prominent brows. Numerous complete skeletons of men belonging to the Cro-Magnon race have been found in Aurignacian layers. Human remains from the Upper Perigordian are generally fragmentary, as are those from the Solutrean, and this gives great importance to the skeleton found in the Protomagdalenian at Pataud, by Movius, as a representative of man at the end of Würm III. From Magdalenian III on, burials were more common, either because there was an increase in population or because there was increased concern over the fate of the deceased. Magdalenian man of the Chancelade race is different from his predecessors but is still dolichocephalic.

Art, the most impressive innovation of the Upper Paleolithic, was not constantly and everywhere at the same height. In England and Belgium, examples are few or mediocre. Art objects are well dated by the assemblages which are to be found with them in the archeological layers. The oldest examples are the animal statuettes of the Aurignacian of Vogelherd, Germany. The statuettes of fat women, called "Venus," are Aurignaco-Perigordian. Their geographical distribution is very wide, from the Atlantic Ocean to the Ukraine, but there are none in Spain. In Magdalenian times, representations of more slender women are engraved on stone or bone. The last one to be found was discovered in 1962 by F. Bordes in the Magdalenian VI of Couze, Périgord (Fig. 10). Beautiful realistic or stylized art objects abound in the sites of France, Spain, and Switzerland, mainly in the Upper Magdalenian levels, but elsewhere they are scarce or totally lacking. Cave art is more limited in distribution. The bas reliefs of animals and, less often, of human figures, which begin in the Upper Solutrean and continue into the Magdalenian, are found only between the Loire and the Pyrenees. Wall engravings and paintings, invented by the Aurignacians, are found throughout the Upper Paleolithic, especially during the Magdalenian. They are numerous in France and Cantabrian Spain, but are represented in Italy only by some schematic figures in the southern part of the peninsula. They are unknown in Great Britain, Belgium, Germany, and Switzerland. The cave art of eastern Spain, attributed to the Upper Paleolithic by Breuil, is probably more recent.

Conclusion

Despite the appearance of continuity, western Europe in the Upper Paleolithic did not have a constant cultural unity. Except in the extraordinarily active and creative center of southwestern France and, up to a point, Cantabrian Spain, this brilliant civilization knew only two great periods of expansion—the Aurignacian, at the beginning of Würm III, and the Magdalenian, during Würm IV. These two great cultures differed considerably east and west of the Rhine, which seems to have been a cultural border. It was between the Loire and the Pyrenees that the art of Paleolithic man knew its longest and most complete development.

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The Radiation Belts, Natural and Artificial

Many characteristics of the radiation belts have been clarified by data obtained by Explorer XV.

C. E. McIlwain

Since the discovery, early in 1958, of the geomagnetically trapped radiation, over 200 detectors of charged particles have been launched into space for the purpose of measuring the fluxes of trapped particles (*1*). In spite of this intensive effort, a clear picture of the fluxes of trapped particles cannot be obtained from the information now available in published form. Some of the factors causing this situation are as follows.

1) The presence of particles of many categories at each position in space makes it difficult to measure any one component. (Plausible but incorrect assumptions as to the composition of the radiation have often led to misinterpretation of data.)

2) The particle fluxes are so intense that the detectors are often jammed.

3) The spatial distribution of any one component is typically quite complex.

4) The spatial distribution depends strongly on the type and energy of the particle.

5) The particle fluxes change with time.

6) Particles have been artificially injected by at least eight high-altitude nuclear detonations. (It is often difficult to decide what fraction of a measured flux was artifically injected.)

On 27 October 1962 the National Aeronautics and Space Administration launched a satellite, Explorer XV, which was specifically designed to obtain data that would fill some of the more serious gaps in the information available at that time. An orbit for Explorer XV was chosen such that the satellite would traverse the region of space containing the highest particle fluxes, and would traverse it in such a manner that nearly complete maps of

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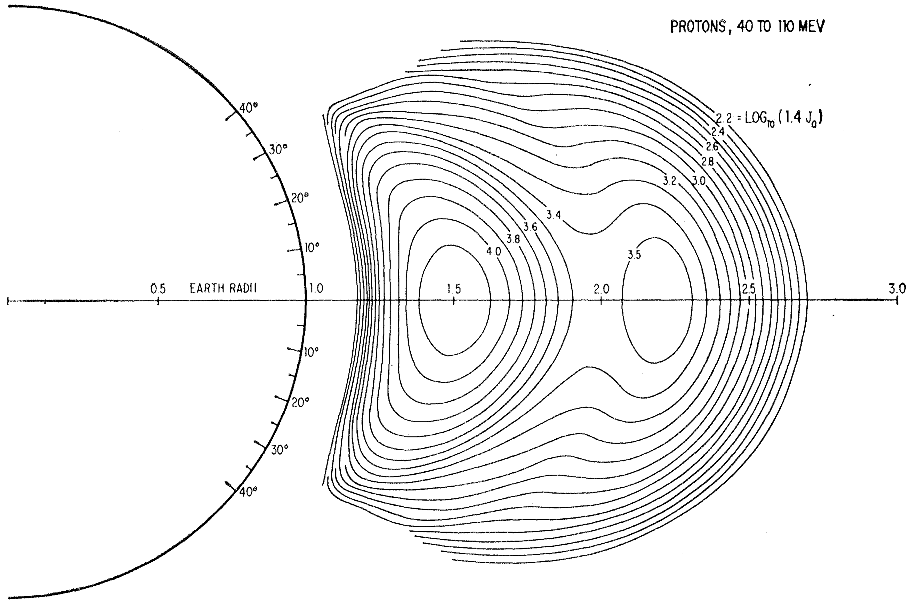

Fig. 1. Contours of constant intensity of high-energy protons plotted in magnetic-dipole coordinates. The horizontal line represents the magnetic equator.

the radiation intensities could be made from the data obtained during periods as short as 1 week. The results given in this article are based primarily on data obtained by the two detectors prepared by the University of California at San Diego which were part of the payload of Explorer XV.

Objectives

The overall objective can be stated very simply: to account for the presence and behavior of all particles trapped in the earth's magnetic field. In order to account for the presence of the particles it is first necessary to measure what is there—that is, to map the distribution of the particles in space. Because of the difficulties mentioned and the fact that the mapping must be done for particles of many different categories, even this first step has not yet been satisfactorily accomplished.

The theory concerning the motion of charged particles in a *static* magnetic field is now essentially complete. Indeed, if the earth's atmosphere were the only agent responsible for perturbation of the motion of particles, it would now be possible to calculate how particles would have to be injected in order to produce the observed fluxes. It is, of course, hoped that knowledge of the way in which the particles are injected will indicate their origin. It is now quite clear, however, that mechanisms associated with fluctuations in the magnetic field cause greater perturbations than are caused by the earth's atmosphere, except at low altitudes where the atmosphere is relatively dense. Unfortunately, the theories so far proposed are woefully inadequate for predicting perturbations of the kind we know, from observation, to be due to fluctuations in the magnetic field. Furthermore, even after adequate theories have been developed, it may be impossible to determine unambiguously the origin of trapped particles of many categories because of the complexity of their behavior.

In spite of the complications introduced by fluctuations in the magnetic field, the theory of particle motion in a static magnetic field can still be of substantial aid in the study of trapped radiation. In particular, it can be used as the basis for constructing a coordinate system which greatly simplifies the organization and interpretation of data.

The coordinates now employed in mapping the intensities of trapped particles (*2*) are essentially those which are obtained if the geographic coordinates are distorted in such a way as to make the earth's magnetic field look like a pure dipole field. A line of force in this dipole field is designated by a parameter L, the magnetic shell parameter, which represents the distance (expressed in earth radii) from the dipole axis, measured along the magnetic equator. As represented with these magnetic coordinates, the earth becomes a rather irregularly shaped object, but the particle fluxes take on a high degree of symmetry, so that longitude and the sign of the latitude can be ignored. Data obtained at any arbitrarily selected location in space can therefore be treated as if they were obtained in a single meridional plane in, say, the Northern Hemisphere. After the particle intensities have been mapped, the inverse transformation can be carried out to determine what the corresponding intensity was at an arbitrarily chosen location in space, even though no data may have been obtained in the vicinity of that location.

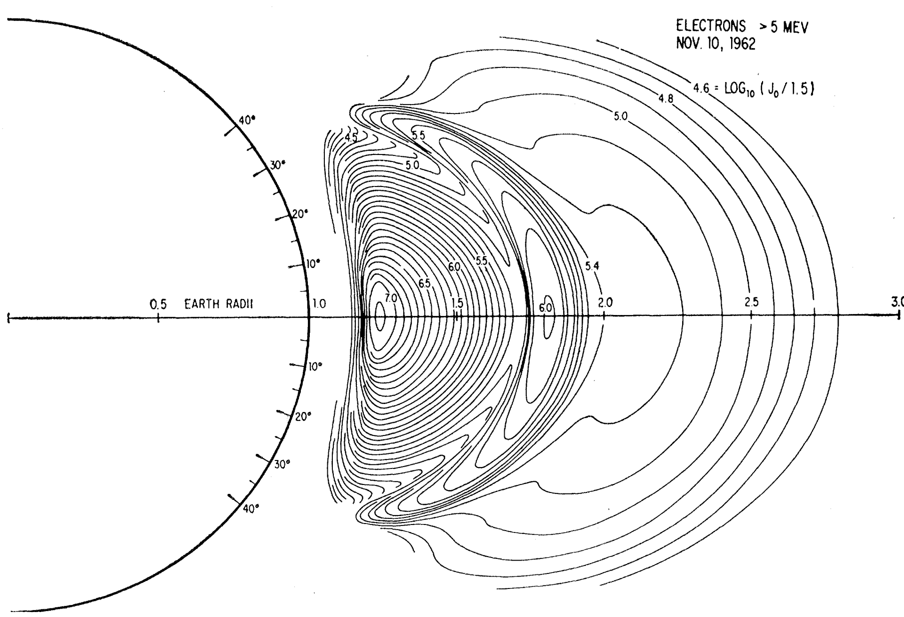

Fig. 2. Spatial distribution of high-energy electrons on 10 November 1962. The intensities represented by adjacent contours differ by a factor of 1.259.

Detectors

One of the University of California detectors on Explorer XV consists of a sphere of plastic scintillator, 4 millimeters in diameter, surrounded by a shield of aluminum of uniform thickness, equivalent to 1.8 grams per square centimeter of surface. Two pulse-height discriminators were used to obtain measures of the fluxes of electrons with energies greater than 5 Mev and of protons with energies between 40 and 110 Mev.

In the other University of California detector a small plastic scintillator is also used; it is heavily shielded in all directions except for a 16 degree cone for which the absorber thickness is only 0.048 gram per square centimeter. Response to proton bombardment is effectively eliminated by counting only small pulses; in this way only fluxes of electrons with energies greater than 0.5 Mev are measured. The average directional intensities obtained with this instrument are converted into omnidirectional intensities by a technique which, in most cases, introduces an error of less than 10 percent.

Particle Flux Maps

The Explorer XV satellite transmitted radiation data for 3 months before some of its electronic components began to malfunction, presumably because of radiation damage. It is not feasible to present each of the 450,000 data points obtained by the University of California detectors during this period. Instead, through the least squares method the results have been reduced to a form in which they can be presented in a more succinct way.

The spatial distribution of the observed intensities of protons with energies between 40 and 110 Mev is shown in Fig. 1. The relative probable errors of the weighted least squares fits were typically less than 2 percent; therefore, the contours of constant intensity are almost completely free of any spurious irregularity. Almost all data previously available on these high-energy protons had been obtained at distances of less than 1.4 earth radii (as measured from the dipole axis along the magnetic equator). Examination of the earlier data readily led to the conclusion that there would be a peak in the distribution at about 1.5 earth radii. Figure 1 shows that this is indeed the case. It had not been suspected, however, that there might be two peaks. The existence of the secondary peak at 2.2 earth radii has now been confirmed by the University of California detectors on the Relay I satellite. The Relay I results also show that there is no second peak in the distribution of protons with energies less than 25 Mev. There is good evidence that the nuclear detonations have not produced any important perturbation in the distribution of the high-energy protons. In particular, the intensities in the region of the U.S. detonation ("Starfish") over Johnston Island on 9 July 1962 are the same as those measured in 1958, except for predictable changes due to the decrease in atmospheric density at high altitudes that is associated with the decrease in solar activity. Of the three Soviet high-altitude detonations of 22 October, 28 October, and 1 November, 1962, the second two, according to the observations of Explorer XV, had no effect on the proton intensities. A 10-percent change at almost any point in the distribution shown in Fig. 1 due to the third of these detonations would have been readily discernible.

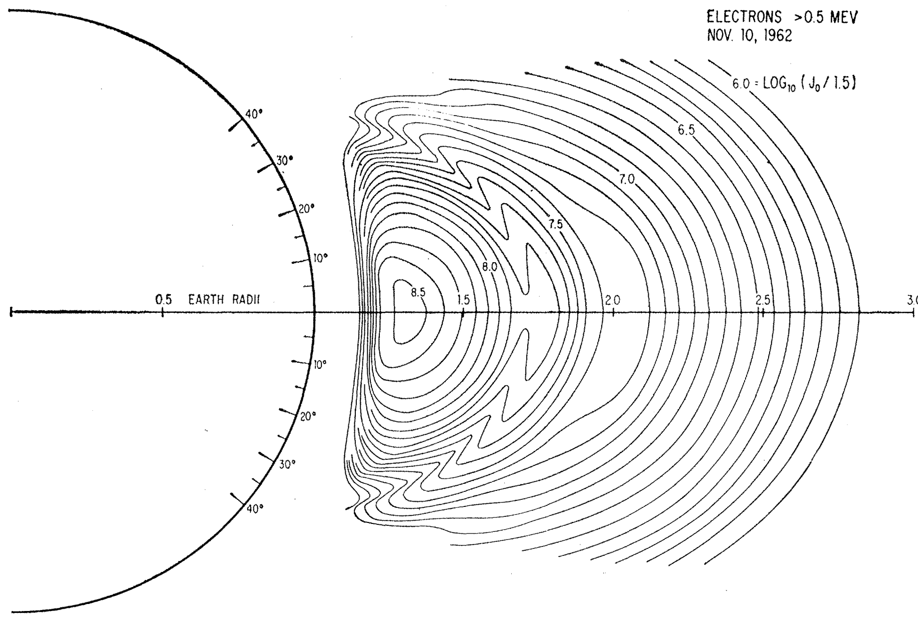

Fig. 3. Spatial distribution of low-energy electrons on 10 November 1962.

The distribution on 10 November 1962 of electrons with energies greater than 5 Mev is shown in Fig. 2. Few, if any, earlier measurements of electrons with energies greater than 5 Mev are available, but extrapolation of measurements of electrons of lower energies leads to the conclusion that almost all of the electrons mapped in Fig. 2 were artificially injected. The inner part of the distribution, below the line of force for which $L = 1.7$, is thought to be associated with the "Starfish" detonation. Most of the high-energy electrons outside $L = 1.7$ are thought to be associated with the three Soviet detonations.

The distribution on 10 November 1962 of electrons with energies greater than 0.5 Mev is shown in Fig. 3. Most of these lower-energy electrons were also artificially injected, but a considerable proportion in the region above $L =$ 1.6 earth radii may be of natural origin. The electron fluxes in the region around 1.3 earth radii are sufficiently intense to constitute a very real radiation hazard to electronic and biological systems.

The distribution of the lower-energy

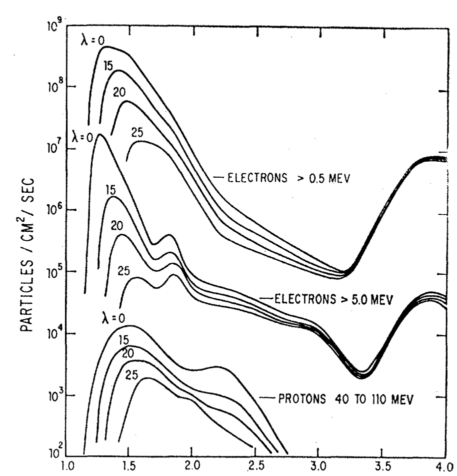

Fig. 4. Particle intensities at different magnetic latitudes on 1 January 1963.

electrons below $L = 1.7$ earth radii may be seen to be quite different from the corresponding distribution of high-energy electrons shown in Fig. 2. In many analyses of earlier data it was assumed that these two distributions were the same. Reinterpretation of these measurements with the aid of the data presented here may explain the apparent disagreement of different sets of data.

When the distributions of Figs. 2 and 3 are integrated over the region within the line of force for which $L = 1.72$, it is found that there were 8.3×10^{24} and 9.1×10^{22} electrons with energies greater than 0.5 and 5 Mev, respectively, present on 10 November 1962. If we assume (*3*) that there were, in all, 10^{27} electrons available from the "Starfish" detonation, and that these electrons had an energy distribution similar to that of the electrons produced by the thermal neutron fission of uranium-235, then we conclude that the numbers of available electrons with energies greater than 0.5 and 5 Mev were 6.8×10^{26} and 8.2×10^{24}, respectively. It may be seen that about 1 or 2 percent of the electrons assumed to be available at the time of the detonation were still trapped in the earth's magnetic field 125 days later. On the inner edge of the distribution, at about 1.17 earth radii, the electron flux increases with altitude as approximately the 150th power of the radial distance. This rate of increase may be near the limit set by diffusion across lines of force.

Communication of Results

Maps of the radiation intensities are very useful in indicating the character of the radiation. In many instances, however, it is important to obtain the best possible values for the intensities at arbitrarily chosen locations, preferably without having to perform tedious graphical interpolations. To meet this need, a computer program has now been set up, in the Fortran language, on the basis of which the computer, upon being given the coordinates of a point in space, proceeds to compute the radiation intensities observed at that point by Explorer XV on 1 January 1963. This program greatly facilitates comparison with other sets of data, computation of the radiation damage which would be received along an arbitrarily selected trajectory, and comparison with theoretical predictions.

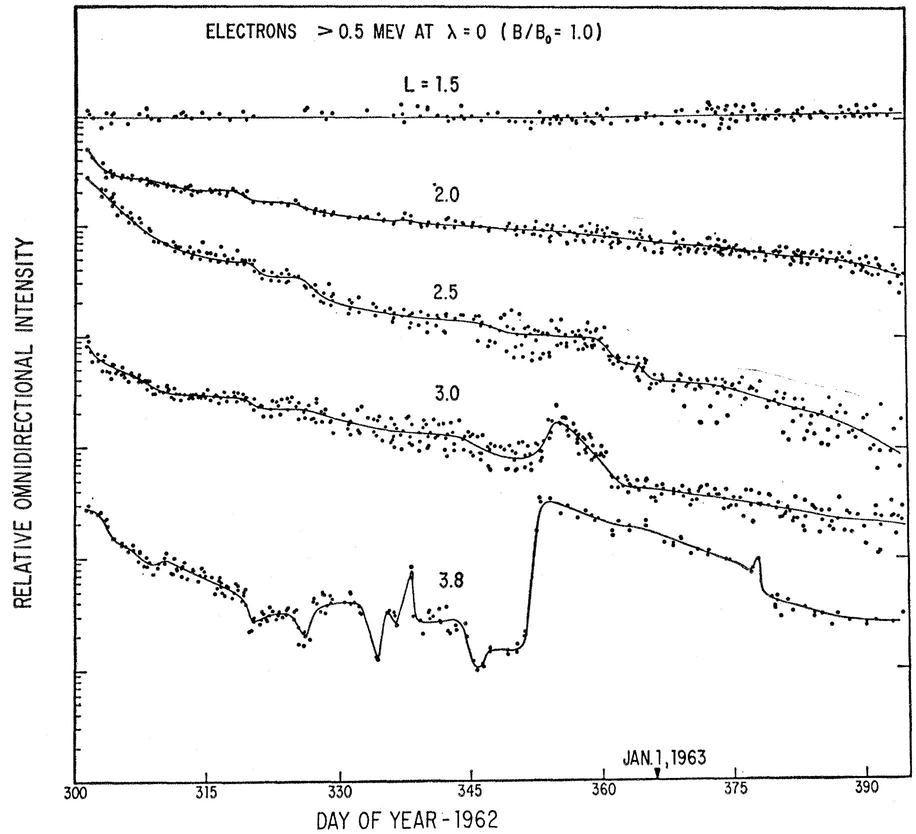

Fig. 5. Time-dependence of intensities of low-energy electrons near the magnetic equator.

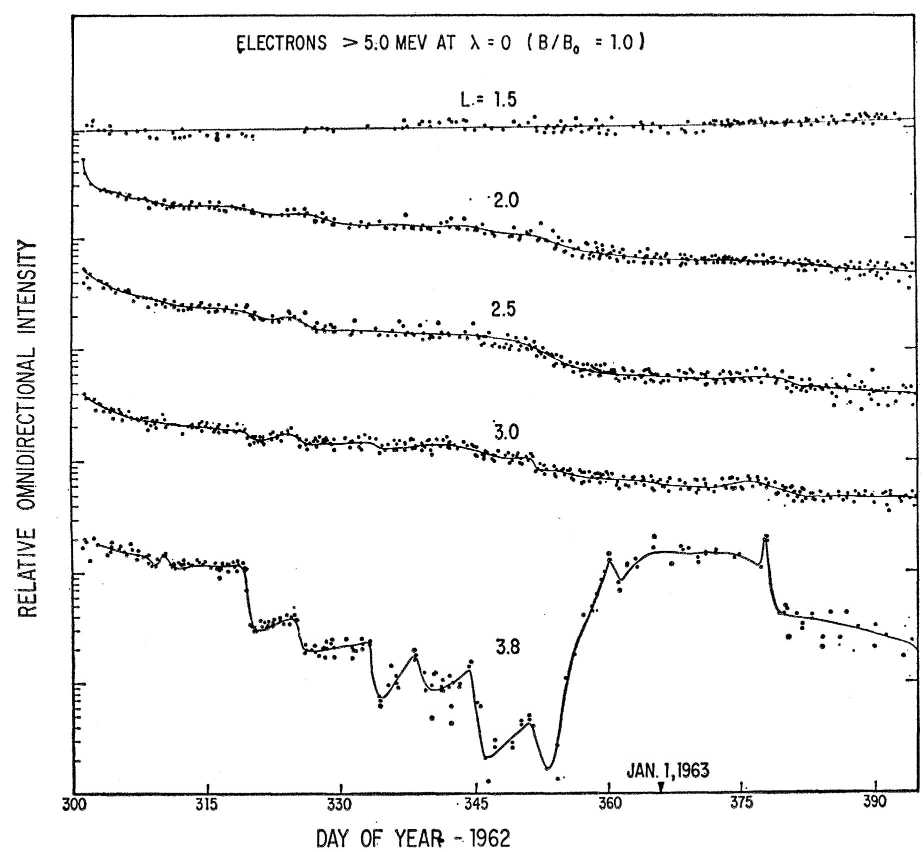

Fig. 6. Time-dependence of intensities of high-energy electrons.

The curves of Fig. 4 were computed with the aid of this computer program and represent the intensities that would have been encountered on 1 January 1963 along radial trajectories at magnetic latitudes of from 0 to 25 degrees.

It is to be hoped that this method of transmitting information by computer program will be used more often now that vast quantities of data are being collected which cannot be adequately presented in printed form.

Time Variations

The relative distribution of the 40- to 110-Mev protons remained remarkably constant during the 3 months of observation. The absolute intensities, however, slowly increased throughout this period, so that at the end of the observations most of the intensities were about 25 percent higher than they were initially. It can be shown that instrumental variations could not have produced a change as large as 10 percent. It seems difficult to avoid the conclusion that a relatively large number of protons were injected, with essentially the same spatial distribution as those already present. The details of the injection rates with respect to time and position are still being studied, but as yet no direct correlation with solar or terrestrial events has been found.

The variations in the fluxes of the electrons with energies greater than 0.5 and 5 Mev are shown in Figs. 5 and 6, respectively. The data points shown correspond to the relative intensities on the magnetic equator at distances from the dipole axis of from 1.5 to 3.8 earth radii. The data for the different locations have been arbitrarily spaced by a factor of about 10, to prevent overlap. The relative absence of variations at 1.5 earth radii is characteristic of all the electrons trapped in the region between $L = 1.25$ and 1.7 earth radii. The time constants for change by a factor of e ($= 2.718$) in this region are typically greater than 1 year and in many cases appear to be greater than 3 years. Should these electrons injected by the "Starfish" detonation continue to decay at the observed rates, it will be possible to detect their presence among the naturally trapped particles for at least 20 years. At some locations in this region the intensity of the electrons is observed to increase slightly with time. While it cannot be proved that this is not an instrumental effect, there is no reason to believe that it is not real. On higher lines of force, both increases and decreases in electron fluxes associated with magnetic disturbances have been observed by instruments on many satellites.

A rapid initial decrease in intensity is observed on the lines of force for which $L > 1.75$. This is apparently due to the fact that the Soviet detonations injected many electrons at relatively low altitudes on these lines of force, and that these electrons were rapidly removed by the earth's atmosphere. After this initial loss of particles in the low-altitude region, the intensities at the magnetic equator (Figs. 5 and 6) were primarily due to the particles which remained in the high equatorial region during their motion along lines of force. At these altitudes of more than 4000 kilometers, the atmospheric density is too low to be important, so the observed changes in intensity must be due to fluctuations in the earth's magnetic field. That this is in fact the case is clearly shown in Figs. 7 and 8, where vertical lines have been drawn at points which represent the times at which magnetometers on the earth's surface detected the onset of small magnetic storms. The time constants for change by a factor of e during these magnetic disturbances are as short as 3 hours, whereas during magnetically quiet periods the time constants are typically greater than 3 months. A decrease in counting rate does not necessarily imply the removal of particles. A decrease in counting rate can also be caused by a lowering of the energy of some of the particles below the threshold of the detector. The magnetic fluctuations which cause the particle intensities to change are presumably generated at the boundary of the earth's magnetic field, in the region beyond 8 earth radii. These fluctuations propagate inward in the form of hydromagnetic waves until they are refracted along lines of force. The Explorer XV observations indicate that waves in one category propagate down to lines of force for which L is as low as 1.7 before being refracted, while waves in another category are refracted in the region around 3.0 earth radii. It is of course possible that some unsuspected phenomenon associated with magnetic fluctuations, rather than the hydromagnetic waves, is responsible for the changes in particle fluxes, but as yet no alternate mechanism has been proposed.

The beginning of a relatively large magnetic storm was observed on 18

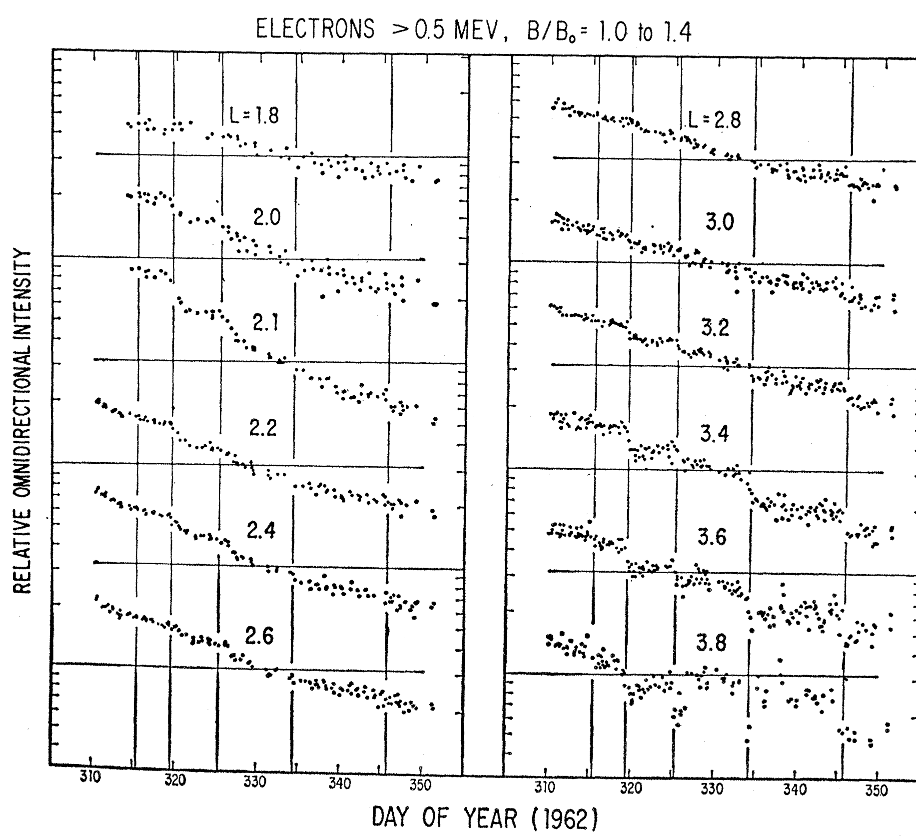

Fig. 7. Time-dependence of intensities of low-energy electrons. The vertical lines indicate times of magnetic disturbances.

December (day 352) 1962. As may be seen in the bottom curve of Fig. 5, the intensity of low-energy electrons on the high lines of force increased by a factor of more than 10. Clearly, the magnetic fluctuations can accelerate particles as well as decelerate them. In the corresponding curve of Fig. 6 it may be seen that the high-energy electrons, which had almost disappeared in previous storms, reappeared during this event with practically their original intensity.

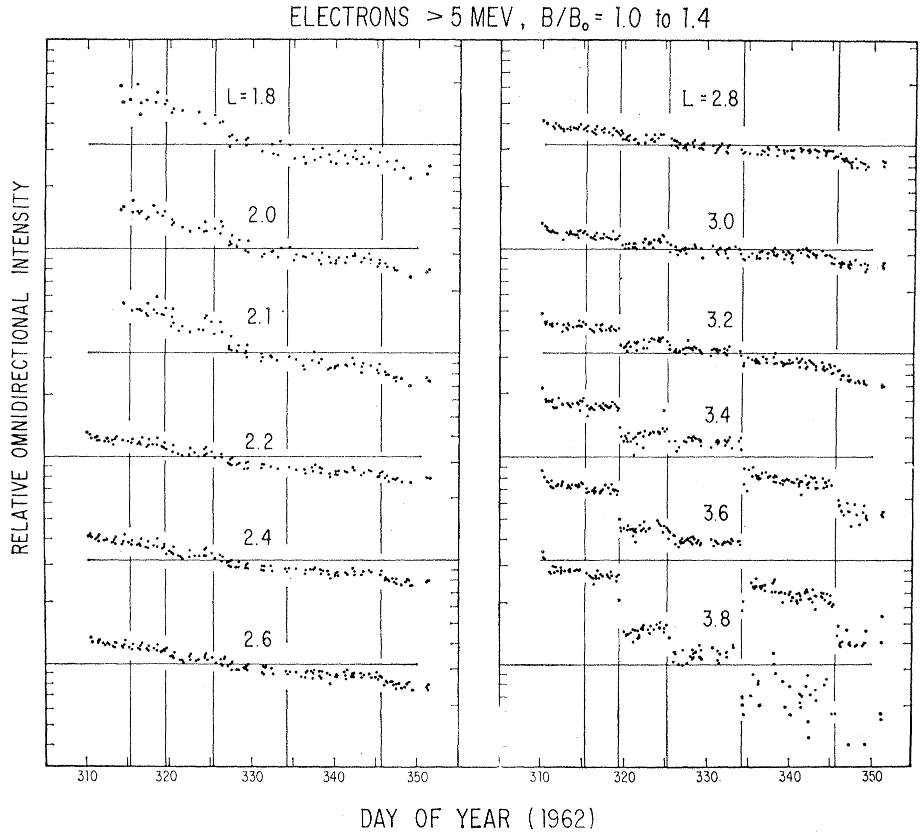

Fig. 8. Time-dependence of intensities of high-energy electrons.

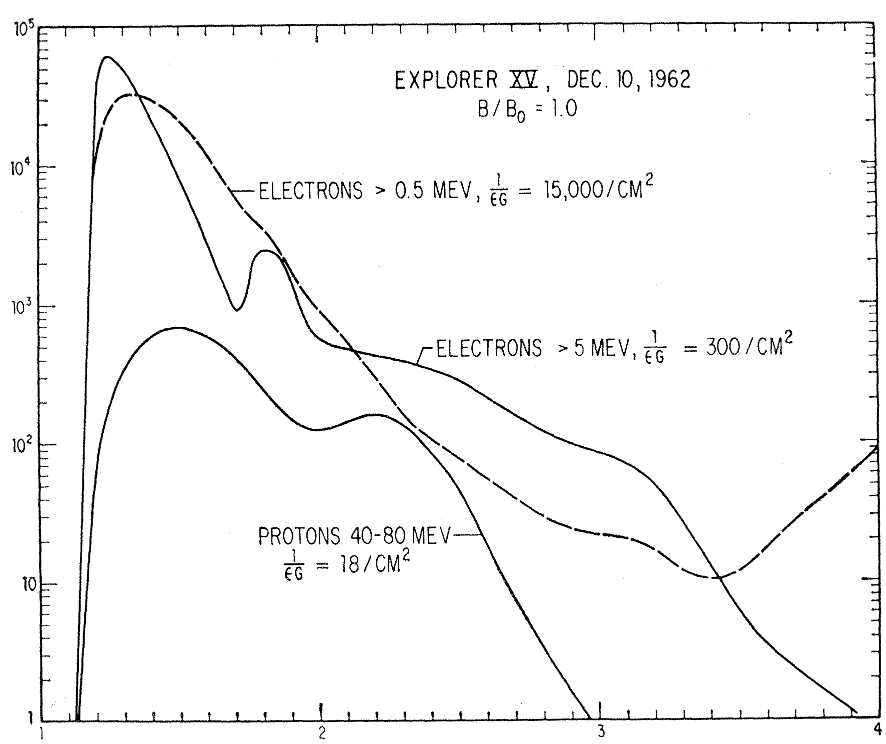

Fig. 9. Altitude-dependence of counting rates for regions near the magnetic equator on 10 December 1962. Heights are expressed in earth radii above the dipole axis.

It is possible that, if high-energy electrons had not been artificially injected onto these lines of force, fewer high-energy electrons would have been present after this event. This raises a serious question as to how long the effects of the artificially injected electrons will remain. Since the rate of complete removal (not just deceleration) may be very slow, a more appropriate question may be: How many times do artificially injected particles have to be accelerated and decelerated before they are to be considered natural?

In considering the dependence on altitude of the intensity of high-energy electrons after the storm of 18 December (Fig. 4), as compared with the dependence before the storm, shown in Fig. 9, it may be seen that an "outer zone" of these electrons had been formed which was quite similar in configuration to the outer zone of the lower-energy electrons.

Figure 4 shows that the peak in the intensities of the high-energy electrons at about 1.8 earth radii—a peak attributed to the Soviet detonations—was still present on 1 January 1963 but that the corresponding peak in the intensities of low-energy electrons was not present. Most of the low-energy electrons in this region after January 1963 were probably of natural origin.

Previous Artificial Injections

In 1958, electrons were injected on lines of force for which L was 1.2, 1.7, and 2.1, respectively, by high-altitude nuclear explosions (*4*). In each case the intensities were observed to decrease rapidly. By interpolation, it was expected that electrons injected on any line of force for which L was between 1.2 and 1.7 would also be rapidly removed. This is unfortunately not the case. It is now clear that the electrons on the line of force for which $L = 1.2$ are removed by the earth's atmosphere, that the electrons on lines of force for which $L \geqq 1.7$ are removed by magnetic fluctuations, and that neither of these effects is important in the intermediate region. Had this been known earlier, the 9 July nuclear test might have been carried out at a high latitude so that the electrons would have been injected on high lines of force where they would have been more rapidly removed. The Soviet nuclear tests were, presumably, carried out at high latitudes because of the fortuitous location of Soviet rocket-launching sites.

Natural Electron Intensities

Few definitive measurements of the natural electron fluxes were made prior to the "Starfish" detonation. In particular, no measurements at all were made in the equatorial region at heights around 1.5 earth radii. Since there is no intrinsic difference between naturally and artificially injected electrons by means of which the natural component can be distinguished, it may be necessary to wait more than 30 years before the natural electron fluxes in the region around 1.5 earth radii can be measured with complete freedom from artificial effects.

The rate of injection of high-energy protons by neutrons produced by cosmic rays striking the atmosphere is adequate to produce the observed fluxes and also the apparent rates of injection. If cosmic ray produced neutrons turn out to be the only source of these fluxes, then the problem of understanding the fluxes of high-energy protons is reduced to that of finding mechanisms through which the trapped protons are perturbed in a manner which produces the spatial distribution that is shown in Fig. 1.

In addition to the high-energy protons, there are vast numbers of low-energy protons trapped in the geomagnetic field. For example, instruments on the Explorer XV and Relay I satellites have measured the fluxes of protons with energies greater than 5.1 and 1.1 Mev and have shown them to be greater than 10^6 and 10^7 particles per square centimeter per second, respectively, in the equatorial region around $L = 2.0$ earth radii. It is not yet known whether the intensity of neutrons produced by galactic and solar cosmic rays is adequate to explain such high fluxes.

The electrons on high lines of force are seen to be accelerated during some magnetic storms. Since there are always large numbers of very-low-energy electrons present which might be accelerated, the origin of the outer-zone electrons is probably irrelevant. In any case, the central problem is to understand the acceleration mechanisms.

Summary

Data on the time- and space-dependence of trapped particles in three categories have been obtained by detectors on the Explorer XV satellite. Some of the more interesting observations are as follows.

1) There is an unexpected secondary peak in the distribution of high-energy protons.

2) The fluxes of high-energy protons slowly increased with time but apparently were not affected by geomagnetic events which caused perturbation of the electron fluxes on the same lines of force.

3) About 1 or 2 percent of the electrons generated by the nuclear detonation of 9 July 1962 were found to be present in the geomagnetic field 125 days later.

4) The electron fluxes in the region between $L = 1.25$ and 1.65 earth radii varied by less than 35 percent over the period from day 110 to day 206 after the detonation of 9 July.

5) The spatial distributions of high- and low-energy electrons are quite different.

6) Electrons in the region above $L = 1.7$ earth radii are strongly perturbed by magnetic disturbances.

7) A "new" outer zone of both high- and low-energy electrons was formed by the magnetic storm which began 18 December 1962.

It is expected that these and other findings obtained by the Explorer XV detectors will be of substantial aid in discovering the mechanisms which control the behavior of geomagnetically trapped particles (*5*).

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5. I thank J. Valerio and A. Devore of the University of California at San Diego, J. Townsend, Jr., of the Goddard Space Flight Center, and G. Frohwein and D. Enemark of the State University of Iowa for their work in connection with the Explorer XV satellite. The research discussed in this article was supported in part by the National Aeronautics and Space Administration (contracts NAS5-3063 and NASr-116).

Science Goes to Washington

Meg Greenfield

In the beginning, a current saying in Washington goes, were the lawyers; next came the economists; and then came the businessmen. Now it is the scientists' turn. This new breed, or more precisely, these new hybrids, who began their more or less reluctant ascent to power during the Second World War, are now so thoroughly enmeshed and infiltrated into every level of government that no one seems capable of stating with any precision just what their function is.

The role of the scientist-in-government as it has evolved in Washington in the past twenty years has been interpreted so loosely, by both the scientists and the administrations that have dealt with them, that each has inflicted punishment on the other, and neither, so far, seems to show any genuine understanding of the duties or requirements of the other. Invariably, science in Washington is science under pressure; it is science having to hurry along, science having to worry about what the Russians might do, what the Congress may say, what Bertrand Russell is likely to think of next. The government in turn has yet to get accustomed to this strange community whose members are given in the best academic tradition to squabbling, back-scratching, and casting doubt on one another's competence—a community that cannot help being politically minded and yet cannot possibly resolve its dissensions according to majority principle.

Miss Greenfield is a writer for the *Reporter*.