NSSDC 70-01

OGO Program Bibliography

Supplement No. 3

January 1970

NATIONAL SPACE SCIENCE DATA CENTER

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OGO PROGRAM BIBLIOGRAPHY

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Compiled By
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NATIONAL SPACE SCIENCE DATA CENTER

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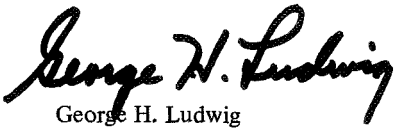
PREFACE

The Orbiting Geophysical Observatory (OGO) Bibliography with its Supplements is published to provide the OGO experimenters with a convenient reference of published and unpublished scientific and technical papers, articles and other documents on the OGO scientific results, experiment instrument design, and spacecraft design and operation. Its primary goal is to facilitate and encourage the early exchange of information among the experimenters to help in meeting one of the OGO primary objectives, the correlation of data from a large variety of related experiments.

Any recommendations for making this document more effective in achieving that goal would be appreciated.



George H. Ludwig
OGO I, III Project Scientist

FOREWORD

This Supplement contains all the new citations collected since the publication of the July 1968 cumulative edition of the OGO Program Bibliography. Additional supplements or a new cumulative edition will be published as sufficient numbers of new citations become available and warrant the printing of a new edition.

Copies of "preprints" of listed articles are distributed to all OGO investigators. Other requests for copies should be directed to the authors.

The principal source of material for the bibliography is supplied by the individual OGO investigators.

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OGO-I EXPERIMENTS

4903 (Bridge, Plasma Faraday Cup)

Vasyliunas, V. M., "A Survey of Low Energy Electrons in the Evening Sector of the Magnetosphere with OGO-I and OGO-III," *J. Geophys Res., 73,* 2839-2884, 1968.

ABSTRACT: Observations of electrons of energy 125 ev to ~2 kev with the OGO-I satellite and of electrons of energy 40 ev to ~2 kev with OGO-III (by means of modulated Faraday cup detectors) are used to investigate the low energy electron population in the magnetosphere within the local time range ~17 to ~22 hours. Intense fluxes of these electrons are confined to a spatial region, termed the plasma sheet, which is an extension of the magnetotail plasma sheet discovered by the Vela satellites and is identified with the soft electron band first detected by Gringauz. The plasma sheet extends over the entire local time range studied in this investigation, from the magnetospheric tail past the dusk meridian toward the dayside magnetosphere. In latitude it is confined to within 4-6 Re of the geomagnetic and/or solar magnetospheric equatorial plane, in agreement with observations already reported from the Vela satellites; no electron fluxes are detected high above the equator, not even very near the magnetopause. In radial distance the plasma sheet is terminated by the magnetopause on the outside and by a well-defined sharp inner boundary on the inside. The inner boundary has been traced from the equatorial region to the highest latitudes investigated, ~40°; during geomagnetically quiet periods it is observed at an equatorial distance of 11 ± Re and appears to extend to higher latitudes along magnetic field lines. Weak or no electron fluxes are found between the inner boundary of the plasma sheet and the outer boundary of the plasmasphere. Detection (by an indirect process) of the very high ion densities within the plasmasphere gives positions for its boundary in good agreement with other determinations. During periods of magnetic bay activity the plasma sheet extends closer to the earth; the inner boundary of the plasma sheet is then found at equatorial distances of 6-8 Re. This is most simply interpreted as the result of an actual inward motion of the plasma during a bay. In one case it was possible to associate the beginning of this motion with the onset of the bay and to estimate an average radial speed of ~12 km/sec, from which an electric field corresponding to ~48 kilovolts across the magnetospheric tail was inferred. Within the plasma sheet the electron population is characterized by densities from 0.3 to 30 cm^{-3} and mean energies from 50 to 1600 ev and higher, with a strong anticorrelation between density and mean energy so that the electron energy density (~1 kev cm^{-3}) and energy flux (~3 ergs cm^{-2} sec^{-1}) show relatively little variation. The lower energies and higher densities tend to occur during periods of geomagnetic disturbance. The non-observation of electrons in regions above the plasma sheet implies an upper limit on the electron density of 5 x 10^{-2} cm^{-3} if their mean energy is assumed to be ~50 ev (typical of the magnetosheath) and 10^{-2} cm^{-3} if the energy is ~1 kev (typical of the plasma sheet). At the inner boundary of the plasma sheet there is a sharp softening of the electron spectrum with decreasing radial distance but apparently little change in the electron density. The electron energy density decreases across the inner boundary roughly as ~exp (distance/0.4 Re) during quiet periods; during times of magnetic bay activity the energy density decreases as ~exp (distance /0.6 Re) and there is a more complicated spatial structure of density and mean energy.

Vasyliunas, V. M., "Low Energy Electrons in the Magnetosphere as Observed by OGO-I and OGO-III," presented at the Summer Institute, Physics of the Magnetosphere, Boston College, June 19-28, 1967, *Physics of the Magnetosphere* (R. L. Carovillano, J. F. McClay, and H. Radoski, eds.), D. Reidel Publishing Co., Dordrecht, 1969.

ABSTRACT: Low energy electrons in the magnetosphere were studied with Faraday cup detectors on OGO-I (100 ev - 2 kev) and OGO-3 (40 ev - 2 kev).

Results are presented which describe the general configuration of the plasma sheet and its termination on the earthward side. Magnetic bays are found to be associated with the extension of the plasma sheet inward several R_e from its quiet-time boundary. (Editor)

4904 (Cline, Positron Search and Gamma-Ray Spectrum)

Cline, T. L., and E. W. Hones, Jr., "Search for Low-Energy Interplanetary Positrons," presented at the 10th International Cosmic-Ray Conference, Calgary, Canada, June 1967; also *Can. J. Phys., 46,* S-527, 1968.

ABSTRACT: Preliminary results of an experiment designed to detect and measure the intensity of interplanetary positrons of energy 0 to 3 MeV with the satellites OGO-I and OGO-III are outlined. Evidence for

a statistically significant counting rate of detected positrons is presented, and the possibility that these particles represent a true primary component rather than a background effect, such as cosmic-ray induced secondaries in the detector, is considered. It is shown that the apparent intensity of low-energy positrons, assuming that value derived from their counting rate, would be consistent with an equilibrium charge ratio. This result would not be predicted with mechanisms involving the ionization of matter or the acceleration of electrons, but would be consistent with a strongly energy-dependent galactic trapping parameter allowing meson-decay electrons to slow down in great abundance, or with the existence of an independent source.

4905 (Konradi, Trapped Radiation, Scintillation Counter)

Konradi, A., "135-1650 Kev Solar Protons after the Flare of July 7, 1966, Observed in the Magnetotail and Magnetosheath," *J. Geophys. Res., 74,* 1158-1163, 1969.

ABSTRACT: Protons with energies E >135 kev were observed in the tail of the magnetosphere after the flare of July 7, 1966. These protons have an isotropic pitch-angle distribution. The maximum intensity of the protons reached ~1.2×10^4 (cm^2 sec ster)$^{-1}$ for particles with P >15 Mv between 1000 and 1100 UT and 1400 and 1500 UT July 8, 1966. The energy spectrum of the protons expressed as an exponential in rigidity indicates a monotonic softening: the characteristic rigidity, P_0, changing from about 50 to 10 Mv. An hour-long excursion of the satellite into the magnetosheath during the peak of the proton flux showed that the proton intensity is lower in the magnetosheath than in the magnetosphere by a factor of 2. The observed pitch-angle distribution is flat in both regions.

4907 (Simpson, Cosmic-Ray Spectra and Fluxes)

Comstock, G. M., C. Y. Fan, and J. A. Simpson, "Energy Spectra and Abundances of the Cosmic-Ray Nuclei Helium to Iron from the OGO-I Satellite Experiment," *Astrophys. J., 155,* Feb. 1969.

ABSTRACT: The differential energy spectra of He, B, C, N, O, Ne, Mg, Si, and the Fe group obtained by the authors above 20 MeV nucleon^{-1} from an experiment on the OGO-I satellite have been re-evaluated by using new detector calibrations and an additional block of data. The results reported now cover the time interval October 1964–November 1965, which spans the period of minimum solar modulation in the 11-year solar-activity cycle. The shapes of the energy spectra are modified at low energy as a result of the new analysis. However, since the shapes of the spectra relative to one another remain essentially the same, the conclusions reached by the authors in their earlier publication remain unchanged.

The relative abundances of the nuclei were re-evaluated. The abundances for several nuclei have now been determined for the two energy intervals 50–100 and 100–200 MeV nucleon^{-1}. In addition to the abundances previously reported by the authors for He to Fe, the abundances for Na, Al, and the nuclear-charge groups (P–K) and Ca–Cr) have been obtained at low energy for the first time. The implications of these abundances for the origin of the low-energy radiation are discussed briefly. The new methods for analysis are described, and the linearity of solid-state-detector response over the nuclear-charge range $Z = 1$ to $Z = 26$ is established.

Comstock, G. M., "Propagation and Source Characteristics Derived from the Low-Energy, Multiply Charged Cosmic Ray Nuclei," *Astrophys. J., 155,* Feb. 1969.

ABSTRACT: Models for the origin and propagation of the cosmic-ray nuclei which assume a uniform particle population defined by a single set of propagation and source characteristics (including recently proposed steady-state models with a broad path-length distribution function) do not look attractive in terms of the nearby interstellar energy spectra derived from recent low-energy measurements made on the OGO-I Earth satellite.

Instead, the properties of these interstellar energy spectra strongly suggest the existence of two distinct particle populations or "components." These two components would result from different types of sources or modes of propagation. We show quantitatively that such two-component models satisfy the present experimental results down to the lowest observed energies over the wide nuclear charge range of helium to iron. The constraints placed by the data on two-component models are discussed with the aid of calculated interstellar energy spectra of the nuclear charge groups He, B, CNO ($6 \leq Z \leq 8$), LH ($10 \leq Z \leq 15$), and the

Fe group ($25 \leq Z \leq 28$) derived for several different sets of source and propagation parameters. These calculated spectra are compared with the observed energy spectra of these charge groups corrected for solar modulation. Physical conditions which may give rise to two distinct particle populations are discussed briefly. The analysis is based on the revised and updated differential kinetic energy spectra measured on the OGO-I satellite and reported by Comstock, Fan, and Simpson.

4909 (Winckler, Arnoldy, Trapped Radiation, Electron Spectrometer)

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "Energetic Solar-Flare X Rays Observed by the OGO Satellites and Their Correlation with Solar Radio and Energetic Particle Emission," presented at the AGU Meeting, Washington, D. C., Apr. 1968.

ABSTRACT: Ionization chambers aboard the OGO-A and OGO-B spacecraft with a 10- to 50-kev response window have detected about thirty solar flare X-ray bursts in the time interval between September 5, 1964, and June 20, 1966. These energetic X-ray bursts have been correlated with 3- and 10-cm solar radio emission and solar-flare electron and proton events measured in space. A proportionality is observed between the time integrated X-ray and radio fluxes, and for a given flare the rise time, decay time, and total duration of the radio and X-ray bursts are similar. All 3- and 10-cm radio bursts greater than 80 flux units are accompanied by an X-ray event greater than 3×10^{-7} erg cm^{-2} sec^{-1}, and the probability of detecting an X-ray event is negligible unless the radio spectrum includes the centimetric range of wavelengths. In comparing energetic X rays with solar particle emission the best correlation seems to exist with the solar electron events observed in space. It is shown that the results are consistent with a source in the flare region consisting of an active volume in a magnetic field containing hot or energetic electrons that lose energy predominantly by collisions with a much cooler gas and produce X rays by bremsstrahlung. The similarity of decay and proportionality between the X rays and microwaves suggests that the same electrons might produce both emissions.

Kane, S. R., and D. J. Hofman, "Difference in Total Ionization Rate of Solar Particles inside and outside the Magnetosphere," presented at the AGU Meeting, Washington, D. C., Apr. 1968.

ABSTRACT: Identical ionization chambers aboard the satellites OGO-1 and OGO-3 are utilized in a comparison of the total ionization rate due to solar particles in front of the magnetosphere and in the magnetospheric tail at $15-20\ R_E$. The ionization chambers consist of a 7-in.-diameter spherical aluminum shell with a wall thickness of 0.81 mm (proton cutoff, 12 mev). The two units have been compared in flight by simultaneously measuring the galactic cosmic-ray background. The ionization rates are in agreement to within 1% using the preflight laboratory calibrations. Although no information can be obtained as to the type of particle or its energy spectrum, the high degree of accuracy in intercomparison and the high degree of sensitivity (0.01 proton/cm^2 sec at 20 Mev) make the ionization chamber a useful tool for studying the spatial characteristics of the radiation. During the period from August 28, 1966, to September 30, 1966, a series of six distinct solar particle events were observed aboard OGO-3. Data from the OGO-1 chamber were obtained during short periods when the satellite was operating. Data from the times of simultaneity are presented and the following results are established: (1) During the early phases of an event, the ion chamber outside the magnetosphere indicates a higher ionization rate than inside the magnetosphere. (2) During the decay phase the two sets of data are in average agreement; however, data from outside the magnetosphere tends to have more structure than that inside the magnetosphere. (3) From the observed roll modulation the degree of anisotropy is found to be considerable outside the magnetosphere. Data from inside the magnetosphere are presently being analyzed for anisotropies.

Kane, S. R., and J. R. Winckler, "An Atlas of 10-50 kev Solar Flare X-Rays Observed by the OGO Satellites 1 January 1967 to 31 December 1967," U. of Minn. Tech. Report CR-134, Apr. 1969.

ABSTRACT: Time-intensity profiles are shown in detail for all 10-50 kev solar flare X-rays observed by the ion chamber on the OGO-I and OGO-III spacecraft.

Kane, S. R., and J. R. Winckler, "Modulation and Heliocentric Gradient of Low Energy Cosmic Rays Near Solar Minimum (1965)," presented at the AGU Meeting, Washington, D.C., Apr. 1969; also U. of Minn. Tech. Report CR-131, Mar. 1969.

ABSTRACT: An analysis of the cosmic ray measurements made with the OGO-I, OGO-III and Mariner IV ion chambers, Mariner IV telescope and Deep River neutron monitor shows the following: (1) The energy dependence of the 11 year variation is in general different than that for a Forbush decrease. (2) As compared to the recovery phase (before May, 1965) the long-term modulation of the low energy (>12 MeV per nucleon) particles was relatively less during the early decreasing phase (June, 1965-December, 1966) giving rise to the "hysterysis" effect. The observed effect was maximum (~13%) from 31 June 1966 to 4 July 1966 and disappeared completely by 22-28 April 1967. (3) The "hysterysis" effect is probably a characteristic of the modulation mechanism. It is not likely to be due to the time variation of a quiescent flux of energetic solar particles. (4) In 1964-1965 the observations are consistent with a heliocentric gradient of 0% per A. U. in the range 1.0-1.28 A. U. and also probably in the range 1.0-1.56 A. U.

Kane, S. R., K. A. Pfitzer, and J. R. Winckler, "Description of Data Plots from the University of Minnesota Ion Chamber and Electron Spectrometer on OGO-I and OGO-III," U. of Minn. Tech. Report CR-127, Feb. 1969.

ABSTRACT: Total ionization rates and 50 keV - 4 meV electron spectra are displayed in a wide variety of plots covering orbits of OGO-I and OGO-III, September 1964 through 1967. This report documents and describes these plots which are now available in the NASA Space Science Data Center.

Pfitzer, K. A., "An Experimental Study of Electron Fluxes from 50 kev to 4 Mev in the Inner Radiation Belt," presented Ph. D. thesis, Aug. 1968, also U. of Minn. Tech. Report CR-123.

ABSTRACT: A five channel magnetic electron spectrometer which is capable of accurately measuring the electron spectrum from 50 kev to 4 Mev is described in this thesis. The five energy channels of the spectrometer are: 50-120 kev, 120-290 kev, 290-690 kev, 690-1700 kev and 1700-4000 kev. The spectrometer consists of two separate detectors operating together to provide double energy selection. The first of these is an electromagnet with a collimating slit having a geometry factor of 8.64×10^{-3} sterad-cm^2. The second detector consists of a heavily shielded scintillation crystal and photomultiplier tube. Since a magnetic field is necessary to bend the electrons into the scintillation detector, the background due to penetrating particles and bremsstrahlung can be measured by going through a complete analysis cycle with the magnetic field turned off. The electron spectrometers were flown on the Orbiting Geophysical Observatories (OGO) I and III.

The two spectrometers which have been cross calibrated in space and shown to agree to within 10% observe the continuing decay of the electrons injected into the inner zone by the nuclear explosion, Starfish, on July 9, 1962. The spectrometers observe a factor of ten decrease in the electron flux over a period of two years from September 1964 to August 1966 in the inner zone below L = 1.8 for electrons of E >290 kev. This decrease is attributed to the decaying Starfish electrons by comparing the decrease and flux levels to experiments which have measured the Starfish decay since shortly after the detonation. The 50-120 kev electrons, however, are observed to increase slightly during this two year period and the 120-290 kev electrons are observed to have a two year decay rate intermediate between the 50-120 kev electrons and the 290-690 kev electrons.

The diffusion-like injection of electrons of energy up to 690 kev deep into the inner zone to L = 1.3, creating a new and stable inner zone of natural origin, was observed following the magnetic storm associated with the September 2, 1966 solar flare. No increase in this region below L = 2.0 was observed for electrons of energy greater than 690 kev. Within one day of the onset of the event a wave of electrons was observed to penetrate to L = 2.0; following this initial wave there is a slow diffusion inward, such that the maximum increase at L = 1.4 (e.g., a factor of 3 increase for 290-690 kev electrons) is reached 30 days after the onset of the event. The increase immediately after the arrival of the wave for L > 2.0 is very large (e.g. more than an order of magnitude for 290-690 kev electrons at L = 2.2); this large increase, however, begins an immediate rapid exponential decay (τ = 13 days at L = 2.2 for 290-690 kev electrons) such that by mid-October the fluxes decayed to prestorm levels. For L < 2.0 on the other hand, no rapid decay is observed and the "new" inner zone resumes the slow decay (τ = 300-400 days) observed during the two years prior to the September 2, 1966 event.

Because of the very slow decay following the injection, the electrons injected by the September 2, 1966 event will decay to the prestorm levels for L < 2.0 in about one year. Therefore, only one or two events of this magnitude would suffice to supply the inner zone electrons (50 < E < 690 kev) below L = 2.0.

The equatorial pitch angle distributions for all L values in the inner zone during the entire two year period including the injection event were found to be flat near $\alpha_0 = 90^\circ$ and drop off rapidly near the loss cone.

Pfitzer, K. A., and J. R. Winckler, "The Decay and Injection of Artificial and Natural Electrons in the Inner Zone," presented at the AGU Meeting, Washington, D. C., Apr. 1968.

ABSTRACT: A five channel magnetic electron spectrometer measuring electrons from 50 kev to 4 Mev flown on the OGO-I and OGO-III satellites studied the long term time and space variations of the inner zone from September 1964 to December 1966, a period of low solar activity. Before September 2, 1966 electrons having energies greater than 290 Kev at L's less than 1.8 are observed to follow the decay curves of the Starfish electrons. 290-690 Kev electrons have decay times of 350, 450 and 450 days for L's of 1.3, 1.5 and 1.7 respectively. The decay rates are energy as well as L dependent, the higher energy electrons decaying more rapidly than the lower energy electrons.

The September 2, 1966 solar flare, one of the first large disturbances of the new solar cycle, was observed to inject electrons of energy less than 690 Kev to L's as low as 1.3; whereas, no increase in the flux was observed for electrons of energy greater than 690 Kev for L's less than 2.0. The number of electrons added to the inner zone between 50-690 Kev by the above event is independent of L, the percentage increase, however, varies from 40% at L = 1.3 to two orders of magnitude at L = 2.4. The large increase for L > 2.0 decays rapidly such that by mid October 1966 poststorm fluxes differ from the pre-storm fluxes by less than 50%. This "new" inner zone then resumes its "slow" decay as observed during the two years prior to the September 2, 1966 event. All electrons above 690 Kev below L = 1.8 can still be referred to as Starfish electrons, whereas those having energy less than 690 Kev are now primarily of natural origin throughout the entire inner zone.

Pfitzer, K. A., and J. R. Winckler, "Experimental Observation of a Large Addition to the Electron Inner Radiation Belt after a Solar Flare Event," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 3-13, 1968; also *J. Geophys. Res.*, (Letters), *73*, 5792-5797, 1968; also U. of Minn. Tech. Report CR-119.

ABSTRACT: The Starfish nuclear explosion (July 9, 1962) introduced a large flux of electrons into the inner zone. This has prevented the study of electrons of natural origin. Magnetic electron spectrometers flown on the OGO 1 and 3 satellites have observed the continuing decay of these Starfish electrons from September 1964 to August 1966. On September 2, 1966 a solar disturbance created a new stable inner zone of natural origin by the injection and diffusion of electrons to L values as low as 1.3. The spectrometer on OGO 3 has observed this new stable inner zone. (Editor)

4910 (Smith, Holzer, Triaxial Search Coil Magnetometer)

Brody, K. I., R. E. Holzer, and E. J. Smith, "2 Hz to 1000 Hz Magnetic Noise in the Quiet Magnetotail," presented at the AGU Meeting, San Francisco, Calif., Dec. 1968.

ABSTRACT: Instabilities and other dissipation mechanisms have been suggested as playing a role in field merging which has been postulated as taking place in the magnetotail. Observations of magnetic and electric field noise near the Neutral Sheet with frequencies which range from the proton gyro frequency to the electron plasma frequency are expected to provide clues to the nature of the field merging process. Described below are observations of magnetic noise in the range of 5 to 900 hz as detected by the OGO-I triaxial search coil experiment, a range which includes several characteristic plasma frequencies.

Frandsen, A. M. A., R. E. Holzer, and E. J. Smith, "OGO Search Coil Magnetometer Experiments," *IEEE Transactions on Geoscience Electronics,* Apr. 1969.

ABSTRACT: The OGO Triaxial Search Coil Magnetometer measures naturally occurring magnetic fluctuations between ~.01 Hz and ~1000 Hz in the space around the earth. The instrument design is described and the design rationale discussed.

The results of the observations on the first five OGO spacecraft in the magnetosphere, magnetotail, magnetosheath and interplanetary medium as well as at hydromagnetic bow shock are summarized and discussed.

Holzer, R. E., M. G. McLeod, J. V. Olson, C. T. Russell, and E. J. Smith, "The Magnetic Component of Plasma Waves Associated with the Interaction of the Magnetosphere and Solar Wind," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 3-13, 1968.

ABSTRACT: The wave structure of the region between the outer magnetosphere and the interplanetary medium has been examined with search coil magnetometers on OGO's 1, 3 and 5 in the frequency range from about .01 hz to 1000 hz. The dominant waves observed throughout the entire region lie in a frequency band below the electron cyclotron frequency. The higher frequency waves in this region are in the whistler mode. In addition there is evidence for waves in lower frequency modes such as the magnetosonic. Bursts of wave energy in the whistler mode, produced at the hydromagnetic bow shock, proceed into the interplanetary medium. The complex spectrum within the bow shock covers a broad frequency band from less than one hertz to a few hundred hertz. Within the magnetosheath away from the shock transition the wave spectrum commonly falls off as f^{-3}. Superimposed upon this spectrum are bursts of energy nearly monochromatic at frequencies from a few tens to a few hundred hertz normally lasting for a few seconds. There is a sharp decrease in the energy density of waves at frequencies above 1 hz as one passes inward across the magnetopause.

The entire wave pattern described above appears to be modulated by the motion of the magnetopause due to the compressional waves observed both inside and outside of the magnetopause boundary. While the bow shock is clearly a source of waves in the magnetosheath, the above results suggest that plasma waves are also produced in the magnetosheath by local instabilities.

Holzer, R. E., M. G. McLeod, C. T. Russell, and E. J. Smith, "The Structure of the Magnetopause and Shock Fronts," presented at the Inter-Union Symposium on Solar Terrestrial Physics, Sept. 1966.

ABSTRACT: OGO-I search coil magnetometer data show that there are rapid changes in the magnetic noise as one crosses the boundaries of the magnetosheath, defined in terms of the region of rapid change in dc magnetic field. The power spectrum of B, much larger in the magnetosheath than outside, decreases about $1/f^3$. Since the oscillations appear to lie below the electron cyclotron frequency, the waves are probably in the whistler mode. Precursors of the shock in the interplanetary medium observed at frequencies up to 5 hz appear to be whistler waves. Just inside the shock magnetic oscillations have amplitudes up to 20γ. These decrease in amplitude as one proceeds into the magnetosheath. The magnetic noise decreases sharply as one crosses the magnetopause into the outer magnetosphere.

McLeod, M. G., R. E. Holzer, and E. J. Smith, "Magnetic Spectra and Cross Spectra in the Magnetosheath in the Frequency Range from .01 to 140 Hz," *EOS Transactions, AGU, 50,* 4, Apr. 1969.

ABSTRACT: Magnetic fluctuations observed in the earth's magnetosheath by the search coil magnetometers on OGO-1 and OGO-3 spacecraft will be described. The power spectral density at a given frequency over the range .01 to 140 Hz varies by a few orders of magnitude during a magnetosheath traversal, has a change in slope from $1/f^2$ to $1/f^3$ slightly above 1 Hz, and the data is consistent with waves having an isotropic distribution of propagation directions in the plasma frame, with no polarization from a statistical point of view.

Smith, E. J., R. E. Holzer, and C. T. Russell, "Magnetic Emissions in the Magnetosheath at Frequencies near 100 Hz," *J. Geophys. Res.* (Letters), *74,* 3027-3036, 1969.

ABSTRACT: Intense, sporadic bursts of narrow-band magnetic noise in the Earth's magnetosheath with frequencies near 100 Hz are reported here. The signals have been detected by search coil magnetometers on board the eccentric orbiting geophysical observatories, OGO's 1, 3 and 5. The tone-like bursts are superposed on the persistent, broadband, extremely low-frequency magnetosheath noise reported previously (Smith, et al., 1967). The bursts commonly have peak signal amplitudes of tenths of gammas and durations from less than one second to tens of seconds. Although apparently sporadic in occurrence, they are customarily observed on every spacecraft transit through the magnetosheath and should be considered a characteristic feature of that region. As such, they belong in the same category as other known dynamic features of the magnetosheath such as energetic electron spikes (Fan, et al., 1964; Anderson et al., 1965) and quasi-periodic magnetic pulsations (Sonett and Abrams, 1963; Siscoe, et al., 1967; Greenstadt, et al., 1967). The

signals are probably transverse electromagnetic waves propagating within the magnetosheath in the whistler mode and are likely to provide evidence concerning wave-particle instabilities in the turbulent magnetosheat plasma.

Smith, E. J., K. I. Brody, R. K. Burton, R. E. Holzer, and C. T. Russell, "Observations of Waves in the Magnetosphere at Frequencies up to 1000 Hz," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 3-13, 1968.

ABSTRACT: The orbiting geophysical observatories contain search coil magnetometer experiments designed to investigate naturally-occurring signals in the extremely low frequency range between 1 and 1000 Hz. Data from OGO-1, 3 and 5 which are in eccentric orbits with apogees exceeding 20 earth radii have been used to conduct a survey of such signals throughout most of the magnetosphere including the magnetic tail All local times have been covered as well as radial distances from 1.1 earth radii to satellite apogee. Data from OGO-2 and 4 which are in polar orbits supplement the other measurements by permitting a complete survey in magnetic latitude and local time of the signals observed just above the ionosphere.

Data accumulated over several years provide a statistical description of the average properties of the signals such as ELF hiss and chorus and their relation to other spatial and temporal parameters. In addition, detailed information is available regarding discrete signals of special interest including triggered emissions and the fine structure of ELF chorus.

The significance of such observations is the information they contain concerning the properties of the plasma inside the magnetosphere and the nature of the various wave-particle interactions such as instabilities that are occurring there.

4911 (Heppner, Rubidium-Vapor and Fluxgate Magnetometer)

Heppner, J. P. "Correlations Between Magnetospheric Magnetic Field Variations and Auroral Electrojet Activity," *Ann. Geophys., 24,* 1-2, 1968.

ABSTRACT: The sudden onset of a negative bay on auroral belt magnetograms accompanies auroral break-up, usually in the magnetic time zone $23^h \pm 1.5^h$, and marks the occurrence of a major perturbation in the electric fields driving the electrojet currents. Correlated changes of either a cause or effect nature are thus expected in the distant magnetosphere along field lines intersecting the affected ionospheric area. *Dungey (1966), Axford (1966),* and subsequently others, have attributed the sudden onset to accelerated field line reconnection and merging deep in the magnetospheric tail with the acceleration of these processes being caused by a sudden change in the solar wind and/or solar-interplanetary field. *Heppner, Sugiura, Skillman, Ledley and Campbell (1967)* disagreed with the Dungey-Axford picture on both morphological grounds and observational grounds based on the space-time distribution of correlated field changes in the tail as measured by the OGO-I (OGO-A) satellite. In particular, considering only the observational results: (a) correlated onsets at the satellite were spatially limited to local time sectors of only a few hours near the onset meridian and to very low latitudes, thus indicating a localized relationship rather than one involving the entire tail, and (b) the onsets at the satellite were found to occur several or more minutes later at the satellite than at the earth's surface, thus indicating a disturbance progressing outward in the tail rather than inward toward the earth from distant tail regions. Consistent with these observations and the morphological considerations, *Heppner* et al. *(1967)* concluded that the immediate cause of the onset had to lie within the auroral ionosphere or on closed magnetospheric field lines in the near tail. It was further postulated that local ionospheric short circuiting between oppositely directed electric fields in the meridian plane provided the most likely explanation.

The published correlations and discussions, noted above, are reviewed in this presentation using more recent observations from the OGO-3 (OGO-B) satellite which further substantiate the OGO-1 results. Attention is then directed to cases where the sudden onset of a negative bay does correlate with the occurrence of a sudden impulse or sudden commencement caused by a change in the solar wind plasma and/or magnetic field. The existence of such correlations does not refute the previous argument that changes external to the geomagnetic cavity are not required to create a sudden negative bay onset. Instead they support the view expressed previously, *Heppner* et al. *(1967),* that an impulse may contribute to accelerating other processes responsible for the bay onset.

Examples of simultaneous impulses and bay onsets were given a number of years ago relative to Explorer-10 measurements, *Heppner, Ness, Scearce* and *Skillman (1963),* near the boundary of the geomagnetic tail.

These examples and more recent measurements illustrate that when a bay onset correlates with a sudden impulse these two magnetogram events occur simultaneously within the one minute resolution of standard recordings and that the impulse is observed several minutes later at a satellite in or near the geomagnetic tail. Thus, the time sequence is not consistent with models requiring reconnection in the tail to produce the bay onset. Explanation as to how a sudden impulse prematurely triggers a sharp bay onset within an existing disturbance pattern can be sought either in terms of direct particle effects (e.g., *Heppner* et al., *1963)* altering the conductivity or in terms of a sudden change in the electric field. It is most appealing to visualize the additional electric field accompanying a sudden impulse as being caused by a rapid convection sweeping through the magnetosphere from front to back as the magnetic field adjusts to a new position at a velocity approaching the Alfven velocity, which will be an order of magnitude or more greater than the usual convective velocities. The motion of magnetospheric flux tubes during an impulse has been calculated by *Sugiura (1965)* who referred to it as a higher mode of convection in the *Axford-Hines (1961)* model. The ionospheric electric field accompanying this convection is likely to be large and it thus offers an attractive explanation for correlated bay onsets if sudden bay onsets are caused by ionospheric short circuiting. In this case, the effects will appear in the auroral ionsphere at approximately the same rate as the impulse as the current adjusts to the perturbed electric field pattern. This is consistent with the lack of any delay between the impulse and the bay onset. Also, in the process of reaching a new electric field equilibrium, ionospheric currents will flow primarily where the conductivity is high. This is consistent with observations that impulse amplitudes are exceptionally great at auroral latitudes during disturbances. An additional effect in establishing a new electric field equilibrium is that transient currents are likely to appear along the magnetic field lines.

References

Axford, W. I., "Magnetic storm effects associated with the tail of the magnetosphere," Proc. of the ESRO Colloquium, Stockholm, November 1965, ESRO SP-8, August 1966.

Axford, W. I. and Hines C. O., "A unifying theory of high-latitude geophysical phenomena and geomagnetic storms," *Can. J. Phys., 39,* 1433-1463, 1961.

Dungey, J. W., "The reconnection model of the geomagnetic tail," Presentation at ESRO Colloquium, Stockholm, November 1965, Imperial College preprint, February 1966.

Heppner, J. P., Ness, N. F., Scearce, C. S. and Skillman, T. L., "Explorer-10 magnetic field measurements," *J. Geophys. Res., 68,* 1-46, 1963.

Heppner, J. P., Sugiura, M., Skillman, T. L., Ledley, B. G. and Campbell, M., "OGO-A Magnetic Field Observations," *J. Geophys. Res., 72,* 5417-5471, 1967.

Sugiura, M., "A sudden change in the solar wind pressure and the outer region of the magnetosphere," *J. Geophys. Res., 70,* 4151-4158, 1965.

Heppner, J. P., "Recent Measurements of the Magnetic Field in the Outer Magnetosphere and Boundary Regions," *Space Science Reviews, 7,* 23-27, 1967.

ABSTRACT: Within the framework of a brief review of recent magnetic field measurements in space, attention is directed to initial findings from the EGO-1 (OGO-A) satellite. Two particularly important results are: (1) circularly polarized, coherent oscillations of large amplitude are found at the bow shock front discontinuity. Study of the characteristics of these oscillations should significantly advance the understanding of collisionless shock waves, and (2) during periods of general magnetic disturbance when the magnetospheric tail field intensity is high, temporary decreases in tail field intensity are found to follow the onset of auroral zone negative bays in the same local time sector. This suggests that during the peak auroral activity which accompanies the onset of negative bays, the tail field in the bay sector partially collapses, or relaxes, from its highly stressed state.

An abnormal distortion of the outer magnetosphere on the day side of the earth coincides with the occurrence of an auroral zone positive bay near the same meridian. These correlations make it evident that a common mechanism is responsible for major changes in the outer magnetospheric field and the magnetic bays accompanying aurora.

Heppner, J. P., "Observations of the Earth's Bow Shock," presented at the Gordon Research Conference, Tilton, N. H., July 1968.

ABSTRACT: Observations of the bow shock have been studied primarily from four aspects: its location in earth coordinates, its detailed cross-sectional structure, the generation of waves at the shock, and up-stream propagation from the shock. Numerous satellites have demonstrated agreement in location with predictions of location based on analogy to hypersonic flow about a blunt body. Treatment of the remaining three aspects of the observations requires measurements of very high time resolution and until very recently such observations have only been available in the form of magnetic field measurements from OGO satellites. These permitted dimensional description in terms of: the sharpness of the undisturbed solar wind interface, the rise time, and the time dimensions of the field pile-up at the shock. Converted to thickness dimensions using a simple model for the velocity of shock motions values of <20, 70, and 250 km, respectively, are derived as being typical.

On many, but not all, shock crossings waves in the magnetic field are encountered superimposed on the shock front. These most commonly fall into two categories by frequency: 0.5 to 1.5 Hz, and a higher frequency, >7 cps. The 0.5 to 1.5 Hz oscillations are circularly polarized, usually occur in packets, and have been identified as being in the low frequency whistler mode. The higher frequency waves have not been identified with certainty. Perturbations up-stream from the shock are most commonly encountered in the form of waves similar to those seen at the shock. Often these appear in the form of 0.5 to 1.5 Hz wave packets.

Electric field measurements at the bow shock have very recently been made. Initial examination gives d. c. values in the millivolt/meter range rather than volt/meter range as predicted in some theories. These also confirm the identification of 0.5 to 1.5 Hz waves as being in the whistler mode.

Heppner, J. P., M. Sugiura, B. G. Ledley, and T. L. Skillman, "Magnetic Field Characteristics Near the Magnetopause," presented at the General Assembly IUGG, St. Gall, Switzerland, Sept. 1967.

ABSTRACT: The high data rates and orbit parameters of OGO satellites have permitted detailed study of magnetic fields near and at the magnetopause from 4^h LT to 20^h LT at magnetic latitudes from equatorial to 50 degrees. Differences in the field characteristics near this boundary as a function of local time and latitude provide information relevant to the fundamental question as to where and how solar plasma enters or transfers energy to the magnetosphere. In particular, the field characteristics in the equatorial sector defined approximately by 4^h to 6^h 30^m LT and $\pm 15^\circ$ magnetic latitude suggests that the boundary in this sector is unstable. Similar field characteristics are observed near the opposite (i.e., evening twilight) equatorial sector on some but not all satellite passes. These observations imply that plasma may readily enter the magnetosphere at equatorial latitudes along the twilight flanks. The subsequent convective flow of this plasma could be an important factor in the formation of a geomagnetic tail.

Sugiura, M., T. L. Skillman, B. G. Ledley, and J. P. Heppner, "Magnetic Field Structure in the Outer Magnetosphere," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 1968.

ABSTRACT: (1) *Shell structure:* The transition from the dipolar to non-dipolar magnetic field characteristic in the outer region of the magnetosphere is discussed using the results of the magnetometer observations made on the OGO-1 and 3 satellites. Under normal quiet conditions the field configuration has dipolar characteristics to a distance of approximately 11 earth-radii on the flanks and the dark side of the magnetosphere. Beyond this distance the dipolar characteristics disappear and the plasma pressure clearly dominates over the magnetic pressure in geomagnetic equatorial regions. However, a shell-like structure frequently exists on the night side outside the dipolar configuration. When the earth is magnetically disturbed the outer boundary of the dipolar region is found to be closer to the earth than in normal conditions.

(2) *Irregularity structure:* Magnetic field irregularities observed in the outer magnetosphere are most prominent in magnitude and in frequency of occurrence in equatorial regions close to the magnetopause. The most active irregularity regions appear at near-equatorial latitudes along the flanks of the magnetosphere near the twilight meridians. The variability here probably exceeds that encountered at similar low latitudes and distances in the magnetospheric tail except during periods of extensive bay activity. The magnetic fields in higher latitudes are, under normal conditions, characterized both in the magnetosphere and the tail by an absence of notable irregularities.

Sugiura, M., T. L. Skillman, B. G. Ledley, and J. P. Heppner, "Propagation of the Sudden Commencement of July 8, 1966, to the Magnetotail," *J. Geophys. Res., 73,* 6699-6709, 1968.

ABSTRACT: A sudden magnetic field increase associated with the July 8, 1966, sudden commencement (sc) was observed by the OGO 3 satellite in the magnetotail. By use of the IMP 3 and Explorer 33 observations made by Ness and Taylor of the interplanetary shock that caused the sc, it is shown that the magnetospheric propagation of the field increase toward the tail is faster than the propagation of the interplanetary shock just outside the bow shock. Conclusions drawn include (1) that the observed magnetic field increase in the tail is unlikely to be due to an increased lateral pressure of the postshock solar wind gas from the side of the tail, and (2) that the transfer of additional polar magnetic flux to the tail due to the increase in the solar wind pressure on the front side of the magnetosphere can account for the observed tail field increase.

4912 (Sagalyn, Spherical Ion and Electron Trap)

Sagalyn, R. C., and M. Smiddy, "Charged Particle Measurement by Means of Electrostatic Probes," COSPAR Research Techniques Instrumentation Manual No. 9, Ed: K. Maeda, Feb. 1967.

ABSTRACT: Multi-electrode analyzers of varying geometry designed to measure the properties of environmental ions and electrons in the ionosphere are described. The measurement of ion and electron densities, temperatures and energy distributions are considered. It is shown that under conditions where the velocity of the vehicle on which the experiment is mounted is large compared to the most probable ion velocity, crude ion mass determination may be obtained.

The theory of the experiment is given in Section I together with the limits of applicability in the upper atmosphere. Details of the basic sensor and associated electronics are given in Section III. In the fourth section problems which arise due to carrying out such experiments on a high speed vehicle with varying flight characteristics such as spin, roll, angle of attack, etc. in a partially ionized gas whose properties may change rapidly in space and time are discussed.

Sagalyn, R. C., and M. Smiddy, "Magnetosphere Plasma Properties During a Period of Rising Solar Activity—OGO-III," presented at the 8th International Space Science (COSPAR) Symposium, London, England, July 1967; also *Space Research VIII,* North-Holland Publishing Co., Amsterdam, Holland, 139-149, 1968.

ABSTRACT: The flux, energy distribution, and concentration of ions and electrons were investigated by means of two omni-directional plasma probes flown on the OGO-III satellite launched 7 June 1966. The measurements cover the energy range 0-1 kev over the altitude region 1.1-20 earth radii (R_e). In the analysis, emphasis is placed on results obtained in the transition region, altitudes where whistler propagation may be significant, and during periods of high solar activity.

The concentration of thermal charged particles decreases with height from $8 \times 10^4/cm^3$ at perigee to a minimum of $5/cm^3$ at apogee. The most rapid changes in density with altitude occur between perigee and $7R_e$. The altitude of maximum density change with height is dependent both on magnetic latitude and position of the satellite with respect to the earth-sun line. The flux of non-thermal charged particles varying between 10^6 and $3 \times 10^9/cm^2$ sec is correlated with the magnetic B and L parameters. Following the solar and magnetic storm which commenced 2 September 1966, the particle flux in the energy range 25 ev to 1 kev decreased by a factor of four in the transition region accompained by an increase in mean particle energy.

Sagalyn, R. C., and M. Smiddy, "Results of Charged Particle Measurements in the Energy Range 0 to 1000 Electron Volts, OGO-A," presented at the 6th International Space Science (COSPAR) Symposium, Buenos Aires, Argentina, May 1965.

ABSTRACT: Results obtained during the first three months of operation of two spherical electrostatic analyzers flown on the OGO-A satellite launched 5 September 1964 are presented. One instrument was designed to measure the density, flux and energy distribution of thermal (0 to 25 electron volts) and non-thermal (20 to 1000 electron volts) electrons in sequence at 12 minute intervals. The second analyzer measured the same properties of positive ions.

Typically the densities of thermal ions and electrons decrease rapidly with altitude between 4 and 6.5 earth radii and then decrease more gradually to a value of approximately 10 particles cm^{-3} at 24 earth radii.

At altitudes above 30,000 km the average energy of positive ions and electrons is found to vary between 5ev, and 7.5 ev. There is found, however, a significant number of particles with energies up to 22 ev. The positive ion flux in the energy range 26 to 1000 ev is found to vary between 10^6 and 10^8 cm^{-2} sec^{-1}; the electron flux varies between 10^7 and 10^9 cm^{-2} sec^{-1}. The average ion energy in the higher energy mode is about 350 ev and is 15 times larger than the average electron energy.

The variations with radial distance and time of charged particle flux, density and energy are presented and discussed. The results are also correlated with solar and magnetic activity.

Sagalyn, R. C., and M. Smiddy, "Results of Low Energy Ion and Electron Measurements in the Magnetosphere - OGO-A," presented at the AGU Meeting, Washington, D. C., Apr. 1965.

Sagalyn, R. C., "Space Electricity: Physical Problems and Experimental Techniques; Problems of Atmospheric and Space Electricity," proceedings of the 3rd International Conference on Atmospheric and Space Electricity, Montreux, Switzerland, May 5-10, 1963, Ed., C. Coroniti, Elsevier Press, 548-565, 1965.

ABSTRACT: In this paper physical processes of importance in influencing the spatial and temporal variations of charged particles, ions, electrons, and protons in the upper atmosphere and interplanetary gas are outlined. Uncertainties that presently exist in the explanation of these phenomena are discussed. In the second part of the report, techniques used to study the properties of charged particles with instruments placed on rockets, satellites and deep space probes are described. Some of the difficulties encountered in trying to make accurate measurements with instruments mounted on vehicles moving at great velocities in a highly variable plasma are discussed.

Shea, J. J., and K. H. Carpenter, "Investigation of Current Voltage Characteristics of Spacecraft Mounted Spherical Electrostatic Analyzers," Cosmic Inc. Final Report, Contract No. F19628-68-C-0021, AFCRL-68-0588, Sept. 7, 1968.

ABSTRACT: The current-voltage characteristic of a spherical probe in a flowing, Maxwellian plasma with an assumed spherically symmetric potential distribution is derived and expanded in Taylors series about plasma potential. The linear terms which are independent of plasma sheath thickness, are applied to reduction of data from spherical electrostatic analyzers. A computer program, written in Fortran IV, uses multidimensional minimization techniques to perform least squares fitting of plasma ion mass, temperature, and density to the linear portion of current and log-current data from spherical analyzers flown in the ionosphere. Analysis of selected data yields reasonable values for plasma parameters and demonstrates the capabilities of this method of data reduction.

Smiddy, M. and R. D, Stuart, "The Characteristics of a Multi-Grid Spherical Sensor in a Drifting Maxwellian Plasma," submitted to *J. Fluid Mech.*

ABSTRACT: An expression is derived for the current to a biased sphere in a flowing Maxwellian plasma. Results for both the retarding and accelerating cases are obtained in closed form and appropriate asymptotic forms are given. The effect of the sheath and the conditions under which the expressions are valid are discussed. The theory is then developed for the case of a multielectrode sensor consisting of a series of concentric spherical grids. Two simple applications are included to illustrate the use of the theory which is of much wider applicability.

Smiddy, M. and R. D. Stuart, "An Analysis of the Behavior of a Multigrid Spherical Sensor in a Drifting Maxwellian Plasma," AFCRL Physical Science Research Paper 34, No. 69-0013, 1969.

ABSTRACT: A theoretical derivation of the characteristic of a spherical probe in a flowing Maxwellian plasma is given together with various limiting forms of the equation. The limitations imposed on the validity of the theory by the characteristics of the sheath are discussed. The theory is then extended to the case of an n-grid sensor. Finally the application of the theory to the determination of plasma parameters from the probe characteristic is discussed.

Stuart, R. D., and M. Smiddy, "The Characteristics of a Space Vehicle Borne Charged Particle Sensor," *J. App. Phys.*

ABSTRACT: An expression is developed for the current flow to n spheres with known potential differences between them in a drifting Maxwellian plasma. By equating this to zero and solving the resulting equation numerically the potential of the spheres relative to the plasma is obtained. A charged particle sensor mounted on a space vehicle is then investigated, represented by a two sphere system. The current-voltage characteristic produced by sweeping the potential difference between the two spheres is obtained and is shown to be distorted by the variation of the vehicle potential. A method of correcting this by the introduction of a third sphere is described. The effects of area ratio, temperature and drift velocity are investigated. An attempt is made to use the method to throw some light on the case where the vehicle is cylindrical. The added complications due to the attitude sensitivity of the system as soon as any electrode becomes non-spherical is immediately apparent. Finally the implications of the theory in the determination of temperature from the sensor characteristic are discussed.

4913 (Whipple, Planar Ion and Electron Trap)

Whipple, E. C., Jr., and L. W. Parker, "Some Effects of Plasma-Vehicle Interaction on Probe Measurements," presented at the Fourth International Conference on the Universal Aspects of Atmospheric Electricity, Tokyo, Japan, May 1968.

Whipple, E. C., Jr., and L. W. Parker, "Theory of an Electron Trap on a Charged Spacecraft," *J. Geophys, Res. 74,* 2962-2971, 1969.

ABSTRACT: A theory is developed for the behavior of an electron trap on a slowly-moving charged spacecraft in the limit of large Debye length and no magnetic field. Analytic expressions are obtained for the current to an aperture electrode and to an internal retarding electrode for all values of aperture and spacecraft potentials. When the spacecraft is repulsive and the aperture grid is less repulsive (or even attractive) a potential barrier exists which reduces the current. The extent of the reduction can be orders of magnitude. As a consequence, the "knee" in the current-voltage curve can yield incorrect values for the electron density and spacecraft potential if conventional Langmuir probe theory is used. When the spacecraft is more attractive than the aperture grid the current is unaffected by the spacecraft potential. It is shown that in the so-called exponential regime of the retarded current, it is impossible for secondary electrons to reach the collector from the adjacent external surfaces of the spacecraft. In the attractive regime the current characteristic is linear for large aperture potentials.

Whipple, E. C., Jr., and L. W. Parker, "Effects of Secondary Electron Emission on Electron Trap Measurements," submitted to *J. Geophys, Res.,* Apr. 1969.

ABSTRACT: The theory developed earlier for the behavior of an electron trap mounted on a charged spacecraft is extended to include the contributions of secondary electrons emitted from the spacecraft surfaces. As in the case of currents from the plasma, the secondary-electron currents depend on the polarity as well as on the magnitude of the probe and satellite potentials. Analytic formulas are derived which reproduce the results of particle trajectory calculations for all probe and satellite potentials, in the limit of large Debye length and no magnetic field. The analysis is based on the structures of appropriate domains in velocity space, and is complicated by the possible presence of a potential barrier for a repulsive satellite, and also by the presence of more than one emitting surface. The distribution and yield of secondary electrons with respect to primary energy and angle is discussed, and it is argued that isotropy in emission directions is consistent with experiment. It is shown, in solar wind measurements where both "hot" and "cold" electron components are sometimes inferred, that while the "hot" component may be correctly attributed to the plasma the "cold" component can at times be attributed to secondaries from the spacecraft surfaces. Incorrect interpretation of the observed currents has led in the past to overestimates of the electron concentration. A correct interpretation leads to electron concentrations in good agreement with positive ion densities measured by other techniques in the solar wind. Measurements of electron concentration and temperature in the magnetosphere and in the solar wind should be viewed critically whenever the inferred temperature is in the range of characteristic secondary electron energies, i.e., a few electron-volts.

Whipple, E. C., Jr., J. W. Hirman, and R. Ross, "A Satellite Ion-Electron Collector: Experimental Effects of Grid Transparency, Photoemission, and Secondary Emission," ESSA Tech. Rept., ERL No. 99-AL1, 1968.

ABSTRACT: The effects of grid transparency, photoemission, and secondary emission on the currents measured by an ion-electron collector experiment flown on OGO I are examined in detail. The calculated grid transparencies agree with laboratory tests. The measured photocurrents as a function of angle of incidence i agree reasonably well with the calculated current assuming the yield is proportional to (cos i + sec i). Equations are derived for the effects of secondary emission on the background currents caused by particles with energies greater than 30 eV, from which the fluxes and yields may at times be calculated. The energies of the primaries can be estimated from the calculated secondary yields.

4914 (Hargreaves, Radio Propagation)

Fritz, R. B., E. R. Schiffmacher, and J. K. Hargreaves, "Response of Ionospheric and Exospheric Electron Contents to a Partial Solar Eclipse," *J. Geophys. Res, 73,* 4994-4998, 1968.

ABSTRACT: The partial solar eclipse on May 9th, 1967 occurred shortly after ground sunrise at Boulder, Colorado, at a time when it was possible to monitor the OGO-I radio beacon experiment. OGO was outbound at a range of approximately 10 earth radii and maintained an almost constant position in the sky. The electron contents measured by the Faraday rotation and phase path methods continued to increase during the eclipse but deviated significantly from the linear increase typical of other sunrise periods. The maximum eclipse effect on total content was reached 35 minutes after maximum obscuration (41% obscured at 300 km altitude) when the equivalent vertical content was estimated to be 3.7×10^{12} electrons/cm^2 (or 24%) below that of a comparable control day. The relative exospheric content exhibited only slight depletion, implying that most of the change was in the F-region rather than the exosphere.

da Rosa, A. V., and O. K. Garriott, "Protonospheric Electron Concentration Profiles," Stanford U. Radioscience Tech. Report SU-SEL-68-044, Mar. 1969.

4915 (Taylor, Atmospheric Mass Spectrum)

Brinton, H. C., R. A. Pickett, and H. A. Taylor, Jr., "Thermal Ion Structure of the Plasmasphere," *Planet. Space Sci., 16, 899-909,* Feb. 1968.

ABSTRACT: The distribution of thermal positive ions of hydrogen and helium in the magnetosphere has been determined from OGO-I ion mass spectrometer measurements made between 23 September 1964 and 17 June 1965. The distribution is strongly controlled by the geomagnetic field, its chief feature being a region of toroidal form, the plasmasphere, bounded approximately by the $L = 4.5$ shell within which the ion concentration decreases slowly with increasing altitude from an initial value of 3×10^3 ions/cm^3 at 2000 km. At the boundary of this region, which is compressed during periods of high magnetic activity, a sharp decrease in the ion concentration by a factor of ten or more for an altitude increase of less than one earth radius is observed, leading to a concentration beyond the boundary of less than 10^2 ions/cm^3. An apparent diurnal expansion in the plasma distribution is centered at 2000 hr. Over most of the altitude range within the plasmasphere the concentrations of H^+ and He^+ are observed in a constant ratio of 300/1, indicating departure from simple diffusive equilibrium. Measurements made by an identical spectrometer on OGO-III generally confirm these properties of the plasmasphere; significant correlation also exists with whistler observations of the magnetospheric thermal electron distribution. Correlation of latitude variations of ion composition measured by the OGO-II spectrometer with the high altitude distributions obtained by OGOs I and III indicate possible ionosphere-magnetosphere coupling.

Taylor, H. A., Jr., H. C. Brinton, and M. W. Pharo, III, "Evidence of Contraction of the Earth's Thermal Plasmasphere subsequent to the Solar Flare Events of 7 and 9 July 1966," reprinted from *Annals of the IQSY, 3.*

ABSTRACT: Direct measurements of thermal H^+ and He^+ in the magnetosphere have been obtained from ion mass spectrometers on Orbiting Geophysical Observatories (OGO) 1 and 3. Typical H^+ profiles exhibit a gradual decrease in concentration with altitude within the plasmasphere, while the outer boundary of the

plasmasphere is characterized by an abrupt decrease in concentration to 5 ions cm^{-3} or less. This boundary, the plasmapause, is observed to move inward and outward in an inverse correlation with the magnetic activity index *Kp*. The magnetosphere was disturbed during the solar flare period 7-9 July 1966, and on 9 July the plasmapause was observed to be unusually low, at $L = 3.3$. This observation contrasted with measurements of the plasmapause on both preceding and succeeding orbits, when in the absence of flares and magnetic disturbance the H^+ boundary was observed to expand to L values as high as 6. These measurements correlate well with "knee" whistler observations of the plasmapause.

Taylor, H. A., Jr., H. C. Brinton, and M. W. Pharo, III, "Contraction of the Plasmasphere During Geomagnetically Disturbed Periods," *J. Geophys, Res., 73,* 961-968, 1968.

ABSTRACT: Direct measurements of the thermal positive ions of hydrogen and helium have been obtained from positive ion mass spectrometers aboard the Orbiting Geophysical Observatories 1 and 3. Observations made during 1965 and 1966 show distributions of H^+ and He^+ extending to altitudes as great as 40,000 kilometers, corresponding to a magnetospheric coordinate of $L = 8$. The outer boundary of the plasmasphere is characterized by an abrupt decrease in the ion concentration. This boundary or plasmapause, defined by the reduction of H^+ concentration to 5×10^0 ions/cm^3 or less, is often quite sharp, with decreases in ion concentration of as much as an order of magnitude occurring within 250 kilometers. The position of the plasmapause is observed to move inward and outward from the earth in an inverse correlation with the planetary magnetic activity index *Kp*, indicating significant large-scale expansion and contraction of the plasmasphere during periods of agitated magnetospheric conditions. The apparent correlation between measurements of the hydrogen ion boundary and the 'knee' whistler evidence of the plasmapause suggests that the mechanism responsible for the depletion of the ionization is effective along the lines of the magnetic field, extending well into the earth's inner atmosphere to 1000 kilometers and below.

Vasyliunas, V. M., "OGO 1 Observations of the Magnetospheric Plasma Sheet and Its Relation to the Auroral Belt," presented at 49th meeting of AGU, Washington, D. C., Apr. 1968.

ABSTRACT: During the fall of 1965 the OGO 1 satellite was able to make observations at distances of 10-20 R_E within the equatorial region of the magnetosphere and also near the Earth (3-5 R_E) at comparatively high geomagnetic latitudes (up to 55° S), both within a single orbit. Electrons in the energy range 125 ev to $\sim$2 kev were measured by means of a Faraday cup. Low-energy electron fluxes could thus be studied within both the well-known equatorial plasma sheet of the magnetospheric tail and within the high-latitude region at nearly the same times. Intense electron fluxes characteristic of the plasma sheet are observed throughout the latitude range scanned. At the closest distances and highest latitudes, however, these fluxes are confined to a well-defined band corresponding to invariant latitudes 68° to $\sim$72° (these observations are mostly in the midnight-to-dawn quadrant, during quiet geomagnetic conditions). These results strongly suggest that the plasma sheet comes down to the Earth at or near the auroral belt. Variations of the electron energy spectrum within the plasma sheet, and in particular the occasional appearance of strong $\lesssim$100-ev electron fluxes coexisting with the usual $\sim$1-kev electrons (thus forming a markedly double-peaked energy spectrum) will be described.

4917 (Helliwell, VLF Noise and Propagation)

Angerami, J. J., "Asymmetric Distortions of the Magnetosphere Observed by Whistlers Received by OGO-I," presented at the URSI Spring Meeting, Ottawa, Ontario, Canada, May 23-26, 1967.

Angerami, J. J., "In Situ Observations of Whistler Ducts by OGO 3," in preparation for submission to *J. Geophys, Res.*

ABSTRACT: While the great majority of ground whistlers are interpreted as *indirect* evidence of magnetospheric ducts, the first *direct* evidence of ducts was obtained from the Stanford broadband VLF experiments on OGO 1 and OGO 3. Five discrete whistler ducts were encountered by OGO 3 on the inbound pass of 15 June 1966. Each duct was characterized by reception at the satellite of ducted whistlers with a distinct spectral shape, along with the high-frequency portions of whistlers that propagated in outer ducts (leakages). The data were interpreted in detail by ray tracing in a model magnetosphere that includes ducts of enhanced ionization. The following conclusions resulted: 1) the L thicknesses of the observed ducts ranged between

0.035 and 0.070 earth radii, and the inter-duct separations ranged between 0.017 and 0.18 earth radii; 2) the longitudinal dimension of the ducts was estimated to be of order 4°, or 0.3 earth radii at the equator, a factor of ~4 - 8 greater than the L dimension; 3) the whistler ducts are much more likely to be enhancements, rather than troughs; 4) the minimum enhancement factors needed to trap frequencies up to half the electron gyrofrequency are of order 8%, smaller values producing upper cutoffs at frequencies below half the gyrofrequency; 5) the upper cutoff of ground whistlers is a trapping (rather than absorption) effect; 6) the hydrostatic type of distribution of ionization along the field lines is applicable in the plasmasphere; 7) the travel times (and frequency of minimum delay) of ducted whistlers can be calculated with good accuracy by assuming purely longitudinal propagation.

Angerami, J. J., and R. L. Smith, "Ducted Whistlers on OGO-I and III," presented at the AGU Meeting, Washington, D. C., *48*, 88, Mar. 1967.

ABSTRACT: Ducted Whistlers received at OGO-I and III present frequency-time characteristics that change discretely with time, corresponding to the motion of the satellite through different ducts of field-aligned enhancements of ionization. It is therefore possible to identify the ducts traversed and measure their sizes and spacings. Whistler data collected by OGO-III on June 15, 1966, between 4.5 and 5 Earth radii near the equatorial plane in the nightside of the Earth, will be presented as evidence for several field-aligned ducts, with widths ranging between 200 and 400 km at the satellite. Although the duct theory of whistler propagation has been supported in the past by VLF data collected by ground stations, the results reported in the present paper represent the first direct evidence of ducts beyond 3 Earth radii. Within the inner ducts there is observed leakage of the higher frequency portions of whistlers traveling in outer ducts. The frequency above which the leakage is observed is approximately half the local gyrofrequency, in accord with the prediction of the ray theory of ducting. It will be shown that the time delays and nose frequencies of the ducted fractional hop whistlers are in good agreement with the calculations if the magnetic field measured at the satellite is used, rather than the Jensen and Cain field, which was about 6% higher at the time considered. Simultaneous VLF recordings at a ground station were used as reference for measurement of the actual time delays.

Angerami, J. J., R. L. Smith, and N. Dunckel, "Analysis of Whistlers Received by the OGO-I Satellite," presented at the Joint URSI-IEEE Spring Meeting, Washington, D. C., Apr. 1966.

ABSTRACT: The broad band VLF receiver aboard the OGO-I satellite picks up whistlers when the spacecraft position is such that $L < 6$ and the geocentric distance is less than 5 earth radii.

Both ducted and non-ducted whistlers are received and, among the former, the ones exhibiting a true noise are especially useful for detailed study of the electron density in the magnetosphere.

Comparison of time delays of whistlers propagating to the satellite from both hemispheres (1^- and 0^+ whistlers) provides a clear-cut distinction between models for the relative electron density distribution along the field lines, supporting the diffusive equilibrium model of the plasmasphere.

Burtis, W. J., and R. A. Helliwell, "Banded Chorus—A New Type of VLF Radiation Observed in the Magnetosphere by OGO 1 and OGO 3," *J. Geophys. Res., 74,* 3002-3010, 1969.

ABSTRACT: Satellites OGO 1 and OGO 3 observe VLF discrete emissions in the magnetosphere primarily in a single, variable frequency band. The frequency f of this 'banded chorus' depends on the equatorial electron gyrofrequency f_{H0} for the field line passing through the satellite, typical ratios of f/f_{H0} being 0.2-0.5. Evidently the emissions are produced near the equator at a fraction of the electron gyrofrequency, as predicted by electron cyclotron resonance generation mechanisms. A secondary dependence of the banded chorus frequency on dipole latitude, such that the lower ratios of f/f_{H0} are found at higher latitudes, is interpreted to mean that the emissions are generated at about half the electron gyrofrequency, but deviate inward from the field line to lower L values as they propagate earthward. Theoretical support is given by ray tracings showing the inward deviation of nonducted whistler-mode radiation due to the curvature of the magnetic field. Banded chorus has been observed at all local times, but is most common in the morning magnetosphere, outside the plasmapause.

Carpenter, D. L., C. G. Park, H. A. Taylor, Jr., and H. C. Brinton, "Multi-Experiment Detection of the Plasmapause from EOGO Satellites and Antarctic Ground Stations," *J. Geophys. Res., 74,* 1837-1847, 1969.

ABSTRACT: Three independent methods of detecting the plasmapause have been compared: (1) the GSFC ion mass spectrometers on OGO 1 and OGO 3; (2) Stanford University/Stanford Research Institute broadband VLF receivers (0.3-12.5 kHz) on OGO 1 and OGO 3; (3) Stanford University broadband VLF receivers at ground stations Eights and Byrd, Antarctica, near the 90° W meridian. In the satellite VLF data the plasmapause crossings are identified by abrupt changes in observed whistler and VLF noise activity and by noise bands of limited duration. In two cases of simultaneous VLF and ion data from the same EOGO satellite, plasmapause crossings were detected by both experiments within less than 0.1 R_E in L value. In eight cases of OGO 1 ion data and simultaneous ground whistler data spaced from 1 to 12 hours from OGO 1 in local time, good agreement was found between the measured plasmapause positions. The comparisons provide new verification of the essentially worldwide extent of the plasmapause and also verify previous indications that the radius of the plasmapause is frequently about constant over large local-time sectors in the range 0-18 LT.

Carpenter, D. L., N. Dunckel, and J. Walkup, "A New Very Low Frequency Phenomenon: Whistlers Trapped Below the Protonosphere," *J. Geophy. Res., 69,* 5009-5018, 1965.

ABSTRACT: A new whistler phenomenon has been identified through measurements at ground stations, on an Aerobee rocket between 100 and 200 km, and on the Alouette satellite at 1000 km. The new phenomenon is called the 'subprotonospheric' or 'SP' whistler, since most of its path appears to be restricted to the region below about 1000 km. The first example of an SP whistler was reported by Barrington and Belrose. In the present report a large number of observations are summarized, and the basic characteristics of the new phenomenon are described. Experimental results are presented which suggest that the whistler ray path is confined to the region between roughly 100- and 1000-km altitude, and that the whistler energy can echo back and forth between these levels. The SP phenomenon occurs mostly at night, typically within a few hours after sunset. SP events are often observed over a period of one or two hours in duration and, for a single Alouette pass, have been observed over a north-south range as great as 2000 km in extent. The evidence suggests that SP phenomenon occurs mostly near sunspot minimum and at dipole latitudes greater than 45 degrees.

Dunckel, N., and R. A. Helliwell, "Whistler and VLF Emission Intensities Observed in the Magnetosphere by the OGO-I Satellite," presented at the Joint URSI-IEEE Spring Meeting, Washington, D. C., Apr. 1966.

ABSTRACT: Measurements of whistlers and VLF emissions at altitudes up to ten earth radii have been made using the Stanford University/Stanford Research Institute VLF/LF receiver on board the OGO-I satellite.

When the satellite is close to the magnetic equator, whistlers are sometimes detected out to L-values of 5 earth radii; however, they are much more common on lower L-shells. The range of occurrence is thus comparable to that of ground whistlers. The highest observed rate of whistler occurrence near the equator, is 45 whistlers per minute at an L-value of 3.2.

When the satellite is far from the magnetic equator whistlers are sometimes detected out to L-values of 6 but again are much more common at lower L-values. The highest observed rate, as measured from dynamic spectra, is 475 per minute at an L-value of 2.7. The strongest whistler observed by the satellite was observed during daytime and had a magnetic intensity of $2 \times 10^{-2}\gamma$.

VLF emissions have been detected by the satellite out to L-values of 9 and beyond. Chorus is detected more than half the time during which the satellite lies within an L-shell of 9. The strongest chorus ever observed, detected at L = 5 and at a magnetic latitude of 40°, had a magnetic intensity of $6 \times 10^{-2}\gamma$.

The L-value of this observation corresponds to that of the maximum chorus detected by Injun III, but the amplitude is seven times stronger than the maximum reported for chorus detected by Injun III. Hiss is less common than chorus and may have a tendency to be restricted to L-values between 3 and 6.

Samples of the data taken by the sweeping receivers when the satellite is close to the magnetic equator have been used in an effort to determine the average VLF signal strength in this region. This average will be compared to the requirements for limitation of trapped particle fluxes by whistler-mode wave interactions.

Dunckel, N., and R. A. Helliwell, "A Study of Emissions Observed in the Magnetosphere and Transition Region," presented at URSI Meeting, Palo Alto, Calif., Dec. 7-9, 1966.

ABSTRACT: The upper cutoff frequency, f_u, of VLF emissions detected by the OGO-I satellite was measured over magnetic latitudes from 0 to 50 degrees and from L = 3 to the boundary of closed field lines as determined by Mead [1964] and Williams and Mead [1965]. The ratio of f_u to f_{H0}, the gyrofrequency at the top of the line of force passing through the satellite, averaged approximately 0.5, seldom exceeded 1.0, and was independent of geomagnetic latitude. These results provide strong support for the theory that emissions are generated by electrons in the vicinity of the magnetic equatorial plane.

Using the temporal and spatial occurrence of emissions as determined from OGO-I data, the diurnal variation of the occurrence of emissions at certain high-latitude VLF ground stations was predicted and found to be in good agreement with observations of emissions at those stations.

Dunckel, N., and R. A. Helliwell, "Whistler-Mode Emissions on the OGO-I Satellite," submitted to *J. Geophys., Res.*

ABSTRACT: This paper describes the spectrum and intensity of whistler-mode emissions detected by OGO 1 from perigee to apogee. One of its major contributions is comprehensive evidence that the upper-frequency end of the emission spectrum is controlled by conditions at the magnetic equator. This is the first experimental confirmation of its kind of an hypothesis often assumed in emission generation theories that emissions are generated near the magnetic equator. Another important contribution is the first determination of the actual emission intensity in the vicinity of the equator. These intensities in db above $10^{-3}\gamma\ (Hz)^{-1/2}$ are plotted in the equatorial plane in terms of LMT, the local mean time, and R_o, the geocentric distance in earth radii. The darker shading represents areas of more intense emission activity. The major features of this figure are the two regions of intense activity near the noon meridian centered at R_o = 4 and 9, and the quiet nightside region commencing at midnight which abruptly becomes more active at 06 hours. The outer active region coincides with the region of strong fluxes of electrons identified by Vasyliunas [*JGR* Dec. 1968], from the M.I.T. modulated Faraday cup detectors on OGO 1 and OGO 3. The quiet nightside region appears to be a different regime.

The broadband intensity of emissions at the equator averaged over all local mean times was estimated as a function of geocentric distance. These values may then be compared with the estimates of emission intensity given by Kennel and Petschek [*JGR*, Jan. 1966] assuming that the maximum radiation belt fluxes between L = 4 and L = 7 are limited by interaction with whistler-mode emissions. Since the intensity estimates all fall close to the measured values, these data verify that the radiation belts are indeed likely to be grossly affected by whistler-mode waves. Further research planned in this area includes a joint study with Vasyliunas to investigate in detail the relationship between emissions and low-energy electron fluxes.

Edgar, B. C., "Application of the Nu Whistler to Magnetospheric Density Profiles," research in progress.

ABSTRACT: At latitudes of 25 to 30° the separate traces of the magnetospherically-reflected whistler are frequently joined at a minimum frequency, resulting in the "Nu" whistler. The position of the reflection of the lowest Nu-whistler frequency is known to be near the satellite, and from this added information we have shown that models of ionization in the magnetosphere that depend only on altitude are not admissible. By applying more sophisticated models, including a latitudinal dependence, additional detail on the plasma density distributions is being obtained.

Edgar, B. C., and R. L. Smith, "Magnetospherically-Reflected Whistlers in OGO-I," presented at the Fall URSI Meeting, Stanford, Calif., 1966.

Edgar, B. C., and R. L. Smith, "A Computer Ray Tracing Interpretation of Certain Aspects of Magnetospherically Reflected Whistlers," presented at the URSI Fall Meeting, Ann Arbor, Mich., Oct. 1967.

ABSTRACT: Since the discovery of magnetospherically reflected (MR) whistlers on the OGO-I satellite, it has been shown that a computer ray tracing program, with ion effects included, can predict the spacing patterns and general shapes of observed MR whistlers as reported by Edgar and Smith. Recent investigations using the computer ray tracing program and the OGO-I MR whistler data show that:

(1) Observation of MR whistlers is generally confined to a region in the magnetosphere bounded by L-shells of 1.5 and 3.0 and by geomagnetic latitudes of 40°N and 40°S. Corresponding limits for starting latitudes of the ray paths are found from analysis to lie between 50°N and 15°N for sources in the northern hemisphere.

(2) The nature of ion composition at a base level of 1000 km in a diffusive equilibrium density model affects the spacing patterns and the nose frequencies of the predicted MR spectrograms. A model consisting of 50% H^+ and 50% O^+ at the base level seems to give best agreement with the data. Increasing the H^+ concentration to 75% and the O^+ concentration to 25% affected the spacing pattern quite adversely. The use of 25% He^+ with 50% H^+ and 25% O^+ tended to lower the predicted nose frequency by 1 kHz.

(3) For the model consisting of 50% H^+ and 50% O^+ at the base level, the computed spacings between MR traces were found to be very sensitive to the magnetic equator position relative to the satellite location. The required accuracy in the computation of the magnetic equator position was obtained using the Jensen-Cain formulation of the magnetic field.

A discussion of the emissions associated with MR whistlers with emphasis on the differences between emission and propagation effects will also be included.

Edgar, B. C., "Anomalous Nose Whistlers in OGO-I," presented at the Joint URSI-IEEE Meeting, Palo Alto, Calif., Dec. 1966.

ABSTRACT: Anomalous nose whistlers have been observed on OGO-I in a region extending twenty degrees to each side of the geomagnetic equator and from L = 1.9 to L = 2.5. These anomalous whistler traces are usually characterized by the following: nose frequencies of 4 kHz or lower, three or more well-defined individual components, and a component spacing pattern that depends on the geomagnetic latitude.

It was initially proposed by Smith that these whistler traces are produced by lightning energy traveling over non-ducted paths that begin at different points at the base of ionosphere. A ray tracing computer program including the effects of ions, initially developed by Kimura and later modified for better accuracy by R. L. Smith and B. C. Edgar, has been used successfully to predict the dispersion, shape, spacing, and nose frequencies of the anomalous nose whistlers, with good agreement with the OGO-I data. The diffusive-equilibrium model of the magnetosphere used, contained three ions, hydrogen, oxygen, and helium. A discussion of the computer results will include the sensitivity of the predicted dispersion curves to the relative ion concentrations.

Ficklin, B., L. H. Rorden, R. A. Helliwell, and N. Dunckel, "Observation of Two New Low-Frequency Noise Phenomena on OGO-I", submitted to *J. Geophys. Res.*

ABSTRACT: Two completely new types of low-frequency magnetic field noise have been detected by the VLF experiment on OGO-1. One type, called *broadband* noise, has a spectrum that covers the entire range of observations from 0.2 to 100 kHz. The other type, called *high-pass* noise, has a spectrum that extends from a lower-cutoff frequency often near 40 kHz to at least 100 kHz. Both appear as bursts lasting of the order of 1 to 30 minutes. A remarkably high correlation has been found between the occurrence of these noises and magnetic conditions at the earth's surface in the polar regions. Not only does this correlation exist on an hour-to-hour basis, but also the commencement of these noises at the satellite has been found to occur within 2 min of the commencement on earth of polar substorm activity, even when the satellite is at geocentric distances of over 18 earth radii.

Helliwell, R. A., D. L. Carpenter, N. Dunckel, J. P. Katsufrakis, R. L. Smith, L. H. Rorden, B. P. Ficklin, H. Guthart, and L. E. Orsak, "Whistler Mode Propagation and Natural Noise Observed in the OGO-I VLF Experiment," presented at the AGU Meeting, Washington, D. C., Apr. 1965.

Helliwell, R. A., and W. Burtis, "Enhancement of Discrete VLF Emissions at One-Half the Electron Gyrofrequency," presented at the Joint URSI-IEEE Meeting. Washington, D. C., Apr. 1969.

ABSTRACT: Discrete VLF emissions generated close to the equatorial plane of the magnetosphere have been observed in well-defined bands by the OGO-1 and OGO-3 satellites. It has been shown that the center frequency of the band varies with satellite position in such a way that this frequency is always close to one-half the minimum gyrofrequency on the ray path from the equatorial plane. This result is explained in

terms of the cyclotron oscillator model of discrete VLF emissions by considering focusing of the radiation. Focusing of longitudinally propagating rays is shown to occur at one-half the gyrofrequency where the refractive index surface flattens out. The amount of focusing is estimated by applying an approximate ray theory treatment to a physical model of the cyclotron oscillator.

Heyborne, R. L., R. L. Smith, and R. A. Helliwell, "A Latitudinal Cutoff of VLF Signals in the Ionosphere," *J. Geophys, Res.*, (in press) 1969.

Heyborne, R. L., "Observations of Whistler-Mode Signals in the OGO Satellites from VLF Ground Station Transmitters," presented at the Joint URSI-IEEE Meeting, Palo Alto, Calif., Dec. 1966; also Stanford U. Ph.D. thesis and SEL Report No. SU-SEL-66-094, Nov. 1966.

ABSTRACT: The field intensities from VLF transmitters (in the vicinity of 20 kHz) as observed from OGO 1 and OGO 2 were surveyed and compared with theoretical predictions. The new observations include a latitudinal cutoff, antipodal enhancements, an equatorial reduction of intensity, unexpected fading patterns, and possible observation of ducted signals.

Paymar, E., J. Katsufrakis, and J. J. Angerami, "VLF Interference Phenomena Detected Near the Magnetic Equator by an Unbalanced Electric Antenna on OGO 4," research in progress.

ABSTRACT: Broadband VLF records from the Stanford experiment on OGO 4 exhibit a pattern of interference at equatorial latitudes that resembles a pseudo-periodic emission. The noises are observed only when the experiment is in the electric-field (E) mode. The period observed is 9.215 seconds, which corresponds to a harmonic of the basic timing frequency and to the medium (16 kb/s) telemetry bit rate of the spacecraft. However, the period remains unchanged when the bit rate is changed. It is inferred that one of the experiments or another satellite subsystem is responsible for the interference.

Rorden, L. H., L. E. Orsak, B. P. Ficklin, and R. H. Stehle, "Instruments for the Stanford University/Stanford Research Institute VLF Experiment (4917) on the EOGO Satellite," Stanford Research Institute Instrument Report, May 1966.

Scarabucci, R. R., J. J. Angerami, and R. A. Helliwell, "OGO-4 Amplitude Measurements of Signals Generated by Ground VLF Transmitters," presented at the 1969 URSI-IEEE Spring Meeting, Washington, D. C.

ABSTRACT: Amplitude measurements of whistler-mode waves set up by ground VLF stations have been carried out aboard the OGO-4 satellite. For VLF stations located at mid and high latitudes the magnetic field strength at the satellite presents several striking features. In the hemisphere of the transmitter the whistler-mode signal is relatively strong near the VLF station, decreasing slowly with the east/west distance and more rapidly with north/south distance from the transmitter. Usually the signal disappears below the background noise around the magnetic equator. This weakening of the signal is caused by an enhancement of absorption around the magnetic equator for daytime and by a defocusing of the whistler-mode waves at nighttime. In the conjugate hemisphere of the transmitter the whistler-mode waves are much stronger than the ionospheric waves set up by leakage from the earth-ionosphere waveguide below the satellite. Consequently the amplitudes in the region conjugate to the transmitter are related to the fields observed in the hemisphere of the transmitter. A prominent feature of the measurements over the conjugate hemisphere is a remarkable enhancement of the signal due to magnetospheric focusing. This region is characterized by signals which may be as much as 20 db stronger than the fields observed near the transmitter. The observations over the conjugate hemisphere also show a high-latitude amplitude cutoff which may be related to the position of the plasmapause. Sometimes a similar high-latitude cutoff is also observed over the transmitter hemisphere. Finally, the differences between day and night measurements will be discussed.

Smith, R. L., "Non-Ducted Whistlers in the Magnetosphere," presented at the Joint URSI-IEEE Spring Meeting, Washington, D. C., Apr. 1966.

ABSTRACT: A common type of whistler observed in the OGO-I satellite is swishy, (has a large spread of time delays) at high frequencies but is fairly pure at the lower frequencies. The appearance resembles that of a

nose whistler, but the apparent nose is frequently at a much lower frequency than that expected for longitudinal propagation to the satellite. For example, in one case the apparent nose frequency was 3 or 4 kHz when the expected nose frequency was 10 kHz. Sometimes the rising portions do not join continuously to the main trace. Other whistlers observed in the same general region do not show the swishy tops and their nose frequencies are closer to the expected value. However, their low frequency dispersions are close to those described above.

Storey (1953) pointed out that propagation delay for frequencies much less than the gyrofrequency is nearly independent of wave normal angle. Smith (1960) showed that for somewhat higher frequencies, whistler waves traveling with large wave normal angles have large propagation delays compared to nearly longitudinal propagation which can occur within field aligned columns of enhanced ionization.

We suggest therefore that the new class of whistlers described above are the result of non-ducted propagation. The lower frequencies would not be affected as much as the higher frequencies, and a small amount of scattering would cause the higher frequencies to have a large spread of time delays.

Thorne, R. M., "Unducted Whistler Evidence for a Secondary Peak in the Electron Energy Spectrum near 10 kev," *J. Geophys Res., 73,* 4895-4904, 1968.

ABSTRACT: The upper and lower frequency cutoffs, as well as certain growth features of magnetospherically-reflected whistlers, are explained in terms of Landau damping by an ambient electron distribution that has a secondary peak in the vicinity of 10 kev.

4920 (Wolff, Wyatt, Gegenschein Photometry)

Wolff, C. L., "The Effect of the Earth's Radiation Belts on an Optical System," presented at the Optics in Space Conference, Southampton, England, Sept. 1965;" also *Applied Optics, 5,* 1838, Nov. 1966; also GSFC X-641-65-433, preprint.

ABSTRACT: A photoelectric optical imaging system has survived one year in the earth's radiation belts with no measurable (<20%) change in sensitivity. The system passes through all of the radiation belts twice every 64 hr, and experiences a noise level equivalent to 400 photons/sec when in their most intense regions. While this noise is far less than that of other photoelectric systems operating in the belts because of the small effective area of the photocathode, the noise per unit cathode area is 1.3×10^5 photons/sec-cm^2, and is similar to the best of the other systems. The number and energy distribution of incident particles is calculated and then combined with shielding estimates to give the total energy absorbed in the optical elements. Radiation damage reports in the literature are shown to be consistent with the lack of a sensitivity change in this orbiting optical system. The effects of particle radiation on optical systems in general is briefly summarized, with emphasis on recent work of others.

OGO-II EXPERIMENTS

C-02 (Helliwell, VLF Emissions)

Bell, T. F., and T. S. Jorgensen, "VLF Auroral Hiss and the Mapping of the Auroral Oval," presented at the International Symposium of Physics of the Magnetosphere, Washington, D. C., Sept. 3-13, 1968.

ABSTRACT: In the present paper the results are reported of a study of a unique, temporally persistent type of VLF auroral hiss which has been detected aboard the POGO satellites (and apparently also detected aboard Alouette I and Injun III). This unusual type of hiss possesses a characteristic spectral form and is observed to be limited spatially to the region of the auroral oval. A comparative study of OGO-II VLF data and Explorer XX topside sounder data suggests strongly that the hiss is associated with large-scale field-aligned irregularities in, or close by, the auroral oval. Although at present a direct connection has not been established between the field-aligned irregularities and the visual aurora, it appears possible that the existence of this form of hiss provides a tool for the continuous mapping of the position of the auroral oval by means of VLF data from polar orbiting satellites.

Bell, T. F., "Stationary Auroral Hiss Forms," submitted to *J. Geophys. Res.*

ABSTRACT: A unique, temporally persistent type of VLF auroral hiss has been detected aboard the OGO 2 and 4 satellites. This unusual type of hiss is limited spatially to the region of the auroral oval, is associated with visual auroral forms and field aligned irregularities, and provides a tool for the continuous mapping of the position of the auroral oval by means of satellite VLF observations. Differences between the low frequency portions of the hiss forms received on magnetic and electric antennas indicate that high intensity electrostatic noise is present in the hiss, possibly due to a two-stream instability process involving precipitating electrons.

Carpenter, D. L., and G. Haerendel, "Comparison of the Plasmapause Position as Determined from OGO-II VLF Data with a Barium Cloud Experiment Near Kiruna, Sweden on April 11, 1967," presented at the Meeting on Electric Fields in the Magnetosphere, Rice University, Mar. 1969.

ABSTRACT: The data from Winkfield and from later hours at Rosman, North Carolina indicate that on this magnetically quiet day and plasmapause was at an invariant latitude slightly poleward of both the release point of the barium and the westward drift path of the cloud. Since the local time was near dusk, the westward drift of the cloud may possibly be interpreted as evidence of the stagnation point or region of extremely low plasma velocities identified in the dusk sector of the magnetosphere by whistler techniques.

Crystal, T., "OGO-2 and OGO-4 Survey of ELF Noise," research in progress.

ABSTRACT: A recent study of OGO-2 and OGO-4 records has centered on the ELF ($\lesssim$1000 Hz) steady hiss and its controlling parameters. It has been found that: (1) the hiss occurs at all latitudes, decreases over the poles and equator, but maximizes both in signal amplitude and in bandwidth at higher latitudes ($50° < \Lambda < 70°$); (2) the hiss has a region of maximum occurrence at 0900-1300 LMT and an occurrence minimum at 2400-0200 LMT; (3) the hiss tends to exhibit a peak in intensity at frequencies near the local proton gyrofrequency Ω_p; and (4) the hiss shows unusual yet consistent behavior around Ω_p, thus providing a definitive means for distinguishing among several types of otherwise quite similar ELF noise bands. For example, the most common type has a sharp, lower frequency cutoff near Ω_p and tends not to occur simultaneously with proton whistlers (see Guthart et al. [*JGR, 73,* 3592, Jun. 1968]). The symmetry of ELF hiss frequency spectra with respect to the equator, its constant presence and uniform nature over wide ranges of Λ seem to imply a steady, equatorial source region extending out to moderate or high L values. There are difficulties with this picture, however, and further studies are being made.

Heyborne, R. L., "Observations of Whistler-Mode Signals in the OGO Satellites from VLF Ground Station Transmitters," presented at the Joint URSI-IEEE Meeting, Palo Alto, Calif., Dec. 1966; also Stanford U. Radioscience Tech. Report SU-SEL-66-094, Nov. 1966. (For abstract, see experiment 4917, OGO-I.)

Heyborne, R. L., R. L. Smith, and R. A. Helliwell, "A Latitudinal Cutoff of VLF Signals in the Ionosphere," submitted to *J. Geophys. Res.*

ABSTRACT: A latitudinal cutoff of signals received in OGO 2 from VLF transmitters is found to occur near 60° invariant latitude. The cutoff may be as severe as 40 db within a latitude change of 2°. Two of the suggested causes of the attenuation are increased absorption at high latitudes, or reflection of transmitted signals at the plasmapause. A region of very intense noise (auroral hiss) occurs at higher latitudes. Sometimes the signals from the transmitters are observed to return at higher latitudes after the noise has decreased.

Jorgensen, T. S., "Interpretation of Auroral Hiss Measured on OGO-II and at Byrd Station in Terms of Incoherent Cerenkov Radiation," *J. Geophys. Res., 73,* 1055-1069, 1968.

ABSTRACT: A wideband noise known as auroral hiss is observed at very low and low frequencies at ground-based stations and on satellites at high magnetic latitudes. Several attempts have been made to explain this noise as incoherent Cerenkov radiation from energetic particles in the magnetosphere, but the conclusions were all negative, as the calculated power was several orders of magnitude below the observed power.

The results of recent observations of auroral hiss and of the low energy electrons with which this noise is strongly correlated suggest that unrealistic models were used in earlier calculations of the total power generated in the magnetosphere by an incoherent Cerenkov process. Therefore it is considered worthwhile to study the Cerenkov radiation again.

This paper discusses a model for a region in space in which the auroral hiss is believed to be generated. It is shown that the total power generated in this region is comparable to the observed power, and it is concluded that auroral hiss may be generated by incoherent Cerenkov radiation from electrons with energies of the order of 1 kev.

Katsufrakis, J., "Differences Between the VLF Magnetic and Electric Field Spectra of the Lower Hybrid Resonance (LHR) Emissions and Associated Phenomena," presented at the Spring URSI Meeting, Washington, D. C. Apr. 1968.

ABSTRACT: Brice and Smith [1965] suggested that the LHR hiss observed on the Alouette I (electric antenna) is characterized by large electric fields, and that this hiss band is found more often on a receiver fed from an electric or dipole antenna than a receiver fed from a magnetic or loop antenna (Injun III).

Since a very large number (~2000) of VLF recordings were available from OGO-II and IV (magnetic antenna), a comparative study of the LHR emissions and associated phenomena as observed on OGO-II, IV, Alouette I, Alouette II, and simultaneous ground VLF recordings was undertaken. The results of this study are the following: 1) the LHR hiss band as discussed by Brice and Smith has never been seen on any of the OGO-II and IV VLF recordings; 2) anomalous-dispersion whistler traces associated with the LHR were observed on Alouette I and II and on OGO-II and IV; and 3) the anomalous-dispersion whistler traces observed on OGO-II and IV lend themselves more readily to quantitative analysis, since the LHR hiss is not observed and does not mask out pertinent features of the traces.

The conclusion by Brice and Smith that the LHR hiss is generated in the immediate vicinity of the satellite is still supported. The new and intriguing dispersion anomalies being observed have not yet been interpreted, but possible propagation factors will be discussed.

Muzzio, J. L. R., "Reflection of Whistlers in the Ionosphere," presented at the URSI Spring Meeting, Washington, D. C., Apr. 1968.

ABSTRACT: Evidence for reflection of downcoming whistlers in the upper ionosphere was found in some VLF recordings of OGO-II and OGO-IV. The frequency-time curve of the whistler follows the Eckersley approximation from higher frequencies down to a region where it starts departing towards increased time delays. After passing through a minimum frequency, the signal rises again, sometimes by ~200 Hz. For the observed occurrences the satellite height ranges from 450 to 600 km and the minimum frequencies from about 400 to 550 Hz. This corresponds to the region of the first cutoff frequency of the "fast" mode below the proton gyrofrequency. For a downward propagating ray, the refractive index drops considerably in this region and the reflection takes place for frequencies just above the cutoff frequency. The whistlers in question have a dispersion of about 30 $\sec^{1/2}$, which, for the latitudes of observation (~40° geomagnetic latitude) suggests an origin in the conjugate hemisphere. An estimate of the H^+ percentage may be made from a knowledge of the reflection frequency and the local magnetic field intensity. The effects described were reproduced very closely using ray tracing techniques for an assumed model ionosphere with ducts. The

presence of ducts was found necessary in order to guide the lower part of the frequency spectrum to the satellite height. Without the ducts the energy in the lower frequencies would be reflected much higher (resulting in an MR whistler) and would not reach the satellite.

Muzzio, J. L. R., "Ion Cutoff Whistlers," *J. Geophys. Res.* (Letters), *73,* 7526-7529, 1968.

ABSTRACT: Broadband VLF receptions on OGO 2 and OGO 4 show evidence of the reflection of downward propagating whistler energy near the region where wave frequency equals a natural propagation cutoff of the medium, namely the first two-ion cutoff below the proton gyrofrequency. The phenomenon is illustrated in Figure 14.1 on frequency-time spectrograms from two passes of OGO 4. The characteristic feature of these spectra is the turning up of the trace around a minimum frequency which is very near but above the local two-ion cutoff frequency mentioned above. For this reason the name "ion cutoff" whistler was suggested. The whistler shape is the result of a reflection of the waves in the ionosphere below the satellite, the minimum frequency being reflected at the vehicle height. A local estimate of the relative concentration of H^+ ions can be made from the ratio of this minimum frequency to the proton gyrofrequency at the satellite.

Scarabucci, R. R., "OGO-4 Amplitude Measurements of Signals from Ground VLF Transmitters," research in progress.

ABSTRACT: A survey has been made of OGO-4 data on spatial variations in the amplitude of fixed-frequency waves from VLF transmitters. The results provide both verification and considerable extension of previous findings by R. L. Heyborne from OGO-2. Particular attention has been paid to amplitude details and to the repeatability of certain effects, such as a maximum in signal amplitude in the region *conjugate* to the transmitter. This effect has been partially explained as a focusing phenomenon. Another highly repeatable effect is a frequency dependent dropout in signal intensity around the magnetic equator. The nighttime manifestation of this phenomenon is interpreted in terms of defocusing, the daytime manifestation in terms of ionospheric absorption.

Taylor, H. A., Jr., H. C. Brinton, D. L. Carpenter, F. M. Bonner, and R. L. Heyborne, "Ion Depletion of the High Latitude Exosphere: Simultaneous OGO-2 Observations of the Light Ion Trough and the VLF Cutoff," in preparation for *J. Geophys. Res.*

ABSTRACT: Two case studies from the early life of OGO 2 show a rapid latitudinal decrease in concentration of the light ions H^+ and He^+ coincident with abrupt changes in VLF whistler and noise activity. Both effects are interpreted as low altitude evidence of the plasmapause.

Walter, F., and J. J. Angerami, "New Evidence of Nonducted Whistler Mode Propagation to the Conjugate Ionosphere: The 'Walking-Trace Whistler,' Doppler Shifts and Focusing," submitted to *J. Geophys. Res.*

ABSTRACT: Evidence for nonducted whistler-mode propagation to the conjugate ionosphere has been found in broadband records from OGO 2 and OGO 4. In natural whistlers this propagation manifests itself as the "walking trace" (WT) whistler. The following features of WT whistlers distinguish them from ducted events: 1) WT whistlers are rising tones; 2) they have not been observed on the ground; 3) in satellites, they are only observed within a few degrees of 51° invariant latitude; 4) their travel times increase rapidly with latitude, so that on frequency-time spectra a succession of WT whistlers appears to "walk through" the much more slowly varying ducted events; 5) they have a lower cutoff at a nearly constant frequency, equal to the maximum value of the lower hybrid resonance frequency above the satellite; 6) WT whistlers exhibit an upper cutoff that decreases with latitude, and is possibly caused by Landau damping at high altitudes beyond $L \cong 3$.

Two effects not detected in natural whistlers but easily seen in nonducted signals from fixed frequency VLF transmitter are doppler shifts (up to hundreds of Hertz) and enhancements of signal strength caused by focusing.

All of the above features have been explained by ray tracing in a model magnetosphere. The ray tracings in most cases are quite sensitive to the details of the model magnetosphere, and there are now evident a variety of diagnostic applications for the new types of signals.

Walter, F., "Nonducted VLF Mode of Propagation in the Magnetosphere: the Walking Trace Whistler, the Doppler Shift and the Enhancement of Signal," presented at the 1969 URSI-IEEE Spring Meeting, Washington, D. C., Apr. 23, 1969.

Wang, T. N. C., and T. F. Bell, "VLF Radiation from Electric Antennas in the Magnetosphere," presented at the Spring URSI Meeting, Washington, D. C., Apr. 1968.

ABSTRACT: It has long been recognized that the operation of a satellite-based VLF transmitter in the magnetosphere would provide a means of performing a number of important and interesting experiments involving wave-particle interaction phenomena, wave propagation phenomena, and plasma diagnostics.

The usefulness of such a transmitter in performing experimental tasks will be limited ultimately by the amount of power that can be radiated into the plasma from the antenna; in some instances the radiation pattern of the antenna will also play a crucial role.

It is the purpose of the present paper to attempt to obtain some insight into the problem of the coupling between a satellite VLF transmitter system and the magnetospheric plasma by the consideration of some idealized cases. Specifically, we calculate the radiation resistance of a thin electric monopole of arbitrary length oriented either parallel or perpendicular to the static magnetic field, as well as the radiation pattern of a small electric dipole oriented parallel to the static magnetic field.

For the case of the monopole, our results give the radiation resistance explicitly as a function of frequency for a range of frequency between the proton and electron gyrofrequencies.

For the dipole, our results show that in the case of low frequency the radiation pattern is confined within a cone of approximately 20° about the static magnetic field and consists of two parts, a zone of normal radiation fields and a zone of interference fields. The detailed pattern inside the confining cone is calculated.

In conclusion, a discussion is given of the implications of our results with respect to the satellite transmitter problem.

C-03 (Morgan, VLF Emissions)

Carden, R. C., T. Laaspere, and B. Pratt, "An Experiment to Study Electric Electromagnetic Fields in the Frequency Range 10 Hz-540 kHz on OGO-F," *IEEE Transactions on Geoscience Electronics,* Apr. 1969.

ABSTRACT: An experiment is described which will extend the frequency range over which "whistler-mode" waves have been observed in the ionosphere. The experiment uses an electric dipole antenna and will therefore also detect the essentially purely electric waves associated with the lower hybrid resonance noise bands. Emphasis is on broadband observations which are made in the bands 0.01-15, 15-30, 92.5-107.5, and 280-295 kHz. The experiment also includes two narrowband receivers (at 200 and 540 kHz) and a subsystem to measure the antenna impedance at four frequencies (8, 24, 104.5, and 285 kHz).

Laaspere, T., M. G. Morgan, and W. C. Johnson, "Observations of Lower Hybrid Resonance Phenomena on the OGO 2 Spacecraft," *J. Geophys. Res., 74,* 141-152, 1969.

ABSTRACT: Audiofrequency noise bands of continuous and triggered types that are evidently associated with the lower hybrid resonance frequency of the ionospheric medium have been observed with Dartmouth's whistler receiver using a 9-ft electric dipole antenna on the OGO 2 spacecraft at heights up to 1500 km (apogee) and at frequencies up to 18 kHz (upper cutoff of the broadband receiver). Previous reports of observations of such bands have all been from the Alouette satellites that also carry whistler receivers equipped with electric dipole antennas. Although the electric dipole on OGO 2 is much shorter than the antennas of Alouette, our results are similar to the Alouette observations. A direct comparison is made of records obtained simultaneously on OGO 2 by Stanford's VLF experiment, which is connected to a loop antenna, and it is shown that triggered LHR emissions are seen almost exclusively on our experiment with the electric dipole antenna, pointing to an electric character of the waves. A new observation made by our experiment is that the upper cutoff frequency of the lower hybrid resonance noise bands triggered by fractional-hop whistlers occasionally displays an envelope that has the shape of an Eckersley whistler. Whereas the results of the experiment are consistent with the interpretation that the lower cutoff frequency of noise bands triggered by whistlers is the lower hybrid resonance frequency of the ionosphere in the vicinity of the satellite, there is at present no satisfactory explanation of the upper cutoff.

Laaspere, T., M. G. Morgan, and C. Y. Wang, "Observation of Triggered Lower Hybrid Resonance Noise Bands by Dartmouth's OGO-II Experiment," presented at the COSPAR Meeting, London, England, July 1967.

ABSTRACT: Audio-frequency noise bands of the continuous and triggered types which are evidently associated with the lower hybrid resonance frequency of the ionospheric medium have been observed with Dartmouth's whistler receiver using an electric dipole antenna on OGO-II at heights up to 1500 km (apogee) and at frequencies up to 18 kHz (upper cutoff of the broadband receiver). Previous reports of observations of such bands have all been from the *Alouette* satellites which also carry whistler receivers equipped with electric dipole antennas. In spite of the fact that the electric dipole on OGO-II is much shorter than the antennas of *Alouette,* our results are similar to the *Alouette* observations, and cast some doubt on some other reports according to which intense electrostatic ion waves or plasma oscillations have been detected. A new observation made by Dartmouth's OGO-II experiment is that the upper cutoff frequency of the lower hybrid resonance noise bands triggered by fractional-hop whistlers occasionally displays an envelope which has the shape of an Eckersley whistler. It is concluded that whereas the results of the experiment agree with the interpretation that the lower cutoff frequency of noise bands triggered by whistlers is the lower-hybrid resonance frequency of the ionosphere in the vicinity of the satellite, there is at present no satisfactory explanation of the upper cutoff.

C-06 (Cain, Rubidium Vapor Magnetometer Magnetic Survey)

Cain, J. C., "Satellite Observations of Quiet Day Magnetic Variations at Low Latitudes," Third International Symposium on Equatorial Aeronomy, Ahmedabad, India, Feb. 1969.

Cain, J. C., and R. Hide, "The Geomagnetic Field at the Core-Mantle Interface," submitted to *Physics of the Earth and Planetary Interiors,* Jan. 1969.

Cain, J. C., A. B. Kahle, and R. H. Ball, "Confirmation of Prediction of Geomagnetic Secular Change," submitted to *Nature,* Feb. 1969.

Cain, J. C., R. A. Langel, and S. J. Hendricks, "First Magnetic Field Results from the OGO-2 Satellite," presented at the Ninth Plenary Meeting of COSPAR, May 13, 1966; also *Space Res., 7,* 1466-1476, 1967.

ABSTRACT: The OGO-2 (1965-81A) satellite was launched 14 October 1965 into an orbit with an inclination of 87.4°, perigee of 414 km and apogee of 1510 km. Digital samples of the total magnetic field F were obtained with a rubidium vapor magnetometer at 0.5 sec intervals (accuracy $\pm 2\gamma$). Root-mean-square differences between the measured field values and those computed from previously derived spherical harmonic expansions were computed. The best comparison of the data is with the GSFC (9/65) field which showed RMS residuals of 47γ. Computation of fields fit to this limited data sample show RMS deviations of 4.1γ using 143 internal spherical harmonics. The residuals from this field show oscillations near the north pole of a few tens of gammas amplitude and irregular structure elsewhere of the order of a few gammas.

Cain, J. C., A. J. Hendricks, R. A. Langel, and W. V. Hudson, "A Proposed Model for the International Geomagnetic Reference Field–1965," *J. of Geomag. and Geoelec., 19,* 335-355, 1967.

ABSTRACT: A best current model of the main geomagnetic field is presented as a response to a need for an "International Geomagnetic Reference Field." This model is described by a series of 120 spherical harmonic coefficients and their first and second time derivatives from an epoch 1960.0. It was derived from a sample of all magnetic survey data available from the interval 1900-1964 plus a recent global distribution of preliminary total field observations from the OGO-2 (1965-81A) spacecraft for epoch 1965.8. A duplicate data selection was made and the resulting field model compared with the first to help evaluate the minimum error. It was noted that the root-mean-square difference between the two models was about 30γ in the force components, 0.04 degrees in dip and 0.3 degrees in declination at the earth's surface for 1965.0.

Cain, J. C., "The Role of the Main Geomagnetic Field in Locating Conjugate Points," *Radio Science, 3,* 766-771, 1968.

ABSTRACT: A sample distribution of conjugate points is calculated from various models of the main geomagnetic field, evaluated at different epochs. A summary of the conclusions is: (1) For $L < 4$ the errors are

of the order of a few tens of kilometers; (2) older models of the field such as the Finch-Leaton give results within a few degrees of the latest more accurate models; (3) use of the eccentric dipole approximation gives errors that range from a few tens of kilometers at high latitude to several hundred kilometers near the equator; and (4) the secular change of conjugate-point locations is very small, averaging 1 to 10 km/yr. Inclusion of Mead's boundary field for a trace from Macquarie Island to Alaska ($L = 5$) shifts the conjugate only about 100 km. It is concluded that for $L \geq 5$ the field line passes through regions where the field intensity is weak enough to require that realistic estimates of the distortions due to plasma interactions be included in conjugate-point determinations. (These estimates are not now available.)

Cain, J. C., and R. Hide, "On the Constancy of the Geomagnetic Field at the Core-Mantle Interface," presented at the 11th National Fall Meeting of the AGU, San Francisco, Calif., Dec. 1968.

ABSTRACT: The vertical flux of the geomagnetic field was studied using the GSFC(12/66) field model extrapolated into the core-mantle boundary. Discounting the anomalous effects of higher order terms ($n^* > 5$) due to the amplification of their errors, it is seen that whereas the main dipole continues to exhibit its continual decrease at the rate of about 6% per century, the total flux is constant to within 0.5% in 60 years. Confirmation of this constancy is given by an independent analysis using only data from the OGO 2 and OGO 4 satellites for 1965.7-1967.9. This last analysis shows an apparent increase in the rate of dipole collapse to almost 8% per century. However, the addition of spherical harmonics up to $n^* = 6$ (48 harmonics) gives a constant average flux to within estimate errors.

Cain, J. C., "Observations of the Equatorial Electrojet by OGO-2 and OGO-4 Spacecraft," presented at the 11th National Fall Meeting of the AGU, San Francisco, Calif., Dec. 1968.

ABSTRACT: The OGO-2 spacecraft passed low over the equatorial electrojet in December, 1965. A small disturbance was detected for the few passes when spacecraft power was sufficient to record magnetic field data. Somewhat higher transits by OGO-4 in September, 1967 were made and the effect of the jet observed. In both of these instances the measurements indicate depressions of the field considerably smaller than predicted by theory.

Cain, J. C., R. A. Langel, and S. J. Hendricks, "Magnetic Chart of the Brazilian Anomaly-A Verification," *Geomagnetism and Aeronomy, 8,* 84-87, 1968 (English edition published by AGU).

ABSTRACT: In a recent paper Konovalova and Nalivayko (1967) have reported the results of the Cosmos-26 and 49 satellites (1964-13 and 69 respectively) in mapping the magnetic "low" in total field which centers on southern Brazil. We wish to take this opportunity to compare their results with an evaluation from a recently derived field model which is partly based on the magnetic field experiment from the OGO-2 satellite (Cain et al., 1967a). These magnetic survey satellites are contributers to the bilateral cooperation between the U. S. and the USSR for the IQSY World Magnetic Survey (Frutkin, 1965).

Langel, R. A., and J. C. Cain, "OGO-2 Magnetic Field Observations During the Magnetic Storm of March 13-15, 1966," *Annales de Geophysique,* 857-869, July 1968.

ABSTRACT: Magnetic field data from the OGO-2 spacecraft and from surface magnetic observatories are analyzed for the period March 13-15, 1966. During this interval there occurred a magnetic storm with a Dst decrease of 122γ.

The results indicate a non-symmetric inflation of the magnetosphere (asymmetric ring current) with the field decrease in the dusk sector a factor of about three more than that in the dawn sector. Within the 10-30γ accuracy of the data, the field disturbance at the satellite was equal to that on the surface at the same local time. From this evidence it is concluded that the source of both Dst and Ds in low latitudes are external to the satellite altitudes (410-1510 km). The disturbance observed near the dusk meridian commenced several hours sooner than that observed near the dawn meridian, reached its maximum intensity in 18 hours and then decayed in another 18 hours to the level seen on the dawn meridian.

Polar ionospheric currents were detected more than 1.5 hour before the storm's main phase. These currents conform to the classical "twocelled" model which includes a concentrated eastward current in the evening local time sector and a concentrated westward current in the morning local time sector. The evening

currents first appear at L = 7.5 and smoothly shift to L = 4.3 at the time of maximum Dst. The morning currents first appear at L = 7.9 and subsequently shift to L = 5.3. The L location of the morning currents is always greater than that of the evening currents. These currents decrease at least by an order of magnitude at the same time as the transition from asymmetric to symmetric inflation is seen at low latitude.

C-11 (Hoffman, Scintillation Detector, Low Energy Trapped Radiation)

Olson, J. V., and R. E. Holzer, "Spectra, Direction of Propagation and Polarization of Waves Associated with the Earth's Bow Shock in the Frequency Range 0.5 to 500 Hz," presented at the AGU Meeting, San Francisco, Calif., Dec. 1968.

ABSTRACT: Magnetic fluctuations associated with the earth's bow shock in the frequency range 0.5 to 500 hz have been measured with the search coil magnetometer on OGO-3. Power spectra have been computed for a number of crossings and show a wide range of frequencies to be present at the shock, extending from less than 1 hz to many hundreds of hz. The magnetic fluctuations are of two basic types. First there is a random background of frequencies which covers a range from below 1 hz to above 100 hz with the dominant peak near 5 hz. Second there is superimposed upon this background packets of coherent, elliptically polarized radiation in the frequency range 10-500 hz. These bursts have amplitudes in the range 0.01 to 0.1γ. Propagation direction of waves relative to the shock will be discussed.

C-15 (Jones, Massenfilter Mass Spectrometer, Neutral Particle and Ion Composition)

Hinton, B. B., R. J. Leite, and C. J. Mason, "Comparison of Water Vapor Measurements from Two Similar Spacecraft," presented at the AGU Meeting, Washington, D. C., Apr. 1969.

ABSTRACT: Neutral particle measurements taken by the same type of sweeping mass spectrometer on OGO-II and OGO-IV permit a comparison of water vapor concentrations as a function of orbital lifetime. Such measurements reflect the outgassing characteristics of two slightly different configurations in the vicinity of the spectrometer. A mylar thermal blanket used on OGO-II was omitted on OGO-IV. Other neutral constituents are examined also.

Hinton, B. B., R. J. Leite, and C. J. Mason, "Neutral Atmospheric Composition Measurements between 100 and 290 Kilometers," presented at the 1968 Spring Meeting of the AGU. Apr. 1968.

ABSTRACT: Composition measurements of the neutral atmosphere over the altitude range of 105 km to 291 km (peak) were made on August 8, 1967 shortly after sunrise at White Sands, N. M. on Aerobee NASA 4.207. The data were obtained with a quadrupole mass spectrometer essentially identical to those presently in orbit on OGO-II and OGO-IV. The rocket instrument sweeps the mass range 0-50 amu in approximately 0.6 seconds; it's sensitivity is 10^{-4} amp/torr with a resolution of 20. The spectrometer was evacuated prior to flight and an ejectable cover removed at 84 km. The masses observed were 44, 40, 32, 28, 18, 16, 14, and 4. Of particular interest is the observed variation of mass 14, tentatively identified as atomic nitrogen, with altitude; it appears to be in general agreement with recent predictions by Ghosh of the distribution and lifetime of N between 100 and 280 km. Preliminary analysis indicates that the concentrations of the various atmospheric species are representative of those characterizing a quiescent atmosphere.

C-16 (Taylor, Bennett Ion Spectrometer, Positive Ion Study)

Brinton, H. C., R. A. Pickett, and H. A. Taylor, Jr., "Thermal Ion Structure of the Plasmasphere," *Planet. Space Sci., 16,* 899-909, 1968. (For abstract, see experiment 4915, OGO-I).

Taylor, H. A., Jr., H. G. Mayr, and H. C. Brinton, "Observation of Thermal Ions of Helium and Hydrogen in the Upper Ionosphere During a Solar Cycle," presented at the COSPAR Meeting, May 1969.

ABSTRACT: High resolution measurements of thermal hydrogen and helium ions have been obtained during 1965-68 from ion spectrometers on the OGO-2 and 4 polar orbiting satellites. Observations obtained

toward the maximum of solar cycle 20 reveal pronounced anomalies in the latitudinal distributions of the light ions. These results, obtained between 400 and 1000 kilometers and over a wide range of local times, include a major trough in which $n(H^+)$ and $n(He^+)$ decrease by as much as a factor of 10 near 60° Λ, associated with the plasmapause. In addition, a broad equatorial trough is observed, in which $n(He^+)$ sometimes decreases by as much as a factor of 10, relative to the midlatitude concentration levels. The strong seasonal asymmetry identified in the dawn-dusk He^+ distributions, coupled with evidence of local magnetic time (longitudinal) correlations, suggests that the equatorial He^+ trough may result from neutral wind–ion drag effects similar to the mechanism proposed by Kohl and King. The implications of such anomalies are that long-term solar cycle variations in the global ion composition are difficult to identify. Nevertheless, OGO-4 results during 1967-68 provide some evidence of an expansion of the helium ion layer.

Taylor, H. A., Jr., H. C. Brinton, M. W. Pharo, III, and N. K. Rahman, "Thermal Ions in the Exosphere; Evidence of Solar and Geomagnetic Control," *J. Geophys. Res., 73,* 5521-5533, 1968.

ABSTRACT: Direct measurements of a pronounced latitudinal variation in the exospheric ion composition have been obtained from the radio frequency ion spectrometer experiment on the Polar Orbiting Geophysical Observatory (OGO 2). Measurements of thermal positive ions obtained in a nearly polar dawn-dusk orbit during mid-October 1965 show that in the altitude range of 415-1525 kilometers the major ion are O^+ and H^+, and the minor constituents are N^+ and He^+. Consistent with this period of low solar activity, He^+ is at all altitudes a minor ion, relative to H^+. Evidence of pronounced solar and geomagnetic control of the ion distributions is further examined by translating the data along magnetic field lines to both (1) a constant 1000-kilometer reference level and (2) the dipole equator, applying chemical and diffusive equilibrium theory. At 100 kilometers O^+ dominates in both the northern and southern polar ionospheres, yielding at lower latitudes where H^+ dominates. The resultant mean ion mass distribution, about 14-16 amu at the poles, and about 4 amu at the equator, is generally consistent with theory and other measurements. The latitudinal asymmetry in the distributions of O^+ and N^+ reflects the control of seasonal temperature differences, while the greater symmetry in the distributions of H^+ and He^+ reveals the strong influence of solar-geomagnetic control of the light ions. The high-latitude ionosphere is marked by two dominant features: (1) a persistent, major trough in $n(H^+)$ and $n(He^+)$ where $n(H^+)$ drops to about 10^2 ions/cm^3 near 60° dipole and (2) a variable poleward peak in which the total ion concentration N_i approaches 10^4 ions/cm^3 near 80° dipole. The pronounced light ion trough, which correlates well with the whistler cutoff, is believed to mark the high-latitude boundary of the thermal plasma that diffuses upward along closed field lines to populate the plasmasphere. Poleward of the trough, the strong fluctuations in the composition and the variability of the amplitude and position of the ionization peak suggest that the polar exosphere is decoupled from the plasmasphere and is probably linked with the solar wind-magnetospheric tail system. Comparison of the extrapolated equatorial N_i profile with thermal ion distributions measured directly in the magnetosphere further supports this interpretation.

Taylor, H. A., Jr., and H. C. Brinton, "Ion Depletion in the High Latitude Exosphere; Simultaneous OGO-2 Observations of the Light Ion Trough and the VLF Cutoff," NASA-GSFC X-621-69-84.

ABSTRACT: Simultaneous observations of positive ion composition, vlf earth to satellite transmission, and whistlers, have been obtained from the OGO-2 satellite during October, 1965 in a polar, dawn-dusk orbit. As the satellite moves poleward above about 55° invariant latitude, sudden depletions of the light ion components of the topside ionosphere are observed, wherein the concentrations of H^+ and He^+ decrease by as much as an order of magnitude within 3° Λ. The light ion trough correlates with similar rapid reductions in the propagation of both man-made and natural vlf signals received at the satellite, where signal intensities are observed to decrease by as much as 20 db, and whistler rates decrease abruptly within 3° Λ. Poleward of the trough, the depleted light ion distributions are characterized by rapid fluctuations in concentration which appear to correlate in some cases with significant enhancements in the vlf noise level. The combined evidence of the light ion depletion and vlf cutoff further identifies the plasmapause as the often abrupt boundary of the plasmasphere. The abruptness of the light ion trough suggests the possibility that the mechanism responsible for the depletion results, under certain conditions, in a sharply defined heating and upward expansion of the lower atmosphere. Limited evidence of vlf absorption as well as abrupt increases in neutral density near the trough zone appear consistent with this possibility.

C-18 (Nilsson, Micrometeorite Detectors)

Nilsson, C. S., and R. B. Southworth, "The Flux of Meteors and Micrometeoroids in the Neighborhood of the Earth," *Physics and Dynamics of Meteors,* ed. by L. Kresak and P. M. Millman, 280-287, D. Reidel Publishing Co., Dordrecht-Holland, 1968.

Nilsson, C. S., F. W. Wright, and D. Wilson, "Attempts to Measure Micrometeoroid Flux on the OGO 2 and OGO 4 Satellites," *J. Geophys, Res.,* under review, 1969.

ABSTRACT: This paper describes the micrometeoroid experiments on the OGO 2 and OGO 4 satellites. The aim of the OGO 2 experiment was to measure the velocities, masses, and orbits of dust particles in the earth's dust cloud. No orbits were determined, and it is questionable whether any micrometeoroids of mass $>10^{-12}$ g impacted on the sensors during the 1300 hr in which good data were obtained. The OGO 4 experiment was modified in an attempt to measure a flux obviously much smaller than previously anticipated. No micrometeoroids capable of penetrating 4000 A of Al have impacted on ionization sensors of total effective area 5 cm^2 ster during 3000 hr exposure. Thus, we find that the flux of micrometeoroids $>10^{-12}$ g in the neighborhood of the earth is less than 2×10^{-3} particles/m^2 sec 2π ster.

Nilsson, C. S., "On Satellite Microphone Techniques," presented at the COSPAR Meeting, London, England, 1967.

OGO-III EXPERIMENTS

B-01 (Anderson, Solar Cosmic-Rays)

Lin, R. P., S. W. Kahler, and E. C. Roelof, "Solar Flare Injection and Propagation of Low Energy Protons and Electrons in the Event of 7-9 July, 1966," *Solar Phys., 4,* 338-360, 1968.

ABSTRACT: Simultaneous observations of the 7-9 July 1966 solar particle event by energetic particle detectors on three satellites, IMP-III, OGO-III and Explorer 33 are utilized to show that large spatial gradients are present in the fluxes of 0.5-20 MeV protons and $\gtrsim$45 KeV electrons. The event is divided into three parts: the ordinary diffusive component, the halo and the core. The core corotates with the interplanetary field, and therefore it and the surrounding halo are interpreted as spatial features which are connected by the interplanetary magnetic field lines to the vicinity of the flare region. Upper limits to the interplanetary transverse diffusion coefficient for 3-20 MeV protons at 1 A.U. are derived from the width of the halo. These are at least two orders of magnitude less than the parallel diffusion coefficient for the same energy particles.

It is argued that the observed flux variations cannot be explained by an impulsive point source injection for any physically reasonable diffusion model. Instead, since the interplanetary transverse diffusion coefficient is small for these low energy particles, the observed spatial features are interpreted as the projection to 1 A.U. by the interplanetary field lines of an extensive injection profile at the sun. The geometry of the injection mechanism is discussed and it is suggested that some temporary storage of the flare particles occurs near the sun.

Kahler, S. W., "The Recurrent Proton Events of June 24 and September 27, 1966," presented at the AAS Special Meeting on Solar Astronomy, Tucson, Arizona, Feb. 1968.

ABSTRACT: The proton events of June 24 and September 27, 1966 which were observed on the OGO-III and IMP-III satellites appear to be recurrent events from the flares of May 28 and September 2, 1966 respectively. The two events show several similar features: (1) they were low energy (several MeV) events; (2) the active region believed to be the source was located at a solar longitude of $\sim$W35°; (3) the protons appear to be associated with geomagnetic disturbances; (4) the events are short lived, indicating that they are narrowly collimated in space. The September 27 particles probably recurred again on October 24, since another short lived, low energy (E > 0.5 MeV) event was seen on IMP-III. A comparison is made with the flare associated recurrent events seen on Explorer 12 in 1961.

Kahler, S. W., "Observations of 3-10 MeV Protons in Energetic Storm Particle Events," Trans. AGU, *49,* 1, 274, 1968.

ABSTRACT: Observations of three energetic storm particle events were made with the University of California scintillation counter on the OGO-III spacecraft. These events occurred on August 29 and September 14, 1966 and February 15, 1967. In each of these events it was observed that the energy spectrum of the 3-10 MeV protons grew softer after the SC storm, but later it became harder. In the case of the August 29 event the softest spectrum and the largest fluxes occur closely in time.

These observations are interpreted in terms of a model of particle diffusion in the solar corona by Reid. It is hypothesized that the plasma cloud which causes the SC connects the earth to the flare region via the interplanetary magnetic field. No evidence is found for either interplanetary trapping or interplanetary acceleration of the energetic storm protons.

Kahler, S. W., K. A. Anderson, and J. H. Primbsch, "Anisotropies of Mev Protons from the Solar Flare of August 28, 1966, and the Geomagnetic Storm of August 29, 1966," *Trans. AGU, 48,* 1, 178, Mar. 1967.

ABSTRACT: The directional properties of the University of California 2-100 Mev proton detector on the OGO-III satellite were used to study the anisotropies of Mev protons from the solar flare of August 28, 1966, and the sudden commencement which occurred at 1314 UT on August 29. Mev proton fluxes following the sudden commencement were greater than 2000 particles/cm^2/sec. Due to the spacecraft spin, the detector traced out a cone of half-angle 52°. Anisotropies of greater than 4 to 1 were seen in the protons following the sudden commencement. Deviations from azimuthal symmetry were present at certain times. Since 32-channel pulse height analysis was employed in the experiment, the anisotropies

of each of the lowest channels could be examined separately. A preliminary analysis shows no energy dependence in the anisotropies observed. Comparison of the data is made with a recent model by Roelof for the diffusion of solar protons by a 1-dimensional 'Browning motion' in the interplanetary field. The large observed anisotropies suggest that not enough scattering by the magnetic irregularities has taken place for the pitch angle distribution of the particles to reach a 'relaxed' or asymptotic distribution.

B-02 (Wolfe, Electrostatic Plasma Analyzer)

Dodson, H. W., E. R. Hedeman, S. W. Kahler, and R. P. Lin, "The Solar Particle Event of July 16-19, 1966 and its Possible Association with a Flare on the Invisible Solar Hemisphere," *Solar Phys.*, 1969 (in press).

ABSTRACT: An energetic solar proton and electron event was observed by particle detectors aboard Explorer 33 (AIMP-1) and OGO-3 during the period July 16-19, 1966. Optical and radio observations of the sun suggest that these particles were produced by a flare which may have occurred on July 16 near the central meridian of the invisible hemisphere. The active region to which the flare is assigned is known to have produced the energetic particle events of July 7 and 28, 1966. The propagation of the particles in the July 16-19 event over the $\sim$180° extent of solar longitude from the flare to the earth is discussed, and it is concluded that there must exist a means of rapidly distributing energetic particles over a large area of the sun. Several possible mechanisms are suggested.

Kahler, S. W., "A Comparison of Energetic Storm Protons to Halo Protons," *Solar Phys.*, 1969 (in press).

ABSTRACT: Satellite observations of solar proton events with a "halo" structure or an energetic storm proton event and an SSC are studied. It is pointed out that some SSC events are associated with a *decrease* in the few MeV cosmic ray fluxes while most are associated with a flux increase. The properties of halo protons and energetic storm protons are compared. It is hypothesized that the two events are similar in origin. The propagation mode of storm particles is discussed. Evidence is presented for a solar, rather than interplanetary origin of storm protons.

B-03 (Bridge, Plasma Faraday Cup)

Vasyliunas, V. M., "A Survey of Low Energy Electrons in the Evening Sector of the Magnetosphere with OGO 1 and OGO 3," *J. Geophys. Res.*, *73*, 2839-2884, 1968. (For abstract, see experiment 4903, OGO-I.)

Vasyliunas, V. M., "Low Energy Electrons in the Magnetosphere as Observed by OGO-I and OGO-III," presented at the Summer Institute, Physics of the Magnetosphere, Boston College, June 19-28, 1967, *Physics of the Magnetosphere* (R. L. Carovillano, J. F. McClay, and H. Radoski, eds.), D. Reidel Publishing Co., Dordrecht, 1969. (For abstract, see experiment 4903, OGO-I.)

B-04 (Cline, Hones, Positron Search and Gamma-Ray Spectrum)

Cline, T. L., and E. W. Hones, Jr., "Interplanetary Positrons Near 1 Mev from other than the $\pi \rightarrow \mu \rightarrow e$ Process," in Contributions to the 1969 Budapest Conference on Cosmic Rays, also GSFC X-611-69-413.

ABSTRACT: Evidence is presented for a spectral component of interplanetary positrons separate from that produced by the decay of interstellar mesons from cosmic-ray interactions. Results from observations made with the OGO-3 satellite indicate the detection of $\gtrsim$0.5 MeV positrons with a differential intensity near 100 m^{-2} sec^{-1} $ster^{-1}$ MeV^{-1}, two decades higher than the maximum expected from cosmic-ray meson production. Data, accumulated for nearly 2 years, have been examined for the existence of temporal or spatial variations; accelerator exposures of the detector are also being made in order to determine if the particles observed in space might be local secondaries. To date, there is no indication of any solar or geophysical production mechanism, or effect local to the detector, which would account for the observed positron rate. The observed cosmic-ray positron intensity taken to be of cosmic-ray origin, is compared with the calculated values for interstellar beta emission by cosmic-ray excited nuclei; qualitative agreement exists only if a high, possibly local, low-energy cosmic-ray intensity is used. A heliocentric acceleration or some quite different source may instead be required to provide the observed intensity.

Cline, T. L., and E. W. Hones, Jr., "Search for Low-Energy Interplanetary Positrons," presented at the 10th International Cosmic-Ray Conference, Calgary, Canada, June 1967; Also *Can. J. Phys., 46,* S-527, 1968. (For abstract, see experiment 4904, OGO-I.)

Cline, T. L., S. S. Holt, and E. W. Hones, Jr., "High-Energy X Rays from the Solar Flare of July 7, 1966," *J. Geophys. Res.* (Letters), *73,* 434-437, 1968; also *Ann. IQSY, 3,* 193-197; GSFC X-611-67-348, Preprint.

ABSTRACT: The time history and differential intensity of solar X-rays of energies from 80 to more than 500 KeV were observed during the flare event of 7 July 1966. These measurements, made from a solar-oriented stable platform on OGO-III, cover the highest differential energy range studied thus far and indicate the greatest intensity in hard X-rays of any solar event observed to date. Three intensity peaks occurred at about 0027, 0029 and 0037 UT, coinciding with the times of microwave and optical intensity maxima. A study of the spectral and temporal characteristics of the X-ray emission, and comparison with the radio and optical data, indicate a non-thermal bremsstrahlung origin for the X-rays.

Holt, S. S., and T. L. Cline, "On the Generation of Synchrotron and X-ray Emission from Electrons with Energy Below Mc^2 in Solar Flares," *Ap. J., 154,* 1027, 1968.

ABSTRACT: An attempt is made to reconcile a single source of electrons with both the hard x-ray and microwave radio emission observed at the peak of the solar flare of 7 July 1966. The spectral and temporal characteristics of the x-ray emission are used to determine the total number of electrons involved in the emission, as well as the shape of the generating electron spectrum. This is the first instance in which a generating electron spectrum has been directly inferred from experimental data. The spectrum is found to be $dJ = A(\gamma - 1)^{-5}\, d\gamma$, which is steep enough such that the bulk of the microwave emission originates from electrons with energies below mc^2. Both the observed x-radiation and synchrotron radiation can be explained in terms of the same electron source if they are generated high in the chromosphere, in the vicinity of the flare site, where the average field is of the order of 1000 gauss.

B-08 (Van Allen, Low Energy Electron and Proton Detector)

Frank, L. A., "Initial Observations of Low-Energy Electrons in the Earth's Magnetosphere with OGO 3," U. of Iowa Report 66-39, Aug. 1966; also *J. Geophys. Res., 72,* 185-195, 1967.

ABSTRACT: Initial observations of electrons over the energy range extending from ~100 ev to 50 kev at geocentric radial distances 8-20 R_E in the dark hemisphere of the earth's magnetosphere with electrostatic analyzers borne on OGO 3 are presented for June 12-13, 1966. The electron differential energy spectrums typically are characterized by a single peak in intensities occurring in the energy range ~0.8-10 kev and at lower energies with increasing geocentric radial distance, by broader widths with decreasing radial distance, and by greater slopes for electron energies $E_e \gtrsim 5$ kev with increasing radial distance. The radial profiles of unidirectional and omnidirectional, integral and differential intensities, and energy densities of electrons within the above energy range are characterized by catastrophic variations in magnitude that are presumably reflections of both temporal and spatial variations in intensities. Beyond ~13 R_E many electron spectrums are 'monoenergetic' to the extent that $\gtrsim$75% of the energy flux is shared among electrons in the energy range 1-3 kev, as an example, although measurable electron intensities are observed over the entire energy range ~400 ev to 50 kev. In contrast with the persistent softening of the electron spectrums with increasing radial distance between 8 and 20 R_E, the electron energy densities in the peaks of intensities do not show a marked radial dependence beyond ~13 R_E. The observed electron ($E_e > 280$ ev) energy densities in the peaks of the radial profiles almost always rise to $\sim 10^{-9}$ erg/cm^3, an effect which may be indicative of an instability or 'saturation' of the local magnetic field, and are significant in substantially distorting the geomagnetic field beyond ~8 R_E. Typical values of the ratios of intensities $J(E_e > 610 \text{ ev})/J(E_e > 45 \text{ kev})$ are 10^4 in the magnetospheric tail. The maximum temporal resolution of the apparatus is ~100 msec: temporal variations of low-energy electron intensities by factors $\gtrsim$2 occurred usually in periods ~seconds to several minutes.

Frank, L. A., "On the Distributions of Low-Energy Protons and Electrons in the Earth's Magnetosphere," *Earth's Particles and Fields,* ed. by Billy M. McCormac, Reinhold Book Corporation, 67-87, 1968.

ABSTRACT: Recent observations of low-energy proton and electron intensities over the energy range ~100 eV to 50,000 eV in the local evening-midnight quadrant of the magnetosphere near the geomagnetic equatorial plane at 5 to 15 R_E (R_E, earth radii) geocentric radial distances are summarized with several comments concerning the relationship of these distributions of low-energy charged particles with earlier measurements. Of particular interest are the morphology of the distributions of low-energy protons of the extraterrestrial ring current during magnetic storms, the temporal variations of low-energy electron spectrums in the outer radiation zone and several salient features of the distributions of low-energy electrons in the vicinity of the 'trapping boundary' in the dark hemisphere of the earth's magnetosphere at ~8 R_E geocentric distance near the magnetic equator.

Frank, L. A., "Several Observations of Low-Energy Protons and Electrons in the Earth's Magnetosphere with OGO-III," U. of Iowa Report 66-48, Nov. 1966; also *J. Geophys. Res., 72,* 1905-1916, 1967.

ABSTRACT: Simultaneous observations of proton (190 ev $\leq E \leq$ 48 kev) and electron (170 ev $\leq E \leq$ 46 kev) differential energy spectrums during segments of three outboard traversals of OGO 3 through the magnetosphere for the period June 11-15, 1966, on L shells 3.3-16 are presented. Proton intensities at $L = 4$ on June 15, 1966, were 8×10^5 $(cm^2 \text{ sec ster})^{-1}$ ($330 \leq E \leq 530$ ev), $\lesssim 1.5 \times 10^6$ $(cm^2 \text{ sec ster})^{-1}$ ($4.7 \leq E \leq 7.6$ kev), and $\lesssim 10^6$ $(cm^2 \text{ sec ster})^{-1}$ ($16 \leq E \leq 26$ kev) and at $L = 7.5$ were $\leq 5 \times 10^4$ $(cm^2 \text{ sec ster})^{-1}$ ($330 \leq E \leq 530$ ev), 4×10^6 $(cm^2 \text{ sec ster})^{-1}$ ($4.7 \leq E \leq 7.6$ kev), and 6×10^6 $(cm^2 \text{ sec ster})^{-1}$ ($16 \leq E \leq 26$ kev) with local pitch angles 78° (±4°) and at a geomagnetic latitude 23° (±1°). Peak intensities of protons ($30 \leq E \leq 48$ kev) were observed at $L \simeq 7.0$. A preliminary order-of-magnitude estimate of the total energy of trapped protons (190 ev $\leq E \leq$ 48 kev) within the earth's magnetosphere is 5×10^{21} ergs, and the estimated contribution from this low-energy proton distribution to the quiet-time terrestrial ring current field at the earth's surface is ~-10γ. A transient, narrow peak of relatively high low-energy proton and electron intensities within the energy range ~300 ev-2 kev at $L \simeq 4$ with width $\Delta L \sim 1$ is also observed. Typical characteristics of proton and electron intensity 'spikes' at peak intensities in the late evening sector of the earth's magnetic tail are (*a*) approximately equal proton (190 ev $\leq E \leq$ 48 kev) and electron (170 ev $\leq E \leq$ 46 kev) energy densities $\sim 10^{-9}$ erg $(cm)^{-3}$ each, (*b*) approximately equal proton and electron densities over the above energy range ~1 $(cm)^{-3}$ each, and (*c*) largely dissimilar differential energy spectrums, proton spectrums with intensity peaks noncoincident in energy with those of the electron intensity peaks and significantly broader (harder) in the high-energy tail ($E \gtrsim 3$ kev) than the relatively steep (soft) electron spectrums in this energy range.

Frank, L. A., "Recent Observations of Low-Energy Charged Particles in the Earth's Magnetosphere," U. of Iowa Report 67-36, July 1967; also *Physics of the Magnetosphere,* ed. by R. L. Carovillano, John F. McClay, and Henry R. Radoski, Dordrecht-Holland: D. Reidel Publishing Company, 271-289, 1968.

ABSTRACT: Several recent observations of low-energy proton and electron intensities within the energy range ~100 ev to 50 keV in the earth's radiation zones with a sensitive array of electrostatic analyzers borne on the earth-satellite OGO III during mid-1966 are summarized. Measurements of charged particles of the extraterrestrial ring current during a moderate geomagnetic storm, of the low-energy proton and electron distributions in the vicinity of the midnight 'trapping boundary' near the magnetic equatiorial plane, and of upper limits for proton and ion (100 eV ≤ E/Q ≤ 50 keV) energy fluxes deep within the inner radiation zone are presented together with several introductory comments concerning the morphology of the omnidirectional intensities of energetic electrons (E ≥ 40 keV, ≥ 230 keV, and ≥ 1.6 MeV) at the magnetic equator in the outer radiation zone.

Frank, L. A., "On the Extraterrestrial Ring Current During Geomagnetic Storms," U. of Iowa Report 67-09, Feb. 1967; also *J. Geophys. Res., 72,* 3753-3767, 1967.

ABSTRACT: Measurements of the differential energy spectrums of protons and electrons, separately, over the energy range extending from ~200 ev to 50 kev with a sensitive array of electrostatic analyzers borne on the earth-satellite OGO 3 reveal large temporal variations in intensities of these low-energy charged particles at low and moderate latitudes in the outer radiation zone during two moderate geomagnetic storms in late June and early July 1966. At $L = 3.5$ on July 9, for example, the intensities of protons ($31 \leq E \leq 49$ kev) increased by factors ≳30 over the pre-storm intensities. The peak proton (200 ev $\leq E \leq$ 50 kev) energy densities

at the magnetic equator for June 23 (relative magnetic quiescence), June 25 (D_{ST} (H) $\simeq$ -30γ), and July 9 (D_{ST} (H) $\simeq$ -50γ) were 9 x 10^{-8} erg (cm^{-3} at L = 6.8, 2 x 10^{-7} erg$(cm)^{-3}$ at L = 4.5, and 5 x 10^{-7} erg$(cm)^{-3}$ at L = 3.3, respectively. This energy density is predominantly shared by protons in the energy range ~3-50 kev. The total energy of these low-energy protons and electrons within the earth's magnetosphere is sufficient to account for the depression of the geomagnetic field (D_{ST} (H)) observed at the earth's surface over low and moderate latitudes; hence these charged particles may be identified as the major contributors to the storm-time extraterrestrial ring current. Electrons (200 ev $\leq E \leq$ 50 kev) are found to provide approximately 25% of this storm-time ring current. The apparent mean lifetimes of low-energy protons in the outer radiation zone are in agreement with calculated lifetimes assuming charge-exchange collisions with the ambient neutral and charged constituents of the terrestrial exosphere as the predominant loss mechanism.

Frank, L. A., and R. L. Swisher, "Energy Fluxes of Low-Energy Protons and Positive Ions in the Earth's Inner Radiation Zone," U. of Iowa Report 67-33, June, 1967; also *J. Geophys. Res.*, (Letters), *73*, 442-444, 1968.

ABSTRACT: A survey of measurements of positive ions in the inner radiation zone with detectors on OGO 3 (100 ev $\leq$ E/Q $\leq$ 50 kev) and Injun 4 (E > 30 kev, 0.5 $\leq$ E $\leq$ 4.2 Mev) yielded upper limits for these fluxes. These fluxes were found to be less by factors of 10-100 than those found by Freeman on Injun 1. (Editor)

Rao, C. S. R., "Local Time Asymmetries in the Increase of Electron Fluxes in the Outer Van Allen Zone during the Substorm," U. of Iowa Report 69-8; submitted to *J. Geophys. Res.*, Feb. 21, 1969.

ABSTRACT: In this paper we study the increase in the fluxes of electrons $E_e \gtrsim$ 40 keV and $E_e \gtrsim$ 120 keV in the outer Van Allen zone at different local times during nighttime magnetic bay activity. Electrons $E_e \gtrsim$ 40 keV show increases in the midnight to afternoon sectors but not in the evening sector during bay activity. Electrons $E_e \gtrsim$ 120 keV do not, however, show significant increases at these times. Also, whereas the increase in the midnight sector occurs immediately after the onset of a bay, a significant increase in the morning sector occurs only later, i.e., during peak or recovery phase of the bay. This time delay is attributed to the time taken by the electrons that are freshly energized in the midnight sector to drift in longitude so as to appear in the morning sector. The absence of increase in the evening sector is believed due to the fact that the freshly energized electrons disappear by the time they drift to that sector.

Swisher, R. L., and L. A. Frank, "Lifetimes for Low-Energy Protons in the Outer Radiation Zone," U. of Iowa Report 68-3, Jan. 1968; also *J. Geophys. Res., 73,* 5665-5672, 1968.

ABSTRACT: The directional differential intensities of protons over the energy range ~200 ev to 50 kev injected into the outer radiation zone (i.e., the extraterrestrial ring current) coincident with the initial phase of the geomagnetic storm during early July 1966 were monitored with a sensitive array of electrostatic analyzers borne on the earth satellite OGO 3. Proton intensities are greatly enhanced throughout the outer radiation zone for L values $\gtrsim$3 during the main phase of this moderate magnetic storm, and the injection mechanism ceases to be effective after the storm main phase for L values $\lesssim$5.5. Proton (30 $\leq E \leq$ 50 kev) intensities are shown to exponentially decay with lifetimes ranging from 15 to 105 hours in substantial agreement with calculated lifetimes invoking measured charge-exchange cross sections for protons incident upon atomic hydrogen and a model of the atomic hydrogen concentration in the earth's exosphere. The atomic hydrogen concentration model for the terrestrial exosphere providing the best fit to the observed proton lifetimes over geocentric radial distances 2.5-4.8 R_E (corresponding to observed concentrations ~200 to 30 hydrogen atoms/cm^3) allows only atoms in ballistic orbits in the exosphere as opposed to a model geocorona that includes an additional atomic hydrogen population in captive elliptical orbits.

B-09 (Winckler, Arnoldy, Trapped Radiation, Electron Spectrometer)

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "Energetic Solar-Flare X Rays Observed by the OGO Satellites and Their Correlation with Solar Radio and Energetic Particle Emission," presented at the AGU Meeting, Washington, D. C., Apr. 1968. (For abstract, see experiment 4909, OGO-I.)

Kane, S. R., and J. R. Winckler, "An Atlas of 10-50 kev Solar Flare X-Rays Observed by the OGO Satellites 1 January 1967 to 31 December 1967," U. of Minn. Tech. Report CR-134, Apr. 1969. (For abstract, see experiment 4909, OGO-I.)

Kane, S. R., and J. R. Winckler, "Modulation and Heliocentric Gradient of Low Energy Cosmic Rays Near Solar Minimum, 1965," presented at the AGU Meeting, Washington, D. C., Apr. 1969; also U. of Minn. Tech. Report CR-131, Mar. 1969. (For abstract, see experiment 4909, OGO-I.)

Kane, S. R., and J. R. Winckler, "Observations of Energetic X Rays and Solar Cosmic Rays Associated with the 23 May 1967 Solar Flare Event," *Solar Physics, 6,* 1969.

ABSTRACT: On 23 May 1967 energetic (10-50 keV) solar flare X-rays were observed by the OGO-III ion chamber during the period 1808-2100 UT. The time-intensity profile for the X-ray event showed three distinct peaks at ~1810, 1841 and 1942 UT. The second peak, which is equivalent to ~2.9 x 10^{-3} ergs cm^{-2} sec^{-1} above 20 keV, is the largest X-ray burst observed so far by the OGO-I and OGO-III ion chambers. The soft (2-12 Å) X-ray observations reported by Van Allen (1968) also show similar peaks, roughly proportional in magnitude to the energetic X-ray peaks. However, the intensity of energetic X-rays peaked in each case 5-10 minutes earlier than the soft X-ray intensity indicating a relatively hard photon energy spectrum near the peak of the energetic X-ray emission. The corresponding time-intensity profile for the solar radio emission also showed three peaks in the microwave region nearly coincident with the energetic X-ray peaks. The third radio peak was relatively rich in the metric emission. Beyond this peak both the energetic X-rays and the microwave emission decayed with a time constant of ~8 minutes while the corresponding time constant for the soft X-rays was ~43 minutes. In view of the earlier findings about the energetic X-rays it is indicated that the 23 May solar X-ray event was similar to those observed earlier. During the 23 May event the integral energy flux spectrum at the time of peak intensity is found to be consistent with the form $\sim e^{-E/E_0}$, E_0 being about 3.3 and 3.7 keV for the peaks at 1841 and 1942, UT, respectively. Assumption of a similar spectrum during the decay phase indicates that the spectral index E_0 decreased nearly exponentially with time.

The OGO-III ion chamber, which is also sensitive to protons ≥12 MeV, observed a solar particle event starting at ~2100 UT on 23 May. It could not be determined uniquely which of the two principal X-ray peaks was associated with the particle event, and in fact both may have contributed. The particle intensity reached its maximum value at ~1003 UT on 25 May 1967. The equivalent peak radiation dosage was ~24 R/hour behind the 0.22 g cm^{-2} thick aluminum wall of the chamber. This peak radiation dosage was considerably smaller than the maximum dosage (~60 R/hour) during the 2 September 1966 solar particle event, the largest event observed so far by the OGO-I and OGO-III satellites. The temporal relationship between the solar X-ray and particle events on 23 May 1967 was similar to that observed in the solar flare events on 7 July 1966, 28 August 1966 and 27 February 1967.

Kane, S. R., and D. J. Hofman, "Difference in Total Ionization Rate of Solar Particles Inside and Outside the Magnetosphere," presented at the AGU Meeting, Washington, D. C., Apr. 1968. (For abstract, see experiment 4909, OGO-I.)

Kane, S. R., K. A. Pfitzer, and J. R. Winckler, "Description of Data Plots from the University of Minnesota Ion Chamber and Electron Spectrometer on OGO-I and OGO-III," U. of Minn. Tech. Report CR-127, Feb., 1969. (For abstract, see experiment 4909, OGO-I.)

Parks, G. K., and J. R. Winckler, "16-Second Periodic Modulations Observed in Hard Solar X-Rays," presented at the AGU Meeting, Washington, D. C., Apr. 1969.

ABSTRACT: The hard X-rays measured on a high-altitude balloon on August 8, 1968 show presence of periodically modulated structures whose energy spectrum hardens at peaks. The Fourier analysis indicates that the modulations have a 16-second periodicity which is probably characteristic of hydromagnetic waves with a wavelength roughly comparable to a small active region. The peak to valley flux ratio measured at the balloon depth varies between 1.5 and 2. The comparison of the balloon X-ray time profile with centimetric radio emission data shows that the two time profiles are well correlated in the onset and duration. However the modulated structures appear strongest at 15,000 MHz but weaker at lower frequencies. The X-ray measurements by satellites reveal that the modulated structures are more pronounced at higher X-ray energies. The soft X-rays ($1 < h\nu < 10$ keV) lasted more than an hour, and show poor correlation with the radio data. The OGO-3 ion chamber ($10 < h\nu < 50$ keV) shows the modulated structures only weakly, presumably due to the presence of abundant soft X-rays. The OGO-5 X-ray spectrometer data show that the modulated structures were persistent at X-ray energies between 40 and 160 keV. Consequently, the modulated structures are an energy dependent phenomena. One concludes that a portion of only the highest frequency radio emission may be attributed to the very energetic electrons.

Pfitzer, K. A., and J. R. Winckler, "Intensity Correlations and Substorm Electron Drift Effects in the Outer Radiation Belt Measured with the OGO-III and ATS-1 Satellites," U. of Minn. Tech. Report CR-136, Apr. 1969.

ABSTRACT: During late December 1966 and January 1967 the elliptically orbiting satellite OGO-III entered the magnetosphere within 30° of the subsolar point and within 10° of the geomagnetic equator. This permits the measurement of r_b, the distance to the magnetosphere boundary, which is a necessary parameter for the Mead model magnetic field calculations. The electron fluxes measured by an electron spectrometer and an ion chamber on OGO-III are correlated with electron fluxes on the geostationary statellite ATS-1 at the exact time when both satellites are on the same drift shells as calculated from the Mead model magnetic field with separations in local time up to 180°. During quiet times an absolute comparison of the fluxes from 50-1000 keV gives a linear relationship indicating agreement of the measurements over a three order of magnitude range of intensities. During substorm increases the ATS-1 measurements have similar profiles but are delayed in time with respect to each other. The observed delays are smaller for higher energy electrons and larger for greater separations in local time. As an example, the measured delays for 50, 150 and 400 keV electrons on January 11, 1967 when the local time separation was 110° are 26, 13-17 and 5 minutes, respectively. The observed delays are consistent with newly created electrons being produced in a region near local midnight. These newly produced electrons then gradient drift past the two satellites. The production region is shown to be 30°-60° in width and about 4 earth radii in depth.

Pfitzer, K. A., "An Experimental Study of Electron Fluxes from 50 kev to 4 MeV in the Inner Radiation Belt," presented thesis, Aug. 1968; also U. of Minn. Tech. Report CR-123. (For abstract, see experiment 4909, OGO-I.)

Pfitzer, K. A., T. W. Lezniak, and J. R. Winckler, "Experimental Verification of Drift Shell Splitting in the Distorted Magnetosphere," submitted to *J. Geophys. Res;* also U. of Minn. Tech. Report CR-133, Apr. 1969.

ABSTRACT: Data from an electron spectrometer on the synchronous orbit satellite ATS-1 and data from an electron spectrometer and ion chamber on the elliptical orbit satellite OGO-III can be used to experimentally test drift shell splitting in the non-dipolar distorted magnetosphere as proposed by Roederer. Quiet day pitch angle distributions obtained by ATS-1 at 6.6 R_e qualitatively confirm the shell splitting by showing that near noon the pitch angle distribution is nearly isotropic whereas near midnight the pitch angle distribution is peaked toward small angles (parallel to the field). Using the Mead model magnetic field for calculating the drift shells for electrons of pitch angle $\alpha = 65°$ and $\alpha = 90°$, as well as the measured pitch angle distribution and measured radial gradient for electrons at local noon, the pitch angle distribution can be calculated as a function of local time for the ATS-1 orbit. The agreement between calculated and measured fluxes is satisfactory not only in the predicting the proper noon to midnight asymmetry (25 to 1 for 500-1000 keV electrons on February 15, 1967) but also in correctly predicting the pitch angle distribution as a function of local time (isotropic at noon but nonisotropic with a 3 to 1 ratio between $\alpha = 65°$ and $\alpha = 90°$ at midnight). However, in one case (15 February, 1967) an asymmetry is observed about local midnight with minimum count rate at 2200 LT, representing a departure from the symmetric Mead model.

Pfitzer, K. A., and J. R. Winckler, "Experimental Observation of a Large Addition to the Electron Inner Radiation Belt after a Solar Flare Event," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C. Sept. 3-13, 1968, also *J. Geophys. Res.* (Letters), *73,* 5792-5797, 1968; also U. of Minn. Tech. Report CR-119. (For abstract, see experiment 4909, OGO-I.)

Pfitzer, K. A., and J. R. Winckler, "The Decay and Injection of Artificial and Natural Electrons in the Inner Zone," presented at the AGU Meeting, Washington D. C., Apr. 1968. (For abstract see experiment 4909, OGO-I.)

Pfitzer, K. A., and J. R. Winckler, "An Experimental Study of Electron Drift Shells in the Distorted Magnetosphere," presented at the AGU Meeting, Washington, D. C., Apr. 1969.

ABSTRACT: Electron fluxes between 50 keV and 1 MeV on drift shells computed from the Mead model (without tail field) have been compared by the statellites ATS-I and OGO-III far apart in local time. The Mead model sub-solar magnetopause distance r_b varied from 9 to 13 and was determined directly by OGO-III within one hour of the drift shell crossing. Agreement to within ±10% over a two order of magnitude intensity range is found except in the evening sector. Two measurements at -50° and -10° local time (0° equals

local midnight) tend to suggest that drift shells in the evening sector lie closer to earth than predicted by the Mead model but move out to the predicted position just after local midnight. This drift shell displacement is consistent with the large asymmetry around local midnight revealed by the ATS-1 measurements, especially during disturbed times, consisting of sudden increases in energetic electron flux and magnetic field strength at synchronous orbit just after local midnight. Correlated rapid changes in outer zone electron intensity have been observed at widely separated points in local time on a time scale short compared to the drift time, indicating that the process controlling the intensity is of a large scale.

Pfitzer, K. A., and J. R. Winckler, "Intensity Correlations and Substorm Electron Drift Effects in the Outer Radiation Belt Measured with the OGO-III and ATS-1 Satellites," U. of Minn. Tech. Report CR-136, Apr., 1969.

ABSTRACT: Electron spectrometers (50-500 keV) show excellent agreement during quiet times at different locations on a common drift shell. During substorms intensity differences are shown to arise from drifting electrons injected near midnight.

B-10 (Smith, Holzer, Triaxial Search Coil Magnetometer)

Frandsen, A. M. A., R. E. Holzer, and E. J. Smith, "OGO Search Coil Magnetometer Experiments," *IEEE Transactions on Geoscience Electronics,* Apr. 1969. (For abstract, see experiment 4910, OGO-I.)

Holzer, R. E., M. G. McLeod, J. V. Olson, C. T. Russell, and E. J. Smith, "The Magnetic Component of Plasma Waves Associated with the Interaction of the Magnetosphere and Solar Wind," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 3-13, 1968. (For abstract, see experiment 4910, OGO-1.)

McLeod, M. G., R. E. Holzer, and E. J. Smith, "Magnetic Spectra and Cross Spectra in the Magnetosheath in the Frequency Range from .01 to 140 Hz.," *EOS Transactions, AGU, 50,* 4, Apr. 1969. (For abstract, see experiment 4910, OGO-1.)

Olson, J. V., R. E. Holzer, and E. J. Smith, "Spectra, Polarization, and Propagation of Waves Near the Earth's Bow Shock," *EOS Transactions, AGU, 50,* No. 4, Apr. 1969.

ABSTRACT: Magnetic fluctuation in the earth's bow shock in the frequency range 0.5 to 500 Hz have been detected by the search coil magnetometer flown on OGO-3. Power spectra of the fluctuations present in a set of shock crossings taken at high data rates shows a broad spectrum of waves to be present in the shock. The spectra obtained during the various crossings are quite similar in shape and amplitude. In addition to a random background of fluctuations short lived, coherent packets of radiation of amplitudes from 0.01 to 0.1 γ are also seen covering a wide range of frequencies. The ellipticity and probable propagation direction of these waves will be discussed.

Russell, C. T., R. E. Holzer, and E. J. Smith, "OGO-3 Search Coil Magnetometer Observations at the Geomagnetic Equator," *EOS Transactions, AGU, 50,* No. 4, Apr. 1969.

ABSTRACT: Both the spectrum analyzer and waveform outputs of the OGO-3 triaxial search coil magnetometer reveal the presence of noise within the magnetosphere confined within a few degrees of the magnetic equator and propagating perpendicular to the magnetic field. This noise occurs between the local proton gyro and lower hybrid resonance frequencies and could resonate with the bounce motion of Van Allen electrons causing the pitch angle diffusion mechanism of Kennel and Petschek. When the plasmapause position is known from measurements on the same spacecraft, it is found that these signals are observed as the satellite crosses the equator only when the traversal of the equator lies within the outer portion of the plasmasphere. A typical amplitude for these signals is 10mγ rms.

Russell, C. T., and K. I. Brody, "Some Remarks on the Position and Shape of the Neutral Sheet," *J. Geophys. Res.* (Letters) *72,* 6104-6106, 1967.

ABSTRACT: It is shown that a relatively simple empirical formula gives a satisfactory approximation to the position of the neutral sheet in the geomagnetic tail.

Russell, C. T., J. V. Olson, R. E. Holzer, and E. J. Smith, "OGO 3 Search Coil Magnetometer Data Correlated with the Reported Crossing of the Magnetopause at 6.6 R_E by ATS 1," *J. Geophys. Res., 73,* 5769-5775, 1968.

ABSTRACT: OGO 3 passed from the outer magnetosphere through the magnetosheath and into the interplanetary medium between 2200 UT, January 13, and 0300 UT, January 14, 1967. This interval includes the time during which the ATS 1 satellite reportedly encountered the magnetopause and magnetosheath at 6.6 R_E. Nearly two hours before the ATS 1 event the OGO 3 search coil magnetometer recorded a normal magnetopause crossing. About half an hour later a sudden increase in the steady magnetic field to an unusually large amplitude for a magnetosheath field was observed. Then, within a minute of the first reported ATS 1 magnetopause crossing, an increase in the amplitude of the magnetic noise was noted. Finally, about 45 minutes after the first ATS 1 crossing the bow shock was crossed at a position that was extremely close to the earth. An analysis of the OGO 3 search coil data fully supports the interpretation of the unusual ATS 1 records as displacements of the magnetopause inside of the ATS 1 orbit.

Russell, C. T., R. E. Holzer, and E. J. Smith, "OGO-III Observations of ELF Noise in the Magnetosphere, 1, Spatial Extent and Frequency of Occurrence," *J. Geophys. Res., 74,* 755-777, 1969.

ABSTRACT: The magnetic noise in the magnetosphere in the frequency range from 10 to 800 Hz has been extensively measured by the spectrum analyzers of the search coil magnetometer on OGO-III. This paper is a statistical study of the spatial extent and frequency of occurrence of noise at the higher end of this passband, at which frequencies noise above the detector thresholds is most common within the magnetosphere. Steady noise and noise bursts are found to constitute two distinct populations. Both the local-time and magnetic latitude distribution of both classes of signals are investigated. When the magnetic latitude distributions are extrapolated downward to 1000-km altitudes, the results are consistent with previous satellite observations at these low altitudes. However, the equatorial distributions cannot be inferred by simply projecting the magnetic noise measured at low altitudes onto the equator along flux tubes. The in situ measurements cannot determine the exact location of the source of all the noise observed. However, it is found that steady noise is definitely generated near 45° magnetic latitude on the dayside of the magnetosphere for L values from 6 to 10 and that bursts are generated near the equator above $L = 6$ from 0400 to 1800 local time. The latter observation can be used to explain the generation of both auroral microbursts and chorus as seen on the ground by means of whistler mode wave growth at the equator supported by a pitch-angle anisotropy maintained by the loss cone.

Smith, E. J., R. E. Holzer, and C. T. Russell, "Magnetic Emissions in the Magnetosheath at Frequencies near 100 Hz," *J. Geophys. Res.* (Letters),*74,* 3027-3036, 1969. (For abstract, see experiment 4910, OGO-I.)

Smith, E. J., K. I. Brody, R. K. Burton, R. E. Holzer, and C. T. Russell, "Observations of Waves in the Magnetosphere at Frequencies up to 1000 Hz," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 3-13, 1968. (For abstract, see experiment 4910, OGO-I.)

Smith, E. J., R. E. Holzer, and M. G. McLeod, "Discrete Magnetic Emissions in the Magnetosheath," *EOS Transactions, AGU, 50,* 4, Apr. 1969.

ABSTRACT: Intense bursts of magnetic noise have been detected in the magnetosheath by search coil magnetometers on OGOs 1, 3 and 5. The emissions are typically narrow band, tone-like bursts with center frequencies near 100 hz. They have peak signal amplitudes of tenths of gammas and durations from tenths to tens of seconds. The emissions are typically observed on every transit of the magnetosheath and are a characteristic feature of that region. The existence of these signals, and some of their properties, were

originally inferred from data provided by a spectrum analyzer flown on OGOs 1 and 3. Recently, OGO-5 provided the first opportunity to obtain triaxial broad band waveforms of the magnetosheath signals with frequency components up to 1000 hz. The OGO-5 data have been analyzed to determine the polarization and direction of propagation of the emissions. The results of this analysis and the wave-particle interactions that may be responsible for the generation of these signals will be discussed.

B-11 (Heppner, Rubidium-Vapor and Fluxgate Magnetometer)

Heppner, J. P. "Correlations Between Magnetospheric Magnetic Field Variations and Auroral Electrojet Activity," *Ann. Geophys., 24,* 1968. (For abstract, see experiment 4911, OGO-I.)

Heppner, J. P., "Observations of the Earth's Bow Shock," presented at the Gordon Research Conference, Tilton, N. H., July 1968. (For abstract see experiment 4911, OGO-I.)

Heppner, J. P., M. Sugiura, B. G. Ledley, and T. L. Skillman, "Magnetic Field Characteristics Near the Magnetopause," presented at the General Assembly IUGG, St. Gall, Switzerland, Sept. 1967. (For abstract see experiment 4911, OGO-I.)

Sugiura, M., T. L. Skillman, B. G. Ledley, and J. P. Heppner, "Holes in the Magnetic Field Near the Magnetopause," presented at the AGU meeting, Washington, D. C., Apr. 1969.

ABSTRACT: Apparent "holes" have been detected in the magnetic field inside and near the magnetopause by the magnetometers aboard the OGO 3 and 5 satellites. These holes are depressions in the magnitude, B, of the magnetic field to low values, sometimes to near zero, each taking place in a duration of about 3 to 20 seconds. Intense plasma fluxes are expected in these diamagnetic holes. The B trace for a hole often resembles the shape of an inverted Gaussian distribution curve, and in a typical case, the variation is remarkably smooth and free of irregular changes. Holes have been found at various local times along the magnetopause. Those observed on the front side of the magnetosphere appear to have greater depths than those found on the flanks. On the front side it is not unusual that the bottom of a hole reaches below 10γ when the surrounding field is 60 to 80γ. Holes appear in isolation, in groups, or sometimes in multiples with two or more members overlapping. "Passing through" a hole, the field direction normally changes very little. Similar diamagnetic holes are encountered more frequently in the magnetosheath than inside the magnetosphere, but often they cannot be distinguished from other irregular changes.

Sugiura, M., T. L. Skillman, B. G. Ledley, and J. P. Heppner, "Magnetic Field Structure in the Outer Magnetosphere," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 1968. (For abstract, see experiment 4911, OGO-I.)

B-12 (Sagalyn, Spherical Ion and Electron Trap)

Sagalyn, R. C., and M. Smiddy, "Magnetosphere Plasma Properties During a Period of Rising Solar Activity – OGO-III," presented at the 8th International Space Science (COSPAR) Symposium, London, England, July 1967; also *Space Research VIII,* North-Holland Publishing Co., Amsterdam, Holland, 139-149, 1968. (For abstract, see experiment 4912, OGO-I.)

Sagalyn, R. C., and M. Smiddy, "Results of Low Energy Ion and Electron Measurements in the Magnetosphere – OGO A" presented at the AGU Meeting, Washington, D. C., Apr. 1965.

Sagalyn, R. C., and M. Smiddy, "Results of Charged Particle Measurements in the Energy Range 0 to 1000 Electron Volts, OGO A" presented at the 6th International Space Science (COSPAR) Symposium, Buenos Aires, Argentina, May 1965. (For abstract, see experiment 4912, OGO-I.)

Sagalyn, R. C., and M. Smiddy, "Charged Particle Measurement by Means of Electrostatic Probes," COSPAR Research Techniques Instrumentation Manual No. 9, Ed., K. Maeda, Feb. 1967. (For abstract, see experiment 4912, OGO-I.)

Sagalyn, R. C., "Space Electricity: Physical Problems and Experimental Techniques," *Problems of Atmospheric and Space Electricity,* proceedings of the 3rd International Conference on Atmospheric and Space Electricity, Montreux, Switzerland, May 5-10, 1963, Ed., C. Coroniti, Elsevier Press, 548-565, 1965. (For abstract, see experiment 4912, OGO-I)

Shea, J. J., and K. H. Carpenter, "Investigation of Current Voltage Characteristics of Spacecraft Mounted Spherical Electrostatic Analyzers," Cosmic Inc. Final Report, – Contract No. F19628-68-C-0021, AFCRL-68-0588, Sept. 7, 1968. (For abstract, see experiment 4912, OGO-I.)

Smiddy, M., and R. D. Stuart, "An Analysis of the Behavior of a Multigrid Spherical Sensor in a Drifting Maxwellian Plasma," AFCRL Physical Science Research Paper 34, No. 69-0013, 1969. (For abstract, see experiment 4912, OGO-I.)

Smiddy, M. and R. D. Stuart, "The Characteristics of a Multi-Grid Spherical Sensor in a Drifting Maxwellian Plasma," Submitted to *J. Fluid Mech.* (For abstract, see experiment 4912, OGO-I.)

Stuart, R. D., and M. Smiddy, "The Characteristics of a Space Vehicle Borne Charged Particle Sensor," *J. of Applied Phys.* (For abstract, see experiment 4912, OGO-I.)

B-13 (Whipple, Planar Ion and Electron Trap)

Whipple, E. C., Jr., J. W. Hirman, and R. Ross, "A Satellite Ion-Electron Collector: Experimental Effects of Grid Transparency, Photoemission, and Secondary Emission," ESSA Tech. Report, ERL No. 99-AL1, 1968. (For abstract, see experiment 4913, OGO-I.)

Whipple, E. C., Jr., and L. W. Parker, "Effects of Secondary Electron Emission on Electron Trap Measurements," submitted to *J. Geophys, Res.,* Apr. 1969. (For abstract, see experiment 4913, OGO-I.)

Whipple, E. C., Jr., and L. W. Parker, "Theory of an Electron Trap on a Charged Spacecraft," *J. Geophys. Res., 74,* 2962-2971, 1969. (For abstract, see experiment 4913, OGO-I.)

Whipple, E. C., Jr., and L. W. Parker, "Theory of Langmuir Probes on Charged Spacecraft," presented at the AGU Meeting, Washington, D. C., Apr. 1969.

Whipple, E. C., Jr., and L. W. Parker, "Some Effects of Plasma-Vehicle Interaction on Probe Measurements," presented at the Fourth International Conference on the Universal Aspects of Atmospheric Electricity, Tokyo, Japan, May 1968.

B-15 (Taylor, Atmospheric Mass Spectrum)

Brinton, H. C., R. A. Pickett, and H. A. Taylor, Jr., "Thermal Ion Structure of the Plasmasphere," *Planet. Space Sci., 16,* 899-909, Feb. 1968. (For abstract, see experiment 4915, OGO-I.)

Taylor, H. A., Jr., H. C. Brinton, and M. W. Pharo, III, "Evidence of Contraction of the Earth's Thermal Plasmasphere Subsequent to the Solar Flare Events of 7 and 9 July 1966," reprinted from *Annals of the IQSY, 3.* (For abstract, see experiment 4915, OGO-I.)

Taylor, H. A., Jr., H. C. Brinton, and M. W. Pharo, III, "Contraction of the Plasmasphere During Geomagnetically Disturbed Periods," *J. Geophys. Res., 73,* 961-968, 1968. (For abstract, see experiment 4915, OGO-I.)

Vasyliunas, V. M., "A Survey of Low Energy Electrons on the Day Side of the Magnetosphere with OGO-3," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 1968; also *J. Geophys. Res., 73,* 7519-7523, 1968.

ABSTRACT: The morphology of low energy electrons in the magnetosphere is studied over the local time range 5-18 hours, using observations of electrons with energies between 40 ev and ~2 kev by means of a modulated Faraday cup flown aboard the OGO-3 satellite. This work is a continuation of a survey at local times 17-22 hours (Vasyliunas, J. Geophys. Res. *73,* 2839, 1968.) Over the dusk-to-midnight quadrant

intense electron fluxes, as previously reported, are confined to the plasma sheet that extends from a well-defined inner boundary (normally located at an equatorial distance of ~10-11 R_e, far outside the plasmasphere) outward into the geomagnetic tail and out to the magnetopause. This plasma sheet can be traced from the night side to approximately 13 hours local time at which point its inner boundary, which has remained sharply defined and located at ~11 R_e, touches the magnetopause. Relatively weak and diffuse electron fluxes appear between the plasma sheet and the plasmapause at ~16 hours and grow in intensity and spatial extent as one goes toward earlier local times. Near the noon meridian these fluxes fill more or less uniformly the entire region between the magnetopause and the plasmasphere (the detector is unable to make usable observations inside the plasmasphere). As one then goes toward the dawn meridian, the electron fluxes become much more intense, reaching and then surpassing the flux levels found in the night-side plasma sheet, and develop a marked radial gradient: the flux is generally most intense near the magnetopause and decreases gradually with decreasing radial distance, without sharp boundaries or sudden changes in energy spectrum. An appreciable electron flux is observed as far inward as the plasmapause within most of the noon-to-dawn quadrant.

B-17 (Helliwell, VLF Noise and Propagation)

Angerami, J. J., "In Situ Observations of Whistler Ducts by OGO 3" in preparation for submission for *J. Geophys. Res.* (Fox abstract see experiment 4917, OGO-I.)

Angerami, J. J., and R. L. Smith, "Ducted Whistlers on OGO-I and III," presented at the AGU Meeting, Washington, D. C., *48,* 88, Mar. 1967. (For abstract, see experiment 4917, OGO-I.)

Burtis, W., and R. A. Helliwell, "Banded Chorus—A New type of VLF Radiation Observed in the Magnetosphere by OGO 1 and OGO 3," *J. Geophys. Res., 74,* 3002-3010, 1969. (For abstract, see experiment 4917, OGO-I.)

Carpenter, D. L., C. G. Park, H. A. Taylor, Jr., and H. C. Brinton, "Multi-Experiment Detection of the Plasmapause from EOGO Satellites and Antarctic Ground Stations," *J. Geophys. Res., 74,* 1837-1847, 1969. (For abstract, see experiment 4917, OGO-I.)

Dunckel, N., and R. A. Helliwell, "Whistler-Mode Emissions on the OGO-I Satellite," submitted to *J. Geophys. Res.* (For abstract see experiment 4917, OGO-I.)

Helliwell, R. A., and W. Burtis, "Enhancement of Discrete VLF Emissions at One-Half the Electron Gyrofrequency," presented at the Joint URSI-IEEE Meeting, Washington, D. C., Apr. 1969. (For abstract, see experiment 4917, (For abstract, see experiment 4917, OGO-I.)

Heyborne, R. L., "Observations of Whistler-Mode Signals in the OGO Satellites from VLF Ground Station Transmitters," presented at the Joint URSI-IEEE Meeting, Palo Alto, Calif., Dec. 1966; also Stanford U. Ph. D. thesis and SEL Report No. SU-SEL-66-094, Nov. 1966. (For abstract, see experiment 4917, OGO-I.)

B-18 (Haddock, Radio Astronomy)

Haddock, F. T., and T. E. Graedel, "Low Frequency Dynamic Spectra of Solar Bursts Observed from OGO-III," *Astron. Journ., 73,* S62, 1968.

ABSTRACT: Solar radio bursts in the 4-2 MHz range have been observed by the University of Michigan Radio Astronomy Observatory experiment aboard the spacecraft OGO-III. Preliminary analysis suggests that all of the common types of meter wave bursts are present at these frequencies. Correlation with higher frequency burst observations is high. Coronal temperatures of the order of 10^5 °K have been derived for the emitting region by standard techniques.

Haddock, F. T., and T. E. Graedel, "Radio Bursts in the Outer Corona," *Sky and Telescope, 36,* 217, 1968.

ABSTRACT: Highlights of the August, 1968 meeting of the American Astronomical Society included a report on solar radio burst detection by the OGO-III and OGO-V spacecraft. Some of the characteristics of the bursts are reported, and typical examples illustrated.

Graedel, T. E., "Dynamic Spectra of 4-2 MHz Solar Bursts: Results from Orbiting Geophysical Observatory III," Ph.D. dissertation, U. of Mich., Jan. 1969; also NASA Contract NAS 5-2051 Final Report, Part I: Scientific.

ABSTRACT: During the period June 7, 1966 to September 30, 1967 the OGO-III experiment detected 218 solar radio bursts in the 4-2 MHz passband, of which 96% were confirmed by higher frequency observations. The frequency drift rate of the bursts ranged from 0.05 to 0.20 MHz/sec, the average being 0.095 ± 0.010 MHz/sec. Burst durations ranged from 20.9 seconds at 4 MHz to 25.6 seconds at 2 MHz. The range in flux densities at 3.5 MHz was 1 to 110 x 10^{-17} watt $M^{-2}Hz^{-1}$. Type V continuum radiation followed the fast drift burst in at least 2% of all cases. No evidence for slow drift (Type II) bursts was found.

Correlation of optical flare and solar burst observations permitted association of about three fourths of the radio bursts with specific solar flares and, hence, with solar plage regions. There appears to be no relationship between the importance of a flare and its ability to produce a low-frequency solar burst. Eight plage regions were associated with 54% of all 4-2 MHz bursts observed. These regions were very large, had major sunspots, and were extremely flare -rich. Three of the regions produced significant numbers of solar radio bursts on two successive rotations. It appears that a significant change in a sunspot group or a filament may be connected with a temporary increase in low-frequency radio burst production from plage region.

The growth and development of fast drift bursts has been studied as a function of the burst emission bandwidth, the electron injection time scale, and the local coronal temperature. This appears to be the first attempt to study the combined effects of these factors on the development of radio bursts, and has permitted a consistent derivation of their values. They are: bandwidth of emission centered on the plasma frequency, 650 ± 250 KHz; time scale of electron injection into the emitting region, 10-20 seconds; temperature of the 3.5 MHz emitting region, 160,000 to 450,000° K. This range of temperatures can be accounted for by a change of a factor of five between different streamer density profiles, while maintaining a constant temperature function with radial distance.

Haddock, F. T., and T. E. Graedel, "Observations of Solar Radio Spectra at Very Low Frequencies," *Astron. Journ., 73,* S180, 1968.

ABSTRACT: The Orbiting Geophysical Observatory satellite, OGO-III, was launched in June, 1966 with twenty scientific experiments on board. The University of Michigan Radio Astronomy Observatory experiment consisted of a dynamic spectrograph designed to record solar burst radiation over the band of 4-2 MHz, with a time resolution of two seconds. The radiometer output is recorded on magnetic tape and converted to dynamic spectrograms on 35 mm film by digital computer techniques. This paper presents the results of fifteen months of low-frequency solar burst observations by the experiment.

For the period 13 June 1966 to 30 September 1967, a total of 218 solar radio bursts have been observed. Most of these are fast-drift bursts (Type III), although Type V continuum has been observed in several cases following the Type III event. The existence of continuum radiation of Types I and IV has not definitely been established.

Comparison of the OGO-III burst data with ground based radio spectral observations results in confirmation of the OGO-III event by the ground stations in 90% of all cases. A concurrent optical flare is also seen in 60% of the OGO-III burst cases.

Initial observational data from the OGO-V radio astronomy experiment is also shown. Many solar bursts are seen at frequencies below 1 MHz, one of which extends to at least 100 KHz and is believed to originate from coronal regions near the orbit of the planet Mercury.

Haddock, F. T., and T. E. Graedel, "Radio Bursts in the Outer Corona," *Sky and Telescope, 36,* 217, 1968.

ABSTRACT: Highlights of the August, 1968 meeting of the American Astronomical Society included a report on solar radio burst detection by the OGO-III and OGO-V spacecraft. Some of the characteristics of the bursts are reported, and typical examples illustrated.

B-19 (Mange, Geocoronal Lyman-Alpha Scattering)

Chubb, T. A., and G. T. Hicks, "Far Ultraviolet Studies of Daytime and Nighttime Aurora," *Transactions, AGU, 50,* 4 Apr. 1969.

ABSTRACT: Observations of auroral displays by means of their far ultraviolet emission has permitted study of some of the characteristics of the displays. Auroras are always present at some level of intensity, although the far ultraviolet intensity can vary by at least a factor of 500. On the average, as Kp increases the auroral brightness increases and the auroral oval expands. The three hour Kp index is only a coarse indicator of aurora intensity. The intensity of individual aurora can differ from the average intensity for a given Kp by a large factor. During Sept. 1967 period, near midday and near midnight aurora were of about equal intensity, whereas during the Feb. 1968 period, the high Kp midnight auroras were about twice as bright as corresponding midday auroras. The main midday auroral displays occur typically at 6 to 8° higher invariant latitude than the main midnight displays. The area around the geomagnetic pole is frequently dark in the far ultraviolet. Near midnight, the high latitude edge of the display typically occurs at 75-82° invariant latitude (Sept. 1967 data).

Mange, P., "The Distribution of Lyman-α Radiations as Observed in the Sky from Satellites OGO 3, OGO 4, and OSO 4," *Trans. AGU, 49,* 1, Mar. 1968.

ABSTRACT: Nitric oxide-filled ion chamber detectors with lithium fluoride windows were carried on satellites OGO 3, OGO 4, and OSO 4 to observe Lyman α radiation scattered from the hydrogen geocorona and the celestial background. Intensities from the night sky along the OGO 3 orbit fell from about 5 kilorayleighs at an altitude of 1/2 Earth radius to 0.73 kR at apogee (19 radii). The instrument on the polar-orbiting OGO 4 vehicle observed zenith and nadir intensities in the night sky at altitudes of about 400-900 km. The OSO 4 instrument scanned the sky from a circular orbit of 560-km altitude and at an elevation of 20° above the satellite wheel, which rotates in a plane intersecting the Sun. Typical nadir/zenith intensity ratios inferred from the data are 0.44 and 1.1 for night and day, respectively. Nadir intensities of 1.3 and 24 kR for night (solar zenith angle about 140°) and day (solar zenith angle about 40°) are characteristic of the current (fall 1967) epoch. Photometric observations of the airglow oxygen lines near 1300 Å are also discussed.

Mange, P., and R. R. Meier, "Lyman-Alpha Intensity and Hydrogen Concentration Beyond 5 Earth Radii," presented at the COSPAR Meeting, Prague, Czechoslovakia, May 11-24, 1969.

ABSTRACT: The intensity of celestial radiation in the 1050-1350 A band (including Lyman-alpha) was measured from the OGO-III spacecraft at altitudes from 5 to 19 earth radii. The variation of intensity with distance reveals (a) a hydrogen density at 30,000 km of about 110 ± 30 atoms cm^{-3} for the summer 1966 epoch, and (b) negligible contribution to the signal by scattering from geocoronal hydrogen at distances beyond 12 radii. An isotropic background of 750 rayleighs from extraterrestrial sources was observed. Asymmetry of intensity variation on either side of apogee suggests an appreciable contribution to the background from the region scanned in the galactic plane. Intensity distributions over ten successive orbits (40 days) are characterized by extreme stability.

Meier, R. R., "Balmer α and Lyman β in the Hydrogen Geocorona," *J. Geophys. Res.*

ABSTRACT: The spherical Lyman β radiative transfer problem is solved for several theoretical models of the hydrogen geocorona. Comparisons of the computed intensities with the experimental observations of Lyman β and Balmer α airglows show that the geocoronal Balmer α contribution is superimposed on a uniform background of about 4R. The 4R background is probably galactic (or extra-galactic) in origin. The column density of hydrogen required to account for the telluric Balmer α component is about 5×10^{13} atoms per cm^{-2} above 650 km for a 950 °K exosphere.

OGO-IV EXPERIMENTS

D-02 (Helliwell, VLF Noise and Propagations)

Angerami, J. J., and D. Gurnett, "Correlation Between VLF Noise Activity Observed from a Javelin Rocket Near Wallops Island and from OGO 4 at 890 km," research in progress.

ABSTRACT: The magnetic and electric VLF receivers carried aboard the Javelin 8.45 rocket (launched from Wallops Island at 0738 UT, 21 September 1967) received a band of noise whose low cutoff decreased towards apogee. The variation was attributed to an altitude effect, and the noise was tentatively interpreted as the "LHR noise" reported by Brice and Smith [*JGR*, Jan. 1965], although a consistent picture was not achieved [Shawhan and Gurnett, *JGR*, Sept. 1968]. Furthermore, analysis of VLF data from OGO 4 has shown that the "LHR noise" is only rarely detected by magnetic antennas.

OGO 4 passed over Wallops Island at 0550 UT, making possible a close correlation with the Javelin data. Analysis of VLF broadband data from the Stanford experiment on OGO 4 showed that the Javelin rocket crossed the plasmapause, thus complicating the interpretation of the rocket data alone. The band of noise observed from the rocket was also detected from OGO 4, and was found to exhibit a lower cutoff at a frequency that changed rapidly with L-value. The lower cutoffs measured at both Javelin and OGO 4 showed the same L-shell variations, with no apparent altitude effect. This suggests that the lower cutoff variation is related to the source of the noise, and that the generation region was above OGO 4.

The position of the plasmapause determined from OGO 4 correlated well with the mid-latitude electron-density trough detected almost simultaneously by Alouette 2 (L. Colin, private communication). Correlation with Taylor's data on light ion concentration (experiment D-16 on OGO 4) is being attempted.

Bell, T. F., "Stationary Auroral Hiss Forms," submitted to *J. Geophys. Res.* (For abstract, see experiment C-02, OGO-II.)

Carpenter, D. L., and D. H. Liebenberg, "Identification from OGO-4 VLF Data of the Position of the Plasmapause during the High-Altitude Solar Eclipse of November 2, 1967 in the South Atlantic," research in progress.

ABSTRACT: The time of the eclipse coincided with a period of increasing magnetic distrubance. There is tentative evidence that by eclipse time, the plasmapause had already been displaced inward to an L value of 3 or less, near the region of the eclipse activity.

Crystal, T., "OGO-2 and OGO-4 Survey of ELF Noise," research in progress. (For abstract, see experiment C-02, OGO-II.)

Katsufrakis, J., E. Paymar, and J. J. Angerami, "Behavior of an Unbalanced Electric Antenna on OGO-2; Interference Phenomena in Sunlight and at Terminator Crossings," research in progress.

ABSTRACT: In one of the modes of operation of the Stanford University/Stanford Research Institute VLF experiment on OGO 4, the loop antenna was connected as an unbalanced electric sensor (E-mode). In this mode the operation of the receiving system was seriously degraded during conditions of solar illumination. The degradation is attributed to fields related to the current from the solar cells, fields sufficiently intense to mask most of the natural signals that might otherwise be observed. The drastic nature of the degradation is illustrated at terminator crossings, during which distinctive variations in the VLF spectra occur and there is an abrupt transition from or to a relatively normal mode of operation in eclipse.

Katsufrakis, J., E. Paymar, and J. J. Angerami, "Detection on OGO 4 of Various Lower Hybrid Resonance (LHR) Wave Phenomena; A Comparison of Results from Electric and Magnetic Sensors," research in progress.

ABSTRACT: The Stanford University/Stanford Research Institute VLF experiment on OGO 4 provided for monitoring of both electric and magnetic ac fields through switching between normal magnetic-loop operation and operation of the loop as an unbalanced electric antenna. Comparisons of the two modes of operation and comparisons between the magnetic mode and results from the Dartmouth University electric dipole (experiment D-03) revealed that lower hybrid resonance (LHR) emissions are observed almost exclusively by the electric antenna. The LHR emissions are thus inferred to be electrostatic in nature. The comparisons of E and H-mode operation also revealed pronounced em wave propagation effects at the LHR frequency. These effects were observed by both the electric and magnetic sensors.

Katsufrakis, J., "Differences Between the VLF Magnetic and Electric Field Spectra of the Lower Hybrid Resonance (LHR) Emissions and Associated Phenomena," presented at the Spring URSI Meeting, Washington, D. C., Apr. 1968. (For abstract see experiment C-02, OGO-II.)

Muzzio, J. L. R., "OGO-4 Observations of Downcoming Proton Whistlers," submitted for presentation at the 1969 URSI-IEEE Spring Meeting, Washington, D. C.

ABSTRACT: Evidence of downward propagation of ELF waves in the ion cyclotron mode was found in low latitude recordings of the OGO-4 satellite. The observed events are proton whistlers that propagate approximately along lines of magnetic field of the earth and are received in the satellite after crossing the magnetic equator. Their frequency-time spectrogram shows a frequency of infinite travel time at the minimum proton gyrofrequency along the path, instead of the gyrofrequency in the vicinity of the vehicle. Actual spectrograms are presented in which proton whistlers simultaneously received from both hemispheres are shown, exhibiting different values of the frequency of infinite travel time. The ones with the lower frequency correspond to the transequatorial or long-hop propagation path. Examples of simultaneous reception of ion cutoff whistlers and long-hop proton whistlers are also shown. The characteristics of these phenomena are fully understood in terms of the properties of refractive index surfaces when multiple ions are allowed for and have been confirmed by the use of ray tracing techniques. Application of these results to the interpretation of certain types of noise bands will be discussed.

Muzzio, J. L. R., "Reflection of Whistlers in the Ionosphere," presented at the URSI Spring Meeting, Washington, D. C., Apr. 1968. (For abstract, see experiment C-02, OGO-II.)

Muzzio, J. L. R., "Downward Propagating Proton Whistlers," submitted to *J. Geophys, Res.*

ABSTRACT: Evidence of downward propagation of ELF waves in the ion cyclotron mode was found in low latitude recordings of the OGO-4 satellite. The observed events are proton whistlers that propagate approximately along geomagnetic field lines and reach the satellite after crossing the magnetic equator.

Muzzio, J. L. R., "Ion Cutoff Whistlers," *J. Geophys. Res.* (Letters), *73,* 7526-7529, 1968. (For abstract, see experiment C-02, OGO-II.)

Scarabucci, R. R., J. J. Angerami, and R. A. Helliwell, "Satellite Observations of Equatorial Absorption and Defocusing of VLF Electromagnetic Waves," presented at the 1969 URSI-IEEE Spring Meeting, Washington, D.C.

ABSTRACT: Amplitude measurements of VLF waves, including both naturally occurring phenomena (whistlers) and man-made signals from VLF transmitters, have been carried out aboard the OGO-4 satellite. Some interesting aspects of these measurements are related to the behavior of the waves near the magnetic equator. (1) Daytime spectrograms taken over the magnetic equator show a remarkable high-frequency cutoff in the amplitude of the VLF whistler waves. The cutoff frequency decreases as the satellite approaches the magnetic equator and sometimes all signals drop below the equipment threshold. This feature is also present when the signals from different VLF transmitters are simultaneously observed. It is shown that the above phenomenon is explained primarily by absorption in the D and E regions of the ionosphere and to a lesser extent by defocusing of the rays in the upper F region. (2) During the night absorption becomes relatively small but nevertheless a dramatic amplitude cutoff may still occur. This nighttime cutoff is explained primarily by defocusing near the equator which is enhanced for nighttime ionization profiles. The defocusing of the VLF waves depends strongly upon the change of ionization-gradient occurring between 500 and 700 km of height and also upon the curvature of the earth's magnetic field around the magnetic equator.

Walter, F., "Nonducted VLF Mode of Propagation in the Magnetosphere: the Walking Trace Whistler, the Doppler Shift and the Enhancement of Signal," presented at the 1969 URSI-IEEE Spring Meeting, Washington, D. C.

ABSTRACT: A new VLF phenomenon has been observed in data from the polar satellites OGO-2 and OGO-4. These whistlers which are called walking trace (WT) whistlers are characterized in a frequency-time spectrogram as rising tones showing a lower cutoff around 5 kHz, an upper cutoff which decreases with latitude, and time delays which increase with frequency and latitude. They have been observed in the range of invariant latitudes from 47° to 56°. It is shown that whistlers with those characteristics can be produced by

tracing rays in a smooth magnetosphere, in which the density model is represented by a diffusive equilibrium model and the earth's magnetic field by a centered dipole. Fixed frequency signals, which received by a satellite at the opposite hemisphere from where they were transmitted, can show characteristics similar to the ones presented by the WT whistlers. Doppler shifts as high as hundreds of Hertz are exhibited by those signals. The Doppler shift increases with latitude and can be positive or negative depending upon the direction of the velocity vector of the satellite. The signals observed at higher latitudes show an enhancement of signal strength. Both the Doppler shift and the enhancement were explained by the same ray tracings used to explain the WT whistlers. Results of nonducted propagation in a geomagnetic field represented by several harmonics are compared in regions of highly distorted field. Effects of the plasmapause on the nonducted propagation are studied, and a new way to investigate the plasmapause is proposed.

Walter, F., and J. J. Angerami, "New Evidence of Nonducted Whistler Mode Propagation to the Conjugate Ionosphere: The 'Walking-Trace Whistler, Doppler Shifts and Focusing,' submitted to *J. Geophys. Res.* (For abstract, see experiment C-02, OGO-II.)

D-06 (Cain, World Magnetic Survey)

Cain, J. C., "Observations of the Equatorial Electrojet by OGO-2 and OGO-4 Spacecraft," presented at the 11th National Fall Meeting of the AGU, San Francisco, Calif., Dec. 1968. (For abstract, see experiment C-06, OGO-II.)

Cain, J. C., and R. Hide, "On the Constancy of the Geomagnetic Field at the Core-Mantle Interface," presented at the 11th National Fall Meeting of the AGU, San Francisco, Calif., 1968. (For abstract, see experiment C-06, OGO-II.)

Cain, J. C., "OGO-4 Observations of the Quiet-Day Magnetic Variations," Third International Symposium on Equatorial Aeronomy, Ahmedabad, India, Feb. 1969.

ABSTRACT: Total field magnetic measurements were made on the OGO-4 spacecraft at intervals during late 1967 and early 1968 when the orbit plane was near local noon. The differences ΔF between the field measured during quiet times and that computed by the POGO(10/68) reference model were compared with predicted values derived from the classic Sq ionospheric current system model at about 100 km altitude. On the basis of this model the measurements should show a weakening of field ($\sim 20\gamma$) slightly equatorward of the foci of the system and be generally weakened above the eastward currents over the equator except for a slight rise of the order of 3γ from the foci values. The observations generally confirm the weakening near the foci and also show the stronger currents in the summer hemisphere. However, instead of a continued depression of field over the equator, one finds an increase to a level comparable with ΔH observations observed at the surface not near the electrojet. For low (< 700 km) satellite passes the electrojet appears as a sharp *depression* as expected over the magnetic dip equator and often not in the center of the equatorial rise in field. It would thus appear that the Sq magnetic field variation cannot be described by an ionospheric current system of which the equatorial electrojet is a part, but must arise from the solar wind pressure. [*Mead,* 1964] and other sources above 1000 km altitude.

D-11 (Hoffman, Low Energy Auroral Particles)

Burton, R. K., R. E. Holzer, and E. J. Smith, "Intense Magnetic Impulses and Chorus Observed in the Auroral Zone During Particle Precipitation," *EOS Transactions, AGU, 50,* No. 4, Apr. 1969.

ABSTRACT: The OGO-4 triaxial search coil magnetometer measures two phenomena in the auroral regions: chorus, a broadband noise generally consisting of overlapping rising tones in the range of 300-900 Hz and intense low frequency magnetic impulses known to be correlated with low energy particle precipitation in the auroral oval. Morphologies of these phenomena will be presented and the correlation between them will be discussed.

Hoffman, R. A., "OGO-4 Satellite Measurements of Low Energy – High Latitude Electron Precipitation," presented at the NATO Advanced Study Institute, Tretten, Norway, Apr. 9-18, 1968.

ABSTRACT: Data from the Auroral Particles Experiment aboard OGO-4 have indicated four regions of low energy electron precipitation at high latitudes. These have been designated by the terms band region, burst region, polar cavity, and the pre-midnight region. The band region is characterized by a relatively structureless, moderately hard precipitation pattern which generally follows the auroral oval, except extends to lower latitudes at noon. It is especially prevalent in the dawn hemisphere. The burst region begins within the band region and extends polewards, reaching up to 85° at noon, and is characterized by usually a very soft spectrum and large structure in the precipitation pattern. The pitch angle distributions of 2.3 kev electrons within the bursts tend towards anisotropic, with the maximum flux directed along the magnetic field into the atmosphere. The polar cavity is an area of no detectable fluxes, while the pre-midnight region displays structured electron fluxes with widely varying spectra. This paper presents a preliminary summary of all the phenomena observed in the high latitude region and analyzed to date.

Hoffman, R. A., and D. S. Evans, "Field-Aligned Electron Bursts at High Latitudes Observed by OGO 4," *J. Geophys Res., 73,* 6201-6214, 1968.

ABSTRACT: In a series of passes in the northern high-latitude region, short bursts of radiation were observed in the energy range 0.7 to 24 kev by detectors aboard the polar orbiting satellite OGO 4. Among these bursts were a number in which the pitch-angle distributions at 2.3 kev displayed a maximum at small angles to the magnetic field lines. From the distributions and energy spectra it is argued that a possible source mechanism for these particles is electric fields parallel to the magnetic field lines at distances of several earth radii. The source particles would then be the ambient thermal plasma, with two markedly different temperature components, one at a few ev, from which the field-aligned radiation originates, and the other greater than an order of magnitude hotter, which produces the isotropic portion of the pitch-angle distribution.

D-13 (Mange, Lyman-Alpha and Ultraviolet Airglow Study)

Hicks, G. T., and T. A. Chubb, "Equatorial Aurora/Airglow in the Far Ultraviolet," Submitted to *J. Geophys. Res.*

ABSTRACT: Far ultraviolet emissions in the equatorial zone have been detected at altitudes less than 500 km with an experiment aboard the OGO-IV polar orbiting satellite. The occurrence frequency was most pronounced in October during the period August 1967 to February 1968. These emissions are seen quite symmetrically in position at 12-15 degrees on either side of the magnetic dip equator completely encircling the earth. In general, the peak intensity of the emissions is the same north and south of the equator, but in some cases the intensity may be three or four times greater on one side than the other. In rare cases, emission will be totally lacking on one side while clearly present on the other. Recent comparisons of "quick-look" simultaneous scanning spectrometer OGO-IV data of Barth shows that the emissions are oxygen lines at 1304 and 1356 A.

Mange, P., "The Distribution of Lyman-α Radiations as Observed in the Sky from Satellites OGO 3, OGO 4, and OSO 4," *Trans. AGU, 49,* 1, Mar. 1968. (For abstract, see experiment B-19, OGO-III.)

Meier, R. R., "Temporal Variations of Solar Lyman-Alpha," submitted to *J. Geophys. Res.*

ABSTRACT: The geocoronal Lyman-α was observed by the OGO-4 spacecraft from August through December, 1967. The emission rate at a fixed orientation with respect to the sun was found to have short term fluctuations of less than ±5% superimposed on a monthly (or 27-day) variation of about 30%. These phenomena are attributed to variability of the Lyman-α flux at the center of the solar emission line.

Meier, R. R., "Observations of Lyman-α and the Atomic Hydrogen Distribution in the Thermosphere and Exosphere," presented at the COSPAR Meeting, Prague, Czechoslovakia, May 11-24, 1969.

ABSTRACT: Observations of Lyman α by the OGO-IV and OSO-IV satellites and Balmer α and Lyman β in the night sky are analyzed by assuming that the radiation is principally due to resonance scattering of solar photons in the atomic hydrogen geocorona.

After correction for the extraterrestrial background, the OGO-IV and OSO-IV observations yielded typical nadir-zenith intensity ratios of 0.84 and 1.20 for night and day (solar zenith angles of 180° and 10°),

respectively, in the autumn 1967 epoch. Nadir intensities of 1.1 and 26 kR for night and day were characteristic of that period.

To interpret these data numerical solutions of radiative transfer equations have been obtained for various models of the geocorona. The results of this analysis indicate that the mean optical depth above 650 km is about 2.7 (1.5×10^{13} atoms cm^{-2}) for an 1100° K exospheric temperature, in agreement with the models of Chamberlain. A diurnal density variation of a factor of 2 is also suggested by the observations.

Radiative transfer methods were also applied to the Lyman β problem and solutions were compared with experimental observation of both Lyman β and Balmer α. The conclusion of this analysis are in agreement with the Lyman α results if a non-terrestrial Balmer α background of some 3.5 to 4R is present in addition to the airglow.

Meier, R. R., and P. Mange, "Geocoronal Atomic Hydrogen Density Obtained by Satellite Lyman-α Measurements," *Trans. AGU,* 4, Apr. 1969.

ABSTRACT: The geocoronal Lyman-α intensity has been observed at zenith and nadir by an experiment on the POGO-4 spacecraft for the period July, 1967 to Jan., 1969. These measurements can be interpreted in terms of specific hydrogen density models by utilizing the theory of radiation transport in an optically thick, spherical scattering medium. Theoretical intensities have been computed for a variety of geocoronal hydrogen distribution for comparison with the experimental observations. This analysis shows that in order to understand the POGO-4 measurements, the mean optical depth above 650 km must be about 2.7 (1.5×10^{13} atom cm^{-2}) for an 1100° K exospheric temperature. A diurnal variation in optical depth from about 2.1 at the sub-solar point to 3.3 at midnight is also suggested by the measurements. An analysis of the Lyman-α intensity in a fixed orientation with respect to the sun shows intensity fluctuations of as much as ±6% over a period of less than a day and a long term periodic variation of 30% over about a one month interval.

Meier, R. R., "Interpretation of Satellite Lyman-α Airglow Measurements," *Trans. AGU, 49,* 1, Mar. 1968.

ABSTRACT: Recently Lyman α experiments have been flown on several satellites (e.g., OGO 4 (NRL), OSO 4 (NRL), OV 1-10 (Aerospace Corp.), OGO 4 (Univ. of Colo.)) to measure the geocoronal airglow. Interpretation of the results from some of these experiments in terms of atomic hydrogen distributions must be done by solving the appropriate spherical radiative transfer equation. Solutions have been obtained for several hydrogen models which vary both as a function of altitude above the Earth and solar zenith angle to include a diurnal variation. The theory requires an optical depth of 1.5-2.5 above 700 km during the day to account for the angular variation of the satellite intensities. A nighttime buildup in hydrogen is also necessary to fit the observed intensities. The required diurnal effect will be discussed.

D-14 (Barth, Ultraviolet Spectra of the Earth's Atmosphere)

Anderson, G. P., "The Vertical Distribution of Ozone Between 35 and 55 Km as Determined from Satellite Ultraviolet Measurements," accepted thesis, Dept. of Astro-Geophysics, U. of Colo., 1969.

ABSTRACT: A method is presented for determining stratospheric ozone concentrations from satellite ultraviolet spectra. The observations of back-scattered radiation from the earth in the spectral region 2550 to 3100 Å were taken by an Ebert-Fastie spectrometer mounted on the polar orbiting satellite, OGO-4.

The observed signal results from the combined effect of ozone absorption and Rayleigh scattering upon the incoming solar radiation. The reduction of the data is accomplished by approximating the integral equation, which described the intensity as a function of wavelength, with standard quadrature techniques and formulating an overdetermined matrix. The inversion of this matrix necessitates the adoption of both a smoothing function and an error estimate.

One set of satellite data was inverted, namely that taken on a pass over Hawaii at the time of a coordinated rocket experiment. The rocket observation of the ozone concentration was used in the analysis to determine the "effective" solar flux which was then applied as a calibration to the satellite data. The resultant satellite ozone profile agreed to within ten percent with the rocket observation between 35 and 55 km.

The inversion technique and calibration were subsequently applied to thirty sets of independent satellite data. The root mean square deviation of this set of equatorial data was five to ten per cent in the altitude range 35 to 55 km.

Anderson, G. P., C. A. Barth, F. Cayla, and J. London, "Satellite Observations of the Vertical Ozone Distribution in the Upper Stratosphere," *Ann. Geophys., 25,* 555, 1969.

ABSTRACT: An Ebert-Fastie ultraviolet spectrometer mounted on a polar-orbiting satellite was used to observe back-scattered radiation in the spectral region 2500-3100Å. A simultaneous set of ozone balloon and rocket observations (Krueger) was used as a calibration for the satellite data. A modified Phillips-Twomey inversion technique was then applied to the data, resulting in a reasonable vertical ozone distribution in the region 35-55km. Computations on independent data verified the dependability of the method.

Barth, C. A., and E. F. MacKey, "OGO-4 Ultraviolet Airglow Spectrometer," *IEEE Transactions on Geoscience Electronics,* Apr. 1969.

ABSTRACT: The OGO-4 ultraviolet airglow spectrometer, which measures the earth's spectrum between 1100 and 3400 Å, consists of an Ebert-Fastie monochromator and two photomultipliers with wide-dynamic range electronics. The cesium telluride photomultiplier channel measures the back-scattered ultraviolet daylight between 1750 and 3400 Å over a dynamic range of 10^4 with a spectral resolution of 20 Å. The cesium iodide photomultiplier channel measures airglow emission lines between 1100 and 1750 Å, even with the fully illuminated earth for a background.

D-15 (Jones, Neutral Particles and Ion Composition Study)

Ghosh, S. N., B. B. Hinton, L. M. Jones, R. J. Leite, C. J. Mason, E. J. Schaefer, and M. Walters, "Atomic Nitrogen in the Upper Atmosphere Measured by Mass Spectrometers," *J. Geophys. Res., 73,* 4425-4426, 1968.

ABSTRACT: In-situ measurements of atomic nitrogen concentrations agreed with theoretical predictions.

Hinton, B. B., R. J. Leite, and C. J. Mason, "Neutral Atmospheric Composition Measurements between 100 and 290 Kilometers," presented at the 1968 Spring Meeting of the AGU. (For abstract, see experiment C-15, OGO-II.)

Hinton, B. B., R. J. Leite, and C. J. Mason, "Comparison of Water Vapor Measurements from Two Similar Spacecraft," presented at the AGU Meeting, Washington, D. C., Apr. 1969. (For abstract, see experiment C-15, OGO-II.)

Hinton, B. B., R. J. Leite, and C. J. Mason, "Nighttime Composition Measurements of the Ionosphere on a Disturbed Day," presented at the AGU Meeting, Washington, D. C., Apr. 1969.

ABSTRACT: The neutral-particle and positive-ion spectrometer on OGO-IV was in operation on September 28, 1967 – a geomagnetically disturbed day. OGO-IV, at this time, experienced near-maximum eclipse durations of approximately 33 minutes while the sub-satellite local time during the eclipses varied slowly. As a result, nighttime ion composition data were obtained covering the latitude interval 86°N to 40° S for an almost constant local time. O^+ and He^+ ion densities, as determined from these data, are presented for six passes through the eclipse during this disturbed day.

Hinton, B. B., R. J. Leite, and C. J. Mason, "Representative Neutral Atomic Oxygen Density Results from OGO-IV Neutral and Ion Mass Spectrometer Experiment," presented at the AGU Meeting, Washington, D. C. Apr. 1969.

ABSTRACT: Neutral atomic oxygen data from several orbits are discussed with emphasis on results for local times near sunrise. One of the orbits is of particular interest since a vertical scan of the atmosphere was obtained by an Aerobee 150 rocket launched nearly in coincidence with the passage of OGO-IV over the rocket range. The rocket and OGO-IV were equipped with similar spectrometers. Comparisions are made with reference atmospheres.

Hinton, B. B., R. D. Kistler, R. J. Leite, and C. J. Mason, "A Sweeping Neutral and Positive Ion Mass Spectrometer for Atmospheric Composition at Satellite Altitudes," *IEEE Transactions on Geoscience Electronics,* Apr. 1969.

ABSTRACT: Accurate in-situ measurements of atmospheric composition are difficult because of the locally disturbed environment resulting from the presence of the vehicle and its instruments. The quadrupole mass spectrometer described here was designed to be immersed directly into the atmosphere with minimal modification of the local environment from ambient conditions.

This design represents a first attempt to develop a sweeping mass spectrometer which performs both neutral particle and positive ion concentration measurements aboard an earth satellite. An open ion source design is utilized to adapt, with minimum degradation, both kinds of particles for the filtering action of the quadrupole field. Six linear ranges of sensitivity are provided to permit complete compositional analysis between altitudes of 300 and 1000 km. The mass range is 0 to 50 u and maximum sensitivities are 10^5 neutral particles per cm^3 per volt output. Neutral particle and positive ion measurements are made sequentially each requiring approximately 36 seconds to complete using a sweep duration of approximately six seconds. On OGO-IV this sweep duration provided a spatial resolution of 0.8 km per mass unit of sweep.

Preliminary results show that the spectrometer is operating within design specifications and the signal-to-noise ratio is excellent. Geo-physical interpretations of these data should aid in the formation of more definitive model atmospheres which are important in such diverse fields as weather prediction, manned space flights. and radio propagation.

D-16 (Taylor, Positive Ion Composition)

Mayr, H. G., J. M. Grebowsky, and H. A. Taylor, Jr., "High Latitude Ion Composition Measurement and the Plasmapause," presented at the AGU Meeting, Apr. 1969.

ABSTRACT: OGO-IV ion composition measurements obtained at dawn and dusk, near 1000 kilometers show under quiet conditions a decrease of the H^+ and an increase of the O^+ densities between L = 2 and 6. To explain this feature and the related sharp decrease of the equatorial H^+ density (plasmapause) observed at high altitudes in the magnetosphere upward fluxes of H^+ which increases with latitude, are required. Beyond the plasmapause it appears that a significant increase of the H^+ upward velocity along lines of magnetic force must be invoked. This is in agreement with current models for the formation of the plasmapause that suggest depletion mechanisms at high altitudes.

Taylor, H. A., Jr., H. G. Mayr, and H. C. Brinton, "Observation of Thermal Ions of Helium and Hydrogen in the Upper Ionosphere During a Solar Cycle," presented at the COSPAR Meeting, May 1969. (For abstract, see experiment C-16, OGO-II.)

D-18 (Nilsson, Micrometeorites)

Nilsson, C. S., F. W. Wright, and D. Wilson, "Attempts to Measure Micrometeoroid Flux on the OGO 2 and OGO 4 Satellites," *J. Geophys. Res.*, under review, 1969. (For abstract, see experiment C-18, OGO-II.)

D-19 (Donley, Ionospheric Composition and Solar Ultraviolet Radiation)

Chandra, S., and B. E. Troy, Jr., "Ion Composition and Temperatures in the Equatorial Topside," presented at the 3rd Equatorial Aeronomy Conference, Ahmedabad, India, Dec. 1968.

ABSTRACT: Direct measurement of temperatures and densities of electron and various ionic constituents [O^+, He^+, H^+] in the equatorial region have been obtained from the retarding potential analyzer experiment aboard the orbiting geophysical observatory [OGO D]. Measurements from the typical day and nighttime passes in 1967 in the altitude range of 400-900 km have yielded the following results.

1. The major ionic constituent in the daytime is O^+ throughout the altitude and latitude range of observations. In the height range of 400-500 km, the latitudinal variation in O^+ shows the well known features of the geomagnetic anomaly. In the altitude range of 900 km O^+, decreases slowly away from the equator. The latitudinal variation in ion temperature shows, in general, an inverse behavior of ion density variation.

2. In the nighttime, the lighter ions (He^+, H^+) become the major constituents and O^+ the minor constituent in the altitude range of 700-900 km in the equatorial region. Their latitudinal variations show inverse relation i.e. the lighter ions decreasing and O^+ increasing towards the pole. The ration of $[H^+]/[O^+]$ varies from about a factor of 10 at the equator to unity in the geomagnetic latitude range of 40°-60°. Beyond

this region O^+ continues to increase and becomes the major ion in the polar region. The latitudinal variations in composition are explained in terms of the latitudinal variation in transition heights. This concept is consistent with the observed changes in electron and ion temperatures.

Troy, B. E., Jr., "Composition and Temperatures of the Topside Ionosphere During Solar Maximum," presented at the Spring AGU Meeting, 1969.

ABSTRACT: Direct measurement of temperatures and densities of various ionic constituents (H^+, He^+, O^+) and electrons have been obtained from the OGO 4 planar retarding potential analyzer in the altitude range 400-900 km. Results of typical passes in 1967 are: 1) Below 500 km, the major constituent is O^+ both day and night, with the latitudinal variation of $[O^+]$ showing the geomagnetic anomaly. 2) Above 700 km at night, the lighter ions (H^+, He^+) dominate in the equatorial region. $[O^+]$ increases toward the poles, exceeding the density of the lighter ions in the geomagnetic latitude range of 40°-60°, until only O^+ is observed near the poles. Above 700 km at day, O^+ dominates throughout the observed latitude range. 3) In general, temperatures show an inverse relation with ion density. The latitudinal variations in composition are explained in terms of the latitudinal variation in transition heights. This concept is consistent with the observed changes in electron and ion temperatures.

D-21 (Kreplin, Solar X-Ray Study)

Horan, D. M., R. W. Kreplin, A. T. McClinton, Jr., and L. C. Schneider, "Using Solar X-Rays as Indicators of Solar Flare Activity," NRL Report No. 6884.

ABSTRACT: X-ray and particle emission during solar flares can sufficiently increase the electron density in the lower regions of the ionosphere to cause disruption of high frequency radio communications. For several years the Naval Research Laboratory has been measuring solar x-ray flux levels in the 0.5-3 A, 1-8 A, 8-20 A, 1-20 A, and 44-60 A bands. Based on these measurements criteria have been established to predict periods of high solar activity during which solar flares capable of disrupting communications might occur. A study of solar flare occurrence and solar x-ray flux levels over fourteen months has shown that solar flares are three times more likely to occur when the criteria are met than when they are not met.

Kreplin, R. W., and P. J. Moser, "Flare X-Ray and Radio Wave Emission," presented at the 10th International Space Science Symposium, Prague, Czechoslovakia, May 1969.

ABSTRACT: SOLRAD 9 (1968-17A) and OGO-IV (1967-73A) have provided nearly continuous measurements of solar X-ray emission since July 1967. A number of X-ray flares, for which there are accompanying cm radio burst data from Sagamore Hill Radio Observatory and from Manila, have been examined in an attempt to clarify the relationship of the two emission processes. Whereas, flare X-rays >20 kev appear to match microwave outbursts closely in time and duration, a steep rise in X-rays observed in the band 0-3 A consistently leads the microwave flash by several minutes. For most flares classified 1B or greater the 0-3 A X-ray flux has risen by an order of magnitude before the sharp rise in microwave emission. Generally, the microwave flush is short lived, but is followed by the post-burst slow decay which matches the duration of soft X-ray emission.

Kreplin, R. W., D. M. Horan, T. A. Chubb, and H. Friedman, "Measurements of Solar X-Ray Emission from the OGO-4 Spacecraft," presented at the 9th International Space Science Symposium, Tokyo, Japan, 1968.

ABSTRACT: Instrumentation aboard OGO-4 monitors solar x-ray fluxes in four bands, 0.5-3A, 1-8 A, 8-16 A, and 44-60 A, with high time resolution and sufficient dynamic range to compare peak fluxes during flares with pre-flare and post-flare conditions. Comparisons with SOLRAD x-ray data obtained with similar detectors during the IQSY show that the "quiet sun" base level in the 8-20 A band had risen in 1967 by a factor of about 30, while in the 1-8 A band the increase has been greater than a factor of 100. The 44-60 A flux has shown an increase of a factor of 10. From a number of large flares recorded by OGO-4 in July and August 1967, it is observed that the flare x-ray emission starts earliest in the shortest wavelengths, the 0.5-3 A band leads the 1-8 A and 8-16 A bands by about one minute. Peak fluxes are also reached earliest at the shortest wavelengths.

OGO-V DESCRIPTION OF EXPERIMENTS

E-01 MEASUREMENT OF ELECTRON TEMPERATURE AND DENSITY IN THE MAGNETOSPHERE, Prof. R. L. F. Boyd, U. College of London

The objective of this experiment is to study electron temperature and density in the magnetosphere to understand the effects of solar winds on the geomagnetic field.

E-02 SPHERICAL ION AND ELECTRON TRAP, Dr. R. C. Sagalyn, AFCRL

The objective of this experiment is to measure densities of particles of both signs in the range 1 to 10^5 cm^{-3}, thermal ion and electron temperature in the range 700 to 100,000° K, flux, densities, and energy distributions of both sign particles in the energy range 25 to 2000 ev, electron flux in the range 3 x 10^5 to 5 x 10^{11} cm^{-2} sec^{-1}, proton flux from 10^5 to 10^{11} cm^{-2} sec^{-1}, and the spacecraft potential with respect to the undisturbed plasma.

E-03 THERMAL ION-ELECTRON, G. P. Serbu, GSFC

Using a gridded Faraday cup, this experiment will measure the integral spectrum of ions and electrons in the energy range 0 to 45 ev.

E-04 SOLAR X-RAYS AND CHARGED PARTICLE DETECTOR, Dr. K. A. Anderson, UCLA

The objective of this experiment is to detect and measure solar X rays (1-90 kev), solar protons (8-300 Mev), and solar alpha particles (30-1200 Mev).

E-05 INTERPLANETARY ELECTRONS, POSITRONS, AND PROTONS, Dr. T. L. Cline, GSFC

The objective of this experiment is to study the production and modulation of quiet time, the enhancement of intensity of protons and electrons during associated plasma and magnetic field activity, the time variations of proton energy spectrum and intensity, low rigidity interplanetary electrons (0.1 - 8 Mev), positrons (0.5 - 8.0 Mev), protons (2 - 70 Mev) and gamma rays (50 - 700 kev).

E-06 ELECTRON AND PROTON SPECTROMETER, Dr. R. D'Arcy, NRL

The objective of this experiment is to measure the low-energy proton and electron lifetimes in the inner belt, an inventory of the low-energy proton distribution in the radiation belts, a differentiation between trapped and transient particles, charged particles, and trapped alpha-particle fluxes.

E-07 LOW ENERGY PROTON AND ELECTRON DIFFERENTIAL ENERGY ANALYZER, Dr. J. A. Van Allen, SUI

Two GM tubes and four electrostatic analyzers will measure the differential energy spectrum of protons and electrons over the range 5 ev, to 50 kev, the earth's magnetosphere and its environs, trapped alpha particles (0.40 - 200 Mev).

E-08 GAMMA RAY ASTRONOMY, Prof. G. W. Hutchinson, U. of Southampton

The purpose of this experiment is to investigate the directions of incidence of cosmic gamma-ray photons of energies approximating 100 Mev.

E-09 COSMIC RAY ELECTRONS, Dr. P. Meyer, U. of Chicago

A particle telescope formed by scintillation counter, gas Cerenkov counter, SSD and CsI scintillation counter, surrounded by two plastic scintillators will measure flux and energy spectrum of electrons with energy between 10 Mev and 150 Mev, flux and energy spectrum of protons with energy between 50 Mev and 1 Bev, flux of protons with energy above 1 Bev, and flux of protons with energy above 14 Bev.

E-10 GALACTIC AND SOLAR COSMIC RAY, Dr. F. B. McDonald, GSFC

Three sets of detectors: (a) a double-oscillator Cerenkov telescope, (b) an E vs dE/dX telescope (15 - 75 Mev), and (c) a solid state detector with anti-coincidence cup will measure the absolute proton flux 0.4 - 1200 Mev, the absolute helium flux 2.0 - 1200 Mev/nucleon, the charge of individual nuclear constituents in the range 2.0 - 12 Mev/nucleon, the flux of 1 - 10 Mev solar and galactic electrons beyond the magnetosphere and to study the isotopic abundance of H, D, T.He^3 and He^4 in the interval 12 - 80 Mev/nucleon.

E-11 TRIAXIAL ELECTRON ANALYZER, Dr. K. W. Ogilvie, GSFC

The objective of this experiment is to determine the energy spectra of electrons arriving at the spacecraft from three directions mutually at right angles, observe electrons in the interplanetary medium insofar as the satellite potential allows, observation of electrons in the transition region, a study of the rate of electrons in the collisionless shock process, search for electrons in the neutral sheet region of the magnetospheric tail, and the study of the acceleration processes for electrons in the transition region and the tail.

E-12 MEASUREMENT OF THE ABSOLUTE FLUX AND ENERGY SPECTRUM OF ELECTRONS, Dr. H. C. Van de Hulst, Netherlands Inst. of Nuclear Physics Research

An estimate of magnetic field of the galaxy, origin of electrons, solar flare electron observation, interplanetary modulation, storage time of electrons in the galaxy, time variations of the electron spectrum, energy spectrum of protons between 20 Gev to 100 Gev, and flux of gamma rays above 500 Mev will be made by a detector with six counters.

E-13 HYDROMAGNETIC WAVES AND THEIR EFFECT ON GEOMAGNETICALLY TRAPPED PARTICLES, Dr. P. J. Coleman, GSFC

The objective of this experiment is to determine the magnetohydrodynamic properties of disturbances in the distant magnetosphere and beyond.

E-14 MAGNETIC FIELD, Dr. P. J. Coleman, GSFC

This experiment is conducted in conjunction with E-13. The magnetometer will measure magnetic field from 0 to ±64,000 Gamma.

E-15 MAGNETIC SURVEY, Dr. J. P. Heppner, GSFC

Objectives of this experiment are to study the magnetosphere and shock boundaries and to measure low magnetic flux fields using rubidium vapor magnetometer and a triaxial flux gate sensor.

E-16 TRIAXIAL SEARCH COIL MAGNETOMETER, Dr. E. J. Smith, JPL

The objective of this experiment is to investigate naturally-occurring magnetic field variations in, and beyond, the magnetosphere in the frequency range 0.01 - 1 kHz.

E-17 PLASMA SPECTROMETER, Dr. C. W. Snyder, JPL

The objective of this experiment is to measure the flux of the solar plasma ions and electrons as a function of energy (a) within the magnetosphere (including the trapped particle belts), (b) in the magnetopause, and (c) in the interplanetary (solar-wind) region; to measure the direction and velocity of the solar wind; to measure the relative abundance of hydrogen and heavier ions in the solar wind; to study the structure and composition of plasma clouds or streams from solar flares; to measure the temporal variations of the quantities above with high resolution in time; to study the nature of the interfaces between the three plasma regions.

E-18 LIGHT-ION MASS MAGNETIC SPECTROMETER, Dr. G. W. Sharp, Lockheed Missiles and Space Co.

A light-ion mass spectrometer will be used to measure the relative abundance of masses, 1, 4 and 16 in the upper ionosphere and exosphere; the construction of height profiles of these ion species: which ion species dominates at a given altitude; the altitude at which domination is changed.

E-19 DELETED

E-20 RADIO ASTRONOMY, Dr. F. T. Haddock, U. of Mich.

The objective of this experiment is to make studies of Solar and Jovian radio noise bursts and possible radio noises originating from earth in the direction of galactic space and map cosmic background noise at 2 MHz using ionospheric focusing, apply AC bias to antenna to measure antenna impedance.

E-21 UV PHOTOMETER EXPERIMENT, Dr. C. A. Barth, U. of Colo.

The primary objective of this experiment is to measure the distribution of neutral hydrogen, Lyman-alpha (1216 Å), and atomic oxygen (1304 Å) out to several Earth radii and determine the effects of variations of solar radiation from the solar cycle and solar perturbations.

E-22 GEOCORONAL LYMAN-ALPHA, Prof. J. E. Blamont

The objective of this experiment is to measure the number density of hydrogen atoms from 100 km to 40,000 km by monitoring the energy flux scattered in the Lyman-alpha line by geocoronal hydrogen atoms; the temperature of geocoronal hydrogen atoms by monitoring the width of the Lyman-alpha line with an absorbing hydrogen cell. To observe the interaction between solar particles and hydrogen during solar events.

E-23 SOLAR X-RAY EMISSIONS, R. W. Kreplin, NRL

The objective of this experiment is to measure X-ray emissions in the 0.6 Å - 6.0 Å region using a xenon filled proportional counter spectrometer.

E-24 DETECTION OF PLASMA WAVES IN THE MAGNETOSPHERE, G. M. Crook, TRW Systems

An orthogonal system of electric and magnetic field antenna will be used to detect and measure electric plasma oscillations and electromagnetic waves (300 Hz to 70 Hz).

E-25 OPEP-2 SCAN MECHANISM, R. Browning, GSFC

E-26 ELECTRIC FIELDS MEASUREMENT, Dr. T. L. Aggson, GSFC

The objective of this experiment is to observe dc electric fields in the outer regions of the magnetosphere, in the transition region, and in the solar wind; monitor $\vec{V} \times \vec{B}$ effects induced by the solar wind, electrostatic and hydromagnetic plasma instabilities in the transition regions, aurorae associated electric fields in the region $6 < L < 8$, time varying electric fields associated with the "slot" region L - 2.5, $\vec{V} \times \vec{B}$ effects in the ionosphere.

E-27 HIGH-Z LOW-E, Dr. J. A. Simpson, U. of Chicago

The objective of this experiment is to straddle the energy of nuclear binding energies and threshold energies for spallation reactions (~2 to 50 Mev/nucleon to: (a) examine the shape of the differential energy spectrum to determine the relative roles of rates of ionization loss and spallation reactions, (b) to extend the measurement of relative abundance of the elements in the range boron through iron, and especially to examine in detail the region around calcium, (c) to search for nuclei of very high charge; Z = 5 to Z = 50, and (d) extend the observation of very heavy nuclei from solar flares to ~2 Mev/nucleon to determine if injectionless acceleration occurs.

OGO-V EXPERIMENTS

E-05 (Cline, Interplanetary Electrons, Positrons, and Protons)

Cline, T. L., and G. Porreca, "Cosmic-Ray Electrons and Positrons of Energies 2 to 9.5 Mev Observed in Interplanetary Space," in Contributions to the 1969 Budapest Conference on Cosmic Rays, also GSFC X-611-69-413.

ABSTRACT: The differential energy spectra of electrons and positrons in the 2 to 9.5 MeV interval have been studied in interplanetary space during solar quiet times following March 1968 with the OGO-5 satellite. The detector flown was designed to separately identify cosmic-ray and solar electrons, positrons, protons and alphas, and solar x-rays; it used new techniques to minimize its background and to determine directly the background encountered. The observed quiet time electron spectrum, approximately of the form 90 $E^{-1.5}$ m^{-2} sec^{-1} $ster^{-1}$ MeV^{-1} from 2 to 9.5 MeV, roughly agrees with the expected unmodulated cosmic-ray knock-on electron spectrum. The positron to electron ratio, totalled for this energy interval, is only 1.8 percent. This is the lowest e^+/e ratio measured in any energy region; it also suggests that this electron component is of knock-on or directly-accelerated origin, rather than of meson-decay of soft-shower origin. The resulting average positron intensity, near 0.2 m^{-2} sec^{-1} $ster^{-1}$ MeV^{-1}, compares with the balloon data above 10 MeV such that all points or upper limits are below the predicted spectrum of cosmic-ray electrons from pion decay by a factor of up to ten. This result indicates a moderate modulation of the positron intensity in the medium-energy region, having a detailed energy dependence yet to be determined.

E-09 (Meyer, Cosmic Ray Electrons)

Parks, G. K., and J. R. Winckler, "16-Second Periodic Modulations Observed in Hard Solar X-Rays," presented at the AGU Meeting, Washington, D. C., Apr. 1969. (For abstract, see experiment B-09, OGO-III.)

E-10 (McDonald, Galactic and Solar-Cosmic Ray)

Teegarden, B. J., V. K. Balasubrahmanyan, D. E. Stilwell, and F. B. McDonald, "Charge and Energy Distribution of Galactic Cosmic Rays in the 3-1000-MeV/Nucleon Interval," *Bull. Am. Phys. Soc.*, II, *13*, 11, 1968.

ABSTRACT: Preliminary results from the Goddard Cosmic-ray experiment on OGO-V (launched 4 March 1968) will be presented. The experiment consists of a system of 3 complementary detectors having overlapping energy responses covering the interval from 3 to 1000 MeV/nucleon. A solid-state dE/dx vs E detector covers the range from 3 to 20 MeV/nucleon. A scintillator dE/dx vs E is used between 18 and 80 MeV/nucleon. This detector also has the capability of measuring high-energy penetrating particles. In this mode 3 separate dE/dx measurements are made on each particle. Through this technique the detector's energy response is extended to 300 MeV/nucleon. A double dE/dx Cerenkov detector sensitive to particles between 100 and 1000 MeV/nucleon completes the experiment. Individual charge resolution is possible from Z = 1 to Z = 20. Differential energy spectra of the various charge components of the primary cosmic radiation in the interval Z = 3-10 are obtained. The abundances Li, Be, B, and F nuclei and their relevance to the propagation of cosmic rays in the instellar medium will be discussed.

E-14 (Coleman, Magnetic Field)

Simmons, L. L., and P. J. Coleman, Jr., "Fluctuations in the Bow-Shock Magnetic Field," submitted at the 1968 Western National Meeting of the AGU.

ABSTRACT: Magnetic-field fluctuations with two distinct periods were recorded with the UCLA magnetometer during a traversal of the earth's bow shock by OGO 5 on March 7, 1968. On the interplanetary side, the fluctuations had a period of about 1.1 sec and an amplitude of 4-6γ peak to peak. In the magnetosheath, the period was about 3 sec and the amplitude was 8-10γ peak to peak. This event included eleven well defined shock crossings. All were similar, the main difference being the rate at which the field changed from its interplanetary to transition region value. The 'magnetosheath' oscillations first appeared in the interplanetary medium just before the shock-related jump in the mean field. The 'interplanetary' oscillations extended for some distance into the magnetosheath. Thus, there was a region centered about the shock jump in which both types of waves coexisted.

Simmons, L. L. and P. J. Colemen, Jr., "Damped Sinusoidal Oscillations in the Interplanetary Magnetic Field," submitted at the 1968 Western National Meeting of the AGU.

ABSTRACT: Magnetic-field observations from UCLA's OGO-5 magnetometer have disclosed the presence of damped, periodic fluctuations, which we interpret as wavetrains in the interplanetary plasma. From March 5-15, 1968, such wavetrains appeared randomly throughout the intervals during which OGO 5 was in near-earth interplanetary space. These waves are circularly polarized with sense of rotation dependent on the direction of the mean magnetic field. The waves occur when the interplanetary field is disturbed. In the spacecraft frame of reference the background disturbance field is characterized by time variations in the magnitude and direction of the magnetic field with periods of 10-100 sec, and vector-component amplitudes of order 10γ. The damped waves superimposed on this disturbed field are observed at several apparently discrete frequencies. The frequencies, as measured in the spacecraft frame, lie between 0.3 and 0.9 Hz. Damping occurs in 3-7 cycles from the beginning of the wavetrain. Wave amplitudes in excess of 8γ have been observed in regions where the ambient field is less than 15γ.

E-15 (Heppner, Magnetic Survey)

Sugiura, M., T. L. Skillman, B. G. Ledley, and J. P. Heppner, "Holes in the Magnetic Field Near the Magnetopause," presented at the AGU Meeting, Washington, D. C., Apr. 1969. (For abstract, see experiment B-11, OGO-III.)

E-16 (Smith, Triaxial Search Coil Magnetometer)

Brody, K. I., C. T. Russell, R. E. Holzer, C. F. Kennel, R. W. Fredricks, and F. L. Scarf, "Nightside Auroral Electric and Magnetic Noise in the Equatorial Plane," *EOS Trans. AGU, 50,* 4, Apr. 1969.

ABSTRACT: OGO-5 has traversed the Earth's nightside auroral zone very near the geomagnetic equator. Supplementary data indicates that OGO-5 was in or near a region of high β electron plasma between geocentric distances of 5-10 R_e. Both the UCLA search coil magnetometer (5 Hz to >1 kHz) and the TRW electric field sensor (.56 to >5 kHz) detected narrow band noise, typically centered from .25-.5 of the local (approximately equatorial) electron gyrofrequency. The noise appears to be electromagnetically polarized, although pure electrostatic bursts also occur. The structure varies from hiss-like bursts to long duration signals with chorus-like structure.

Brody, K. I., R. E. Holzer, C. F. Kennel, E. J. Smith, R. W. Fredricks, and F. L. Scarf, "Night Side Auroral Electric and Magnetic Noise in the Equatorial Plane," presented at the 1969 URSI Spring National Meeting.

ABSTRACT: OGO-5 has traversed the earth's night side auroral zone very near the geomagnetic equator. Supplementary data indicates that OGO-5 was in or near the inner portion of the electron plasma sheet between geocentric distances of 5-10 R_e. Both the UCLA search coil magnetometer (0.15 - 1.4 kHz) and the TRW electric field sensor (0.56 - >5 kHz) detected narrow band noise, typically centered from 0.25 - 0.5 of the local (~equatorial) electron gyrofrequency. The noise appears to be electromagnetically polarized, although pure electrostatic bursts also occur. The structure varies from hiss-like bursts to long duration signals with chorus-like structure.

Frandsen, A. M. A., R. E. Holzer, and E. J. Smith, "OGO Search Coil Magnetometer Experiments," *IEEE Transactions on Geoscience Electronics,* Apr. 1969. (For abstract, see experiment 4910, OGO-I.)

Holzer, R. E., M. G. McLeod, J. V. Olson, C. T. Russell, and E. J. Smith, "The Magnetic Component of Plasma Waves Associated with the Interaction of the Magnetosphere and Solar Wind," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 3-13, 1968. (For abstract, see experiment 4910, OGO-I.)

Russell, C. T., J. V. Olson, R. E. Holzer, and E. J. Smith, "OGO-5 Search Coil Magnetometer Observations in the Magnetosphere," *EOS Trans. AGU, 50,* 4, Apr. 1969.

ABSTRACT: The telemetered output of the OGO-5 search coil magnetometer includes an analog waveform signal in the frequency band from 1 to 1000 Hz. A study of the dynamic spectra of magnetospheric signals, near the equatorial plane, utilizing this capability has been undertaken. Presently data are available only in the dawn hemisphere. In this region, the noise in the plasmasphere consists of broadband hiss and whistlers. Outside the plasmasphere the noise is much more structured usually consisting of trains of risers or narrow band emissions with variable amplitude. The risers have durations ranging from less than one-half second to several seconds. Often the durations and repetition rate of the risers are similar to those of electron microbursts. The center frequency of the band in which the noise external to the plasmasphere exists always decreases as a function of radial distance. Dynamic spectra of signals typical of each region will be presented.

Smith, E. J., R. E. Holzer, and M. G. McLeod, "Discrete Magnetic Emissions in the Magnetosheath," *EOS Trans. AGU 50,* 4, Apr. 1969. (For abstract, see experiment B-10, OGO-III.)

Smith, E. J., K. I. Brody, R. K. Burton, R. E. Holzer, and C. T. Russell, "Observations of Waves in the Magnetosphere at Frequencies up to 1000 Hz," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., Sept. 3-13, 1968. (For abstract, see experiment 4910, OGO-I.)

Smith, E. J., R. E. Holzer, and C. T. Russell, "Magnetic Emissions in the Magnetosheath at Frequencies Near 100 Hz," *J. Geophys. Res. (Letters), 74,* 3027-3036, 1969. (For abstract, see experiment 4910, OGO-I.)

E-18 (Sharp, Light-Ion Mass Magnetic Spectrometer)

Harris, K. K., and G. W. Sharp, "Early Topside Ionospheric Composition Results from OGO-V," presented at the 1968 AGU Fall Meeting, San Francisco, Calif.

ABSTRACT: The first few orbits of data obtained from the light ion mass spectrometer flown on the OGO-V spacecraft have been reduced and analyzed. These results give the ambient, thermal ion concentrations of H^+, He^+ and O^+. It is observed in the near perigee regions that the H^+ ion concentration is essentially symmetric with respect to altitude about perigee; however, the He^+ ion concentration and O^+ ion concentration show distinct asymmetries. The O^+ ion concentration on the outbound path shows a significantly larger gradient than the inbound O^+ ion concentration. This is probably due to local time considerations inasmuch as the outbound path is in darkness whereas the inbound path is sunlit. The He^+ ion concentration on the outbound path is nearly an order of magnitude less than its value on the inbound path. This condition persists both inside and outside the earth's shadow. The crossover from H^+ dominant to O^+ dominant occurs rather abruptly at altitudes ranging from 560 km to 750 km.

Sharp, G. W., and K. K. Harris, "OGO-V Ion Mass Spectrometer Measurements of Solar Wind Particles in the Magnetosheath," presented at the 1968 AGU Fall Meeting, San Francisco, Calif.

ABSTRACT: The ion mass spectrometer flown on OGO-V is a magnetic-focus spectrometer such that protons with about 500 ev of energy are focused and detected, with heavier, singly charged ions requiring less energy for focus. OGO-V was launched into a highly eccentric orbit on March 4, 1968. As initially launched the spacecraft passes through the Magnetosheath twice in the approximately 63 hour period of the orbit. At times significant ion currents are detected by the spectrometer in the magnetosheath in the proton energy range of 0-500 ev. Data from the magnetosheath on the inbound passes of 12 March and 14 March are analyzed. Many of these data show an almost flat distribution of particle energies over the 0-500 volt energy range. However, there are times when the energy distribution shows a broad peak at 400 volts and other times when the distribution has a sharp peak at 475 volts. Particle fluxes as high as 1×10^7 cm^{-2} sec^{-1} were observed with 1×10^3 cm^{-2} sec^{-1} being the smallest flux detectable by the instrument.

E-20 (Haddock, Radio Astronomy)

Haddock, F. T., and T. E. Graedel, "Radio Bursts in the Outer Corona," *Sky and Telescope, 36,* 217, 1968. (For abstract, see experiment B-18, OGO-III.)

Haddock, F. T., and T. E. Graedel, "Observations of Solar Radio Spectra at Very Low Frequencies," *Astron. J., 73,* S180, 1968.

ABSTRACT: The Orbiting Geophysical Observatory satellite, OGO-III, was launched in June, 1966 with twenty scientific experiments on board. The University of Michigan Radio Astronomy Observatory experment consisted of a dynamic spectrograph designed to record solar burst radiation over the band of 4-2 MHz, with a time resolution of two seconds. The radiometer output is recorded on magnetic tape and converted to dynamic spectrograms on 35 mm film by digital computer techniques. This paper presents the results of fifteen months of low-frequency solar burst observations by the experiment.

For the period 13 June 1966 to 30 September 1967, a total of 218 solar radio bursts have been observed. Most of these are fast-drift bursts (Type III), although Type V continuum has been observed in several cases following the Type III event. The existence of continuum radiation of Types I and IV has not definitely been established.

Comparison of the OGO-III burst data with ground based radio spectral observations results in confirmation of the OGO-III event by the ground stations in 90% of all cases. A concurrent optical flare is also seen in 60% of the OGO-III burst cases.

Initial observational data from the OGO-V radio astronomy experiment is also shown. Many solar bursts are seen at frequencies below 1 MHz, one of which extends to at least 100 kHz and is believed to originate from coronal regions near the orbit of the planet Mercury.

E-24 (Crook, Detection of Plasma Waves in the Magnetosphere)

Fredricks, R. W., C. F. Kennel, F. L. Scarf, G. M. Crook, and I. M. Green, "Detection of Electric Field Turbulence in the Earth's Bow Shock," Space Sciences Laboratory, Oct. 23, 1968.

ABSTRACT: Observations of low frequency fluctuating electric fields, associated with two crossings of the earth's bow shock by OGO-V, are presented. It is shown that electric field components with frequencies comparable to the local electron plasma frequency, which are significant in the solar wind, are quenched by the shock. Low frequency components (0156-3.0 kHz) are enhanced at the shock by two orders of magnitude above their upstream values and then relax downstream. Some of the more intense electric field impulses appear to correlate with regions of large gradients in *(B)* within the shock. No significant magnetic field components of comparable frequencies are observed. It is suggested that the electric field turbulence is produced by a current driven instability, perhaps of the ion acoustic wave.

Fredricks, R. W., F. L. Scarf, G. M. Crook, I. M. Green, and C. F. Kennel, "OGO-5 Observations of Anomalous Resistivity in the Bow Shock," presented at the 1969 URSI Spring National Meeting.

ABSTRACT: During periods of relatively steady solar wind flow, OGO-5 magnetic and electric field detectors have observed microstructure in the bow shock layer consisting of a large amplitude MHD structure upon which is superimposed a fine structure of intense and highly localized electrostatic turbulence in the range 200 Hz to some 3 kHz. These latter can be explained as non-linearly saturated ion acoustic waves produced by a streaming instability in the regions of large electron current density producing the gradients in the MHD structure. We can estimate the joule heating of protons in these electrostatic turbulence regions from J_e^2/σ_{eff}, where J_e is the current density and σ_{eff} is the effective conductivity due to turbulent wave-particle collisions. The formula of Sagdeev $\sigma_{eff} \simeq \omega pe^2/4\pi\nu_{eff}$ with $\nu_{eff} \simeq 0.1\ \omega pi$ can explain up to 50 percent of proton randomization in the shock layers observed by OGO-5. Comparison of observations and theoretical heating models will be made.

Fredricks, R. W., F. L. Scarf, G. M. Crook, I. M. Green, and C. F. Kennel, "OGO-5 Observations of Electrostatic Plasma Oscillations in the Magnetopause Layer," presented at the 1969 URSI Spring National Meeting.

ABSTRACT: The possible existence of the two-stream (electrostatic) plasma wave instability in a Chapman-Ferraro sheath was predicted by Bernstein, Fredricks, and Scarf (J.G.R. *69,* 1964), who observed that large currents of hot electrons streaming through cooler protons should trigger not only the electron oscillation branch at ω_{pe} as postulated by Piddington (J.G.R. *65,* 1960), but also the ion acoustic branch at $\omega \lesssim \omega_{pi}$.

The TRW electric field experiment aboard OGO-5 has detected plasma oscillations, in several magnetopause crossings, at frequencies near ω_{pe} and ω_{pi}, as well as at other frequencies. These observations will be presented and discussed within the framework of previous theoretical predictions, and evidence for specific wave mode identifications will be presented.

Kennel, C. F., R. W. Fredricks, and F. L. Scarf, "OGO-5 Observations of Auroral Electric Field Noise Above the Equatorial Electron Cyclotron Frequency," presented at the 1969 URSI Spring National Meeting.

ABSTRACT: On several occasions, OGO-5 apparently traversed the inner portion of the electron plasma sheet between 5-10 R_e near the geomagnetic equator. Electric field emissions near but above the local (~equatorial) cyclotron frequency, which we tentatively identify as electrostatic electron cyclotron waves, were detected. Near 5 R_e, intense emissions at 30-70 kHz, which may not be cyclotron waves, were also observed. Examples of the data will be presented, and will be compared with the requirements of auroral precipitation theories.

Scarf, F. L., I. M. Green, R. W. Fredricks, and M. Neugebauer, "Detection of Interplanetary 70 kHz Noise Bursts Near the Local Critical Frequency," presented at the 1969 URSI Spring National Meeting.

ABSTRACT: On April 5, 1968 a flare-associated sudden commencement was detected at 1328 UT, as OGO-5 was outbound through the bow shock region. Several hours later the solar wind speed became steady ($v \simeq 406$ km/sec) and exceptionally high densities ($N_e > 70/cm^3$) were encountered. Between 1820 and 1845 UT the flux decreased by a moderate factor and large amplitude 70 kHz noise bursts were sporadically detected on the VLF electric and magnetic sensors during this period. We have interpreted the oscillations with correlated E and B components as electromagnetic waves having $n^2 = 1 - \omega_p^2/\omega^2 < 1$, and direct comparison with the plasma probe density estimate gives an absolute calibration for that instrument. The measured wave amplitudes are also used to evaluate the local density from the relation $n = cB/E$, leading to an absolute calibration for the electric dipole within the streaming plasma. We find that all measured or deduced densities are in agreement and are compatible with the interpretation that the correlated noise bursts represent electromagnetic waves with ω near the local plasma resonance frequency.

OGO-VI DESCRIPTION OF EXPERIMENTS

F-01 MICROPHONE DENSITY GAGE, Dr. G. W. Sharp, Lockheed Missiles and Space Co.

The experiment's objective is to measure, in situ, the spatial and temporal variations in the neutral atmospheric density around the OGO-F orbit. In particular, latitude variation, day-night variations, and solar activity-correlated variation in the atmospheric density will be the objects of this study.

F-02 ELECTRON TEMPERATURE AND DENSITY, Dr. A. F. Nagy, U. of Mich.

The objectives of this experiment are to measure the ambient electron temperature and density in the upper atmosphere and to provide information on the equilibrium potential of the spacecraft.

F-03 IONOSPHERIC DUCT DETECTOR, Dr. W. B. Hanson, Southwest Center for Advanced Studies

The objectives of this experiment are to measure ion temperature, ion composition, and ion concentration, and, to identify irregularities in ion concentration.

F-04 NEUTRAL ATMOSPHERIC COMPOSITION, C. A. Reber, U. of Mich.

The primary objective of this experiment is to study the behavior of the concentrations of the major constituents (N_2, O_2, O, He, and H_2) of the earth's neutral atmosphere during varying solar activity and magnetic disturbances, and during diurnal, seasonal, and latitudinal variations. A secondary objective is to obtain accurate measurements of the concentration of trace constituents of the earth's neutral atmosphere.

F-05 MASS SPECTROMETER, Dr. R. Pickett, GSFC

The primary objective of this experiment is to study the atmospheric thermal positive ion concentration and mass in the range from 1 to 45 amu.

F-06 ION MASS SPECTROMETER, Dr. W. B. Hanson, Southwest Center for Advanced Studies

The objective of this experiment is to measure the ambient ion composition along the vehicle path for those positively charged ions in the range from 1 to 40 amu/electronic charge.

F-07 GAS-SURFACE ENERGY TRANSFER PROBE, Dr. D. McKeown, Faraday Laboratories

The experiment measures the kinetic-energy flux of the upper atmosphere relative to the orbiting satellite and what fraction of this energy is transferred at normal incidence to Au and Al surfaces. The primary objective of the experiment is to determine the energy accommodation and drag coefficients for high and low atomic weight metals. A secondary objective is to determine variations in upper atmospheric density occurring diurnally, with latitude and with changes in solar activity by monitoring variations in the kinetic-energy flux of the upper atmosphere.

F-08 SOLAR X-RAY EMISSIONS, R. W. Kreplin, NRL

The objective of this experiment is the understanding of the solar flare phenomena through the measurement of their X-ray emissions in the 2- to 150-kev range. The instrumentation is capable of differentiating between thermal and nonthermal processes in the flare mechanism; and, it will obtain X-ray emission history to aid in explaining flare-associated sudden ionospheric disturbance phenomena that affect the D region.

F-09 SOLAR EXTREME ULTRAVIOLET EMISSIONS, Dr. D. E. Bedo, AFCRL

The objective of this experiment is to monitor radiation intensities in the ultraviolet portion (160 Å to 1600 Å) of the solar spectrum.

F-10 SOLAR ULTRAVIOLET ENERGY SURVEY, Dr. V. H. Regener, U. of N. M.

The primary objective of this experiment is to monitor continuously the intensity of solar radiation in the ultraviolet region of the spectrum over the wavelength range from 1850 to 3500 angstroms. Solar radiation at these wavelengths is largely responsible for the dissociation of oxygen in the upper atmosphere, for the existence and the vertical distribution of atmospheric ozone, and for the temperature distribution in the upper atmosphere.

F-11 AIRGLOW AND AURORAL EMISSIONS, Prof. J. E. Blamont, U. of Paris

During airglow and auroral phenomena, this experiment will study the emitting regions at 6300 angstroms (red line of atomic oxygen) and 3914 angstroms (0-0 band of the first negative system of nitrogen, N_2^+).

F-12 CELESTIAL LYMAN-ALPHA MEASUREMENT, Dr. M. A. Clark, Aerospace Corp.

The objective of this experiment is to measure the zenith angle distribution of Lyman-alpha radiation on a global basis. The primary source of the radiation is the sun, and the distribution occurs by resonant scattering from the neutral hydrogen geocorona. From such measurements it should be possible to deduce the density variation and extent of the hydrogen atmosphere. Measurements of the distribution of radiation within 0.1 angstrom of resonance should give information regarding the hydrogen temperature. It may be possible to make some observation of Lyman-alpha from interplanetary neutral hydrogen.

F-13 ULTRAVIOLET PHOTOMETER, Dr. C. A. Barth, U. of Colo.

The objectives of this experiment are (1) to measure the intensities of hydrogen (1216 Å) and oxygen (1304 Å) in airglow, (2) to measure the densities of atomic hydrogen and atomic oxygen above orbit, (3) to measure the intensity of the ultraviolet electron-excited and ultraviolet proton-excited aurora, and (4) to measure the spatial distribution (in local time and latitude) and the temporal changes (with solar and geophysical activity) of objectives (1) through (3).

F-14 SHAPE LINE OF THE 6300-ANGSTROM AIRGLOW EMISSION, Prof. J. E. Blamont, U. of Paris

The objectives of this experiment are (1) to study the shape and width of the oxygen red line at 6300 angstroms emitted in the airglow, and (2) to study the evolution of the Doppler temperature obtained from this line width.

F-15 AURORAL PARTICLE, Dr. D. S. Evans, GSFC

The objective of this experiment is to measure, with high energy resolution, the spectrum of auroral particles over the energy range 0.7 to ~20 kev and to investigate, with high time and spatial resolution, the variations in the down flux of these particles. Exposure of systematic behavior in these parameters, either in themselves or against such factors as local time or latitude, should shed light on the processes that energize and precipitate these particles.

F-16 TRAPPED AND PRECIPITATING ELECTRONS, Dr. T. A. Farley, UCLA

The objectives of this experiment are (1) to discover the mechanism by which electrons are precipitated into the atmosphere at L values of 2 and greater, (2) to understand the relationship between particle precipitation and particle trapping in the outer radiation zone, (3) to relate the phenomenon of particle precipitation to the structure of the magnetosphere, particularly with the neutral point on the day side and the extended tail on the night side, and (4) to correlate particle precipitation with other time-varying phenomena, such as local magnetic and electric field variations, large-scale geomagnetic disturbances, and auroral displays.

F-17 TRAPPED AND PRECIPITATING ELECTRONS, Dr. D. J. Williams, GSFC

The experiment's objective is to measure the intensities of trapped and precipitated electrons in the $E_e \geq 30$ kev, ≥100 kev, ≥300 kev, and ≥1 Mev integral energy ranges. The intended OGO-F orbit is suitable for obtaining measurements in these ranges because it offers (1) a high sampling density during periods of observation

of the magnetic coordinates, (2) knowledge of which field line is being observed, and (3) a large loss cone and consequent ease of sampling precipitated electrons.

F-18 NEUTRON MONITOR, Dr. E. L. Chupp, U. of N. H.

The objective of this experiment is to monitor the integrated neutron flux over a large region of space and time. A relatively simple "standardized" space-neutron detector will be used. The detector will monitor the total neutron flux in the energy interval $1 < E10 < 10^7$ ev and the energy spectrum and flux in the range $1 < E < 10$ Mev (the fast neutron flux).

F-19 LOW-ENERGY SOLAR COSMIC RAY, Dr. A. J. Masley, McDonnell Douglas Corp.

The objective of this experiment is to perform an investigation of solar cosmic radiation and to relate the results to solar and ionospheric studies. The cosmic ray objectives include the following: (1) a measurement of changes in the energy and intensity distribution of solar particles, as a function of time, and (2) a determination of the geomagnetic cutoff, as a function of latitude, and (3) a study of the variation in the ratio of the intensities of alpha particles and protons.

F-20 COSMIC RAY STUDY, Dr. E. C. Stone, Cal. Tech.

The objective of this experiment is to study the following aspects of galactic and solar particle radiation: (1) the acceleration and injection of high-energy particles (protons, alphas, and electrons) by the sun, and their storage and propagation in interplanetary space, and (2) solar-induced changes in the earth's magnetosphere, deduced from modifications in geomagnetic cutoffs, and (3) the nature of the small fluxes of solar particles that produce polar cap absorption, and (4) the shapes of the galactic proton, alpha, and electron spectra and their variation under solar modulation.

F-21 MAGNETIC FIELD MEASUREMENTS, Dr. J. C. Cain, GSFC

The objective of this experiment is the understanding of the physical processes creating and altering the main geomagnetic field and the sources external to the earth's surface contributing to the ambient field in the F-layer. If possible, gross features of surface magnetic anomalies will be located and mapped for use by geologists. The external sources to be investigated include tidal oscillations of the ionosphere by the gravitational gradients of the sun and moon (lunisolar magnetic variations) and diurnal changes on quiet days (Sq). During periods of magnetic disturbance, the effect of trapped plasma and variations in the external pressure on the magnetosphere will be evaluated (Dst/DS). One of the main functions of the analysis will be to separate the magnetic variations seen at the earth's surface that arise from the ionosphere from those with sources in the trapping and boundary regions.

F-22 SEARCH COIL MAGNETOMETER, Dr. E. J. Smith, UCLA

The objective of this experiment is to investigate natural magnetic field variations within the ionosphere and lower magnetosphere in the frequency range of 0.01 to 1 kHz.

Signals originating within or above the ionosphere have been detected at the earth's surface throughout this frequency range. Several species of micropulsations are known to exist below 1 Hz, and hydromagnetic emissions between 1 and 5 Hz have been found to exhibit a complex frequency-time behavior. At higher frequencies and at high latitudes, auroral zone emissions (in bands below 500 Hz and from 500 to 1500 Hz) and extremely low frequency whistlers have been observed. Satellite measurements by Gurnett and O'Brien have produced evidence of relatively strong signals above the ionosphere with frequency components as low as the low frequency cutoff of 200 Hz. The presence of signals at 700 Hz was also indicated.

F-23 DC ELECTRIC FIELD MEASUREMENTS, Dr. T. L. Aggson, GSFC

The objective of this experiment is to measure dc electric field intensity in the magnetosphere. Aurora and high-latitude ionospheric electric currents, magnetic field-aligned irregularities, plasma waves, and the different forms of irregularities previously observed by rocket measurements will be of particular interest.

F-24 VLF NOISE AND PROPAGATION MEASUREMENT, Prof. R. A. Helliwell, Stanford U.

The primary objectives of this experiment are the measurement of the polarization, wave-normal direction, and the E/H ratio of signals in the frequency range 30 Hz to 30 kHz.

The secondary objectives include the measurement of antenna impedance and current with and without bias, the measurement of the phase and amplitude of VLF transmitter signals, the measurement of the integrated natural VLF noise, and the measurement of the observed ion-gyrofrequency whistlers. The latter measurements will be compared with the data observed by ion probes and with the magnetometer observations.

F-25 WHISTLER AND LOW FREQUENCY ELECTRIC FIELD STUDY, Prof. T. Laaspere, Dartmouth College

The main objective of this experiment is to study the electric field of waves (e.g., whistlers) over an extended range of frequencies (10 Hz to 540 kHz). Another objective is to measure the impedance of the experiment's electric dipole antenna at several frequencies (8, 24, 103, and 284 kHz).

F-26 SODIUM EXCITATION MEASUREMENTS, Dr. T. M. Donahue, U. of Pittsburgh

The objective of this experiment is to measure the variation of the absolute brightness of the sodium D lines and the atomic oxygen green line (5577 angstroms) during the day, twilight, and night airglows.

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