ_5-invariance requires the nucleon-pion interaction Lagrangian density to be of the form

$$\mathcal{L}_{\mathrm{int}} = \frac{f_\pi}{m_\pi} \tfrac{1}{2}\, \bar{\psi} i \gamma_\mu (1+\gamma_5) \vec{\tau} \psi \cdot \frac{\partial}{\partial x_\mu} \vec{\phi}. \tag{1}$$

The symbol ψ stands for the nucleon wave function, $\vec{\phi}$ for the π-meson field, and the arrows refer to isotopic spin components. It is easily seen, however, that the vector part of this interaction gives no contribution in zeroth order by virtue of the continuity equation and hence no effects of parity nonconservation can occur in this order.

This fact suggests a generalization of (1). Let us write the baryon-pion interaction Lagrangian density in the form

$$\mathcal{L}_{\mathrm{int}} = \frac{f_\pi}{m_\pi}\left(\vec{j}_\mu + \vec{j}_\mu{}^A\right) \cdot \frac{\partial}{\partial x_\mu} \vec{\phi}, \tag{2}$$

where $\vec{j}_\mu{}^A$ denotes an axial vector current. This interaction should be determined in such a way that $\vec{j}_\mu$ occurring in (2) is identical to the total isotopic spin vector current following from the Lagrangian and hence obeys the continuity equation

$$\frac{\partial}{\partial x_\mu} \vec{j}_\mu = 0. \tag{3}$$

The idea of a coupling with the total current is similar to the Feynman–Gell-Mann hypothesis that total currents are coupled in weak interactions.[4] Since in the present case, however, the current is obtained from the interaction itself, a "self-consistent" procedure is necessary. The explicit form for $\mathcal{L}_{\mathrm{int}}$ which fulfills the conditions (2) and (3) is

$$\mathcal{L}_{\mathrm{int}} = \frac{f_\pi}{m_\pi} Q\{\vec{j}_\mu{}^0 + \vec{j}_\mu{}^A\} \cdot \frac{\partial}{\partial x_\mu} \vec{\phi}. \tag{4}$$

The operator Q is defined through its operation on any isotopic-spin vector $\vec{X}$ by

$$Q\{\vec{X}\} = \frac{1}{1+(f_\pi/m_\pi)^2 \phi^2}\left(\vec{X} + \frac{f_\pi}{m_\pi}[\vec{\phi}\times\vec{X}] + \frac{f_\pi{}^2}{m_\pi{}^2}\vec{\phi}(\vec{\phi}\cdot\vec{X})\right). \tag{5}$$

$\vec{j}_\mu{}^0$ denotes the isotopic spin vector current for free fields. The relative coefficients of its different parts are determined from the requirement of isotopic spin invariance of the Lagrangian.

$$\vec{j}_\mu{}^0 = \tfrac{1}{2}\bar{\psi} i\gamma_\mu \vec{\tau}\psi + [\vec{\bar{\Sigma}} \times \gamma_\mu \vec{\Sigma}] + \tfrac{1}{2}\bar{\Xi} i\gamma_\mu \vec{\tau}\Xi + \pi\text{- and } K\text{-meson currents.} \tag{6}$$

The γ_5-invariance requirement which we want to impose on (4) determines now the axial vector current $\vec{j}_\mu{}^A$ uniquely. Thus the relative baryon-pion coupling constants are given by the coefficients appearing in (6).

The continuity equation which follows from the new Lagrangian automatically assures that the interaction Lagrangian density, Eq. (4), can be replaced by an effective interaction with a pure axial vector coupling. Hence parity remains