Meetings

Radiation Trapped in Earth's Magnetic Field

Radiation surrounding Earth seems to consist of electrons and protons trapped in Earth's magnetic field. This radiation was the subject of an advanced-study institute ("Radiation trapped in the earth's magnetic field") held in Bergen, Norway, 16 August–3 September 1965.

Theoretical predictions, and reporting of experimental data, require suitable models of Earth's magnetic field and space coordinate system. C. McIlwain showed that his commonly used coordinate system is suitable for interpreting the entire stable trapping region and is as good as the accuracy of the magnetic field used. To achieve accuracy, the intensity of Earth's magnetic field must be known within less than 1 percent at every point in space. The current McIlwain Space Model uses the Jensen-Cain 1962 magnetic-field model. J. Cain compared the available representations of Earth's field. Much of Earth's surface is poorly measured and very few data exist from above a few tenths of an Earth radius. A 1965 field is available, but is still inadequate, especially for low-altitude mirror work in the Atlantic anomaly. POGO-I satellite data (launch date, October 1965) are essential for reducing the field inaccuracies to the same degree as the other errors. When POGO-I data become available in the form of a revised field by Cain, McIlwain will revise his space model. Beyond the stable trapping region defined by McIlwain's model there is no suitable coordinate system.

Although many investigators have reported experimental observations in the natural belts (including J. Van Allen, G. McIlwain, B. O'Brien, H. Elliot, and D. Rose), one cannot yet briefly summarize the apparent characteristics of the belts. Observations are insufficient to resolve diurnal, 27-day-solar-cycle, 11-year-solar-cycle, and secular variations. Differences between diffusion and acceleration of trapped radiation and the characteristics of its disturbances cannot be resolved. Apparently, matched pairs of satellites separated by a short distance are necessary to resolve temporal and spatial variations, especially in the outer belt.

Observational evidence of sources and sinks (origins and losses) of trapped radiation was summarized by J. Van Allen. Neutron albedo decay can only explain the very-high-energy protons ($E > 100$ Mev) in the inner belt; the remainder of the belts (99 percent) must, directly or indirectly, have the solar wind as a source. For the lower portions of the inner belt ($L \leqq 1.25$), M. Walt's atmospheric-loss model fits well. At higher altitudes (L values) unknown processes provide the loss mechanisms: for example, the outer belt is significantly affected by magnetic storms, but it is not yet possible to distinguish between diffusion and acceleration of trapped radiation.

The relation of auroras to precipitation of charged particles was discussed by B. Maehlum and B. O'Brien. It is not possible to determine whether aurora particles are trapped, where they came from, how they got there, or whether they are inside or outside either the stable trapping region or the magnetosphere. Backscattering is important, and the energy spectrum from the trapped radiation is different. Concurrent ground and satellite measurements are needed.

The fragmentary data on the solar wind, bow shock, transition region, and magnetopause were presented by J. Coon and L. Frank. There was much interest in the solar wind, which shows significant changes within a few minutes. It is impossible to tell whether the anticorrelated proton and electron fluctuations were real or whether the bow shock was passing back and forth across the satellite. The tail is characterized as "confused" because there is no apparent symmetry—no continuous streaming or flux stability. E. Parker emphasized that the basic processes in the outer magnetosphere must be studied before models can be suitably developed. Stability is a very important consideration in the interaction of the solar wind and the magnetosphere. Without instabilities, the thermal pressure would close the tail at 10^2 Earth radii; but experiment shows that the tail is longer, therefore instabilities are important. Collisionless shocks have never been duplicated in the laboratory, and so it is important to investigate such shocks in space. Parker believes that the trapped radiation gets some acceleration locally, and diffusion is produced by magnetic-field fluctuations. A particle going from 10 into 2 Earth radii would enhance its energy more than 100 times. J. Dungey believes that there should be electric (E) fields parallel with the magnetic field (B); Parker, however, believes that there is sufficient thermal plasma to keep these E fields zero. E fields parallel with B can be obtained only when the current density exceeds the ability of the ambient free electrons to transport it. Therefore, if the plasma is not measured, all kinds of parallel E fields can be hypothesized.

Discussion was spirited between A. Dessler and J. Dungey concerning models of the outer magnetosphere. Dessler's model is a nonmerging type, that is, the tail is open; there is an extensive neutral sheet behind Earth and the tail extends to 10^5 Earth radii or more, finally terminating where the solar wind is stopped by the galactic magnetic field. The shock boundary at the outer edge of the magnetosheath is thin (less than 1000 km), and there is no turbulence or wave action in the magnetosheath (that is, the transition region); the result is a very stable magnetopause. In order to reach the polar caps, particles must diffuse into the tail and then back along the tail to the poles, whereas particles reaching lower latitudes need diffuse only across the front surface of the magnetopause. Therefore diffusion to lower latitudes is easier and more rapid than to the polar cap.

The merging model provides for at least one truly neutral point where the field lines in the tail come together; this point is about 10^3 Earth radii behind Earth. The model also has conditions under which the field lines reconnect to the interplanetary field in the vicinity of the dawn and dusk terminators. Reconnection of field lines on the day side increases the tail flux; reconnection on the night side decreases the tail flux.

In Dessler's model, deposition by radiation at the poles (polar cap events) would start at low latitudes and move toward the pole; in Dungey's model the whole polar cap would experience absorption at the same time. Van Allen and H. Stolov said that all events studied by them began at the pole and should satisfy Dungey's model. Van Allen also pointed out that Mariner IV was within about 4 Earth radii of the Earth-Sun-line extension, for 2 weeks at 3300 Earth radii, without observing particle or magnetic-field change associated with the tail. Dessler felt that this did not prove that the tail was closed, but Van Allen concluded that if you do not measure it it is not there.

The experimentalists were amused by the intuitive theoretical discussions and tried to determine which measurements may prove useful. It seems important to measure the proton and electron energies at many locations across the bow shock, transition region, and magnetopause. Two satellites are necessary to resolve spatial and temporal variations; the distance between them should be less than 1000 km. The boundary of the bow shock should be carefully measured with a magnetometer and plasma probe.

The use of sources of artificial radiation for studying fundamental processes in the Van Allen belt was discussed by N. Christofilos. Sufficient quantities of radiation must be injected into a narrow L shell in order to follow temporal and spatial changes. Electrons and protons are not attractive because of the high ambient levels and because they are naturally injected in an unknown fashion. Christofilos advocated using positrons and alpha particles; he preferred the latter. C. Roberts pointed out that, if whistlers are important for diffusion, positrons will not provide the correct data. R. Hynds and others objected to injection of alpha particles before the natural flux and energies are measured; such measurements may require several years.

Since previous high-altitude, nuclear detonations have provided very essential experimental data on the radiation belt, some researchers advocate an International Test Series of small nuclear detonations at different altitudes. Except in the outer part of the outer belt, effective lifetime information has come only from nuclear tests.

Results from the Star Fish test of 9 July 1962 were presented by J. Van Allen. He found that 3 percent of the Star Fish electrons were trapped at 10 hours, the electrons were a fission spectrum, and essentially none were injected beyond 0.5 Earth radii (*L* of 1.5). Van Allen contrasted his analysis with the Hess-Nakada model, which showed 25 percent trapped, some even beyond two Earth radii. Hess had based most of his data on W. Brown's Telstar-I data. Hess and Brown have revised their estimates. Brown's first estimate was that over 25 percent of the electrons were trapped, but more detailed analysis reduced the percentage to 10. If a soft spectrum (as measured by Harry West) is assumed, the inventory is about 6 percent. Hess and Brown concede that the soft electrons above *L* of 1.5 may be due to some acceleration of natural electrons, such as by an MHD shock; however, since the slot between the inner and outer belts was obscured for 2 weeks, some kind of catastrophic effect was produced by Star Fish. J. Zinn and S. Colgate discussed Star Fish expansion phenomena. Although there are major uncertainties, Colgate found that shock heating could account for the enhancement in soft electrons found above *L* of 1.5.

Additional observational data were presented for Star Fish and the three Soviet high-altitude nuclear tests by C. McIlwain, H. West, W. Brown, H. Elliot, and Van Allen, with tentative remarks on diffusion, pitch-angle realignment, lifetimes, and other factors.

The basic processes produced in solar cells and transistors by trapped electrons and protons are poorly understood, but W. Brown and J. Martin have taken sufficient experimental data to develop empirical procedures that provide for the design of reliable systems with predictable results. According to W. Keller and D. Adams, the shielding provided by space vehicles and the dose within can be adequately determined. There is no hazard in orbits of up to 500- to 800-km altitude, but the center of the inner belt is very hazardous for manned satellites. Human response to radiation must be refined before the radiation hazard for man in space can be fully assessed.

The study institute was sponsored by NATO, ONR, and ARO. The proceedings will be published by D. Reidel Publishing Company, Dordrecht, Holland. The participants generally agreed on a 2-week meeting in 1967. Special emphasis will be on the outer magnetosphere; injection, acceleration, diffusion, and precipitation of particles; and lifetimes and experimental observations of particles.

BILLY M. MCCORMAC
IIT Research Institute, Chicago, Illinois

Photon and Electron Impact

Phenomena related to photon and electron impact were the main topics of a symposium at the 13th annual conference on mass spectrometry and allied topics, held 16–21 May 1965 in St. Louis, Missouri.

In the opening lecture on photoionization processes, particularly in diatomic molecules, J. A. R. Samson (Geophysical Corporation of America) outlined the ways in which vacuum ultraviolet radiation can be absorbed by gaseous molecules; he pointed out the interest in knowing individual cross sections for each of the processes. He discussed the techniques for investigating these processes at photon energies greater than the first ionization threshold, and illustrated them with a description of the measurements of a new ionization threshold for molecular oxygen at 11.85 ev. R. I. Schoen (Boeing Scientific Research Laboratories) continued with a description of processes resulting from absorption of photons in polyatomic molecules. He described the production of molecular ions in ground electronic or vibrational states or in an excited electronic vibrational state, or dissociative ionization. As each process is reflected in a loss of energy available to the emitted electron, they may be identified by the use of electron-retarding potential studies. The apparently increasing importance of the role of autoionization was discussed. The relation of the retarding-potential studies to studies of fluorescence stimulated by vacuum ultraviolet radiation was also mentioned.

The photoionization of some atoms and diatomic molecules was reviewed by F. J. Comes (Institute of Physical Chemistry, University of Bonn). Comes reported on absolute cross sections for rare gases measured from onset of