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PLASMA PHYSICS ABSTRACTS

1 JANUARY 1972 THROUGH 31 DECEMBER 1972

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, 1971. The numbering scheme continues consecutively with that used in this earlier report.

A. THEORETICAL

44. Conductivity of a Two-Dimensional Guiding Center Plasma
D. Montgomery and F. Tappert (Bell Labs.)
Physics of Fluids, 15, 683 (1972).

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
Physics of Fluids, 15, 815 (1972).

The thermal equilibrium coefficient of spatial diffusion transverse to a strong uniform d. c. 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.

46. Two-Dimensional Vortex Motion and "Negative Temperatures"
D. Montgomery
Physics Letters, 39A, 1 (1972).

A recent numerical integration of the two-dimensional Navier-Stokes equations has tentatively identified an "ergodic boundary" in the space of initial conditions for the turbulent flow. An explanation is suggested in terms of negative temperatures, for a point vortex model.

47. Simulation of the "Negative Temperature" Instability for Line Vortices
G. Joyce and D. Montgomery
Physics Letters, 39A, 371 (1972).

Numerical simulation of the Onsager "negative temperature" instability for a large number of discrete line vortices is reported.

48. Multiple Soliton Production and the Korteweg-deVries Equation
N. Hershkowitz, T. Romesser, and D. Montgomery
Phys. Rev. Letters, 29, 1586 (1972).

Compressive square-wave pulses are launched in a double-plasma device. Their evolution is interpreted according to the Korteweg-de Vries description of Washimi and Taniuti. Square-wave pulses are an excitation for which an explicit solution of the Schrodinger equation permits an analytical prediction of the number and amplitude of emergent solitons. Bursts of energetic particles (pseudowaves) appear above excitation voltages greater than an electron thermal energy, and may be mistaken for solitons.

49. STRONGLY MAGNETIZED CLASSICAL PLASMA MODELS
D. Montgomery
U. of Iowa Report 72-17; to be published by Gordon and Breach.
[Material presented at the Les Houches Summer School of Theoretical Physics, France, July, 1972. 153 pp. No abstract.]

50. Negative Temperature States for the Two-Dimensional Guiding-Center Plasma
G. Joyce and D. Montgomery
U. of Iowa Report 72-28; submitted to Journal of Plasma Physics.

Theoretical development and numerical simulation are presented for the two-dimensional electrostatic guiding-center plasma with positive total interaction energy. This is a system for which equilibrium statistical mechanics predicts that no spatially homogeneous thermal equilibrium state will exist. The non-existence of the homogeneous thermal equilibrium state is associated with the phenomenon of "negative temperatures". Quasi-stable spatially inhomogeneous states are shown to form, and are characterized by macroscopic spatially-separated vortex structures.

B. IONOSPHERIC ABSTRACTS

29. VLF Hiss and Related Plasma Observations in the Polar Magnetosphere
D. A. Gurnett and L. A. Frank
J. Geophys. Res., 77, 172, 1972.

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
J. Geophys. Res., 77, 1137, 1972.

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
J. Geophys. Res., 19, 3411, 1972.

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 High Latitude Convection Electric Fields
D. P. Cauffman and D. A. Gurnett
Space Science Reviews, 11, 111, 1972.

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 ±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 $\sim$ 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 ($\sim$ 5° INV wide) zones adjacent to the reversal. (2) For $\sim$ 15% of reversals > 0.75 km/sec anti-sunward convection has been observed across the entire polar cap along the trajectory of the Injun 5 spacecract. 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, B. M. McCormac, ed., Reinhold Book Company (Dordrecht, Holland), 1972.

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.

34. Sheath Effects and Related Charged Particle Acceleration by Jupiter's Satellite Io
D. A. Gurnett
Astophys. J., 175, 525, 1972.

Several current theories on the Jovian decametric radio emission, and its modulation by the satellite Io, assume that the plasma within the magnetic flux tube passing through Io is 'frozen' to the motion of Io. This paper considers the effects of the plasma sheath around Io on the interaction of Io with the Jovian magnetosphere. It is found that under some conditions the plasma sheath around Io can effectively insulate the magnetospheric plasma from the motional electric field generated within Io, thus preventing the plasma from being forzen to the motion of Io. Under these conditions large potentials are developed across the plasma sheath and emitted photo-electrons can be accelerated to high energies. The sheath voltages which develop are controlled by the ionospheric conductivity at the base of the Io flux tube, as well as other plasma parameters at Io. A simplified model illustrating these basic effects is discussed.

35. Direct Observations of Low-Energy Solar Electrons Associated with a Type III Solar Radio Burst
L. A. Frank and D. A. Gurnett
Solar Physics (accepted for publication), 1973.

A highly anisotropic packet of solar electron intensities was observed on 6 April 1971 with a sensitive electrostatic analyzer array on the earth-orbiting satellite IMP-6. The anisotropies of intensities at electron energies of several keV were factors $\geqslant 10$ favoring the expected direction of the interplanetary magnetic lines of force from the sun. The directional, differential intensities of solar electrons were determined over the energy range 1 to 40 keV and peak intensities were 10^2 $(cm^2\text{-sec-sr-eV})^{-1}$ at 1 to 3 keV. This anisotropic packet of solar electrons was detected at the satellite for a period of 4200 seconds and was soon followed by isotropic intensities for a relatively prolonged period. This impulsive emission was associated with the onsets of an optical flare, soft x-ray emission and a radio noise storm at centimeter wavelengths on the western limb of the sun. Simultaneous measurements of a Type III radio noise burst at kilometric wavelengths with a plasma wave instrument on the same satellite showed that the onsets for detectable noise levels ranged from 500 seconds at 178 kHz to 2700 seconds at 31.1 kHz. The corresponding drift rate requires a speed of $\sim 0.1c$ for the exciting particles if the emission is at the electron plasma frequency. The corresponding electron energy of ~ 3 keV is in excellent agreement with the above direct observations of the anisotropic electron packet. Further supporting evidence that several-keV solar electrons in the anisotropic packet are associated with the emission of Type III radio noise beyond ~ 30 solar radii is provided by their time-of-arrival at earth and the relative durations of the radio noise and the solar electron packet. Electron intensities at

$E \geqslant 45$ keV and the isotropic intensities of lower-energy solar electrons are relatively uncorrelated with the measurements of Type III radio noise at these low frequencies. The implications of these observations relative to those at higher frequencies, and heliocentric radial distances $\leqslant 30$ solar radii, include apparent deceleration of the exciting electron beam with increasing heliocentric radio distance.

36. Observed Relationships Between Electric Fields and Auroral Particle Precipitation
D. A. Gurnett and L. A. Frank
J. Geophys. Res. (accepted for publication), 1973.

Simultaneous electric field and plasma observations with the low-altitude, polar orbiting satellite Injun 5 have provided a comprehensive survey of convection electric fields and their association with magnetospheric plasma phenomena. The most prominent features of the convection electric fields are reversals located at high magnetic latitudes, with generally anti-sunward convection poleward and sunward convection equatorward of the electric field reversal location. The electric field reversal is interpreted as the boundary between open and closed magnetic field lines.

During local day the electric field reversal is observed to coincide with the equatorward boundary of the polar cusp. The plasma flow in the dayside polar cusp region is dominantly east-west, away from the stagnation point, with the convection velocities typically ~ 1 km $(\text{sec})^{-1}$. At local evening "inverted V" electron precipitation bands are observed near or at the position of the electric field reversal. In the local late-evening sector the electric field reversal becomes less distinct and often no single, well-defined electric field reversal can be identified. In all cases the "inverted V" electron precipitation events are closely associated with large, typically > 30 mV $(\text{m})^{-1}$, irregular electric field fluctuations with time scales of a few seconds or less. Often these fluctuations comprise distinct "spikes" of a few seconds duration or less, which can be identified with distinct boundaries or other features of the electron precipitation. In the local midnight sector convection electric fields > 50 mV $(\text{m})^{-1}$ associated with plasma-sheet electrons have been observed extending deep into the magnetosphere, equatorward of the electron ($E > 45$ keV) trapping boundary. These convection electric fields are characterized by considerably smaller fluctuations relative to those observed within the "inverted V" electron precipitation bands.

To investigate the electric field and plasma interrelationships during a polar magnetic substorm, a series of passes obtained prior to and during a substorm is presented. Large, anti-sunward convection velocities were detected over the polar cap several tens of minutes before the onset of the expansive phase of the substorm. These convection velocities gradually decreased during the decay phase of the substorm. Our measurements of enhanced anti-sunward flow over the polar cap region are generally consistent with several current ideas concerning the origin of substorms.

37. Electric Field and Plasma Observations in the Magnetosphere
D. A. Gurnett
Critical Problems of Magnetospheric Physics, Proceedings of the Joint COSPAR/IAGA/URSI Symposium, Madrid, Spain, 11-13 May 1972.

Satellite-borne electric field measurements using the double probe technique have now provided a comprehensive survey of convection electric fields at low altitudes in the magnetosphere. The most prominent features of the convection electric fields are reversals located at high magnetic latitudes, with generally anti-sunward convection poleward and sunward convection equatorward of the electric field reversal location. The electric field reversal is usually coincident with the "trapping boundary" for electrons with energies $E > 45$ keV and is interpreted as the boundary between open and closed magnetic field lines. On the day side of the magnetosphere the electric field reversal is observed to coincide with the equatorward boundary of the polar cusp. In the local afternoon and evening regions "inverted V" electron precipitation bands occur at or near the electric field reversal and in regions usually characterized by large fluctuations in the electric field. In the local midnight region strong convection electric fields have also been observed deep within the magnetosphere, near the equatorward boundary of the plasma sheet. Recent measurements of electric fields near the "inverted V" electron precipitation bands suggests that these events are associated with large electrostatic potential gradients along the geomagnetic field.

38. Plasma Wave Observations Near the Plasmapause with the S^3-A Satellite
R. R. Anderson and D. A. Gurnett
J. Geophys. Res. (accepted for publication), 1973.

In this paper we describe the electric field noise phenomena observed by the S^3-A spacecraft near the plasmapause during the magnetic storm of December 16-17, 1971. The most striking and unusual feature of these storm time electric field observations is the occurrence of a region of intense low-frequency (20 Hz to 500 Hz) electrostatic noise bursts just outside the plasmapause boundary. These noise bursts occurred concurrent with the rapid decrease in $24.3 \leq E \leq 35.1$ keV ring current protons mirroring near the equator during this storm and may be responsible for the pitch angle diffusion and loss of these particles. The characteristics of other phenomena, such as whistlers, ELF hiss, and banded chorus, observed near the plasmapause during this period are also discussed.

39. Magnetospheric Electron Density Measurements from Upper Hybrid Resonance Noise Observed by IMP-6
R. R. Shaw and D. A. Gurnett
J. Geophys. Res. (submitted for publication), 1973.

A band of naturally occurring radio noise between the local electron plasma frequency and the upper hybrid resonance frequency is frequently observed by the University of Iowa plasma wave experiment on the IMP-6 satellite. This radio noise band has been observed over a large range of geocentric radial distances extending from well inside the plasmapause boundary to greater than 10 earth radii in the outer magnetosphere. The center frequency of the noise band decreases systematically with increasing radial distance and changes abruptly at the plasmapause boundary, typically from about 100 kHz just inside the plasmapause to about 10 to 30 kHz outside of the plasmapause. The broadband electric field strength of this noise is very small, seldom exceeding 10 microvolts $(\text{meter})^{-1}$, and probably could not be detected without using long electric antennas of the type used on IMP-6.

Because of the association of this noise band with the upper hybrid resonance frequency and the similarity to previous observations at much lower altitudes in the ionosphere we have called this noise "upper hybrid resonance noise" to be consistent with previous terminology. It is believed that this noise is produced by incoherent Cerenkov emission from super-thermal electrons. Since the cutoff frequencies of the upper hybrid resonance noise band can be measured very accurately and since the characteristic frequencies of the ambient plasma are expected to be almost completely unaffected by the presence of the satellite it is possible to obtain very accurate (few percent) and reliable electron density measurements from the cutoff frequencies of this noise. Electron densities as low as $0.1\ \text{cm}^{-3}$ have been measured in the region outside of the plasmapause with this technique.

In some cases a second very narrow noise band has been observed at a frequency slightly above the second harmonic of the electron gyrofrequency. This noise band is thought to be associated with the electrostatic Bernstein mode which occurs at frequencies near the second harmonic of the electron gyrofrequency.