PLASMA PHYSICS ABSTRACTS

1 JANUARY 1969 THROUGH 31 DECEMBER 1969

by

David C. Montgomery

Donald A. Gurnett

Department of Physics and Astronomy

THE UNIVERSITY OF IOWA

Iowa City, Iowa

PLASMA PHYSICS ABSTRACTS

1 JANUARY 1969 THROUGH 31 DECEMBER 1969

by

David C. Montgomery

Donald A. Gurnett

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

A similar collection of abstracts was issued on December 31, 1968. The numbering scheme continues consecutively with that used in this earlier report.

A. THEORETICAL

21. Shock-like Solutions of the Electrostatic Vlasov Equation
David Montgomery and Glenn Joyce
Journal of Plasma Physics 3, 1 (1969)

It is shown how to construct shock-like time independent solutions of the electrostatic Vlasov and Poisson Equations in one dimension. The positive ions are assumed to be at zero temperature. The electrostatic potential is assumed to increase monotonically through the shock from zero to a constant value. The most important feature of the solution is a population of trapped electrons in the shocked plasma. In contrast to time-independent solutions based upon fluid equations, there is no upper limit on the amplitude of the shock.

22. Nonlinear Vlasov Plasmas: Initial Value Problem and Response to an External Field
David Montgomery
[Published in Proceedings of Summer School on "Statistical Physics of Charged Particle Systems," Kyoto, Japan, Sept. 2-6, 1968; by Benjamin (U. S.) and Syokabo (Japan).]

Numberical solutions of collisionless plasma problems due to Armstrong and Harding are reviewed. Phenomena considered are: (1) nonlinear Landau damping; (2) development of the two-stream instability; (3) response of a Vlasov plasma to a rapidly varying electric field; (4) response of a Vlasov plasma to a low-frequency electric field; (5) damping of perturbations on non-uniform equilibria; and (6) formation of a shielding cloud around test charges. In most cases it is concluded that physical interpretations by means of elementary arguments involving particle "trapping" are adequate (more precisely, involving the interaction of particles with field components which appear to them to be nearly time independent). Several additional problems which should be susceptible to the same techniques are suggested.

23. Numerical Studies of Nonlinear Ion Acoustic Waves
T. P. Armstrong (University of Kansas) and D. Montgomery
[Published by U. S. A. E. C. in: Proceedings of A. P. S. Topical Conference on Numerical Simulation

of Plasma, Los Alamos, New Mexico, Sept. 13-20 (1968), Report LA-3900.]

The nonlinear Vlasov equation for ions coupled with a fluid model for the neutralizing electrons has been integrated numerically. Collisionless damping of ion acoustic waves has been observed in the model. The characteristics of the damping of large amplitude waves are qualitatively similar to experimental observations as well as to prior numerical calculations on the damping of electron plasma oscillations. Namely, the initial damping is more severe than that expected from linearized theory and the long time regime has smaller than the linear damping rate.

24. Numerical Study of Charged Particle Heating by Plasma Turbulence
S. Peter Gary and David Montgomery
[Published by U. S. A. E. C. in: Proceedings of A. P. S. Topical Conference on Numerical Simulation of Plasma, Los Alamos, New Mexico, Sept. 18-20 (1968), Report LA-3990.]

We report numerical calculations of the heating of charged particles by turbulent electric fields. The fields are given, and are not required to be self-consistently supported by the particles. Three types of wave spectra are treated, each of which is analytically unmanageable: (1) many waves, constant phases and velocities; (2) one wave, randomly interrupted phase; (3) one wave, slowly varying wave number at constant frequency. Large particle energization is found in the last two cases. In all three cases, the results can be qualitatively understood by elementary arguments related to particle "trapping."

25. Particle Acceleration by Electrostatic Waves with Spatially Varying Phase Velocities
S. P. Gary, David Montgomery, and Daniel W. Swift (University of Alaska)
Journal of Geophysical Research 73, 7524 (1968).

[No Abstract.]

26. Oscillations Present in Plasma-Electron Heating by an Electron Beam
I. Alexeff, G. E. Guest, D. Montgomery, R. V. Neidigh, and D. J. Rose (other authors from Oak Ridge National Laboratory)
Physical Review Letters 21, 344 (1968)

Oscillations of electrostatic fields present when electrons are strongly heated by electron-beam plasma

interaction reveal large-amplitude oscillations with $|\omega/k| \lesssim v_b$, the electron-beam speed; $\omega \lesssim \omega_{ce}/10$, where ω_{ce} is the electron gyrofrequency; coherence lengths of roughly a few wavelengths (<< plasma length); and maximum electrostatic potential in the wave approaching the applied beam voltage. A gross compatibility is found between the observed frequencies and wavelengths and the predictions of a linear theory.

27. Experimental Strong Turbulent Heating
R. V. Neidigh, I. Alexeff, G. E. Guest, W. D. Jones, D. C. Montgomery, D. J. Rose, W. L. Stirling (other authors from Oak Ridge National Laboratory)
Paper CN-24/L-2 at International Atomic Energy Agency Conference on Controlled Fusion, Novosibirsk, U. S. S. R. (August 1968)
[Published in Proceedings.]

Experiments at ORNL are exploring the strong turbulent interaction between a steady-state, magnetically collimated electron beam and its self-generated plasma.

The technology to maximize ion heating is being developed in Burnout V, a simple mirror device with magnetic fields of 50-25-50 kG, and with an axial electron beam (6 A at 10 kV) which gives a beam power density in the plasma exceeding one kW cm^{-3}. Necessary, but not sufficient evidence for a true thermonuclear temperature is the observed 10^3 sec^{-1} cm^{-3} plasma source of 3-MeV protons identifying D-D reactions. Spectral measurements of recombination radiation reveal a line width corresponding to an ion energy of 0.5 keV. Analysis of charge-exchanged neutral atoms reveals the energy spectrum in more detail with a maximum between 100-500 eV and as much as 10 percent near one keV. A flux of 3×10^{14} cm^{-2} sec^{-1} of 100 keV deuterons escapes the midplane perimeter. Calorimetric probes measure a plasma heating effect equivalent to 0.5 keV ion bombardment at 2.5×10^{12} cm^{-3}. The rate of decrease of spectral radiation toward the plasma center establishes an electron density of at least 2.5×10^{12} cm^{-3}. The confinement time, 2×10^{-4} sec estimated from density and energy balance, agrees well with the measured spectral-light decay time and is equivalent to hundreds of ion transits through the plasma. Ion heating has been observed to increase strongly with increasing magnetic field strength, suggesting a direction for future development.

28. Fluctuations in Monatomic Gases
David Montgomery
Physics of Fluids 12, 804, 1969

We treat the problem of calculating distribution-function auto-correlations of the form $\langle f(\vec{x}_1,\vec{v}_1,t_1)f(\vec{x}_2,\vec{v}_2,t_2)\rangle$ for a dilute monatomic gas. Two-time probability distributions of the type introduced by Rostoker for the plasma case are used. A perturbation expansion in the density is performed on the generalized BBGKY hierarchy which results. It is shown that the problem of determining the fluctuation spectra can be reduced to solving for a function which obeys the linearized kinetic equation for a dilute neutral gas with a particular choice of initial conditions, a result previously obtained by van Leeuwen and Yip, using diagrammatic perturbation theory. In the limit of infinite wavelengths and hard-sphere interactions, this equation reduces to the linearized Boltzmann equation.

29. A Simple Gigacycle Correlator
I. Alexeff, R. V. Neidigh, and W. R. Wing (University of Iowa)
International Journal of Engineering Science 7, 531, 1969

A gigacycle (beyond 2000 Mc) correlator has been developed with commercially available components. The basic components comprise two sampling oscilloscopes, a pulse generator, an analogue multiplier, a waveform averager, and a display oscilloscope. The oscilloscope output permits "real time" display of the correlation functions as they are computed over 100 sampling points. The device can correlate over a time interval that is adjustable from 2 nsec to 100 μsec. The instrument offers an improvement in frequency response of three orders of magnitude over any of the automatic correlators presently in the literature. Its maximum sensitivity without preamplification is about 2 mV. Its particular advantage is that it needs no alterations of its commercially available components, leaving them free for individual conventional use. Use of a single sampling oscilloscope for correlation studies is also discussed.

30. Propagation of Ion Acoustic Waves in a Magnetic Field
Glenn Joyce (The University of Iowa) and R. A. Dory (Oak Ridge National Laboratory)
[to be published in Physics of Fluids April 1970]

The properties of low frequency electrostatic waves propagating at various angles to a magnetic field in a plasma are studied. Numerical calculations are used to determine the phase velocities, group velocities, damping decrements and propagation directions for frequencies between zero and twice the ion cyclotron frequency. A model is presented which simulates experimental time-of-flight studies of finite wave packets generated by sine wave bursts.

31. Numerical Study of Weakly Unstable Electron Plasma Oscillations
Thomas P. Armstrong and David Montgomery
Physics of Fluids 12, 2094, 1969

The initial value problem for an unstable electron plasma has been solved by numerically integrating the Vlasov equation in one dimension. The situation chosen is the familiar "bump-on-the-tail" situation of quasi-linear theory. The solution is followed well beyond the point at which the electrostatic field energy has reached its maximum value. The electric field spectrum is eventually dominated by the single most linearly unstable wave number, which lies in the middle of the allowed range of wave numbers; it undergoes what appear to be the beginnings of gentle long-period oscillations characteristic of trapped-particle periodicities. It is argued that differences from quasi-linear predictions may be explained in terms of the level of initial excitations, or "noise," from which the instability is assumed to proceed.

32. Quasilinear Theory of the Ion-Wave Instability
David Montgomery and George Vahala
[accepted for Third European Fusion Cpnference and Symposium on Beam-Plasma Interactions, Utrecht, Netherlands, June 23-27, 1969; to be published in Proceedings.]

The ion-wave instability is treated within the framework of two-species quasilinear theory. The electrons are assumed to drift, relative to the ions, along a strong d.c. magnetic field. Such situations can arise both in laboratory discharges and in the solar wind. It is found that, as in the case of unstable electron plasma oscillations in the one-species plasma, there exists a unique final state for a given set of initial conditions; the spectral density of the fluctuating electric field can be determined. The results differ in some respects from the more usual quasi-linear results. Some speculations on the three dimensional case (no strong d.c. magnetic field) are offered.

33. Thermal Relaxation in One and Two Dimensional Plasma Models
D. Montgomery and C. W. Nielson
[to be published in Physics of Fluids, 1970]

Thermal relaxation of stable one and two dimensional plasmas is followed in time by particle-in-cell numerical computation. The predicted dependences of relaxation rate on plasma parameter are observed.

34. Validity of the Electrostatic Approximation
David Montgomery
[to be published in Physics of Fluids, 1970]

Criteria are derived for the existence of normal modes in a magnetized plasma for which $|\nabla \times \vec{E}| << |\nabla \cdot \vec{E}|$. The condition is different from the frequently quoted condition of thermal pressure << magnetic pressure.

B. IONOSPHERIC ABSTRACTS

14. VLF Emissions During Magnetic Storms and their Association with 40 keV Electrons
David P. Cauffman and Donald A. Gurnett
Journal of Geophysical Research 74, 1144, (1969)

Spectrograms of very low frequency radio noise recorded by University of Iowa satellite Injun 3 at invariant latitudes greater than 50°N are used to determine the behavior of VLF emissions during magnetic storms. Variations in the wide-band intensity of VLF emissions from L = 3 to L = 8 are studies for the period from 28 April to 28 August 1963 by means of the automatic gain control levels of the satellite VLF receiver.

During a sudden-commencement magnetic storm the VLF emission called polar chorus characteristically appears at the onset of the storm, may increase in upper frequency extent to ∿5 kHz, may change from spike to burst structure (normal chorus), occurs over the greatest area on the fourth day of the storm, subsequently fades into low frequency, spike-structure polar chorus again and eventually disappears into the ELF hiss band generally present. Chorus occurrence shows symmetry about the 9:00 - 21:00 magnetic local time meridian with a large maximum in magnetic morning and a smaller maximum in magnetic evening. Daily regions of occurrence are shown for the duration of a prototypical storm.

15. Ionospheric Observation of VLF Electrostatic Noise Related to Harmonics of the Proton Gyrofrequency
S. R. Mosier and D. A. Gurnett
Nature 223, 605, (1969)

An observation of electrostatic noise bands observed with the Javelin 8.46 sounding rocket is presented. It is shown that these noise bands are related to harmonics of the proton gyrofrequency. This observation is believed to be the first confirmation of ion gyrofrequency harmonic effects in the ionosphere.

16. VLF Electric and Magnetic Fields Observed in the Auroral Zone with the Javelin 8.46 Sounding Rocket
D. A. Gurnett and S. R. Mosier
Journal of Geophysical Research 74, 3979, (1969)

Results of the Javelin 8.46 VLF electric and magnetic fields experiment flown from Ft. Churchill, Canada, on May 25, 1968, are discussed. This experiment carried three orthogonal magnetic loop antennas, three orthogonal long (3.16 meters) electric dipoles, two short (42 cm) electric dipoles, and six wideband (30 Hz to 10 kHz) receiver for amplifying signals from the various VLF antennas. Intense noise bursts with frequencies less than about 1.5 kHz were observed on all the electric antennas below 500 km altitude, but not on the loop antennas. The precession and spin modulation of these noise bursts suggest that the noise is generated by an interaction between the payload and the surrounding plasma. High frequency electrostatic noise bursts, from 5 to 30 kHz, were observed throughout the flight. These noise bursts, similar in some respects to lower hybrid resonance noise commonly observed with satellite VLF electric field experiments, also appear to involve an interaction between the payload and the surrounding plasma. Attenuation bands at harmonics of the proton gyrofrequency were also found in the frequency spectra of electric field noise observed during a portion of the flight.

17. Initial Observations of VLF Electric and Magnetic Fields with the Injun 5 Satellite
D. A. Gurnett, G. W. Pfeiffer, R. R. Anderson, S. R. Mosier, and D. P. Cauffman
Journal of Geophysical Research 74, 4631, (1969)

The Injun 5 satellite, launched into a low altitude (677 to 2528 km) polar orbit on August 8, 1968, carried a very-low-frequency (VLF) electric and magnetic fields experiment covering the frequency range from DC to 105 kHz for electric fields and 30 Hz to 10 kHz for magnetic fields. This paper describes the VLF experiment and presents initial results of immediate interest.

Broad-band (30 Hz to 10 kHz) electric field intensities are found to be remarkably small, typically less than 100 μvolt/meter and seldom greater than 1 mvolt/meter. Most of the common types of VLF electromagnetic noise, electron and proton whistlers, chorus, ELF hiss, VLF hiss, and periodic emissions, have been observed simultaneously with both the electric and magnetic antennas, thus providing an excellent check on the operation of the electric antenna. Phase measurements between the electric and magnetic fields have been used to determine the direction of propagation, up or down the geomagnetic field. New phenomena observed include

(1) spin modulation of lower hybrid resonance noise, (2) multiple frequency noise bands possibly related to lower hybrid resonance noise, (3) a narrow bandwidth electric field enhancement near the two-ion cutoff frequency, and (4) noise bands associated with harmonics of the proton gyrofrequency.

18. VLF Measurements of the Poynting Flux Along the Geomagnetic Fields with the Injun 5 Satellite
S. R. Mosier and D. A. Gurnett
Journal of Geophysical Research 74, 5675, (1969)

The direction of the Poynting flux, up or down the geomagnetic field, has been determined for several types of VLF radio noise phenomena observed with the Injun 5 satellite, thereby providing information about the source region of these waves and their propagation in the ionosphere. Determinations of the Poynting flux direction of proton whistlers show that they are propagating up the geomagnetic field lines in accordance with the accepted theory of proton whistler propagation, thus providing a good check on the experimental technique. Initial measurements are presented on the Poynting flux direction of ELF hiss, periodic emission, VLF hiss, and chorus. Of particular interest is a new type of VLF emission called a saucer which is found to be propagating upward from a source below the satellite. A qualitative explanation of the frequency-time shape of this new type of emission is presented.

19. Satellite Measurements of DC Electric Fields in the Ionosphere
D. A. Gurnett
Particles and Fields in the Magnetosphere, 309, Reinhold Book Co., N. Y. (B. M. McCormac, ed.), [to be published, 1970]

This paper presents initial results from the DC electric field experiment on the low altitude polar orbiting INJUN 5 satellite. At low latitudes, where the ionospheric plasma is expected to corotate with the Earth, the only observed electric field is the $\vec{V} \times \vec{B}$ electric field due to the motion of the satellite through the ionosphere. Comparisons of the computed $\vec{V} \times \vec{B}$ field agree with the measured electric field within about ±10 mV/meter. At the plasmapause boundary small changes (~5 to 15 mV/meter) in the dc electric field are observed which are believed to be due to magnetospheric convection phenomena at the plasmapause boundary. At high latitudes large amplitude (~100 mV/meter) electric field irregularities and distrubances, believed to be due to ionospheric electric fields, are observed on virtually every passage over the polar regions. Long period electric field oscillations with periods

on the order of 15 seconds are also commonly observed at high latitudes.

20. Observations of 8-AMU/Unit Charge Ion Cyclotron Whistlers
D. A. Gurnett and P. Rodriguez
[to be published in Journal of Geophysical Research, 1970]

A new type of ion cyclotron whistler associated with ions having a mass-to-charge ratio of 8-amu/unit charge is reported from very-low-frequency (VLF) radio noise observations with the Injun 5 satellite. This observation confirms earlier measurements by the Explorer 31 satellite identifying the presence of 8-amu/unit charge ions in the ionosphere and represents the third type of ion cyclotron whistlers found in satellite VLF data. From crossover frequency measurements the fractional concentration of the 8-amu/unit charge ions has been determined to be a few percent or less. This new ion cyclotron whistler has been observed most often during local night, at altitudes ranging from 1200 km to 2100 km and invariant latitudes from 37° to 58°.