mesons to the nucleon anomalous moments. These results will be published in a separate note.

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Suggestion Concerning the Nature of the Cosmic-Ray Cutoff at Sunspot Minimum

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UNDER quiet solar conditions near sunspot minimum, no cosmic rays with magnetic rigidity less than ~1.5 Bev appear to reach the earth.[1,2] An attempt to explain this cutoff as arising from a solar magnetic field of dipolar form was made many years ago by Janossy.[3] The solar magnetic moment demanded by this explanation is too high, however, by a factor ~10 to be in accord with the modern solar magnetic measurements of Babcock and Babcock.[4] The present note offers a suggestion for explaining the cutoff, not in terms of a solar field, but of an interstellar magnetic field, the possible importance of which has been noted by Davis.[5]

Two main steps are concerned in the following argument, one a consideration of the magnetic field of the earth and the other a consideration of the interstellar field. Both these issues are concerned with the diffuse gas that probably exists in interplanetary space.[6] The density of the gas in the neighborhood of the earth is usually set[7] at $\sim 10^{-21}$ g/cm^3. With the gas mainly composed of hydrogen atoms, this density corresponds to $\sim 10^3$ atoms/cm^3. Since a considerable fraction of the atoms appears to be ionized, there must be a strong interaction between the gas and the terrestrial magnetic field. The interaction must produce a gross modification of the earth's field at distances away from the earth where the magnetic energy density is less than $\frac{1}{2}\rho v^2$, ρ being the gas density and v the streaming velocity relative to the earth. That is to say, there must be a gross modification of the earth's field at and beyond a distance where the magnetic intensity is of order $(4\pi\rho v^2)^{\frac{1}{2}}$. With $\rho \simeq 10^{-21}$ g/cm^3 and $v \simeq 30$ km/sec, this gives an intensity $\sim 3\times10^{-4}$ gauss, and the terrestrial field falls to such an intensity at a distance of about 10 earth radii. Beyond this distance gross modification from a dipolar form of field must occur. It is emphasized that the general orders of magnitude appearing in this result are quite insensitive to the particular values chosen for ρ and v—the distance in question being proportional to $\rho^{\frac{1}{6}}$ and to $v^{\frac{1}{3}}$.

The question now arises as to what form the modification will take. Two possibilities seem to exist. If the lines of force of the terrestrial field extend outwards into the gas beyond about 10 earth radii, they will be twisted and contorted by the motion of the gas, the nature of the deformation depending on the detailed flow of the gas. The other possibility is that the lines of the earth's field close up within a distance of ~10 earth radii and that they do not penetrate outwards beyond this distance and are then not subject to violent deformation. In this case, any gas that is present within a distance of order 10 earth radii will have its motion controlled by the terrestrial field; it will move along with the earth around the sun and it will rotate with the earth. Of these two possibilities the second seems the more likely, although a strict proof appears difficult. In what follows, the second possibility will be assumed.

Turning now to the interstellar gas, it is at once apparent that cosmic rays within the interstellar gas cannot reach the neighborhood of the earth unless the interstellar gas itself approaches close to the earth—at any rate this is so if the magnetic field within the gas has an intensity comparable with the average value of order 10^{-5} gauss that is currently supposed. Thus, for example, a proton of energy 10 Bev moves around the lines of force of a field of intensity 10^{-5} gauss in a circle with radius close to 3×10^{12} cm. Unless the interstellar gas approaches within this distance of the earth, or unless the interstellar magnetic field happens to be much less than 10^{-5} gauss in the vicinity of the solar system, such a particle cannot reach the earth; it remains "attached" to the interstellar magnetic field which it cannot leave. Since a distance of 3×10^{12} cm is small compared with the dimensions of the solar system and since an exceptionally weak field in the vicinity of the solar system seems implausible, it is reasonable to conclude that the interstellar gas penetrates the solar system. Accordingly the interplanetary gas apparently cannot be derived wholly from the sun as some authors have supposed, unless the cosmic rays are wholly of solar origin which again seems unlikely.

One point remains before the main conclusion is reached. The value of 10^{-5} gauss usually quoted for the interstellar magnetic field refers to the average situation within the interstellar medium. In particular, it refers to a gas density of order 10^{-24} g/cm^3. Any compression of the interstellar gas by the gravitational field of the sun must increase the magnetic intensity, an isotropic compression causing an increase by the two-thirds power of the gas density. Thus if we regard the interstellar gas as supplying a major contribution to an interplanetary gas density of order 10^{-21} g/cm^3, the enhancement of the magnetic intensity by compression is likely to be of order 10^2, yielding a field $\sim10^{-3}$ gauss.

Recapitulating the various points of the above argument, it is plausible to suppose that the earth's field becomes closed at a distance from the earth of about 10 radii. At this distance we pass from a terrestrial field of order 3×10^{-4} gauss to a magnetic field derived from the interstellar medium, the latter probably having an intensity of a similar order.

The question now arises as to whether a cosmic-ray particle initially attached to the lines of force of the interstellar field can make a transition to the lines of force of the earth's field, which it must do if it is to reach the surface of the earth. A reasonable criterion for such a transition to be possible is that the radius of the orbit of the particle be comparable with, or greater than a distance $\sim$10 earth radii. With an interstellar magnetic intensity $\sim10^{-3}$ gauss, the least proton energy that satisfied this criterion is $\sim$1 Bev. Although no reliance can be placed on exact numerical values, it is clear that the cutoff provided by the present considerations agrees in order of magnitude with the observed cutoff.

No attempt can be made within the scope of this Letter to discuss modifications that might be produced by streams of particles and perhaps by cosmic rays ejected from the sun. It is believed, however, that such events can be fitted into the above scheme in a satisfactory way.

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Mass Difference between the Σ^+ and Σ^- Hyperons and the Mass of the K^- Meson*

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In a systematic study of 900 K^- stars found in emulsion by area scanning, two events were found which are interpreted as the capture of K^- mesons at rest by hydrogen. One event produced a Σ^+ hyperon and the other a Σ^- hyperon, via the following reactions:

$$K^-+p\rightarrow\Sigma^++\pi^-+Q_1, \qquad (1)$$

$$K^-+p\rightarrow\Sigma^-+\pi^++Q_2. \qquad (2)$$

The principal basis for interpreting these two events as captured in hydrogen is the collinearity of the Σ hyperon and the π meson. In the first case (event 788), the Σ^+ hyperon and the π^- meson tracks have a dip of only 5° and therefore the collinearity could be tested with some precision. The two tracks were found to be collinear within one-half of a degree, which is about the precision of the measurement of the dip angle. The projected angle was measured to be 180° to within 10′. In the second case (event 818) the dip angle of the Σ^- hyperon and the π^+ meson is 37 degrees. The hyperon and the π meson were found to be oppositely directed within 0.4 ± 1.0 degree. The projected angle was found to be 180° 12′±15′.

It might be argued that these two events may be the capture of a K^- meson in a heavy element with an invisible recoil, and that the collinearity is due to a chance coincidence. An estimate of the probability of finding one such event out of 900 stars is about 2×10^{-2}.[1] This probability is further reduced because in general the range of the Σ hyperon from a nonhydrogen capture will be substantially different from that in a hydrogen capture. The absence of Auger electrons in both events is consistent with hydrogen captures.

In the first case (event 788), the Σ^+ hyperon decayed from rest into a proton of range 1609 ± 23 microns. The range of the proton from the Σ^+ hyperon is strong evidence that the Σ^+ hyperon decayed from rest. The range of the Σ^+ hyperon was found to be 804 ± 5 microns. Using these data, one can proceed in either of two ways: if the mass of the K^- meson is assumed to be that of the K^+ meson, the mass of the Σ^+ hyperon can be found; or if the known mass[2] of the Σ^+ hyperon is used, the mass of the K^- meson can be determined. Since the Σ^+ hyperon mass has been measured to a greater precision than the K^- meson mass, we take the latter approach. Using the range-energy relationship of Barkas,[3] the energy of the Σ^+ hyperon is found to be 13.87 ± 0.16 Mev, where the mass of the Σ^+ hyperon is taken to be 2327.4 m_e. The error in the energy of the Σ^+ hyperon includes the uncertainties due to straggling and variations in stopping power. The kinetic energy of the π meson is then calculated to be 89.5 ± 0.8 Mev. The Q_1 of reaction (1) is 103.4 ± 1.0 Mev. The mass of the K^- meson is then 966.7 ± 2 m_e.[4] This mass measurement agrees very well with previous K^--meson mass measurements.[5] The equivalence of the mass of the K^- meson and the mass of the τ^+ meson[6] (966.1 ± 0.7 m_e) confirms the hypothesis that the K^- meson is the charge conjugate of the K^+ meson.

In the second case (event 818) the Σ^- hyperon track travels into an adjacent pellicle, and stops after a total range of 670 ± 15 microns. The Σ^- hyperon does not produce a visible star at the end of its range but there appears to be a short track of a low-energy electron, suggesting the capture of a negative particle. The energy of the Σ^- hyperon is 12.5 ± 0.2 Mev assuming