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PLASMA PHYSICS ABSTRACTS

1 JANUARY 1971 THROUGH 31 DECEMBER 1971

by

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This collection of abstracts represents those plasma physics publications from the Department of Physics at the University of Iowa which are considered relevant to NASA Grant NGL-16-001-043.

The last such collection was issued on December 31, 1970. The numbering scheme continues consecutively with that used in this earlier report.

A. THEORETICAL

36. Theory of the Unmagnetized Plasma
D. Montgomery
[Book; 400 pp.; published by Gordon & Breach Science Publishers; New York, London, Paris; Sept., 1971; Library of Congress Catalog Card Number: 75-141052 ISBN 0 677 03350 0 ; 0 677 03355 1.]

[No Abstract]

37. Comment on Negative Diffusion Coefficients in Quasi-linear Theory
D. Montgomery and S. Bodner
J. Plasma Phys., 5, 131 (1971).

A recent paper on quasilinear theory by Klozenberg and Bernstein is commented upon. It is argued that improper treatment of the perturbed electron distribution for damped waves has led to a diffusion-type equation with a negative diffusion coefficient.

38. Parametric Amplification of Alfvén Waves
G. Vahala and D. Montgomery
Physics of Fluids, 14, 1137 (1971).

A calculation describing the parametric amplification of Alfvén waves in a uniform, perfectly-conducting, magneto-hydrodynamic fluid is reported. The calculation has been motivated by a recent experiment of Lehane and Paoloni. A magnetically-supported uniform column of the magnetohydro-dynamic fluid is imagined to be subjected to an externally-imposed, sinusoidally-varying, magnetic field which can be idealized as spatially-uniform. It is shown that a certain class of Alfvén waves which have an axial wavelength long compared to the radius of the column can be parametrically amplified in the case where their frequency and the modulating frequency satisfy certain integer quotient relations. The mathematical behavior is determined by Mathieu equations.

39. Electric Conductivity of Weakly Turbulent Plasmas
Y. H. Ichikawa (visitor from Nihon University, Tokyo) and K. Nishikawa
Physics of Fluids, 13, 2541 (1970).

The static electric conductivity of weakly turbulent plasmas has been examined on the basis of a kinetic equation for the linear response to the one particle distribution function. Within the regime of neglecting the mode-coupling terms, the high frequency turbulent fluctuations associated with the electron plasma wave gives rise to a modification of the ordinary collisional conductivity through the adiabatic interaction between the particles and the turbulent fluctuations. On the other hand, the low frequency turbulent fluctuation due to the ion oscillation mode determines the relaxation process in the system through the resonant interaction, and gives rise to a finite conductivity even in the collisionless plasmas.

40. Effects of Bunched Ion Bursts on Apparent Nonlinear Ion Acoustic Waves
Y. H. Ichikawa (visitor from Nihon University, Tokyo)
Physics of Fluids, 14, 569 (1971).

The bunching effects of ions at the excitation grid in a typical ion acoustic wave experiment are examined by applying the generalized quasi-linear theory of Al'tshul and Karpman to a simple model of the grid-plasma system.

The resulting bunched ion bursts exhibit amplitude modulation at a distance far from the grid. The characteristics of this amplitude modulation are in complete agreement with the recently observed results of Sato et al. who interpreted their results in terms of nonlinear Landau damping of ion acoustic waves.

41. Kinetic Theory of a Two Dimensional Magnetized Plasma
G. Vahala and D. Montgomery
J. Plasma Phys., 6, 425 (1971).

Several features of the equilibrium and non-equilibrium statistical mechanics of a two-dimensional plasma in a uniform d.c. magnetic field are investigated. The calculations have been motivated by the recent derivation of Bohm's diffusion coefficient given by Taylor & McNamara for this system. The charges interact only through electrostatic (logarithmic) potentials. The problem is considered both with and without the guiding-centre approximation. With the guiding centre approximation, an appropriate Liouville equation and BBGKY hierarchy predict no approach to thermal equilibrium for the spatially uniform case. For the spatially non-uniform situation,

a guiding-centre 'Vlasov' equation is discussed, and is solved in special cases. The most interesting features of thermal equilibrium theory (with and without the guiding-centre approximation) are (i) a collapse of the system above a critical value of the plasma parameter, and (ii) a divergence in the electric field fluctuation spectrum (minus the self-energy terms) for small plasma parameter and very large systems. For the non-equilibrium, non-guiding-centre case, a Boltzmann equation and a Fokker-Planck equation are derived in the appropriate limits. The latter is more tractable than the former, and can be shown to obey conservation laws and an H-theorem, but contains a divergent integral, which must be cut off on physical grounds. Several unsolved problems are posed.

42. Brownian Motion from Boltzmann's Equation
D. Montgomery
Physics of Fluids, 14, 2088 (1971).

Two apparently disparate lines of inquiry in kinetic theory are shown to be equivalent: (1) Brownian motion as treated by the (stochastic) Langevin equation and Fokker-Planck equation; and (2) Boltzmann's equation. The method is to derive the kinetic equation for Brownian motion from the Boltzmann equation for a two-component neutral gas by a simultaneous expansion in the density and mass ratios.

43. Kubo Conductivity of a Strongly Magnetized Two-Dimensional Plasma
D. Montgomery and F. Tappert (Bell Labs.)
Physical Review Letters, 27, 1419 (1971).

The Kubo formula is used to evaluate the bulk electrical conductivity of a two dimensional guiding-center plasma in a strong dc magnetic field. The particles interact only electrostatically. An "anomalous" electrical conductivity is derived for this system which parallels a recent result of Taylor and McNamara for the coefficient of spatial diffusion.

44. Conductivity of a Two-Dimensional Guiding Center Plasma
D. Montgomery and F. Tappert (Bell Labs.)
[Univ. of Iowa Report 71-42; Submitted to Physics of Fluids.]

The Kubo method is used to calculate the electrical conductivity of a two-dimensional strongly-magnetized plasma. The particles interact through (logarithmic) electrostatic potentials and move with their guiding center drift velocities

(Taylor-McNamara model). The thermal equilibrium d.c. conductivity can be evaluated analytically, but the a.c. conductivity involves numerical solution of a differential equation. Both conductivities fall off as the inverse first power of the magnetic field strength.

45. Three-Dimensional Plasma Diffusion in a Very Strong Magnetic Field
D. Montgomery, C.-S. Liu (Institute for Advanced Study), and G. Vahala
[Univ. of Iowa Report 71-43; submitted to Physics of Fluids].

The thermal equilibrium coefficient of spatial diffusion transverse to a strong uniform dc magnetic field is calculated for a fully ionized plasma. The particles are assumed to move transverse to the field only as a consequence of the $\vec{E} \times \vec{B}$ drift, but to move freely parallel to it. The particles interact only electrostatically. The calculation is done at large, but fixed and finite, plasma volume. It is shown that, as $B \to \infty$, the leading term of the coefficient of transverse spatial diffusion falls off as $O(1/B)$, but contains a multiplicative factor which goes to zero as the plasma volume becomes infinite. The method of calculation fails for unbounded plasmas.

B. IONOSPHERIC ABSTRACTS

21. Conjugate Photoelectron Impact Ionization
S. D. Shawhan, L. P. Block, and C.-G. Falthammar
J. Atmos. Terr. Phys., 32, 1885-1900 (1970).

The exchange of photoelectrons between inospheres in a matter of minutes rather than at the slow ambipolar speed is discussed. It is shown that the electron density may be affected by secondary processes resulting from the conjugate photoelectron flux but not by the flux itself.

The flux spectrum of conjugate photoelectrons throughout the day at the solstices for minimum solar activity is calculated for 55° N. geographic latitutde over Europe, using a method previously employed by NISBET. Summer escaping flux values range up to 9×10^{12} electrons m^{-2} sec^{-1} and winter values to 5×10^{12} electrons m^{-2} sec^{-1}. Compared at specific solar zenith angles the computed values are in good agreement with recent satellite measurements. Approximately half of this flux is lost by Coulomb collisions along the field line path. The resulting flux arriving at the local ionosphere produces ionization by inelastic collisions in the atmosphere. This additional ionization is about 3% of the

ionization from local processes at summer noon and 48% at winter noon. During winter nighttime this conjugate photoelectron ionization can be significant for several hours.

Although small in magnitude, this additional ionization should systematically modify the summer total electron content depending on geographic location. The large seasonal differences in the relative impact ionization may explain in part the F-layer seasonal anomaly. This source may be important for maintaining and causing enhancements in the winter nighttime ionosphere.

22. An Experimental Study of VLF Mode Coupling and Polarization Reversal
P. Rodriguez and D. A. Gurnett
J. Geophys. Res., 76, 960-971 (1971).

Below the proton gyrofrequency, both polarization reversal and mode coupling of the right and left hand modes of propagation can occur. In this paper an experimental study of polarization reversal and mode coupling of electron and proton whistlers is presented. The occurrence of polarization reversal for a whistler signal observed in the ionosphere is indicated by the presence of a proton whistler. Mode coupling between the right and left hand modes of propagation is indication by the occurrence of both electron and proton whistler signals at the same frequency.

Mode coupling is observed to occur most frequently over a range of about 35°-55° magnetic latitude. Below about 35° magnetic latitude, polarization reversal is the predominant effect, whereas above about 55° magnetic latitude neither mode coupling nore polarization reversal occur and proton whistlers are not observed. These results are compared with existing theories to explain this latitude dependence.

23. Theory of the Injun 5 VLF Poynting Flux Measurements
S. R. Mosier and D. A. Gurnett
J. Geophys. Res., 76, 972-977 (1971).

This paper presents the theory of the VLF Poynting flux measurement technique used on the Injun 5 satellite. This technique consists of using one electric antenna and one magnetic antenna, both oriented perpendicular to the geomagnetic field and to each other, to determine the direction of the VLF Poynting flux up or down the geomagnetic field. The conditions for which the Poynting flux direction determinations are valid are considered, including the effects of errors in the magnetic orientation of the spacecraft and the simultaneous presence of many waves.

24. Poynting Flux Studies of Hiss with the Injun 5 Satellite
S. R. Mosier
J. Geophys. Res., 76, 1713-1728 (1971).

A study of very-low-frequency hiss emissions in the region 677 to 2528 km and 35° to 75° invariant latitude (in the northern hemisphere) using the Injun 5 Poynting flux measurement technique is presented. Downgoing ELF hiss is observed over the entire region of altitude-invariant latitude space under study, whereas ELF hiss having an upward-directed net Poynting flux is only observed at invariant latitudes below about 60°. A new propagation phenomenon is proposed in which downgoing ELF hiss may propagate across the plasmapause boundary to lower latitudes and become subsequently reflected and trapped within the plasmasphere. Measurements indicate that at least part of the VLF hiss which is observed by the Injun 5 satellite must be generated above the Injun 5 altitude range. A new type of sub-auroral-zone VLF hiss has been observed called mid-latitude hiss.

25. Color Spectrograms of VLF Poynting Flux Data
D. A. Gurnett, S. R. Mosier, and R. R. Anderson
J. Geophys. Res., 76, 3022-3033 (1971).

This paper discusses a new method of processing the VLF electric and magnetic field data from the Injun 5 satellite to produce color frequency-time spectrograms with the color indicating the Poynting flux direction, up or down the geomagnetic field. The Poynting flux sensing technique used on Injun 5 employs one electric antenna and one magnetic antenna both oriented perpendicular to the geomagnetic field and to each other. With this antenna geometry the Poynting flux direction, up or down the geomagnetic field, can be determined from the cross-correlation between the electric and magnetic field signals. The technique used to process these signals employs a new type of spectrum analyzer/cross-correlator to determine the cross-correlation between the electric and magnetic field signals as a function of frequency and time. These data can be displayed as a two color frequency-time spectrogram using appropriate display techniques. A survey of complex VLF radio noise phenomena analyzed using this technique is presented.

26. Whistlers with Harmonic Bands Caused by Multiple Stroke Lightning
R. R. Shaw and D. A. Gurnett
J. Geophys. Res., 76, 1851-1854 (1971).

Whistlers received with the Injun 5 satellite are frequently observed to have bands with decreased signal

amplitude at equally spaced frequency intervals. The frequency spacing between the bands is typically about 10 to 30 Hz. As many as 30 such bands have been observed on a single whistler.

Because the frequency spacing of these bands is comparable to the gyrofrequency of several types of positive ions found in the ionosphere (particularly O^+ or N^+) it was initially thought that these bands may be produced by a hot plasma effect resulting from wave-particle interactions at harmonics of the ion gyrofrequency. Subsequent investigations have shown that the bands are instead due to double or multiple strokes in the initial lightning discharge which result in destructive interference of the whistler signals at equally spaced frequency intervals. The frequency spacing between the interference bands is given by the inverse of the time interval between the lightning strokes. This simple explanation for these bands accounts for a number of peculiar characteristics which could not be accounted for with the gyrofrequency harmonic interaction hypothesis.

27. Double-Probe Measurements of Convection Electric Fields with the Injun 5 Satellite
D. P. Cauffman and D. A. Gurnett
J. Geophys. Res., 76, 6014-6027 (1971).

This paper reports on the operation and results of the double-probe DC electric field experiment on the low altitude polar orbiting Injun 5 satellite. At middle and low latitudes, where the convection electric field is generally very small, the operation of the double-probe electric field antenna is investigated by comparing measured electric fields with the $\vec{V}_s x \vec{B}$ electric field generated by the satellite motion through the ionosphere. Errors caused by sunlight shadows on the probes, wake effects, and antenna impedance variations are discussed.

At high latitudes convection electric fields greater than 30 mV/meter, and sometimes greater than 100 mV/meter, are frequently observed in the auroral zone. A common feature of these high latitude convection fields is the occurrence of abrupt reversals in the east-west convection velocity at auroral zone latitudes. For dusk-dawn local times, these reversals generally correspond to an east-west flow away from the sun on the high latitude side of the reversal and toward the sun on the low latitude side. Over the polar region above the auroral zone the convection velocity is usually small. At the plasmapause/light ion trough boundary small 10 to 20 mV/meter, electric field perturbations are sometimes observed, corresponding to generally westward convection outside the plasmasphere.

At high altitudes, above about 1500 km, over the auroral zone/polar cap regions irregular electric field "noise" with amplitudes from 10 to 30 mV/meter is consistently observed. Possible explanations of the high altitude electric field noise are discussed.

Results are consistent with measurements using the barium cloud drift technique. Convection observed is also compared with models of magnetospheric structure and with models of substorms and aurorae.

28. Distributions of Plasmas and Electric Fields over the Auroral Zones and Polar Caps
L. A. Frank and D. A. Gurnett
J. Geophys. Res., 76, 6829-6846 (1971).

Simultaneous observations of DC electric fields and low-energy charged particles at low altitudes over the earth's auroral zones and polar caps were obtained with the satellite Injun 5. Several of the principal results for several passes of the satellite through the evening and dawn local time sectors are summarized as follows.

1. The most prominent features of the convection electric fields are reversals located at high magnetic latitudes in the dawn and evening sectors.
2. The east-west convection velocity is usually anti-sunward at latitudes above the reversal boundary and sunward at latitudes below the reversal boundary.
3. The convection electric field reversals in the dawn and evening sectors are coincident with the 'trapping boundary' for energetic electrons $E>45$ keV. This trapping boundary is observationally identified with the high-latitude termination of measurable electron intensities as viewed with a detector with generous geometry factor. This trapping boundary is not synonymous with the high-latitude limit of durable trapping, i.e., an electron with these energies is not necessarily able to execute a complete longitudinal drift motion.
4. Over the polar caps the convection velocities are small, or below the instrumental threshold of typically $\sim$0.75 kilometers $(\text{sec})^{-1}$, relative to the convection velocities in the vicinity of the reversals.
5. The polar cap region is characterized by an absence of measurable low-energy proton and electron intensities.
6. Inverted 'V' precipitation events, which are characterized by increasing average electron energies to a peak energy and a subsequent decrease in

energy as the satellite passes through this intense precipitation event, are located near or at the convection field reversals (and hence also the trapping boundaries) or within regions of measurable convection electric fields poleward of the trapping boundary.

7. Field-aligned electron angular distributions occur at and above the trapping boundary and within the inverted 'V' precipitation events.
8. Diffuse precipitation zones of electrons and proton intensities with spectrums similar to those observed in the near-earth plasma sheet are located at latitudes below the trapping boundary and within the region of sunward convection velocities. The ratios of intensities at pitch angles $\alpha=0°$ to those measured at $\alpha=90°$ (Northern hemisphere) are usually $\lesssim 1$.
9. During a magnetic substorm the overall configuration of the convection velocities and plasma regions remained similar to those observed during quiescent periods except that convection velocities and particle intensities increased and the locations of these phenomena in magnetic latitude varied.

These observations are interpreted in terms of a magnetospheric model as deduced from plasma observations in the distant magnetosphere and in terms of essential elements for any credible theory of auroral arcs, in particular those associated with inverted 'V' precipitation bands.

29. VLF Hiss and Related Plasma Observations in the Polar Magnetosphere
D. A. Gurnett and L. A. Frank
[Univ. of Iowa Report 71-19; accepted for publication in J. Geophys. Res.].

This paper presents a study of auroral zone VLF hiss and low-energy charged particle observations with the Injun 5 satellite. The results of this study provide a direct verification of the association between auroral zone VLF hiss and intense fluxes, 10^4 to 10^7 electrons $(cm^2\text{-sec-sr-eV})^{-1}$, of low-energy electrons with energies on the order of 100 eV to several keV. On the dayside of the magnetosphere, these low-energy electrons are identified with the dayside polar cusp region observed at higher latitudes with the IMP-5 satellite. At other local times, through the dawn and dusk regions and into the nightside of the magnetosphere, the VLF hiss and low-energy electron precipitation regions are believed to correspond to the extension of the dayside polar

cusp into the distant plasma sheet and downstream magnetosheath on the nightside of the magnetosphere. Intense fluxes of upgoing electrons are often observed in a narrow latitudinal band near the low-energy electron precipitation bands. These upgoing electrons are believed to be associated with another type of VLF emission called a saucer, which is frequently observed with Injun 5.

On the basis of present models, the observed VLF hiss intensities cannot be accounted for by incoherent Cerenkov radiation from the observed electron fluxes, indicating that a coherent plasma instability mechanism is involved in some, if not all, of the VLF hiss generation. A model for the generation regions of VLF hiss and saucer emissions is discussed.

30. Observed Correlations Between Auroral and VLF Emissions
S. R. Mosier and D. A. Gurnett
[Univ. of Iowa Report 71-21; accepted for publication in J. Geophys. Res.].

This paper presents a series of simultaneous observations of very-low-frequency radio noise by the Injun 5 satellite and of visual aurora along the same geomagnetic field line by the Fort Churchill Auroral Observatory. Seven cases from the period of August 29, 1968, to March 4, 1969, are discussed. In five of the seven cases studied VLF hiss is observed in association with auroral light emissions. These cases typically show the occurrence of VLF hiss in the general region of the auroral arc, with significant changes in the VLF frequency spectrum sometimes observed in the immediate vicinity of the auroral arc. One event for which the associated charged particle fluxes have been analyzed is investigated in detail. The VLF radio noise intensity for this event is among the largest observed with Injun 5 and is much greater than can presently be explained by an incoherent Cerenkov radiation mechanism.

31. ELF Noise Bands Associated with Auroral Arcs
D. A. Gurnett and L. A. Frank
[Univ. of Iowa Report 71-28; submitted to J. Geophys. Res.].

This paper reports on observations of a new type of ELF noise band which is closely associated with low-energy electron precipitation events and auroral arcs. These observations have been made at relatively low altitudes (<3000 km) with the polar orbiting satellite Injun 5. These noise bands typically have a center frequency of from 100 to 300 Hz and often appear to consist of many nearly monochromatic bursts, typically of a few seconds duration, superimposed to

give the observed spectrum of the emission. These ELF noise bands are only observed in a relatively narrow (few degree) latitudinal region in the auroral zone. The local time distribution of these ELF noise bands has not been investigated in detail, however ELF noise bands of this type have been observed throughout the local time range from 12:00 to 22:00.

In considering the possible explanations of these ELF noise bands, it is noted that the spectral characteristics of this noise are very similar to a type of narrow-band magnetic noise called 'lion's roar' which has been observed at much higher altitudes in the magnetosheath with the satellite OGO-5. It is suggested that the ELF noise bands observed at low altitudes with Injun 5 are produced by lion's roar emissions which have propagated down 'open' magnetic field lines from the magnetosheath region to the Injun 5 altitude.

32. Satellite Measurements of Magnetospheric Convection
D. P. Cauffman and D. A. Gurnett
[Submitted to Space Science Reviews, 1971].

This paper reports on the results of the first satellite experiments to measure magnetospheric convection electric fields using the double-probe technique. The earliest measurements were made with the low altitude (680-2530 km) polar orbiting Injun 5 spacecraft (launched August, 1968). The Injun 5 data are discussed in detail. The results are compared with the preliminary findings of the DC electric field experiment on the polar orbiting OGO-6 satellite (400-1100 km, launched June, 1969).

In addition to DC electric fields, the Injun 5 spacecraft also measures electric antenna impedance and thermal and energetic charged particle densities. Knowledge of these parameters makes possible a detailed investigation of the operation of the electric antenna system. We report on this investigation and discuss errors attributed to sunlight shadows on the probes, wake effects, and other factors. Under favorable conditions the Injun 5 experiment can measure DC electric field magnitudes as small as $\pm$10 mV/meter.

Reversals in the DC electric field at auroral zone latitudes are the most significant convection electric field effect identified in the Injun 5 data. Electric field magnitudes of typically 30 mV/meter, and sometimes 100 mV/meter, are associated with reversals. Electric field reversals occur on $\sim$36% of auroral zone traversals, at about 70° to 80° invariant latitude, at all local times, and in both hemispheres. The latitude of a reversal often changes markedly on time scales less than 2 hours. Electric potentials of greater than 40 keV are associated with these high latitude electric fields. Reversals occur at the boundary of measurable intensities of >45 keV electrons and are coincident with inverted 'V' type low energy electron precipitation events. In almost all cases

the $\vec{E} \times \vec{B}/B^2$ plasma convection velocities associated with reversals are directed east or west, with anti-sunward components at higher latitudes and sunward components at lower latitudes. Maximum convection velocities are typically ∿1.5 km/sec and ordinarily occur at the auroral zone near the reversal. Two extreme (and many intermediate) configurations of anti-sunward plasma convection have been observed to occur on the high latitude side of electric field reversals: (1) Ordinarily, >0.75 km/sec convection is limited to narrow (∿5° INV wide) zones adjacent to the reversal. (2) For ∿14% of reversals >0.75 km/sec anti-sunward convection has been observed across the entire polar cap along the trajectory of the Injun 5 spacecraft. A summary pattern of >0.75 km/sec polar thermal plasma convection is presented.

The implications of the DC electric field measurements for magnetospheric and auroral structure are summarized, and a list of specific recommendations for improving future experiments is presented.

33. Injun 5 Observations of Magnetospheric Electric Fields and Plasma Convection
D. A. Gurnett
[Earth's Particles and Fields, paper presented at the Summer Advanced Study Institute, Cortina, Italy, September 1971, accepted for publication].

Recent measurements of magnetospheric electric fields with the satellite Injun 5 have provided a comprehensive global survey of plasma convection at low altitudes in the magnetosphere. A persistent feature of these electric field observations is the occurrence of an abrupt reversal in the convection electric field at auroral zone latitudes. The plasma convection velocities associated with these reversals are generally directed east-west, away from the sun on the poleward side of the reversal, and toward the sun on the equatorward side of the reversal. Convection velocities over the polar cap region are normally less than those observed near the reversal region. The electric field reversal is observed to be coincident with the 'trapping boundary' for electrons with energies E>45 keV. Near local noon the region of anti-sunward convection poleward of the electric field reversal/trapping boundary corresponds to the low-altitude extension of the polar cusp plasma. Intense 'inverted V' electron precipitation events associated with auroral arcs are also observed near and poleward of the electric field reversal/trapping boundary. These observations are discussed in terms of a current model of magnetospheric convection.